Chapter 2 Solutions

profit), s.t. \( 5x_1 + 5x_2 \leq 300 \) (legs),
\( 0.6x_1 + 1.5x_2 \leq 63 \) (assembly hours), \( x_1 \leq 50 \)
(wood tops), \( x_2 \leq 35 \) (glass tops), \( x_1 \geq 0 \),
\( x_2 \geq 0 \)

All optimal from \( x = (30, 30) \) to \( x = (17.5, 35) \).

2.2. (a) \( \max 11x_1 + 17x_2 \) (max total return), s.t. \( x_1 + x_2 \leq 12 \) ($12 million investment), \( x_1 \leq 10 \) (max $10 million domestic), \( x_2 \leq 7 \) (max $7 million foreign),
\( x_1 \geq 0.5x_2 \) (domestic at least half foreign),
\( x_2 \geq 0.5x_1 \) (foreign at least half domestic),
\( x_1 \geq 0, x_2 \geq 0 \) (b) \( x_1^{*}= \text{domestic} = $5 \text{ million}, \)
\( x_2^{*}= \text{foreign} = $7 \text{ million} \)

2.3. (a) \( \min 3x_1 + 5x_2 \) (min total cost), s.t.
\( x_1 + x_2 \geq 50 \) (at least 50 thousand acres),
\( x_1 \leq 40 \) (at most 40 thousand from Squawking Eagle), \( x_2 \leq 30 \) (at most 30

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\(^1\)Supplement to the 2nd edition of *Optimization in Operations Research* by Ronald L. Rardin, Pearson

As of September 24, 2015

\[ x_1 \geq 0, \]
\[ x_2 \geq 0 \] (b) \[ x_1' = \text{Squawking Eagle}=40 \] thousand, \[ x_2' = \text{Crooked Creek}=10 \] thousand
(a) max $x_1$ (max beef content), s.t.

$x_1 + x_2 \geq 200$ leaves no feasible.

(b) $x_1 \geq 0, x_2 \geq 0$ (b) $x_1^*=$ beef=25g,

$x_2^*=$ chicken=100g

(c) $x_1 + x_2 \geq 125$ (weight at least 125),

$2.5x_1 + 1.8x_2 \leq 350$ (calories at most 350),

$0.2x_1 + 0.1x_2 \leq 15$ (fat at most 15),

$3.5x_1 + 2.5x_2 \leq 360$ (sodium at most 360),

(d) $x_1 \geq 0, x_2 \geq 0$ (b) $x_1^*=$ beef=25g,

$x_2^*=$ chicken=100g

(e) $x_2 = 0$ leaves no feasible.

2.4. Improves forever in direction $\Delta x_1 = 1,$

$\Delta x_2 = -1.$
Improve forever in direction $\Delta x_1 = 1$, $\Delta x_2 = -2$.

2.5. (a) max $450v + 200c$ (max total profit), s.t. $10v + 7c \leq 70000$ (water at most 70000 units), $v + c \leq 10000$ (total acreage 10000), $v \leq 7000$ (at most 70% vegetables), $c \leq 7000$ (at most 70% cotton), $v \geq 0$, $c \geq 0$ (b) $v^* = 7000$, $c^* = 0$

No solution with $v + c = 10000$.

2.6. (a) min $x_1 + x_2$ (min used stock), s.t. $5x_1 + 3x_2 \geq 15$ (cut at least 15 long rolls), $2x_1 + 5x_2 \geq 10$ (cut at least 10 short rolls), $x_1 \leq 4$ (at most 4 times on pattern 1), $x_2 \leq 4$ (at most 4 times on pattern 2), $x_1, x_2 \geq 0$ and integer. (b) Partial cuts make no physical sense because all unused material is scrap. (c) Either $x^*_1 = x^*_2 = 2$, or $x^*_1 = 3$, $x^*_2 = 1$
(e) Both (2, 2) and (3, 1) are feasible and lie on the best contour of the objective.

2-7. (a) min $16x_1 + 16x_2$ (min total wall area), s.t. $x_1, x_2 = 500$ (500 sq ft pool), $x_1 \geq 2x_2$ (length at least twice width), $x_2 \leq 15$ (width at most 15 ft), $x_1 \geq 0$, $x_2 \geq 0$
(b) $x_1^*=$ length = 33 1/3 ft, $x_2^*=$ width = 15 ft

(c) $x_1 \leq 50$ leaves no feasible.

2-9.

(b) min $x_2$ (c) min $x_1 + x_2$ (d) max $x_2$ (e) $x_2 \leq 1/2$
2-11. (a) \[ \min_{i=3}^{4} \sum_{j=1}^{2} y_{i,j} \]
(b) \[ \max_{p=1}^{4} a_{i,j} y_{i,j} \]
(c) \[ \min_{t=1}^{5} \delta_{i,j} y_{i,j} \]
(d) \[ 4 \sum_{j=1}^{i} y_{i,j} = s_{i}, i = 1, \ldots, 3 \]
(e) \[ j \sum_{i=1}^{4} a_{i,j} y_{i,j} = c_{i}, i = 1, \ldots, 3 \]

2-12. (a) \[ \sum_{i=1}^{17} x_{i,j,t} \leq 200, j = 1, \ldots, 5; t = 1, \ldots, 7; \text{35 constraints} \]
(b) \[ 5 \sum_{j=1}^{7} x_{5,j,t} \leq 4000; \text{1 constraint} \]
(c) \[ j \sum_{i=1}^{17} x_{i,j,t} \geq 100, i = 1, \ldots, 17; t = 1, \ldots, 7; \text{119 constraints} \]

2-13. model; param m; param n; param p; set products := 1 .. m; set lines := 1 .. n; set weeks := 1 .. p; var x[i] in products, j in lines, t in weeks/ >= 0; subject to # part (a) linecap /j in lines, t in weeks/: \[ \sum_{i} x[i,j,t] \leq 200; \] # part (b) prod5lim: \[ \sum_{j} x[5,j,t] \leq 4000; \] # part (c) minprod[n/i in products, t in weeks/: \[ \sum_{j} x[i,j,t] \geq 100; \] # data; param m := 47; param n := 9; param q := 10;
2-16. (a) \[ f(y_{1,2,3}) \Delta (y_{1})^{2} y_{2}/y_{3}, \]
(b) \[ g_{1}(y_{1}, y_{2}, y_{3}) \Delta y_{1} + y_{2} + y_{3}, b_{1} = 13, \]
(c) \[ g_{2}(y_{1}, y_{2}, y_{3}) \Delta 2y_{1} - y_{2} + 9y_{3}, b_{2} = 0, \]
(d) \[ g_{3}(y_{1}, y_{2}, y_{3}) \Delta y_{1}, b_{3} = 0, g_{4}(y_{1}, y_{2}, y_{3}) \Delta y_{2}, b_{4} = 0, \]
(e) \[ g_{5}(y_{1}, y_{2}, y_{3}) \Delta y_{3}, b_{5} = 0, \]
2-17. (a) Linear because LHS is a weighted sum of the decision variables. (b) Linear because both LHS and RHS are weighted sums of the decision variables. (c) Nonlinear because LHS has reciprocal 1/\(x_{i}\). (d) Linear because LHS is a weighted sum of the decision variables. (e) Nonlinear because LHS has \(x_i^2\) terms. (f) Nonlinear because LHS has log(\(x_i\)) term, and RHS has a product of
variables. (g) Nonlinear because LHS has max operator. (h) Linear because LHS is a weighted sum of the decision variables.

2-18. (a) LP because the objective and all constraints are linear. (b) NLP because of the nonlinear objective function with reciprocal of \( w_2 \). (c) NLP because of the nonlinear first constraint. (d) LP because the objective and all constraints are linear.

2-19. (a) Continuous because fractions make sense. (b) Discrete because they either closed or not. (c) Discrete because a specific process must be used. (d) Continuous because fractions can probably be ignored.

\[
\sum_{j=1}^{3} x_j + x_2 + x_4 + x_5 \geq 2 (c) x_3 + x_8 \leq 1 \quad (d)
\]

(max total score), s.t.
700x_1 + 400x_2 + 300x_3 + 600x_4 \leq 1000 ($1

(b) Fund 2 and 4, i.e. \( x^* = x^* = 0 \),

2 = x_4 = 1

2-22. (a) min 43y_1 + 175y_2 + 60y_3 + 35y_4 (min total land cost), s.t. \( y_2 + y_4 \geq 1 \) (service NW), \( y_1 + y_2 + y_3 \geq 1 \) (service SW), \( y_2 + y_3 \geq 1 \) (service capital), \( y_1 + y_4 \geq 1 \) (service NE), \( y_1 + y_2 + y_3 \geq 1 \) (service SE), \( y_j = 0 \) or 1, \( j = 1, \ldots, 4 \) (b) Build 3 and 4, i.e. \( y^* = y^* = 0 \), \( y^* = y^* = 1 \)

2-23. (a) ILP because the objective and all constraints are linear, but variables are discrete. (b) NLP because the objective is nonlinear and all variables are continuous. (c) INLP because the objective is nonlinear and variables are discrete. (d) LP because the objective and all constraints are linear, and all

the one constraint is nonlinear, and \( z_3 \) are discrete. (f) ILP because the objective and all constraints are linear, but variables \( z_1 \) and \( z_3 \) are discrete. (g) LP because the objective and all constraints are linear, and all variables are continuous. (h) NLP because the objective is nonlinear and \( z_3 \) is discrete.

2-24. (a) Model (d) because LP’s are generally more tractable than ILP’s. (b) Model (d) because LP’s are generally more tractable than NLP’s. (c) Model (d) because LP’s are generally more tractable than INLP’s. (d) Model (f) because ILP’s are generally more tractable than INLP’s. (e) Model (g) because LP’s are generally more tractable than ILP’s.

2-25.

Alternative optima from \( x^* \)

1 = 8, \( x_2 = 0 \) to \( x_1 = 8, x_2 = 12 \)

2-26.

Unique optimum \( x^*_1 = 0, x^*_2 = 4 \) (c) Helping one can hurt the other.
2.27. (a) min
\[0.092x_4 + 0.112x_5 + 0.141x_6 + 0.420x_9 + 0.719x_{12}\] (total cost),
\[s.t. x_4 + x_5 + x_6 + x_9 + x_{12} = 16000\] (16000m line),
\[0.279x_4 + 0.160x_5 + 0.120x_6 + 0.065x_9 + 0.039x_{12} \leq 1600\] (at most 1600 Ohms resistance),
\[0.00175x_4 + 0.00130x_5 + 0.00161x_6 + 0.00095x_9 + 0.00048x_{12} \leq 8.5\] (at most 8.5 dBell attenuation),
\[x_4, x_5, x_6, x_9, x_{12} \geq 0\]
(b) Nonzeros: \(x^* = 1000, x^{**} = 15000\)

2.28. (a) Pump rates are the decisions to be made.
(b) \(u_j\) is the capacity of pump \(j\), \(c_j\) is the pumping cost of pump \(j\)
(c) min \(\sum_{j=1}^{10} c_j x_j\)
(d) \(x_1 + x_4 + x_7 \leq 3000\) (well 1), \(x_2 + x_5 + x_8 \leq 2500\) (well 2), \(x_3 + x_6 + x_9 + x_{10} \leq 7000\) (well 3)
(e) \(x_j \leq u_j, j = 1, \ldots, 10\)
(f) \(\sum_{j=1}^{10} x_j \geq 10000\)
(g) \(x_j \geq 0, j = 1, \ldots, 10\)
(h) A single objective LP because the one objective and all constraints are linear, and all variables are continuous.
(i) \(x_1^* = x_2^* = x_3^* = 1100, x_4^* = x_5^* = 1500, x_6^* = 1400, x_7 = 400\)

2.29. (a) The decisions to be made are which projects to undertake.
(b) \(p_j\) is the profit for project \(j\), \(m_j\) is the man-days required on project \(j\), and \(t_j\) is the CPU time required on project \(j\).
(c) max \(\sum_{j=1}^{8} p_j x_j\)
(d) \(7 \leq \sum_{j=1}^{8} m_j x_j \leq 240 \leq 10\)
(e) \(\sum_{j=1}^{8} t_j x_j \leq 1000\) (computer time), \(\sum_{j=1}^{8} x_j \geq 3\) (select at least 3); \(x_3 + x_4 + x_5 + x_8 \geq 1\) (include at least 1 of director’s favorites)
(f) \(x_j = 0\) or 1, \(j = 1, \ldots, 8\)
(g) A single objective ILP because the one objective and all constraints are linear, but variables are discrete.

2.30. (a) We must decide what quantities to move from surplus sites to fulfill each need.
(b) \(s_i\) is the supply available at \(i\), \(r_j\) is the quantity needed at \(j\), \(d_{i,j}\) is the distance from \(i\) to \(j\).
(c) min \(\sum_{i=1}^{7} \sum_{j=1}^{4} d_{i,j} x_{i,j}\)
(d) \(\sum_{j=1}^{4} x_{i,j} = s_i, i = 1, \ldots, 4\)
(e) \(\sum_{i=1}^{4} x_{i,j} = 7, j = 1, \ldots, 7\)
(f) \(x_{i,j} \geq 0, i = 1, \ldots, 4, j = 1, \ldots, 7\)
(g) A single objective LP because the one objective and all constraints are linear, and all variables are continuous.
(h) Nonzeros: \(x^*_{1,1} = 81, x^*_{2,1} = 93, x^*_{3,1} = 166, x^*_{4,1} = 90, x^*_{5,1} = 85, x^*_{6,1} = 145, x^*_{7,1} = 301, x^*_{8,1} = 166, x^*_{9,1} = 105, x^*_{10,1} = 99\)

2.31. (a) The values to be chosen are the
coefficients in the estimating relationship.

(b) \[ \min \sum_{j=1}^{n} c_j - k/(1 + e^{a+bj}) \] (min total squared error)

(c) Single objective NLP because the objective is quadratic, there are no constraints, and all variables are continuous.

2-32. (a) The decisions to be made are where to assign each teacher.

(b) \[ \min \sum_{i=1}^{22} \sum_{j=1}^{22} c_{i,j} x_{i,j} \] (min total cost),

\[ \max \sum_{i=1}^{22} \sum_{j=1}^{22} t_{i,j} x_{i,j} \] (max total teacher preference), \[ \max \sum_{i=1}^{22} \sum_{j=1}^{22} s_{i,j} x_{i,j} \] (max total supervisor preference), \[ \max \sum_{i=1}^{22} \sum_{j=1}^{22} P_{i,j} x_{i,j} \] (max total principal preference)

(c) \[ x_{i,j} = 1, \ i = 1, \ldots, 22 \] (each teacher i)

(d) \[ x_{i,j} = 1, \ j = 1, \ldots, 22 \] (each school j)

(e) \[ x_{i,j} = 0 \text{ or } 1, \ i, j = 1, \ldots, 22 \]

(f) A multiobjective ILP because the 4 objectives and all constraints are linear, but variables are discrete.

2-33. (a) Each task must go to Assistant 0 or Assistant 1.

(b) \[ \max (100(1-x_1) + 80x_1 + 85(1-x_2) + 70x_2 + 40(1-x_3) + 90x_3 + 45(1-x_4) + 85x_4 + 70(1-x_5) + 80x_5 + 82(1-x_6) + 65x_6) \]

(c) \[ x_5 = x_6 \]

(d) \[ x_5 = x_6 \]

(e) \[ x_j = 0 \text{ or } 1, \ j = 1, \ldots, 6 \]

(f) A single objective ILP because the one objective and all constraints are linear, but variables are discrete.

(g) \[ x_1^* = x_5^* = x_4^* = 1, \text{ others } = 0 \]

2-34. (a) Batch sizes are the decisions to be made.

(b) \[ \min x_j/d_j, \ j = 1, \ldots, 4 \] (each burger j)

(c) \[ \frac{4}{j=1} t_j d_j / x_j \leq 60 \]

(d) \[ 0 \leq x_j \leq u_j, \ j = 1, \ldots, 4 \]

(e) Multiobjective NLP because the first

(b) Relatively large values can be rounded if fractional without much loss, and continuous is more tractable.

(c) \[ c_{i,j} \] the cost of moving a car from i to j, \[ p_j \] the number of cars presently at j, \[ n_j \] the number of cars required at j

(d) \[ \min \sum_{i=1}^{5} \sum_{j=1,i\neq j}^{5} c_{i,j} x_{i,j} \]

(e) \[ i=1, \ldots, 5 \]

(f) \[ x_{i,j} \geq 0, \ i, j = 1, \ldots, 5, \ i \neq j \]

(g) A single objective LP because the one objective and all constraints are linear, and all variables are continuous.

(h) Nonzero values: \[ x^* \]

2-36. (a) We must decide how much of what fuel to burn at each plant.

(b) \[ \min \sum_{p=1}^{4} \sum_{f=1}^{23} c_{f,p} x_{f,p} \]

(c) \[ \min \sum_{f=1}^{4} \sum_{p=1}^{23} s_f x_{f,p} \]

(d) \[ \sum_{f=1}^{4} \sum_{p=1}^{23} c_{f,p} x_{f,p} \geq r_p, \ p = 1, \ldots, 23 \] (each plant p); 23 constraints

(e) \[ x_{f,p} \geq 0, \ f = 1, \ldots, 4, \ p = 1, \ldots, 23 \]

(f) A multiobjective LP because the 2 objectives and all constraints are linear, and all variables are continuous.

2-37. (a) The available options are to buy whole logs or green lumber.

(b) Relatively large magnitudes can be rounded without much loss, and continuous is more tractable.

(c) \[ \min \sum_{i=10}^{15} \sum_{i,j=15}^{20} \sum_{i=1}^{1.55} y_1 + 1.30 y_2 \]

(d) \[ \sum_{i=10}^{15} \sum_{i,j=15}^{20} \sum_{i=1}^{1.55} y_1 + 1.30 y_2 \]

(e) \[ x_{10} + x_{15} + x_{20} \leq 1500 \] (drying capacity)

(drying capacity) constraint is nonlinear and all variables are
continuous.
2-35. (a) The issue is how many cars to move from where to where.

(f) $x_{10} \leq 50$ (size 10 log availability),
    $x_{15} \leq 25$ (size 15 log availability), $x_{20} \leq 10$
    (size 20 log availability), $y_1 \leq 5000$ (grade 1 green lumber availability)
(g) $x_{10}, x_{15}, x_{20}, y_1, y_2 \geq 0$
(h) A single objective LP because the one
objective and all constraints are linear, and all variables are continuous.

(i) \( x_{10}^* = 50, x_{15}^* = 25, x_{20}^* = 5, y^* = 5000, \)
y
2.38. (a) Decisions to be made are when to schedule each film.

(b) \( \min \sum_{j=1}^{m-1} \sum_{j=j+1}^{m} a_{j,j} \sum_{t=1}^{n} x_{j,t} y_{j,t} \)
(c) \( \sum_{t=1}^{n} x_{j,t} = 1, j = 1, \ldots, m \) (each film j).
(d) \( \sum_{t=1}^{n} x_{j,t} \leq 4, t = 1, \ldots, n \) (each time t).
(e) \( x_{j,t} = 0 \text{ or } 1, j = 1, \ldots, m; t = 1, \ldots, n \)
(f) A single objective INLP because the one objective is nonlinear, and variables are discrete.
(g) model; \( m; n; \) set films = 1 .. m; set slots := 1 .. n; var \( x/j \) in films, \( t \) in slots /
binary; \( a/j \) in films, \( j/p \) in films /
minimize totconflict: \( \sum_{j} x/j \in \text{films}. \)
(j) \( \text{in films}. \) \( j < m \) and \( j/p > \)

2.39. (a) We need to decide both which offices to open and how to service customers from them.
(b) Offices must either be opened or not.
(c) \( f_i \) \( \text{fixed cost of site } i, c_{i,j} \) \( \text{unit cost of audits at } j \) from \( i, r_j \) \( \text{required number of audits in state } j \)
(d) \( \min \sum_{i=1}^{5} c_{i,j} r_j x_{i,j} + \sum_{i=1}^{5} f_i y_i \)
(e) \( \sum_{i=1}^{5} x_{i,j} = 1, j = 1, \ldots, 5 \) (each location \( j \))

(f) \( x_{i,j} \leq y_i, i, j = 1, \ldots, 5 \) (each site \( i, \) location \( j \) combination)
(g) \( x_{i,j} \geq 0, i, j = 1, \ldots, 5, y_i = 0 \) or \( 1, i = 1, \ldots, 5 \)
(h) A single objective ILP because the one objective and all constraints are linear, but the \( y_i \) variables are discrete.
(i) Nonzeros:
\( x_{2,2}^* = x_{2,4}^* = x_{3,3}^* = x_{5,5}^* = 1, \)
y
2.40. (a) \( \max \sum_{j=1}^{8} x_{j} \leq 4, x_1 + x_2 + x_3 \geq 2, \)
\( x_4 + x_5 + x_6 + x_7 + x_8 \geq 4, x_2 + x_3 + x_4 + x_8 \geq 2, x_1 \ldots x_8 = 0 \) or \( 1 \) (b)
model; \( n; \) set games := 1 .. n; \#ratings \( r/j \) in games; \#home?
\( h/j \) in games; \#state? \( s/j \) in games; \#cover? \( x/j \) in games /
binary; maximize totrat: \( \sum_{j} x/j \text{in games}. \)
\( r/j \text{in games}. / \sum_{j} x/j = 2; \)
away: \( \sum_{j} x/j \text{in games}/(1-h[j]) \times x[j] \)
>= 1; state: \( \sum_{j} x/j \text{in games}/s[j] \times x[j] \)
>= 2; \( m; \) set games := 8; \( r := 1 \)
3.0 2 3.7 3.2 6.4 1.8 5 1.5 6 1.3 7
1.6 8 2.0; \( h := 1 \) 1 2 1 3 1 4 0 5
0 6 0 7 0 8 0; \( s := 1 \) 0 2 1 3 1 4
1 5 0 6 0 7 0 8 1; (c) \( \text{The model is an ILP because all constraints and the objective are linear, but decision variables are binary.} \)
2.41. (a) \( \text{How to divide funds is the issue.} \)
(b) \( \max \sum_{j=1}^{n} y/j x/j \)
(c) \( \min \sum_{j=1}^{n} r/j x/j \)
(d) \( \sum_{j=1}^{n} x/j = 1 \)
(e) \( x/j \geq j, j = 1, \ldots, n \) (each category \( j \))
(f) \( x_j \leq u_j, j = 1, \ldots, n \) (each category \( j \))
(g) A multiobjective LP because the 2 objectives and all constraints are linear, and all variables are continuous.

2-42. (a) The issue is which module goes to which site.
(b) If \( x_{i,j} > x_{i,j} \cdot x_{i} = 1 \) the \( i \) is at \( j \) and \( i \) is at \( j \), so wire \( d_{j,i} \) will be required. Summing over all possible location pairs captures the wire requirements for \( i \) and \( i \).
(c) \[
\begin{align*}
m-1 & \quad m & \quad n & \quad n \\
i=1 & \quad i=i+1 & \quad a_{i,i} & \quad j=1 & \quad j=d_{j,i} \cdot x_{i,j} x_{i,j} \cdot j \\
x_{i,j} = 1, & \quad i = 1, \ldots, m \text{ (each module)} & \quad j = 1 \\
i & \quad m & \quad x_{i,j} \leq 1, & \quad j = 1, \ldots, n \text{ (each site)}
\end{align*}
\]
(f) \( x_{i,j} = 0 \) or \( 1, \quad i = 1, \ldots, m, \quad j = 1, \ldots, n \)
(g) Single objective INLP because the one objective is nonlinear and variables are discrete. (h) model; param m; param n; set modules := 1 .. m; set sites := 1 .. n; var x[i] in modules, j in sites / binary; param a[i] in modules, ip in modules /; param d[j] in sites, jp in sites /; minimize totdist: sum i in modules, ip in modules: i < m and ip > i / a[i,ip] * j in sites, jp in sites: j < n and jp > j /
\sum [j, ip] * j[i,j] * x[i,j] * (ip, jp); subject to all i / i in modules /: sum j in sites / x[i,j] = 1; all j / j in sites /: sum i in modules / x[i,j] <= 1;
2-43. \( \text{max} 199x_1 + 229x_2 + 188x_3 + 205x_4 - 180y_1 - 242y_2 - 497y_3, \) subject to,
\[
\begin{align*}
23x_3 & + 41x_4 \leq 2877y_1, & 14x_1 + 29x_2 \leq 2333y_2, \\
11x_3 & + 27x_4 \leq 3011y_3, \\
x_1 + x_2 + x_3 + x_4 & \geq 205, & y_1 + y_2 + y_3 \leq 2, \\
x_1, \ldots, x_4 \geq 0, & y_1, \ldots, y_3 = 0 \text{ or } 1
\end{align*}
\]
2-44. \( \text{max} 11x_{1,1} + 15x_{1,2} + 19x_{1,3} + 10x_{1,4} + \\
19x_{2,1} + 23x_{2,2} + 44x_{2,3} + 67x_{2,4} + 17x_{3,1} + \\
18x_{3,2} + 24x_{3,3} + 55x_{3,4}, \) subject to,
\[
\begin{align*}
15x_{1,1} + & \quad 24x_{2,1} + 17x_{3,1} \leq 7600, & 19x_{1,2} + 26x_{2,2} + \\
13x_{3,2} \leq 8200, & \quad 23x_{1,3} + 18x_{2,3} + 16x_{3,3} \leq 6015, \\
14x_{1,4} + 33x_{2,4} + 14x_{3,4} \leq 5000, & \quad 31x_{1,1} + 26x_{2,1} + \\
21x_{3,1} \leq 6600, & \quad 25x_{1,2} + 28x_{2,2} + 17x_{3,2} \leq 7900, \\
39x_{1,3} + & \quad 22x_{2,3} + 20x_{3,2} \leq 5055, & 29x_{1,4} + \\
31x_{2,4} + 18x_{3,4} \leq 7777, & \quad x_{1,1} + x_{2,1} + x_{3,1} \geq 200, \\
x_{1,2} + x_{2,2} + x_{3,2} \geq 300, & \quad x_{1,3} + x_{2,3} + x_{3,3} \geq \\
250, \quad x_{1,4} + x_{2,4} + x_{3,4} \geq 500, & \quad x_{j,t} \geq 0, \quad j = 1, \ldots, 3, \quad t = 1, \ldots, 4.
\end{align*}
\]
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