Operation Research I

Computer Based Group Assignment

CASE STUDY: KALPAVRUKSHA SILK COMPANY

ABSTRACT

In this paper we present the case study from **Kalpavruksha silk company.** It focuses on the formulation of the plan to specify the optimal purchase , production scheduling and sales plan for the company for the next twelve weeks. Kalpavruksha silk company has been struggling to stay afloat due to increased costs, obsolescence of machinery and reduced profit margins. The company's mounting losses have forced the General Manager to re-examine the entire working of the company in the framework of yearly planning, right from the purchase of "cocoons," a raw material for reeling silk, to the processing aspects and the sale of silk yarn.In order to process the problem a support tool has been developed which incorporates a linear programming problem as a central feature. The details of the model are described in this report along with various results.

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INTRODUCTION

The Kalpavriksha Silk Company has been engaged in the production and marketing of high quality silk for the last four decades. The company was the market leader in the field of quality silk. However, in recent years, it has been struggling to stay afloat due to increased costs, obsolescence of machinery and reduced profit margins. The company's mounting losses have forced the General Manager to re-examine the entire working of the company in the framework of yearly planning, right from the purchase of "cocoons," a raw material for reeling silk, to the processing aspects and the sale of silk yarn. With a view to improve the effectiveness and efficiency of the company, the General Manager has decided to examine the purchase, production scheduling and sales plan for the company. To start with, he has decided to develop a plan for the forthcoming quarter to decide how much of raw material to purchase and at what time point, how much of each type of silk produce and when, how much of raw material and silk inventory to carry during various periods as well as when and what quantity of silk yarn to sell. Once successful in developing an appropriate methodology, his objective is to extend the rationale for annual operating plans. Briefly, the process of manufacturing silk yarn involves stifling, reeling and re-reeling. The stifling process kills the pupae within the cocoons so that the cocoon can be stored for a few weeks before being taken for further processing known as reeling. The stifling process has an important bearing on the quality of raw silk. Reeling is the process of producing the raw silk from the cocoons. The company has two kinds of reeling mechanisms, namely Charaka and Filature (reeling on a multi-end machine). The raw silks produced from them differ in respect of quality as also productivity. Filature silk is finer as compared to the Charaka silk. Before reeling, cocoons are sorted as good and bad cocoons (includes "double" cocoons). Good quality cocoons can be used for producing filature silk, while double cocoons can be used only for producing dupion silk on the chakras. Of course, dupion silk can be produced using good cocoons also; in the past this was considered an inefficient practice. However, a recent trend, indicating better margins for dupion, has resulted in some companies using good quality cocoons for dupion silk also.

THE PROBLEM

QUESTIONS:

1.Formulate the problem discussed in the case in the framework of a Linear Programming model.

2.Interpret the L.P. results, by providing the recommendations in the form of simple tables/reports that could be easily understood by the management and supervisory staff.

3.What should be the quantity of cocoons purchased, utilized and inventory held for different weeks?

4.What should be the quantity of filature silk produced, sold and inventory held for the different weeks?

5.What should be the quantity of dupion silk produced, sold and inventory held for different weeks?

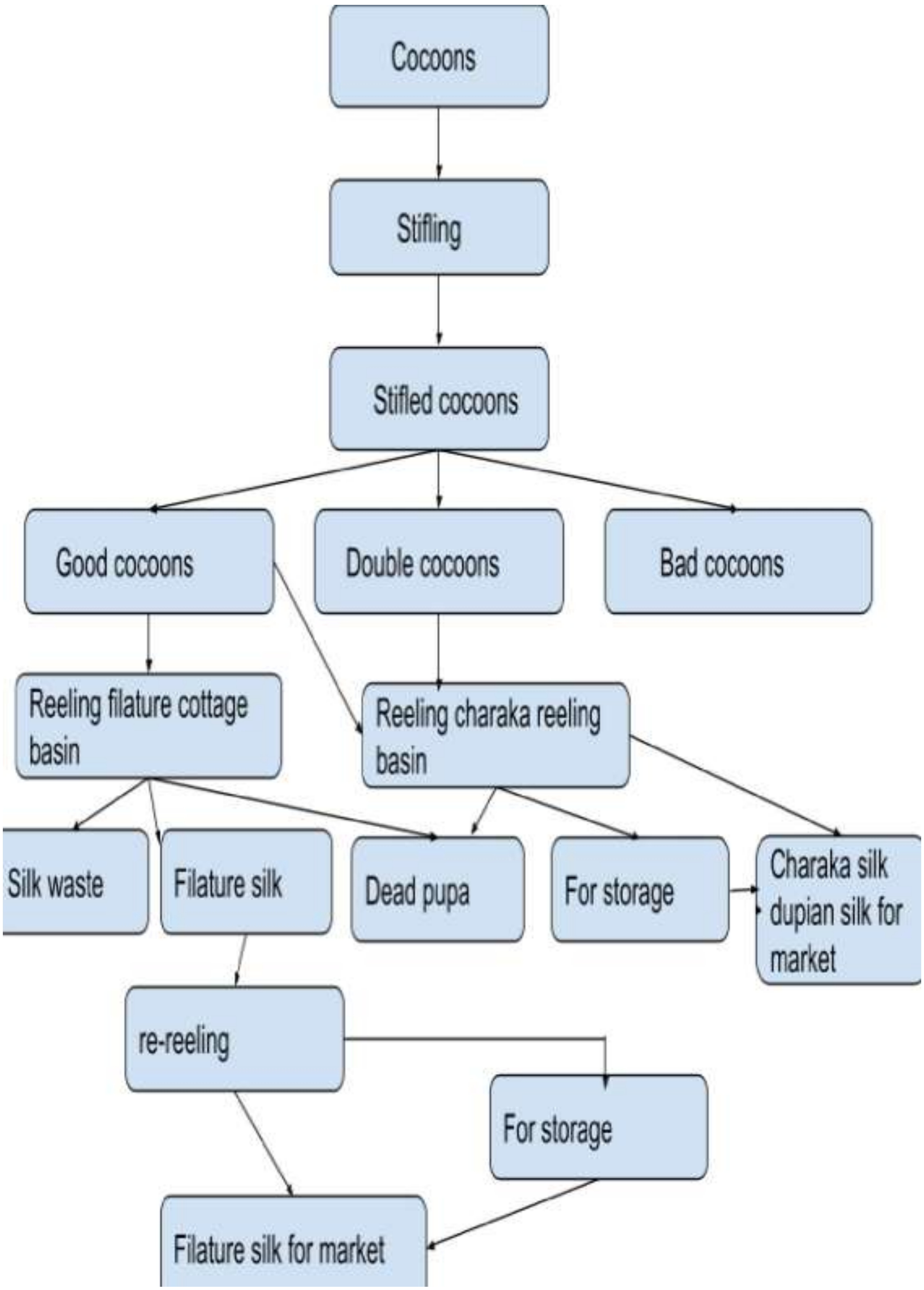
6.What is the ideal number of reeler and re-reeler days required for filature and dupion silk?

7.Suppose wages for reelers and re-reelers are considered as fixed cost, what is the resulting net profit?

8.Suppose the Renditta for filature and/or dupion silk changes, what are the changes in the solution?

9.If the productivity for filature and/or dupion silk changes, what are the associated changes in the solution?

PROBLEM ANALYSIS



$x_i =$ cocoon purchased in kg per week

$y_i =$ filature silk sold in kg per week

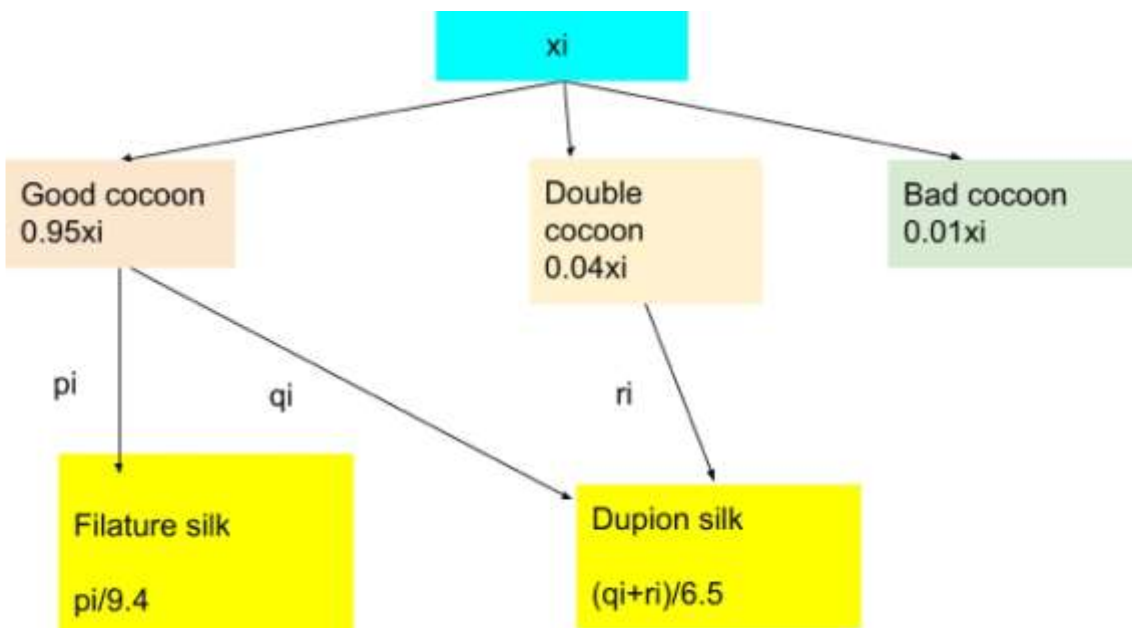
$z_i =$ dupion silk sold in kg per week

$p_i =$ good cocoon used for filature silk per week

$q_i =$ good cocoon used for dupion silk per week

$r_i =$ double cocoon used for dupion silk per week

$Where\ ,\ i = 1, 2, 3, \ldots\ldots\ldots\ldots, 12$



Filature silk produced=pi/9.4
Dupion silk produced =(qi+ri)/6.5

Filature basin constraint

$$\sum_{i=1}^{12} \frac{pi}{9.4 \cdot 0.8 \cdot 6} + \sum_{i=1}^{12} \frac{pi}{9.4 \cdot 6 \cdot 2.4} \leq 70$$

charka constraint

$$\sum_{i=1}^{12} \frac{qi + ri}{1.2 \cdot 6 \cdot 6.5} \leq 5$$

reeler constraint

$$\sum_{i=1}^{12} \frac{p_i}{0.8 \cdot 6 \cdot 9.4} + \sum_{i=1}^{12} \frac{q_i + r_i}{1.2 \cdot 6 \cdot 6.5} \leq 60$$

re − reeler constraint

$$\sum_{i=1}^{12} \frac{p_i}{6 \cdot 9.4 \cdot 2.4} \leq 20$$

Silk sold <= Silk Produced

Filature

$$9.4 \times y_1 \leq p_1$$

$$9.4\left(y_1 + y_2\right) \leq p_2 + p_1$$

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$$9.4 \times \sum_{i=1}^{12} y_i = \sum_{i=1}^{12} p_i$$

Dupion

$$6.5 \times z_1 \leq q_1 + r_1$$

$$6.5\left(z_1 + z_2\right) \leq q_1 + r_1 + q_2 + r_2$$

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$$6.5 \times \sum_{i=1}^{12} z_1 = \sum_{i=1}^{12} \left(q_i + r_i\right)$$

Constraint related with inventory

$$p_1 + q_1 \leq 0.95\, x_1$$

$$p_1 + q_1 + p_2 + q_2 \leq \left(x_1 + x_2\right)$$

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$$\sum_{i=1}^{12} \left(p_1 + q_1\right) \leq 0.95 \left(\sum_{i=1}^{12} x_i\right)$$

$$r_1 \leq 0.04\, x_1$$

$$r_1 + r_2 \leq 0.04\, x_2$$

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$$\sum_{i=1}^{12} \left(r_i\right) \leq 0.04 \left(\sum_{i=1}^{12} x_i\right)$$

Given:

l_i = Purchased price of cocoon.

m_i = Sales price of filature silk.

n_i = Sales price of Dupion silk.

- Total price of Silk =

$$\sum_{i=1}^{12}\left(m_i \cdot y_i + n_i \cdot z_i\right)$$

- Total price of cocoon =

$$\sum_{i=1}^{12}\left(l_i \cdot x_i\right)$$

- Total wages of workers =

$$\sum_{i=1}^{12} 50 \cdot 6\left[\frac{(p_i)}{9.4 \cdot 0.8 \cdot 6} + \frac{(q_i + r_i)}{6.5 \cdot 1.2 \cdot 6} + \frac{(p_i)}{9.4 \cdot 2.4 \cdot 6}\right]$$

- Total price of Bad cocoon =

$$10\sum_{i=1}^{12} 0.01x_i$$

- Total price of dead pupae =

$$0.6\sum_{i=1}^{12} 0.2x_i$$

- Total price of Silk =

$$50\sum_{i=1}^{12} 0.025a_i$$

- Inventory cost of cocoon =

$$\sum_{i=1}^{12} (li) \left[\sum_{j=1}^{i} (xi - pi - qi - ri) \right]$$

- Inventory cost of filature Silk =

$$\sum_{i=1}^{12} mi\left[\sum_{j=1}^{i} \left(\frac{pi}{9.4} - yi \right)\right]$$

- Inventory cost of Dupion Silk =

$$\sum_{i=1}^{12} ni\left[\sum_{j=1}^{i} \left(\frac{(qi + ri)}{6.5} - Zi \right)\right]$$

- <u>**Objective Function=>**</u>

Maximize:

$$Z = \sum_{1}^{12} \left(m_i \cdot y_i + n_i . z_i \right) - \sum_{1}^{12} (li \cdot xi) - \sum_{i=1}^{12} 50 \cdot 6 \left[\frac{\left(p_i\right)}{9.4 \cdot 0.8 \cdot 6} + \frac{\left(q_i + r_i\right)}{6.5 \cdot 1.2 \cdot 6} + \frac{\left(p_i\right)}{9.4 \cdot 2.4 \cdot 6} \right]$$

$$+ 10 \sum_{i=1}^{12} 0.01 x_i + 0.6 \sum_{i=1}^{12} 0.2 x_i + 50 \sum_{i=1}^{12} 0.025 a_i$$

$$- \sum_{i=1}^{12} l_i \left[\sum_{j=1}^{i} \left(x_i - p_i - q_i - r_i \right) \right] - \sum_{i=1}^{12} m_i \left[\sum_{j=1}^{i} \left(\frac{p_i}{9.4} - y_i \right) \right] - \sum_{i=1}^{12} n_i \left[\sum_{j=1}^{i} \left(\frac{\left(q_i + r_i\right)}{6.5} - Z_i \right) \right]$$

2.Interpret the L.P. results, by providing the recommendations in the form of simple tables/reports that could be easily understood by the management and supervisory staff.

Week	Cocoons purchased (x_i)	Filature sold (y_i)	Dupion sold (z_i)	Good Cocoon for Filature Silk (p_i)	Good Cocoon for Dupion Silk (q_i)	Double Cocoon for Dupion Silk (r_i)
1	2493.474	252.00	15.34445	2368.8	0	99.738
2	4986.947	0.00	30.68891	2368.8	0	199.477
3	0	0.00	0.00	2368.8	0	0
4	7480.421	0.00	0.00	2368.8	0	65.216
5	0	0.00	0.00	2368.8	0	234
6	0	1260.00	82.03336	2368.8	0	234
7	2493.474	252.00	15.34445	2368.8	0	99.73
8	2493.474	0.00	15.34445	2368.8	0	99.73
9	9973.895	0.00	0.00	2368.8	0	0
10	0	0.00	0.00	2368.8	0	234
11	0	0.00	0.00	2368.8	0	0
12	0	0.00	61.37781	2368.8	0	164.95

3.What should be the quantity of cocoons purchased, utilized and inventory held for different weeks?

Week	Cocoons Purchased	Cocoons Utilised	Inventory held
1	2493.474	2468.539	24.935
2	4986.947	2568.278	2443.604
3	0.00	2368.8	74.804
4	7480.421	2368.8	5186.425
5	0.00	2368.8	2817.625
6	0.00	2702.017	115.608
7	2493.474	2468.539	140.543
8	2493.474	2468.539	165.478
9	9973.895	2368.8	7770.573
10	0.00	2368.8	5401.773
11	0.00	2368.8	3032.973
12	0.00	2767.756	265.217

4.What should be the quantity of filature silk produced, sold and inventory held for the different weeks?

Week	Filature produced	Filature sold	Inventory held
1	252	252.00	0.00
2	252	0.00	252
3	252	0.00	504
4	252	0.00	756
5	252	0.00	1008
6	252	1260.00	0.00
7	252	252.00	0.00
8	252	0.00	252
9	252	0.00	504
10	252	0.00	756
11	252	0.00	1008
12	252	0.00	1260

5.What should be the quantity of dupion silk produced, sold and inventory held for different weeks?

Week	Dupion produced	Dupion sold	Inventory held
1	15.344	15.34445	0.00
2	30.688	30.68891	0.00
3	0.00	0.00	0.00
4	10.0333	0.00	10.0333
5	36	0.00	46.0333
6	36	82.03336	0.00
7	15.344	15.34445	0.00
8	15.344	15.34445	0.00
9	0.00	0.00	0.00
10	36	0.00	36
11	0.00	0.00	36
12	25.377	61.37781	0.00

6.What is the ideal number of reeler and re-reeler days required for filature and dupion silk?

Week	Reeler for Filature	Re Reeler for Filature	Reeler for Dupion
1	53	18	3
2	53	18	5
3	53	18	0
4	53	18	2
5	53	18	5
6	53	18	5
7	53	18	3
8	53	18	3
9	53	18	0
10	53	18	5
11	53	18	0
12	53	18	4

7.Suppose wages for reelers and re reelers are considered as fixed cost, what is the resulting net profit?

Net Profit – Rupees. 551551.8

8.Suppose the Renditta for filature and/or dupion silk changes, what are the changes in the solution?

- We get less silk for the same number of raw material is the renditta increases.
- More number of reelers and re-reelers days will be required to handle the increased raw materials which will further reduce the profit
- **Hence, the profit margin will reduce with the increase in renditta,**

9.If the productivity for filature and/or dupion silk changes, what are the associated changes in the solution?

- If filature productivity rises but dupion keeps the same, we'll be able to generate more filature while using fewer reelers, and vice versa.
- More reelers and re-reelers needed due to lesser productivity.

LINGO Code

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MAX = ( 932.17*y1+849.37*y2+825.25*y3+828.46*y4+851.64*y5+859.94*y6+811.56*y7+770.58*y8+
729.73*y9+713.91*y10+731.70*y11+783.02*y12 ) +
      ( 561.79*z1+518.35*z2+483.14*z3+488.30*z4+496.92*z5+509.17*z6+488.22*z7+454.57*z8+
431.33*z9+413.20*z10+420.72*z11+447.84*z12 ) -
      ( 81.94*x1+75*x2+77.15*x3+74.72*x4+76.96*x5+76.18*x6+70.63*x7+67.95*x8+61.69*x9+
63.68*x10+64.79*x11+67.23*x12 ) +
      0.1*( x1+x2+x3+x4+x5+x6+x7+x8+x9+x10+x11+x12 ) + 1.25*( p1+p2+p3+p4+p5+p6+p7+p8+p9
+p10+p11+p12 ) + 0.12*(  x1+x2+x3+x4+x5+x6+x7+x8+x9+x10+x11+x12 )-
      300*( ((p1+p2+p3+p4+p5+p6+p7+p8+p9+p10+p11+p12)/45.12) + ((q1+q2+q3+q4+q5+q6+q7+q8
+q9+q10+q11+q12)/46.8)+((r1+r2+r3+r4+r5+r6+r7+r8+r9+r10+r11+r12)/46.8) +
      ((p1+p2+p3+p4+p5+p6+p7+p8+p9+p10+p11+p12)/135.36) ) - (0.15/52)*( 9687.33*(0.106*p1-
y1)+8755.16*(0.106*p2-y2)+7905.79*(0.106*p3-y3)+7080.54*(0.106*p4-y4) +
      6252.08*(0.106*p5-y5)+5400.44*(0.106*p6-y6)+4540.5*(0.106*p7-y7)+3728.94*(0.106*p8-
y8)+2958.36*(0.106*p9-y9)+2228.63*(0.106*p10-y10)+1514.72*(0.106*p11-y11)+
      783.02*(0.106*p12-y12)+ 5713.55*(0.154*(q1+r1)-z1)+5151.76*(0.154*(q2+r2)-z2)+
4633.41*(0.154*(q3+r3)-z3)+4150.27*(0.154*(q4+r4)-z4)+3661.97*(0.154*(q5+r5)-z5)+
      3165.05*(0.154*(q6+r6)-z6)+2655.88*(0.154*(q7+r7)-z7)+2167.66*(0.154*(q8+r8)-z8)+
1713.09*(0.154*(q9+r9)-z9)+1281.76*(0.154*(q10+r10)-z10)+868.56*(0.154*(q11+r11)-z11)+
      447.84*(0.154*(q12+r12)-z12)+ 857.92*(0.99*x1-p1-q1-r1)+775.98*(0.99*x2-p2-q2-r2)+
700.98*(0.99*x3-p3-q3-r3)+623.83*(0.99*x4-p4-q4-r4)+549.11*(0.99*x5-p5-q5-r5)+
      472.15*(0.99*x6-p6-q6-r6)+395.97*(0.99*x7-p7-q7-r7)+ 325.34*(0.99*x8-p8-q8-r8)+
257.39*(0.99*x9-p9-q9-r9)+195.7*(0.99*x10-p10-q10-r10)+132.02*(0.99*x11-p11-q11-r11)+67.23
*(0.99*x12-p12-q12-r12));


  q1 <= 0.95*x1-p1;
  q2 <= 0.95*x2-p2+0.95*x1-p1-q1;
  q3 <= 0.95*x3-p3+0.95*x2-p2-q2+0.95*x1-p1-q1;
  q4 <= 0.95*x4-p4+0.95*x3-p3-q3+0.95*x2-p2-q2+0.95*x1-p1-q1;
  q5 <= 0.95*x5-p5+0.95*x4-p4-q4+0.95*x3-p3-q3+0.95*x2-p2-q2+0.95*x1-p1-q1;
  q6 <= 0.95*x6-p6+0.95*x5-p5-q5+0.95*x4-p4-q4+0.95*x3-p3-q3+0.95*x2-p2-q2+0.95*x1-p1-q1;
  q7 <= 0.95*x7-p7+0.95*x6-p6-q6+0.95*x5-p5-q5+0.95*x4-p4-q4+0.95*x3-p3-q3+0.95*x2-p2-q2+
0.95*x1-p1-q1;
  q8 <= 0.95*x8-p8+0.95*x7-p7-q7+0.95*x6-p6-q6+0.95*x5-p5-q5+0.95*x4-p4-q4+0.95*x3-p3-q3+
0.95*x2-p2-q2+0.95*x1-p1-q1;
  q9 <= 0.95*x9-p9+0.95*x8-p8-q8+0.95*x7-p7-q7+0.95*x6-p6-q6+0.95*x5-p5-q5+0.95*x4-p4-q4+
0.95*x3-p3-q3+0.95*x2-p2-q2+0.95*x1-p1-q1;
  q10<= 0.95*x10-p10+0.95*x9-p9-q9+0.95*x8-p8-q8+0.95*x7-p7-q7+0.95*x6-p6-q6+0.95*x5-p5-q5
+0.95*x4-p4-q4+0.95*x3-p3-q3+0.95*x2-p2-q2+0.95*x1-p1-q1;
  q11<= 0.95*x11-p11+0.95*x10-p10-q10+0.95*x9-p9-q9+0.95*x8-p8-q8+0.95*x7-p7-q7+0.95*x6-
p6-q6+0.95*x5-p5-q5+0.95*x4-p4-q4+0.95*x3-p3-q3+0.95*x2-p2-q2+0.95*x1-p1-q1;
  q12 = 0.95*x12-p12+0.95*x11-p11-q11+0.95*x10-p10-q10+0.95*x9-p9-q9+0.95*x8-p8-q8+0.95
*x7-p7-q7+0.95*x6-p6-q6+0.95*x5-p5-q5+0.95*x4-p4-q4+0.95*x3-p3-q3+0.95*x2-p2-q2+0.95*x1-
p1-q1;

  r1 <= 0.04*x1;
  r2 <= 0.04*x2+0.04*x1-r1;
  r3 <= 0.04*x3+0.04*x2-r2+0.04*x1-r1;
  r4 <= 0.04*x4+0.04*x3-r3+0.04*x2-r2+0.04*x1-r1;
  r5 <= 0.04*x5+0.04*x4-r4+0.04*x3-r3+0.04*x2-r2+0.04*x1-r1;
  r6 <= 0.04*x6+0.04*x5-x5+0.04*x4-r4+0.04*x3-r3+0.04*x2-r2+0.04*x1-r1;
  r7 <= 0.04*x7+0.04*x6-r6+0.04*x5-x5+0.04*x4-r4+0.04*x3-r3+0.04*x2-r2+0.04*x1-r1;
  r8 <= 0.04*x8+0.04*x7-r7+0.04*x6-r6+0.04*x5-x5+0.04*x4-r4+0.04*x3-r3+0.04*x2-r2+0.04*x1-
r1;
  r9 <= 0.04*x9+0.04*x8-r8+0.04*x7-r7+0.04*x6-r6+0.04*x5-x5+0.04*x4-r4+0.04*x3-r3+0.04*x2-
r2+0.04*x1-r1;
  r10<= 0.04*x10+0.04*x9-r9+0.04*x8-r8+0.04*x7-r7+0.04*x6-r6+0.04*x5-x5+0.04*x4-r4+0.04
*x3-r3+0.04*x2-r2+0.04*x1-r1;
  r11<= 0.04*x11+0.04*x10-r10+0.04*x9-r9+0.04*x8-r8+0.04*x7-r7+0.04*x6-r6+0.04*x5-x5+0.04
*x4-r4+0.04*x3-r3+0.04*x2-r2+0.04*x1-r1;
  r12 = 0.04*x12+0.04*x11-r11+0.04*x10-r10+0.04*x9-r9+0.04*x8-r8+0.04*x7-r7+0.04*x6-r6+
0.04*x5-x5+0.04*x4-r4+0.04*x3-r3+0.04*x2-r2+0.04*x1-r1;

  9.4*(y1) <= (p1);
  9.4*(y1+y2) <= (p1+p2);
  9.4*(y1+y2+y3) <= (p1+p2+p3);
  9.4*(y1+y2+y3+y4) <= (p1+p2+p3+p4);
  9.4*(y1+y2+y3+y4+y5) <= (p1+p2+p3+p4+p5);
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9.4*(y1+y2+y3+y4+y5+y6) <= (p1+p2+p3+p4+p5+p6);
9.4*(y1+y2+y3+y4+y5+y6+y7) <= (p1+p2+p3+p4+p5+p6+p7);
9.4*(y1+y2+y3+y4+y5+y6+y7+y8) <= (p1+p2+p3+p4+p5+p6+p7+p8);
9.4*(y1+y2+y3+y4+y5+y6+y7+y8+y9) <= (p1+p2+p3+p4+p5+p6+p7+p8+p9);
9.4*(y1+y2+y3+y4+y5+y6+y7+y8+y9+y10) <= (p1+p2+p3+p4+p5+p6+p7+p8+p9+p10);
9.4*(y1+y2+y3+y4+y5+y6+y7+y8+y9+y10+y11) <= (p1+p2+p3+p4+p5+p6+p7+p8+p9+p10+p11);
9.4*(y1+y2+y3+y4+y5+y6+y7+y8+y9+y10+y11+y12) = (p1+p2+p3+p4+p5+p6+p7+p8+p9+p10+p11+p12);

6.5*(z1) <= (q1+r1);
6.5*(z1+z2) <= (q1+r1+q2+r2);
6.5*(z1+z2+z3) <= (q1+r1+q2+r2+q3+r3);
6.5*(z1+z2+z3+z4) <= (q1+r1+q2+r2+q3+r3+q4+r4);
6.5*(z1+z2+z3+z4+z5) <= (q1+r1+q2+r2+q3+r3+q4+r4+q5+r5);
6.5*(z1+z2+z3+z4+z5+z6) <= (q1+r1+q2+r2+q3+r3+q4+r4+q5+r5+q6+r6);
6.5*(z1+z2+z3+z4+z5+z6+z7) <= (q1+r1+q2+r2+q3+r3+q4+r4+q5+r5+q6+r6+q7+r7);
6.5*(z1+z2+z3+z4+z5+z6+z7+z8) <= (q1+r1+q2+r2+q3+r3+q4+r4+q5+r5+q6+r6+q7+r7+q8+r8);
6.5*(z1+z2+z3+z4+z5+z6+z7+z8+z9) <= (q1+r1+q2+r2+q3+r3+q4+r4+q5+r5+q6+r6+q7+r7+q8+r8+q9
+r9);
6.5*(z1+z2+z3+z4+z5+z6+z7+z8+z9+z10) <= (q1+r1+q2+r2+q3+r3+q4+r4+q5+r5+q6+r6+q7+r7+q8+r8
+q9+r9+q10+r10);
6.5*(z1+z2+z3+z4+z5+z6+z7+z8+z9+z10+z11) <= (q1+r1+q2+r2+q3+r3+q4+r4+q5+r5+q6+r6+q7+r7
+q8+r8+q9+r9+q10+r10+q11+r11);
6.5*(z1+z2+z3+z4+z5+z6+z7+z8+z9+z10+z11+z12) = (q1+r1+q2+r2+q3+r3+q4+r4+q5+r5+q6+r6+q7
+r7+q8+r8+q9+r9+q10+r10+q11+r11+q12+r12);

p1  <= 70*6*0.8*9.4*0.75;
p2  <= 70*6*0.8*9.4*0.75;
p3  <= 70*6*0.8*9.4*0.75;
p4  <= 70*6*0.8*9.4*0.75;
p5  <= 70*6*0.8*9.4*0.75;
p6  <= 70*6*0.8*9.4*0.75;
p7  <= 70*6*0.8*9.4*0.75;
p8  <= 70*6*0.8*9.4*0.75;
p9  <= 70*6*0.8*9.4*0.75;
p10 <= 70*6*0.8*9.4*0.75;
p11 <= 70*6*0.8*9.4*0.75;
p12 <= 70*6*0.8*9.4*0.75;

q1  + r1   <= 1.2*6*5*6.5;
q2  + r2   <= 1.2*6*5*6.5;
q3  + r3   <= 1.2*6*5*6.5;
q4  + r4   <= 1.2*6*5*6.5;
q5  + r5   <= 1.2*6*5*6.5;
q6  + r6   <= 1.2*6*5*6.5;
q7  + r7   <= 1.2*6*5*6.5;
q8  + r8   <= 1.2*6*5*6.5;
q9  + r9   <= 1.2*6*5*6.5;
q10 + r10  <= 1.2*6*5*6.5;
q11 + r11  <= 1.2*6*5*6.5;
q12 + r12  <= 1.2*6*5*6.5;

p1  <= 20*2.4*6*9.4;
p2  <= 20*2.4*6*9.4;
p3  <= 20*2.4*6*9.4;
p4  <= 20*2.4*6*9.4;
p5  <= 20*2.4*6*9.4;
p6  <= 20*2.4*6*9.4;
p7  <= 20*2.4*6*9.4;
p8  <= 20*2.4*6*9.4;
p9  <= 20*2.4*6*9.4;
p10 <= 20*2.4*6*9.4;
p11 <= 20*2.4*6*9.4;
p12 <= 20*2.4*6*9.4;

0.319*p1  + 0.308*q1   + 0.308*r1  <= 864;
0.319*p2  + 0.308*q2   + 0.308*r2  <= 864;
0.319*p3  + 0.308*q3   + 0.308*r3  <= 864;
0.319*p4  + 0.308*q4   + 0.308*r4  <= 864;
```

```
  0.319*p5  + 0.308*q5   + 0.308*r5  <= 864;
  0.319*p6  + 0.308*q6   + 0.308*r6  <= 864;
  0.319*p7  + 0.308*q7   + 0.308*r7  <= 864;
  0.319*p8  + 0.308*q8   + 0.308*r8  <= 864;
  0.319*p9  + 0.308*q9   + 0.308*r9  <= 864;
  0.319*p10 + 0.308*q10  + 0.308*r10 <= 864;
  0.319*p11 + 0.308*q11  + 0.308*r11 <= 864;
  0.319*p12 + 0.308*q12  + 0.308*r12 <= 864;

END
```

LINGO Results

```
LINGO/WIN64 19.0.40 (26 Apr 2021), LINDO API 13.0.4099.270

Licensee info: Eval Use Only
License expires:  3 MAY 2022

Global optimal solution found.
Objective value:                              284718.5
Infeasibilities:                              0.000000
Total solver iterations:                            60
Elapsed runtime seconds:                          0.21

Model Class:                                        LP

Total variables:                     72
Nonlinear variables:                  0
Integer variables:                    0

Total constraints:                   97
Nonlinear constraints:                0

Total nonzeros:                     929
Nonlinear nonzeros:                   0
```

Variable	Value	Reduced Cost
Y1	252.0000	0.000000
Y2	0.000000	0.8929231
Y3	0.000000	27.46303
Y4	0.000000	26.63356
Y5	0.000000	5.843346
Y6	1260.000	0.000000
Y7	252.0000	0.000000
Y8	0.000000	3.942154
Y9	0.000000	47.01498
Y10	0.000000	64.93997
Y11	0.000000	49.20933
Y12	1260.000	0.000000
Z1	15.34445	0.000000
Z2	30.68891	0.000000
Z3	0.000000	21.79435
Z4	0.000000	18.02802
Z5	0.000000	10.81658
Z6	82.03336	0.000000
Z7	15.34445	0.000000
Z8	15.34445	0.000000
Z9	0.000000	12.94815
Z10	0.000000	32.23446
Z11	0.000000	25.90638
Z12	61.37781	0.000000
X1	2493.474	0.000000
X2	4986.947	0.000000
X3	0.000000	2.027020
X4	7480.421	0.000000
X5	0.000000	71.86817
X6	0.000000	1.164536
X7	2493.474	0.000000
X8	2493.474	0.000000
X9	9973.895	0.000000
X10	0.000000	1.813828
X11	0.000000	2.741972
X12	0.000000	4.996947
P1	2368.800	0.000000
P2	2368.800	0.000000
P3	2368.800	0.000000
P4	2368.800	0.000000
P5	2368.800	0.000000
P6	2368.800	0.000000

P7	2368.800	0.000000
P8	2368.800	0.000000
P9	2368.800	0.000000
P10	2368.800	0.000000
P11	2368.800	0.000000
P12	2368.800	0.000000
Q1	0.000000	2.635501
Q2	0.000000	2.294447
Q3	0.000000	4.574510
Q4	0.000000	3.926658
Q5	0.000000	73.76821
Q6	0.000000	7.369132
Q7	0.000000	2.523852
Q8	0.000000	5.097472
Q9	0.000000	0.1578176
Q10	0.000000	0.1578176
Q11	0.000000	0.1578202
Q12	0.000000	0.1578176
R1	99.73895	0.000000
R2	199.4779	0.000000
R3	0.000000	0.000000
R4	65.21684	0.000000
R5	234.0000	0.000000
R6	234.0000	0.000000
R7	99.73895	0.000000
R8	99.73895	0.000000
R9	0.000000	0.000000
R10	234.0000	0.000000
R11	0.000000	0.2538462E-05
R12	164.9558	0.000000

Row	Slack or Surplus	Dual Price
1	284718.5	1.000000
2	0.000000	7.260246
3	2368.800	0.000000
4	0.000000	0.6557746
5	4737.600	0.000000
6	2368.800	0.000000
7	0.000000	4.845281
8	0.000000	2.806826
9	0.000000	6.718824
10	7106.400	0.000000
11	4737.600	0.000000
12	2368.800	0.000000
13	0.000000	62.83976
14	0.000000	6.919193
15	0.000000	2.280063
16	0.000000	0.7922423E-02
17	234.0000	0.000000
18	0.000000	3.442474
19	0.000000	0.000000
20	0.000000	5.380447
21	0.000000	1.779169
22	398.9558	0.000000
23	164.9558	0.000000
24	164.9558	0.000000
25	0.000000	62.68194
26	0.000000	8.999578
27	2368.800	0.000000
28	4737.600	0.000000
29	7106.400	0.000000
30	9475.200	0.000000
31	0.000000	5.410702
32	0.000000	4.189243
33	2368.800	0.000000
34	4737.600	0.000000
35	7106.400	0.000000
36	9475.200	0.000000

37	0.000000	83.54029
38	0.000000	6.932392
39	0.000000	2.293984
40	0.000000	0.000000
41	65.21684	0.000000
42	299.2168	0.000000
43	0.000000	3.449040
44	0.000000	5.393589
45	0.000000	1.785094
46	0.000000	0.1352452E-01
47	234.0000	0.000000
48	234.0000	0.000000
49	0.000000	69.09721
50	0.000000	8.910536
51	0.000000	7.219868
52	0.000000	7.263233
53	0.000000	7.948796
54	0.000000	7.986575
55	0.000000	8.024980
56	0.000000	7.502752
57	0.000000	6.164745
58	0.000000	12.92318
59	0.000000	12.96836
60	0.000000	13.00296
61	0.000000	13.03979
62	134.2611	0.000000
63	34.52211	0.000000
64	234.0000	0.000000
65	168.7832	0.000000
66	0.000000	69.84293
67	0.000000	3.442601
68	134.2611	0.000000
69	134.2611	0.000000
70	234.0000	0.000000
71	0.000000	0.1336154E-03
72	234.0000	0.000000
73	69.04421	0.000000
74	338.4000	0.000000
75	338.4000	0.000000
76	338.4000	0.000000
77	338.4000	0.000000
78	338.4000	0.000000
79	338.4000	0.000000
80	338.4000	0.000000
81	338.4000	0.000000
82	338.4000	0.000000
83	338.4000	0.000000
84	338.4000	0.000000
85	338.4000	0.000000
86	77.63320	0.000000
87	46.91361	0.000000
88	108.3528	0.000000
89	88.26601	0.000000
90	36.28080	0.000000
91	36.28080	0.000000
92	77.63320	0.000000
93	77.63320	0.000000
94	108.3528	0.000000
95	36.28080	0.000000
96	108.3528	0.000000
97	57.54642	0.000000