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M/CS 335

**Lab 01**

**2-27:**

For this problem we have 10 total variables Pn, n=1-10, each one signifying the amount of water flowing at each pump 1-10, in gal/min.

**Model:** Minimize cost = 0.05(p1 + p2 + p3) + 0.07(p4 + p5 + p6) + 0.13(p7 + p8 + p9 + p10)

s.t.

p1 + p2 + p3 <= 3000

p2 + p5 + p8 <= 2500

p3 + p7 + p9 + p10 <= 7000

p1 + p2 + p3 + p4 + p5 + p6 + p7 + p8 + p9 + p10 >= 10,000

pn >= 0 for all n

This model works because we have the coefficients for cost per gallon pumped, being 0.05, 0.07, 0.13 and we can use the flow rate as our variables giving us $/gal/min. The first 3 constraints are so that our pumps do not exceed the limit for each well 1, 2, and 3. The fourth constraint is to meet the minimum requirement to satisfy the water demand. The final constraint is for nonnegativity.

**Mathematica input:**

Minimize[{0.05\*(p1 + p2 + p3) + 0.07\*(p4 + p5 + p6) +

0.13\*(p7 + p8 + p9 + p10),

p1 + p4 + p7 <= 3000,

p2 + p5 + p8 <= 2500,

p3 + p6 + p9 + p10 <= 7000,

p1 + p2 + p3 + p4 + p5 + p6 + p7 + p8 + p9 + p10 >= 10000,

0 <= p1 <= 1100,

0 <= p2 <= 1100,

0 <= p3 <= 1100,

0 <= p4 <= 1500,

0 <= p5 <= 1500,

0 <= p6 <= 1500,

0 <= p7 <= 2500,

0 <= p8 <= 2500,

0 <= p9 <= 2500,

0 <= p10 <= 2500},

{p1, p2, p3, p4, p5, p6, p7, p8, p9, p10}]

**Mathematica output:**

{772., {p1 -> 1100., p2 -> 1100., p3 -> 1100., p4 -> 1500.,

p5 -> 1400., p6 -> 1500., p7 -> 0., p8 -> 0., p9 -> 0.,

p10 -> 2300.}}

**Solution table:**

|  |  |
| --- | --- |
| Pumping station: | Amount of water to pump (gal/min): |
| 1 | 1100 |
| 2 | 1100 |
| 3 | 1100 |
| 4 | 1500 |
| 5 | 1400 |
| 6 | 1500 |
| 7 | 0 |
| 8 | 0 |
| 9 | 0 |
| 10 | 2300 |
| Total cost: | $772 per minute |

If the city of Lancaster wants to meet its water pumping needs as cheaply as possible, they will need to pump 1100 gal/min at pump 1, 2, and 3. As well as 1500 at pump 4 and 6, 1400 at pump 5, and 2300 at pump 10. Pumps 7, 8, and 9 must be turned off. The lowest possible price is $772 per minute to meet the needs of the city.

**2-29:**

There are 28 total variables in this problem. (7 total locations earth is needed) x (4 sites with surplus earth) = 28 total variables. Each Vij for i=1-7, j=1-4 represents the volume of earth being moved from location j to location i.

**Model:** Minimize (distance times volume) = (26 v11) + (28 v12) + (20 v13) + (26 v14) + (12 v21) + (14 v22) + (26 v23) + (10 v24) + (10 v31) + (12 v32) + (20 v33) + (4 v34) + (18 v41) + (20 v42) +(2 v43) + (16 v44) + (11 v51) + (16 v52) + (6 v53) + (24 v54) + (8 v61) + (10 v62) + (22 v63) + (14 v64) + (20 v71) + (22 v72) + (18 v73) + (21 v74)

s.t.

v11 + v21 + v31 + v41 + v51 + v61 + v71 <= 660,

v12 + v22 + v32 + v42 + v52 + v62 + v72 <= 301,

v13 + v23 + v33 + v43 + v53 + v63 + v73 <= 271,

v14 + v24 + v34 + v44 + v54 + v64 + v74 <= 99,

v11 + v12 + v13 + v14 >= 247,

v21 + v22 + v23 + v24 >= 394,

v31 + v32 + v33 + v34 >= 265,

v41 + v42 + v43 + v44 >= 105,

v51 + v52 + v53 + v54 >= 90,

v61 + v62 + v63 + v64 >= 85,

v71 + v72 + v73 + v74 >= 145,

Vij >= 0 for all i,j

Given the distance between every location (in hundreds of meters), we simply multiply that by the volume (meters cubed) moved between them. This gives us some form of “work” to be interpreted by the engineer to decide how to tackle this earth moving problem. The first four constraints ensure that we do not exceed the available earth at each site. The next 7 ensure that site needing earth receives enough, then of course we have the nonnegativity constraints.

**Mathematica input:**

Minimize[{26 v11 + 28 v12 + 20 v13 + 26 v14 + 12 v21 + 14 v22 +

26 v23 + 10 v24 + 10 v31 + 12 v32 + 20 v33 + 4 v34 + 18 v41 +

20 v42 + 2 v43 + 16 v44 + 11 v51 + 16 v52 + 6 v53 + 24 v54 +

8 v61 + 10 v62 + 22 v63 + 14 v64 + 20 v71 + 22 v72 + 18 v73 +

21 v74,

v11 + v21 + v31 + v41 + v51 + v61 + v71 <= 660,

v12 + v22 + v32 + v42 + v52 + v62 + v72 <= 301,

v13 + v23 + v33 + v43 + v53 + v63 + v73 <= 271,

v14 + v24 + v34 + v44 + v54 + v64 + v74 <= 99,

v11 + v12 + v13 + v14 >= 247,

v21 + v22 + v23 + v24 >= 394,

v31 + v32 + v33 + v34 >= 265,

v41 + v42 + v43 + v44 >= 105,

v51 + v52 + v53 + v54 >= 90,

v61 + v62 + v63 + v64 >= 85,

v71 + v72 + v73 + v74 >= 145,

v11 >= 0, v12 >= 0, v13 >= 0, v14 >= 0, v21 >= 0, v22 >= 0, v23 >= 0, v24 >= 0, v31 >= 0, v32 >= 0, v33 >= 0, v34 >= 0, v41 >= 0, v42 >= 0, v43 >= 0, v44 >= 0, v51 >= 0, v52 >= 0, v53 >= 0, v54 >= 0, v61 >= 0, v62 >= 0, v63 >= 0, v64 >= 0, v71 >= 0,v72 >= 0,v73 >= 0, v74 >= 0},

{v11, v12, v13, v14, v21, v22, v23, v24, v31, v32, v33, v34, v41,

v42, v43, v44, v51, v52, v53, v54, v61, v62, v63, v64, v71, v72,

v73, v74}]

**Mathematica output:**

{17592, {v11 -> 81, v12 -> 0, v13 -> 166, v14 -> 0, v21 -> 93,

v22 -> 301, v23 -> 0, v24 -> 0, v31 -> 166, v32 -> 0, v33 -> 0,

v34 -> 99, v41 -> 0, v42 -> 0, v43 -> 105, v44 -> 0, v51 -> 90,

v52 -> 0, v53 -> 0, v54 -> 0, v61 -> 85, v62 -> 0, v63 -> 0,

v64 -> 0, v71 -> 145, v72 -> 0, v73 -> 0, v74 -> 0}}

**Solution table:**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Volume to be moved (m^3) | Surplus site: 1 | 2 | 3 | 4 |
| Need site: 1 | 81 | 0 | 166 | 0 |
| 2 | 93 | 301 | 0 | 0 |
| 3 | 166 | 0 | 0 | 99 |
| 4 | 0 | 0 | 105 | 0 |
| 5 | 90 | 0 | 0 | 0 |
| 6 | 85 | 0 | 0 | 0 |
| 7 | 145 | 0 | 0 | 0 |
| Total “work”: | 17,592 meters cubed times distance in hundreds of meters |  |  |  |

To do the least amount of “work” the team should send 81 cubic meters of earth to the Extension from the Apron, and 166 from the Cargo area. 93 cubic meters from the Apron moved to the dry pond along with 301 from the Term. Roads will need to be filled with 166 m^3 from the Apron and 99 from Access. Cargo will move 105 cubic meters to the Parking lot. The final earth to be moved comes from the Apron and it is 90 cubic meters, 85 cubic meters, and 145 cubic meters being sent to the Fire station, the Industrial park, and the Perimeter road respectively.