

# 全国第四届研究生数学建模竞赛



题号  D

Clark-Wright

摘 要:

Clark-Wright      Dijkstra

Dijkstra

$X_1$

Clark-Wright

3

[  $X_1 Z_{10} Z_9 Z_8 Z_7 Z_5 Z_6 Z_5 X_1$  ]      [  $X_1 Z_{14} Z_{16} Z_{15} Z_{11} Z_{12} X_1$  ]

[  $X_1 Z_{13} Z_1 Z_2 Z_3 Z_4 X_1$  ]

4 70 3 92 4 32

348

76 6

Clark-Wright

7

Clark-Wright

15

5

10

2436km

7308

参赛密码 \_\_\_\_\_

(由组委会填写)

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**1.**

X1 16 Z1, Z2, ....., Z16  
 08:00 X1 16:00 X1  
 D 65  
 2 =( )-  
 ( )/ ( ) \*2  
 /

**2.**

X1  
 3  
 16:00 8:00  
 2  
 16-8-2 6

**3.**

**3.1**

- 1
- 2
- 3
- 4

**3.2**

$\{Z_0, Z_1, Z_2 \dots Z_{16}\}$   $X_1$  16  $Z_0$   
 $\delta_k^j = \begin{cases} 1 & X_1 \\ 0 & X_1 \end{cases} \begin{matrix} k \\ k \end{matrix} \begin{matrix} Z_j \\ Z_j \end{matrix}, j=1,2,\dots,16;$   
 $d_{ij} \quad Z_i \quad Z_j \quad i, j = 0,1,\dots,16;$   
 $a_i \quad Z_i \quad i = 1,2,\dots,16$

$$b_i \quad Z_i \quad i = 1, 2, \dots, 16$$

$$f(i, j, k) = \begin{cases} 1, & X_i \quad k \\ 0, & Z_i \rightarrow Z_j \end{cases}$$

$$i, j = 0, 1, \dots, 16$$

$$g(j, k) = \begin{cases} i, & f(i, j, k) = 1 \\ -1, & \end{cases}$$

$$Z(j, k) \quad k \quad Z_j \quad Z_j \quad j = 0, 1, \dots, 16;$$

T k  
C  
S

### 3.3

1

2

3

(1)

(2) ;

(3)

f

X<sub>1</sub>

I

$$\min f = k$$

$$\begin{cases}
\frac{\sum_{i,j} f(i,j,k)d_{ij}}{v} + S(\sum_j \delta_k^j) \leq T \\
\sum_j a_j \delta_k^j \leq C \\
\sum_j b_j \delta_k^j \leq C \\
Z(j,k) = Z(g(j,k),k) - a_i(g(j,k)) + b_i(g(j,k)) \leq C \\
\sum_k \delta_k^j \geq 1
\end{cases} \quad (1)$$

$$\begin{aligned}
& 1 \quad \frac{\sum_{i,j} f(i,j,k)d_{ij}}{v} + S(\sum_j \delta_k^j) \leq T \\
& \sum_j a_j \delta_k^j \leq C \qquad \qquad \qquad \sum_j b_j \delta_k^j \leq C \\
& Z(j,k) = Z(g(j,k),k) - a_i(g(j,k)) + b_i(g(j,k)) \leq C \\
& \sum_k \delta_k^j \geq 1
\end{aligned}$$

$$\begin{aligned}
& \sum_{i,j} f(i,j,k)d_{ij} \times \frac{2C - \sum_j \delta_k^j (a_i + b_i)}{2C} \times 2 \\
& \qquad \qquad \qquad X_1 \qquad \qquad \qquad \text{II}
\end{aligned}$$

$$\min g = \sum_k \sum_{i,j} f(i,j,k)d_{ij} \times \frac{2C - \sum_j \delta_k^j (a_i + b_i)}{2C} \times 2$$

$$\begin{cases}
\frac{\sum_{i,j} f(i,j,k)d_{ij}}{v} + S(\sum_j \delta_k^j) \leq T \\
\sum_j a_j \delta_k^j \leq C \\
\sum_j b_j \delta_k^j \leq C \\
Z(j,k) = Z(g(j,k),k) - a_i(g(j,k)) + b_i(g(j,k)) \leq C \\
\sum_k \delta_k^j \geq 1
\end{cases} \quad (2)$$

1 8 2 4 7 1  
 $X_1$

III

$$\min F_i = Mk + \sum_k \sum_{i,j} f(i, j, k) d_{ij} \times \frac{2C - \sum_j \delta_k^j (a_i + b_i)}{2C} \times 2$$

$$s.t. \left\{ \begin{array}{l} \frac{\sum_{i,j} f(i, j, k) d_{ij}}{v} + S(\sum_j \delta_k^j) \leq T \\ \sum_j a_j \delta_k^j \leq C \\ \sum_j b_j \delta_k^j \leq C \\ Z(j, k) = Z(g(j, k), k) - a_i(g(j, k)) + b_i(g(j, k)) \leq C \\ \sum_k \delta_k^j \geq 1 \end{array} \right. \quad (3)$$

$M$

$M = 100$

### 3.4 Clark-Wright

#### 3.4.1

“ ”

“ ”

Clark-Wright [1]  
 Clark-Wright

Clark-Wright

#### 3.4.2 Clark-Wright

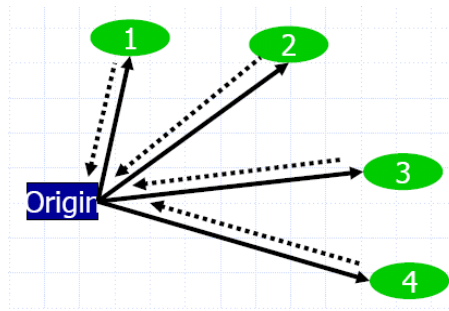
Clark-Wright

$N$

$\{ Z = Z_i, i = 1, 2, \dots, N \}$

$X_1 \{ X_1 Z_1 X_1, X_1 Z_2 X_1, \dots, X_1 Z_N X_1 \}$

1-1



1-1

1-2

X1

$(Z_i, i=1,2,\dots,5)$

$X_1 Z_1 X_1, X_1 Z_2 X_1, \dots, X_1 Z_N X_1 \quad c_{ij} \quad i \quad j$

$$\text{Savings} = c_{i0} + c_{oj} - c_{ij} \quad \text{if} \quad 2c_{oi} + 2c_{oj} > c_{oi} + c_{jo} + c_{ij} \quad (4)$$

1

$$S(1,2) = 10 + 15 - 8 = 17$$

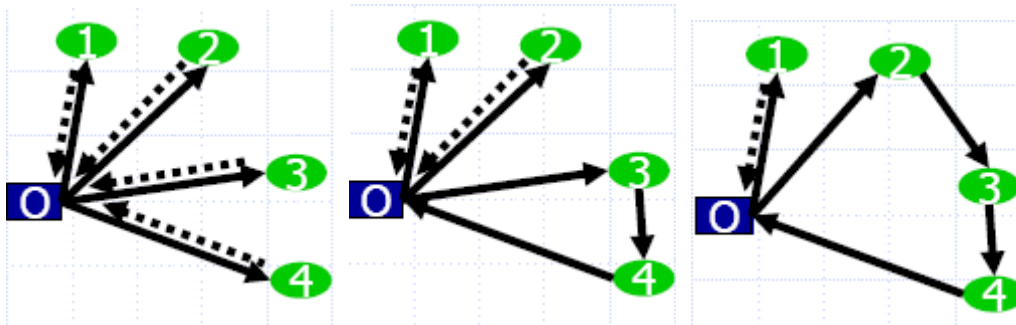
$$S(1,3) = 10 + 19 - 23 = 6$$

$$S(1,4) = 10 + 22 - 35 = -3$$

$$S(2,3) = 15 + 19 - 12 = 22$$

$$S(2,4) = 15 + 22 - 21 = 16$$

$$S(3,4) = 19 + 22 - 5 = 36$$



(a)tour=132

(b)tour=96

(c)tour=74

1-2

1-1

i \ j	0	1	2	3	4
0		10	15	19	22
1			8	23	35
2				12	21
3					5

### 3.4.3 Clark-Wright

Clark-Wright

“

”

Dijkstra

Clark-Wright

Dijkstra

1-2 1-3

	1-2 X1										inf						
	X1	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9	Z10	Z11	Z12	Z13	Z14	Z15	Z16
X1	0	27	44	17	11	27	42	Inf	Inf	Inf	20	25	21	21	18	27	Inf
Z1	27	0	31	27	49	Inf	Inf	Inf	Inf	Inf	Inf	Inf	52	21	41	Inf	Inf
Z2	44	31	0	19	Inf	27	32	Inf	Inf	Inf	47	Inf	Inf	Inf	50	Inf	Inf
Z3	17	27	19	0	14	Inf	Inf	Inf	Inf	Inf	30	Inf	Inf	Inf	31	Inf	Inf
Z4	11	49	Inf	14	0	13	20	Inf	Inf	28	15	Inf	Inf	Inf	15	25	30
Z5	27	Inf	27	Inf	13	0	9	21	Inf	26	26	Inf	Inf	Inf	28	29	Inf
Z6	42	Inf	32	Inf	20	9	0	13	Inf	32	Inf	Inf	Inf	Inf	Inf	33	Inf
Z7	Inf	Inf	Inf	Inf	Inf	21	13	0	19	Inf	Inf	Inf	Inf	Inf	Inf	Inf	Inf
Z8	Inf	Inf	Inf	Inf	Inf	Inf	Inf	19	0	11	20	Inf	Inf	Inf	Inf	33	21
Z9	Inf	Inf	Inf	Inf	28	26	32	Inf	11	0	10	20	Inf	Inf	29	14	13
Z10	20	Inf	47	30	15	26	Inf	Inf	20	10	0	8	Inf	Inf	14	9	20
Z11	25	Inf	Inf	Inf	Inf	Inf	Inf	Inf	Inf	20	8	0	23	Inf	Inf	14	Inf
Z12	21	52	Inf	Inf	Inf	Inf	Inf	Inf	Inf	Inf	Inf	23	0	27	22	Inf	Inf
Z13	21	21	Inf	Inf	Inf	Inf	Inf	Inf	Inf	Inf	Inf	Inf	27	0	Inf	Inf	Inf
Z14	18	41	50	31	15	28	Inf	Inf	Inf	29	14	Inf	22	Inf	0	11	Inf
Z15	27	Inf	Inf	Inf	25	29	33	Inf	33	14	9	14	Inf	Inf	11	0	9
Z16	Inf	Inf	Inf	Inf	30	Inf	Inf	Inf	21	13	20	Inf	Inf	Inf	Inf	9	0

	1-3 X1										Dijkstra						
	X1	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9	Z10	Z11	Z12	Z13	Z14	Z15	Z16
X1	0	27	44	17	11	27	42	44	40	30	20	25	21	21	18	27	36
Z1	27	0	31	27	49	51	58	71	67	57	47	52	52	21	41	52	61
Z2	44	31	0	19	33	27	32	45	64	53	47	55	57	52	50	56	63
Z3	17	27	19	0	14	27	34	47	49	39	30	37	38	38	31	38	44
Z4	11	49	33	14	0	13	20	33	35	28	15	23	32	32	15	25	30

Z5	27	51	27	27	13	0	9	21	37	26	26	34	45	45	28	29	38
Z6	42	58	32	34	20	9	0	13	32	32	35	43	52	52	35	33	42
Z7	44	71	45	47	33	21	13	0	19	30	39	47	65	65	48	44	40
Z8	40	67	64	49	35	37	32	19	0	11	20	28	51	61	34	33	21
Z9	30	57	53	39	28	26	32	30	11	0	10	20	41	51	29	14	13
Z10	20	47	47	30	15	26	35	39	20	10	0	8	31	41	14	9	20
Z11	25	52	55	37	23	34	43	47	28	20	8	0	23	46	22	14	23
Z12	21	52	57	38	32	45	52	65	51	41	131	23	0	27	22	33	42
Z13	21	21	52	38	32	45	52	65	61	51	41	46	27	0	39	48	57
Z14	18	41	50	31	15	28	35	48	34	29	14	22	22	39	0	11	20
Z15	27	52	56	56	25	29	33	44	33	14	9	14	33	48	11	0	9
Z16	36	61	63	44	30	38	42	40	21	13	20	23	42	57	20	9	0

Clark-Wright

6

5

5

$5\frac{7}{12}$

30 /

165

165

4.

1

2

$\{X_1Z_1X_1, X_1Z_2X_1, \dots, X_1Z_NX_1\}$

3

$s_{ij}$

$\{s_{ij}, i, j = 1, 2, \dots, N\}$

4

$s_{ij}$

$\{s_{ij}\}$

5

$t_{ij}=1$

y z

$t_{ij}=0$

i

$t_{io}=2$

$t_{io}=2$

6

p  $\{s_{ij}\}$

7

p



a.  $t_{i0} > 0 \quad t_{j0} > 0 \quad i \quad j$

b.

c.

d.

$$\begin{matrix} 8 & 6 & & p & & 10 \\ & & 6 & & & \\ 9 & 6 & & & & \end{matrix}$$

a.  $t_{ij} = 1$

b.  $\sum_{j=0}^{i-1} t_{ij} + \sum_{j=j+1}^N t_{ij} = 2 \quad t_{ij}$

c.  $Q_k$

$$\begin{matrix} 10 & P & & p & & (10) & & 6 \\ 11 & & & & & & & \end{matrix}$$

**5.**

Matlab                  Dijkstra      Clark-Wright                   $k_{\min} = 3$

3

3

1-4

						(
	$X_1 Z_{10} Z_9 Z_8 Z_7 Z_6 Z_5 X_1$	109	4	4.13	64	331
	$X_1 Z_{14} Z_{16} Z_{15} Z_{11} Z_{12} X_1$	105	0	3.92	61	
	$X_1 Z_{13} Z_1 Z_2 Z_3 Z_4 X_1$	117	0	4.32	51	
	$X_1 Z_2 Z_5 Z_6 Z_7 Z_8 Z_9 X_1$	153	5	5.6	62	386
	$X_1 Z_{12} Z_{11} Z_{15} Z_{16} Z_{10} X_1$	107	0	3.98	57	
	$X_1 Z_4 Z_{14} Z_3 Z_1 Z_{13} X_1$	126	0	4.62	57	
	$X_1 Z_{10} Z_9 Z_8 Z_7 Z_6 Z_5 X_1$	109	4	4.13	64	331
	$X_1 Z_4 Z_{14} Z_{16} Z_{15} Z_{11} Z_{12} X_1$	113	5	4.27	65	
	$X_1 Z_{13} Z_1 Z_2 Z_3 X_1$	109	0	3.97	42	

## 5.1

Clark-Wright

$$X_1 Z_{14} Z_{16} Z_{15} Z_{11} Z_{12} X_1 \quad X_1 Z_{14} Z_{15} Z_{16} Z_{15} Z_{11} Z_{12} X_1 \quad Z_{14} Z_{15} Z_{16} Z_{11} Z_{12}$$

$$X_1 Z_2 Z_5 Z_6 Z_7 Z_8 Z_9 X_1 \quad X_1 Z_2 Z_5 Z_6 Z_7 Z_8 Z_9 Z_{10} X_1 \quad Z_2 Z_5 Z_6 Z_7 Z_8 Z_9$$

$$X_1 Z_4 Z_{14} Z_{16} Z_{15} Z_{11} Z_{12} X_1 \quad X_1 Z_4 Z_{14} Z_{15} Z_{16} Z_{15} Z_{11} Z_{12} X_1 \quad Z_4 Z_{14} Z_{16} Z_{15} Z_{11} Z_{12}$$

## 5.2

Clark-Wright

$$\frac{\sum_{i,j} f(i,j,k) d_{ij}}{v} + S(\sum_j \delta_k^j) \leq T$$

T

T 6

6

2

Clark-Wright

1

$$X_1 \rightarrow Z_{10} \rightarrow Z_9 \rightarrow Z_8 \rightarrow Z_7 \rightarrow Z_5 \rightarrow Z_6 \rightarrow Z_5 \rightarrow X_1$$

348

$[X_1Z_{10}Z_9Z_8Z_7Z_5Z_6Z_5X_1, X_1Z_{14}Z_{16}Z_{15}Z_{11}Z_{12}X_1, X_1Z_{13}Z_1Z_2Z_3Z_4X_1]$

$$\begin{aligned} \min f &= \sum_k \sum_{i,j} f(i, j, k) d_{ij} \times \sum_{i,j} f(i, j, k) \times \frac{2C - \sum_k \delta_k^j (a_i + b_i)}{2C} \times 2 \\ &= \left( \frac{1}{130} \times 126 + \frac{15}{130} \times 105 + \frac{28}{130} \times 117 \right) \times 2 \\ &\approx 76.6 \end{aligned}$$

2

3

$X_1 \rightarrow Z_{10} \rightarrow Z_9 \rightarrow Z_8 \rightarrow Z_7 \rightarrow Z_5 \rightarrow Z_6 \rightarrow Z_5 \rightarrow X_1$

21 9 13 17

5

3

### 5.3

348

12.93

76.6

1-5

	$X_1Z_{10}Z_9Z_8Z_7Z_5Z_6Z_5X_1$	126	0	4.70	64
	$X_1Z_{14}Z_{16}Z_{15}Z_{11}Z_{12}X_1$	105	0	3.92	61
	$X_1Z_{13}Z_1Z_2Z_3Z_4X_1$	117	0	4.32	51

1.

3 /

2

1

18:00

D

6

1

20

5000

3000

D

X1, X2, ....., X5

km

2-1

	D	X1	X2	X3	X4	X5
D	0	92	89	98	66	124
X1	92	0	62	116	158	107
X2	89	62	0	54	155	169
X3	98	116	54	0	133	204
X4	66	158	155	133	0	119
X5	124	107	169	204	199	0

3.

3.1

1

2

3

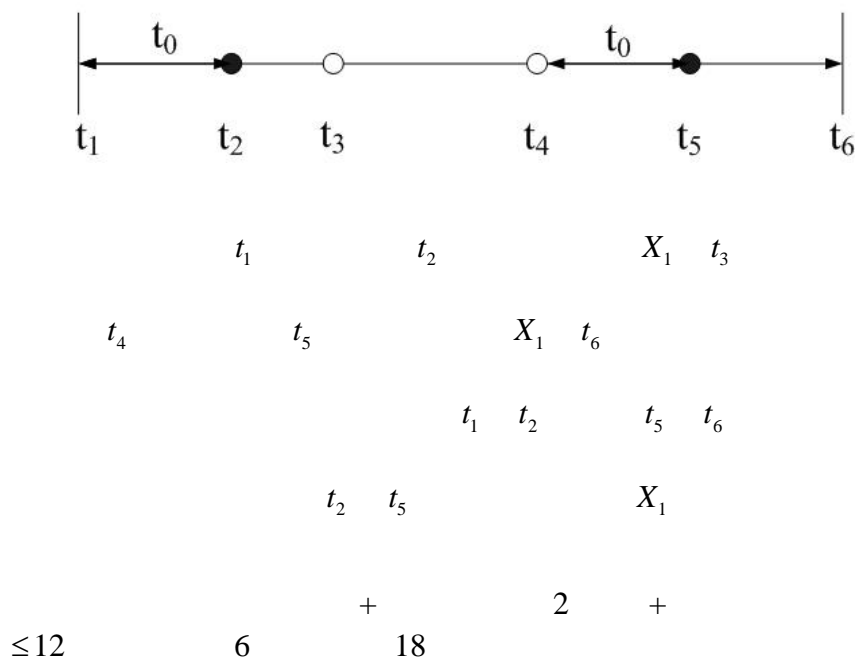
4

### 3.2

$$\begin{aligned}
 & Z_i \quad X_{i-73} \quad i = 74, 75, 76, 77, 78. \\
 \delta_k^j = & \begin{cases} 1 & D \quad k \quad Z_j \\ 0 & \end{cases} \quad j = 58, 59, \dots, 78; \\
 \delta_k^j(\lambda) = & \begin{cases} 1 & X_{\lambda-73} \quad k \quad Z_j \\ 0 & \end{cases} \quad \lambda = 74, 75, 76, 77, 78 \\
 X_{ij} : & \quad Z_i \quad Z_j \quad i, j = 1, 2, \dots, 78 \\
 f(i, j, k) = & \begin{cases} 1, & D \quad k \quad Z_i \rightarrow Z_j \\ 0 & D \quad k \quad Z_i \rightarrow Z_j \end{cases} \\
 f_\lambda(i, j, k) = & \begin{cases} 1, & X_{\lambda-73} \quad k \quad Z_i \rightarrow Z_j \\ 0 & X_{\lambda-73} \quad k \quad Z_i \rightarrow Z_j \end{cases}
 \end{aligned}$$

### 3.3

#### 3.3.1



### 3.3.2

$$\begin{aligned}
 & \min k \\
 & s.t. \left\{ \begin{array}{l}
 \sum_k \delta_k^j(\lambda) \geq 1 \quad \forall j, \quad \forall \lambda = 74, \dots, 78; \quad (2-1) \\
 \sum_k \delta_k^j \geq 1 \quad \forall j; \quad (2-2) \\
 \sum_i f(i, j, k) = \sum_j f(i, j, k) \quad \forall k; \quad (2-3) \\
 \sum_i f_\lambda(i, j, k) = \sum_j f_\lambda(i, j, k) \quad \forall k, \quad \forall \lambda = 74, \dots, 78; \quad (2-4) \\
 \frac{\sum_{i,j} f(i, j, k) X_{ij}}{65} + \sum_{j=58}^{74} \delta_k^j * \frac{1}{12} + \sum_{j=74}^{78} \delta_k^j * \frac{1}{6} \leq 5; \quad (2-5) \\
 \frac{\sum_{i,j} f(i, j, k) X_{ij}}{65} + 2 + \sum_{j=58}^{74} \delta_k^j * \frac{1}{12} + \sum_{j=74}^{78} \delta_k^j * \frac{1}{6} + \sum_{\lambda=74}^{78} \sum_j \delta_k^j(\lambda) * \frac{1}{12} \quad (2-6) \\
 + \frac{\sum_{i,j} f_\lambda(i, j, \gamma) X_{ij}}{30} \leq 12, \quad \forall k, \forall \gamma, \forall \lambda = 74, \dots, 78
 \end{array} \right.
 \end{aligned}$$

2-1

5

2-5

2-6

2-3

2-4

6

2-2

11

### 3.3.3

$$\begin{array}{ccc}
 D & X_i, (i=1, \dots, 5) & D \\
 \\ \\ \\
 1 & X1 & X1 \\
 & n & c_1, c_2, \dots, c_n \\
 & & c = \sum_{i=1}^n c_i.
 \end{array}$$

2

X1

X1

$$T = \frac{\max_{1 \leq i \leq n} c_i}{30}$$

A.

Dijkstra

Clark-Wright

1 2 3 4

a.

b.

c.

2-2 X1

km	1	2	3	4
1	313	151	106	90
2		159	105	100
3			109	109
4				69
	313	310	320	368
	313/30 10 26	159/30 5 18	109/30 3 38	109/30 3 38

10 1 300  
2  
160 3 2  
4 3 X1 2 3

2-3 X2

km	1	2	3	4
1	227	167	141	99
2		76	107	89
3			58	107
4				59
	227	243	306	354
	227/30 7 34	167/30 5 34	141/30 4 42	107/30 3 34

2 3 4

2-4 X3

km	1	2	3	4
1	176	134	120	94

2		68	68	68
3			62	52
4				62
	176	202	250	276
	176/30 5 52	134/30 4 28	120/30 4	94/30 3 8
	2	1 3		

2-5 X4

km	1	2	3	4
1	273	187	148	109
2		86	80	103
3			86	71
4				56
	273	273	314	339
	273/30 9 6	187/30 6 6	148/30 4 56	109/30 3 38
	3	2 4		

2-6 X5

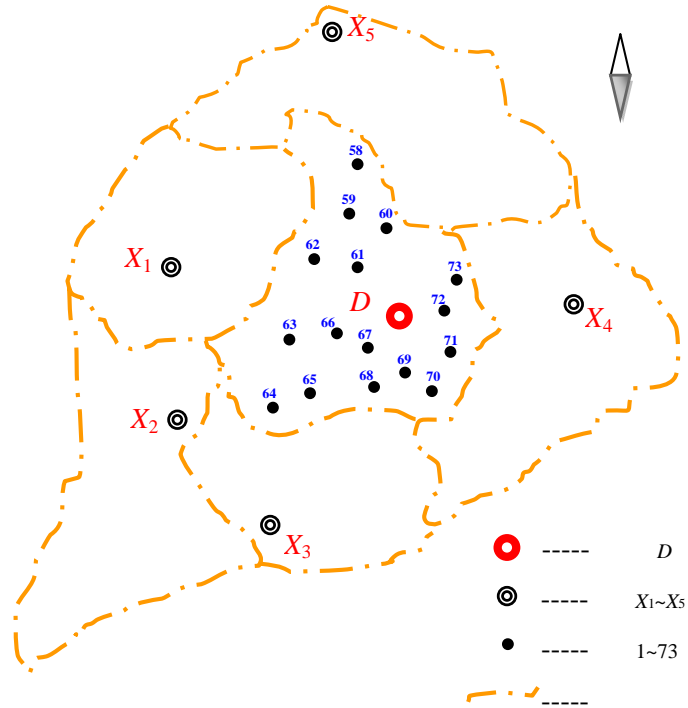
km	1	2	3	4
1	301	164	153	132
2		164	132	136
3			129	107
4				72
	301	328	414	447
	301/30 10 2	164/30 5 37	153/30 5 6	136/30 4 32
	2 3	4		

**B.**

$$D, \quad X_i, (i=1, \dots, 5) \quad Z_i$$

$$(i=58, 59, \dots, 73) \quad 2-1$$





2-1

$D$   
7

1

		km
	$Z_{67}, Z_{64}, X_2, X_3, Z_{65}, Z_{63}, Z_{66}$	269
	$Z_{60}, Z_{59}, X_5, Z_{58}, Z_{61}$	263
	$X_1, Z_{62}$	184
	$Z_{72}, X_4, Z_{73}, Z_{71}, Z_{69}, Z_{70}, Z_{68}$	236

2

		km
	$Z_{67}, Z_{64}, X_2, X_3, Z_{65}, Z_{68}$	266
	$Z_{60}, Z_{59}, X_5, Z_{58}, Z_{61}$	263
	$Z_{66}, Z_{63}, X_1, Z_{62}$	203
	$Z_{69}, Z_{70}, Z_{71}, Z_{72}, X_4, Z_{73}$	197

3

		km
	$Z_{64}, X_2, X_3, Z_{65}, Z_{67}$	254
	$Z_{60}, Z_{59}, X_5, Z_{58}, Z_{61}$	263
	$Z_{66}, Z_{63}, X_1, Z_{62}$	203
	$Z_{72}, X_4, Z_{73}, Z_{71}, Z_{69}, Z_{70}, Z_{68}$	236

4

		km
	$Z_{64}, X_2, X_3, Z_{65}, Z_{67}$	254
	$Z_{61}, Z_{59}, X_5, Z_{58},$	248
	$Z_{66}, Z_{63}, X_1, Z_{62}, Z_{60}$	239
	$Z_{72}, X_4, Z_{73}, Z_{71}, Z_{69}, Z_{70}, Z_{68}$	236

5

		km
	$X_2, X_3, Z_{65}, Z_{67}$	244
	$X_5, Z_{58}, Z_{61}$	248
	$X_1, Z_{62}, Z_{59}, Z_{60}$	233
	$Z_{71}, Z_{69}, Z_{70}, Z_{68}, Z_{66}, Z_{63}, Z_{64}$	211
	$Z_{72}, X_4, Z_{73}$	144

6

		km
	$Z_{67}, Z_{64}, X_2, X_3$	251
	$X_5, Z_{58}, Z_{61}$	248
	$Z_{66}, Z_{63}, Z_{65}, Z_{68}, Z_{69}, Z_{70}, Z_{71}$	154

	$X_1, Z_{62}, Z_{59}, Z_{60}$	233
	$Z_{72}, X_4, Z_{73}$	144

7

		km
	$Z_{67}, Z_{64}, X_2, X_3, Z_{64}$	253
	$X_5, Z_{58}, Z_{61}$	248
	$Z_{66}, Z_{63}, Z_{65}, Z_{69}, Z_{70}, Z_{71}$	149
	$X_1, Z_{67}, Z_{59}, Z_{60}$	233
	$Z_{72}, X_4, Z_{73}$	144

C

2 5 2 6

$$\begin{aligned}
 & \left[ \frac{\sum_{i,j} f(i,j,k)X_{ij}}{65} + \sum_{j=58}^{74} \delta_k^j * \frac{1}{12} + \sum_{j=74}^{78} \delta_k^j * \frac{1}{6} \leq 5 \right. \\
 s.t. & \left[ \frac{\sum_{i,j} f(i,j,k)X_{ij}}{65} + 2 + \sum_{j=58}^{74} \delta_k^j * \frac{1}{12} + \sum_{j=74}^{78} \delta_k^j * \frac{1}{6} + \sum_{\lambda=74}^{78} \sum_j \delta_k^j(\lambda) * \frac{1}{12} \right. \\
 & \left. \left[ \frac{\sum_{i,j} f_\lambda(i,j,\gamma)X_{ij}}{30} \leq 12, \right. \right. \\
 & \left. \left. \forall k, \forall \gamma \right. \right. \\
 & \left. \left. \forall \lambda = 74, \dots, 78 \right. \right]
 \end{aligned}$$

$Z_{67}, Z_{64}, X_2, X_3, Z_{65}, Z_{63}, Z_{66}$  2

5

269km,  $X_2$  1

$$269/65 + 2 \times \frac{1}{6} + 5 \times \frac{1}{12} = 4.89 \leq 5 \quad 6 \quad 11$$

$$269/65 + 2 \times \frac{1}{6} + 5 \times \frac{1}{12} + 227/30 + 10 \times \frac{1}{12} = 13.23 > 12$$

4

1					2					3				
	1	2	3	4		1	2	3	4		1	2	3	4
X1	N	Y	Y	Y	X1	N	Y	Y	Y	X1	N	Y	Y	Y
X2	N	N	Y	Y	X2	N	N	Y	Y	X2	N	N	Y	Y
X3	N	Y	Y	Y	X3	N	Y	Y	Y	X3	N	Y	Y	Y
X4	N	N	Y	Y	X4	N	Y	Y	Y	X4	N	N	Y	Y
X5	N	N	Y	Y	X5	N	N	Y	Y	X5	N	N	Y	Y

4					5					6				
	1	2	3	4		1	2	3	4		1	2	3	4
X1	N	Y	Y	Y	X1	N	Y	Y	Y	X1	N	Y	Y	Y
X2	N	N	Y	Y	X2	N	Y	Y	Y	X2	N	N	Y	Y
X3	N	Y	Y	Y	X3	N	Y	Y	Y	X3	N	Y	Y	Y
X4	N	N	Y	Y	X4	N	Y	Y	Y	X4	N	Y	Y	Y
X5	N	Y	Y	Y	X5	N	Y	Y	Y	X5	N	Y	Y	Y

7				
	1	2	3	4
X1	N	Y	Y	Y
X2	N	N	Y	Y
X3	N	Y	Y	Y
X4	N	Y	Y	Y
X5	N	Y	Y	Y

1 2 3 4  
N No

1 2 3 4

Y Yes

D

	X1	X2	X3	X4	X5		
1	2	3	2	3	3	17	2498
2	2	3	2	2	3	16	2434
3	2	3	2	3	3	17	2502
4	2	3	2	3	2	16	2437
5	2	2	2	2	2	15	2436
6	2	3	2	2	2	16	2449
7	2	3	2	2	2	16	2446

5

5  
2436km

2  
7308

15

15

6 00 5

$D \rightarrow X_2 \rightarrow X_3 \rightarrow Z_{65} \rightarrow Z_{67} \rightarrow D$

$$D \rightarrow X_5 \rightarrow Z_{58} \rightarrow Z_{61} \rightarrow D$$

$$D \rightarrow X_1 \rightarrow Z_{62} \rightarrow Z_{59} \rightarrow Z_{60} \rightarrow D$$

$$D \rightarrow Z_{71} \rightarrow Z_{69} \rightarrow Z_{70} \rightarrow Z_{68} \rightarrow Z_{66} \rightarrow Z_{63} \rightarrow Z_{64} \rightarrow D$$

$$D \rightarrow Z_{72} \rightarrow X_4 \rightarrow Z_{73} \rightarrow D.$$

			13	45	5
D	X1		7	25	1
X1	8	25		2	

$$X_1 \rightarrow Z_3 \rightarrow Z_2 \rightarrow Z_5 \rightarrow Z_6 \rightarrow Z_7 \rightarrow Z_8 \rightarrow Z_9 \rightarrow Z_{10} \rightarrow Z_{11} \rightarrow Z_4 \rightarrow X_1$$

$$X_1 \rightarrow Z_{13} \rightarrow Z_{12} \rightarrow Z_{11} \rightarrow Z_{15} \rightarrow Z_{16} \rightarrow Z_{14} \rightarrow X_1$$

			7	23	1
D	X2				
X2	8	23		2	

$$X_2 \rightarrow Z_{21} \rightarrow Z_{22} \rightarrow Z_{23} \rightarrow Z_{24} \rightarrow Z_{25} \rightarrow Z_{26} \rightarrow Z_{20} \rightarrow Z_{19} \rightarrow X_2$$

$$X_2 \rightarrow Z_{17} \rightarrow Z_{18} \rightarrow X_2$$

			8	23	1
D	X3				
X3	9	23		2	

$$X_3 \rightarrow Z_{28} \rightarrow Z_{31} \rightarrow Z_{29} \rightarrow Z_{30} \rightarrow Z_{32} \rightarrow Z_{33} \rightarrow X_3$$

$$X_3 \rightarrow Z_{27} \rightarrow X_3$$

			7	23	1
D	X4				
X4	8	23		2	

$$X_4 \rightarrow Z_{36} \rightarrow Z_{34} \rightarrow Z_{35} \rightarrow Z_{37} \rightarrow Z_{38} \rightarrow Z_{39} \rightarrow Z_{40} \rightarrow X_4$$

$$X_4 \rightarrow Z_{41} \rightarrow Z_{42} \rightarrow Z_{43} \rightarrow X_4$$

			7	55	1
D	X5				
X5	8	55		2	

$$X_5 \rightarrow Z_{51} \rightarrow Z_{46} \rightarrow Z_{44} \rightarrow Z_{45} \rightarrow Z_{47} \rightarrow Z_{48} \rightarrow Z_{49} \rightarrow Z_{50} \rightarrow X_5$$

$$X_5 \rightarrow Z_{54} \rightarrow Z_{55} \rightarrow Z_{56} \rightarrow Z_{57} \rightarrow Z_{52} \rightarrow Z_{53} \rightarrow X_5$$

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