A Strategy for Distributing the Ambulance

Abstract

The declining number of volunteers has significantly impaired emergency medical services (EMS) around the city of Ithaca. The local government is trying to work out a new plan for restricting the response time of the ambulance to no more than 6 minutes. Hence, in our paper, we will help the local government achieve it, but only consider the urban area, through mathematical modeling.

First, we establish a **Maximum Coverage Model (MCM)**. Based on our experience, we give the maximum coverage radius 2.5km without considering many factors. We also ignore the varying call volume from one area to another and each possible ambulance site will be equipped with no more than one ambulance. Then we use Google Maps to get all possible ambulance sites and mark them, considering only a small area of the urban area for the purpose of simplication. Next, we alter the number of the selected sites from these possible sites to achieve the optimal coverage rate through writing a python program; and we find that when we select three sites, we can achieve a 94% coverage rate, and can ensure that in all the covered area, the response time will be within 6 minutes. When we continue to increase the selected sites, the coverage rate will vary slightly.

Since many factors are ignored in our first model, we proceed to build an improved model, including a **Coverage Radius Model (CRM)** and an **Ambulance Demand Conversion Model (ADCM)**. We study the effects of various factors like population density on the call volume in different areas by **Analytic Hierarchy Process (AHP)**, and find that the distribution of the population is the only major factor. Next, we consider the effects of the real situation on the maximum coverage radius of an ambulance site, then build a formula, and obtain a new radius 1.3 km. Since we have known the total call volume for a year around the city of Ithaca, we use a **fuzzy model** to describe the relationship between the needed ambulances and the call volume, and obtain that the total needed number of ambulances in the urban area is 16. Then we apply the new radius to our first model, and obtain that the optimal number of the ambulance site is 13. Furthermore, based on the difference of population density, we first equip each site with one ambulance, and then the remaining three ambulances are assigned to the three different areas with relatively higher population densities.

Key words: maximum coverage model, site selection, AHP, fuzzy model.

Contents

1 Introduction

1.1 Background

Ambulance services are provided almost wherever there is a certain population by the local governments. When the unexpected accident and injury occur, the shorter the response time is, the greater the likelihood of saving a human life or even more is. However, the shorter response time largely depends on whether the location of the ambulances is reasonable and whether the number of ambulances is sufficient in a region. Both these two conditions, however, would consume considerable labor cost and equipment cost. Lack of medical workers in a region tends to cause the poor performance of ambulances services. Ithaca, a small city in Tompkins County of the United States, is no exception to this.

In the past, a large number of residents in Ithaca volunteered to assist medical workers in providing ambulance services; but these days, the number has declined dramatically as a result of strained relations between volunteers and lack of training [1]. To make matters even worse, non-serious calls for 911 have experienced a significant increase in the past ten years [1]. In consequence, the authorities of Ithaca are trying to work out a new strategy for positioning sufficient ambulances around the city for improvements of ambulance services.

1.2 Restatement of the Problem

In order to help determine the optimal location and number of ambulances for the city of Ithaca, we are required to perform the following tasks. First, we need to restrict the response time to less than 6 minutes through reasonably distributing the ambulances for Ithaca—including the reasonable location and reasonable number of ambulances; meanwhile, some areas within Ithaca are allowed to be treated with longer response time for higher utility of ambulances. In addition, we are required to offer an executive summary to Bangs Ambulance Inc. as an explanation for the advantages of our new strategy; moreover, we need to justify why the response time in some areas is longer than 6 minutes, if it is.

1.3 Assumptions and justifications

Assumptions and justifications for our model are as follows:

- **We rule out the effects of traffic jams and traffic light and terrible weather on the response time of ambulances** because many parts of the world allow ambulances outside the traffic rules, and other vehicles are supposed to give way to the passing ambulances.
- Since a large area of Ithaca is flat land, we assume that **all the roads involved are flat**.
- In view of the overall urban planning of Ithaca, we assume that **the main roads of the city are straight**.

- **The speed of the ambulance is constant, and the driver has the same driving ability** for considering a basic model.
- **Ambulances can only travel on the main roads and will not be able to take a shortcut**, considering the reality that ambulances rarely take a shortcut.

2 Max Coverage Model (MCM)

To arrange the location of the ambulance, we have assumed that all the concerned roads are straight, and that the ambulance will only travel on the straight roads, through examining the actual streets of Ithaca on Google maps. We set up multiple sites in the city to place ambulances in; each site will be equipped with merely one ambulance. Since the ambulance needs to reach the target rescue point within 6 minutes, we have a circular rescue area for each ambulance site.

The circular area represents the maximum coverage of each ambulance site. Note that any point that the ambulance in a certain site is capable of reaching within 6 minutes belongs to the maximum coverage of that site. If an ambulance travels along a straight line to the target rescue point — without altering its driving direction, the radius of the circular area is 3.5 km with the response time 6 minutes and the ambulance's speed 35 km/h. Given the reality that the ambulance driver often has to alter its driving direction at some turning points to reach the target point, the actual value of the radius is less than the theoretical value. Hence, we consider the following two situations.

- The ambulance reaches the target rescue point without altering its traveling direction, which will enhance the radius of the maximum rescue coverage area.
- The ambulance reaches the target rescue point after altering its traveling directions several times, which will reduce the value of the covering radius.

2.1 Notations

Symbols	Descriptions
$\boldsymbol{N}$	All the possible calling points that calls may come from, denoted by the set N = {1,2,3,…,n}
$\boldsymbol{M}$	All the needed ambulance sites, denoted by the set M = {1,2,3,…,n}
$\boldsymbol{d_i}$	The call volume in the i-th calling points
$\boldsymbol{D_j}$	The coverage of the j-th ambulance site.
$\boldsymbol{p}$	The total number of the ambulance sites
$\boldsymbol{A(j)}$	All the calling points covered by the j-th ambulance site, denoted by the set A(j)
$\boldsymbol{B(i)}$	All the ambulance sites that may cover the i-th calling points, denoted by the set B(i)
$\boldsymbol{x_j}$	It only has two possible values 0 and 1. when the value is 0, we will place no ambulance in the j-th ambulance site; otherwise, one will be assigned $j \in M$

y_{ij}	The overlapped area of the i-th calling point and the j-th ambulance site.

2.2 The Distribution of Ambulance Sites

In order for the covering radius to agree with the reality, we assume that the covering radius of an ambulance site is 2 km.

We then use the circular area with the radius 2 km to cover the city of Ithaca, and our objective is to use the fewest circular areas to cover the most areas of Ithaca. In other words, we will arrange for the fewest ambulances around the city of Ithaca to allow the response time to be within 6 minutes, wherever the call comes from. Hence, we will build our basic model on the Maximum Covering Linear Programming (MCLP), which is as follows.

$$\begin{cases} \boldsymbol{max} \sum\limits_{j \in M} \sum\limits_{i \in A(J)} d_i y_{ij} \\ \sum\limits_{j \in B(i)} y_j \leq 1, i \in N \\ \sum\limits_{i \in A(j)} d_i y_{ij} \leq D_j x_j, j \in M \\ \sum\limits_{j \in M} x_j = p \\ x_i \in \{0, 1\}, j \in M \\ y_{ij} \geq 0, i \in N, j \in M \end{cases} \tag{1}$$

The layout goal of the ambulance sites is to use relatively fewer ambulances to cover more parts of the entire city of Ithaca rather than to use more ambulances to cover the entire city of Ithaca. Thus, it is certain that calls from some areas will not get a response time within 6 minutes. However, our strategy will save the local government considerable labor cost and economic cost; meanwhile, the extreme majority of calls for 911 in the city of Ithaca will be responded to within 6 minutes. Finally, through solving our basic model, we will obtain the least number of ambulances to be placed in the city of Ithaca. To produce a vivid result, we use the tool Fishnet in ARCGIS to study a small part of Ithaca. According to the map of Ithaca on Google Maps, we dismiss some points as the possible ambulance sites and obtain all the possible ambulance sites as follows.

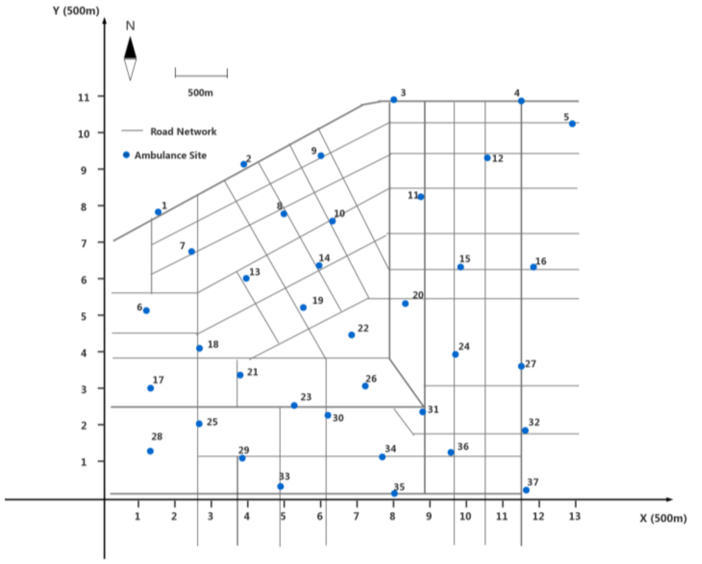

Figure 1 All the possible sites in the considered area

Next, we establish the coordinate system and number each possible ambulance site to determine the relative position of all the possible ambulance sites. We then apply MCLP to analyze all the sites. Using the python program, we compute that these three sites will achieve a 96% coverage rate of the selected area of Ithaca— number 11, number 18 and number 32. Furthermore, when we proceed to use more possible sites, the coverage rate will vary slightly, and the overlapped area of the coverage of different possible sites will increase significantly. Hence, we finally choose the above three sites to place ambulances in — one in each site— so that citizens in the selected area can call for help at any place of this area, and they can get help within 6 minutes. The locations of these three sites are presented as follows.

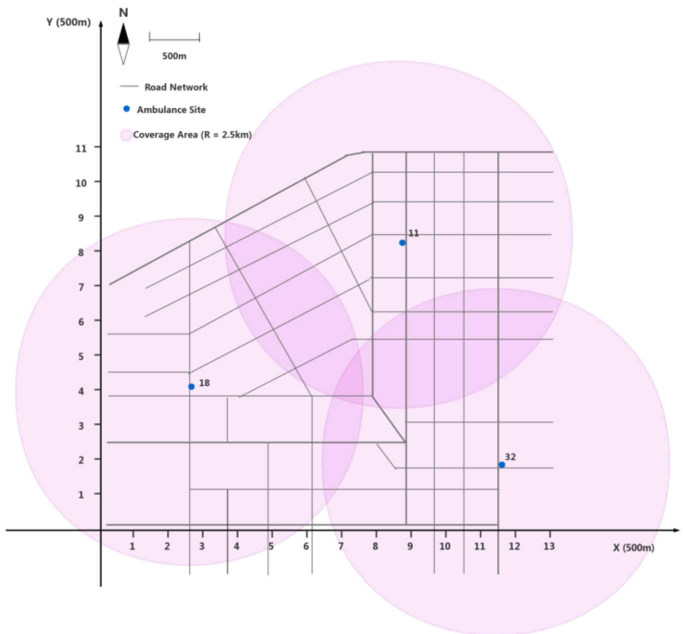

Figure 2 The selected sites

Finally, when we vary the number of the ambulance site, we obtain the following results.

2.3 Weaknesses of Maximum Coverage Model

Although our basic model can produce seemingly satisfactory results, it is too simplified. As a consequence, it has the following shortcomings.

- We did not consider the difference of the call volume in different parts of the city of Ithaca.
- We ignored the situation that multiple points would call the same ambulance site for help during the same time period, and only placed an ambulance in each ambulance site.
- We only selected a small area of the city of Ithaca to study the optimal location of the ambulance site and the optimal number of ambulances around this area.

3 The Improvement of Maximum Coverage Model

To address the problems with our basic model, we will take more factors into account, including the population size, number of elderly people, economic conditions and public security status in different areas of the city of Ithaca.

3.1 Notations

Symbols	Descriptions
CV	the call volume
AN	the needed number of ambulances
SN	the number of the already determined site for ambulances

3.2 Assumptions and Justifications of Our Improved Model

Our assumptions and justifications for our improved model are as follows

- Each ambulance site will be able to have more than one ambulance so that they can respond to multiple calls at the same time, especially when it is Friday nights or weekends [1].
- It is certain that different areas of Ithaca have different call volumes at most times. Hence, we find it necessary to analyze the previous four factors to determine their effects on the call volume of different areas.

3.3 Evaluation Process

We have obtained that the total call volume in the entire Ithaca is 4091 per year. Since we only study the urban area of Ithaca, we will use Analytic Hierarchy Process to determine the call volume in the urban area. First, we build an AHP hierarchy and prioritize the four criteria from the highest priority to the lowest. Considering the reality, we choose the priority on criteria as follows: Security, Seniors, Population, Economy. We then obtain a 4 by 4 comparison matrix as follows.

Table 1 Judgement Matrix for Evaluation Demand

	Security	Senior	Population	Economy
Security	1	2	4	5
Senior	1/2	1	3	4
Population	1/4	1/3	1	3
Economy	1/5	1/4	1/3	1

Finally, we perform other AHP procedures to obtain the following results.

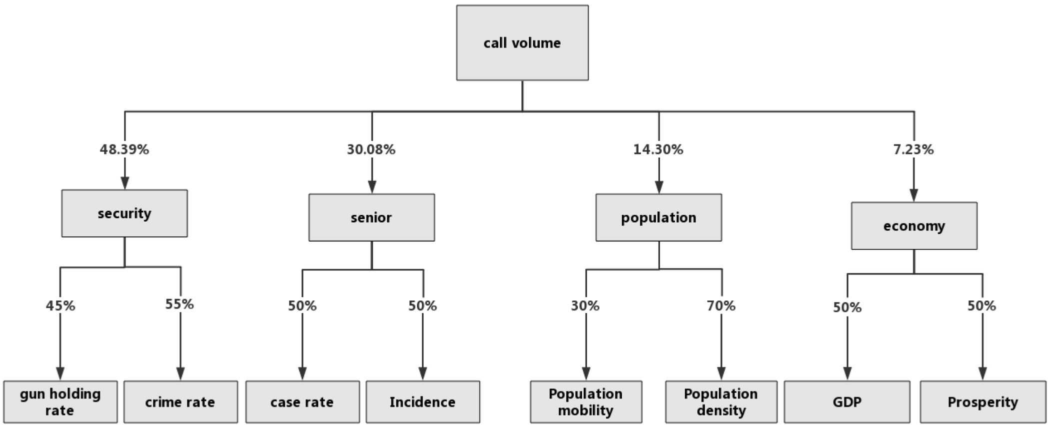

Figure 3 The relative importance of the four criteria

Hence, we compute that the call volume in the urban area of Ithaca is 2562.

3.4 Ambulance Demand Conversion Model (ADC)

In this section, we use fuzzy mathematics to describe the relationship between the annual call volume and the reasonable number of ambulances in the urban area of Ithaca. Then we have

$$\boldsymbol{AN} = \frac{\left(\sqrt{\boldsymbol{CV}} - \mathbf{1.3}\,\boldsymbol{log}\sqrt{\boldsymbol{CV}}\right)}{\mathbf{2.5}} - \mathbf{2} \qquad (\mathbf{2})$$

Next, we substitute the annual call volume of the urban area into it, and obtain AN=2562, which means that the total number of ambulances for the urban area should be 2562.

Next, we need to complete the assignment by the subsequent comparison. There are three main situations that may occur in a certain area.

1. SN = AN

In this case, the optimal option is to place just one ambulance in each ambulance site.

2. SN < AN

This means that after we assign one ambulance to each site in this area, there are at least one ambulance left. Considering that large population density is often associated with high call volume, for the possible remaining ambulance, we will continue to assign them (or it) to each site based on the difference of their population density. Hence, during the same time period, multiple calls can be handled equally due to more than one ambulance.

3. SN > AN

In this case, there will be some sites equipped with no ambulance, and we will first assign the ambulance to those with higher population density. Therefore, some ambulance sites will cover larger areas, and the response time may exceed 6 minutes with lower probability.

3.5 Coverage Radius Model (CRM)

In our basic model, we can get the radius of the coverage area by multiplying time by velocity. Owing to failure to consider many external factors, the radius of the coverage area is not precise and it cannot represent the actual coverage of the ambulance site in Ithaca city. Hence, we construct the **coverage radius model (CAM)** to calculate the radius of the coverage by combing the actual situation.

$$\boldsymbol{r = (1-\alpha)(1-\ \beta)(1-\ \gamma)v(t-st-rt)} \qquad (3)$$

Where r denotes the radius of the coverage area, α denotes the influence factor of transportation, β denotes the complexity of roads, γ denotes the influence factor of weather, v denotes the chosen average velocity of all ambulances, t denotes the average response time, st denotes the schedule time, rt denotes the reaction time of drivers.

In order to calculate the real radius of the coverage area, we select the following parameter values.

$\alpha = 0.1$ Base on the data from the global bank, we find that the traffic congestion in Ithaca is not frequent. Hence we set the influence factor of transportation as 0.1.

$\beta = 0.4$ Base on the map of Ithaca, we analyze the complexity of roads.

Finally, we set the complexity of roads as 0.4

$\gamma = 0$ In order to simplify our model, we only consider the radius of the coverage in good weather. So we set the influence factor of weather as 1

$\mathrm{v} = 32\mathrm{km/h}$ we set the velocity of ambulance as 32km/h

$\mathrm{t} = 6\mathrm{minutes}$ we set the average respond time as 6minutes

$\mathrm{st} = 45\mathrm{s}$ Through our survey, we find that the Ithaca medical center takes an average of 45 seconds from receiving a call to dispatching an ambulance. Hence we set the schedule time as 45s.

$\mathrm{rt} = 30\mathrm{s}$ Through our survey, we find that the average response time of ambulance drivers from receiving calls to actually driving takes 30 seconds. So we set the reaction time of drivers as 45s.

From the above data, we compute that the maximum coverage radius is

$$\boldsymbol{r = 1.3km}$$

4 Model Solving

We examine all the possible sites for placement of ambulances in the urban area of Ithaca, and mark them in Google Maps. Owing to parking limits, we will only choose some of them as the placement point of the ambulances. To achieve the selection, we will use our basic model again here. All possible ambulance sites are as follows.

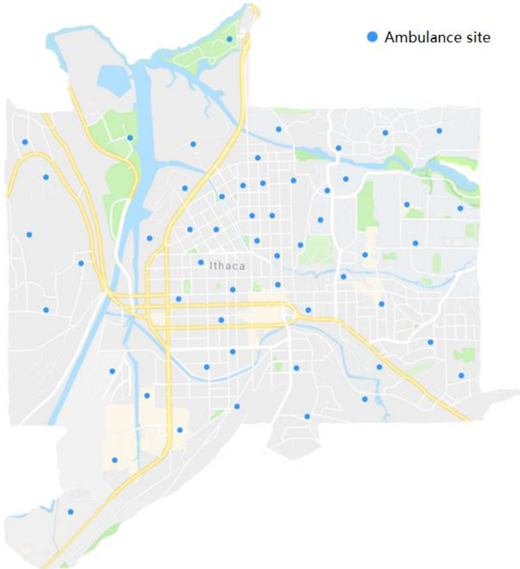

Figure 4 All possible ambulance sites

Here we revise and execute the python program used in our basic model and apply the maximum coverage model (coverage radius = 1.3km) to find that only 13 placement points are needed to achieve 90% coverage for the urban area of Ithaca as follows (Fig.3).

Figure 5 Selected sites and their entire coverage

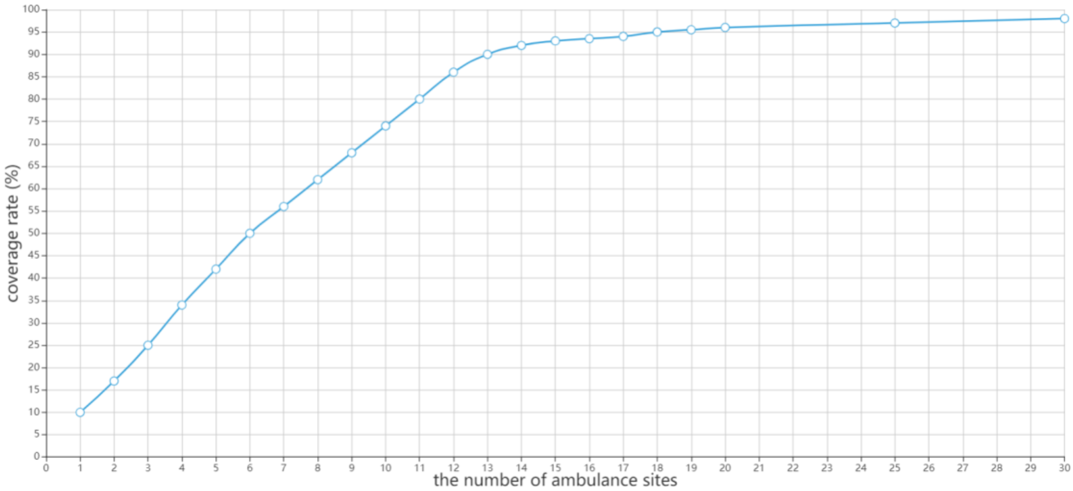

Figure 6 The Relation of Ambulance Site Number and Coverage Rate

As the above figure shows, with the increasing number of chosen sites, the coverage will increase little, and the overlapped area will increase significantly. To help reduce labor cost and vehicle cost for the local government, we finally determine that the local government should build 13 ambulance sites.

We have obtained before that AN=16. Since AN>SN, we first place 13 ambulances in each site separately. For the remaining 3 ambulances, based on the distribution of the population, we assign the three ambulances to the three sites with relatively higher population densities. The graph of the population density (Fig.5) and the final distribution of ambulance sites (Fig.6) are as follows.

Figure 7 Distribution of the population density in Ithaca [3]

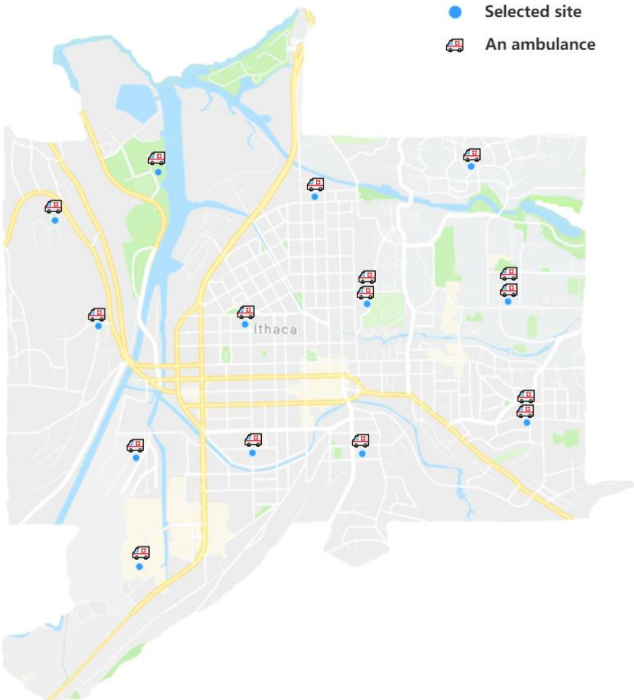

Figure 8 The final distribution of the sites and ambulances

In conclusion, to restrict the response time to no more than 6 minutes, the local government should build 13 ambulance sites and place 16 ambulances in the main urban area.

5 Sensitivity Analyses

5.1 The Sensitivity Analysis of AHP

First calculate the Consistency Index CI:

$$CI = \frac{\lambda_{max} - n}{n-1}$$

Then fine the mean Random Consistency Index RI (Table 2)

Table 2 Mean Random Consistency Index of Each Scale

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

Then, we calculate the average of the largest eigenvalue $\bar{\lambda}_{max}$.

Finally calculate the consistency ratio CR:

$$CR = \frac{CI}{RI} = \ 0.0429$$

(When $CR < 0.1$, it holds that the consistency of the judgement matrix is acceptable.)

5.2 The Sensitivity Analysis of ADCM

We compare a lot of actual data with our results, and find that the model fit well with the actual data. Hence our model is relatively sensitive.

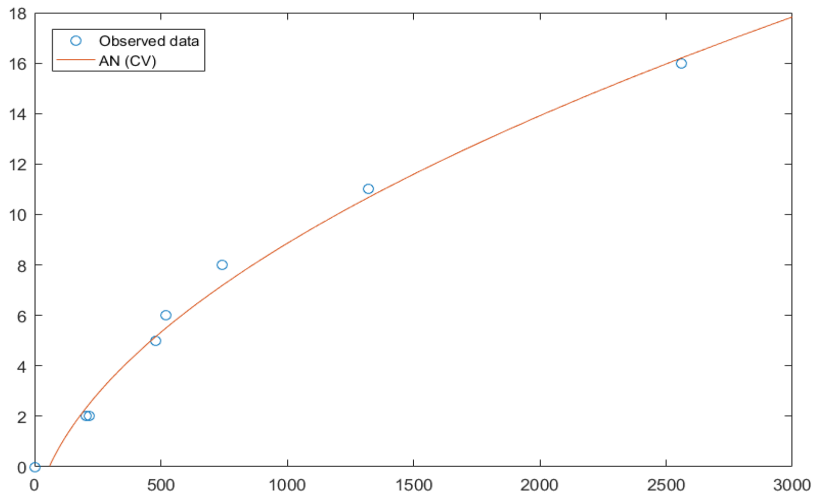

Figure 9 Fitting Simulation of ADCM

5.3 The Sensitivity Analysis of CRM

The basic function of coverage radius is $\boldsymbol{r = v * t}$. We consider some external factors and design parameters α, β and γ to describe the external influence. Since we set them based on our experience, it is necessary to analyze the effects of their change on the coverage radius. When we change them by 0.1 each time, we find that all the three parameters significantly influence the coverage radius when the change reaches 0.3. Hence, to produce a precise result, we should use more accurate methods to estimate them.

6 Strengths and Weaknesses

6.1 Strengths

- Our models use precise and up-to-date data to ensure the reliability of results
- Based on the Maximum Coverage Model, we use the Coverage Radius Model. We obtain the precise results by precise coverage radius, considering the actual situation of Ithaca.
- Our model is well transplanted and can be extensively applied to other areas.
- Our model is simple to implement.

6.2 Weaknesses

- Owing to lack of the precise data, we ignore some useful indicators such as accident rate in the urban area. This may lead to errors in the results of our model.
- Many topography factors are ignored in our model. Hence, our model may not be applicable to some areas with complex topography.

7 Conclusion

We establish a maximum coverage model, a coverage radius model and an ambulance demand conversion model to determine the number of the ambulance sites in the main urban area of Ithaca. The Analytic Hierarchy Process is used to assess the call volume in the Ithaca area from four aspects: urban security, aging, population, and economy. The call volume determines the needed ambulance in an area. Therefore, we design an ambulance demand conversion model to determine the reasonable number of the ambulances assigned to the main city of Ithaca. In order to make the model more accurate, we also review a large number of data from the World Bank. Finally, we conduct a sensitivity analysis of the established model, discuss the advantages and disadvantages of the model and the future of the model.

8 Executive Summary

The necessity of reducing dependence on the number of emergency medical workers for Ithaca city has been fully demonstrated by the declining volunteers and the worsening Emergency Medical Services (EMS) around Ithaca caused by the decline. Hence, we will help Ithaca fix it through directing our strategy towards using fewer ambulances to cover a larger rescue area in order for the response time around Ithaca to be within 6 minutes. The underlying logic is that as the determined ambulances become more, the labor cost and vehicle cost will increase significantly.

Through developing an optimization model and refining it, we have that the optimal numbers of the ambulance site and the ambulance are 13 and 16, respectively. Many factors contribute to the reliability and feasibility of our modeling results. First, we spend considerable effort on the possible effects of the actual situation. For instance, when we determine the needed number of the ambulance, we attach great importance to the effect of the call volume in an area. It is apparent that when we arrange for insufficient ambulances to respond to calls in an area with higher call volume, it means risking a number of residents' lives because some calling points will be treated with a longer response time than 6 minutes; also that when we provide superfluous ambulances for an area with lower call volume like the remote countryside, enormous labor and money will have to be wasted. Furthermore, although the ambulance is outside the traffic rule, there are still many other factors associated with the response time such as bad weather, traffic jams, and the effectiveness of the ambulance site. In fact, it sometimes occurs that the ambulance has no other lane to finish overtaking. Therefore, we are able to determine the average speed of the ambulance with high accuracy. Finally, since not all points in an area are appropriate for the placement of the ambulance, we first identify all possible ambulance sites, and then through modeling, we can select the optimal distribution.

Second, we also perform considerable sensitivity analysis. We find that our modeling results are quite sensitive to the change in the value of parameters. Therefore, it is reasonable to indicate that our model is robust and applicable.

Finally, we have the confidence to assure you that our strategy is worth a try.

9 Reference

[1] http://www.shihang.org

[2] https://www.ithaca.com/news/high-call-volumes-cultural-issues-equal-high-stress-for-emergency/article_b1325ce6-2f97-11e8-a818-573327660413.html

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[4] Daijun Yin. “Research on Generalized Maximum Coverage Model in Application Facility Location”. Chinese & Foreign Entrepreneurs, 2010

[5] Zhifen Chen, et al. “Optimizing the Location and Layout of Urban Fire Station and Its Enlightenment to Xiongan New District”. Journal of Safety Science and Technology, 2018

[6] Wei Meng, et al. “Evaluation of Project Location Based on Analytic Hierarchy Process and Multi-factor Weighted Average Method”. Logistics Technology, 2018.

10 Appendix

10.1 Consistency Analysis

```matlab
disp('Please Enter the order of matrix A:');
A=input('A=');
[n,n]=size(A);
x=ones(n,100);
y=ones(n,100);
m=zeros(1,100);
m(1)=max(x(:,1));
y(:,1)=x(:,1);
x(:,2)=A*y(:,1);
m(2)=max(x(:,2));
y(:,2)=x(:,2)/m(2);
p=0.0001;i=2;k=abs(m(2)-m(1));
while   k>p
   i=i+1;
   x(:,i)=A*y(:,i-1);
   m(i)=max(x(:,i));
   y(:,i)=x(:,i)/m(i);
   k=abs(m(i)-m(i-1));
end
a=sum(y(:,i));
w=y(:,i)/a;
t=m(i);
disp(w);
```

```
CI=(t-n)/(n-1);RI=[0 0 0.52 0.89 1.12 1.26 1.36 1.41 1.46 1.49 1.52 1.54 1.56 1.58 1.59];
CR=CI/RI(n);
if CR<0.10
        disp('Pass the consistency verification!');
        disp('CI=');disp(CI);
        disp('CR=');disp(CR);
end
```

10.2 Solution Code

```python
import functools
from math import (log, sqrt, pi)
from openpyxl import (Workbook, load_workbook)
from types import (FunctionType, LambdaType)



class Point(object):  # make point
    def __init__(self, x: float = 0, y: float = 0):
        self.x = x
        self.y = y

    def __add__(self, other):
        return Point(self.x + other.x, self.y + other.y)

    def __sub__(self, other):
        return Point(self.x - other.x, self.y - other.y)



class PopulationDensity(Point):
    def __init__(self, p: Point, density: float):
        super().__init__(p.x, p.y)
        self.density = density



class Sites(Point):
    def __init__(self, p: Point, number: int, id: int):
        super().__init__(p.x, p.y)
        self.number = number
        self.id = id



def read_file(filename: str) -> list:  # read xlsx file
    wb = load_workbook(filename)
```

```python
    sheet = wb.active
    return [[cell.value for cell in row] for row in sheet.rows]


def ambulance_number(cv: int) -> int:  # ANM
    return int(1 if cv < 60 else (sqrt(cv) - 1.3 * sqrt(log(cv))) / 2.5 - 2)


def coverage_radius(**kwargs: object) -> float:  # CRM
    if "v" in kwargs and "t" in kwargs:
        m = {}
        for k in kwargs.keys():
            m[k] = kwargs.get(k, 0)
        return float((1 - m["a"]) * (1 - m["b"]) * (1 - m["c"]) * m["v"] * (m["t"] - m["st"] - m["rt"]))
    else:
        raise ValueError("need argument v,t")


def distance(p1: Point, p2: Point) -> float:
    return sqrt((p1.x - p2.x) ** 2 + (p1.y - p2.y) ** 2)


def triangle_area(a: float, b: float, c: float) -> float:
    p = 1 / 2 * (a + b + c)
    return sqrt(p * (p - a) * (p - b) * (p - c))


def polygon_area(profile: list) -> float:
    e: Point = profile[0]
    area: float = 0
    for i in range(1, len(profile) - 1):
        area += triangle_area(
            distance(e, profile[i]),
            distance(e, profile[i + 1]),
            distance(profile[i], profile[i + 1])
        )
    return area


def ambulance_sites(init_point: list, city_profile: list, r: float) -> list:
    area: float = polygon_area(city_profile)
    city_area = area
    selected_point = []
    while True:
```

```
        coverage_rate: float = 0
        max_coverage_rate: float = 0
        point: Point = Point()
        for p in init_point:
            rest_area: float = 0
            for p1 in city_profile:
                if distance(p, p1) < r:
                    rest_area = (1 / 4 * pi * (r - distance(p, p1)) ** 2)
            coverage_rate = (pi * r * r - rest_area) / area
            if max_coverage_rate < coverage_rate:
                point = p
                max_coverage_rate = coverage_rate
        init_point.remove(point)
        selected_point.append(point)
        area -= max_coverage_rate * area
        if area / city_area < 0.1:
            break
    return selected_point


def resolve() -> list:
    AN: float = ambulance_number(cv=2562)

    population_density: list = sorted([
        PopulationDensity(Point(x, y), d) for [x, y, d] in read_file("population_density.xlsx")
    ], key=lambda v: v[2])

    r: float = coverage_radius(
        a=0.1,
        b=0.4,
        c=0,
        v=32 * 1000 / 3600,
        t=6 * 60,
        st=45,
        rt=45
    )
    sites: list = ambulance_sites(
        init_point=[
            Point(a, b) for [a, b] in read_file("sites_position.xlsx")  # the data of
        ],
        city_profile=[
            Point(x, y) for [x, y] in read_file("city_profile.xlsx")
        ],
        r=r
```

```
    )
    SN = len(sites)
    ans: list = []
    if SN < AN:
        i = 0
        for p in sites:
            ans.append(Sites(p, id=i, number=1))
            i += 1
        t = AN - SN
        max_density = population_density[0:t - 1]
        while t > 0:
            for p in ans:
                for d in max_density:
                    if distance(p, d) < r:
                        p.number += p.number + 1
                        t -= 1
                        break
    elif SN == AN:
        i = 0
        for p in sites:
            ans.append(Sites(p, id=i, number=1))
            i += 1
    else:
        t = AN
        max_density = population_density[0:t - 1]
        while t > 0:
            for p in ans:
                for d in max_density:
                    if distance(p, d) < r:
                        p.number += p.number + 1
                        t -= 1
                        break
    return ans


if __name__ == "__main__":
    ans: list = resolve()
    print(ans)
```