IEOR 240 Final Project
Lake Saddleback Development Corporation: Final Report
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INTRODUCTION

Lake Saddleback Development Corporation (LSDC) is developing a community of homes and condominiums around a section of Lake Saddleback, Texas. It currently owns 300 acres of land on and near the lake and the company is looking to develop a variety of properties at this location to maximize its profits. The development plan should offer an appropriate variety of different home plans in different products, and the specific constraints are listed in the formulation below.

FORUMULATION

The linear program developed in this case is intended to provide a recommendation for the development plan for LSDC. First, the following assumptions are necessary for defining the problems presented in the case as well as developing the linear program:

Key Assumptions:

1. The percentages in "Variety" represent the percentages of total units, not total area
2. The "Premium" constraints are expressed in percentages of total units, not total area.
3. The number of each type of house to build will be kept as linear variables instead of integer, to keep the formulation purely linear. The modified problem will also keep said variables linear for the sake of consistency. Therefore, the number of house to build and total profit in the solutions suggested is subject to rounding errors.

Parameters:

According to the information given, we can calculate the selling price and total land sizes required for each plan. In addition, net profit of Grand Estates is 22% of its selling price, net profit of Glen Wood is 18% of its selling price, net profit of Lakeview is 20% of its selling price, and net profit of Country Condominiums is 25% of its selling price.

Grand Estates:

Lot Size:

Each unit of Grand Estates plans (The Trump, The Vanderbilt, The Hughes, The Jackson, The Trump on the lake, The Vanderbilt on the lake, The Hughes on the lake, The Jackson on the lake):

1/2 (acre) * 43560 (square feet/acre) = 21780 square feet

Parking: (number of outside parking space required = number of bedrooms - number of car garage)

The Trump and The Trump on the lake:

200 (square feet/parking) * (5 - 3) = 400 square feet

The Vanderbilt and The Vanderbilt on the lake:

200 (square feet/parking) * (4 - 3) = 200 square feet

The Hughes and The Hughes on the lake:

200 (square feet/parking) * (4 - 3) = 200 square feet

The Jackson and The Jackson on the lake:

200 (square feet/parking) * (3 - 3) = 0 square feet

Roads:

1000 square feet per house

Total Land Sizes: (Total = Lot Size + Parking + Roads)

The Trump:

21780 + 400 + 1000 = 23180 square feet

The Vanderbilt:

21780 + 200 + 1000 = 22980 square feet

The Hughes:

21780 + 200 + 1000 = 22980 square feet

The Jackson:

21780 + 0 + 1000 = 22780 square feet

The Trump on the lake:

21780 + 400 + 1000 = 23180 square feet

The Vanderbilt on the lake:

21780 + 200 + 1000 = 22980 square feet

The Hughes on the lake:

21780 + 200 + 1000 = 22980 square feet

The Jackson on the lake:

21780 + 0 + 1000 = 22780 square feet

Selling Price:

The Trump:

700 thousand dollars

The Vanderbilt:

680 thousand dollars

The Hughes:

650 thousand dollars

The Jackson:

590 thousand dollars

The Trump on the lake:

700,000 * (1 + 0.3) + 50,000 = 960,000 = 960 thousand dollars

The Vanderbilt on the lake:

680,000 * (1 + 0.3) + 50,000 = 934,000 = 934 thousand dollars

The Hughes on the lake:

650,000 * (1 + 0.3) + 50,000 = 895,000 = 895 thousand dollars

The Jackson on the lake:

590,000 * (1 + 0.3) + 50,000 = 817,000 = 817 thousand dollars

Glen Wood Collection:

Lot Size: (Lot Size = Ground Area of House + Yard Size + Garage Size)

Minimum lot size is 1/10 (acre) * 43560 (square feet/acre) = 4356 square feet

Grand Cypress:

0.75 * 2800 + 0.75 * 2800 + 750 = 4950 square feet

Grand Cypress Premium:

1/4 (acre) * 43560 (square feet/acre) = 10890 square feet

Lazy Oak:

0.75 * 2400 + 0.75 * 2400 + 500 = 4100 < 4356 square feet

Therefore Lot size for Lazy Oak is 4356 square feet.

Wind Row:

0.75 * 2200 + 0.75 * 2200 + 500 = 3800 < 4356 square feet

Therefore Lot size for Wind Row is 4356 square feet.

Orangewood:

1800 + 1200 + 500 = 3500 < 4356 square feet

Therefore Lot size for Orangewood is 4356 square feet.

Parking: (number of outside parking space required = number of bedrooms - number of car garage)

Grand Cypress:

200 (square feet/parking) * (4 - 3) = 200 square feet

Grand Cypress Premium:

200 (square feet/parking) * (4 - 3) = 200 square feet

Lazy Oak:

200 (square feet/parking) * (4 - 2) = 400 square feet

Wind Row:

200 (square feet/parking) * (3 - 2) = 200 square feet

Orangewood:

200 (square feet/parking) * (3 - 2) = 200 square feet

Roads:

1000 square feet per house

Total Land Sizes: (Total = Lot Size + Parking + Roads)

Grand Cypress:

4950 + 200 + 1000 = 6150 square feet

Grand Cypress Premium:

10890 + 200 + 1000 = 12090 square feet

Lazy Oak:

4356 + 400 + 1000 = 5756 square feet

Wind Row:

4356 + 200 + 1000 = 5556 square feet

Orangewood:

4356 + 200 + 1000 = 5556 square feet

Selling Price:

Grand Cypress:

420 thousand dollars

Grand Cypress Premium:

420,000 + 40,000 = 460,000 = 460 thousand dollars

Lazy Oak:

380 thousand dollars

Wind Row:

320 thousand dollars

Orangewood:

280 thousand dollars

Lakeview Patio Homes:

Lot Size: (Lot Size = Ground Area of House + Yard Size + Garage Size)

Minimum lot size is 1/10 (acre) * 43560 (square feet/acre) = 4356 square feet

Bayview:

0.75 * 2000 + 0.5 * 0.75 * 2000 + 600 + 500 = 3350 < 4356 square feet

Therefore Lot size for Bayview is 4356 square feet.

Bayview Premium:

1/6 (acre) * 43560 (square feet/acre) = 7260 square feet

Storeline:

0.75 * 1800 + 0.5 * 0.75 * 1800 + 600 + 500 = 3125 < 4356 square feet

Therefore Lot size for Storeline is 4356 square feet.

Docks Edge:

1500 + 900 + 500 = 2900 < 4356 square feet

Therefore Lot size for Docks Edge is 4356 square feet.

Golden Pier:

1200 + 900 + 500 = 2600 < 4356 square feet

Therefore Lot size for Golden Pier is 4356 square feet.

Parking: (number of outside parking space required = number of bedrooms - number of car garage)

Bayview:

200 (square feet/parking) * (4 - 2) = 400 square feet

Bayview Premium:

200 (square feet/parking) * (4 - 2) = 400 square feet

Storeline:

200 (square feet/parking) * (3 - 2) = 200 square feet

Docks Edge:

200 (square feet/parking) * (3 - 2) = 200 square feet

Golden Pier:

200 (square feet/parking) * (2 - 2) = 0 square feet

Roads:

1000 square feet per house

Total Land Sizes: (Total = Lot Size + Parking + Roads)

Bayview:

4356 + 400 + 1000 = 5756 square feet

Bayview Premium:

7260 + 400 + 1000 = 8660 square feet

Storeline:

4356 + 200 + 1000 = 5556 square feet

Docks Edge:

4356 + 200 + 1000 = 5556 square feet

Golden Pier:

4356 + 0 + 1000 = 5356 square feet

Selling Price:

Bayview:

300 thousand dollars

Bayview Premium:

300,000 + 30,000 = 330,000 = 330 thousand dollars

Storeline:

270 thousand dollars

Docks Edge:

240 thousand dollars

Golden Pier:

200 thousand dollars

Country Condominiums:

Lot Size:

Each unit of Country Condominiums plans (Country Stream, Weeping Willow, Picket Fence) is 1500 square feet

Parking: (number of outside parking space required = number of bedrooms - number of car garage)

Country Stream:

200 (square feet/parking) * (3 - 0) = 600 square feet

Weeping Willow:

200 (square feet/parking) * (2 - 0) = 400 square feet

Picket Fence:

200 (square feet/parking) * (2 - 0) = 400 square feet

Roads:

1000 square feet per house

Total Land Sizes: (Total = Lot Size + Parking + Roads)

Country Stream:

1500 + 600 + 1000 = 3100 square feet

Weeping Willow:

1500 + 400 + 1000 = 2900 square feet

Picket Fence:

1500 + 400 + 1000 = 2900 square feet

Selling Price:

Country Stream:

220 thousand dollars

Weeping Willow:

160 thousand dollars

Picket Fence:

140 thousand dollars

Thus, all of the parameters for all the products and different home plans can be summarized in Table 1 below.

Table 1: Parameters for LSDC products

Plan	Selling Price	Size	Bedrooms	Stories	Garage Size	Ground Area	Yard Size	Garage Size	Lot Size	Parking	Roads	Total
Grand Estates												
The Trump	$700,000	4000	5	2	3	-	-	-	21780	400	1000	**23180**
The Vanderbilt	$680,000	3600	4	2	3	-	-	-	21780	200	1000	**22980**
The Hughes	$650,000	3000	4	1	3	-	-	-	21780	200	1000	**22980**
The Jackson	$590,000	2600	3	1	3	-	-	-	21780	0	1000	**22780**
The Trump on the Lake	$960,000	4000	5	2	3	-	-	-	21780	400	1000	**23180**
The Vanderbilt on the Lake	$934,000	3600	4	2	3	-	-	-	21780	200	1000	**22980**
The Hughes on the Lake	$895,000	3000	4	1	3	-	-	-	21780	200	1000	**22980**
The Jackson on the Lake	$817,000	2600	3	1	3	-	-	-	21780	0	1000	**22780**
Glen Wood Collection												
Grand Cypress	$420,000	2800	4	2	3	2100	2100	750	4950	200	1000	**6150**
Grand Cypress Premium	$460,000	2800	4	2	3	-	-	-	10890	200	1000	**12090**
Lazy Oak	$380,000	2400	4	2	2	1800	1800	500	4356	400	1000	**5756**
Wind Row	$320,000	2200	3	2	2	1650	1650	500	4356	200	1000	**5556**
Orangewood	$280,000	1800	3	1	2	1800	1200	500	4356	200	1000	**5556**
Lakeview Patio Homes												
Bayview	$300,000	2000	4	2	2	1500	1350	500	4356	400	1000	**5756**
Bayview Premium	$330,000	2000	4	2	2	-	-	-	7260	400	1000	**8660**
Storeline	$270,000	1800	3	2	2	1350	1275	500	4356	200	1000	**5556**
Docks Edge	$240,000	1500	3	1	2	1500	900	500	4356	200	1000	**5556**
Golden Pier	$200,000	1200	2	1	2	1200	900	500	4356	0	1000	**5356**
Country Condominiums												
Country Stream	$220,000		3		0	-	-	-	1500	600	1000	**3100**
Weeping Willow	$160,000		2		0	-	-	-	1500	400	1000	**2900**
Picket Fence	$140,000		2		0	-	-	-	1500	400	1000	**2900**

Decision Variable:

Below is a list of decision variables that are used in this linear program:

- *x_total*, number of total units built.
- *x_GE*, number of total Grand Estates built.
- *x_GWC*, number of total Glen Wood Collection built.
- *x_LPH*, number of total Lakeview Patio Homes built.
- *x_CC*, number of total Country Condominiums built.
- *x_trump*, number of The Trump built.
- *x_trump_lake*, number of The Trump on the lake built.
- *x_vand*, number of The Vanderbilt built.
- *x_vand_lake*, number of The Vanderbilt on the lake built.
- *x_hughes*, number of The Hughes built.
- *x_hughes*_lake, number of The Hughes on the lake built.
- *x_jack*, number of The Jackson built.
- *x_jack_lake*, number of The Jackson on the lake built.
- *x_GC*, number of Grand Cypress built.
- *x_GC_prem*, number of Grand Cypress premium built.
- *x_LO*, number of Lazy Oak built.
- *x_WR*, number of Wind Row built.
- *x_orange*, number of Orangewood built.

- *x_bay*, number of Bayview built.
- *x_bay_prem*, number of Bayview premium built.
- *x_store*, number of Storeline built.
- *x_DE*, number of Docks Edge built.
- *x_GP*, number of Golden Pier built.
- *x_CS*, number of Country Stream built.
- *x_WW*, number of Weeping Willow built.
- *x_PF*, number of Picket Fence built.

Objective Function:

The objective for this linear program is to maximize LSDC's profits from the development, which is given by:

Maximize *0.22 * (x_trump_lake * 960 + x_trump * 700 + x_vand_lake * 934 + x_vand * 680*
*+ x_hughes_lake * 895 + x_hughes*650 + x_jack_lake*817 + x_jack*590)*
*+ 0.18 * (x_GC * 420 + x_GC_prem * 460 + x_LO * 380 + x_WR * 320 + x_orange * 280)*
*+ 0.2 * (x_bay * 300 + x_bay_prem * 330 + x_store * 270 + x_DE * 240 + x_GP*200)*
*+ 0.25 * (x_CS * 220 + x_WW * 160 + x_PF*140)*

Constraints:

The linear program is subjected to the following constraints:

1. The number of total built units equals the sum of all products
   x_total = x_GE + x_GWC+ x_LPH + x_CC
2. The makeup of Grand Estate Series
   x_GE = x_trump_lake + x_trump + x_vand_lake + x_vand + x_hughes_lake + x_hughes + x_jack_lake + x_jack
3. The makeup of Glen Wood Collection
   x_GWC = x_GC + x_GC_prem + x_LO + x_WR + x_orange
4. The makeup of Lakeview Patio Homes
   x_LPH = x_bay + x_bay_prem + x_store + x_DE + x_GP
5. The makeup of Country Condos
   x_CC = x_CS + x_WW + x_PF
6. Available acres of land to develop must not exceed 300
   *(x_trump_lake + x_trump) * 23180 + (x_vand_lake + x_vand + x_hughes_lake + x_hughes) * 22980+ (x_jack_lake + x_jack) * 22780 + x_GC * 6150 + x_GC_prem * 12090 + (x_LO + x_bay) * 5756+ (x_WR + x_orange + x_store + x_DE) * 5556 + x_bay_prem * 8660 + x_GP * 5356+ x_CS * 3100 + (x_WW + x_PF) * 2900*
   *<= 300 * 43560*
7. 50 one-half acres on the lake is dedicated to Grand Estate
   x_trump_lake + x_vand_lake + x_hughes_lake + x_jack_lake <= 50

8. No more than 25% of the total Grand Cypress models are premium
   $x\_GC\_prem <= (x\_GC + x\_GC\_prem) * 0.25$
9. No more than 25% of the total Bayview models are premium
   $x\_bay\_prem <= (x\_bay + x\_bay\_prem) * 0.25$
10. Total parking space dedicated to this project must not exceed 15 acre
    $(x\_trump\_lake + x\_trump + x\_LO + x\_bay + x\_bay\_prem + x\_WW + x\_PF) * 400 + (x\_vand\_lake + x\_vand + x\_hughes\_lake + x\_hughes + x\_GC + x\_GC\_prem + x\_WR + x\_orange + x\_store + x\_DE) * 200 + x\_CS * 600$
    $<= 15 * 43560$
11. Variety for 2 bedrooms: lower bound
    $x\_GP + x\_WW + x\_PF >= 0.15 * x\_total$
12. Variety for 2 bedrooms: upper bound
    $x\_GP + x\_WW + x\_PF <= 0.25 * x\_total$
13. Variety for 3 bedrooms: lower bound
    $x\_jack + x\_jack\_lake + x\_WR + x\_orange + x\_store + x\_DE + x\_CS >= 0.25 * x\_total$
14. Variety for 3 bedrooms: upper bound
    $x\_jack + x\_jack\_lake + x\_WR + x\_orange + x\_store + x\_DE + x\_CS <= 0.4 * x\_total$
15. Variety for 4 bedrooms: lower bound
    $x\_vand + x\_vand\_lake + x\_hughes + x\_hughes\_lake + x\_GC + x\_GC\_prem + x\_LO + x\_bay + x\_bay\_prem$
    $>= 0.25 * x\_total$
16. Variety for 4 bedrooms: upper bound
    $x\_vand + x\_vand\_lake + x\_hughes + x\_hughes\_lake + x\_GC + x\_GC\_prem + x\_LO + x\_bay + x\_bay\_prem$
    $<= 0.4 * x\_total$
17. Variety for 5 bedrooms: lower bound
    $x\_trump + x\_trump\_lake >= 0.05 * x\_total$
18. Variety for 5 bedrooms: upper bound
    $x\_trump + x\_trump\_lake <= 0.15 * x\_total$
19. Grand Estate mix: lower bound
    $x\_GE >= 0.15 * x\_total$
20. Grand Estate mix: upper bound
    $x\_GE <= 0.35 * x\_total$
21. Glen Wood mix: lower bound
    $x\_GWC >= 0.15 * x\_total$
22. Glen Wood mix: upper bound
    $x\_GWC <= 0.35 * x\_total$
23. Lakeview Patio mix: lower bound
    $x\_LPH >= 0.15 * x\_total$

24. Lakeview Patio mix: upper bound
    $x\_LPH <= 0.35 * x\_total$
25. Condos mix: lower bound
    $x\_CC >= 0.15 * x\_total$
26. Condos mix: upper bound
    $x\_CC <= 0.35 * x\_total$
27. Trump mix: lower bound
    $x\_trump + x\_trump\_lake >= 0.2 * x\_GE$
28. Vanderbilt mix: lower bound
    $x\_vand + x\_vand\_lake >= 0.2 * x\_GE$
29. Hughes mix: lower bound
    $x\_hughes + x\_hughes\_lake >= 0.2 * x\_GE$
30. Jackson mix: lower bound
    $x\_jack + x\_jack\_lake >= 0.2 * x\_GE$
31. Trump mix: upper bound
    $x\_trump + x\_trump\_lake <= 0.35 * x\_GE$
32. Vanderbilt mix: upper bound
    $x\_vand + x\_vand\_lake <= 0.35 * x\_GE$
33. Hughes mix: upper bound
    $x\_hughes + x\_hughes\_lake <= 0.35 * x\_GE$
34. Jackson mix: upper bound
    $x\_jack + x\_jack\_lake <= 0.35 * x\_GE$
35. GC mix: lower bound
    $x\_GC + x\_GC\_prem >= 0.2 * x\_GWC$
36. LO mix: lower bound
    $x\_LO >= 0.2 * x\_GWC$
37. WR mix: lower bound
    $x\_WR >= 0.2 * x\_GWC$
38. Orange mix: lower bound
    $x\_orange >= 0.2 * x\_GWC$
39. GC mix: upper bound
    $x\_GC + x\_GC\_prem <= 0.35 * x\_GWC$
40. LO mix: upper bound
    $x\_LO <= 0.35 * x\_GWC$
41. WR mix: upper bound
    $x\_WR <= 0.35 * x\_GWC$
42. Orange mix: upper bound
    $x\_orange <= 0.35 * x\_GWC$
43. bay mix: lower bound

*x_bay + x_bay_prem >= 0.2 * x_LPH*

44. Storeline mix: lower bound
    *x_store >= 0.2 * x_LPH*
45. DE mix: lower bound
    *x_DE >= 0.2 * x_LPH*
46. GP mix: lower bound
    *x_GP >= 0.2 * x_LPH*
47. Bay mix: upper bound
    *x_bay + x_bay_prem <= 0.35 * x_LPH*
48. Storeline mix: upper bound
    *x_store <= 0.35 * x_LPH*
49. DE mix: upper bound
    *x_DE <= 0.35 * x_LPH*
50. GP mix: upper bound
    *x_GP <= 0.35 * x_LPH*
51. CS mix: lower bound
    *x_CS >= 0.2 * x_CC*
52. WW mix: lower bound
    *x_WW >= 0.2 * x_CC*
53. PF mix: lower bound
    *x_PF >= 0.2 * x_CC*
54. CS mix: upper bound
    *x_CS <= 0.35 * x_CC*
55. WW mix: upper bound
    *x_WW <= 0.35 * x_CC*
56. PF mix: upper bound
    *x_PF <= 0.35 * x_CC*
57. Appearance's sake: 70% or below single-family homes are two story
    x_trump + x_trump_lake + x_vand + x_vand_lake + x_GC + x_GC_prem + x_LO + x_WR+ x_bay + x_bay_prem + x_store
    *<= (x_GE + x_GWC + x_LPH) * 0.7*
58. Affordable housing: 15% or more affordable homes
    *x_GP + x_WW + x_PF >= x_total * 0.15*

SOLUTION

Solving the linear program using AMPL, we found that LSDC will maximize its profit while meeting all constraints and regulations by following the development plan in Table 2. The maximum profit would be roughly $122,609,000.

Table 2: LSDC Development Plan to Maximize Profit

Product/Plan	**Units to Develop**
Grand Estate Total:	265
The Trump	67
The Vanderbilt	58
The Hughes	45
The Jackson	45
The Trump on the Lake	26
The Vanderbilt on the Lake	8
The Hughes on the Lake	8
The Jackson on the Lake	8
Glen Wood Collection Total:	617
Grand Cypress	216
Grand Cypress Premium	0
Lazy Oak	154
Wind Row	123
Orangewood	123
Lakeview Patio Homes Total:	294
Bayview	103
Bayview Premium	0
Storeline	68
Docks Edge	65
Golden Pier	59

Country Condominiums:	588
Country Stream	206
Weeping Willow	206
Picket Fence	176
TOTAL	**1764**

DISCUSSION

Sensitivity Analysis

To maximize profit, Lake Saddleback Development Corporation build 0 Grand Cypress premium and Bayview premium, which are *non-basic variables*. Except these two home plans, all other home plans in different products are non-zero, which are *basic variables*.

Change of coefficients

- **Non-basic variables**

1. *What are the opportunity costs for Grand Cypress premium and Bayview premium ?*

Table 1: Sensitivity Analysis of Zero Home Plans (Non-basic Variables)

_varname	_var	_var.rc	_var.down	_var.up	_var.current
x_GC_prem	0	-47.2747	-1.00E+20	130.075	82.8
x_bay_prem	0	-20.6321	-1.00E+20	86.6321	66

The opportunity cost for Grand Cypress premium and Bayview premium are -47.2747 and -20.6321. In this maximization problem, the unit profit for Grand Cypress premium needs to increase by more than $47.27 so that LSDC will build more than 0 of such home plan. This reduced cost corresponds to the allowable increase $130.075 (82.8+47.2747=130.075).

The unit profit for premium Bayview needs to increase by more than $20.63 before LSDC would build any of this home plan. This opportunity cost correspond to the allowable increase $86.6321 (66+20.6321=86.6321).

- **Basic Variables**

2. *How much unit profit of other home plans (basic variables) can go up or down without changing the current optimal number of home plans? What does it imply in this case?*

All other unit profits of home plans can go up without changing the optimal solution within the bounds. Specific values can be found from the following table.

Table 2: Sensitivity Analysis of Non-zero Home Plans (Basic Variable)

_varname	_var	_var.rc	_var.down	_var.up	_var.current
x_trump	66.62	0	151.431	155.32	154
x_trump_lake	26	0	209.88	1.00E+20	211.2
x_vand	58.1571	0	149	152.163	149.6
x_vand_lake	8	-1.32	-1.00E+20	206.8	205.48
x_hughes	44.9257	0	139.7	143.6	143
x_hughes_lake	8	-3.3	-1.00E+20	200.2	196.9
x_jack	44.9257	0	122.54	141.756	129.8
x_jack_lake	8	-7.26	-1.00E+20	187	179.74
x_GC	216.113	0	71.9898	851.358	75.6
x_LO	154.367	0	59.4129	71.9701	68.4
x_WR	123.493	1.78E-15	-21.1939	66.5489	57.6
x_orange	123.493	1.78E-15	-28.3939	60.5467	50.4
x_bay	102.911	0	55.8276	93.0289	60
x_store	67.6273	0	48	54.6	54
x_DE	64.687	0	47.4	54	48
x_GP	58.8063	-7.11E-15	-123.914	67.8963	40
x_CS	205.822	0	27.3554	632.983	55
x_WW	205.822	0	35	617.983	40
x_PF	176.419	0	-9.85582	40	35

For example, the optimal solution would remain unchanged if the unit profit of The Trump goes up from $154 to $155.32, or goes down to $151.432.

As this is a maximization problem, we evaluate new optimal objective value by increasing unit profit of each home plan to its upper bound. The new optimal objective value is:

$$
\begin{aligned}
&+\infty * x\_trump\_lake + 155.32 * x\_trump + 206.8 * x\_vand\_lake + 152.163 * x\_vand \\
&\quad + 200.2 * x\_hughes\_lake + 143.6 * x\_hughes + 187 * x\_jack\_lake + 141.756 * x\_jack \\
&\quad + 851.358 * x\_GC + 71.9701 * x\_LO + 66.5489 * x\_WR + 60.5467 * x\_orange \\
&\quad + 93.0289 * x\_bay + 54.6 * x\_store + 54 * x\_DE + 67.8963 * x\_GP \\
&\quad + 632.983 * x\_CS + 617.983 * x\_WW + 40 * x\_PF \\
&\quad = +\infty
\end{aligned}
$$

The new optimal objective value can be infinity, as the profit margin of *The Trump on the lake* can increase to infinity. There are only 50 half-acre lots on the lake, and the optimal solution has assigned all resources to build 26 The Trump, 8 The Vanderbilt, 8 The Hughes, and 8 The Jackson. Regardless of how high the profit margin of The Trump increase, LSDC does not have

additional resources to build the 27th The Trump on the lake. Hence, its profit margin can increase infinitely.

Change of Right-hand Side

- **Binding constraints**

An example the change of b_i of binding constraints: a change of constraint would lead to a change of optimal point.

3. *What is the maximum potential increase in profit when an extra half-acre lots on the lake is available? What would be the new optimal objective value?*

Table 3: Sensitivity Analysis of Lake

_conname	_con	_con.slack	_con.current	_con.down	_con.up
lake	57.2	0	50	32	116.62

The shadow price of lake is 57.2, which means that the total profit will increase at $57,200 per half-acre lots on the lake. Hence, $57,200 is the maximum increase in profit that LSDC will get when Grand Estate Series homes use an extra one-half acre lots on the lake .

The upper bound of lake constraint is $116,620, and lower bound is 32. Through calculation, we know that the allowable increase is 66.62, 33.24% higher than the current constraint. Increasing the lake to its upper bound ($116,620), we will increase the optimal point by $3,810,660 (shadow price*allowable increase = $57,200*66.62). The new objective value increases from $122,609,000 to $126,419,660

- **Non-binding Constraint**

4. *What is the maximum potential increase in profit when an extra unit of affordable housing is available? What would be the new optimal objective value?*

Table 4: Sensitivity Analysis of Affordable Housing

_conname	_con	_con.slack	_con.current	_con.down	_con.up
affordable	0	176.419	0	-1.00E+20	176.419

The shadow price of affordable housing is 0, which means that the total profit would not change with the change of affordable housing. When the affordable housing changes within the range of (-∞, 176.419), the optimal solution and objective value would be unchanged. This is an example of non-binding constraint: a change of constraint would have no impact on the optimal objective value.

5. *Which constraints can we change to increase the total profits? Which constraints cannot?*

Table 5: Sensitivity Analysis of All Constraints

conname	Type	con	con.slack	con.current	con.down	con.up
total	binding	5.21308	0	0	-40	21
grand_estate	binding	67.1456	0	0	-9	6
glen_wood	binding	-9.61272	0	0	-9	6
lakeview_patio	binding	2.95312	0	0	-38	6
condos	binding	25.0196	0	0	-26	13
land	binding	0.00917083	0	13068000	3668410	15268100
lake	binding	57.2	0	50	32	117
GC_premium	non-binding	0	54	0	-54	10000000000000000000
bay_premium	non-binding	0	26	0	-26	10000000000000000000
parking	non-binding	0	94152	653400	559248	10000000000000000000
2b_lowerbound	non-binding	0	176	0	-10000000000000000000	176
2b_upperbound	binding	33.4242	0	0	-26	13
3b_lowerbound	non-binding	0	197	0	-10000000000000000000	197
3b_upperbound	non-binding	0	68	0	-68	10000000000000000000
4b_lowerbound	non-binding	0	151	0	-10000000000000000000	151
4b_upperbound	non-binding	0	113	0	-113	10000000000000000000
5b_lowerbound	non-binding	0	4	0	-10000000000000000000	4
5b_upperbound	non-binding	0	172	0	-172	10000000000000000000
GE_lowerbound	binding	-59.3477	0	0	-13	20
GE_upperbound	non-binding	0	353	0	-353	10000000000000000000
GWC_lowerbound	non-binding	0	353	0	-10000000000000000000	353
GWC_upperbound	binding	16.4548	0	0	-24	20
LPH_lowerbound	non-binding	0	29	0	-10000000000000000000	29
LPH_upperbound	non-binding	0	323	0	-323	10000000000000000000
CC_lowerbound	non-binding	0	323	0	-10000000000000000000	323
CC_upperbound	non-binding	0	29	0	-29	10000000000000000000
trump_lowerbound	non-binding	0	40	0	-10000000000000000000	40
vand_lowerbound	non-binding	0	13	0	-10000000000000000000	13
hughes_lowerbound	binding	-0.6	0	0	-9	6
jack_lowerbound	binding	-11.9658	0	0	-9	6
trump_upperbound	binding	2.56583	0	0	-4	13
vand_upperbound	non-binding	0	26	0	-26	10000000000000000000
hughes_upperbound	non-binding	0	40	0	-40	10000000000000000000
jack_upperbound	non-binding	0	40	0	-40	10000000000000000000
GC_lowerbound	non-binding	0	93	0	-10000000000000000000	93
LO_lowerbound	non-binding	0	31	0	-10000000000000000000	31
WR_lowerbound	binding	-8.96583	0	0	-62	31
orange_lowerbound	binding	-10.1658	0	0	-9	6
GC_upperbound	binding	3.58669	0	0	-62	31
LO_upperbound	non-binding	0	62	0	-62	10000000000000000000
WR_upperbound	non-binding	0	93	0	-93	10000000000000000000
orange_upperbound	non-binding	0	93	0	-93	10000000000000000000
bay_lowerbound	non-binding	0	44	0	-10000000000000000000	44
store_lowerbound	non-binding	0	9	0	-10000000000000000000	9
DE_lowerbound	non-binding	0	6	0	-10000000000000000000	6
GP_lowerbound	binding	-39.59	0	0	-13	5
bay_upperbound	binding	4.16583	0	0	-35	9
store_upperbound	non-binding	0	35	0	-35	10000000000000000000
DE_upperbound	non-binding	0	38	0	-38	10000000000000000000
GP_upperbound	non-binding	0	44	0	-44	10000000000000000000
CS_lowerbound	non-binding	0	88	0	-10000000000000000000	88
WW_lowerbound	non-binding	0	88	0	-10000000000000000000	88
PF_lowerbound	non-binding	0	59	0	-10000000000000000000	59
CS_upperbound	binding	51.59	0	0	-26	13
WW_upperbound	binding	5	0	0	-29	59
PF_upperbound	non-binding	0	29	0	-29	10000000000000000000
appearance	binding	6	0	0	-9	6
affordable	non-binding	0	176	0	-10000000000000000000	176

If we increase binding constraints up to their upper bound, we would increase the total profits by the product of shadow price times allowable increase. Lake is an example. From this table, we label constraints with binding/non-binding, and non-binding constraints are highlighted with

light orange. The change of non-binding constraints would have no impact on the optimal objective value. In addition, we strickdown negative lower bounds of binding constraints, as negative numbers do not have real-world meaning here.

MODIFIED PROBLEM:

Two months after providing the first report, some modifications are made on the situation. In turn, the following new formulation is made to take into account the new requirements given and providing a new solution that is optimized for the new situation.

CHANGE IN FORMULATION

Because the new change in formulation will use binary integer variables to simulate if/else statements, the following parameter is defined to make it possible: M= 999999999. M is just a very large number that makes formulation easier.

According to the 4 new modifications, changes are made in decision variables, objective functions and constraints.

Key Assumptions:

1. If the number of Country Condominiums sold is the same as another type of product. The ranking of the product will be favoring LSDC, meaning if Country Condominiums and another type of product both have the highest number sold. LSDC will still pay 2% on the revenue from CC, instead of 4%.
2. The Sports/Recreational Complex will increase the selling prices of products. The increased selling prices will also be subject to the Luxury Tax introduced in the modified problem.
3. The number of each type of house to build will be kept as linear variables instead of integer for the sake of consistency. Therefore, the number of house to build and total profit in the solutions suggested is subject to rounding errors.

1. Ignoring the maximum minimum requirements on variety

No change is made to decision variables and objective functions

Change in Constraints

The following constraints from the original formulation are deleted:

variety for 2 bedroom: lower bound

x_GP + x_WW + x_PF >= 0.15 * x_total;

variety for 2 bedroom: upper bound

x_GP + x_WW + x_PF <= 0.25 * x_total;

variety for 3 bedroom: lower bound

x_jack + x_jack_lake + x_WR + x_orange + x_store + x_DE + x_CS >= 0.25 * x_total;

variety for 3 bedroom: upper bound

x_jack + x_jack_lake + x_WR + x_orange + x_store + x_DE + x_CS <= 0.4 * x_total;

variety for 4 bedroom: lower bound

x_vand + x_vand_lake + x_hughes + x_hughes_lake + x_GC + x_GC_prem + x_LO + x_bay + x_bay_prem >= 0.25 * x_total;

variety for 4 bedroom: upper bound

x_vand + x_vand_lake + x_hughes + x_hughes_lake + x_GC + x_GC_prem + x_LO + x_bay + x_bay_prem <= 0.4 * x_total;

variety for 5 bedroom: lower bound

x_trump + x_trump_lake >= 0.05 * x_total;

variety for 5 bedroom: upper bound

x_trump + x_trump_lake <= 0.15 * x_total;

This is simply because the modification is to ignore the constraints listed above. No other modifications are made.

*2. Ignoring the **Affordable Housing** requirements, instead use the **Luxury Tax** requirement as stated in the modified problem statement*

Change in Decision Variable

The following Decision Variables are added:

y_GE binary, binary integer variable such that when GE sells more than CC = 1; 0 otherwise
y_GWC binary, binary integer variable such that when GWC sells more than CC = 1; 0 otherwise
y_LPH binary, binary integer variable such that when LPH sells more than CC = 1; 0 otherwise

t_1 >= 0, the additional tax to be paid if CC sells more than GE
t_2 >= 0, the additional tax to be paid if CC sells more than GWC
t_3 >= 0, the additional tax to be paid if CC sells more than LPH
CC_tax >= 0, the total tax amount for Country condo. Created to linearize the objective function

Change in Objective Function

The objective function is modified to the following, the highlighted elements are relevant to this specific modified requirement:

Maximize: a_1 + (0.22-0.08)* (x_trump_lake * 960 + x_trump * 700 + x_vand_lake * 934 + x_vand * 680 + x_hughes_lake * 895 + x_hughes * 650 + x_jack_lake * 817 + x_jack * 590) + a_2 + (0.18-0.08) * (x_GC * 420 + x_GC_prem * 460 + x_LO * 380 + x_WR * 320 + x_orange * 280) + a_3 + (0.2-0.08) * (x_bay * 300 + x_bay_prem * 330 + x_store * 270 + x_DE * 240 + x_GP * 200) + a_4 + 0.25 * (x_CS * 220 + x_WW * 160 + x_PF * 140) - CC_tax - recreation * 8000;

As both the luxury tax and the profit are calculated as percentage of the selling price, the subtraction highlighted removes said tax from the overall profit. The CC_Tax term takes into account the tax for Country condo, which is more complicated and its formulation is in the constraints below

Change in Constraints

The following constraints from the original formulation is deleted:

Affordability constraint: x_GP + x_WW + x_PF >= x_total * 0.15;

As the modification requires the removal of above constraint.

The following constraints are added:

comparing the sells of GE to CC, if GE Sells more, y_GE = 1, 0 otherwise

x_GE >= x_CC - M*(1-y_GE);
x_GE <= x_CC +M*y_GE;

Note: There are only two situations when both of the conditions hold. When GE sells more than CC, and y_GE = 1, or when GE sells less than CC and y_GE = 0. Therefore, this pair of constraints simulate the if/else condition needed.

comparing the sells of GWC to CC, if GE Sells more, y_GWC = 1, 0 otherwise

x_GWC >= x_CC - M*(1-y_GWC);
x_GWC <= x_CC +M*y_GWC;

comparing the sells of LPH to CC, if LPH Sells more, y_GE = 1, 0 otherwise

x_LPH >= x_CC - M*(1-y_LPH);

x_LPH <= x_CC +M*y_LPH;

Assuming the tax rate on CC is 8%, for every other product line that sells more than CC, the total tax paid will be reduced by 2% of the total revenue from CC.

CC_tax = 0.08* (x_CS * 220 + x_WW * 160 + x_PF * 140) - t_1 - t_2 - t_3;

if GE Sells more than CC, t_1 will be 2% of the total revenue of CC

t_1 <= (1 - y_GE) * M;

t_1 <= 0.02 * (x_CS * 220 + x_WW * 160 + x_PF * 140);

Note: Between this pair of constraints, when y_GE = 0, t_1 has to be 0, when y_GE = 1, t_1 = 0.02 * (x_CS * 220 + x_WW * 160 + x_PF * 140). Because in order to maximize the total profit, CC_tax needs to be minimized CC_tax, which in turn, means t_1 needs to be maximized. Therefore, the largest t_1 can be will always be the smaller value of the two constraints.

if GWC Sells more than CC, t_1 will be 2% of the total revenue of CC

t_2 <= (1 - y_GWC) * M;

t_2 <= 0.02 * (x_CS * 220 + x_WW * 160 + x_PF * 140);

if LPH Sells more than CC, t_1 will be 2% of the total revenue of CC

t_3 <= (1 - y_LPH) * M;

t_3 <= 0.02 * (x_CS * 220 + x_WW * 160 + x_PF * 140);

3. Modify" Each of the Grand Estate series plans must have at least eight units on the lake." to "At least three of the Grand Estate series plan must have at least eight units on the lake."

Change in Decision Variable

The following decision variables are added:

trump_lake_eight binary, binary variable if trump has 8 units or more on the lake = 1; 0 otherwise
vand_lake_eight binary, binary variable if vanderbuilt has 8 units or more on the lake = 1; 0 otherwise
hughes_lake_eight binary, binary variable if hughes has 8 units or more on the lake = 1; 0 otherwise
jackson_lake_eight binary, binary variable if jackson has 8 units or more on the lake = 1; 0 otherwise

No Change in Objective Function

Change in Constraints

In the original formulation, each of the Grand Estate series plans must have at least 8 units on the lake. Therefore, in the modified situation, the constraint on the following decision variables are changed from >= 8 to >= 0.

x_trump_lake >= 8;	x_trump_lake >= 0;
x_vand_lake >= 8;	x_vand_lake >= 0;
x_hughes_lake >= 8;	x_hughes_lake >= 0;
x_jack_lake >= 8;	x_jack_lake >= 0;

If number of The Trump on the lake more than eight, then =1, 0 otherwise

x_trump_lake >= 8 - M*(1 - trump_lake_eight);:
8 >= x_trump_lake - M*trump_lake_eight;

Note: There are only two situations when both of the conditions hold. When x_trump_lake >= 8 and trump_lake_eight = 1, or when x_trump_lake <= 8 and trump_lake_eight = 0. Therefore, this pair of constraints simulate the if/else condition needed.

If number of The Vanderbilt on the lake more than eight, then =1, 0 otherwise

x_vand_lake >= 8 - M*(1 - vand_lake_eight);
8 >= x_vand_lake - M*vand_lake_eight;

If number of The Hughes on the lake more than eight, then =1, 0 otherwise

x_hughes_lake >= 8 - M*(1 - hughes_lake_eight);
8 >= x_hughes_lake - M*hughes_lake_eight;

If number of The Jackson on the lake more than eight, then =1, 0 otherwise

x_jack_lake >= 8 - M*(1 - jackson_lake_eight);
8 >= x_jack_lake - M*jackson_lake_eight;

At least three of the Grand Estate series plan must have at least eight units on the lake

trump_lake_eight + vand_lake_eight+ hughes_lake_eight+jackson_lake_eight >= 3;

4. Building the recreational complex

Change in Decision Variable

The following decision variables are added:

recreation, a binary integer variable, if LSDC should build the recreation complex =1, =0 otherwise
a_1 >= 0, additional profit from Grand Estate when recreation is built taking into account the luxury tax
a_2 >= 0, additional profit from Glen wood when recreation is built taking into account the luxury tax
a_3 >= 0, additional profit from LPH when recreation is built taking into account the luxury tax
a_4 >= 0, additional profit from CC when recreation is built taking into account the luxury tax

Change in Objective Function

The objective function is modified to the following, the highlighted elements are relevant to this specific modified requirement:

Maximize: a_1 + (0.22-0.08)* (x_trump_lake * 960 + x_trump * 700 + x_vand_lake * 934 + x_vand * 680 + x_hughes_lake * 895 + x_hughes * 650 + x_jack_lake * 817 + x_jack * 590) + a_2 + (0.18-0.08) * (x_GC * 420 + x_GC_prem * 460 + x_LO * 380 + x_WR * 320 + x_orange * 280) + a_3 + (0.2-0.08) * (x_bay * 300 + x_bay_prem * 330 + x_store * 270 + x_DE * 240 + x_GP * 200) + a_4 + 0.25 * (x_CS * 220 + x_WW * 160 + x_PF * 140) - CC_tax - recreation * 8000;

As stated above, a_1, a_2, a_3 and a_4 represents the additional profit from each product, details will be discussed below in their respective constraint. The " - recreation*8000 " term will substrate the cost of building the recreational complex from the profit if it is planned to be built.

Change in Constraints

The following constraints are modified:

Land constraint, the recreational complex requires 10 acres from the land (highlighted):

(x_trump_lake + x_trump) * 23180 + (x_vand_lake + x_vand + x_hughes_lake + x_hughes) * 22980 + (x_jack_lake + x_jack) * 22780 + x_GC * 6150 + x_GC_prem * 12090 + (x_LO + x_bay) * 5756 + (x_WR + x_orange + x_store + x_DE) * 5556 + x_bay_prem * 8660 + x_GP * 5356 + x_CS * 3100 + (x_WW + x_PF) * 2900 <= (300 - 10*recreation) * 43560;

The following constraints are added:

The additional profit generated by GE if the recreational complex is planned to be built

a_1 <= recreation * M;

a_1 <= 0.92 * 0.05 * (x_trump_lake * 960 + x_trump * 700 + x_vand_lake * 934 + x_vand * 680 + x_hughes_lake * 895 + x_hughes * 650 + x_jack_lake * 817 + x_jack * 590);

Note: Between this pair of constraints, when recreation = 0, a_1 has to be 0, when recreation = 1, t_1 = 0.92 * 0.05 * (x_trump_lake * 960 + x_trump * 700 + x_vand_lake * 934 + x_vand * 680 + x_hughes_lake * 895 + x_hughes * 650 + x_jack_lake * 817 + x_jack * 590). Because in order to maximize the total profit a_1 needs to be maximized. Therefore, the largest a_1 can be will always be the smaller value of the two constraints.

The additional profit generated by GWC if the recreational complex is planned to be built

a_2 <= recreation * M;

a_2 <= 0.92 * 0.03 * (x_GC * 420 + x_GC_prem * 460 + x_LO * 380 + x_WR * 320 + x_orange * 280);

The additional profit generated by LPH if the recreational complex is planned to be built

```
a_3 <= recreation * M;
a_3 <= 0.92 * 0.02 * (x_bay * 300 + x_bay_prem * 330 + x_store * 270 + x_DE * 240 + x_GP *
        200);
```

The additional profit generated by CC if the recreational complex is planned to be built

```
a_4 <= recreation * M;
a_4 <= 0.92 * 0.03 * (x_CS * 220  + x_WW * 160 + x_PF * 140) + rt_1 + rt_2 + rt_3;
```

The rt_1, rt_2, and rt_3 terms is used in a similar fashion as t_1, t_2, and t_3 to account for the tax reduction on the additional revenue generated if the recreational complex is built.

If GE Sells more than CC, rt_1 will be 2% of the additional revenue of CC from the recreational complex

```
rt_1 <= (1 - y_GE) * M;
rt_1 <= 0.02 * 0.03 * (x_CS * 220  + x_WW * 160 + x_PF * 140);
```

If GWC Sells more than CC, rt_2 will be 2% of the additional revenue of CC

```
rt_2 <= (1 - y_GWC) * M;
rt_2 <= 0.02 * 0.03 * (x_CS * 220  + x_WW * 160 + x_PF * 140);
```

If LPH Sells more than CC, rt_3 will be 2% of the additional revenue of CC

```
rt_3 <= (1 - y_LPH) * M;
rt_3 <= 0.02 * 0.03 * (x_CS * 220  + x_WW * 160 + x_PF * 140);
```

SOLUTION

After modifying the formulation and solving the now mixed integer linear program using AMPL, we found that LSDC will maximize its profit while meeting all constraints and regulations by following the development plan in Table 6, notably, building the Sports/Recreational Complex. The maximum profit would be roughly $90,350,900.

Table 6: LSDC Modified Development Plan to Maximize Profit

Product/Plan	**Units to Develop**
Recreational Complex	1
Grand Estate Total:	257
The Trump	56
The Vanderbilt	56

The Hughes	43
The Jackson	51
The Trump on the Lake	34
The Vanderbilt on the Lake	8
The Hughes on the Lake	8
The Jackson on the Lake	0
Glen Wood Collection Total:	600
Grand Cypress	210
Grand Cypress Premium	0
Lazy Oak	150
Wind Row	120
Orangewood	120
Lakeview Patio Homes Total:	257
Bayview	90
Bayview Premium	0
Storeline	56
Docks Edge	60
Golden Pier	51
Country Condominiums:	600
Country Stream	210
Weeping Willow	210
Picket Fence	180
TOTAL	**1715**

DISCUSSION

Profit

Compare to the original problem, the total profit decreased from $122,609,000 to $90,350,900, a reduction of $32,258,100 or 26.3%. This is due to the fact that the number of house to be built decreased significantly after the modification. Although the selling prices increased with the implementation of the Sports/Recreational Complex, the change from **Affordability Housing** constraint to **Luxury Tax** had a larger effect on the profit margin. Also, there is tax incentive to make CC the most sold type of housing. Considering the constraint that CC can not be 35% of all the houses, this really reduced the total number of other products and only gave a minor increase to the number of CCs, which is less profitable anyway. The 10 acre taken by the Sports/Recreational Complex also reduces the total number of house; however, the additional price, hence profit, contributed by Recreational Complex makes up for the space used. This is the reason why AMPL suggested building the Recreational Complex.

Revenue

Despite having a lower total profit, the modified problem has a higher total revenue comparing to the original problem. The total revenue (units * selling price) in the original problem is $590,869,250. In the modified problem the revenue is $592,816,457. The 0.33% revenue increase is caused by building the Sports/Recreational Complex. However, the reduced number of houses, the cost of building the complex, and especially the tax still made the profit of the modified situation a lot worse.

Tax

The total amount of tax paid is a noteworthy data point and showed in Table 7.. LSDC will pay a total of $40,931,797, which is about 6.9% of the total revenue. GC, GWC, and LPH are charged at 8%. CC is charged at 2%.

Table 7: Tax Breakdown In The Modified Situation

Product/Plan	**Tax(**$1,000**)**
Grand Estate Total:	40,931
The Trump	3,296
The Vanderbilt	3,217
The Hughes	2,373
The Jackson	2,550

The Trump on the Lake	2,741
The Vanderbilt on the Lake	627
The Hughes on the Lake	601
The Jackson on the Lake	0
Glen Wood Collection Total:	17,909
Grand Cypress	7,272
Grand Cypress Premium	0
Lazy Oak	4,700
Wind Row	3,166
Orangewood	2,770
Lakeview Patio Homes Total:	5,449
Bayview	2,204
Bayview Premium	0
Storeline	1,228
Docks Edge	1,175
Golden Pier	840
Country Condominiums:	2,165
Country Stream	952
Weeping Willow	693
Picket Fence	519
TOTAL	**40,932**

Variety

Although the modified problem ignores the variety constraint on the maximum and minimum of house types with regards to bedroom numbers, we can still calculate the percentage of each room type and see if loosening the constraint has helped us achieve the optimal solution.

Table 8: Percentage Of Home Types Regarding Bedroom Numbers

Home Type	Minimum	**Percentage**	Maximum
Two-bedroom homes	15%	**25.75%**	25%
Three-bedroom homes	25%	**36.00%**	40%
Four-bedroom homes	25%	**33.00%**	40%
Five-bedroom homes	5%	**5.25%**	15%

As we can see, all types of homes still satisfies the original constraint except Two-bedroom homes, which is over the maximum percentage by 0.75%. This is expected since majority of CCs are two-bedroom homes and the ratio of CC is significantly increased in the modified problem due to the tax incentive discussed above.

Lot Sizing

As the constraint on lakeside homes changed from "Each of the Grand Estate series plans must have at least eight units on the lake." to "At least three of the Grand Estate series plan must have at least eight units on the lake." The optimal quantity to build of the home plan with lowest profit margin() - Jacksons on the lake is dropped from 8 to 0 and the quantity of the home plan with highest profit margin - Trump on the lake, is increased from 26 to 34 as shown in Table 7.

SUMMARY

Based on the prompt and assumptions, in the original problem LSDC should follow the plan showed in Table 2. For the modified problem LSDC should build the Sports/Recreational Complex and follow the plan showed in Table 6.

APPENDIX

Original Formulation

```
# decision variables
var x_total >= 0;
var x_GE >= 0;
var x_GWC >= 0;
var x_LPH >= 0;
var x_CC >= 0;
## GRAND ESTATES
var x_trump >= 0;
var x_trump_lake >= 8; # each of the Grand Estate series plans must have at least 8 units on the lake
var x_vand >= 0;
var x_vand_lake >= 8;
var x_hughes >= 0;
var x_hughes_lake >= 8;
var x_jack >= 0;
var x_jack_lake >= 8;
## GLEN WOOD COLLECTION
var x_GC >= 0;
var x_GC_prem >= 0;
var x_LO >= 0;
var x_WR >= 0;
var x_orange >= 0;
## LAKEVIEW PATIO HOMES
var x_bay >= 0;
var x_bay_prem >= 0;
var x_store >= 0;
var x_DE >= 0;
var x_GP >= 0;
## COUNTRY CONDOMINIUMS
var x_CS >= 0;
var x_WW >= 0;
var x_PF >= 0;

# objective
maximize profit:
        0.22 * (x_trump_lake * 960 + x_trump * 700 + x_vand_lake * 934 + x_vand * 680
        + x_hughes_lake * 895 + x_hughes * 650 + x_jack_lake * 817 + x_jack * 590)
        + 0.18 * (x_GC * 420 + x_GC_prem * 460 + x_LO * 380 + x_WR * 320 + x_orange * 280)
        + 0.2 * (x_bay * 300 + x_bay_prem * 330 + x_store * 270 + x_DE * 240 + x_GP * 200)
        + 0.25 * (x_CS * 220  + x_WW * 160 + x_PF * 140);

# constraints
```

```
# total number of properties is the sum of all properties
subject to total:
        x_total = x_GE + x_GWC+ x_LPH + x_CC;

# the make-up of Grand Estate Series
subject to grand_estate:
        x_GE = x_trump_lake + x_trump + x_vand_lake + x_vand + x_hughes_lake + x_hughes
        + x_jack_lake + x_jack;

# the make-up of Glen Wood Collection
subject to glen_wood:
        x_GWC = x_GC + x_GC_prem + x_LO + x_WR + x_orange;

# the make-up of Lakeview Patio Homes
subject to lakeview_patio:
        x_LPH = x_bay + x_bay_prem + x_store + x_DE + x_GP;

# the make-up of Country Condos
subject to condos:
        x_CC = x_CS  + x_WW + x_PF;

# available land to build properties on
subject to land:
        (x_trump_lake + x_trump) * 23180 + (x_vand_lake + x_vand + x_hughes_lake +
x_hughes) * 22980
        + (x_jack_lake + x_jack) * 22780 + x_GC * 6150 + x_GC_prem * 12090 + (x_LO +
x_bay) * 5756
        + (x_WR + x_orange + x_store + x_DE) * 5556 + x_bay_prem * 8660 + x_GP * 5356
        + x_CS * 3100 + (x_WW + x_PF) * 2900 <= 300 * 43560;

# 50 1/2 acres (units) on the lake is dedicated to Grand Estate
subject to lake:
        x_trump_lake + x_vand_lake + x_hughes_lake + x_jack_lake <= 50;

# no more than 25% of the total Grand Cypress models are premium
subject to GC_premium:
        x_GC_prem <= (x_GC + x_GC_prem) * 0.25;

# no more than 25% of the total Bayview models are premium
subject to bay_premium:
        x_bay_prem <= (x_bay + x_bay_prem) * 0.25;

# total parking space dedicated to this project
subject to parking:
        (x_trump_lake + x_trump + x_LO + x_bay + x_bay_prem + x_WW + x_PF) * 400 +
(x_vand_lake + x_vand
        + x_hughes_lake + x_hughes + x_GC + x_GC_prem + x_WR + x_orange + x_store +
x_DE) * 200
```

```
        + x_CS * 600 <= 15 * 43560;

# variety for 2 bedroom: lower bound
subject to 2b_lowerbound:
        x_GP + x_WW + x_PF >= 0.15 * x_total;

# variety for 2 bedroom: upper bound
subject to 2b_upperbound:
        x_GP + x_WW + x_PF <= 0.25 * x_total;

# variety for 3 bedroom: lower bound
subject to 3b_lowerbound:
        x_jack + x_jack_lake + x_WR + x_orange + x_store + x_DE + x_CS >= 0.25 * x_total;

# variety for 3 bedroom: upper bound
subject to 3b_upperbound:
        x_jack + x_jack_lake + x_WR + x_orange + x_store + x_DE + x_CS <= 0.4 * x_total;

# variety for 4 bedroom: lower bound
subject to 4b_lowerbound:
        x_vand + x_vand_lake + x_hughes + x_hughes_lake + x_GC + x_GC_prem + x_LO
        + x_bay + x_bay_prem >= 0.25 * x_total;

# variety for 4 bedroom: upper bound
subject to 4b_upperbound:
        x_vand + x_vand_lake + x_hughes + x_hughes_lake + x_GC + x_GC_prem + x_LO
        + x_bay + x_bay_prem <= 0.4 * x_total;

# variety for 5 bedroom: lower bound
subject to 5b_lowerbound:
        x_trump + x_trump_lake >= 0.05 * x_total;

# variety for 5 bedroom: upper bound
subject to 5b_upperbound:
        x_trump + x_trump_lake <= 0.15 * x_total;

# Grand Estate mix: lower bound
subject to GE_lowerbound:
        x_GE >= 0.15 * x_total;

# Grand Estate mix: upper bound
subject to GE_upperbound:
        x_GE <= 0.35 * x_total;

# Glen Wood mix: lower bound
subject to GWC_lowerbound:
        x_GWC >= 0.15 * x_total;
```

```
# Glen Wood mix: upper bound
subject to GWC_upperbound:
        x_GWC <= 0.35 * x_total;

# Lakeview Patio mix: lower bound
subject to LPH_lowerbound:
        x_LPH >= 0.15 * x_total;

# Lakeview Patio mix: upper bound
subject to LPH_upperbound:
        x_LPH <= 0.35 * x_total;

# Condos mix: lower bound
subject to CC_lowerbound:
        x_CC >= 0.15 * x_total;

# Condos mix: upper bound
subject to CC_upperbound:
        x_CC <= 0.35 * x_total;

# Trump mix: lower bound
subject to trump_lowerbound:
        x_trump + x_trump_lake >= 0.2 * x_GE;

# Vanderbilt mix: lower bound
subject to vand_lowerbound:
        x_vand + x_vand_lake >= 0.2 * x_GE;

# Hughes mix: lower bound
subject to hughes_lowerbound:
        x_hughes + x_hughes_lake >= 0.2 * x_GE;

# Jackson mix: lower bound
subject to jack_lowerbound:
        x_jack + x_jack_lake >= 0.2 * x_GE;

# Trump mix: upper bound
subject to trump_upperbound:
        x_trump + x_trump_lake <= 0.35 * x_GE;

# Vanderbilt mix: upper bound
subject to vand_upperbound:
        x_vand + x_vand_lake <= 0.35 * x_GE;

# Hughes mix: upper bound
subject to hughes_upperbound:
        x_hughes + x_hughes_lake <= 0.35 * x_GE;
```

```
# Jackson mix: upper bound
subject to jack_upperbound:
        x_jack + x_jack_lake <= 0.35 * x_GE;

# GC mix: lower bound
subject to GC_lowerbound:
        x_GC + x_GC_prem >= 0.2 * x_GWC;

# LO mix: lower bound
subject to LO_lowerbound:
        x_LO >= 0.2 * x_GWC;

# WR mix: lower bound
subject to WR_lowerbound:
        x_WR >= 0.2 * x_GWC;

# Orange mix: lower bound
subject to orange_lowerbound:
        x_orange >= 0.2 * x_GWC;

# GC mix: upper bound
subject to GC_upperbound:
        x_GC + x_GC_prem <= 0.35 * x_GWC;

# LO mix: upper bound
subject to LO_upperbound:
        x_LO <= 0.35 * x_GWC;

# WR mix: upper bound
subject to WR_upperbound:
        x_WR <= 0.35 * x_GWC;

# Orange mix: upper bound
subject to orange_upperbound:
        x_orange <= 0.35 * x_GWC;

# bay mix: lower bound
subject to bay_lowerbound:
        x_bay + x_bay_prem >= 0.2 * x_LPH;

# storeline mix: lower bound
subject to store_lowerbound:
        x_store >= 0.2 * x_LPH;

# DE mix: lower bound
subject to DE_lowerbound:
        x_DE >= 0.2 * x_LPH;
```

```
# GP mix: lower bound
subject to GP_lowerbound:
        x_GP >= 0.2 * x_LPH;

# bay mix: upper bound
subject to bay_upperbound:
        x_bay + x_bay_prem <= 0.35 * x_LPH;

# storeline mix: upper bound
subject to store_upperbound:
        x_store <= 0.35 * x_LPH;

# DE mix: upper bound
subject to DE_upperbound:
        x_DE <= 0.35 * x_LPH;

# GP mix: upper bound
subject to GP_upperbound:
        x_GP <= 0.35 * x_LPH;

# CS mix: lower bound
subject to CS_lowerbound:
        x_CS >= 0.2 * x_CC;

# WW mix: lower bound
subject to WW_lowerbound:
        x_WW >= 0.2 * x_CC;

# PF mix: lower bound
subject to PF_lowerbound:
        x_PF >= 0.2 * x_CC;

# CS mix: upper bound
subject to CS_upperbound:
        x_CS <= 0.35 * x_CC;

# WW mix: upper bound
subject to WW_upperbound:
        x_WW <= 0.35 * x_CC;

# PF mix: upper bound
subject to PF_upperbound:
        x_PF <= 0.35 * x_CC;

# Appearance's sake: 70% or less single family home could be two story units
subject to appearance:
        x_trump + x_trump_lake + x_vand + x_vand_lake + x_GC + x_GC_prem + x_LO +
x_WR
```

```
        + x_bay + x_bay_prem + x_store <= (x_GE + x_GWC + x_LPH) * 0.7;

# affordable housing must be at least 15% of total
subject to affordable:
        x_GP + x_WW + x_PF >= x_total * 0.15;
```

Original Solution

```
: _objname    _obj      _varname        _var       :=
1    profit   122609   x_total         1764.19
2       .        .     x_GE            264.629
3       .        .     x_GWC           617.467
4       .        .     x_LPH           294.032
5       .        .     x_CC            588.063
6       .        .     x_trump         66.62
7       .        .     x_trump_lake    26
8       .        .     x_vand          58.1571
9       .        .     x_vand_lake     8
10      .        .     x_hughes        44.9257
11      .        .     x_hughes_lake   8
12      .        .     x_jack          44.9257
13      .        .     x_jack_lake     8
14      .        .     x_GC            216.113
15      .        .     x_GC_prem       0
16      .        .     x_LO            154.367
17      .        .     x_WR            123.493
18      .        .     x_orange        123.493
19      .        .     x_bay           102.911
20      .        .     x_bay_prem      0
21      .        .     x_store         67.6273
22      .        .     x_DE            64.687
23      .        .     x_GP            58.8063
24      .        .     x_CS            205.822
25      .        .     x_WW            205.822
26      .        .     x_PF            176.419
;
```

Original Sensitivity Report

: _objname _obj _varname _var _var.rc _var.down
:=
1 profit 122609 x_total 1764.19 0 -27.0341
2 . . x_GE 264.629 1.77636e-14 -283.928
3 . . x_GWC 617.467 -1.5099e-14 -15.7588
4 . . x_LPH 294.032 -7.99361e-15 -32.7828
5 . . x_CC 588.063 -3.55271e-15 -13.4567
6 . . x_trump 66.62 0 151.431
7 . . x_trump_lake 26 0 209.88
8 . . x_vand 58.1571 0 149
9 . . x_vand_lake 8 -1.32 -1e+20
10 . . x_hughes 44.9257 0 139.7
11 . . x_hughes_lake 8 -3.3 -1e+20
12 . . x_jack 44.9257 0 122.54
13 . . x_jack_lake 8 -7.26 -1e+20
14 . . x_GC 216.113 0 71.9898
15 . . x_GC_prem 0 -47.2747 -1e+20
16 . . x_LO 154.367 0 59.4129
17 . . x_WR 123.493 1.77636e-15 -21.1939
18 . . x_orange 123.493 1.77636e-15 -28.3939
19 . . x_bay 102.911 0 55.8276
20 . . x_bay_prem 0 -20.6321 -1e+20
21 . . x_store 67.6273 0 48
22 . . x_DE 64.687 0 47.4
23 . . x_GP 58.8063 -7.10543e-15 -123.914
24 . . x_CS 205.822 0 27.3554
25 . . x_WW 205.822 0 35
26 . . x_PF 176.419 0 -9.85582
;
$2 = _var.current
: _var.up $2 _conname _con _con.slack
:=
1 67.4313 0 total 5.21308 -1.13687e-13
2 88.4853 0 grand_estate 67.1456 -1.42109e-14
3 192.661 0 glen_wood -9.61272 0
4 11.5601 0 lakeview_patio 2.95312 0
5 202.294 0 condos 25.0196 -2.84217e-14
6 155.32 154 land 0.00917083 0
7 1e+20 211.2 lake 57.2 0
8 152.163 149.6 GC_premium 0 54.0283
9 206.8 205.48 bay_premium 0 25.7278
10 143.6 143 parking 0 94151.7
11 200.2 196.9 2b_lowerbound 0 176.419
12 141.756 129.8 2b_upperbound 33.4242 5.68434e-14
13 187 179.74 3b_lowerbound 0 197.001
14 851.358 75.6 3b_upperbound 0 67.6273

```
15    130.075    82.8    4b_lowerbound        0            151.426
16    71.9701    68.4    4b_upperbound        0            113.202
17    66.5489    57.6    5b_lowerbound        0            4.41048
18    60.5467    50.4    5b_upperbound        0            172.009
19    93.0289    60      GE_lowerbound        -59.3477     0
20    86.6321    66      GE_upperbound        0            352.838
21    54.6       54      GWC_lowerbound       0            352.838
22    54         48      GWC_upperbound       16.4548      0
23    67.8963    40      LPH_lowerbound       0            29.4032
24    632.983    55      LPH_upperbound       0            323.435
25    617.983    40      CC_lowerbound        0            323.435
26    40         35      CC_upperbound        0            29.4032
27    .          .       trump_lowerbound     0            39.6943
28    .          .       vand_lowerbound      0            13.2314
29    .          .       hughes_lowerbound    -0.6         0
30    .          .       jack_lowerbound      -11.9658     0
31    .          .       trump_upperbound     2.56583      0
32    .          .       vand_upperbound      0            26.4629
33    .          .       hughes_upperbound    0            39.6943
34    .          .       jack_upperbound      0            39.6943
35    .          .       GC_lowerbound        0            92.62
36    .          .       LO_lowerbound        0            30.8733
37    .          .       WR_lowerbound        -8.96583     0
38    .          .       orange_lowerbound    -10.1658     0
39    .          .       GC_upperbound        3.58669      0
40    .          .       LO_upperbound        0            61.7467
41    .          .       WR_upperbound        0            92.62
42    .          .       orange_upperbound    0            92.62
43    .          .       bay_lowerbound       0            44.1048
44    .          .       store_lowerbound     0            8.82095
45    .          .       DE_lowerbound        0            5.88063
46    .          .       GP_lowerbound        -39.59       0
47    .          .       bay_upperbound       4.16583      0
48    .          .       store_upperbound     0            35.2838
49    .          .       DE_upperbound        0            38.2241
50    .          .       GP_upperbound        0            44.1048
51    .          .       CS_lowerbound        0            88.2095
52    .          .       WW_lowerbound        0            88.2095
53    .          .       PF_lowerbound        0            58.8063
54    .          .       CS_upperbound        51.59        0
55    .          .       WW_upperbound        5            0
56    .          .       PF_upperbound        0            29.4032
57    .          .       appearance           6            -8.52651e-14
58    .          .       affordable           0            176.419
;
: _con.current    _con.down       _con.up       :=
1          0      -39.8737        20.5723
2          0       -8.68621        5.94208
```

3	0	-8.78681	5.89591
4	0	-37.6129	5.89537
5	0	-26.004	13.3492
6	13068000	3668410	15268100
7	50	32	116.62
8	0	-54.0283	1e+20
9	0	-25.7278	1e+20
10	653400	559248	1e+20
11	0	-1e+20	176.419
12	0	-26.155	13.3098
13	0	-1e+20	197.001
14	0	-67.6273	1e+20
15	0	-1e+20	151.426
16	0	-113.202	1e+20
17	0	-1e+20	4.41048
18	0	-172.009	1e+20
19	0	-12.8021	19.8532
20	0	-352.838	1e+20
21	0	-1e+20	352.838
22	0	-24.0158	20.3857
23	0	-1e+20	29.4032
24	0	-323.435	1e+20
25	0	-1e+20	323.435
26	0	-29.4032	1e+20
27	0	-1e+20	39.6943
28	0	-1e+20	13.2314
29	0	-8.82095	5.88063
30	0	-8.81976	5.88116
31	0	-4.41077	13.2287
32	0	-26.4629	1e+20
33	0	-39.6943	1e+20
34	0	-39.6943	1e+20
35	0	-1e+20	92.62
36	0	-1e+20	30.8733
37	0	-61.6884	30.8879
38	0	-8.81976	5.88116
39	0	-61.8618	30.8446
40	0	-61.7467	1e+20
41	0	-92.62	1e+20
42	0	-92.62	1e+20
43	0	-1e+20	44.1048
44	0	-1e+20	8.82095
45	0	-1e+20	5.88063
46	0	-13.3071	4.8015
47	0	-35.3029	8.81976
48	0	-35.2838	1e+20
49	0	-38.2241	1e+20
50	0	-44.1048	1e+20

```
51          0    -1e+20            88.2095
52          0    -1e+20            88.2095
53          0    -1e+20            58.8063
54          0      -26.1654         13.3071
55          0      -29.4032         58.8063
56          0      -29.4032       1e+20
57          0       -8.82095         5.88063
58          0    -1e+20           176.419
```

Modified Formulation

```
#parameter
param M = 999999999;

# decision variables
var x_total >= 0;
var x_GE >= 0;
var x_GWC >= 0;
var x_LPH >= 0;
var x_CC >= 0;
## GRAND ESTATES
var x_trump >= 0;
var x_trump_lake >= 0; # each of the Grand Estate series plans must have at least 8 units on the lake
var x_vand >= 0;
var x_vand_lake >= 0;
var x_hughes >= 0;
var x_hughes_lake >= 0;
var x_jack >= 0;
var x_jack_lake >= 0;
## GLEN WOOD COLLECTION
var x_GC >= 0;
var x_GC_prem >= 0;
var x_LO >= 0;
var x_WR >= 0;
var x_orange >= 0;
## LAKEVIEW PATIO HOMES
var x_bay >= 0;
var x_bay_prem >= 0;
var x_store >= 0;
var x_DE >= 0;
var x_GP >= 0;
## COUNTRY CONDOMINIUMS
var x_CS >= 0;
var x_WW >= 0;
var x_PF >= 0;

var y_GE binary; # GE sells more than CC = 1; 0 otherwise
```

```
var y_GWC binary;  # GWC sells more than CC = 1; 0 otherwise
var y_LPH binary;  # LPH sells more than CC = 1; 0 otherwise

var t_1 >= 0; # additional tax to be paid if CC sells more than GE
var t_2 >= 0; # additional tax to be paid if CC sells more than GWC
var t_3 >= 0; # additional tax to be paid if CC sells more than LPH
var CC_tax >= 0; # total tax amount for Country condo. Created to linearize the objective
function

var trump_lake_eight binary; # if trump has 8 units or more on the lake = 1; 0 otherwise
var vand_lake_eight binary; # if vanderbuilt has 8 units or more on the lake = 1; 0 otherwise
var hughes_lake_eight binary; # if hughes has 8 units or more on the lake = 1; 0 otherwise
var jackson_lake_eight binary; # if jackson has 8 units or more on the lake = 1; 0 otherwise

var recreation binary; # to build recreation complex or not
var a_1 >= 0; # additional $$$ from Grand Estate when recreation is built
var a_2 >= 0; # additional $$$ from Glen wood when recreation is built
var a_3 >= 0; # additional $$$ from LPH when recreation is built
var a_4 >= 0; # additional $$$ from CC when recreation is built
var rt_1 >= 0; # additional tax to be paid if CC sells more than GE and a recreational complex is
built
var rt_2 >= 0; # additional tax to be paid if CC sells more than GWC and a recreational complex
is built
var rt_3 >= 0; # additional tax to be paid if CC sells more than LPH and a recreational complex
is built


# objective
maximize profit:
        a_1 + (0.22-0.08) * (x_trump_lake * 960 + x_trump * 700 + x_vand_lake * 934 +
x_vand * 680
        + x_hughes_lake * 895 + x_hughes * 650 + x_jack_lake * 817 + x_jack * 590)
        + a_2 + (0.18-0.08) * (x_GC * 420 + x_GC_prem * 460 + x_LO * 380 + x_WR * 320 +
x_orange * 280)
        + a_3 + (0.2-0.08) * (x_bay * 300 + x_bay_prem * 330 + x_store * 270 + x_DE * 240 +
x_GP * 200)
        + a_4 + 0.25 * (x_CS * 220  + x_WW * 160 + x_PF * 140) - CC_tax - recreation * 8000;

# New constraints

# Comparing the sells of GE to CC, if GE Sells more, y_GE = 1, 0 otherwise
subject to rank_CC_GE_1:
        x_GE >= x_CC - M*(1-y_GE);

subject to rank_CC_GE_2:
        x_GE <= x_CC +M*y_GE;

# Comparing the sells of GWC to CC, if GE Sells more, y_GE = 1, 0 otherwise
```

```
subject to rank_CC_GWC_1:
        x_GWC >= x_CC - M*(1-y_GWC);

subject to rank_CC_GWC_2:
        x_GWC <= x_CC +M*y_GWC;

# Comparing the sells of LPH to CC, if GE Sells more, y_GE = 1, 0 otherwise
subject to rank_CC_LPH_1:
        x_LPH >= x_CC - M*(1-y_LPH);

subject to rank_CC_LPH_2:
        x_LPH <= x_CC +M*y_LPH;

# CCTAX is the total amount of tax paid from the CC product line. This constraint is used to
linearize cc_tax in objective function. Assuming 8% tax is taken, then if CC ranks higher in the
product line, t_1, t_2 or t_3 amount of tax will be returned.
subject to CCTAX:
        CC_tax = 0.08* (x_CS * 220  + x_WW * 160 + x_PF * 140) - t_1 - t_2 - t_3;

# If GE Sells more than CC, t_1 will be 2% of the total revenue of CC
subject to t1_1:
        t_1 <= (1 - y_GE) * M;

subject to t1_2:
        t_1 <= 0.02 * (x_CS * 220  + x_WW * 160 + x_PF * 140);

# If GWC Sells more than CC, t_2 will be 2% of the total revenue of CC
subject to t2_1:
        t_2 <= (1 - y_GWC) * M;

subject to t2_2:
        t_2 <= 0.02 * (x_CS * 220  + x_WW * 160 + x_PF * 140);

# If LPH Sells more than CC, t_3 will be 2% of the total revenue of CC
subject to t3_1:
        t_3 <= (1 - y_LPH) * M;

subject to t3_2:
        t_3 <= 0.02 * (x_CS * 220  + x_WW * 160 + x_PF * 140);

#At least three of the Grand Estate series plan must have at least eight units on the lake
subject to three_Grand_Estate:
trump_lake_eight + vand_lake_eight+ hughes_lake_eight+jackson_lake_eight >= 3;

#number of The Trump on the lake more than eight
subject to trump_eight_1:
x_trump_lake >= 8 - M*(1 - trump_lake_eight);
```

```
subject to trump_eight_2:
8 >= x_trump_lake - M*trump_lake_eight;

#number of The Vanderbilt on the lake more than eight
subject to vand_eight_1:
x_vand_lake >= 8 - M*(1 - vand_lake_eight);

subject to vand_eight_2:
8 >= x_vand_lake - M*vand_lake_eight;

#number of The Hughes on the lake more than eight
subject to hughes_eight_1:
x_hughes_lake >= 8 - M*(1 - hughes_lake_eight);

subject to hughes_eight_2:
8 >= x_hughes_lake - M*hughes_lake_eight;

#number of The Jackson on the lake more than eight
subject to jackson_eight_1:
x_jack_lake >= 8 - M*(1 - jackson_lake_eight);

subject to jackson_eight_2:
8 >= x_jack_lake - M*jackson_lake_eight;

# Additional profit if the recreational complex is built.
# linearize recreation * grand estates revenue
subject to a_11:
        a_1 <= recreation * M;

subject to a_12: # the 0.92 takes into account the 8% luxury tax
        a_1 <= 0.92 * 0.05 * (x_trump_lake * 960 + x_trump * 700 + x_vand_lake * 934 +
x_vand * 680
        + x_hughes_lake * 895 + x_hughes * 650 + x_jack_lake * 817 + x_jack * 590);

# linearize recreation * glen wood revenue
subject to a_21:
        a_2 <= recreation * M;

subject to a_22:
        a_2 <= 0.92 * 0.03 * (x_GC * 420 + x_GC_prem * 460 + x_LO * 380 + x_WR * 320 +
x_orange * 280);

# linearize recreation * lakeview revenue
subject to a_31:
        a_3 <= recreation * M;

subject to a_32:
```

```
        a_3 <= 0.92 * 0.02 * (x_bay * 300 + x_bay_prem * 330 + x_store * 270 + x_DE * 240 +
x_GP * 200);

# linearize recreation * country condominium revenue
subject to a_41:
        a_4 <= recreation * M;

subject to a_42: # the rt_1, rt_2, rt_3 applies the same logic as the t_1, t_2, t_3 luxury tax
section from above
        a_4 <= 0.92 * 0.03 * (x_CS * 220  + x_WW * 160 + x_PF * 140) + rt_1 + rt_2 + rt_3;

# If GE Sells more than CC, rt_1 will be 2% of the additional revenue of CC from the
recreational complex
subject to rt1_1:
        rt_1 <= (1 - y_GE) * M;

subject to rt1_2:
        rt_1 <= 0.02 * 0.03 * (x_CS * 220  + x_WW * 160 + x_PF * 140);

# If GWC Sells more than CC, rt_2 will be 2% of the additional revenue of CC from the
recreational complex
subject to rt2_1:
        rt_2 <= (1 - y_GWC) * M;

subject to rt2_2:
        rt_2 <= 0.02 * 0.03 * (x_CS * 220  + x_WW * 160 + x_PF * 140);

# If LPH Sells more than CC, rt_3 will be 2% of the additional revenue of CC from the
recreational complex
subject to rt3_1:
        rt_3 <= (1 - y_LPH) * M;

subject to rt3_2:
        rt_3 <= 0.02 * 0.03 * (x_CS * 220  + x_WW * 160 + x_PF * 140);



# Original Constraints
# total number of properties is the sum of all properties
subject to total:
        x_total = x_GE + x_GWC+ x_LPH + x_CC;

subject to grand_estate:
        x_GE = x_trump_lake + x_trump + x_vand_lake + x_vand + x_hughes_lake + x_hughes
        + x_jack_lake + x_jack;

subject to glen_wood:
        x_GWC = x_GC + x_GC_prem + x_LO + x_WR + x_orange;
```

```
subject to lakeview_patio:
        x_LPH = x_bay + x_bay_prem + x_store + x_DE + x_GP;

subject to condos:
        x_CC = x_CS  + x_WW + x_PF;

# available land to build properties on
subject to land:
        (x_trump_lake + x_trump) * 23180 + (x_vand_lake + x_vand + x_hughes_lake +
x_hughes) * 22980
        + (x_jack_lake + x_jack) * 22780 + x_GC * 6150 + x_GC_prem * 12090 + (x_LO +
x_bay) * 5756
        + (x_WR + x_orange + x_store + x_DE) * 5556 + x_bay_prem * 8660 + x_GP * 5356
        + x_CS * 3100 + (x_WW + x_PF) * 2900 <= (300 - 10*recreation) * 43560;

# 50 1/2 acres (units) on the lake is dedicated to Grand Estate
subject to lake:
        x_trump_lake + x_vand_lake + x_hughes_lake + x_jack_lake <= 50;

# no more than 25% of the total Grand Cypress models are premium
subject to GC_premium:
        x_GC_prem <= (x_GC + x_GC_prem) * 0.25;

# no more than 25% of the total Bayview models are premium
subject to bay_premium:
        x_bay_prem <= (x_bay + x_bay_prem) * 0.25;

# total parking space dedicated to this project
subject to parking:
        (x_trump_lake + x_trump + x_LO + x_bay + x_bay_prem + x_WW + x_PF) * 400 +
(x_vand_lake + x_vand
        + x_hughes_lake + x_hughes + x_GC + x_GC_prem + x_WR + x_orange + x_store +
x_DE) * 200
        + x_CS * 600 <= 15 * 43560;

# Grand Estate mix: lower bound
subject to GE_lowerbound:
        x_GE >= 0.15 * x_total;

# Grand Estate mix: upper bound
subject to GE_upperbound:
        x_GE <= 0.35 * x_total;

# Glen Wood mix: lower bound
subject to GWC_lowerbound:
        x_GWC >= 0.15 * x_total;
```

```
# Glen Wood mix: upper bound
subject to GWC_upperbound:
        x_GWC <= 0.35 * x_total;

# Lakeview Patio mix: lower bound
subject to LPH_lowerbound:
        x_LPH >= 0.15 * x_total;

# Lakeview Patio mix: upper bound
subject to LPH_upperbound:
        x_LPH <= 0.35 * x_total;

# Condos mix: lower bound
subject to CC_lowerbound:
        x_CC >= 0.15 * x_total;

# Condos mix: upper bound
subject to CC_upperbound:
        x_CC <= 0.35 * x_total;

# Trump mix: lower bound
subject to trump_lowerbound:
        x_trump + x_trump_lake >= 0.2 * x_GE;

# Vanderbilt mix: lower bound
subject to vand_lowerbound:
        x_vand + x_vand_lake >= 0.2 * x_GE;

# Hughes mix: lower bound
subject to hughes_lowerbound:
        x_hughes + x_hughes_lake >= 0.2 * x_GE;

# Jackson mix: lower bound
subject to jack_lowerbound:
        x_jack + x_jack_lake >= 0.2 * x_GE;

# Trump mix: upper bound
subject to trump_upperbound:
        x_trump + x_trump_lake <= 0.35 * x_GE;

# Vanderbilt mix: upper bound
subject to vand_upperbound:
        x_vand + x_vand_lake <= 0.35 * x_GE;

# Hughes mix: upper bound
subject to hughes_upperbound:
        x_hughes + x_hughes_lake <= 0.35 * x_GE;
```

```
# Jackson mix: upper bound
subject to jack_upperbound:
        x_jack + x_jack_lake <= 0.35 * x_GE;

# GC mix: lower bound
subject to GC_lowerbound:
        x_GC + x_GC_prem >= 0.2 * x_GWC;

# LO mix: lower bound
subject to LO_lowerbound:
        x_LO >= 0.2 * x_GWC;

# WR mix: lower bound
subject to WR_lowerbound:
        x_WR >= 0.2 * x_GWC;

# Orange mix: lower bound
subject to orange_lowerbound:
        x_orange >= 0.2 * x_GWC;

# GC mix: upper bound
subject to GC_upperbound:
        x_GC + x_GC_prem <= 0.35 * x_GWC;

# LO mix: upper bound
subject to LO_upperbound:
        x_LO <= 0.35 * x_GWC;

# WR mix: upper bound
subject to WR_upperbound:
        x_WR <= 0.35 * x_GWC;

# Orange mix: upper bound
subject to orange_upperbound:
        x_orange <= 0.35 * x_GWC;

# bay mix: lower bound
subject to bay_lowerbound:
        x_bay + x_bay_prem >= 0.2 * x_LPH;

# storeline mix: lower bound
subject to store_lowerbound:
        x_store >= 0.2 * x_LPH;

# DE mix: lower bound
subject to DE_lowerbound:
        x_DE >= 0.2 * x_LPH;
```

```
# GP mix: lower bound
subject to GP_lowerbound:
        x_GP >= 0.2 * x_LPH;

# bay mix: upper bound
subject to bay_upperbound:
        x_bay + x_bay_prem <= 0.35 * x_LPH;

# storeline mix: upper bound
subject to store_upperbound:
        x_store <= 0.35 * x_LPH;

# DE mix: upper bound
subject to DE_upperbound:
        x_DE <= 0.35 * x_LPH;

# GP mix: upper bound
subject to GP_upperbound:
        x_GP <= 0.35 * x_LPH;

# CS mix: lower bound
subject to CS_lowerbound:
        x_CS >= 0.2 * x_CC;

# WW mix: lower bound
subject to WW_lowerbound:
        x_WW >= 0.2 * x_CC;

# PF mix: lower bound
subject to PF_lowerbound:
        x_PF >= 0.2 * x_CC;

# CS mix: upper bound
subject to CS_upperbound:
        x_CS <= 0.35 * x_CC;

# WW mix: upper bound
subject to WW_upperbound:
        x_WW <= 0.35 * x_CC;

# PF mix: upper bound
subject to PF_upperbound:
        x_PF <= 0.35 * x_CC;
# Appearance's sake
subject to appearance:
        x_trump + x_trump_lake + x_vand + x_vand_lake + x_GC + x_GC_prem + x_LO +
x_WR
        + x_bay + x_bay_prem + x_store <= (x_GE + x_GWC + x_LPH) * 0.7;
```

Modified Solution

:	_objname	_obj	_varname	_var	:=
1	profit	90350.9	x_total	1715.48	
2	.	.	x_GE	257.322	
3	.	.	x_GWC	600.418	
4	.	.	x_LPH	257.322	
5	.	.	x_CC	600.418	
6	.	.	x_trump	56.0628	
7	.	.	x_trump_lake	34	
8	.	.	x_vand	56.3305	
9	.	.	x_vand_lake	8	
10	.	.	x_hughes	43.4644	
11	.	.	x_hughes_lake	8	
12	.	.	x_jack	51.4644	
13	.	.	x_jack_lake	0	
14	.	.	x_GC	210.146	
15	.	.	x_GC_prem	0	
16	.	.	x_LO	150.105	
17	.	.	x_WR	120.084	
18	.	.	x_orange	120.084	
19	.	.	x_bay	90.0628	
20	.	.	x_bay_prem	0	
21	.	.	x_store	55.7531	
22	.	.	x_DE	60.0418	
23	.	.	x_GP	51.4644	
24	.	.	x_CS	210.146	
25	.	.	x_WW	210.146	
26	.	.	x_PF	180.126	
27	.	.	y_GE	0	
28	.	.	y_GWC	0	
29	.	.	y_LPH	0	
30	.	.	t_1	2101.46	
31	.	.	t_2	2101.46	
32	.	.	t_3	2101.46	
33	.	.	CC_tax	2101.46	
34	.	.	trump_lake_eight	1	
35	.	.	vand_lake_eight	1	
36	.	.	hughes_lake_eight	1	
37	.	.	jackson_lake_eight	0	
38	.	.	recreation	1	
39	.	.	a_1	8438.08	
40	.	.	a_2	5998.9	
41	.	.	a_3	1228.66	
42	.	.	a_4	3089.15	
43	.	.	rt_1	63.0439	
44	.	.	rt_2	63.0439	
45	.	.	rt_3	63.0439	