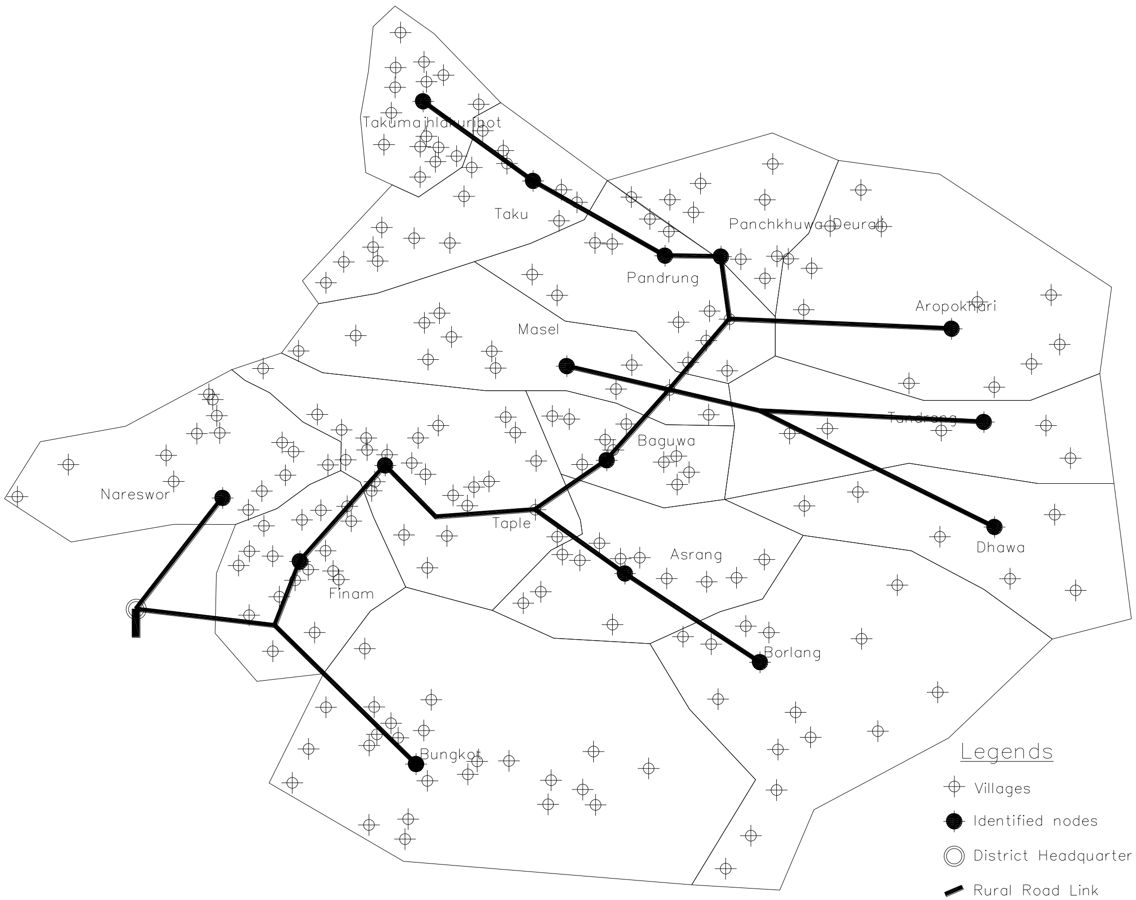
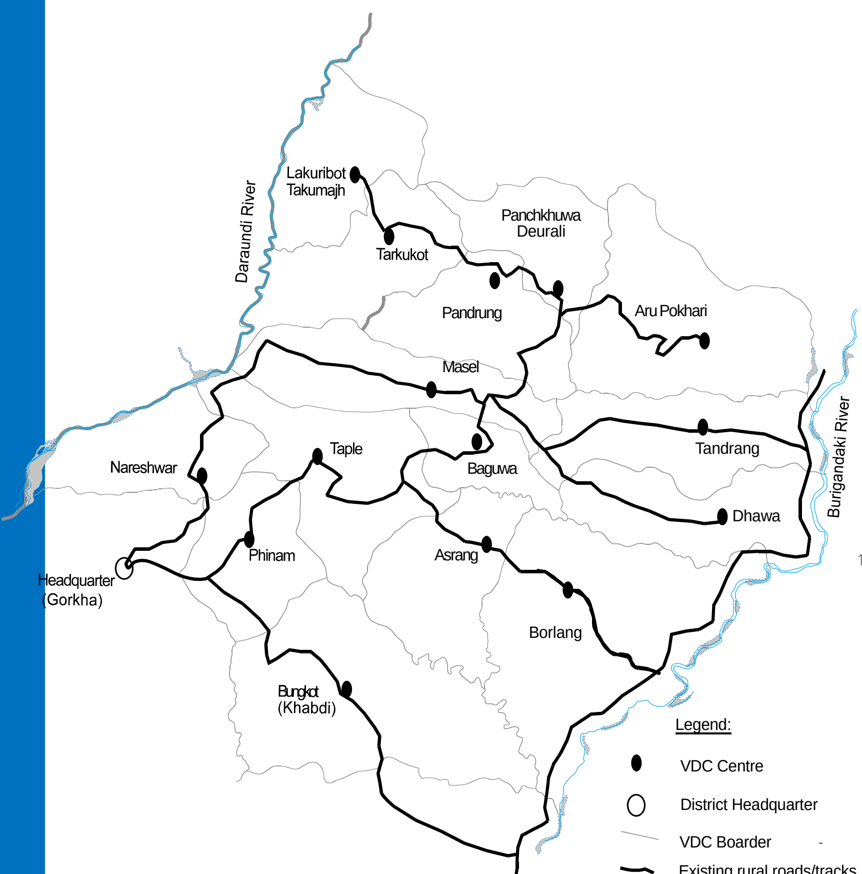
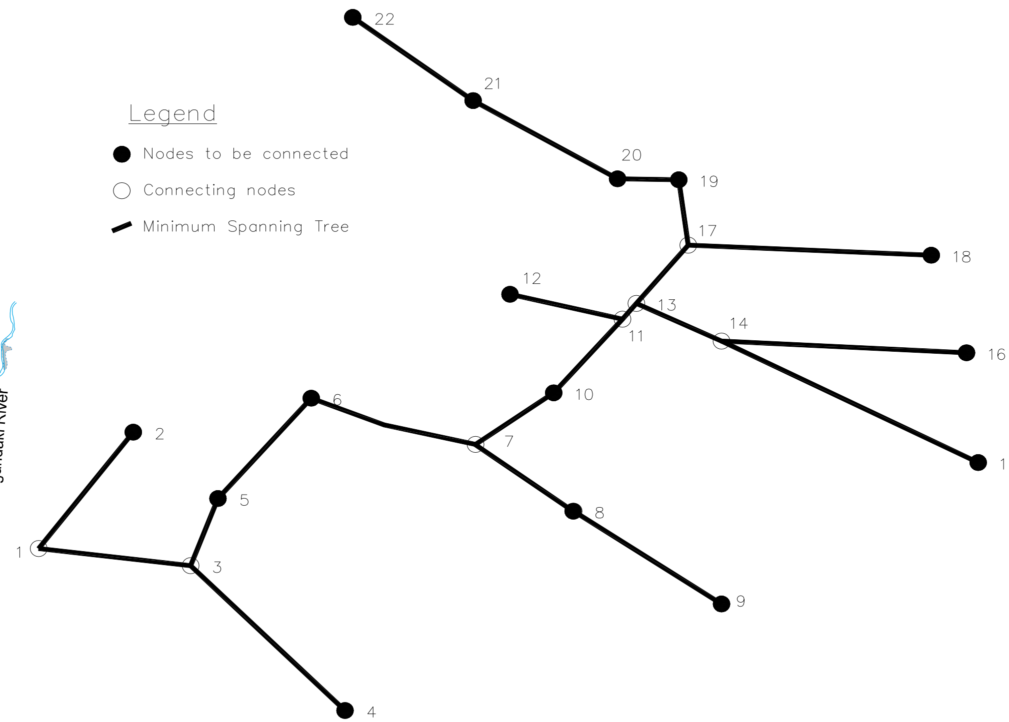
ROAD SURFACE OPTIMIZATION MULTI-OBJECTIVE ANALYSIS

Definition of nodal points



Minimum Spanning Tree





Network Intervention at Different Budgets

Budget (NRs) in millions	Links and Distance (km)																				
	1-2	1-3	3-4	3-5	5-6	6-7	7-8	7-10	8-9	10-11	11-12	11-13	13-14	13-17	14-15	14-16	17-18	17-19	19-20	20-21	21-22
	5.75	3.52	6	3.34	3.44	5.7	2.69	4.12	4.2	2.49	1.74	0.7	1.5	2.78	7.73	7.35	5.57	2.1	1.2	3.28	5.12
		A		A	A	A		A		A	A	A	A			A					
15																					
20																					
25																					
30																					
35																					
40																					
45																					
50																					
55																					

Note: A = Asphalt G = Gravel

Multi-objective Problem

- Minimization of operation cost in road networks
  - Depends on road lengths
  - Surface types
- High demands for upgrading

Objective Functions

- Minimization of user operation cost
- Maximization of population coverage

Notations

- S is the set of road surface options S=(s1, s2, s3) (for earthen, gravel, and asphalt respectively).
- W_{ij} is the weightage to the link (i,j).
- C_{ij}^{s} is the travel cost/unit flow over s on link(i,j).
- d_{ij} is the distance from node i to node j.
- c_{ij}^{s} is the operating cost per unit flow of traveling over s on link(i,j).
- O_{ij}^{s} is the operating cost on link (i,j) over s, where $O_{ij}^{s} = d_{ij} . c_{ij}^{s}$.
- B is an available investment budget
- I_{ij}^{s}, and is the cost of improving link (i,j) with s.
- I_{ij}^{s} =1 if a link (i,j) is built with s, 0 otherwise.

Optimization Model

Minimise:

$$z = \sum_{s=1}^{3} \sum_{(i,j)\in L} W_{ij}\ O_{ij}^{s} x_{ij}^{s} \qquad (1)$$

Subject to:

$$\sum_{s=1}^{3} \sum_{(i,j)\in L, i<j} I_{ij}^{s} x_{ij}^{s} \leq B \qquad (2)$$

$$\sum_{s=1}^{3} x_{ij}^{s} = 1\ \forall (\mathrm{i},\mathrm{j}) \in \mathrm{L} \qquad (3)$$

Multi-objective Analysis

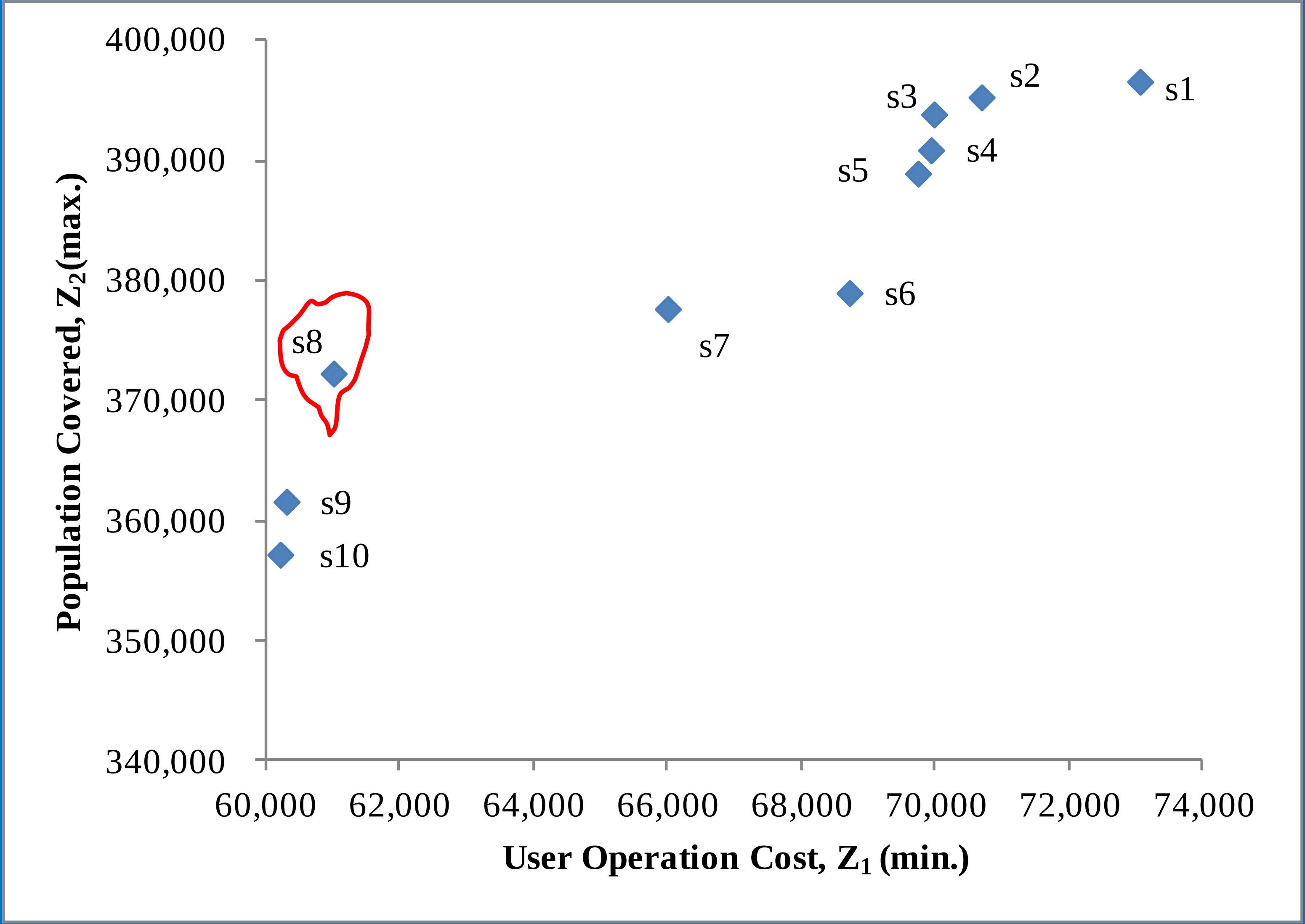
$$Minimize: \quad z_1 = \sum_{s=1}^{3} \sum_{(i,j)\in L, i<j} W_{ij} O_{ij}^{s} x_{ij}^{s}$$

$$Maximize: \quad z_2 = \sum_{s=1}^{3} \sum_{(i,j)\in L, i<j} P_{ij} x_{ij}^{s}$$

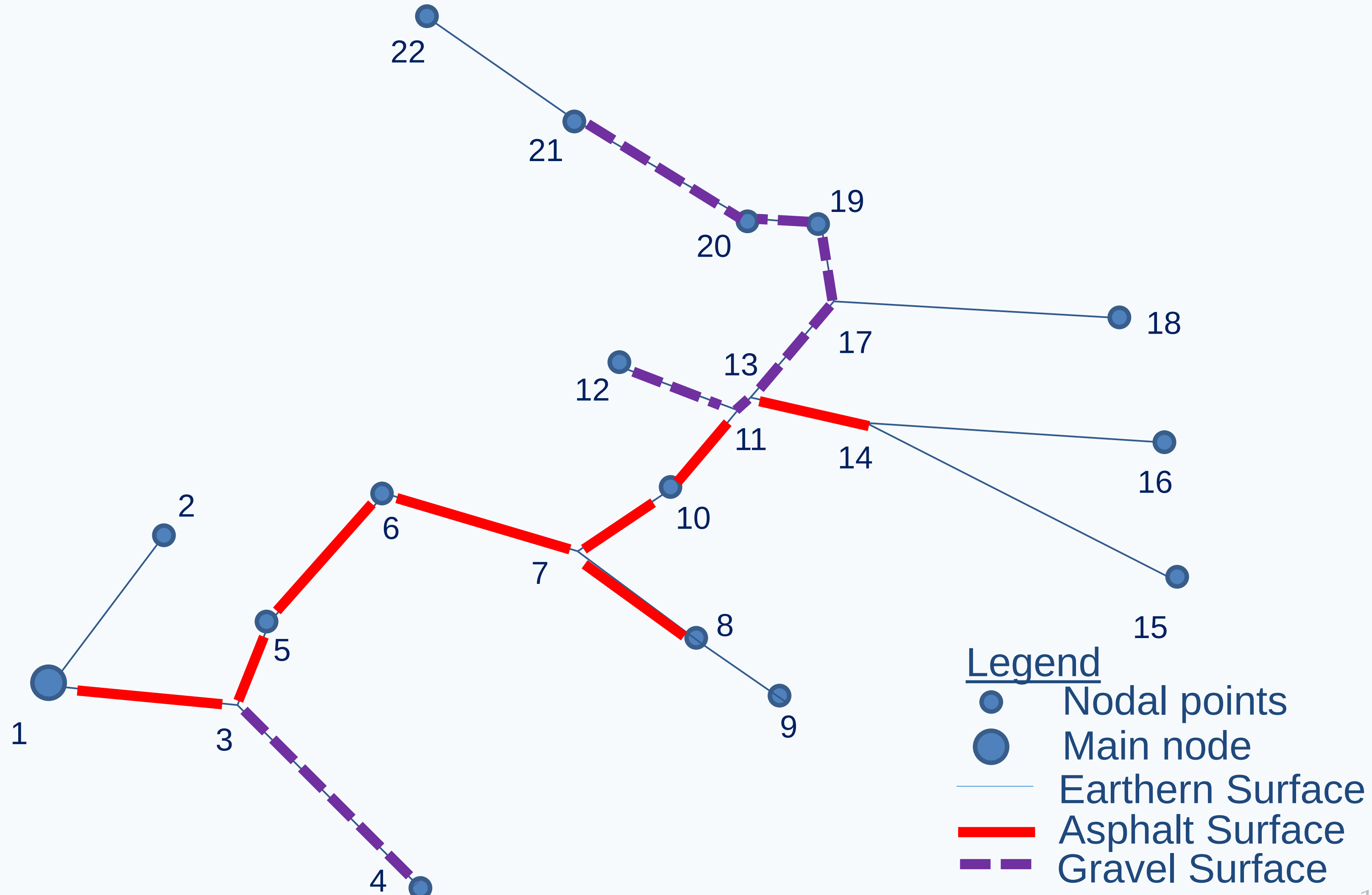
$$Subject\ to: \quad \sum_{s=1}^{3} \sum_{(i,j)\in L, i<j} I_{ij}^{s} x_{ij}^{s} \le B$$

$$\sum_{s=1}^{3} x_{ij}^{s} = 1 \quad \forall (i,j) \in L, i < j, \forall s \in S$$

Non-dominated solutions



Solution s8



22
21
19
20
18
17
13
12
11
14
16
2
6
10
7
15
8
5
1
3
9
4
Legend
Nodal points
Main node
Earthern Surface
Asphalt Surface
Gravel Surface

Conclusions

- Provides a portfolio of suggested links with different types of road surface
- Can be a more practical and realistic approach

Conclusions

- Development of multi-objective rural road network model with two objectives
  - Minimization of user operation costs
  - Maximization of population covered
- Offers alternative solutions for a budget
- Considers different types of road surfaces (earthen, gravel, or asphalt)
- Pareto optimal solutions can be interesting to decision makers with different optimal alternatives

MPL

```
{   MOProblem.mpl   }
TITLE
MOP;
INDEX
i     := 1..22
j     := i;
DATA
UeOperation :=            50.64;
UgOperation :=            45.64;
UpOperation :=            36.79;
UeImprove :=              00000;
UgImprove :=              5000000;
UpImprove :=              10000000;
W[i,j] := ( );
 B   := 100000000*8;
d[i,j] := (   );
DECISION VARIABLES
eX[i,j] WHERE (d>0 AND i<j);
gX[i,j] WHERE (d>0 AND i<j);
pX[i,j] WHERE (d>0 AND i<j);
bb;
OBJ_F1;
OBJ_F2;
 MODEL
!MIN F1 = SUM(i,j:W*d*UeOperation*eX WHERE (d>0 AND i<j)) + SUM(i,j:
W*d*UgOperation*gX WHERE (d>0 AND i<j)) + SUM(i,j: W*d*UpOperation*pX WHERE (d>0
AND i<j));
!MAX F2 = SUM(i,j:eX*P WHERE (d>0 AND i<j)) + SUM(i,j: gX*P WHERE (d>0 AND i<j)) +
SUM(i,j: pX*P WHERE (d>0 AND i<j));
MIN F2 = SUM(i,j: d*UeImprove*eX WHERE (d>0 AND i<j)) + SUM(i,j: d*UgImprove*gX
WHERE (d>0 AND i<j)) + SUM(i,j: d*UpImprove*pX WHERE (d>0 AND i<j))
```

```
SUBJECT TO
 ! cnt1: SUM(i,j: eX WHERE (d>0 AND i<j)) + SUM(i,j: gX WHERE (d>0 AND i<j)) + SUM(i,j: pX
WHERE (d>0 AND i<j))=21;
cnt2: eX[1,2] + gX[1,2] + pX[1,2] = 1;
cnt3: eX[1,3] + gX[1,3] + pX[1,3] = 1;
cnt4: eX[3,4] + gX[3,4] + pX[3,4] = 1;
cnt5: eX[3,5] + gX[3,5] + pX[3,5] = 1;
cnt6: eX[5,6] + gX[5,6] + pX[5,6] = 1;
cnt7: eX[6,7] + gX[6,7] + pX[6,7] = 1;
cnt8: eX[7,8] + gX[7,8] + pX[7,8] = 1;
cnt9: eX[8,9] + gX[8,9] + pX[8,9] = 1;
cnt10: eX[7,10] + gX[7,10] + pX[7,10] = 1;
cnt11: eX[10,11] + gX[10,11] + pX[10,11] = 1;
cnt12: eX[11,12] + gX[11,12] + pX[11,12] = 1;
cnt13: eX[11,13] + gX[11,13] + pX[11,13] = 1;
cnt14: eX[13,14] + gX[13,14] + pX[13,14] = 1;
cnt15: eX[13,17] + gX[13,17] + pX[13,17] = 1;
cnt16: eX[14,15] + gX[14,15] + pX[14,15] = 1;
cnt17: eX[14,16] + gX[14,16] + pX[14,16] = 1;
cnt18: eX[17,18] + gX[17,18] + pX[17,18] = 1;
cnt19: eX[17,19] + gX[17,19] + pX[17,19] = 1;
cnt20: eX[19,20] + gX[19,20] + pX[19,20] = 1;
cnt21: eX[20,21] + gX[20,21] + pX[20,21] = 1;
cnt22: eX[21,22] + gX[21,22] + pX[21,22] = 1;
cnt65: SUM(i,j: d*UeImprove*eX WHERE (d>0 AND i<j)) + SUM(i,j: d*UgImprove*gX WHERE (d>0
AND i<j)) + SUM(i,j: d*UpImprove*pX WHERE (d>0 AND i<j)) <= B;
OBJ_F1 = SUM(i,j:W*d*UeOperation*eX WHERE (d>0 AND i<j)) + SUM(i,j: W*d*UgOperation*gX
WHERE (d>0 AND i<j)) + SUM(i,j: W*d*UpOperation*pX WHERE (d>0 AND i<j));
!OBJ_F2 = SUM(i,j:eX*P WHERE (d>0 AND i<j)) + SUM(i,j: gX*P WHERE (d>0 AND i<j)) + SUM(i,j:
pX*P WHERE (d>0 AND i<j));
 OBJ_F2 = SUM(i,j: d*UeImprove*eX WHERE (d>0 AND i<j)) + SUM(i,j: d*UgImprove*gX WHERE
(d>0 AND i<j)) + SUM(i,j: d*UpImprove*pX WHERE (d>0 AND i<j))
!OBJ_F1 <  3661 ;
!OBJ_F2 >  3661 ;
 BINARY
  eX[i,j] WHERE (d>0 AND i<j);
gX[i,j] WHERE (d>0 AND i<j);
pX[i,j] WHERE (d>0 AND i<j);


END
```