Erin Alltop
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HW 6
CS325 – Fall 2017

1. In this code, the graph the variables represent the vertices and edges of the graph. For example, da-dh <= 4 means that the distance from vertex H to A has a weight of 4, da-df <=5 means that the distance from vertex F to H has a weight of 5, and so on and so forth. ds represents the starting vertex (G) and dt represents the terminating vertex (C).

a) **The distance of the shortest path from G to C is 16 as found in the LINDO code below**:

```
max dt
ST
   ds = 0
   da - dh <= 4
   da - df <= 5
   db - dh <= 9
   db - da <= 8
   db - df <= 7
   dt - df <= 3
   dt - db <= 4
   dd - dt <= 3
   dd - ds <= 2
   dd - de <= 9
   de - db <= 10
   de - dd <= 25
   de - df <= 2
   df - da <= 10
   df - dd <= 18
   ds - de <= 7
   dh - ds <= 3
END
```

```
LP OPTIMUM FOUND AT STEP      0

       OBJECTIVE FUNCTION VALUE

       1)       16.00000

 VARIABLE        VALUE          REDUCED COST
       DT        16.000000          0.000000
       DS         0.000000          0.000000
       DA         7.000000          0.000000
       DH         3.000000          0.000000
       DF        17.000000          0.000000
       DB        12.000000          0.000000
       DD         2.000000          0.000000
       DE        19.000000          0.000000
```

b) **The distances of the shortest paths from G to all other vertices:**

```
max dt + da + db + dd + de + dh + df
ST
   ds = 0
   da - dh <= 4
   da - df <= 5
   db - dh <= 9
   db - da <= 8
   db - df <= 7
   dt - df <= 3
   dt - db <= 4
   dd - dt <= 3
   dd - ds <= 2
   dd - de <= 9
   de - db <= 10
   de - dd <= 25
   de - df <= 2
   df - da <= 10
   df - dd <= 18
   ds - de <= 7
   dh - ds <= 3
END
```

```
LP OPTIMUM FOUND AT STEP      6

       OBJECTIVE FUNCTION VALUE

       1)       76.00000

 VARIABLE        VALUE          REDUCED COST
       DT        16.000000          0.000000
       DA         7.000000          0.000000
       DB        12.000000          0.000000
       DD         2.000000          0.000000
       DE        19.000000          0.000000
       DH         3.000000          0.000000
       DF        17.000000          0.000000
       DS         0.000000          0.000000
```

2. Silk, Poly, Blend 1, and Blend 2 are represented in this code as s, p, b, and c respectively. The objective function was created by adding the profit per tie of each type of material. The constraints were created by the yards available per month of each material and the monthly minimum and maximum units of each type of material.

The optimal numbers of ties of each type to maximize profit:

Silk = 7000

Poly = 13625

Blend 1 = 13100

Blend 2 = 8500

```
max 3.45s + 2.32p + 2.81b + 3.25c
ST
   0.125s <= 1000
   0.08p + 0.05b + 0.03c <= 2000
   0.05b + 0.07c <= 1250
   s >= 6000
   s <= 7000
   p >= 10000
   p <= 14000
   b >= 13000
   b <= 16000
   c >= 6000
   c <= 8500
END
```

Objective function
Silk material <= to 1000 yds/mo
Poly blend material <= 2000 yds/mo
Cotton material <= 1250 yds/mo
Silk monthly minimum is 6000
Silk monthly maximum is 7000
Poly monthly minimum is 10000
Poly monthly maximum is 14000
Blend1 monthly minimum is 13000
Blend1 monthly maximum is 16000
Blend2 monthly minimum is 6000
Blend2 monthly maximum is 8500

```
LP OPTIMUM FOUND AT STEP      4

        OBJECTIVE FUNCTION VALUE

        1)      120196.0

 VARIABLE        VALUE          REDUCED COST
        S      7000.000000          0.000000
        P     13625.000000          0.000000
        B     13100.000000          0.000000
        C      8500.000000          0.000000


       ROW   SLACK OR SURPLUS     DUAL PRICES
        2)       125.000000          0.000000
        3)         0.000000         29.000000
        4)         0.000000         27.200001
        5)      1000.000000          0.000000
        6)         0.000000          3.450000
        7)      3625.000000          0.000000
        8)       375.000000          0.000000
        9)       100.000000          0.000000
       10)      2900.000000          0.000000
       11)      2500.000000          0.000000
       12)         0.000000          0.476000

NO. ITERATIONS=       4
```

3. The variables in this code are representative of the plants, warehouses, and retail stores – represented by P, W, and R respectively along with their edges. For example, P1W1 represents the edge between Plant 1 and Warehouse 1. The objective equation was created by adding each shipping possibility and their respective costs of shipping. The constraints were established by adding the relevant shipping routes from plants to be less than or equal to their supply, adding the relevant shipping routes to the retail stores from the warehouses that supply them to be greater than or equal to the demand, as well as adding warehouse constraints so that the amount shipped to a warehouse is equal to the amount that leaves the warehouse (with no storage).

The minimized cost is $17,100.

```
min 10P1W1 + 15P1W2 + 11P2W1 + 8P2W2 + 13P3W1 + 8P3W2 + 9P3W3 + 14P4W2 + 8P4W3 + 5W1R1 +
6W1R2 + 7W1R3 + 10W1R4 + 12W2R3 + 8W2R4 + 10W2R5 + 14W2R6 + 14W3R4 + 12W3R5 + 12W3R6 + 6W3R7
ST
   P1W1 + P1W2 <= 150
   P2W1 + P2W2 <= 450
   P3W1 + P3W2 + P3W3 <= 250
   P4W2 + P4W3 <= 150
   W1R1 >= 100
   W1R2 >= 150
   W1R3 + W2R3 >= 100
   W1R4 + W2R4 + W3R4 >= 200
   W2R5 + W3R5 >= 200
   W2R6 + W3R6 >= 150
   W3R7 >= 100
   P1W1 + P2W1 + P3W1 - W1R1 - W1R2 - W1R3 - W1R4 >= 0
   P1W2 + P2W2 + P3W2 + P4W2 - W2R3 - W2R4 - W2R5 - W2R6 >= 0
   P3W3 + P4W3 - W3R4 - W3R5 - W3R6 - W3R7 >= 0
END
```

Total supply from Plant 1 <= 150
Total supply from Plant 2 <= 450
Total supply from Plant 3 <= 250
Total demand from Retail 1 >= 100
Total demand from Retail 2 >= 150
Total demand from Retail 3 >= 100
Total demand from Retail 4 >= 200
Total demand from Retail 5 >= 200
Total demand from Retail 6 >= 150
Total demand from Retail 7 >= 100
The last three constraints ensure that the product going into each individual warehouse equals the product leaving the warehouse.

The optimal shipping routes and minimum cost:

```
LP OPTIMUM FOUND AT STEP     13

        OBJECTIVE FUNCTION VALUE

        1)      17100.00

 VARIABLE        VALUE          REDUCED COST
     P1W1       150.000000          0.000000
     P1W2         0.000000          8.000000
     P2W1       200.000000          0.000000
     P2W2       250.000000          0.000000
     P3W1         0.000000          2.000000
     P3W2       150.000000          0.000000
     P3W3       100.000000          0.000000
     P4W2         0.000000          7.000000
     P4W3       150.000000          0.000000
     W1R1       100.000000          0.000000
     W1R2       150.000000          0.000000
     W1R3       100.000000          0.000000
     W1R4         0.000000          5.000000
     W2R3         0.000000          2.000000
     W2R4       200.000000          0.000000
     W2R5       200.000000          0.000000
     W2R6         0.000000          1.000000
     W3R4         0.000000          7.000000
     W3R5         0.000000          3.000000
     W3R6       150.000000          0.000000
     W3R7       100.000000          0.000000
```

4. The variables in this code are representative of the ingredients of the salad:

Tomato	t
Lettuce	L
Spinach	sp
Carrot	c
Sunflower Seeds	ss
Smoked Tofu	st
Chickpeas	cp
Oil	o

a. The objective equation was created by minimizing the calories of each ingredient by adding them together. The problem calls for meeting all nutritional needs, so the constraints were created by adding together the relevant nutrient of each nutrient and assigning it the correct inequality. The price of the salad was represented by the variable "pr" and is calculated in the last constraint.

The salad with minimized calories that meets all nutritional needs is 114.75 calories and costs $2.33.

```
min 21t + 16L + 40sp + 41c + 585ss + 120st + 164cp + 884o
ST
   0.85t + 1.62L + 2.86sp + 0.93c + 23.4ss + 16st + 9cp + 0o >= 15
   0.33t + 0.20L + 0.39sp + 0.24c + 48.7ss + 5st + 2.6cp + 100o >= 2
   0.33t + 0.20L + 0.39sp + 0.24c + 48.7ss + 5st + 2.6cp + 100o <= 8
   4.64t + 2.37L + 3.63sp + 9.58c + 15ss + 3st + 27cp + 0o >= 4
   9t + 28L + 65sp + 69c + 3.80ss + 120st + 78cp + 0o <= 200
   0.4t + 0.4sp + 0.4L + 0.4c + 0.4ss + 0.4st + 0.4cp + 0.4o - 1sp - 1L <= 0
   1t + 0.75L + 0.50sp + 0.50c + 0.45ss + 2.15st + 0.95cp + 2o - pr = 0
END
```

Objective function – min calories
At least 15 grams of protein
At least 2 grams of fat
At most 8 grams of fat
At most 200 mg of sodium
At least 40% leafy greens by mass
Profit of salad by ingredients

```
LP OPTIMUM FOUND AT STEP      12

        OBJECTIVE FUNCTION VALUE

        1)      114.7541

 VARIABLE        VALUE          REDUCED COST
        T         0.000000        16.901640
        L         0.585480         0.000000
       SP         0.000000        14.513662
        C         0.000000        36.289616
       SS         0.000000       408.387970
       ST         0.878220         0.000000
       CP         0.000000        97.551910
        O         0.000000       886.404358
       PR         2.327283         0.000000


      ROW    SLACK OR SURPLUS      DUAL PRICES
        2)         0.000000        -7.650273
        3)         2.508197         0.000000
        4)         3.491803         0.000000
        5)         0.022248         0.000000
        6)        78.220139         0.000000
        7)         0.000000         6.010929
        8)         0.000000         0.000000

NO. ITERATIONS=      12
```

b. This problem is set up very similarly to part A. All the nutritional constraints remain the same. This time, we are minimizing the cost, so the objective has changed to reflect this. To obtain the calories, a new variable "cal" was created and made into the final constraint to obtain the calories of the salad that has the minimum cost.

The minimized cost of the salad is $1.55 and contains 278.49 calories.

```
min 1t + 0.75L + 0.50sp + 0.50c + 0.45ss + 2.15st + 0.95cp + 2o
ST
   0.85t + 1.62L + 2.86sp + 0.93c + 23.4ss + 16st + 9cp + 0o >= 15
   0.33t + 0.20L + 0.39sp + 0.24c + 48.7ss + 5st + 2.6cp + 100o >= 2
   0.33t + 0.20L + 0.39sp + 0.24c + 48.7ss + 5st + 2.6cp + 100o <= 8
   4.64t + 2.37L + 3.63sp + 9.58c + 15ss + 3st + 27cp + 0o >= 4
   9t + 28L + 65sp + 69c + 3.80ss + 120st + 78cp + 0o <= 200
   0.4t + 0.4sp + 0.4L + 0.4c + 0.4ss + 0.4st + 0.4cp + 0.4o - 1sp - 1L <= 0
   21t + 16L + 40sp + 41c + 585ss + 120st + 164cp + 884o - cal = 0
END
```

Objective function – min cost
At least 15 grams of protein
At least 2 grams of fat
At most 8 grams of fat
At most 200 mg of sodium
At least 40% leafy greens by mass
Calories of each salad

```
LP OPTIMUM FOUND AT STEP      3

        OBJECTIVE FUNCTION VALUE

        1)      1.554133

 VARIABLE        VALUE          REDUCED COST
        T         0.000000          1.002081
        L         0.000000          0.402912
       SP         0.832298          0.000000
        C         0.000000          0.486914
       SS         0.096083          0.000000
       ST         0.000000          0.405609
       CP         1.152364          0.000000
        O         0.000000          7.281258
      CAL       278.488403          0.000000

      ROW    SLACK OR SURPLUS      DUAL PRICES
        2)         0.000000         -0.131261
        3)         6.000000          0.000000
        4)         0.000000          0.051847
        5)        31.576324          0.000000
        6)        55.651089          0.000000
        7)         0.000000          0.241358
        8)         0.000000          0.000000

NO. ITERATIONS=       3
```