Optimization of recovery strategy in emergency rescue phase of traffic network based on variable repair level

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Abstract: major disasters often cause varying degrees of damage to traffic sections and paralyze the traffic network, which not only brings hidden dangers to the safety of people's lives and property, but also makes rescue more difficult. Therefore, restoring the connectivity of the traffic network is the primary task. Based on the variable repair level of the road section, this paper proposes an optimization model of the recovery strategy in the emergency rescue phase, and uses "Monte Carlo simulation" to carry out 10 million cycles to obtain the optimal dispatch strategy and recovery strategy. Through the actual case analysis, it is concluded that the model in this paper can be applied to large-scale traffic network restoration projects and give efficient and reasonable rescue strategies.

Key words: recovery strategy; mixed integer nonlinear programming; Monte Carlo simulation; variable repair level; "S" curve

1. Introduction

The restoration of the traffic network after the disaster is a complex and long-term system engineering, and presents the characteristics of stage, path selection and maintenance scheduling. In the emergency recovery stage, due to the constraints of funds, resources and other conditions, the rescue work has to aim at restoring the connectivity of the critical path, but limited by the optimal rescue time, the decision-maker needs to determine the repair order of the critical path according to the rescue resources, objectives and so on[2]. The identification and selection of critical paths have been applied in many fields. Among the common problems applied to the evacuation and emergency supply of emergency traffic[3,4,6,9], Li Mi[3] and others studied how to identify the type of traffic path according to the solution equation of the emergency traffic assignment matrix according to the prediction of traffic demand in the case of emergency evacuation and material entry in the urban area. The identification and selection of critical paths are also needed in the recovery of the traffic network[2]. Based on the resilience engineering and network optimization theory, Li Zhaolong[2] and others used genetic algorithm and Frank Wolfe algorithm to solve the user equilibrium assignment problem to determine the critical path and recovery time sequence that need to be restored first. In the direction of emergency decision information extraction[5,14], which involves the identification and judgment of traffic section types, Zhao Qiansheng[5] and others studied the extraction of spatial entity object information in emergency decision-making in emergencies based on complex spatial relationship theory, including the judgment of road topology structure to identify the path. From the perspective of users, some scholars have studied the impact of traffic information on users' travel path selection. Liu Kai[7] and others have established a mixed user equilibrium model under the guidance of traffic information, taking into account the impact of inertial and non-inertial travelers on path selection.

The research background of this paper is the optimization of recovery strategy in the emergency rescue stage. The first problem to be solved is to find a suitable way to measure the completion of the rescue work and quantitatively express the rescue ability of the whole project. In the current study, the definition method of the measurement tool for the completion of the recovery problem is defined by the recovery time[1,2], cumulative cost[1,2], traffic demand[13]. Based on the resilience theory and from the perspective of network science, Li Zhaolong[1,2] and others defined new resilience indicators according to the recovery time and cumulative loss to measure the completion of the rescue work, and studied the recovery strategy of the traffic network in the emergency rescue stage. Referring to the definition method of resilience, this paper defines "rescue capability" and applies it to measure the completion of rescue work.

In addition, during the recovery of traffic sections, the recovery process usually meets the "S" type recovery curve function. Due to the diminishing marginal effect, when the connectivity of the recovered sections is closer to 100%, the marginal recovery degree is lower. Considering that under the time constraint of the emergency recovery phase, the primary task is to restore the necessary connectivity of the road section, so the repair work of each road section does not need to be completed to 100%. On the premise of ensuring the necessary connectivity of the road section, the marginal reduction of the recovery degree should be avoided as far as possible to ensure the maximum repair efficiency. Based on the fact that the recovery process of the road section meets the "S" curve function, this paper quantifies the recovery process, puts forward the recovery concept of "variable repair level", makes a decision on the recovery degree of each damaged road section, and obtains the recovery strategy of each damaged road section.

2. Model and method

2.1 Variable setting

The sets and parameters involved in the model in this paper are shown in Table 1, including three sets: the damaged road section set, the rescue team set, and the OD pair set of the traffic network. The parameter contains a fixed upper or lower bound in the model constraint. At the same time, the model includes some calculation variables, as shown in Table 2. The calculation variables are calculated by decision variables and parameters. There are two kinds of decision variables in the model: dispatch variable and recovery variable.

Table 1: definition of set and parameter symbols

Symbol	Meaning
Aggregate	
$A=\{1,2,\ldots,i\}$	The collection of damaged sections in the traffic network, where each section is represented by i;
$K=\{1,2,\ldots,j\}$	The rescue teams are assembled, and each rescue team unit is represented by j;
$W=\{1,2,\ldots,w\}$	The set of OD pairs in the damaged traffic network, where each OD pair is represented by w;
Parameter	
M	Total OD pairs of the road network;
c_i	Capacity of section i;
$f_i(t)$	The flow of section i;
u	The parameter of the constant term of the link recovery function;
r	The parameter of the constant term of the link recovery function;
m	The balance denominator value, set as the minimum value;
$recovery\_initial_i$	The state of section i before rescue;
$z_{i,w}$	Indicates whether section i belongs to w, if it is included in w, the value is 1, otherwise it is 0;
Imp_{set}	The lower limit of the total importance of the repaired road section;
$Congest_{set}$	Set the lower limit of the total congestion degree of the repaired road section;
$Ttravel_i^{freeflow}$	Free flow travel time of section i;
recovery_{set}	The degree to which the set road section should be restored;
$\text{recovery}\_ave_{set}$	The average recovery degree to which the set total road section should be restored;
$length_i$	Length of section i;
$adjust\_index_i$	The adjustment coefficient of the recovery degree function of road section i to ensure that the function passes through the (0,$recovery\_initial_i$) point;
$distance_{i,j}$	The flight distance from the rescue base station j to the section i;
T_{limit}	Total time constraints;
$cost\_fix_i$	Fixed repair cost of section i;
$cost_{limit}$	Total cost constraints;

Table 2: symbolic definitions of calculation variables and decision variables

Symbol	Meaning
Calculated variable	
$\text{recovery}_i(t)$	The recovery function of section i, which changes with time t;
$Trepair_i$	Repair time of section i;
$Tfly_{i,j}$	The flight time of the rescue base station j transporting the rescue unit to the road section i;
Imp_i	Importance of section i;
$Ttravel_i(t)$	Travel time of section i, the function of flow ;
$Congest_i$	Congestion degree of section i;
$Trepair\_total_i$	The time spent of road section i recovering from 0 to ;
$Trepair\_initial_i$	The time spent of road section i recovering from 0 to ;
cost_i	Repair cost of section i;
Decision variable	
x_total_i	The total number of rescue units dispatched by the rescue base station to section i;
$x_{i,j}$	Number of rescue units dispatched by rescue base station j to section i;
recovery_total_i	The final recovery degree of section i;

2.2 Index definition

2.2.1 Define the repair time of damaged road sections

In this paper, the recovery process of the damaged road section is described as an “S” curve, so the function of the whole recovery process with respect to time is a classical sigmoid function, and the following relationship is obtained:

$$\text{recovery}_i(t) = \frac{u}{u + e^{r-t}} \qquad (1)$$

Where u and r are the constant parameters of the function. Affected by the actual situation, the constant terms of the numerator and denominator in the function should be equal. In the initial state, the recovery degree of section i is.

According to formula (1), the calculation formula of repair time can be obtained:

$$Trepair_i = r - \ln(\frac{u}{\text{recovery}_i} - u) \qquad (2)$$

For the convenience of calculation, the values of parameters u and r in the function are all 1.

In this paper, the rescue base station dispatches different numbers of rescue units to the damaged road section, so the rescue and repair speed of each road section varies according to the number of dispatched rescue units and the attributes of the road section. In this paper, the total number of rescue units and the length of the road section itself are selected as two parameters of the function to affect the repair speed of the road section. When the length of the road section is longer, the repair speed is slower. Therefore, we get the repair function of the road section as follows:

Therefore, the formula of road repair time is obtained:

$$\begin{aligned}\text{recovery}_i(t) &= \frac{u * x\_total_i}{u * x\_total_i + e^{r*adjust\_index_i - \frac{t}{length_i}}} \\ &= \frac{x\_total_i}{x\_total_i + e^{adjust\_index_i - \frac{t}{length_i}}}, i \in A\end{aligned} \qquad (3)$$

2.2.2 Definition of rescue capability

Considering that the overall goal is to recover as many damaged sections as possible within the "prime time", so as to maximize the connectivity of the traffic network, this paper takes the total time spent by the rescue team in the rescue process, including the rescue time and the time spent by the rescue team from the base station to the designated section, as the embodiment of the rescue ability of the whole system engineering:

$$\text{Recapability} = \sum_{i \in A} \frac{1}{(Trepair_i + \sum_{j \in K} Tfly_{i,j})} \qquad (4)$$

2.3 Model description

The overall objective of the model is to maximize the rescue capability, so the objective function of the model is:

$$MAX = \text{Recapability} * \frac{x\_total_i}{x\_total_i + m} \qquad (5)$$

Considering that in the rescue strategy, not all road sections may be repaired by the rescue team during the "golden rescue time", the formula is set $\frac{x\_total_i}{x\_total_i + m}$, where m is the minimum value; when section i is sent to the rescue team for repair, the formula value is infinitely close to 1; when there is no rescue team to repair, the formula value is 0.

At the same time, the model meets the following constraints:

$$x\_total_i = \sum_{j \in K} x_{i,j}, \forall i \in A \qquad (6)$$

Constraint (6) defines the decision variable. The value of x_total_i is the total number of rescue units dispatched for section i, including the rescue units of each rescue base station.

$$Imp_i = \frac{\sum_{w \in W} z_{i,w}}{M}, \forall i \in A \qquad (7) \qquad\qquad \sum_{i \in A}\left(Imp_i * \frac{x\_total_i}{x\_total_i + m} \right) \geq Imp_{set} \qquad (8)$$

Constraint (7) defines the calculation method of the importance degree of road section i, which means that the number of OD pairs included in road section i accounts for the proportion of all OD pairs. When the importance degree value is greater, it means that road section i is included by more OD pairs, and road section i is more likely to be the key road section of the traffic network, so the whole traffic network is more likely to pass through road section i. Constraint (8) means that the sum of the importance of all repaired damaged sections must be at least at the level of Imp_{set}, the constraint guides the rescue team to repair the road sections with high importance as much as possible, that is, the key road sections.

$$Ttravel_i(t) = Ttravel_i^{freeflow} * (1 + h * (\frac{f_i(t)}{c_i})^g), i \in A \qquad (9) \qquad\qquad Congest_i = \frac{Ttravel_i(t)}{Ttravel_i^{freeflow}} = (1 + h * (\frac{f_i(t)}{c_i})^g), i \in A \qquad (10)$$

$$\sum_{i \in A}\left(Congest_i * \frac{x\_total_i}{x\_total_i + m} \right) \geq Congest_{set} \qquad (11)$$

Constraint (9) uses the BPR function to define the link travel time, where $Ttravel_i^{freeflow}$ is the free flow passage time of section i, $f_i(t)$ is the real-time flow of section i, C_i is the capacity of section i, and h and g are the parameters of the function itself; constraint (10) defines the congestion degree of section i as the ratio of the travel time of section i to the free flow travel time; constraint (11) means that the total congestion degree of all repaired sections should be within the level of $Congest_{set}$, the constraint guides the rescue team to repair the road sections with high congestion as much as possible.

$$\text{recovery}\_total_i * \frac{x\_total_i}{x\_total_i + m} \geq \text{recovery}_{set}, \forall i \in A \qquad (12)$$

$$\frac{\sum_{i \in A} \text{recovery}\_total_i}{road\_number} \geq \text{recovery}\_ave_{set} \qquad (13)$$

$$\text{recovery}\_initial_i \leq \text{recovery}\_total_i \leq 1, \forall i \in A \qquad (14)$$

Constraint (12) indicates that the final recovery degree of all repaired sections shall be within recovery_{set}. Constraint (13) indicates that the average value of the final recovery degree of all road sections should be within $\text{recovery}\_ave_{set}$. Constraint (14) specifies the value range of decision variables recovery_total_i.

According to formula (3), $\text{recovery}\_initial_i$ equals to $\text{recovery}_i(0)$. Therefore, the constraint is satisfied:

$$\frac{x\_total_i}{x\_total_i + e^{adjust\_index_i}} = \text{recovery}\_initial_i, \forall i \in A \quad (15)$$

Constraint (15) makes the recovery function always meet the initial value of $\text{recovery}\_initial_i$.

$$\sum_{i \in A} x_{i,j} = engineer\_number, \forall j \in K \qquad (16)$$

Constraint (16) means that all rescue units in the rescue base station are dispatched to participate in the rescue work.

$$Trepair\_total_i = length_i * (\ln(\frac{\text{recovery}\_total_i}{1 - \text{recovery}\_total_i}) - \ln(x\_total_i) + adjust\_index_i), \forall i \in A \quad (17)$$

$$Trepair\_initial_i = length_i * (\ln(\frac{\text{recovery}\_initial_i}{1 - \text{recovery}\_initial_i}) - \ln(x\_total_i) + adjust\_index_i), \forall i \in A \quad (18)$$

$$Trepair_i = Trepair\_total_i - Trepair\_initial_i, \forall i \in A \qquad (19)$$

$$Tfly_{i,j} = \frac{\text{distance}_{i,j}}{flyspeed}, \forall i \in A, \forall j \in K \qquad (20)$$

$$\sum_{i \in A} \left[\left(Trepair_i + \sum_{j \in K} Tfly_{i,j} \right) * \frac{x\_total_i}{x\_total_i + m} \right] \leq T_{\text{limit}} \quad (21)$$

Formula (17) gives the repair time of section i from complete damage to the final recovery degree. Formula (18) gives the repair time of section i from complete damage to initial recovery. Formula (19) gives the true repair time of the road section from the initial recovery degree to the final recovery degree. Formula (20) gives the flight time of the rescue unit from the rescue base station to the designated repair section i. Constraint (21) such that the total repair time of all repaired sections and the flight time to reach the sections must be within the "golden rescue time" T_{limit}.

$$\text{cost}_i = index * Trepair_i + \text{cost}\_fix_i, \forall i \in A \qquad (22)$$

$$\sum_{i \in A} \left(\text{cost}_i * \frac{x\_total_i}{x\_total_i + m} \right) \geq \text{cost}_{\text{limit}} \qquad (23)$$

Formula (22) gives the repair cost of each section i, including fixed cost and variable cost, and the repair cost is a function of repair time. Constraint (23) is a cost constraint, so that the total repair cost of all repaired sections shall not exceed the cost constraint value $\text{cost}_{\text{limit}}$.

2.4 Optimization model

In this model, due to the decision variable $x_{i,j}$ is the number of rescue units dispatched by the rescue base station j to the road section i, and the decision variable $x_{i,j}$ is the total number of rescue units dispatched by the rescue base station to section i, so the values of the above two decision variables should be integers. Among the constraints, some constraints include the calculation of multiplication between decision variables, so they comply with nonlinear constraints. To sum up, this paper uses the mixed integer nonlinear programming (MINLP) method

$$MAX = \text{Recapability} * \frac{x\_total_i}{x\_total_i + m} = \sum_{i \in A} \frac{1}{(Trepair_i + \sum_{j \in K} Tfly_{i,j})} * \frac{x\_total_i}{x\_total_i + m}$$

$$s.t.\begin{cases} x\_total_i = \sum_{j \in K} x_{i,j}, \forall i \in A \\ Imp_i = \frac{\sum_{w \in W} z_{i,w}}{M}, \forall i \in A \\ \sum_{i \in A} \left(Imp_i * \frac{x\_total_i}{x\_total_i + m} \right) \geq Imp_{set} \\ Ttravel_i(t) = Ttravel_i^{freeflow} * (1 + h * (\frac{f_i(t)}{c_i})^g), i \in A \\ Congest_i = \frac{Ttravel_i(t)}{Ttravel_i^{freeflow}} = (1 + h * (\frac{f_i(t)}{c_i})^g), i \in A \\ \sum_{i \in A} \left(Congest_i * \frac{x\_total_i}{x\_total_i + m} \right) \geq Congest_{set} \\ \text{recovery}\_total_i * \frac{x\_total_i}{x\_total_i + m} \geq \text{recovery}_{set}, \forall i \in A \\ \frac{\sum_{i \in A} \text{recovery}\_total_i}{road\_number} \geq \text{recovery}\_ave_{set} \\ \text{recovery}\_initial_i \leq \text{recovery}\_total_i \leq 1, \forall i \in A \\ \frac{x\_total_i}{x\_total_i + e^{adjust\_index_i}} = \text{recovery}\_initial_i, \forall i \in A \\ \sum_{i \in A} x_{i,j} = engineer\_number, \forall j \in K \\ Trepair\_total_i = length_i * (\ln(\frac{\text{recovery}\_total_i}{1 - \text{recovery}\_total_i}) - \ln(x\_total_i) + adjust\_index_i), \forall i \in A \\ Trepair\_initial_i = length_i * (\ln(\frac{\text{recovery}\_initial_i}{1 - \text{recovery}\_initial_i}) - \ln(x\_total_i) + adjust\_index_i), \forall i \in A \\ Trepair_i = Trepair\_total_i - Trepair\_initial_i, \forall i \in A \\ Tfly_{i,j} = \frac{\text{distance}_{i,j}}{flyspeed}, \forall i \in A, \forall j \in K \\ \sum_{i \in A} \left[\left(Trepair_i + \sum_{j \in K} Tfly_{i,j} \right) * \frac{x\_total_i}{x\_total_i + m} \right] \leq T_{\text{limit}} \end{cases}$$

$$\begin{cases} \cos t_i = index * Trepair_i + \cos t\_fix_i, \forall i \in A \\ \sum_{i \in A} \left(\text{cost}_i * \frac{x\_total_i}{x\_total_i + m} \right) \geq \text{cost}_{\text{limit}} \end{cases}$$

3. Experimental design

In this case, a regional traffic road network is used, and the network information of the traffic road network is generated according to the GIS model, as shown in the figure. The whole network includes 62 nodes and 122 traffic roads. The area surrounded by the dotted line belongs to the disaster affected area. The disaster occurs in the center of the dotted line area, which involves 30 traffic roads. Therefore, the research object of this paper is the 30 damaged roads in the affected area, that is, the red section in the figure. In addition, the rescue base station involved in this paper is randomly set as a red dot area in the figure. Specifically, at node 8, the rescue base station transmits rescue units to 30 damaged roads in the affected area.

According to the attribute data of road sections, the calculation variables in the model are calculated. When the disaster occurs, 30 road sections in the affected area are damaged to varying degrees. Other parameter settings: the value of Imp_{set} is 0.5; the value of $Congest_{set}$ is 39; the value of recovery_{set} is 0.6; the value of $\text{recovery}\_ave_{set}$ is 0.5; the value of T_{limit} is 150; the value of $\text{cost}_{\text{limit}}$ is 1500.

In addition, the number of rescue units sent by the rescue base station to the damaged road section is 450. In the following case results, because this case is solved by MATLAB nonlinear programming, the selection of initial value has a certain impact on the operation results, so the effectiveness of finding initial value before and after using the “Monte Carlo simulation” algorithm is verified later.

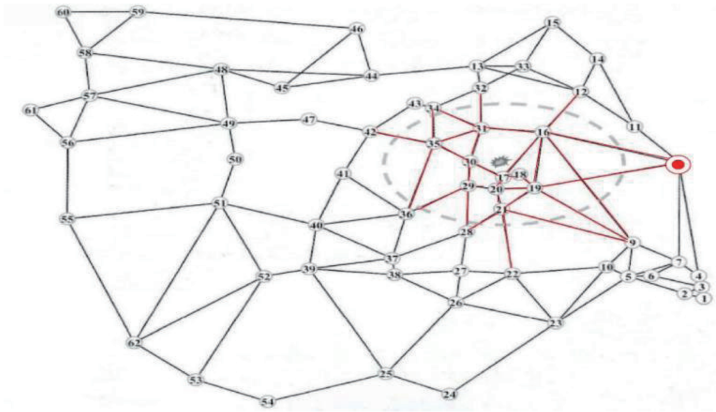

Figure 1: GIS model case diagram

4 Experimental results and analysis

In this case, the "Monte Carlo method" is used to set the number of iterations to 10 million, and define a 10 million random array within its own value range for each decision variable, and take the initial value according to the constraint conditions in the cycle.

The initial policy set is obtained through operation:

Table 3: initial value of Monte Carlo simulation dispatch strategy

x_total_i	Value	x_total_i x_total_i	Value	x_total_i	Value
X (1)	1.554407494	X (11)	1.609000726	X (21)	19.84717905
X (2)	24.2251207	X (12)	8.279677357	X (22)	11.83568896
X (3)	9.370208996	X (13)	9.204132041	X (23)	3.704922722
X (4)	3.548348638	X (14)	18.64496581	X (24)	20.59989943
X (5)	3.133330011	X (15)	19.18369028	X (25)	15.86998046
X (6)	15.49735847	X (16)	10.20490364	X (26)	0.333362369
X (7)	11.90010287	X (17)	19.89667523	X (27)	7.506127636
X (8)	2.957039059	X (18)	14.11513272	X (28)	18.24105002
X (9)	23.19357967	X (19)	24.77268866	X (29)	8.035176815
X (10)	17.42097752	X (20)	18.5174372	X (30)	7.249942984

Table 4: initial values of Monte Carlo simulation repair strategy

recovery_total_i	Value	recovery_total_i	Value	recovery_total_i	Value
Recovery (1)	0.7078	Recovery (11)	0.3318	Recovery (21)	0.4507
Recovery (2)	0.5817	Recovery (12)	0.9210	Recovery (22)	0.8294
Recovery (3)	0.8217	Recovery (13)	0.5949	Recovery (23)	0.4101
Recovery (4)	0.2751	Recovery (14)	0.5769	Recovery (24)	0.6759
Recovery (5)	0.7779	Recovery (15)	0.4286	Recovery (25)	0.5449
Recovery (6)	0.7630	Recovery (16)	0.7450	Recovery (26)	0.4886
Recovery (7)	0.4525	Recovery (17)	0.3561	Recovery (27)	0.9723
Recovery (8)	0.4677	Recovery (18)	0.6335	Recovery (28)	0.4091
Recovery (9)	0.7542	Recovery (19)	0.5508	Recovery (29)	0.7338
Recovery (10)	7.2499	Recovery (20)	0.9555	Recovery (30)	0.6958

According to the initial value obtained from "Monte Carlo simulation", it is substituted into the nonlinear programming solution. When the iteration reaches 3000 times, the operation stops and reaches the upper limit of the operation. Finally, the repair strategy is obtained as follows:

As shown in Figure 2, in the dispatch strategy finally obtained from the initial value obtained through "Monte Carlo simulation", the dispatched rescue units in sections 2, 9 and 19 are basically at the level of 24 rescue units, and the corresponding actual sections are sections 18, 37 and 47. At the same time, sections 4, 11, 23 and 26 are basically not dispatched by rescue units, and the corresponding actual sections are sections 21, 39, 66 and 69.

Let's take a look at the recovery strategy obtained through "Monte Carlo simulation":

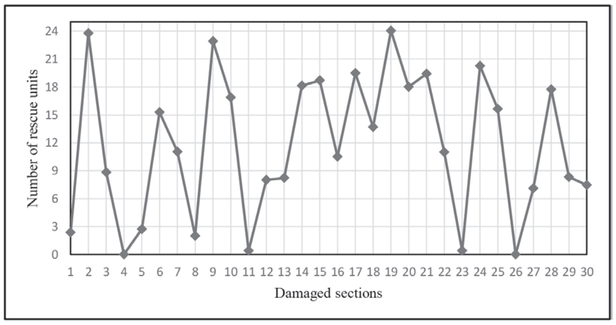

Figure 2: Monte Carlo simulation dispatch strategy diagram

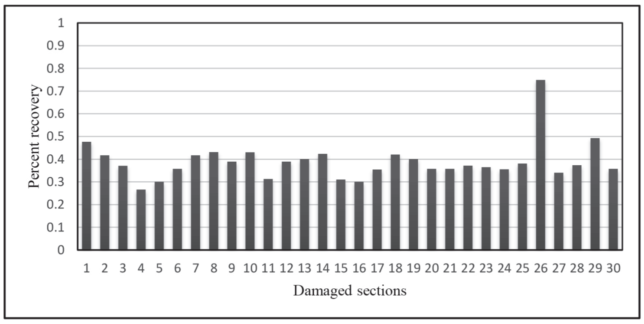

Figure 3: schematic diagram of Monte Carlo simulation recovery strategy

As shown in Figure 3, the final recovery strategy of 30 damaged road sections remains at the level of 30%, of which the final recovery level of road section 26 is 74.85%, corresponding to the actual road section 69.

The final objective function value is 2.1171, and the corresponding rescue ability is 47.23%.

5. Conclusion and prospect

Based on the variable repair level, this paper establishes the optimization model of the recovery strategy of the traffic network in the emergency rescue stage, which solves the problems of resource allocation and road repair level in the recovery process of the traffic network. At the same time, this paper has made the following innovations and contributions:

(1) In this paper, the mixed integer nonlinear programming method is used to establish the optimization model of the recovery strategy in the emergency rescue stage of the traffic network based on the variable repair level. The feasibility of the model is proved by the case study using the “Monte Carlo simulation” algorithm, so that the necessary connectivity of more sections can be restored as much as possible in the “golden rescue time”;

(2) Based on the nature of the “S” type recovery curve of the damaged road section, this paper functions the relationship between the “recovery degree” and “time” of the road section, so as to quantitatively calculate the “repair time” of the road section;

(3) Based on the nature of the “S” type recovery curve of the damaged road section, this paper proposes the variable repair level of the road section, that is, the repair of the road section does not need to be repaired to 100%, and makes the repair degree controllable.

Through the analysis of the case, the corresponding dispatch strategy and recovery strategy are obtained. The results of the case show that the model and the “Monte Carlo simulation” algorithm applied in this paper can be applied to large-scale traffic network disaster relief and recovery projects, and can give a more reasonable and effective strategy. And through the “Monte Carlo simulation” 10 million times of cycle simulation, the results are more practical.

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Simplifying the complex and abstract concept of calculus -- Taking the concept of limit as an example

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Abstract: calculus is a very important content of higher mathematics, and it is also a compulsory course of basic economic mathematics for some economics and management majors. However, the concept of calculus is very abstract, and there are many symbols in the concept, so the concept of calculus has always been a difficulty in teaching and students' understanding. Therefore, when most students learn calculus, they begin to have irresistible resistance from the concept, which leads to the gradual decline of their enthusiasm for calculus learning. Therefore, the teaching of calculus abstract concept is very important. We should try to instantiate the abstract concept, integrate theory with practice, make the abstract concept easy to understand, and pave the way for the subsequent study of calculus content, so that students can experience the wonder and fun of mathematics in their future study.

Key words: calculus; Abstract concept of calculus; Instantiation of abstract concepts; Integrating theory with practice

1 The origin of calculus

Calculus is a branch of mathematics that studies the differentiation and integration of functions and related concepts and applications. It is a basic subject of mathematics. Calculus was born in the 17th century, mainly from the huge impetus of politics, economy and society to mathematics. At that time, mathematicians could not solve the following problems: finding area, volume and acceleration; In solving these practical problems, a series of explorations and researches were gradually produced, such as solving tangent problems and extreme value problems. Then in the second half of the 17th century, calculus was initially formed through the improvement of Newton and Leibniz, and it was not until the 19th century that the theory of calculus was improved and used today.

The limit thought in calculus, as early as the 3rd century A.D., has been produced in ancient China. At that time, when the famous mathematician Liu Hui calculated the PI, he created the circle cutting technique, which is the typical application of limit thought. Liu Hui pointed out that the circumference of a circle consists of multiple positive 6×2N-1 is composed of the perimeter of the side shape. With the constant increase of the coefficient n, this value is also infinitely close. To verify this conclusion, he set the circumference of the circle as s and inscribed the circle with 6×2N-1 regular polygon is set as Si (i=1,2, n). With the constant increase of coefficient n, S1, S2,... Sn form a sequence of numbers. When the value of n is larger, the error between the circumference of the inscribed regular polygon and the

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