Bilkent University
Department of Industrial Engineering

IE 400 - Principles of Engineering Management

Term Project

Group: 41

Çağatay Şafak, 21902730, Section 2
Ayşe Kelleci, 21902532, Section 2

Instructor: Taghi Khaniyev

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1. Depot-Train Assignment Problem

Objective Function:

$$Minimize(\sum_{i=1}^{15}((startToX_i + endToX_i) \times x_{i1}) + (startToY_i + endToY_i) \times x_{i2}))$$

Decision Variable(s):

$$x_{ij} = \{1\ if\ train\ i\ is\ assigned\ to\ depot\ j,\ 0\ otherwise\}$$

Parameter(s):

$$pathStartingWith_{ik} = \{1\ if\ the\ start\ node\ of\ the\ path\ of\ train\ i\ is\ node\ k,\ 0\ otherwise\}$$

$$startToX_i = The\ distance\ from\ the\ start\ node\ of\ the\ path\ of\ train\ i\ to\ depot\ X$$

$$endToX_i = The\ distance\ from\ the\ end\ node\ of\ the\ path\ of\ train\ i\ to\ depot\ X$$

$$startToY_i = The\ distance\ from\ the\ start\ node\ of\ the\ path\ of\ train\ i\ to\ depot\ Y$$

$$endToY_i = The\ distance\ from\ the\ end\ node\ of\ the\ path\ of\ train\ i\ to\ depot\ Y$$

Constraint(s):

$$\sum_{i=1}^{15}(x_{i1}) \geq 5$$

$$\sum_{i=1}^{15}(x_{i2}) \geq 5$$

$$\sum_{k=1}^{8}(\sum_{i=1}^{15}(x_{ij} \times pathStartingWith_{ik})) \leq 3$$

$$x_{i1} + x_{i2} = 5,\ for\ all\ i$$

Objective Value and Values for Decision Variables:

$$Objective\ value\ =\ 35.0$$

Rows are assigned depots, columns are assigned trains.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
X	1	1	0	0	0	1	0	1	1	0	1	1	0	0	1
Y	0	0	1	1	1	0	1	0	0	1	0	0	1	1	0

Here is the result (screenshot):

```
PS C:\Users\User\Desktop\ders\ie400\ie400-project\ie400-project> py part1.py
Version identifier: 22.1.1.0 | 2023-06-15 | d64d5bd77
CPXPARAM_Read_DataCheck                          1
Found incumbent of value 45.000000 after 0.00 sec. (0.00 ticks)
Tried aggregator 3 times.
MIP Presolve eliminated 25 rows and 22 columns.
MIP Presolve added 1 rows and 1 columns.
MIP Presolve modified 5 coefficients.
Aggregator did 9 substitutions.
All rows and columns eliminated.
Presolve time = 0.08 sec. (0.06 ticks)

Root node processing (before b&c):
  Real time             =    0.08 sec. (0.06 ticks)
Parallel b&c, 12 threads:
  Real time             =    0.00 sec. (0.00 ticks)
  Sync time (average)   =    0.00 sec.
  Wait time (average)   =    0.00 sec.
                          ------------
Total (root+branch&cut) =    0.08 sec. (0.06 ticks)
Obj Value: 35.0
Values of Decision Variables: [1.0, 0.0, 1.0, 0.0, 0.0, 1.0, 0.0, 1.0, 0.0, 1.0, 1.0, 0.0, 0.0, 1.0, 1.0, 0.0, 1.0, 0.0, 0.0, 1.0, 1.0, 0.0, 1.0, 0.0, 0.0, 1.0, 0.0, 1.0, 1.0, 0.0]
PS C:\Users\User\Desktop\ders\ie400\ie400-project\ie400-project>
```

2. Railway Development Project

Objective Function:

$$Minimize(totalEnergyCost\ +\ totalPurchaseCost\ +\ totalStationCost)$$

Decision Variable(s):

$$N_i = \{1\ if\ train\ i\ is\ assigned\ to\ depot\ X,\ 0\ if\ train\ is\ assigned\ to\ depot\ Y\}$$

$$E_i = \{1\ if\ train\ i\ is\ an\ electric\ train, 0\ if\ train\ i\ is\ a\ diesel\ train\}$$

$$c_{ijt}\ =\ \{1\ if\ train\ i\ is\ being\ charged\ at\ node\ j\ in\ time\ t,\ 0\ otherwise\}$$

$$s_j = Number\ of\ electric\ charging\ stations\ at\ node\ j$$

Parameter(s):

$$IN\_DEPOT\_CHARGE\_STATION = \$1000000$$

$$ON\_ROUTE\_CHARGE\_STATION = \$350000$$

$$IN\_DEPOT\_FUEL\_STATION = \$800000$$

$$ELECTRIC\_PURCHASE = \$750000$$

$$DIESEL\_PURCHASE = \$250000$$

$$ELECTRIC\_ENERGY\_BWH = \$20000$$

$$DIESEL\_ENERGY\_BWH = \$100000$$

$$pathDurations_i = path\ durations\ of\ train\ i = \{1, 15\}$$

$$exact\_timestamps_{ik} = total\ elapsed\ time\ for\ train\ i\ at\ the\ k'th\ node\ of\ its\ path$$

$$exact\_paths_{ik} = k'th\ node\ of\ train\ i$$

$$totalEnergyCost = \sum_{i=1}^{15} (pathDurations_i \times E_i \times ELECTRIC\_ENERGY\_BWH) + \sum_{i=1}^{15} (pathDurations_i \times (1 - E_i) \times DIESEL\_ENERGY\_BWH)$$

$$totalPurchaseCost = \sum_{i=1}^{15} (E_i \times ELECTRIC\_PURCHASE + (1 - E_i) \times DIESEL\_PURCHASE)$$

$$totalStationCost = \sum_{j=1}^{8} ((S_i \times ON\_ROUTE\_CHARGE\_STATION) + (ceil)\left(\sum_{j=1}^{15} E_i \times N_i/3\right) \times IN\_DEPOT\_CHARGING\_STATION + (ceil)\left(\sum_{j=1}^{15} E_i \times (1 - N_i)/3\right) \times IN\_DEPOT\_CHARGING\_STATION + (ceil)\left(\sum_{j=1}^{15} (1 - E_i) \times N_i/2\right) \times IN\_DEPOT\_FUEL\_STATION + (ceil)\left(\sum_{j=1}^{15} (1 - E_i) \times (1 - N_i)/2\right) \times IN\_DEPOT\_FUEL\_STATION)$$

$$J_{ik} = Remaining\ energy\ of\ train\ i\ at\ k'th\ node\ of\ exact\_path_{i,k}$$

$$J_{ik} = E_i \times ((1 - c_{i,j,t}) \times (J_{i(k-1)} - (exact\_timestamps_{i,k} - exact\_timestamps_{i,(k-1)}) + c_{i,exact\_paths_{i,k},exact\_timestamps_{i,k}} \times 8) + (1 - E_i) \times 20$$

Constraint(s):

$$\sum_{i=1}^{15} c_{i,j,t} <= S_j\ for\ j = \{1, 8\}\ t = \{1, 20\}$$

$$J_{i(k-1)} - (pathTime[i][k] - pathTime[i][k-1]) >= 0$$

$$J_{i0} = (1 - E_i) \times 20 + E_i \times 8$$

Objective Value and Values for Decision Variables:

```
Train 0 is electric
Train 1 is electric
Train 2 is electric
Train 3 is electric
Train 4 is electric
Train 5 is electric
Train 6 is electric
Train 7 is electric
Train 8 is electric
Train 9 is electric
Train 10 is electric
Train 11 is electric
Train 12 is electric
Train 13 is electric
Train 14 is electric
Node F has 1.0 charging stations
Node A has 1.0 charging stations
Node H has 1.0 charging stations
Node X has 1.0 charging stations
Node C has 1.0 charging stations
Node B has 1.0 charging stations
Node D has 1.0 charging stations
Node E has 1.0 charging stations
Node G has 1.0 charging stations
Final Total Cost: 20090000.0
PS C:\Users\User\Desktop\ders\ie400\ie400-project\
```

As can be seen, all trains are determined to be electric trains. Nodes A, B, C, D, E, F, G, H (all nodes) and depot X are determined to include an electric charge station. There exists no fuel station due to the lack of diesel trains. Depot Y does not include any electric charge station. All nodes include just one electric charge station.

Lastly, the total cost is $20,090,000.