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Modelling of Real-Life Mixed Integer Programming Problems: Comprehensive Tourism Service Center Converge Problem

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Abstract:

This paper uses the Mixed Integer Programming (MIP) model to plan the Comprehensive Tourism Service Centers (CTSC) in Gusu District, Suzhou, to meet the increasing demands of tourists and alleviate the excessive pressure on existing facilities. Since the end of the COVID-19 epidemic, Suzhou's tourism industry has steadily grown, particularly in Gusu District, where scenic spots are concentrated. Tourist numbers surge, especially during holidays like Labor Day, Mid-Autumn Festival, and National Day. However, the district's narrow streets, crowded traffic, and increasing visitor flow have highlighted the insufficiency of current visitor centers. By establishing CTSCs, which provide essential services such as rest areas, basic shopping, and emergency medical assistance, tourism quality can be enhanced while relieving pressure on existing centers. Given the district's high density of protected buildings and construction challenges, the MIP model simplifies Gusu District into a point-line map, calculating the optimal locations for CTSCs under various constraints to connect attractions and improve the overall visitor experience within a limited budget and space.

Keywords: Mixed integer programming; Gusu district; Optimal locations.

1. Introduction

Since the end of the COVID-19 epidemic, Suzhou's tourism industry has developed steadily, espe- cially in the areas where scenic spots are concentrated (Gusu District), and the number of tourists has been increasing. Especially on Labor Day, Mid-Autumn Festival, National Day and other long holidays, there will be a period when tourism demand breaks out. In consideration of the actual situ- ation in Gusu District, the traffic is relatively crowded, the streets are relatively narrow, and the flow of people is increasing, so the demand for the visitor center is extremely insufficient. The purpose of setting up CTSC is to connect different scenic spots to provide convenient services for tourists, such as rest areas, basic shopping areas,

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and necessary emergency medical assistance services.

The set of comprehensive tourism service center greatly relieve the pressure on the internal service center of the scenic area, which has greatly facilitated tourists to rest during the tour and improve the quality of tourism. Considering the problems of more protected buildings, high block density and difficult construction in Gusu District, how to choose the right place to build CTSC has become a challenging problem. Therefore, the goal is to build enough CTSC in a limited budget and area to cover popular attractions in Gusu District, connect different attractions, and provide better tourism services for tourists.

2. Literature Review

The MIP model can be used to identify the key factors that affect the cost of freight transportation, so that the results of the heuristic and meta-heuristic methods can be used to reduce costs [1]. The near- optimal arrangement method of self-scheduling based on preference can be found by using MIP model. It is used to meet the staff arrangements of enterprises with irregular working hours. It can also be used to assist CTSC in site selection [2]. A multi-period facility location problem involving several operational features has been investigated. CTSC is a static location problem, which can be applied to this model [3]. An important function of CTSC is to provide basic medical services, and according to its service scope and service efficiency attenuation, MIP model can be used to improve the service efficiency of CTSC [4].Previously, a ternary quadratic linear model formula was used to plan project scheduling problems with time constraints. All exact and heuristic solution procedures use a new and powerful time planning method. Can be used to optimize small and medium-sized projects [5]. The nonlinear model plays a very effective role in solving the complex customer visit problem and optimizing the arrangement of commercial products in the domestic market [6]. However, for the comprehensive needs of passengers, the conventional mathematical model can not be effectively solved. Therefore, the proposed MIP model can help optimize the location problem of CTSC. The problem is modeled as Multi-Objective OPTW with MIP and CP and solved [7]. In solving nonlinear non- convex optimization problems, it is difficult to obtain the global optimal solution, and there may be convergence problems. Based on the exact linearized measurement equation, a robust state estimation method with mixed integer linear programming is proposed [8]. Based on the optimization modeling theory, a block merging mixed integer programming model is proposed, which maintains the grid pattern of urban roads. It helps to coordinate the relationship between transportation and CTSC [9].

3. Methodology

Since the site selection and setting of CSTC need to cover all attractions. In order to simplify the problem and facilitate understanding and calculation, the whole Gusu is divided into two areas, with a main road (Bachelor Street) as the east-west area, all tourist attractions simplified into hollow points, and the alternative area as solid points i, and the radius of its service is r. The service scope and maximum service capacity of CSTC are known, and all alternative areas allow the construction of new buildings. On the basis of covering all tourist attractions as much as possible and maximizing service carrying capacity, how to choose the right location and reduce costs as much as possible under a limited public budget are concerned. In Gusu District, 15 alternative points for CSTC was selected for Fig. 1 [10]. This way of solving the real problems in travelling area and different situation of transportation and population densities is a simple MIP Acknowledgments.

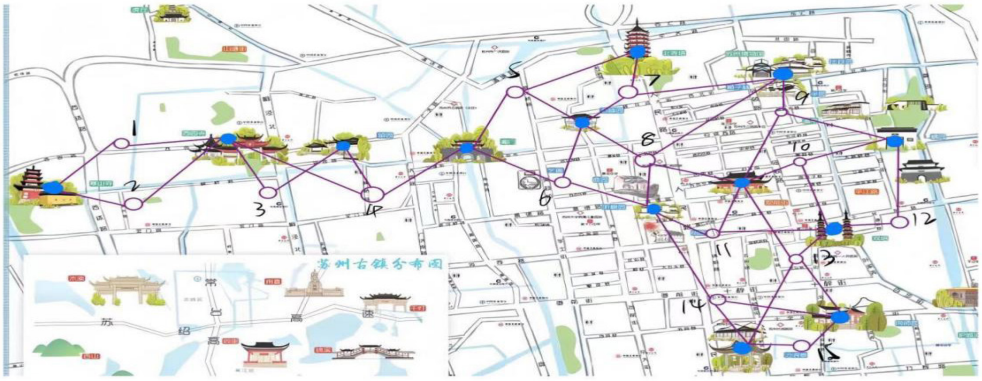

Fig. 1 Distribution map of the scenic area in Gusu District

3.1 Inputs and Point Selection Logic

It is selected a total of 13 scenic spots and preliminary set up the site selection points of 15 scenic service stations. The siteselection points of these service stations are represented by 1-15 hollow circles on the map.

- N1:(simplication for Location 1) It is located on the northside of Xiyuan Road, it connects Hanshan Temple and Xiyuan Temple, and is located in the middle of Hanshan Temple and Xiyuan Temple to provide services for tourists in the two scenic spots.
- N2: It is located on the east side of the West Ring Road, connecting Hanshan Temple and Xiyuan Temple, which is closer to Hanshan Temple.
- N3: It is located on the west side of Tongjing North Road, connecting Xiyuan Temple and Lingering Garden, providing convenient services for tourists of Xiyuan Temple and Lingering Garden.
- N4: It is located on the west side of Guangji Nan Road, it connects Xiyuan Temple, Lin- gering Garden and Chang Gate, providing services for tourists in these three scenic spots, and is close to the toilet in the south.
- N5: It is located on the west side of Taohua Bridge Road, it connects the Chang Gate, North Temple Tower and Wufeng Park, which is convenient to provide services for tourists in these three scenic spots.
- N6: It is located on the east side of Wufengfang, connected to Wufeng Garden, listening to Maple Garden, Chang Gate, and near Qu Garden and art Garden.
- N7: It is located on the west side of Renmin Road, near the North Temple Pagoda, con- nectingWufeng Garden and Suzhou Museum. The reason for the choice is convenient trans- portation
- N8: It is located in the north of Quyuan, it is connected to Wufeng Garden, Suzhou Mu- seum, Listening to Maple Garden, Guanqian Street, and close to the hospital.
- N9: It is located in the south of the Suzhou Museum, connected to the Suzhou Museum, Guanqian Street, Yingyuan, and near the Foolish Administrator's Garden on the north side.
- N10: It is located in the east of Guanqian Street, it connects Guanqian Street, Cherry Garden and Twin Towers. The reason for the choice is convenient transportation
- N11: It is located in the south of Listening-maple Garden, connecting listening-maple Garden, Guanqian Street and Twin towers.
- N12: It is located on the northside of Baibu Street, connecting Ying Garden, Twin towers and Teacher of the Net Garden. The reason for the choice is convenient transportation
- N13: It is located the northside of Shizi Street, it connects Guanqian Street, Twin Towers, Canglang Pavilion and Teacher of the Net Garden, and is close to the First People's Hospital of Suzhou.
- N14: It is located on the southside of Shizi Street, it is connected to Listening to Maple Garden, Teacher Garden and Canglang Pavilion. The reason for choosing is the same as N13.
- N15: It is located on the north side of Zhuhui Road, it connects Canglang Pavilion and Teacher of the Net Garden. The reason for choosing is to provide services for tourists in these two scenic spots.

3.2 The assumptions

It assumed that:

- Each CTSC service coverage is the same of 6 unit distance.
- Each path can be simplified into a straight line and the distance is kept as an integer.
- Each CTSC has different establishing costs.
- The maximum service capacity of each CTSC is the same.
- A questionnaire has been made in response to the tourists' requirements for distance be- tween the different tourist attractions and CTSC.

4. MIP Model

To simplify the modelling, the points from the map and plot the unit length were extracted on the simplified graph as Fig. 2. Table 1 is variables used in this modelling.

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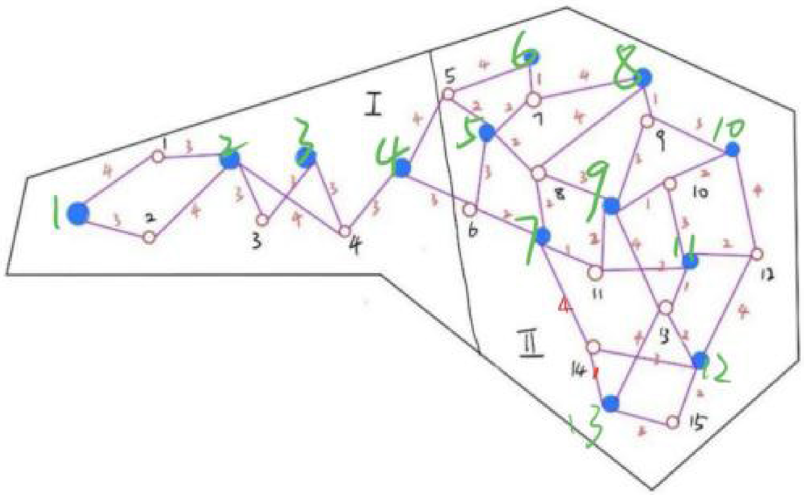

Fig. 2 Simplified graph of map

Table 1. Variables used in this modelling

Symbol	Definition
M ∈ {1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15}	The set of candidate sites establishing CSTC
N ∈ {1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13}	The set of requirement points in a region
di	The minimum demand of the ith block
Dj	The capacity of jth CSTC
xj ∈ {0, 1}	Where 1 means establishing a CSTC and 0 means not establishing
A(i)	The set of CTSCj which can service requirement point i
yij	The demand of requirement point i which is allotted to CSTCj
cj	The cost of establishing a CSTC at point j

4.1 Objective Function

$$y = \min \sum_{j=1}^{m} cj\ xj \qquad (1)$$

The problem's objective function is to reduce the overall cost of CSTC stations. The goal is to reach a position where can develop a minimum cost of requirements points of CTSC while meeting all of the requirements y represents the demand of requirement point i which is allotted to CSTC j,c represents. The cost of establishing a CSTC at point j,x represents the selected point.Tables 1,2,and 3 show the rest variables used in the model.

4.2 Constraints

$$\sum_{j \in A(i)} yi,j \geq 1,\ i \in N \qquad (2)$$

Table 2. Variables used in this modelling

CSTC	Cj
1	3
2	2
3	3
4	1
5	3
6	3
7	4

8	3
9	2
10	4
11	1
12	3
13	2
14	3
15	2

Table 3 Variable range

N	A(i)
1	1,2
2	1,2,3,4
3	3,4
4	4,5,6
5	5,6,7,8,10,11
6	5,6,7,8,9
7	5,6,7,8,9,10,11,12,14
8	7,8,9,10,11
9	6,8,9,10,11,12,13
10	8,9,10,11,12,13
11	8,10,11,12,13,14,15
12	10,11,12,13,14,15
13	11,13,14,15

First and foremost, it must be ensured that every requirement point can, in theory, be satisfied by at least one CSTC.

$$\sum_{j\in A(i)} \text{diyi,j} \le \text{Dj xj}, j \in M \quad (3)$$

Second, the maximum carrying capacity that the CSTC itself is capable of carrying will not be exceeded by the service capacity of the same CSTC chosen by several demand locations.

Additionally, none of the variables can be negative; that is, none of the variables can be higher than or equal to 0, which would not suit the real-world scenario.

5. Computational Results

Gurobi is used in Python in conjunction with assumptions and constraints to determine the model's optimal solution. The outcomes are displayed below. The model contains 13 demand points and 15 potential site selection points, and the cost of site selection points is [3, 2, 3, 1, 3, 3, 4, 3, 2, 4, 1, 3, 2, 3, 2, 2, 2, 2, 2], respectively. The coverage relationship between requirement point and site selection point is defined by a dictionary data, for example, requirement point 1 can be covered by site selection points 1 and 2, and requirement point 5 can be covered by site selection points 5, 6, 7, 8, 10, and 11. From these relationships, the program constructs a 13x15 matrix that represents whether each requirement point is covered by a site selection point. The model sets binary decision variables to indicate whether to select a site selection point, and requires each demand point to be covered by at least one site selection point. The objective function is to minimize the total cost of all selected location points. Finally, the model outputs the selected location point and the minimized total cost by optimizing the solution, which helps to optimize the location configuration of facilities in the actual scenario. Based on the output, facility locations 2, 4, 9, and 11 are selected (Select[1], Select[3], Select[8], and Select[10] are all 1), which means that the facility should be established at these locations.

6 indicates that the total facility construction cost is 6, which is the mini-

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mum cost under the condition that all demand points are served by at least one facility.

According to the map and combined with the optimal solution obtained by Python, to visualize the data, the obtained results are presented on the map as line segments between two points. The illustration further proves that demand points can be covered by CSTC.

6. Sensitivity Analysis

Sensitivity analysis for maximum bearing capacity examines how variations in input parameters affect the maximum load-bearing capacity Dj.

It assumed that each CSTC has the same carrying capacity based on the information above, and obtained the best outcome: The least amount of money can be used to cover the entire area if the service station is constructed at candidate sites 2, 4, 9, and 11.

However, each service station's capacity may vary depending on the real circumstances. Next, it can first make the average assumption that each candidate site among the CSTC selected has a maximum carrying capacity of 5. The best outcome can be achieved and the lowest construction cost are obtained when the real maximum capacity is 5. Next, it will be examined scenarios in which the real maximum capacity is either less than or greater than five.

For instance, when Dj = 1, there is no way to solve the problem because the selected candidate sites are unable to meet all of the requirements; this means that additional sites must be chosen, which raises the cost of building. When the maximum capacity is fewer than five, the same outcomes hold true.

When the real maximum capacity was greater than 5, the ideal solution was still 2, 4, 9, 11, with the account of the building cost. Here, requirement points 2, 7, 8, 9, and 10 were covered by both Candidate sites 2 and 4, and requirement points 7, 8, 9, and 10 were covered by Candidate sites 9 and 11. In other words, requirement points 2, 7, 8, 9, and 10 were covered repeatedly. This outcome contributes to giving travelers options, which in turn serves to spread out the number of visitors and raises the standard of service.

In addition, it can be considered more uncertain real-world scenarios in order to construct several CTSC with various scales.

7. Conclusion

By creating the tourism service station CTSC, it aims to improve services for tourists during peak hours at the picturesque area. The distance between the service station and the beautiful place was converted into discrete data of points, and the first chosen 15 points based on the convenience of transportation in order to create the mathematical model. Next, an integer linear programming technique will be used to solve this problem. To be more precise, the problem was solved using gurobi and Python in order to find the best way to lower the CTSC construction costs. Future research could explore more advanced optimization techniques and consider additional factors, such as real-time visitor flow data or environmental impacts, to further refine.

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