Research on Optimization Algorithm of Traffic Control during Urban Emergency Rescue

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Abstract

Traffic control during urban emergency rescue is conducive to the rapid rescue of the affected areas, but excessive control scheme will have negative impacts. This paper proposed an innovative idea to optimize the traffic control scheme during emergency rescue, constructed temporary traffic control model -fMTCE for meeting the requirements that the emergency supplies arrive at disaster area in time as well as minimizing the impact of social order, introduced the gravity model to improve the travel time function, and gave the optimal temporary control scheme based on genetic algorithm. Results show that the fMTCE model is efficient which can reduce the negative impact of the control scheme while meeting demands of the rescue.

Keywords

Urban emergency rescue, Traffic control, Optimization algorithm.

1. Introduction

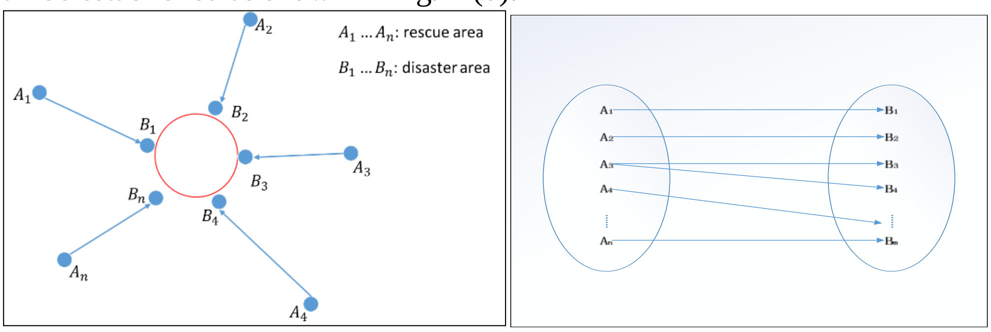
Rapid development of social economy makes urban traffic become more complex and difficult to control. Especially in cases of emergency, traffic would fall into chaos if lacking effective response measures. To ensure sufficient supplies are delivered timely to the disaster area, authorities often take temporary traffic control. Without effective dispersion the accident will bring massive traffic flow increase and cause adverse effects like traffic congestion. Appropriate management and control help personnel evacuation and supplies transportation. However, if control scheme is designed extensively, control type and control time expand randomly, the negative effects will be more obvious. Therefore, in terms of protecting public travel rights authorities need urgently more intelligent and scientific approaches.

Domestic and foreign scholars conducted lots of research on the traffic management and optimization problems under normal conditions, and achieved fruitful results. But so far, few scholars launched in-depth study to temporary traffic control as the optimization goal. After summing-up relevant research results in recent years, it can be roughly split into the following cases.(1) Wang Wei, Ren Gang etc[1][2]. studied in detail the optimization of urban traffic control/management scheme under normal conditions and did important pioneering work; Hong K L[3] stated the necessity of traffic control in rescue process; Chen Qun[4], GuoRenyong[5] etc. took the traffic planning and assignment model after banning left turn into consideration; Qian Yongsheng[6] discussed the setting of highway control measures in abnormal circumstances; GaoYunfeng[7] etc. researched the impact of design of intersection traffic lights on emergency supplies transportation. Although the above researches provided theoretical foundation for traffic control study, they didn't involve the special circumstance of temporary traffic control in emergency events. (2) ShenJinsheng[8], Hu Yunchao[9] studied the impact of urban traffic control on urban distribution optimization. Such studies involved temporary traffic control and also proposed feasible control scheme, but didn't consider the characteristics of temporary control scheme and its optimizability. (3) Feng [10] introduced traffic control factors and built the bi-level programming, multi-target traffic control model against the background of Taiwan “9.21” earthquake, but which only considered controlling in and out of different vehicles while neglecting the social impact that control may bring; Ma Zujun and Li Shuanglin[11] established the emergency supplies scheduling optimization scheme against the background of Wenchuan “5.12” earthquake, which considered effects of the traffic control such as least emergency time and least disturbance, but didn’t consider key issues like importance and controllability of the road section. Maria A[12] built the traffic control model for supplies transportation and personnel evacuation based on frequent earthquake in southern Greece, which is the latest study but didn’t consider social impact either. Meanwhile, there aren’t any new research findings in outlining temporary control territory, choosing control method, optimizing control time as well as the impact of intersection turning etc.

Based on the above analysis, we proposed a balanced temporary traffic control model- fMTCE (Fixed Metropolitan Traffic Control and Equilibrium Model) which can meet both the requirements that the emergency supplies arrive at disaster area in time as well as minimizing the impact of social order. To achieve this goal, this paper designed several control styles, introduced vertex and edge betweenness indexes to evaluate the controllability of road sections, introduced the gravity model to improve the travel time function, and gave the optimal temporary control scheme based on improved genetic algorithm. Results show that fMTCE model can give the temporary traffic control optimization scheme efficiently which can greatly reduce the negative impact of the control scheme while meeting demands of the rescue.

2. Traffic Control Model

After a sudden emergency, authorities need to arrange relief workers and supplies in very short time. As shown in Fig. 1 (a), we divide the city area into rescue area and disaster area, and rescue areas provide supplies to disaster areas. Define retrieval spots set as A, and supplies reception spots (disaster area) as B. According to the principle of proximity, the rescue relationship from elements in set A to B can be established as shown in Fig. 1 (b).



(a) (b)

Fig. 1 Corresponding support relationship between outer rescue area and disaster area

Definition 1 Emergency path: is a unidirectional channel between the rescue spot and disaster spot to make sure rescue vehicles pass through the complex road network quickly in the limited time. Road sections included in the emergency path are called emergency sections, and the cross nodes among Roads sections are called emergency nodes. Use binary group($epath^*_{o,d}, cp^*_{o,d}$)to represent optimal temporary control scheme of the system, in which $epath^*_{o,d}$ is the emergency path corresponds to start and end points od of the supplies, and $cp^*_{o,d}$is the optimal control scheme for the path.

Definition2 Control Domain (CD in short) means the emergency path in control as well as the network structure composed of road sections and junctions directly connected to the path. In Fig. 2, red junctions and sections make up the emergency path and road sections and junctions directly connected to the path (dot line) which are directly affected by control measure are counted into control domain together. While area outside the control domain is social vehicles’ main bypass area and called diverging area in this paper. Area out of diverging area is little affected by the control and usually not considered. In this paper we call it outer area.

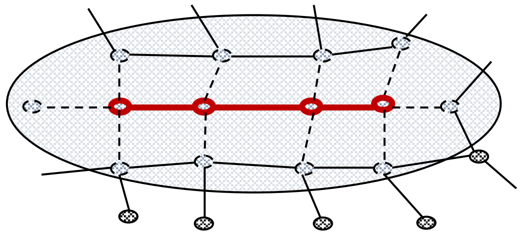


Fig. 2 Sketch map of the control area

Definition3 Control node: means the cross points in control domain CD. As shown in Fig. 2, nodes in the dash area are called control nodes. We use triple group vnode:=<pos, CVB-SP, pd, degree> to represent the control node, in which pos means nodal co-ordinate, CVB-SP means vertex betweenness of the node, pd is the population density index around the node, and degree is degree of the node. Vertex betweenness [13] of node i can be calculated with (1).

$$CV_{B-SP}(i) = \sum_{s,t\in L,s\neq t} \frac{\sigma_{st}(i)}{\sigma_{st}} \quad (1)$$

In (1), σ_{st} is the number of shortest paths from node s to t, $\sigma_{st}(i)$ is the number of paths above via node i. The larger the betweenness is, the more important the node is in network. Pd is rounded to 1~4, representing the population density around the node, which means small, normal, dense and very dense population in turn.Now we define the importance of node i as (2).

$$vip_i = \alpha_1 CV_{B-SP}(i) + \alpha_2 \frac{pd_i - avg(pd)}{\max(pd)} \quad (2)$$

In (2), pdi means population density of node i, avg(pd)means the average population density of all nodes, max(pd)means the biggest population density where $\alpha_1, \alpha_2 > 0$ and $\alpha_1 + \alpha_2 = 1$. Generally, $\alpha_1$is equal to 0.8 and α_2 is equal to 0.2.

Definition4 Control style of road section: used to restrict permission for social vehicles in control domain CDto pass through the road section. As shown in Fig. 3, this paper designs three kinds of control styles: no control (0), partial control (1) and total control (2). Partial control means emergency vehicles using the dedicated lanes, while social vehicles can only use partial of the rest roads in order to try to reduce the negative effect brought by the control. In terms of control strength, total control has greatest influence to social vehicles, partial control takes second place and no control is the least. Therefore, from the perspective of reducing social impact, total control should be restrictively used.

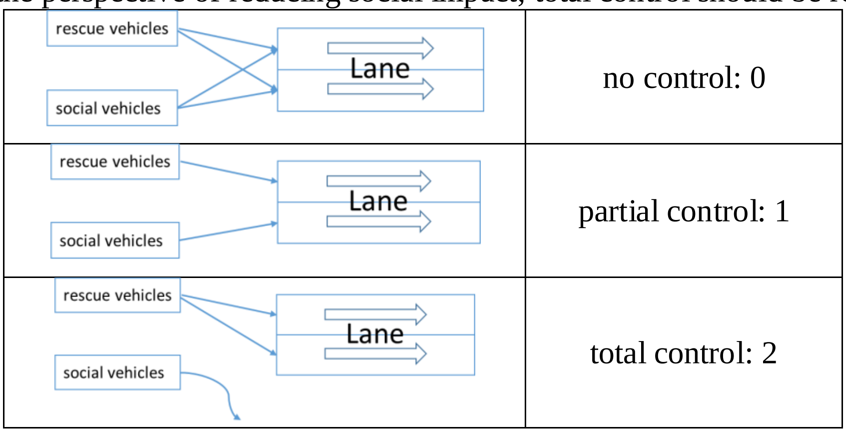


Fig. 3 Control style of road section

3. Traffic Control Model

3.1 Problem Formulation

Set $G = (N, L)$as the road network, N is the set of all nodes and n is the count of all nodes. L is the set of all directed sides (road sections) and l is the count of sides. Suppose that all roads are bidirectional. Define node d as the disaster spot and node o as the rescure spot, xo is supplies amount of node o provided to node d. Define the limitied time of node d for supplies as R>0.Divide node d into two complementary sub-graphs - diverging area G' (no control) and control domain CD, where

$G' = (N', L'), CD = (N'', L'')$. Obviously $N = N' \cup N'', L = L' \cup L''$. Some symbols are defined as follows: (1) cSytlei,j:control style of road <i,j>, 0 means no control, 1 partial control and 2 total control, $< i,j > \in L''$; (2) cIntensityi,j:control intensity of road section <i,j>, $cIntensity_{i,j} \in [0,1]$, $< i,j > \in L''$;(3)eL: set of all emergency sections in emergency path;(4)eL_s : set of all sections that are identified as control style sin some emergency path, s=0~2, meaning control style 0, 1 and 2; (5)$socL$: set of all sections that social vehicles can drive in, $socL = L - eL_2$;(6)$\bar{x}_{i,j}$: traffic flow of road section <i,j> in normal situation, $< i,j > \in L$;(7)$x_{i,j}$: traffic flow of road section <i,j>under control, $< i,j > \in L$;(8)$C_{i,j}$:traffic capacity of road section <i, j>, $< i,j > \in L$;(9)deltx: traffic flow increase caused by rescue vehicles on the emergency path during control; (10) MaxCT: max control time that our society can endure;(11) MaxTol: max tolerance that society have to endure; (12)$\bar{t}_{i,j}$: time needed to pass through road section <i,j>in normal situation, $< i,j > \in L$;(13)$soc\_t_{i,j}$: time needed for social vehicles to pass through road section <i,j>during control, $< i,j > \in L$;(14)$eme\_t_{i,j}$:time needed for emergency vehicles to pass through road section <i,j>during control, $< i,j > \in L''$;(15)φ: psychological impact factorof control, referring to the percentage that control makes social vehicles bypass, $\varphi \in (0,1)$.

3.2 Mathematical Model

Based on above, the optimization model for the problem is built as below

$$min\, z_1 = Tol = \frac{1}{M} \sum_{<i,j> \in L} (soc\_t_{i,j} - \bar{t}_{i,j}),\ \text{M>1} \tag{3}$$

s.t.

$$Ct = \sum_{<i,j> \in epath_{o,d}} eme\_t_{i,j} + \max(eme\_t_{i,j} | < i,j > \in epath_{o,d}) \le R \tag{4}$$

$$MaxCT \ge 0 \tag{5}$$

$$MaxTol \ge 0 \tag{6}$$

$$R \ge 0 \tag{7}$$

$$Tol \le MaxTol \tag{8}$$

$$Ct \le MaxCT \tag{9}$$

$$cIntensity_{i,j} = \begin{cases} 0 & , cStyle_{i,j} = 0 \\ loc & , cStyle_{i,j} = 1, < i,j > \in L'', loc \in (0,1) \\ 1 & , cStyle_{i,j} = 2 \end{cases} \tag{10}$$

(3) is the objective function to minimize disturbance degree, which describes the degree by comparing the changes of road impedance before and after the control; (4) is used to calculate control time, the first part is the time needed for vehicles to pass through the emergency path, the second part is the longest time to pass through all road sections of the emergency path, and the sum is defined as control time of any section, which ensures emergency supplies can be delivered to the disaster area within time limit R; (5) is the nonnegative constraint of the max control time; (6) is the nonnegative constraint of the max disturbance degree; (7) is the nonnegative constraint of the time limit for emergency supplies delivery; (8) ensures that the disturbance degree not exceed tolerance MaxTol; (9) ensures the control time not exceed the MaxCT; (10) means control intensity of the road.

4. Determination of Control Style and Travel Time Function

4.1 Selection of Control Style

Edge betweenness of road section<i, j>is used to describe its importance in the road network, as shown in formula (11).

$$CA_{B-SP}(i,j) = \sum_{s \ne t, s,t \in L} \frac{\tau_{st}(i,j)}{\sigma_{st}} \tag{11}$$

Definition of $\sigma_{st}$is same as formula (1), and $\tau_{st}(i,j)$ is the path number that via road section<i, j>among the shortest paths between nodes s and t. Obviously, the larger edge betweenness is, the more importance the road section is in the road network. When selecting the control style, we need to fully consider the edge and vertex betweenness and its environmental characteristics. Based on formula (11), define its importance index in the road network.

$$sip_{i,j} = \beta_1 CA_{B-SP}(i,j) + \beta_2 vip(i) + \beta_3 vip(j) \tag{12}$$

In (12), we define $\beta_1, \beta_2, \beta_3 > 0$ and $\beta_1 + \beta_2 + \beta_3 = 1$. The bigger the population density around the road, the greater the traffic flow it takes and the more importance the road section is. Important sections are suitable for looser control type, because though strict one is conducive to rescue vehicles pass-through, it can have bad influence to more social vehicles.

4.2 Road Travel Time Function Based on Gravity Model

4.2.1 Estimate of the Spillover Traffic Flow in the Control Domain

During control period, there are two reasons for the spillover of traffic flow in the control domain: the first is social vehicles bypass because of control and the second is the rapid spread of control information affects people's travel psychology. According to (10), traffic flow of the social vehicles passable roads after the control is

$$x_{i,j} = \begin{cases} deltx + (1-\varphi)\vec{x}_{i,j}, & cStyle_{i,j} = 0, <i,j> \in eL^k \\ (1-\varphi)\vec{x}_{i,j}, & cStyle_{i,j} = 0, <i,j> \in L'' - eL^k \\ \frac{1}{1-cIntensity_{i,j}}(1-\varphi)\vec{x}_{i,j}, & cStyle_{i,j} = 1, <i,j> \in L'' \end{cases} \tag{13}$$

We also found that when $cStyle_{i,j} = 0$, the spillover traffic flow of road <i,j>is $\varphi\vec{x}_{i,j}$; when $cStyle_{i,j} = 1$, the spillover traffic flow of road <i,j>is $(1 - cIntensity_{i,j})\varphi\vec{x}_{i,j}$; and when $cStyle_{i,j} = 2$, the spillover traffic flowis $\vec{x}_{i,j}$ because the road forbids social vehicles to pass through. Define $ov_{i,j}$as the spillover traffic flow of road <i,j>, and OV as the total spillover traffic flow of control domain CD, there is

$$ov_{i,j} = \begin{cases} (1 - cIntensity_{i,j})\varphi\vec{x}_{i,j}, & cStyle_{i,j} = 0 \text{ or } 1 \\ \vec{x}_{i,j}, & cStyle_{i,j} = 2 \end{cases} \tag{14}$$

$$OV = \sum_{<i,j>\in L''}^{n} ov_{i,j} \tag{15}$$

4.2.2 Attraction of the Diverging Area to Traffic Flow of the Control Domain

Because of influence of the control, social traffic flow within control domain CD will be squeezed into the diverging areaG', which can be understood as:$G'$is attractive to traffic flow within CD and this causes social vehicles' traffic flow within CD decrease while social vehicles' traffic flow within G'increase. And with increase of the distance from node i to CD in G', the influence degree is gradually lessening, as shown in Fig 4.

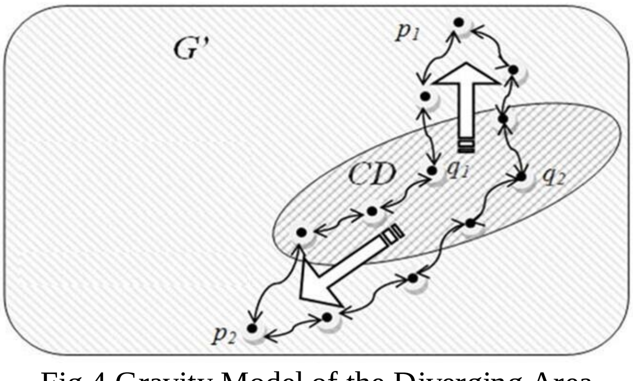


Fig.4 Gravity Model of the Diverging Area

When $\forall p \in N', \forall q \in N''$, we define node p's unidirectional attraction to node q:

$$\bar{f}_{p,q} = \mu \frac{(c_p/cur_p) \cdot cur_q}{d_{p,q}^2 layer_{p,q}^2} \tag{16}$$

c_p is traffic capacity of node p, $c_p = \sum_{p' \in Neighbor(p)} c_{p,p'}$, in which $c_{p,p'}$ means traffic capacity of road section <p,p'>; cur_p、cur_q are current traffic flow of the two nodes, $cur_p = \sum_{p' \in Neighbor(p)} x_{p,p'}$, $cur_q = \sum_{q' \in Neighbor(q)} x_{q,q'}$,Neighbor (.)is set of the node's direct neighbors; $d_{p,q}$、$layer_{p,q}$are separatelylength of the shortest path between node p and q and relevant layers. If they are direct neighbors then $layer_{p,q} = 1$. (16) shows that attraction of node p in area G'to node q in area CD, which is in inverse proportion to their squared distance; the bigger the current traffic flow of node p, the smaller the attraction to q is; the bigger the current traffic flow of node q, the bigger the attraction of node p to q is; $\mu > 0$ is the normalization factor, used to adjust values (0, 1) of $\tilde{f}_{p,q}$. Based on (16), we can get the attraction of node i in diverging area G'to all social vehicles in control area CD

$$\gamma_i = \frac{avg(\sum_{\forall q \in CD, q \neq i} \tilde{f}_{i,q})}{\sum_{j \in G'} avg(\sum_{\forall q \in CD, q \neq j} \tilde{f}_{j,q})} \tag{17}$$

Attraction of node i has important effects on the traffic flow changes of the control road. The greater the node attraction, the more obvious the traffic flow change of the road connected to the node. According to (17), nodes in the diverging area G 'will attract the total spillover traffic flow of the control domain CD according to a certain proportion, and $\sum_{i \in G'} \gamma_i = 1$. Therefore, according to the total spillover traffic flow OV of the control domain to the diverging area, change of traffic flow at each node can be estimated, and then travel time of all road sections after control can be got.

4.2.3 Improvement of the Travel Time Function

We improved the BPR function of Federal Highway Administration by using attractive parameters and took it as the travel time function of all road sections after control.

$$t_{i,j} = t_{i,j}(0)\left[1 + \alpha\left(\frac{\vec{x}_{i,j}}{C_{i,j}}\right)^{\beta}\right] \tag{18}$$

In (18), α、β are called regression coefficient, typically α is equal to 0.15 andβ is equal to 4. And $t_{i,j}(0)$ is the free flow driving time of <i,j>. For emergency vehicles, $\forall < i,j > \in L''$,combining with (13), we have

$$eme\_t_{i,j} = \begin{cases} t_{i,j}(0)[1 + \alpha\left(\frac{deltx + (1-\varphi)\vec{x}_{i,j}}{C_{i,j}}\right)^{\beta}] & , \quad cStyle_{i,j} = 0 \\ t_{i,j}(0) & , \quad cStyle_{i,j} = 1\text{或}2 \end{cases} \tag{19}$$

For social vehicles, it can be divided into "driving in control domain CD" and "driving in diverging area G'" based on its driving position. In control domain CD, for social vehicles $\forall < i,j > \in L''$ we have

$$soc\_t_{i,j} = t_{i,j}(0)\left[1 + \alpha\left(\frac{x_{i,j}}{C_{i,j}}\right)^{\beta}\right] \tag{20}$$

Take (13) into (20), we get

$$soc\_t_{i,j} = \begin{cases} t_{i,j}(0)\left[1 + \alpha\left(\frac{deltx + (1-\varphi)\vec{x}_{i,j}}{C_{i,j}}\right)^{\beta}\right], \; cStyle_{i,j} = 0,, < i,j > \in eL \\ t_{i,j}(0)\left[1 + \alpha\left(\frac{(1-\varphi)\vec{x}_{i,j}}{C_{i,j}}\right)^{\beta}\right], \; cStyle_{i,j} = 0, < i,j > \in L'' - eL \\ t_{i,j}(0)\left[1 + \alpha\left(\frac{(1-\varphi)\vec{x}_{i,j}}{(1 - cIntensity_{i,j})C_{i,j}}\right)^{\beta}\right], \; cStyle_{i,j} = 1, < i,j > \in L'' \end{cases} \tag{21}$$

In diverging area G', for social vehicles $\forall < i,j > \in L'$. Since all nodes there have attraction to traffic flow in control area CD, traffic flow on road <i, j>will increase. Based on Formula (15) and (17), traffic flow of road <i, j>is

$$x_{i,j} = \frac{\gamma_i}{Odegree_i} OV + \vec{x}_{i,j} \quad (22)$$

$Odegree_i$ is the very original degree of node i. Because of bi-directional roads are considered in this paper, there is $Odegree_i = 0.5degree_i$. Its role is to averagely distribute the traffic flow attracted to node i to itsdirectly connected road <i, j>. Take (22) into (20) ,we get

$$soc\_t_{i,j} = t_{i,j}(0) \left[1 + \alpha \left(\frac{\frac{\gamma_i}{Odegree_i} OV + \vec{x}_{i,j}}{c_{i,j}} \right)^{\beta} \right] \quad (23)$$

Take (21) and (23) into (3) and we can get disturbance degree of the control scheme. After comparing different control schemes, the optimal one will be obtained.

4.3 Solution to the Temporary Optimal Control Scheme Based on Improved GA Algorithm

4.3.1 Solution Algorithm of the Temporary Optimal Control Scheme

In this paper, we put forward the control scheme solution algorithm with the improved genetic algorithm as the core, and solving steps are as follows:

Step1. Initialization, input the road network data before control and the supplies demand information between *od*;

Step2. According to the od demand, use ant colony optimization algorithm (ACO) to calculate the *TopN* shortest paths between *od* as alternative emergency path and get the set $EPath_{o,d}$; buildthe alternative control area set based on all emergency paths;

Step3: According to the network data before control, get the travel time of all road sections in normal situation;

Step 4: Select randomly an alternative control area from the set, use the improved GA algorithm to generate control type of the road section,and use Formula (19), (21), (23) to calculate travel time of all roads ections after control; under the premise satisfying all constraints of the emergency rescue, calculate the dissatisfaction degree of social vehicles and control time of the area based on Formula (3), (4) and iteratively get the local optimal control scheme of this emergency area;

Step 5: Select another alternative emergency area, repeatedly execute Step4, and comparatively get current optimal control scheme; after completing calculation of all alternative emergency areas, compare and get the optimal temporary control scheme and then output.

4.3.2 Analysis of Time Complexity

Suppose the shortest path between two nodes in road network G, betweenness of node and road section, importance parameter, travel time of all roads under no control situation are all known, based on the steps stated in 3.3.1, main steps of the algorithm and the complexity analysis is below:

In a rectangular area *tG* within G containing od use Ant Colony Algorithm to get the *TopN* shortest paths between *od* as emergency path. Time complexity of this step is about $O(cn^4)$, in which cn means the number of nodes within tG, generally cn $\propto \sqrt{n}$ and the complexity does not exceed $O(n^3)$; the purpose of not choosing the whole road network Gbut using its subset tGis to downsize the network and reduce the complexity of the algorithm. The main calculation process includes: confirm control domain CD via all roads and nodes in ergodic graph G, confirm control style based on road importance, calculate the total spillover traffic flow in control domain CD, attraction ability of nodes in diverging area G' to traffic flow, travel time of all roads as well as tolerance of social vehicles and control time. When using GA algorithm, suppose size of population is P, the biggest iteration time is Max I and then the time complexity of calculating the optimal control scheme on one emergency path is O(*n*+l),complexity of confirming control style of some individual in the population is $O(l'')$, complexity of calculatingspillover traffic flow in control domain is $O(l'')$, in which l'' is the number of road sections in control domain CD, complexity of calculating attraction ability of road sections in diverging area G' to traffic flow is $2O(l' \times l'')$, complexity of calculating travel time, control time and tolerance of social vehicles of all roads is $2O(l)$; and then complexity of one GA algorithm is $P \times MaxI \times 2O(l'') + 2O(pq) + 2O(l)$, and the complexity of getting the optimal control scheme in this control domain is $O(n+l) + P \times MaxI \times 2O(l'') + 2O(l' \times l'') + 2O(l) \leq 2O(n) + P \times MaxI \times 2O(n) + 2O(n^2) + 2O(n) = 2O(n^2) + (P \times MaxI + 4)O(n)$.

Analysis found that complexity of our algorithm is relevant to the count of network nodes, population size of the GA algorithm and the count of iterations, but generally complexity will not exceed $O(n^2)$.That is to say, our algorithm is polynomial algorithm, and can get satisfied solution in a short time.

5. Example Analysis

5.1 Example Construction and Parameter Specification

This paper takes the example of Sioux-Fall road network [15] in American Northridge Earthquake. It is a small network with 24 nodes, 76 road sections, as shown in Fig. 5. All road sections have been marked the number, capacity (unit: 5000Vol/h, i.e. 5000 standard cars per hour) and driving time (h) in format "road number (capacity, driving time)". Traffic demand among all nodes is shown in Table 1 and population density index of all nodes and its neighboring area is shown in Table 1.

In the experiment, set the increase of traffic flow caused by transporting emergency supplies as deltx= 1.401 (100 Vol/h), the max control time that society can bear as MaxCT = 45 h, the longest delivery time emergency supplies require as R = 40 h, the max tolerance of society to traffic control as MaxTol = 20%, psychological impact factor $\varphi = 0.4$. In GA algorithm, selection operator uses tournament algorithm, crossover operator uses uniform crossover strategy and mutation operator uses uniform mutation strategy; the population number is 20 and iterations number is at most 1000. In addition, to reflect the dynamic characteristics when making the control scheme, psychological impact factor and control intensity are both set as variables.

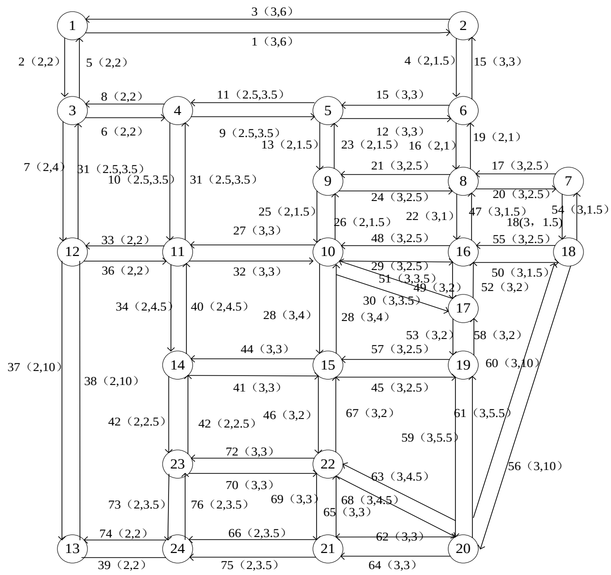


Fig. 5 Sioux-Fall Network Topology

Table 1 Traffic demand among all nodes (unit: 100 vol/h)

D/O	1。	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	0	1	1	5	2	3	5	8	5	13	5	2	5	3	5	5	4	1	3	3	1	4	3	1
2	1	0	1	2	1	4	2	4	2	6	2	1	3	1	1	4	2	0	1	1	0	1	0	0
3	1	1	0	2	1	3	1	2	1	3	3	2	1	1	1	2	1	0	0	0	0	1	1	0
4	5	2	2	0	5	4	4	7	7	12	15	6	6	5	5	8	5	1	2	3	2	4	5	2
5	2	1	1	5	0	2	2	5	8	10	5	2	2	1	2	5	2	0	1	1	1	2	1	0
6	3	4	3	4	2	0	4	8	4	8	4	2	2	1	2	9	5	1	2	3	1	2	1	1
7	5	2	1	4	2	4	0	10	6	19	5	7	4	2	5	14	10	2	4	5	2	5	2	1
8	8	4	2	7	5	8	10	0	8	16	8	6	6	4	6	22	14	3	7	9	4	5	3	2
9	5	2	1	7	8	4	6	8	0	28	14	6	6	6	10	14	9	2	4	6	3	7	5	2
10	13	6	3	12	10	8	19	16	28	0	39	20	19	21	40	44	39	7	18	25	12	26	18	8

11	5	2	3	15	5	4	5	8	14	39	0	14	10	16	14	14	10	2	4	6	4	11	13	6
12	2	1	2	6	2	2	7	6	6	20	14	0	13	7	7	7	6	2	3	5	3	7	7	5
13	5	3	1	6	2	2	4	6	6	19	10	13	0	6	7	6	5	1	3	5	4	12	11	4
14	3	1	1	5	1	1	2	4	6	21	16	7	6	0	13	7	7	1	3	5	4	12	11	4
15	5	1	1	5	2	2	5	6	10	40	14	7	7	13	0	12	15	2	8	11	8	26	10	4
16	5	4	2	8	5	9	14	22	14	44	14	7	6	7	12	0	28	5	13	16	6	12	5	3
17	4	2	1	5	2	5	10	14	9	39	10	6	5	7	15	28	0	6	17	17	6	17	6	3
18	1	0	0	1	0	1	2	3	2	7	2	2	1	1	2	5	6	0	3	4	1	3	1	0
19	3	1	0	2	1	2	4	7	4	18	4	3	3	3	8	13	17	3	0	12	4	12	3	1
20	3	1	0	3	1	3	5	9	6	25	6	5	5	5	11	16	17	4	12	0	12	24	7	4
21	1	0	0	2	1	1	2	4	3	12	4	3	4	4	8	6	6	1	4	12	0	18	7	5
22	4	1	1	4	2	2	5	5	7	26	11	7	12	12	26	12	17	3	12	24	18	0	21	11
23	3	0	1	5	1	1	2	3	5	18	13	7	11	11	10	5	6	1	3	7	7	21	0	7
24	1	0	0	2	0	1	1	2	2	8	6	5	4	4	4	3	3	0	1	4	5	11	7	0

5.2 Experimental Results and Analysis

In this experiment, rescue spot/disaster spot od are nodes 1 and 20. In accordance with requirements of the algorithm, the finally got overall optimal solution is the best of all control schemes within the control domain. Experiments found that when the control domain was designed based on the shortest path between od area, the overall optimal solution can be got, which is consistent with "the shortest priority" idea when this algorithm designed the emergency road. The algorithm parameters and control scheme are shown in Table 2, and the emergency path are expressed with road section number: section 1→ section 4→ section 16→ section 22→section 49→section 37→ section 59

Table 2 Algorithm validity of control scheme (deltx=1.401（100Vol/h）, MaxCT=45(h), MaxTol= 20%, φ=0.8, cIntensity= 0.5)

No.	Control Style	Time / interference	Overflow traffic flow（100Vol/h）	Proportion of partial control
1	[(1, 0), (4, 2) ,(16, 1), (22, 2), (49, 0), (53, 1), (59, 2)]	39.41/ 0.25%	40.406	13/36
2	[(1, 0), (4, 1) ,(16, 0), (22, 0), (49, 1), (53, 2), (59, 0)]	31.98/ 0.08%	20.206	7/36
3	[(1, 0), (4, 1), (16, 1), (22, 0), (49, 2), (53, 2), (59, 0)]	39.94/ 0.01%	34.966	7/36
4	[(1, 1), (4, 1), (16, 1), (22, 0), (49, 2), (53, 2), (59, 0)]	39.94/ 0.008%	31.798	8/36
5	[(1, 0), (4, 2) ,(16, 0), (22, 0), (49, 1), (53, 2), (59, 0)]	31.97/ 0.005%	26.02	6/36

The second column in Table 2 is control styles of roads on the emergency path in 5 optimal control schemes, number on the left in the parenthesis is road number and the underlined number on the right is control style. Analysis found that with partial control, because of social vehicles can still drive on part of roads within the control area, road utilization can be effectively guaranteed, which directly causes the spillover traffic flow in the control area and disturbance degree greatly reduced. As for optimization goal of the model, Plan 5 is the optimal solution, whose social influence is the least (0.005%), and control time is also the shortest (31.97 h). Without partial control style, too much overall control style will seriously change the road network structure. As a result, its traffic ability will be greatly reduced and the spillover traffic flow will increase considerably, thus causing the diverging area to receive too much traffic flow increase, and seriously affect traffic of social vehicles. The experimental results powerfully show the correctness of the algorithm in this paper, and the Fig. 6 shows the control area, diverging area distribution, control styles of all roads in the control area of control scheme 5, as well as the traffic flow distribution after control.

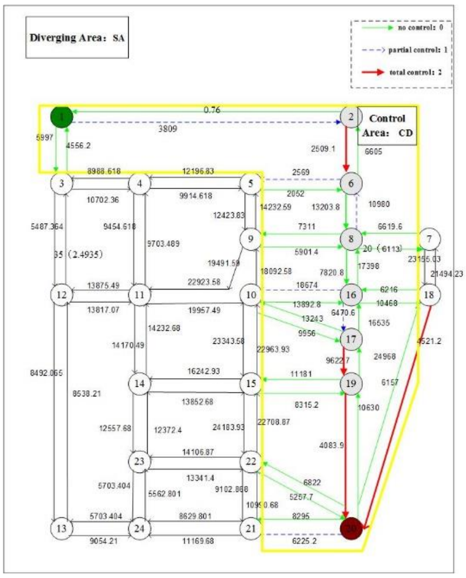


Fig. 6 the Optimal Control Scheme

6. Conclusion

Balanced traffic control scheme can help meet the demand of emergency rescue time and at the same time minimize its bad impact on society. The *fMTCE* model and relevant algorithms proposed in this paper, considered termination method of the optimization scheme of the emergency path and control domain, to make full use of the road capacity and reduce change in the network connectivity, proposed a variety of control styles with changeable control intensity and built method for diverging area to attract and distribute spillover traffic flow of the control area and improved the *BPR* function according to different road areas. By improving genetic algorithm to generate a variety of control schemes, and dynamically processing parameters like the control strength, psychological impact factor etc., influence rule of the above two parameters on the control scheme was found, and correctness and effectiveness of the model and algorithm in this paper get verified. But this study still has the following problems: 1) the example size is quite small, and influence of many parameters ability still needs detailed validation;2) the model takes traffic flow in normal situation as invariant without considering the dynamic characteristic of the road traffic flow;3) the model did not consider the practical problems like damage and emergency rehabilitation of the road;4) when designing the control area and diverging area, it did not consider influence of the urban road network topology characteristics. In future we will further research these several areas.

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