

Homework 1 Advanced Analytics and Metaheuristics

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1. To examine this story, we create a table:

Baby Yoda Tells Truth	gurump = yes	pvlork = yes	Possible
T	T	T	N
T	T	F	N
T	F	T	N
T	F	F	N
F	T	T	N
F	T	F	Y
F	F	T	Y
F	F	F	N

I will assume that a sinister lying creature always lies (even though we know this too not be true eg. politicians).

Let's examine each with our information. We were told that the words meant yes or no so we assume that they cannot both mean the same thing. This eliminates half of our truth table. Next, we see that if Jedi would tell the truth, the statement cannot be. You would not answer yes to a wrong question. Similarly you cannot have the third entry either as you will tell the truth. We move on to sith liars. If gurump means No and asked if it means yes, a liar would reply in the affirmative. This means the logic on the sixth one is possible. We see the seventh is also possible. Since gurump is yes and the creature lies, we would answer no or pvlork. Thus we see that Baby Yoda is a liar. We cannot however determine the meaning of gurump and pvlork.

2. I am going to state the problem here

A portfolio manager in charge of a bank portfolio has \$10 million to invest. The securities available for purchase, as well as their respective quality ratings, maturities, and yields, are shown in Table

Name	Type	QS Moody's	QS Banks	Years to M	Yield to m	After-tax yield
A	Municipal	Aa	2	9	4.3%	4.3%
B	Agency	Aa	2	15	5.4	2.7
C	Government	Aaa	1	4	5.0	2.5
D	Government	Aaa	1	3	4.4	2.2
E	Municipal	Ba	5	2	4.5	4.5

The bank places the following policy limitations on the portfolio manager's actions:

- (a) Government and agency bonds must total at least \$4 million.
- (b) The average quality of the portfolio cannot exceed 1.4 on the bank's quality scale. (Note that a low number on this scale means a high-quality bond.)
- (c) The average years to maturity of the portfolio must not exceed 5 years.
- (a) Assuming that the objective of the portfolio manager is to maximize after-tax earnings and that the tax rate is 50 percent, what bonds should he purchase?
- (b) If it became possible to borrow up to \$1 million at 5.5 percent before taxes, how should his selection be changed?
- (a) We'll start by stating the objective function, the return on investment after taxes:

$$P(\vec{x}) = 0.043x_A + 0.027x_B + 0.025x_C + 0.022x_D + 0.045x_E$$

This is the function that we wish to maximize.

Next we examine each of the constraints. There is a total of 10 million to invest

$$\sum x_i \leq 10000000$$

We need a total of at least 4 million in government and agency bonds so

$$x_B + x_C + x_D \geq 4000000$$

Then we want the average on the banks quality scale to not exceed 1.4 so

$$\frac{2x_A + 2x_B + x_C + x_D + 5x_E}{\sum x_i} \leq 1.4$$

We need to make this linear for AMPL (I learned after only a few minutes of face to keyboard)

$$2x_A + 2x_B + x_C + x_D + 5x_E - 1.4 \sum x_i \leq 0$$

Which can be simplified to (but was not required in AMPL)

$$0.6x_A + 0.6x_B - 0.4x_C - 0.4x_D + 3.6x_E \leq 0$$

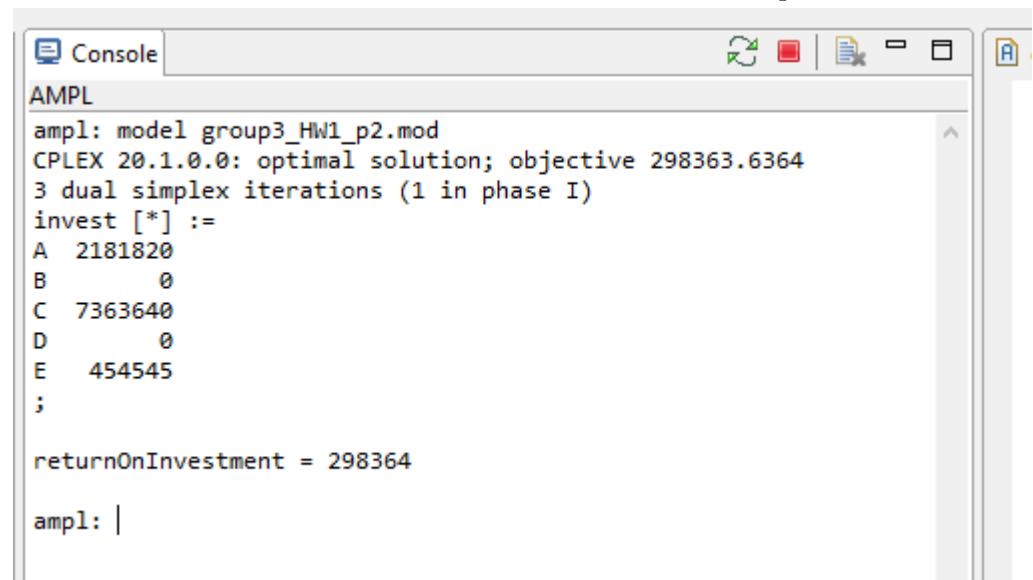
Lastly we wanted the average years to maturity to be less than 5 so

$$\frac{9x_A + 15x_B + 4x_C + 3x_D + 2x_E}{\sum x_i} \leq 5$$

This simplifies to

$$4x_A + 10x_B - x_C - 2x_D - 3x_E \leq 0$$

With all of this we code it into AMPL and arrive at the output:



```

Console
AMPL
ampl: model group3_HW1_p2.mod
CPLEX 20.1.0.0: optimal solution; objective 298363.6364
3 dual simplex iterations (1 in phase I)
invest [*] :=
A 2181820
B 0
C 7363640
D 0
E 454545
;
returnOnInvestment = 298364
ampl: |

```

- (b) For the second part of the problem, we add the additional condition that we can take out a loan of up to 1 million at 5.5%. This will change our objective function in significant ways and add an extra variable x_{loan} . We examine the new objective, we will use the before tax rates and recognize that Municipal bonds grow tax

free. We also note that our total interest is subtracted from our tax liability

$$\begin{aligned}
 z &= \text{interestEarned} - \text{interestPaid} - \text{taxesPaid} \\
 &= \sum_i \text{BeforeTaxRates}_i x_i - 0.055x_{\text{loan}} - 0.5(\text{taxableIncome}) \\
 &= 0.043x_A + 0.054x_B + 0.05x_C + 0.044x_D + 0.045x_E - 0.055x_{\text{loan}} \\
 &\quad - 0.5(0.054x_B + 0.05x_C + 0.044x_D - 0.055x_{\text{loan}})
 \end{aligned}$$

The total amount invested must also change

$$\sum x_i \leq 10000000 + x_{\text{loan}}$$

Of course there are the restrictions on the loan too

$$0 \leq x_{\text{loan}} \leq 1000000$$

The rest of the constraints remain unchanged. Running it through AMPL arrives at the solution:

```

Console
AMPL
ampl: model group3_HW1_p2.1.mod
CPLEX 20.1.0.0: optimal solution; objective 300700
5 dual simplex iterations (3 in phase I)
invest [*] :=
A 2400000
B 0
C 8100000
D 0
E 5e+05
;
borrowedFunds = 1e+06
ampl: |

```

3. I am going to state the problem here:

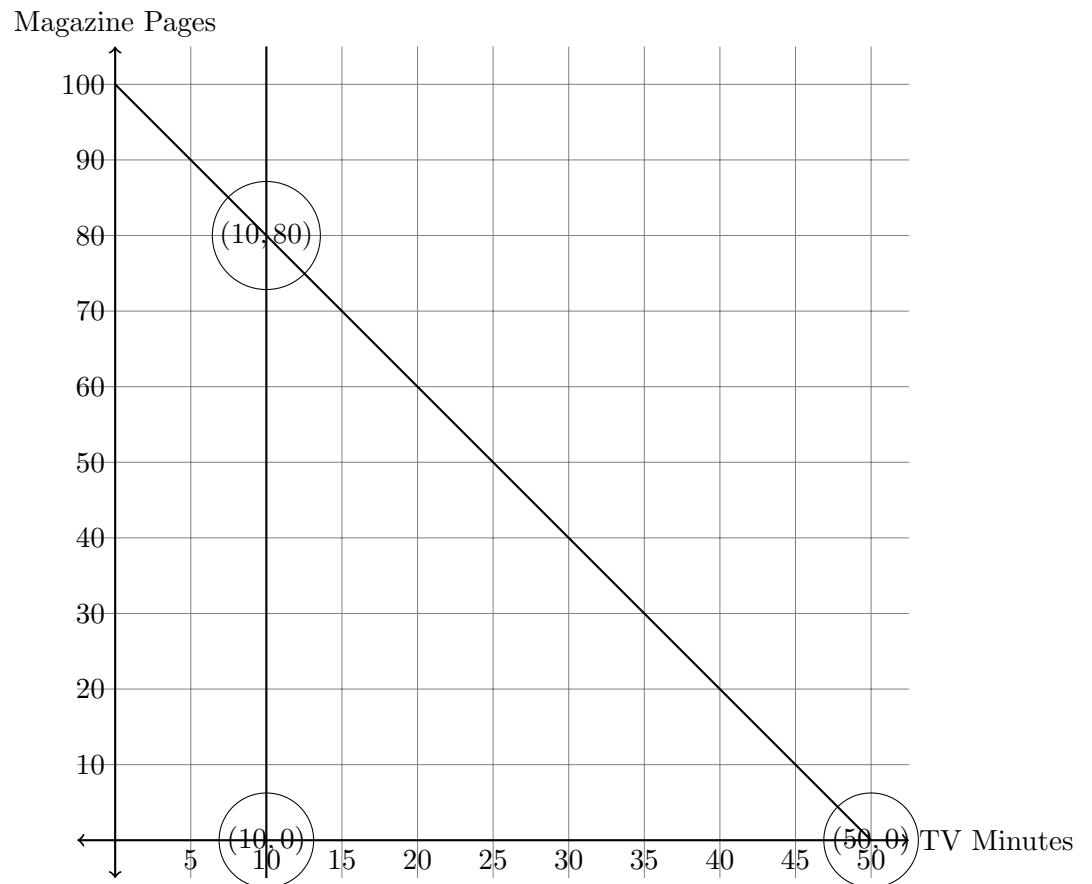
This exercise starts with a two-variable linear program similar in structure to the one of Sections 1.1 and 1.2, but with a quite different story behind it.

- (a) You are in charge of an advertising campaign for a new product, with a budget of \$1 million. You can advertise on TV or in magazines. One minute of TV time costs \$20,000 and reaches 1.8 million potential customers; a magazine page costs \$10,000 and reaches 1 million. You must sign up for at least 10 minutes of TV time. How should you spend your budget to maximize your audience? Formulate the problem in AMPL and solve it. Check the solution by hand using at least one of the approaches described in Section 1.1.
 - (b) It takes creative talent to create effective advertising; in your organization, it takes three person-weeks to create a magazine page, and one person-week to create a TV minute. You have only 100 person-weeks available. Add this constraint to the model and determine how you should now spend your budget.
 - (c) Radio advertising reaches a quarter million people per minute, costs \$2,000 per minute, and requires only 1 person-day of time. How does this medium affect your solutions?
 - (d) How does the solution change if you have to sign up for at least two magazine pages? A maximum of 120 minutes of radio?
- (a) We begin by stating the objective function to maximize, eyeballs:

$$z = 1.8x + 1y$$

Where x is minutes of TV time, y is pages in a magazine and z is million viewers. Next we set the two constraints, at least 10 minutes of TV and no more than \$1 million spent.

$$\begin{aligned} x &\geq 10 \\ 20000x + 10000y &\leq 1000000 \end{aligned}$$



We see the corner points of the feasible set as possible solutions.

We are left to find the maximum:

Point	z	Optimizer
$(10, 80)$	$18 + 80 = 98$	Max
$(10, 0)$	$18 + 0 = 18$	Min
$(50, 0)$	$90 + 0 = 90$	

We repeat the same system

in AMPL and arrive at the same solution

```
Console
AMPL
ampl: model group3_HW1_p3.mod
CPLEX 20.1.0.0: optimal solution; objective 98
0 dual simplex iterations (0 in phase I)
time [*] :=
  TV 10
  mag 80
;

totalFunds = 0.0001

eyeBalls = 98

ampl: |
```

- (b) For this part, we repeat the exercise adding the additional requirement of creative time

$$1x + 3y \leq 100$$

We see this changes our maximum, to 92 million people.

```
Console
AMPL
ampl: model group3_HW1_p3b.mod
CPLEX 20.1.0.0: optimal solution; objective 92
2 dual simplex iterations (1 in phase I)
time [*] :=
  TV 40
  mag 20
;

eyeBalls = 92

ampl:
```

- (c) For the next question we add radio into the advertising mix. This will add a new variable and change all the constraints and objective. We also note that the 2D graphical method will no

longer be available to us to check our solution.

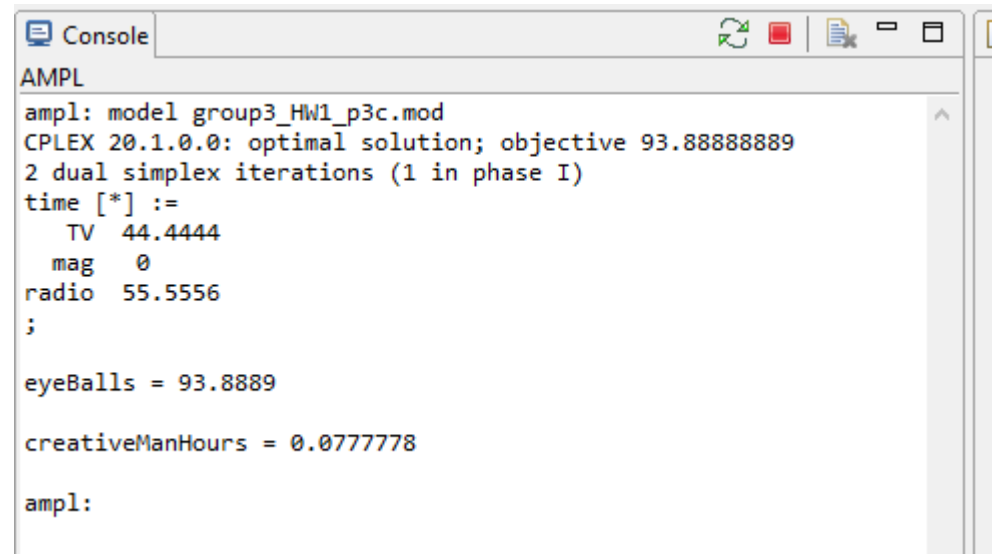
$$z = 1.8x_{TV} + 1x_{magazine} + 0.25x_{radio}$$

$$x_{TV} \geq 10$$

$$20000x_{TV} + 10000x_{magazine} + 2000x_{radio} \leq 1000000$$

$$1x_{TV} + 3x_{magazine} + 1x_{radio} \leq 100$$

We change notation here too, applying subscripts to be more descriptive of our vector x .



```
Console
AMPL
ampl: model group3_HW1_p3c.mod
CPLEX 20.1.0.0: optimal solution; objective 93.88888889
2 dual simplex iterations (1 in phase I)
time [*] :=
TV 44.4444
mag 0
radio 55.5556
;
eyeBalls = 93.8889
creativeManHours = 0.0777778
ampl:
```

We should take a moment to examine this solution. It slightly increases our total number of customers 93.89 million but includes no magazine advertizing. It also requires fractional time in TV and radio. While these are possible it is not known to the authors if this is available in the Ad world.

- (d) To add the condition of at least two pages of magazine, we add the condition

$$x_{magazine} \geq 2$$


```
AMPL
ampl: model group3_HW1_p3d.mod
CPLEX 20.1.0.0: optimal solution; objective 93.7
2 dual simplex iterations (1 in phase I)
time [*] :=
    TV  44
    mag  2
    radio 50
;

totalFunds = 8.61111e-05

creativeManHours = 0.0777778

ampl: |
```

We can add the requirement of no more than 120 minutes of radio but that will not change the results. We include that constraint for completeness and rerun similar code to above.

$$x_{radio} \leq 120$$

```
Console
AMPL
ampl: model group3_HW1_p3d.mod
CPLEX 20.1.0.0: optimal solution; objective 93.7
3 dual simplex iterations (2 in phase I)
time [*] :=
    TV  44
    mag  2
    radio 50
;

totalFunds = 8.61111e-05

creativeManHours = 0.0777778

ampl: |
```

We should not that viewership numbers are high with this model and there are no fractional pages or minutes required to achieve this solution

4. We'll repeat the question here

The steel model of this chapter can be further modified to reflect various changes in production requirements. For each part below, explain the modifications to Figures 1-6a and 1-6b that would be required to achieve the desired changes. (Make each change separately, rather than accumulating the changes from one part to the next.)

- (a) How would you change the constraints so that total hours used by all products must equal the total hours available for each stage? Solve the linear program with this change, and verify that you get the same results. Explain why, in this case, there is no difference in the solution.
- (b) How would you add to the model to restrict the total weight of all products to be less than a new parameter, `max_weight`? Solve the linear program for a weight limit of 6500 tons, and explain how this extra restriction changes the results.
- (c) The incentive system for mill managers may tend to encourage them to produce as many tons as possible. How would you change the objective function to maximize total tons? For the data of our example, does this make a difference to the optimal solution?
- (d) Suppose that instead of the lower bounds represented by `commit[p]` in our model, we want to require that each product represent a certain share of the total tons produced. In the algebraic notation of Figure 1-1, this new constraint might be represented as

$$X_j \geq s_j \sum_{k \in P} X_k, \forall j \in P$$

where s_j is the minimum share associated with project j . How would you change the AMPL model to use this constraint in place of the lower bounds `commit[p]`? If the minimum shares are 0.4 for bands and plate, and 0.1 for coils, what is the solution? Verify that if you change the minimum shares to 0.5 for bands and plate, and 0.1 for coils, the linear program gives an optimal

solution that produces nothing, at zero profit. Explain why this makes sense.

- (e) Suppose there is an additional finishing stage for plates only, with a capacity of 20 hours and a rate of 150 tons per hour. Explain how you could modify the data, without changing the model, to incorporate this new stage.