

HW 3 – Business Analytics (6 pts maximum).

This page provides guidelines for this homework assignment. Questions start from the next page.

To solve part b) and d) of the problem you will need to do the following:

- a. Use the Generalized Analytics Procedure (GAP) to set up your problem as follows:
 - i. Define your model in words
 1. Identify the objective function in words
 2. Identify the random variables in words (none in this HW)
 3. Identify the decision variables in words
 4. Identify the constraints in words
 - ii. Formulate your model mathematically
 1. Define the random variables (none in this HW)
 2. Define the decision variables
 3. Define the objective function in terms of decision variables
 4. Define the constraints in terms of the decision variables. Please include any non-negativity constraints in your formulation
- b. Set up the problem in Excel and use Solver to find the optimal values of the decision variables. Ask Solver to create an Answer Report and, if necessary, a Sensitivity Report.
- c. Answer the questions stated in the problem (in words).

Please submit only one file in PDF format with your write-up. Do not submit your Excel file. Your writeup must include the answer report and the sensitivity report generated by Excel Solver, whenever needed. If you make any additional assumptions, state them clearly.

Joe's Lawn Sign Co

Your entrepreneurial uncle Joe is running a lawn sign business. Joe manufactures the following three types of lawn signs:

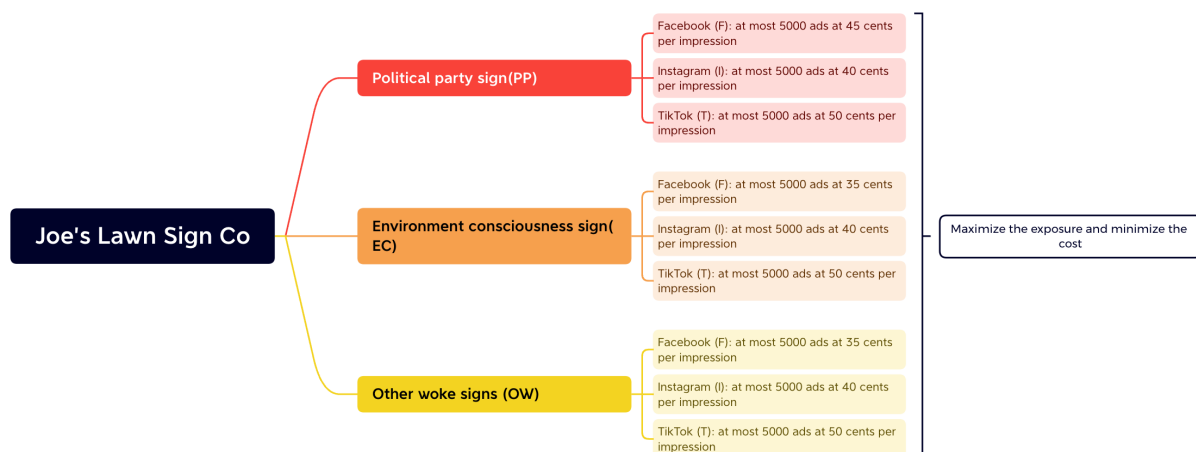
- Political Party signs (PP)
- Environmental Consciousness signs (EC)
- Other Woke signs (OW)

To help Joe sell his products, you decided to develop a new online ad placement strategy. Currently, the following channels offer to host ads at the following base price:

- Facebook (F): at most 5000 ads at 35 cents per impression
- Instagram (I): at most 5000 ads at 40 cents per impression
- TikTok (T): at most 5000 ads at 50 cents per impression

Additionally, Facebook has a surcharge of 10 cents per impression for political ads, which would apply to PP but not to EC or OW.

- a) Draw a network diagram to represent the problem. You can either draw the diagram by hand and take a picture of your drawing, or use Word/PPT.



- b) If Joe has a budget of \$5K for this fall's advertising campaign, how should he allocate ads to channels to generate the greatest number of impressions?
- Define your model in words
 - Identify the objective function in words

Joe needs to maximize the impression to increase sales while minimize the advertisement costs.

2. Identify the random variables in words (none in this HW)

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3. Identify the decision variables in words

The decision variables are the number of each products' each platforms advertisement.

4. Identify the constraints in words

Joe has a budget of \$5K for the campaign. And each platform has a maximize requirements for 5000 ads.

- ii. Formulate your model mathematically

1. Define the random variables (none in this HW)

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2. Define the decision variables

Let X_{ij} be the number of each products on the platform (here i denotes the products type, while j denotes the platform)

So X_{PPF} X_{PPI} X_{PPT} , X_{ECF} X_{ECI} X_{ECT} , X_{OWF} X_{OWI} X_{OWT} be the variables.

3. Define the objective function in terms of decision variables

Let Y to be the total impression of the campaign, then we have:

$$Y = X_{PPF} + X_{PPI} + X_{PPT} + X_{ECF} + X_{ECI} + X_{ECT} + X_{OWF} + X_{OWI} + X_{OWT}$$

4. Define the constraints in terms of the decision variables. Please include any non-negativity constraints in your formulation

$$0.45X_{PPF} + 0.4X_{PPI} + 0.5X_{PPT} + 0.35X_{ECF} + 0.4X_{ECI} + 0.5X_{ECT} + 0.35X_{OWF} + 0.4X_{OWI} + 0.5X_{OWT} \leq 5000$$

$$X_{PPF} + X_{ECF} + X_{OWF} \leq 5000$$

$$X_{PPI} + X_{ECI} + X_{OWI} \leq 5000$$

$$X_{PPT} + X_{ECT} + X_{OWT} \leq 5000$$

All variables should be integer.

Objective Cell (Max)

Cell	Name	Original Value	Final Value
\$B\$10	Total Net Present Value XPPF	12500	12500

Variable Cells

Cell	Name	Original Value	Final Value	Integer
\$B\$3	XPPF	0	0	Integer
\$C\$3	XPPI	5000	5000	Integer
\$D\$3	XPPT	2500	2500	Integer
\$E\$3	XECF	5000	5000	Integer
\$F\$3	XECI	0	0	Integer
\$G\$3	XECT	0	0	Integer
\$H\$3	XOWF	0	0	Integer
\$I\$3	XOWI	0	0	Integer
\$J\$3	XOWT	0	0	Integer

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
\$K\$15	Maximum Budget Left Hand	5000	\$K\$15<=\$M\$15	Binding	0
\$K\$16	Maximum Ads Left Hand	5000	\$K\$16<=\$M\$16	Binding	0
\$K\$17	Left Hand	5000	\$K\$17<=\$M\$17	Binding	0
\$K\$18	Left Hand	2500	\$K\$18<=\$M\$18	Not Binding	2500
\$B\$3:\$J\$3=Integer					

Decision Variables												
	XPPF	XPPI	XPPT	XECF	XECI	XECT	XOWF	XOWI	XOWT			
Objective Coefficients												
Net Present Value												
Objective Value												
Total Net Present Value												
Constraints												
Constraint Name												
Maximum Budget	\$0.45	\$0.40	\$0.50	\$0.35	\$0.40	\$0.50	\$0.35	\$0.40	\$0.50	Left Hand	Operator	Right Hand
Maximum Ads	1	1	1	1	1	1	1	1	1	5000	<=	5000
										5000	<=	5000
										2500	<=	5000

So he should allocate 5000 FB, 2500 Instagram, and 5000 Tiktok advertisements to the PP products to get a 12500 impressions.

- c) If Joe decides to advertise on TikTok, he will need to hire someone to produce ads (since TikTok ads run in video format). Your friend Silvia offered to help with the production of ads for TikTok for a fee of 20 cents per impression. You can assume that ads for other channels can be produced at no cost. How would this change your solution from b)?

Since we add a cost that ads for TikTok for a fee of 20 cents per impression, the model will stay the same, while the constraints will be as followed.

$$0.45X_{PPF} + 0.4X_{PPI} + 0.7X_{PPT} + 0.35X_{ECF} + 0.4X_{ECI} + 0.7X_{ECT} + 0.35X_{OWF} + 0.4X_{OWI} + 0.7X_{OWT} \leq 5000$$

$$X_{PPF} + X_{ECF} + X_{OWF} \leq 5000$$

$$X_{PPI} + X_{ECI} + X_{OWI} \leq 5000$$

$$X_{PPT} + X_{ECT} + X_{OWT} \leq 5000$$

All variables should be integer.

Objective Cell (Max)

Cell	Name	Original Value	Final Value
\$B\$10	Total Net Present Value XPPF	11785	11785

Variable Cells

Cell	Name	Original Value	Final Value	Integer
\$B\$3	XPPF	0	0	Integer
\$C\$3	XPPI	5000	5000	Integer
\$D\$3	XPPT	1785	1785	Integer
\$E\$3	XECF	5000	5000	Integer
\$F\$3	XECI	0	0	Integer
\$G\$3	XECT	0	0	Integer
\$H\$3	XOWF	0	0	Integer
\$I\$3	XOWI	0	0	Integer
\$J\$3	XOWT	0	0	Integer

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
\$K\$15	Maximum Budget Left Hand	5000	\$K\$15<=\$M\$15	Not Binding	0.5
\$K\$16	Maximum Ads Left Hand	5000	\$K\$16<=\$M\$16	Binding	0
\$K\$17	Left Hand	5000	\$K\$17<=\$M\$17	Binding	0
\$K\$18	Left Hand	1785	\$K\$18<=\$M\$18	Not Binding	3215
\$B\$3:\$J\$3=Integer					

Decision Variables	XPPF	XPPI	XPPT	XECF	XECI	XECT	XOWF	XOWI	XOWT								
Objective Function																	
Subject to Constraints																	
Maximum Budget	0.45	0.4	0.7	0.35	0.4	0.7	0.35	0.4	0.7								
Maximum Ads	1	1	1	1	1	1	1	1	1								
Integer	1	1	1	1	1	1	1	1	1								

Decision Variables												
	XPPF	XPPI	XPPT	XECF	XECI	XECT	XOWF	XOWI	XOWT			
	0	5000	1785	5000	0	0	0	0	0			
Objective Coefficients												
Net Present Value:	XPPF	XPPI	XPPT	XECF	XECI	XECT	XOWF	XOWI	XOWT			
	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00			
Objective Value												
Total Net Present Value	11785											
Constraints												
Constraint Name	Coefficients									Conditions		
	XPPF	XPPI	XPPT	XECF	XECI	XECT	XOWF	XOWI	XOWT	Left Hand	Operator	Right Hand
Maximum Budget	\$0.45	\$0.40	\$0.70	\$0.35	\$0.40	\$0.70	\$0.35	\$0.40	\$0.70	5000	<=	5000
Maximum Ads	1			1			1			5000	<=	5000
		1			1			1		5000	<=	5000
			1			1			1	1785	<=	5000

It will change the Tiktok advertisements(impressions) from 12500 to 11785.

- d) Suppose now that Joe wants to have at least 6000 ads for PP, 6000 ads for EC, and 2000 ads for OW across all three channels (F, I, and T). In addition to the same variable cost structure in part c), there is a one-time fixed cost of using the three channels. The fixed costs of using F, I, and T are \$80, \$1000, and \$60, respectively. The capacities of the three channels remain the same as in the base setting. If Joe does not have a budget upfront, how should Joe allocate ads to channels to minimize the total fixed and variable costs while meeting the minimum requirement on the number of ads? (Please note that this requires a new formulation following the GAP.)

1. Identify the objective function in words

Joe needs to maximize the impression to increase sales while minimize the advertisement variable and fixed costs.

2. Identify the random variables in words (none in this HW)

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3. Identify the decision variables in words

The decision variables are the number of each products' each platforms advertisement.

4. Identify the constraints in words

At least 6000 ads for PP, 6000 ads for EC, and 2000 ads for OW across all three channels (F, I, and T).

- iii. Formulate your model mathematically

1. Define the random variables (none in this HW)

-

2. Define the decision variables

Let X_{ij} be the number of each products on the platform(here i denotes the products type, while j denotes the platform)

So X_{PPF} X_{PPI} X_{PPT} , X_{ECF} X_{ECI} X_{ECT} , X_{OWF} X_{OWI} X_{OWT} be the variables.

3. Define the objective function in terms of decision variables

Let Y to be the total cost of the campaign, then we have:

$$Y = 0.45X_{PPF} + 0.4X_{PPI} + 0.7X_{PPT} + 0.35X_{ECF} + 0.4X_{ECI} + 0.7X_{ECT} + 0.35X_{OWF} + 0.4X_{OWI} + 0.7X_{OWT} + 80 + 1000 + 60$$

4. Define the constraints in terms of the decision variables. Please include any non-negativity constraints in your formulation

$$X_{PPF} + X_{PPI} + X_{PPT} \geq 6000$$

$$X_{ECF} + X_{ECI} + X_{ECT} \geq 6000$$

$$X_{OWF} + X_{OWI} + X_{OWT} \geq 2000$$

$$X_{PPF} + X_{ECF} + X_{OWF} \leq 5000$$

$$X_{PPI} + X_{ECI} + X_{OWI} \leq 5000$$

$X_{PPT} + X_{ECT} + X_{OWT} \leq 5000$

All variables should be integer.

Decision Variables																			
	XPPF	XPPI	XPPT	XECF	XECI	XECT	XOWF	XOWI	XOWT										
	0	2000	4000	3000	3000	0	2000	0	0										
Objective Coefficients																			
Net Present Values:	XPPF	XPPI	XPPT	XECF	XECI	XECT	XOWF	XOWI	XOWT										
	\$0.45	0.4	0.7	0.35	0.4	0.7	0.35	0.4	0.7										
Objective Value																			
Total Net Present Value																			
Constraints																			
Constraint Name																			
	XPPF	XPPI	XPPT	XECF	XECI	XECT	XOWF	XOWI	XOWT	Left Hand	Operator	Right Hand							
MINIMUM Ads	1	1	1	1	1	1	1	1	1	-SUMPRODUCT(\$B\$3:\$B3,\$B1:\$B15)	>=	6000							
										-SUMPRODUCT(\$B\$3:\$B3,\$B16:\$B16)	>=	6000							
										-SUMPRODUCT(\$B\$3:\$B3,\$B17:\$B17)	>=	2000							
										-SUMPRODUCT(\$B\$3:\$B3,\$B18:\$B18)	>=	5000							
MAXIMUM Ads	1			1			1			-SUMPRODUCT(\$B\$3:\$B3,\$B19:\$B19)	<=	5000							
		1			1			1		-SUMPRODUCT(\$B\$3:\$B3,\$B20:\$B20)	<=	5000							

Decision Variables																			
	XPPF	XPPI	XPPT	XECF	XECI	XECT	XOWF	XOWI	XOWT										
	0	2000	4000	3000	3000	0	2000	0	0										
Objective Coefficients																			
Net Present Values:	XPPF	XPPI	XPPT	XECF	XECI	XECT	XOWF	XOWI	XOWT										
	\$0.45	\$0.40	\$0.70	\$0.35	\$0.40	\$0.70	\$0.35	\$0.40	\$0.70										
Objective Value																			
Total Net Present Value	7,690.00																		
Constraints																			
Constraint Name																			
	XPPF	XPPI	XPPT	XECF	XECI	XECT	XOWF	XOWI	XOWT	Left Hand	Operator	Right Hand							
MINIMUM Ads	1	1	1							6000	>=	6000							
				1	1	1				6000	>=	6000							
							1	1	1	2000	>=	2000							
MAXIMUM Ads	1			1			1			5000	<=	5000							
		1			1			1		5000	<=	5000							
			1			1			1	4000	<=	5000							

Objective Cell (Min)

Cell	Name	Original Value	Final Value
\$B\$10	Total Net Present Value XPPF	7,690.00	7,690.00

Variable Cells

Cell	Name	Original Value	Final Value	Integer
\$B\$3	XPPF	0	0	Integer
\$C\$3	XPPI	2000	2000	Integer
\$D\$3	XPPT	4000	4000	Integer
\$E\$3	XECF	3000	3000	Integer
\$F\$3	XECI	3000	3000	Integer
\$G\$3	XECT	0	0	Integer
\$H\$3	XOWF	2000	2000	Integer
\$I\$3	XOWI	0	0	Integer
\$J\$3	XOWT	0	0	Integer

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
\$K\$15	MINIMUM Ads Left Hand	6000	\$K\$15>=\$M\$15	Binding	0
\$K\$16	Left Hand	6000	\$K\$16>=\$M\$16	Binding	0
\$K\$17	Left Hand	2000	\$K\$17>=\$M\$17	Binding	0
\$K\$18	MAXIMUM Ads Left Hand	5000	\$K\$18<=\$M\$18	Binding	0
\$K\$19	Left Hand	5000	\$K\$19<=\$M\$19	Binding	0
\$K\$20	Left Hand	4000	\$K\$20<=\$M\$20	Not Binding	1000
\$B\$3:\$J\$3=Integer					

Joe should allocate 2000 Instagram, 4000 Tiktok advertisements for PP, and 3000 Facebook and 3000 Instagram advertisements for EC, and 2000 Facebook advertisements for OW and spend \$7,690.