Solution Manual for Optimization in Operations Research 2nd Edition Rardin 0134384555 9780134384559

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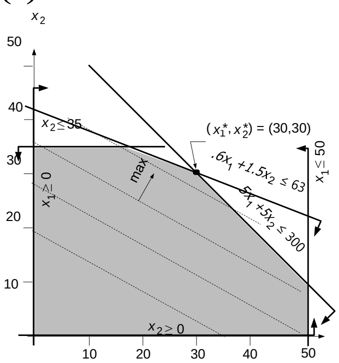
Solution Manual:

Chapter 2 Solutions [1] [2]

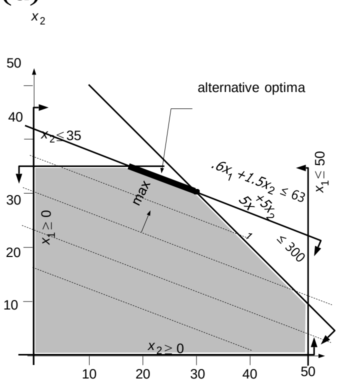
profit), s.t. $5x_1 + 5x_2 \le 300$ (legs), $0.6x_1 + 1.5x_2 \le 63$ (assembly hours), $x_1 \le 50$ (wood tops), $x_2 \le 35$ (glass tops), $x_1 > 0$, $x_2 > 0$

1 2

(c)



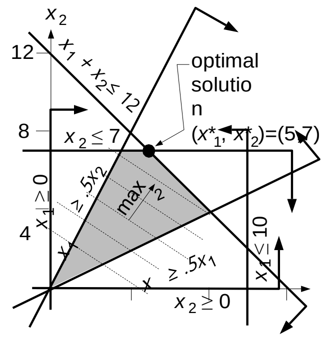
(d)



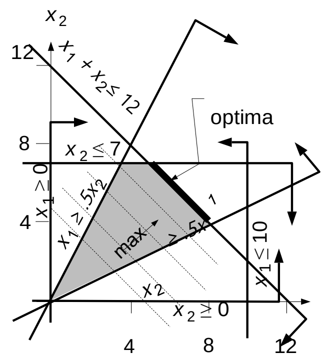
All optimal from x = (30, 30) to x = (17.5, 35).

2-2. (a) max $.11x_1 + .17x_2$ (max total return), s.t. $x_1 + x_2 \le 12$ ($12 million investment), $x_1 \le 10$ (max $10 million domestic), $x_2 \le 7$ (max $7 million foreign), $x_1 > .5x_2$ (domestic at least half foreign), $x_2 > .5x_1$ (foreign at least half domestic), $x_1 > 0$, $x_2 > 0$ (b) x_1^*=domestic=$5 million, x_2^*= foreign=$7 million

(c)



(d)



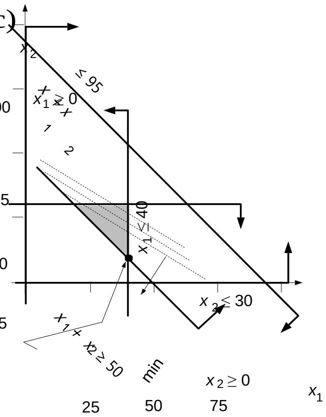
All optimal from x = (5, 7) to x = (8, 4).

2-3. (a) min $3x_1 + 5x_2$ (min total cost), s.t. $x_1 + x_2 > 50$ (at least 50 thousand acres), $x_1 \le 40$ (at most 40 thousand from Squawking Eagle), $x_2 \le 30$ (at most 30 thousand from Crooked Creek), $x_1 > 0$, $x_2 > 0$ (b) x_1^*=Squawking Eagle=40 thousand, x_2^*=Crooked Creek=10 thousand

[1] Supplement to the 2nd edition of *Optimization in Operations Research*, by Ronald L. Rardin, Pearson Higher Education, Hoboken NJ, ©2017.

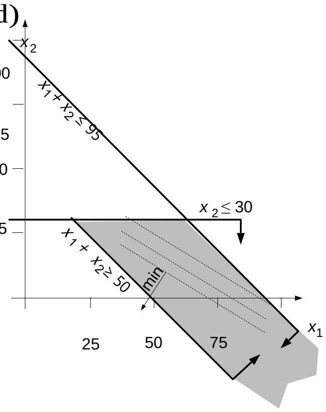
[2] As of September 24, 2015

(c)



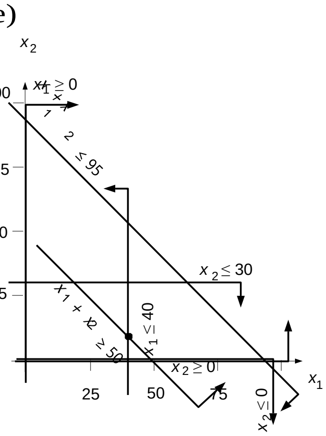
optimal solution $(x_1^*, x_2^*) = (40,10)$

(d)



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

(e)



$x_2 = 0$ leaves no feasible.

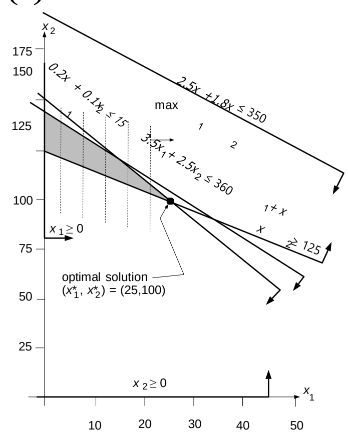
2-4. (a) max x_1 (max beef content), s.t.

$x_1 + x_2 > 125$ (weight at least 125),
$2.5x_1 + 1.8x_2 \le 350$ (calories at most 350),

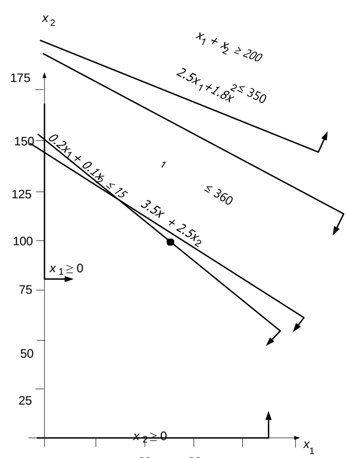
$0.2x_1 + 0.1x_2 \le 15$ (fat at most 15),

$3.5x_1 + 2.5x_2 \le 360$ (sodium at most 360),
$x_1 > 0$, $x_2 > 0$ (b) x_1^*=beef=25g, x_2^*=chicken=100g

(c)



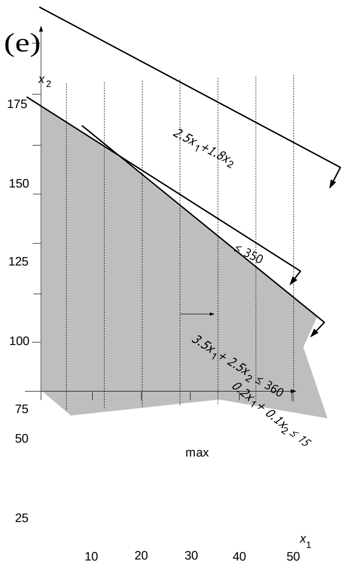
(d)



$x_1 + x_2 > 200$ leaves no feasible.

3

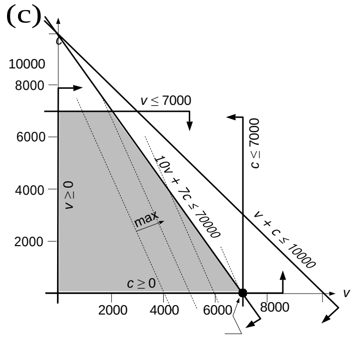
(e)



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

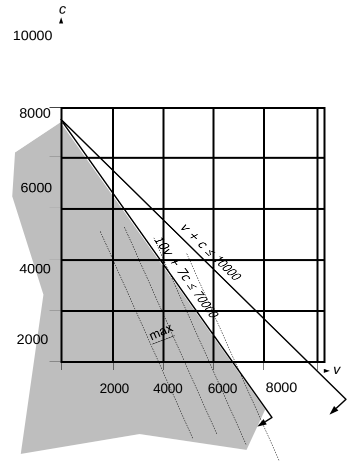
2-5. (a) max $450v + 200c$ (max total profit), s.t. $10v + 7c \leq 70000$ (water at most 70000 units), $v + c \leq 10000$ (total acreage 10000), $v \leq 7000$ (at most 70% vegetables), $c \leq 7000$ (at most 70% cotton), $v > 0$, $c > 0$ (b) $v^* = 7000$, $c^* = 0$

(c)



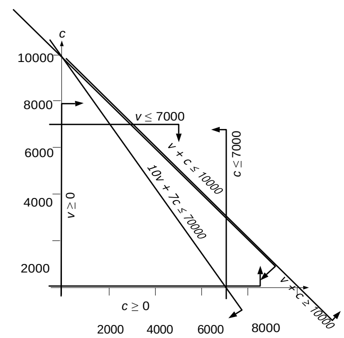
optimal solution (v^*, c^*) = (7000,0)

(d)



Improves forever in direction $\Delta v = 10$, $\Delta c = -7$.

(e)



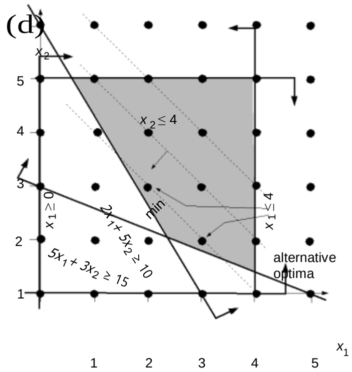
No solution with $v + c = 10000$.

2-6. (a) min $x_1 + x_2$ (min used stock), s.t. $5x_1 + 3x_2 > 15$ (cut at least 15 long rolls), $2x_1 + 5x_2 > 10$ (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), $x_1, x_2 > 0$ and integer. (b) Partial cuts make no physical sense because all unused material is scrap. (c)

Either $x_1^* = x_2^* = 2$, or $x_1^* = 3$, $x_2^* = 1$

 4

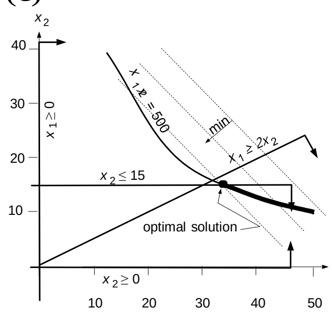
(d)



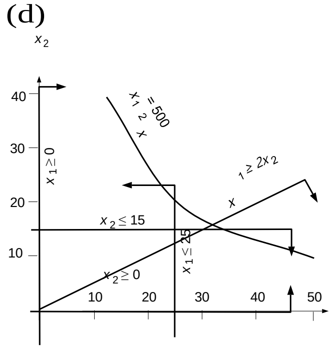
(e) Both (2, 2) and (3, 1) are feasible and lie on the best contour of the objective.

2-7. (a) min $16x_1 + 16x_2$ (min total wall area), s.t. $x_1x_2 = 500$ (500 sqft pool), $x_1 > 2x_2$ (length at least twice width), $x_2 \le 15$ (width at most 15 ft), $x_1 > 0$, $x_2 > 0$ (b) x_1^*=length=33$\frac{1}{3}$ feet, x_2^*=width=15 feet

(c)



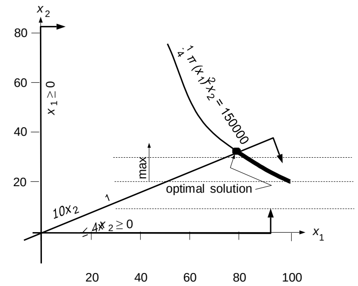
(d)



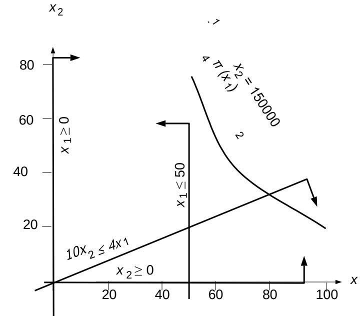
$x_1 \le 25$ leaves no feasible.

2-8. (a) max x_2 (max number of floors), s.t. $\pi/4(x_1)^2x_2 = 150000$ (150000 sqft floor space), $10x_2 \le 4x_1$ (height at most 4 times diameter), $x_1 > 0$, $x_2 > 0$ (b) x^*_1 = diameter = 78.16 feet, x_2^* = floors = 31.26

(c)



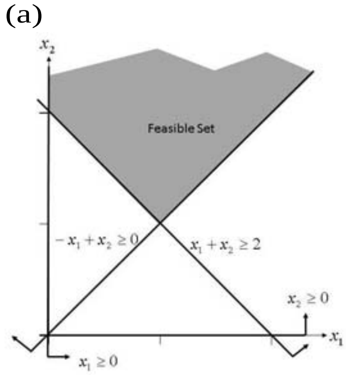
(d)



$x_1 \le 50$ leaves no feasible.

2-9.

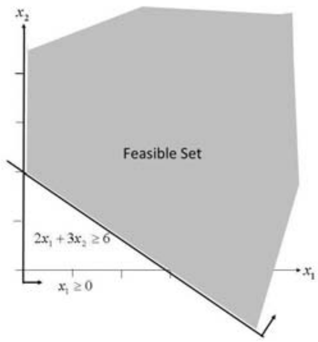
(a)



(b) min x_2 (c) min $x_1 + x_2$ (d) max x_2 (e) $x_2 \le 1/2$

2-10.

(a)



(b) min $z_1 + z_2$ (c) min z_1 (d) max z_1 (e) $z_1 + z_2 < 1$

2-11. (a) min $\sum_{i=3}^{4} i \sum_{j=1}^{2} y_{i,j}$

(b) max $\sum_{i=1}^{4} i y_{i,3}$
(c) max $\sum_{i=1}^{p} a_i y_{i,4}$
(d) min $\sum_{i=1}^{t} \delta_i y_i$

(e) $\sum_{j=1}^{4} y_{i,j} = s_i,\ i = 1, \ldots, 3$
(f) $\sum_{j=1}^{4} a_{j,i} y_j = c_i,\ i = 1, \ldots, 3$

2-12. (a) $\sum_{i=1}^{17} z_{i,j,t} < 200,\ j = 1, \ldots, 5; t = \ldots, 7$; 35 constraints

(b) $\sum_{j=1}^{5} \sum_{t=1}^{7} z_{5,j,t} < 4000$; 1 constraint

(c) $\sum_{j=1}^{5} z_{i,j,t} > 100,\ i = 1, \ldots, 17; t = 1, \ldots, 7$; 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 in products} x[i,j,t] <= 200;
# part (b)
prod5lim: sum {j in lines, t in weeks} x[5,j,t] <= 4000;
# part (c)
minprodn{i in products, t in weeks}: sum {j in lines} x[i,j,t] >= 100;
#
data; param m := 17; param n := 5; param p := 7;

2-14. (a) $\sum_{j=1}^{9} z_{i,j,t} < p_i,\ i = 1, \ldots, 47; t = 1, \ldots, 10$; 470 constraints
(b) $0.25 \sum_{i=1}^{47} \sum_{j=1}^{9} z_{i,j,t} < \sum_{i=1}^{47} z_{i,4,t}; t = 1, \ldots, 5$; 5 constraints
(c) $z_{i,1,t} > z_{i,j,t}\ i = 1, \ldots, 47;\ j = 1, \ldots, 9;\ t = 1, \ldots, 10$; 4230 constraints

2-15. model; param m; param n; param q; set plots := 1 .. m; set crops := 1 .. n; set years := 1 .. q; param p {i in plots }; var x{i in plots, j crops, t in years} >= 0; subject to
part (a)
acrelims {i in plots, t in years }:

sum {j in crops } x[i,j,t] <= p[i];

part (b)
crop4min {t in years: t <= 5 }:
0.25* sum {i in plots, j in crops }

x[i,j,t] <= sum {i in plots } x[i,4,t];
# part (c)

beam1st {i in plots, j in crops, t in years}: x[i,1,t] >= x[i,j,t];
#

data; param m := 47; param n := 9; param q := 10;

2-16. (a) $f(y_1, y_2, y_3) \triangleq (y_1)^2 y_2 / y_3$, $g_1(y_1, y_2, y_3) \triangleq y_1 + y_2 + y_3,\ b_1 = 13$, $g_2(y_1, y_2, y_3) \triangleq 2y_1 - y_2 + 9y_3,\ b_2 = 0$, $g_3(y_1, y_2, y_3) \triangleq y_1,\ b_3 = 0,\ g_4(y_1, y_2, y_3) \triangleq y_3,\ b_4 = 0$
(b) $f(y_1, y_2, y_3) \triangleq 13y_1 + 22y_2 + 10y_2y_3 + 100$, $g_1(y_1, y_2, y_3) \triangleq y_1 - y_2 + 9y_3,\ b_1 = -5$, $g_2(y_1, y_2, y_3) \triangleq 8y_2 - 4y_3,\ b_2 = 0,\ g_3(y_1, y_2, y_3) \triangleq y_1,\ b_3 = 0,\ g_4(y_1, y_2, y_3) \triangleq y_2,\ b_4 = 0$, $g_5(y_1, y_2, y_3 \triangleq y_3,\ b_5 = 0$,

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 $1/z_9$. (d) Linear because LHS is a weighted sum of the decision variables. (e) Nonlinear because LHS has $(z_j)^2$ terms. (f) Nonlinear because LHS has $\log(z_1)$ term, and RHS has a product of

6

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.

$j=1$

$z_1 + z_2 + z_4 + z_5 > 2$ (c) $z_3 + z_8 < 1$ (d)

(max total score), s.t.
$700z_1 + 400z_2 + 300z_3 + 600z_4 < 1000$ ($1

(b) Fund 2 and 4, i.e. $z^* = z^* = 0$,

1 3

$_2 = z_4 = 1$
2-22. (a) min $43y_1 + 175y_2 + 60y_3 + 35y_4$ (min total land cost), s.t. $y_2 + y_4 > 1$ (service

NW), $y_1 + y_2 + y_4 > 1$ (service SW), $y_2 + y_3 > 1$ (service capital), $y_1 + y_4 > 1$

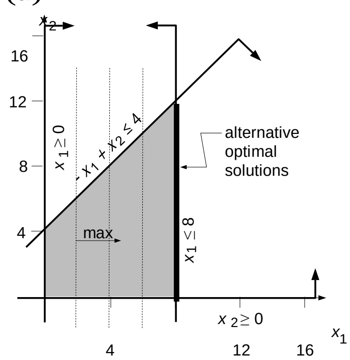
(service NE), $y_1 + y_2 + y_3 > 1$ (service SE), $y_j = 0$ or 1, $j = 1, \ldots, 4$ (b) Build 3 and 4, i.e. $y^* = y^* = 0, y^* = y^* = 1$
2-23. (a) ILP because the objective and all constraints are linear, but variables are discrete. (b) NLP because the objective is nonlinear and all variables are 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) INLP 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 generatlly more tranctable than ILP's.

2-25.

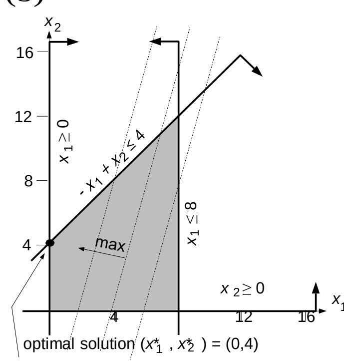
(a)



Alternative optima from $z^*_1 = 8, z_2 = 0$ to $z_1 = 8, z_2 = 12$

* *

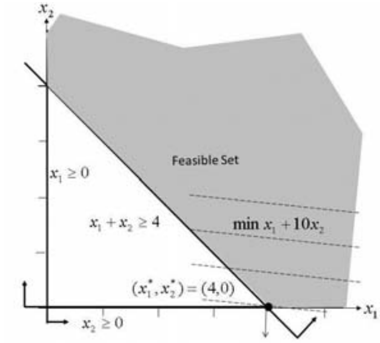
(b)



Unique optimum $z_1^* = 0, z_2^* = 4$ (c) Helping one can hurt the other.

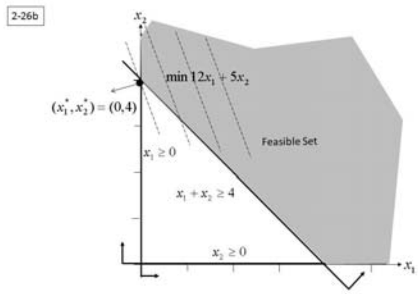
2-26.

(a)



Unique optimum $a_1^* = 4$, $a_2^* = 0$

(b)



Unique optimum $a_1^* = 0$, $a_2^* = 4$ (c) Helping one can hurt the other.

2-27. (a) min $.092a_4 + .112a_5 + .141a_6 + .420a_9 + .719a_{12}$ (min total cost),
s.t. $a_4 + a_5 + a_6 + a_9 + a_{12} = 16000$ (16000m line),
$.279a_4 + .160a_5 + .120a_6 + .065a_9 + .039a_{12} < 1600$ (at most 1600 Ohms resistance),
$.00175a_4 + .00130a_5 + .00161a_6 + .00095a_9 + .00048a_{12} < 8.5$ (at most 8.5 dBell attenuation),
$a_4, a_5, a_6, a_9, a_{12} > 0$
(b) Nonzeros: $a_5^* = 1000$, $a_{12}^* = 15000$

2-28. (a) Pump rates are the decisions to be made.
(b) $u_j \triangleq$ the capacity of pump j, $c_j \triangleq$ the pumping cost of pump j
(c) min $\sum_{j=1}^{10} c_j a_j$
(d) $a_1 + a_4 + a_7 < 3000$ (well 1),
$a_2 + a_5 + a_8 < 2500$ (well 2),
$a_3 + a_6 + a_9 + a_{10} < 7000$ (well 3)
(e) $a_j < u_j$, $j = 1, \ldots, 10$
(f) $\sum_{j=1}^{10} a_j > 10000$
(g) $a_j > 0$, $j = 1, \ldots, 10$
(h) A single objective LP because the one objective and all constraints are linear, and all variables are continuous.
(i) $a_1^* = a_2^* = a_3^* = 1100$, $a_4^* = a_6^* = 1500$, $a_5^* = 1400$, $a_7^* = 400$; $a_8^* = a_{10}^* = 0$, $a_9^* = 1900$

2-29. (a) The decisions to be made are which projects to undertake.
(b) $p_j \triangleq$ the profit for project j, $m_j \triangleq$ the man-days required on project j, and $t_j \triangleq$ the CPU time required on project j.
(c) max $\sum_{j=1}^{8} p_j a_j$
(d) $7 < \sum_{j=1}^{8} m_j a_j / 240 < 10$
(e) $\sum_{j=1}^{8} t_j a_j < 1000$ (computer time),
$\sum_{j=1}^{8} a_j > 3$ (select at least 3);
$a_3 + a_4 + a_5 + a_8 > 1$ (include at least 1 of director's favorites)
(f) $a_j = 0$ or 1, $j = 1, \ldots, 8$
(g) A single objective ILP because the one objective and all constraints are linear, but variables are discrete.
(h) $a_1^* = a_3^* = a_6^* = a_7^* = 1$, others $= 0$

2-30. (a) We must decide what quantities to move from surplus sites to fulfill each need.
(b) $s_i \triangleq$ the supply available at i, $r_j \triangleq$ the quantity needed at j, $d_{i,j} \triangleq$ the distance from i to j.
(c) min $\sum_{i=1}^{4} \sum_{j=1}^{7} d_{i,j} a_{i,j}$
(d) $\sum_{j=1}^{7} a_{i,j} = s_i$, $i = 1, \ldots, 4$
(e) $\sum_{i=1}^{4} a_{i,j} = r_j$, $j = 1, \ldots, 7$
(f) $a_{i,j} > 0$, $i = 1, \ldots, 4$, $j = 1, \ldots, 7$
(g) A single objective LP because the one objective and all constraints are linear, and all variables are continuous.
(h) Nonzeros: $a_{1,1}^* = 81$, $a_{1,2}^* = 93$, $a_{1,3}^* = 166$, $a_{1,5}^* = 90$, $a_{1,6}^* = 85$, $a_{1,7}^* = 145$, $a_{2,2}^* = 301$, $a_{3,1}^* = 166$, $a_{3,4}^* = 105$, $a_{4,3}^* = 99$

2-31. (a) The values to be chosen are the

8

coefficients in the estimating relationship.

(b) min $\sum_{j=1}^{n} \left(c_j - k/(1 + e^{a+bf_j}) \right)^2$ (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 $\sum_{i=1}^{22} \sum_{j=1}^{22} c_{i,j} a_{i,j}$ (min total cost), max $\sum_{i=1}^{22} \sum_{j=1}^{22} t_{i,j} a_{i,j}$ (max total teacher preference), max $\sum_{i=1}^{22} \sum_{j=1}^{22} s_{i,j} a_{i,j}$ (max total supervisor preference), max $\sum_{i=1}^{22} \sum_{j=1}^{22} p_{i,j} a_{i,j}$ (max total principal preference)

(c) $\sum_{j=1}^{22} a_{i,j} = 1$, $i = 1, \ldots, 22$ (each teacher i)

(d) $\sum_{i=1}^{22} a_{i,j} = 1$, $j = 1, \ldots, 22$ (each school j)

(e) $a_{i,j} = 0$ 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 $100(1 - a_1) + 80a_1 + 85(1 - a_2) + 70a_2 + 40(1 - a_3) + 90a_3 + 45(1 - a_4) + 85a_4 + 70(1 - a_5) + 80a_5 + 82(1 - a_6) + 65a_6$

(c) $\sum_{j=1}^{6} a_j = 3$

(d) $a_5 = a_6$

(e) $a_j = 0$ 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) $a_2^* = a_3^* = a_4^* = 1$, others $= 0$

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

(b) min a_j/d_j, $j = 1, \ldots, 4$ (each burger j)

(c) $\sum_{j=1}^{4} t_j d_j / a_j < 60$

(d) $0 < a_j < u_j$, $j = 1, \ldots, 4$

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

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

(d) min $\sum_{i=1}^{5} \sum_{j=1, j=i}^{5} c_{i,j} a_{i,j}$

(e) $\sum_{i=1, i=k}^{5} a_{i,k} - \sum_{j=1, j=k}^{5} a_{k,j} = n_k - p_k$, $k = 1, \ldots, 5$ (each region k)

(f) $a_{i,j} > 0$, $i, j = 1, \ldots, 5$, $i = j$

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

(h) Nonzero values: $a^*_{4,2} = 115$, $a^*_{4,3} = 165$, $a^*_{5,1} = 85$, $a^*_{5,3} = 225$

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

(b) min $\sum_{f=1}^{4} \sum_{p=1}^{23} c_{f,p} a_{f,p}$

(c) min $\sum_{f=1}^{4} s_f \sum_{p=1}^{23} a_{f,p}$

(d) $\sum_{f=1}^{4} e_f a_{f,p} > r_p$, $p = 1, \ldots, 23$ (each plant p); 23 constraints

(e) $a_{f,p} > 0$, $f = 1, \ldots, 4$, $p = 1, \ldots, 23$; 92 constraints

(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 $70a_{10} + 200a_{15} + 620a_{20} + 1.55y_1 + 1.30y_2$

(d) $100(.09)a_{10} + 240(.09)a_{15} + 400(.09)a_{20} + .10y_1 + .08y_2 > 2350$

(e) $a_{10} + a_{15} + a_{20} < 1500$ (sawing capacity), $100a_{10} + 240a_{15} + 400a_{20} + y_1 + y_2 < 26500$ (drying capacity)

(e) Multiobjective NLP because the first constraint is nonlinear and all variables are continuous.

2-35. (a) The issue is how many cars to move from where to where.

(f) $a_{10} < 50$ (size 10 log availability), $a_{15} < 25$ (size 15 log availability), $a_{20} < 10$ (size 20 log availability), $y_1 < 5000$ (grade 1 green lumber availability)

(g) $a_{10}, a_{15}, a_{20}, y_1, y_2 > 0$

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

(i) $a^*_{10} = 50$, $a^*_{15} = 25$, $a^*_{20} = 5$, $y^*_1 = 5000$, $y^*_2 = 8500$

2-38. (a) Decisions to be made are when to schedule each film.

(b) min $\sum_{j=1}^{m-1} \sum_{j'=j+1}^{m} a_{j,j'} \sum_{t=1}^{n} a_{j,t} a_{j',t}$

(c) $\sum_{t=1}^{n} a_{j,t} = 1, j = 1, \ldots, m$ (each film j)

(d) $\sum_{j=1}^{m} a_{j,t} < 4, t = 1, \ldots, n$ (each time t)

(e) $a_{j,t} = 0$ 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; param m; param n; set films := 1 .. m; set slots := 1 .. n; var x{j in films, t in slots } binary; param a{ j in films, jp in films }; minimize totconflict: sum{ j in films, jp in films: j < m and jp > j } a[j,jp]*sum {t in slots} x[j,t]*x[jp,t]; subject to allin {j in films}: sum{ t in slots } x[j,t] = 1; max4 {t in slots}:sum{j in films} x[j,t] <= 4;

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) $f_i \triangleq$ fixed cost of site i, $c_{i,j} \triangleq$ unit cost of audits at j from i, $r_j \triangleq$ required number of audits in state j

(d) min $\sum_{i=1}^{5} \sum_{j=1}^{5} c_{i,j} r_j a_{i,j} + \sum_{i=1}^{5} f_i y_i$

(e) $\sum_{i=1}^{5} a_{i,j} = 1, j = 1, \ldots, 5$ (each location j)

(f) $a_{i,j} < y_i, i, j = 1, \ldots, 5$ (each site i, location j combination)

(g) $a_{i,j} > 0, i, j = 1, \ldots, 5, y_i = 0$ 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:

$a^*_{2,2} = a^*_{2,4} = a^*_{3,1} = a^*_{3,3} = a^*_{5,5} = 1$,

$y^*_2 = y^*_3 = y^*_5 = 1$ (j) model; param m; param n; set sites := 1 .. m; set states := 1 .. n; var x{i in sites, j in states } >= 0; var y{i in sites } binary; param c {i in sites, j in i in sites } binary; param r { j in states }; minimize totcost: sum{i in sites, j in states} c[i,j]*r[j]*x[i,j] + sum{i in sites}f[i]*y[i]; x[j,t]*x[jp,t]; subject to doeach{j in states}: sum{i in sites}x[i,j] = 1; switch {i in sites, j in states }: x[i,j] <= y[i]; data; param m := 5; param n := 5; param f := 1 160 2 49 3 246 4 86 4 100; param r := 1 200 2 100 3 300 4 100 5 200; param c: 1 2 3 4 5 := 1 0.0 0.4 0.8 0.4 0.8 2 0.7 0.0 0.8 0.4 0.4 3 0.6 0.4 0.0 0.5 0.4 4 0.6 0.4 0.9 0.0 0.4 5 0.9 0.4 0.7 0.4 0.0 ;

2-40. (a) max $\sum_{j=1}^{8} r_j a_j$, subject to,

$\sum_{j=1}^{8} a_j < 4$, $a_1 + a_2 + a_3 > 2$, $a_4 + a_5 + a_6 + a_7 + a_8 > 1$, $a_2 + a_3 + a_4 + a_8 > 2$, $a_1 \ldots a_8 = 0$ or 1 (b) model; param n ; set games := 1 .. n; #ratings param r{j in games}; #home? param h{j in games}; #state? param s{j in games}; #cover? var x{j in games} binary; maximize totrat: sum{j in games} r[j]*x[j]; subject to capacity: sum{j in games} x[j] <= 4; home: sum{j in games} h[j]*x[j] >= 2; away: sum{j in games}(1-h[j])* x[j] >= 1; state: sum{j in games}s[j]*x[j] >= 2; data; param n := 8; param 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; param h:=1 1 2 1 3 1 4 0 5 0 6 0 7 0 8 0; param s:=1 0 2 1 3 1 4 1 5 0 6 0 7 0 8 1; (c) The model is an ILP because all constraints and the objective are linear, but decision variables are binary.

2-41. (a) How to divide funds is the issue.

(b) max $\sum_{j=1}^{n} v_j a_j$

(c) min $\sum_{j=1}^{n} r_j a_j$

(d) $\sum_{j=1}^{n} a_j = 1$

(e) $a_j > l_j, j = 1, \ldots, n$ (each category j)

(f) $a_j < u_j$, $j = 1, \dots, n$ (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 $a_{i,j} a_{i',j'} = 1$ the i is at j and i' is at j', so wire $d_{j,j'}$ will be required. Summing over all possible location pairs captures the wire requirements for i and i'.

(c) min

$$\sum_{i=1}^{m-1} \sum_{i'=i+1}^{m} a_{i,i'} \sum_{j=1}^{n} \sum_{j'=1}^{n} d_{j,j'} a_{i,j} a_{i',j'}$$

(d) $\sum_{j=1}^{n} a_{i,j} = 1$, $i = 1, \dots, m$ (each module i)

(e) $\sum_{i=1}^{m} a_{i,j} < 1$, $j = 1, \dots, n$ (each site j)

(f) $a_{i,j} = 0$ or 1, $i = 1, \dots, m$, $j = 1, \dots, n$

(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] sum{j in sites, jp in sites: j < n and jp > j } d[j,jp]*x[i,j]*x[ip,jp]; subject to alli {i in modules }: sum{ j in sites } x[i,j] = 1; allj { j in sites }: sum { i in modules } x[i,j] <= 1;

2-43. max $199a_1 + 229a_2 + 188a_3 + 205a_4 - 180y_1 - 224y_2 - 497y_3$, subject to, $23a_3 + 41a_4 < 2877y_1$, $14a_1 + 29a_2 < 2333y_2$, $11a_3 + 27a_4 < 3011y_3$, $a_1 + a_2 + a_3 + a_4 > 205$, $y_1 + y_2 + y_3 < 2$, $a_1, \dots, a_4 > 0$, $y_1, \dots, y_3 = 0$ or 1

2-44. max $11a_{1,1} + 15a_{1,2} + 19a_{1,3} + 10a_{1,4} + 19a_{2,1} + 23a_{2,2} + 44a_{2,3} + 67a_{2,4} + 17a_{3,1} + 18a_{3,2} + 24a_{3,3} + 55a_{3,4}$, subject to, $15a_{1,1} + 24a_{2,1} + 17a_{3,1} < 7600$, $19a_{1,2} + 26a_{2,2} + 13a_{3,2} < 8200$, $23a_{1,3} + 18a_{2,3} + 16a_{3,3} < 6015$, $14a_{1,4} + 33a_{2,4} + 14a_{3,4} < 5000$, $31a_{1,1} + 26a_{2,1} + 21a_{3,1} < 6600$, $25a_{1,2} + 28a_{2,2} + 17a_{3,2} < 7900$, $39a_{1,3} + 22a_{2,3} + 20a_{3,2} < 5055$, $29a_{1,4} + 31a_{2,4} + 18a_{3,4} < 7777$, $a_{1,1} + a_{2,1} + a_{3,1} > 200$, $a_{1,2} + a_{2,2} + a_{3,2} > 300$, $a_{1,3} + a_{2,3} + a_{3,3} > 250$, $a_{1,4} + a_{2,4} + a_{3,4} > 500$, $a_{j,t} > 0$, $j = 1, \dots 3$, $t = 1, \dots 4$.