Planning problems in multiple missile launches

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Abstract

The missile is playing an increasingly important role in future military operations and the maneuvering line is becoming especially important. The timing and route arrangement of missile launchers is a combinatorial optimization problem. Resolving the problem requires full consideration of node conflicts, invisibility, and time constraints at transfer point. This paper presents a global traversal search algorithm based on the Dijkstra algorithm. Based on the minimum total exposure time, a multi-wave missile launch optimization model is established. This model can solve the problem of combinatorial optimization better. An example is given in the example of the 2017 national postgraduate mathematical modeling competition. Not only the maneuver path of 24 launchers is given, but also the arrival time and departure time of each node are clearly calculated. The results show that the research results can provide effective engineering guidance for missile launch time planning.

Keywords

Global search; Multi-wave missile; the Dijkstra algorithm; combinatorial optimization problem.

1. Introduction

With the continuous development of the missile weapon system, the missile will play an increasingly important role in the future combat, and the development of the missile launch route directly determines the duration of total exposure[1-5]. In order to achieve quick maneuver and short exposure time, we must have reasonable maneuver scheme[6-7]. In order to improve the survivability of the missile troops and mobility, conventional missiles use vehicle-mounted launchers, mostly hidden in standby region standby at ordinary times, after accept the mission, the vehicle emission devices from standby regional carrying missiles along the road motor to specify the launch point implementation[8]. Each launcher can only carry one bomb. In multiple wave emission, each round after the shooting, vehicle emission devices need immediate maneuver to reprint region (used in the missile lifting device to launch special area) to reload, motor to the next wave of time specified in the launch point to implement. Ji et al[9] articles for practical problems such as the simplified, involve multiple wave time during a crackdown on task, the main consideration of the current wave of time influence on the next wave of time task allocation, so it is concluded that the results of the general not the global optimal solution. In this paper, we mainly consider the shortest distance, but the problem of waiting for vehicles and the problems on the road will not be fully considered. In Song et al, the model does not consider the complex constraints such as queuing, time window, and reprinting regional capacity constraints[10]. In Wang et al[11], according to the national military strategy, to missile weapons configuration is divided into two kinds of peacetime and wartime, although has certain rationality, but did not discuss the relationship between the two. In this paper, considering each other conflict, the conflict of overtaking, reproduced conflict, single and double lane, different models, consider the arrangement of the loader from the global perspective In detail, the paper puts forward to the departure time of each node and leave the moment, and calculate the two wave of launches the minimum exposure time.

2. Planning model of multi-wave missile launch

The missile launcher went along with the combat troops. Initially launchers on the regional hidden in standby, combat troops to receive order to launch, missile launchers are assigned to the corresponding missile launch base to implement volley tasks, and then reload the missile launcher to reprint district, to launch base of next volley task. For n wave missions, suppose the missile type is $A,B,C,D,\ldots$. The number of missiles in the i distribution center is x_i , and the coordinates of the standby region, the transfer area and the missile launch base are D_i , Z_i and F_i respectively. The existing m missile launchers are deployed on average in standby areas $\{D_1, D_2, \ldots D_N\}$, reprint territory $\{Z_1, Z_2, \ldots Z_M\}$, The missile launch site includes $\{F_1, F_2, \ldots F_L\}$. The overall exposure time (the total amount of ammunition for all missile launches) is as short as possible under the premise of completing the missile-firing mission.

2.1 Model Building

For n wave of missile volley task, it can be divided into $2n-1$ phases, the first two wave time (that is, the former three stages) respectively from standby region to launch base to launch to regional, reprinted from wave 1 times reprinted region to wave 2 missile launch base wave 2 times. Since the third wave and subsequent launch are similar to the second wave, the analogy thought is adopted to simplify the later stage. A systematic analysis of the division $2n-1$ stage is carried out. In order to minimize the total exposure time of all missile launchings, the following objective function is established:

$$\min T = T_l + T_w - T_s - T_Z \tag{1}$$

$$T_l = \sum_k \sum_i \sum_{l=1}^{n_{k,i-1}} t_{p_{k,l}^i p_{k,l+1}^i}$$

$$T_w = \sum_k \sum_i \sum_{l=1}^{n_{k,i}} w_{p_{k,l}^i}$$

$$T_s = \sum_k w_{k,1}^1$$

$$T_z = \sum_k \left(w_{k,n_{k,2}}^2 + w_{k,1}^3 \right)$$

T represents total exposure time; T_l denotes the total driving time of all vehicle launchers on the path; T_w denotes the total waiting time of all the vehicle launchers in all nodes; T_s denotes the total time of departure of all vehicle-mounted launchers in standby area; T_z denotes the total time of loading and waiting for all vehicle-mounted launchers. $t_{p_{k,l}^i p_{k,l+1}^i}$ denotes the time spent in the i phase of the mobile path of the k vehicle launcher in phase l; $w_{k,l}^i$ represents the time required to wait at the l node for the k vehicle launcher in phase i;The maneuver time of paragraph l . $t_{p_{k,l}^i p_{k,l+1}^i} = \dfrac{d_{p_{k,l}^i, p_{k,l+1}^i}}{v_k}$.

First stage: In the standby area to the first launch point, the following constraints are set up to consider the conditions such as the collision, overtaking conflict, single lane, and different types of vehicles in each stage.

$$s_k^1 \in \{D_1, D_2\} \tag{2}$$

$$e_k^1 \in \{F_1, F_2, \cdots, F_{60}\} \tag{3}$$

$$f_{p_{k,l}^1, p_{k,l+1}^1} = 1 \tag{4}$$

$$\left(p_{k_i,l}^1, p_{k_i,l+1}^1 \right) = -\left(p_{k_j,m}^1, p_{k_j,m+1}^1 \right) \left| \Delta t_{p_{k_i,l}^1 p_{k_i,l+1}^1}^{k_i} \cap \Delta t_{p_{k_j,m}^1, p_{k_j,m+1}^1}^{k_j} = \phi \right. \tag{5}$$

$$\sum_{l=1}^{n_{k,l-1}} t_{p_{k,l}^{1},p_{k,l+1}^{1}} + \sum_{l=1}^{n_{k,l}} w_{k,l}^{i} = t_{mission}^{1} \tag{6}$$

In the above formula: s_k^i represents the starting point of the planning path of the k launcher in stage i. e_k^i represents the end point of the planning path of the k launcher in stage i. $f_{p_{k,l}^i,p_{k,l+1}^i}$ represents the connectivity judgment for path$\left(p_{k,l}^i, p_{k,l+1}^i\right)$ of the k launcher in stage i : A value of 1 is connected, and 0 means that the path is discontinuous. $\Delta t^{k_i}_{p_{k,l}^1,p_{k,l+1}^1}$ represents the time interval between the two adjacent nodes in the path $\left(p_{k,l}^i, p_{k,l+1}^i\right)$ of the k_i launcher in phase i; $w_{k,n_{k,l}}^1$ denotes the time waiting for a k launcher at the end of phase 1 (launch point); $t_{mission}^1$ represents the time of action that the first wave hit;

Equation (2) represents the starting constraint; Equation (3) denotes the end constraint; Formula (4) indicates that the k-mounted launcher should be connected through the adjacent node path in stage I, indicating the continuity constraint of the path; Type (5) any two road intersection node to travel time interval Φ empty set, in order to avoid the one-way road condition to be reserved, said conflicting constraints; Formula (6) indicates that the total time of all launchers before launch is consistent, indicating that the time constraint of the shooting time.

For the further analysis of equation (5), the following relation exists.

$$\begin{cases} \Delta t^{k}_{p_{k,l}^1,p_{k,l+1}^1} = \left[T^{k}_{p_{k,l}^i} + w_{k,l}^1, T^{k}_{p_{k,l+1}^i} \right] \\ T^{k_i}_{p_{k,l}^i} = \sum_{m=1}^{l-1} \left(t_{p_{k,m}^1,p_{k,m+1}^1} + w_{k,m}^1 \right) \end{cases} \tag{7}$$

$T^{k_i}_{p_{k,l}^i}$ represents the moment of the first phase k launch device of stage i, which reaches the l node.

The second stage: the first launch point to the transfer area, considering the collision of the meeting vehicles at each stage, reprinting the conflict, overtaking conflict, single lane, setting up the following constraints.

$$s_k^2 = e_k^1 \tag{8}$$

$$e_k^2 \in \{Z_1, Z_2, ..., Z_6\} \tag{9}$$

$$f_{p_{k,l}^2,p_{k,l+1}^2} = 1 \tag{10}$$

$$\left\{ \left(p_{k_i,l}^2, p_{k_i,l+1}^2\right) = -\left(p_{k_j,m}^2, p_{k_j,m+1}^2\right) \middle| \Delta t^{k_i}_{p_{k,l}^2,p_{k,l+1}^2} \cap \Delta t^{k_j}_{p_{k_j,m}^2,p_{k_j,m+1}^2} = \phi \right\} \tag{11}$$

$$\left\{ k_i \neq k_j, e_{k_i}^2 = e_{k_i}^2 \middle\| T^{k_i}_{p^2_{k_i,n_{k_i,2}}} - T^{k_j}_{p^2_{k_j,n_{k_j,2}}} \right| \geq 10 \right\} \tag{12}$$

Similar to the first stage, equation (8) represents the starting point constraint; Equation (9) represents the endpoint constraint; Equation (10) represents path continuity constraint; Equation (11) represents conflict constraint; Due to the need to reload ten minutes, so for the same region of the reprinted launchers, reload time with each other by at least 10 minutes, the time of arrival in transfer point (included in the reproduced region the waiting time of $w_{k,n_{k,2}}^2$) for 10 minutes or more.

The third stage: Reposting the location to the second launch point, considering the collision of the meeting vehicles at various stages, overtaking conflict, single lane and dual carriageway, establishing the following constraints:

$$s_k^3 = e_k^2 \tag{13}$$

$$e_k^3 \in \{F_1, F_2, ..., F_{60}\}, e_k^3 \neq e_k^1 \tag{14}$$

$$f_{p_{k,l}^3, p_{k,l+1}^3} = 1 \tag{15}$$

$$\left\{ \left(p_{k_i,l}^3, p_{k_i,l+1}^3 \right) = -\left(p_{k_j,m}^3, p_{k_j,m+1}^3 \right) \middle| \Delta t_{p_{k,l}^3, p_{k,l+1}^3}^{k_i} \cap \Delta t_{p_{k_j,m}^3, p_{k_j,m+1}^3}^{k_j} = \phi \right\} \tag{16}$$

$$\left(\sum_{l=1}^{n_{k,2}-1} t_{p_{k,l}^2, p_{k,l+1}^2} + \sum_{l=1}^{n_{k,2}} w_{k,l}^2 \right) + \left(\sum_{l=1}^{n_{k,3}-1} t_{p_{k,l}^3, p_{k,l+1}^3} + \sum_{l=1}^{n_{k,3}} w_{k,l}^3 \right) = t_{mission}^2 \tag{17}$$

$$\begin{cases} \Delta t_{p_{k,l}^1, p_{k,l+1}^1}^k = \left[T_{p_{k,l}^i}^k + w_{k,l}^1, T_{p_{k,l+1}^i}^k \right] \\ T_{p_{k,l}^i}^{k_i} = \sum_{m=1}^{l-1} (t_{p_{k,m}^1, p_{k,m+1}^1} + w_{k,m}^1) \end{cases}$$

On subsequent stages, namely stage to the first (2 n - 1) (n > 2) stage, since the launch of 3 wave time and later with similar wave 2 times, so take a simple analogy thought on the back of the stage. The even phase is based on stage 2 model, and the odd phase is based on stage 3 model, and the relevant models of successive stages are established successively.

2.2 Global traversal search algorithm steps and processes

According to the above model, in solving the problem, the method adopted in this paper is global traversal search, and the thought process of the algorithm is shown below.

Step1 Dijkstra algorithm is used to calculate the shortest distance between points.

Step2 Look for all the paths of the starting point d1-f-z-f and determine whether the F in each path is the same, if it is in Step3, if it is not in step4;

Step3 The path is invalid;

Step4 Put it in the Path ;

Step5 In the Path, we start from D1 and D2 and find 12 combinations together. If the F in the 24 paths is all different, if the same goes into step6, if the difference goes into step7;

Step6 The scheme is invalid;

step7 The scheme is put into the feasible scheme M;

step8 Find the distance and the smallest 20 solutions from the feasible solution M.

step9 Each node's arrival and departure times are arranged in this 20 plan to avoid conflicts.

Step10 The output of the scheme with the shortest exposure time in 20 schemes.

3. Example simulation solution

3.1 Problem description

Vehicle emission devices from A participating in combat operations with A total of 24 units, according to the different of launcher is roughly divided into three categories A, B, C, A, B, C three kinds of transmitters respectively the number of 6, 6, 12, before A mission, on average, deployed in two standby region (D1, D2). There are 6 reprinted areas (Z01 ~ Z06) and 60 launching points (F01 ~ F60) in the combat zone, each of which can accommodate only one launcher. Each transfer area can hold up to 2 launchers, but it can't work at the same time. It takes 10 minutes to reprint the work. The type and quantity of each reprint area can meet the demand. The relevant road conditions are shown in figure 1 (road node J01 ~ J62), and coordinate data of relevant elements are shown in annex 1.The main road in figure 1 (the red line in the picture) is a dual carriageway, which can be used in both vehicles. Other roads (the blue line in the figure) are single-lane and can only be parked at each road node. A, B, C three kinds of launching device on the main road the average speed of 70 km/h, 60 km/hour, 50 km/h, on the other road the average speed of 45 km/h, 35 km/h, 30 km/h. After receiving the mission, the unit requires that the total exposure time (the total exposure time of all the launchers) is the shortest. This problem of exposure time Refers to the vehicle emission devices from standby regional moment until second launch wave moment of time The launcher located within the regional reprinted time is not included in the exposure time The ministry accept to implement two wave volley task (volley means the same wave of missiles at the same time), each wave of time 24 missile launch.

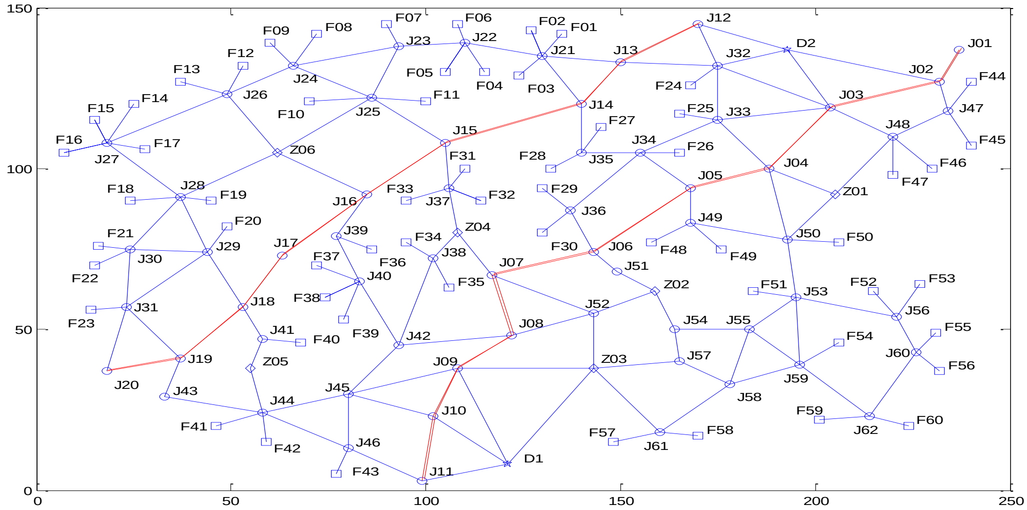

Figure 1 Road map of battle area.

Standby area (D1, D2).There are 6 reprinted areas in the combat zone (Z01 ~ Z06) and 60 launching points (F01 ~ F60). Their coordinates are shown in the following table (1).

3.2 Problem solving

The universality of the model is established according to the above, the subject of the relevant parameters can be obtained after generation into the model of this problem, using global traversal search algorithm, and through the Matlab programming for solving the problem, finally obtaining the optimal 24 sets of two waves of launcher route scheme is as follows (table 1).

Table 1

Vehicle launcher number	Standby area	Node number																			
A01	D1	J11	J10	J9	J45	J44	F42	J44	Z5	J41	F40										
A02	D1	J11	J10	J9	J9	J42	J39	F34	J39	Z4	J39	F35									
A03	D1	J11	J10	J9	J45	J46	F43	J46	J44	Z5	J44	F41									
A04	D2	J2	J47	F44	J47	J2	J3	J4	Z01	J50	F50										
A05	D2	J2	J47	F45	J47	J2	J3	J4	Z01	J50	J53	F51									
A06	D2	J2	J47	J49	F47	J49	J3	J4	Z01	J41	J33	F25									
B01	D1	J11	J10	J9	J9	J52	J7	J4	J37	F31	J37	Z04	J37	F32							
B02	D1	J11	J10	J9	J3	J61	F59	J61	Z03	J61	F57										
B03	D1	J11	J10	J9	J9	J42	J40	J39	F36	J39	J16	Z06	J29	F19							
B04	D2	J2	J47	J49	F46	J49	J3	J4	Z01	J4	J5	J49	F49								
B05	D2	J2	J3	J4	J5	J49	F49	J49	J5	J6	J7	Z04	J37	F33							
B06	D2	J2	J3	J4	J5	J6	J36	F30	J36	F30	J36	J6	Z02	J51	J6	J36	F29				
C01	D1	J11	J10	J9	J8	J42	J40	F38	J40	J39	J16	Z06									
C02	D1	J11	J10	J9	J8	J42	J40	F37	J40	J39	J16	Z06									
C03	D1	J11	J10	J9	J8	J42	J40	F39	J40	J39	J16	Z06									
C04	D1	J11	J10	J9	J45	J44	J19	J41	J19	J29	F20	J29	J19	J41	Z05	Z41	J19	J19	F15		
C05	D1	J11	J10	J9	J8	J52	J55	J45	J55	J53	J56	F52	J56	J53	J50	Z01	J50	J53	J31	F23	
C06	D1	J11	J10	J9	J8	J52	J7	J4	J37	J15	J25	J24	F9	J24	J25	Z06	J29	J27	J56	F53	
C07	D2	J2	J3	J32	F24	J32	J33	J4	Z01	J4	J5	J34	F26								
C08	D2	J2	J3	J4	J5	J34	J35	F27	J35	F27	J35	J5	J6	J51	Z02	J54	J55	J59	F54		
C09	D2	J2	J3	J4	J5	J34	J35	F29	J35	J14	J15	Z06	J25	J23	F7						
C10	D2	J2	J3	J32	J13	J21	J22	J23	J25	Z06	J29	J30	F21								
C11	D2	J2	J3	J32	J13	J21	J22	J23	J25	Z06	J29	J30	F22								
C12	D2	J2	J3	J32	J13	J21	J22	J23	J25	Z06	J26	J24	F9								

The path of the surface is drawn and summarized in the combat road network, and the following emission path is summarized (2).

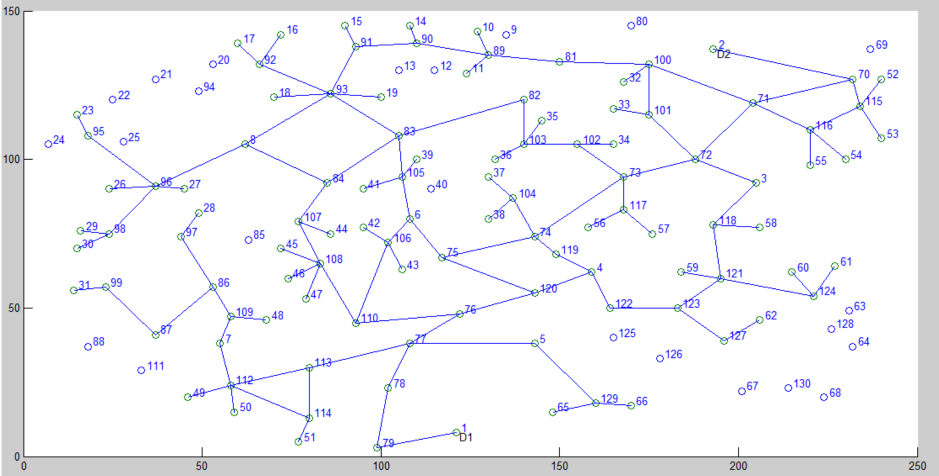

Fig2 schematic diagram of the launch path

Can be seen from table 1, the scenario except A01 C07, C10 these outside, other routes are relatively short, and the time of each node in the planning, effectively solve the conflict of single and double lane, reprinted time conflict. From figure 2, it can be seen that the route distribution of the planning is relatively uniform, and the total exposure time of two simultaneous shots of the 24 vehicle launcher is 10620.7min.The average exposure time of each vehicle launcher is 3.69h.The path planning of the vehicle and the arrival time at each node and in the appendix of the departure time (table 2, table 3, table 4, table 5) are described in detail.

4. Conclusion

In this paper, considering each other conflict, conflict reprinted build constraint condition, such as from the global perspective to solve the combinatorial optimization problem, detailed depiction in the experimental simulation results in different time of node, help to improve the conventional missile survivability of the battle command automation and forces, has the very strong practical significance for military operations guide. There should be a lot of emergencies in the real world war, and the model is not flexible. Then there is the need for a breakthrough in dynamics.

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Appendi

Table 2 Time planning 1

Launch number	Standby area code	Departure time	Road node number	Arrived in time	Leave the time	Road node number	Arrived in time	Leave the time	Road node number	Arrived in time	Leave the time
A01	D1	271.6	J11	301.7	301.7	J10	319.0	319.0	J9	332.9	332.9
A02	D1	249.9	J11	280.0	280.0	J10	297.3	297.3	J9	311.2	311.2
A03	D1	280.0	J11	310.1	310.1	J10	327.5	327.5	J9	341.3	341.3
A04	D2	333.8	J2	387.5	387.5	J47	399.8	399.8	F44	414.2	748.0
A05	D2	331.5	J2	385.2	385.2	J47	397.5	397.5	F45	414.2	745.7
A06	D2	310.7	J2	364.4	364.4	J47	376.7	376.7	J48	398.2	398.2
B01	D1	171.2	J11	209.9	209.9	J10	230.1	230.1	J9	246.2	246.2
B02	D1	216.9	J11	255.6	255.6	J10	275.8	275.8	J9	292.0	292.0
B03	D1	190.6	J11	229.3	229.3	J10	249.5	249.5	J9	265.7	265.7
B04	D2	277.5	J2	346.5	346.5	J47	362.3	362.3	J48	389.9	389.9
B05	D2	231.5	J2	300.5	300.5	J3	329.6	329.6	J4	354.5	354.5
B06	D2	196.8	J2	265.8	265.8	J3	294.9	294.9	J4	319.8	319.8
C01	D1	181.1	J11	226.3	226.3	J10	250.5	250.5	J9	269.9	269.9
C02	D1	177.6	J11	222.7	222.7	J10	247.0	247.0	J9	266.3	266.3
C03	D1	176.4	J11	221.6	221.6	J10	245.8	245.8	J9	265.2	265.2
C04	D1	94.3	J11	139.4	139.4	J10	163.6	163.6	J9	183.0	183.0
C05	D1	57.0	J11	102.1	102.1	J10	126.4	126.4	J9	145.7	145.7
C06	D1	0.0	J11	45.1	45.1	J10	69.4	69.4	J9	88.8	88.8
C07	D2	216.7	J2	297.2	297.2	J3	332.2	332.2	J32	395.8	395.8
C08	D2	160.9	J2	241.5	241.5	J3	276.4	276.4	J4	306.2	306.2
C09	D2	160.9	J2	241.5	241.5	J3	276.4	276.4	J4	306.2	306.2
C10	D2	91.5	J2	172.0	172.0	J3	206.9	206.9	J32	270.5	270.5
C11	D2	128.0	J2	208.5	208.5	J3	243.4	243.4	J32	307.0	307.0
C12	D2	127.8	J2	208.4	208.4	J3	243.3	243.3	J32	306.9	306.9

Table 3 Time planning 2

Road node number	Arrived in time	Leave the time	Road node number	Arrived in time	Leave the time	Road node number	Arrived in time	Leave the time	Road node number	Arrived in time	Leave the time
J45	371.7	371.7	J44	402.1	402.1	F42	414.2	685.8	J44	426.3	426.3
J8	325.9	325.9	J42	364.8	364.8	J38	402.7	402.7	F34	414.2	664.1
J45	380.1	380.1	J46	402.8	402.8	F43	414.2	694.2	J46	425.6	425.6
J47	428.6	428.6	J2	440.9	440.9	J3	465.9	465.9	J4	487.2	487.2
J47	430.9	430.9	J2	443.2	443.2	J3	468.2	468.2	J4	489.4	489.4
F47	414.2	724.9	J48	430.2	430.2	J3	454.7	454.7	J4	476.0	476.0
J8	263.4	263.4	J52	301.4	301.4	J7	350.5	350.5	J4	377.6	377.6
J3	352.0	352.0	J61	397.0	397.0	F58	414.2	631.1	J61	431.4	431.4
J8	282.9	282.9	J42	332.9	332.9	J40	371.2	371.2	J39	397.3	397.3
F46	414.2	691.7	J48	438.4	438.4	J3	469.9	469.9	J4	494.7	494.7
J5	375.3	375.3	J49	394.2	394.2	F48	414.2	645.7	J49	434.2	434.2
J5	340.7	340.7	J6	372.7	372.7	J36	397.2	397.2	F30	414.2	611.0
J8	290.6	290.6	J42	348.9	348.9	J40	393.6	393.6	F38	414.2	595.3
J8	287.0	287.0	J42	345.3	345.3	J40	390.0	390.0	F37	414.2	591.8
J8	285.9	285.9	J42	344.2	344.2	J40	388.9	388.9	F39	414.2	590.6
J45	241.3	241.3	J44	286.9	286.9	J5	315.5	315.5	J41	334.5	334.5
J8	166.4	166.4	J52	210.7	210.7	J2	245.6	245.6	J54	271.6	271.6
J8	109.4	109.4	J52	153.7	153.7	J7	211.0	211.0	J4	242.6	242.6
F24	414.2	630.9	J32	432.6	432.6	J33	466.6	466.6	J4	506.3	506.3
J5	331.3	331.3	J34	365.3	365.3	J35	395.3	395.3	F27	414.2	575.1
J5	331.3	331.3	J34	365.3	365.3	J35	395.3	395.3	F28	414.2	575.1
J13	320.6	320.6	J21	360.7	360.7	J22	401.5	401.5	F6	414.2	505.7
J13	357.0	357.0	J21	397.2	397.2	F3	414.2	542.1	J21	431.2	431.2
J13	356.9	356.9	J21	397.1	397.1	F2	414.2	542.0	J21	431.3	431.3

Table 4 Time planning 3

Road node number	Arrived in time	Leave the time	Road node number	Arrived in time	Leave the time	Road node number	Arrived in time	Leave the time	Road node number	Arrived in time
Z5	445.4	701.2	J41	713.9	713.9	F40	727.3			
J38	425.7	425.7	Z4	439.0	700.8	J38	714.2	714.2	F35	727.3
J44	458.4	458.4	Z5	477.5	691.3	J44	710.4	710.4	F41	727.3
Z01	512.2	685.3	J50	709.9	709.9	F50	727.3			
Z01	514.5	663.7	J50	688.2	688.2	J53	712.4	712.4	F51	727.3
Z01	501.0	662.2	J4	687.2	687.2	J33	713.7	713.7	F25	727.3
J37	401.8	401.8	F31	414.2	585.4	J37	426.6	426.6	Z04	450.8
Z03	476.4	661.1	J61	706.1	706.1	F57	727.3			
F36	414.2	604.8	J39	431.1	431.1	J16	457.2	457.2	Z06	502.5
Z01	527.0	636.0	J4	668.2	668.2	J5	689.0	689.0	J49	707.9
J5	453.0	453.0	J6	485.1	485.1	J7	512.0	512.0	Z04	539.1
J36	431.2	431.2	J6	455.7	455.7	J51	470.3	470.3	Z02	490.2
J40	434.8	434.8	J39	465.2	465.2	J16	495.8	495.8	Z06	548.6
J40	438.4	438.4	J39	468.8	468.8	J16	499.3	499.3	Z06	552.2
J40	439.5	439.5	J39	470.0	470.0	J16	500.5	500.5	Z06	553.3
J18	356.9	356.9	J29	395.3	395.3	F20	414.2	508.4	J29	433.1
J55	309.6	309.6	J53	340.8	340.8	J56	394.2	394.2	F52	414.2
J37	270.9	270.9	J15	298.9	298.9	J25	346.1	346.1	J24	390.9
Z01	543.9	610.6	J4	648.2	648.2	J5	673.2	673.2	J34	707.3
J35	433.1	433.1	J34	463.1	463.1	J5	497.1	497.1	J6	535.5
J35	433.1	433.1	J14	463.1	463.1	J15	507.5	507.5	J16	538.2
J22	426.8	426.8	J23	460.9	460.9	J25	495.8	495.8	Z06	554.6
J22	472.0	472.0	J23	506.0	506.0	J25	540.9	540.9	Z06	599.8
J22	472.1	472.1	J23	506.1	506.1	J25	541.1	541.1	Z06	599.9

Table 5 Time planning 4

Leave the time	Road node number	Arrived in time	Leave the time	Road node number	Arrived in time	Leave the time	Road node number	Arrived in time	Leave the time	Road node number	Arrived in time	Leave the time	Road node number	Arrived in time	Leave the time	Road node number	Arrived in time	Leave the time	Road node number	Arrived in time	Leave the time	Road node number	Arrived in time
687.7	J37	712.0	712.0	F32	727.3																		
664.4	J28	713.5	713.5	F19	727.3																		
707.9	F49	727.3																					
683.0	J37	707.2	707.2	F33	727.3																		
651.2	J51	671.2	671.2	J6	685.8	685.8	J36	710.3	710.3	F29	727.3												
643.9	J28	701.2	701.2	F18	727.3																		
640.4	J25	699.2	699.2	F11	727.3																		
636.4	J25	695.2	695.2	F10	727.3																		
433.1	J18	471.5	471.5	J41	493.9	493.9	Z05	512.9	594.2	J41	617.1	617.1	J18	639.5	639.5	J19	666.7	666.7	J31	709.2	709.2	F23	727.3
471.2	J56	434.2	434.2	J53	487.6	487.6	J50	523.8	523.8	Z01	560.7	577.5	J50	614.4	614.4	J53	650.6	650.6	J56	704.0	704.0	F53	727.3
390.9	F8	414.2	414.2	J24	437.5	437.5	J25	482.2	482.2	Z06	541.1	603.8	J28	661.1	661.1	J27	712.1	712.1	F15	727.3			
707.3	F26	727.3																					
535.5	J51	552.5	552.5	Z02	575.8	604.8	J54	630.8	630.8	J55	668.8	668.8	J59	702.9	702.9	F54	727.3						
538.2	Z06	591.0	618.3	J25	677.1	677.1	J23	712.1	712.1	F7	727.3												