An Integer Programming Application: Meal Plans using Fast Food Chains

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Agenda

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I. Introduction & Problem Statement

II. Business Model and Data

III. Mathematical Model

IV. Implementation

V. Conclusion and Discussion

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Introduction & Problem Statement

Goal:

- Optimize a diet consisting entirely of fast food and fast-casual restaurants near University City for Drexel University students in lieu of Campus dining or cooking.

Benefit:

- Target cost effective model
- Ensure nutritional goals are met
- Adaptive model (time frame, food, restaurants)

Methodology:

- Mixed Integer Linear Programming
- Minimum Cost Objective Function
- Targeted Personal Constraints:
  - Individual Health Goals
  - Exercise Habits
  - Physical Characteristics:
    - Height
    - Weight
    - Gender

Practical Objective & Constraints

Objective Function

minimize:

Total Cost =

∑ [Cost per Item of Food][Quantity of Item Consumed]*

Constraint Type	Description:
Nutritional Requirements	Required values of Calories, Protein, Fat, Carbs, Sodium, Fiber, Sugar, & Cholesterol
Balanced Diet	Must eat breakfast, lunch and dinner every day
Variety	Cannot repeat restaurants more than once in a day, or two days in a row

Data, Parameters, & Variables

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Data:

- Collected from 11 restaurants initially, 1 excluded
- For each menu item:
  - Classify as Breakfast or Lunch/Dinner
  - Price
  - Nutrients

Sets:

B: A set of Breakfast Foods
L: A set of lunch Foods
D: a set of dinner foods
N: a set of nutrients
T: a set of days you are building meal plans for
R: A set of Restaurants
M: B, L or D

Parameters:

- $a_{Mn} \geq 0$
  - units of nutrients per menu item
- $z_n \geq 0$
  - units of nutrients required per day
- $c_m \geq 0,$
  - cost per menu item
- $v_{br}\ binary,$
  - Matrix that associates items tor restaurants

Variables:

- Integer: Quantity of menu item/day
  $BX_{bt} \geq 0$
  - $LX_{lt} \geq 0$
  - $DX_{dt} \geq 0$
- Binary: Attended Restaurant?
  - BY_{rt}
  - LY_{rt}
  - DY_{rt}

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Mixed Integer Programming Model

Objective Function

minimize:

$$Total\ Cost = \sum_{\substack{t\ in\ T \\ b\ in\ B \\ l\ in\ L \\ d\ in\ D}} c_b BX_{bt} + c_l BX_{lt} + c_d BX_{dt}$$

Constraint Type	Description:
Nutritional Requirements	$a_{bn}BX_{bt} + a_{ln}BX_{lt} + a_{dn}BX_{dt} \geq z_n$ for each n in N and t in T
Balanced Diet	$\sum_{b\ in\ B} BX_{bt} \geq 1$ for each t in T $\sum_{l\ in\ L} LX_{lt} \geq 1$ for each t in T $\sum_{d\ in\ D} LX_{dt} \geq 1$ for each t in T
Variety	$\sum_{r\ in\ R} BY_{rt} \leq 1$ for each t in T $\sum_{r\ in\ R} LY_{rt} \leq 1$ for each t in T $\sum_{r\ in\ R} DY_{rt} \leq 1$ for each t in T

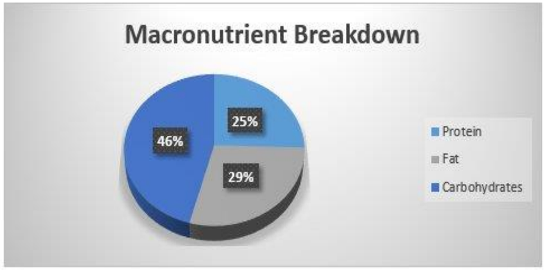
Model Implementation

Decision Support System: Nutritional Requirements

User Information		
Sex	Male	
Weight	147	lbs.
Height	64	Inches
Age	30	Years
Acitivity Level	Moderately active	e Guide for Details
Weight Goal -	Maintain	
Protein Intake (grams/lb)	1	Suggest 0.6 - 1 g/lb of body weight
Fat Intake (gram/lb)	0.5	Suggest 0.3 - 0.6 g/lb of body weight
Carb Intake	----	Calculated based on remaining calories after protein and fat have been subtracted from TDEE

Your BMR:	1538	Calories/Day
Your TDEE:	2307	Calories/Day

Activity Level Guide	
Sedentary	Little or no Exercise/ desk job
Lightly active	Light exercise/ sports 1 to 3 days/ week
Moderately active	Moderate Exercise, sports 3 to 5 days/ week
Very active	Heavy Exercise/ sports 6 to 7 days/ week
Extremely active	physical job/ training 2 x/ day



Daily Intake:

Suggested Calories	Protein (g)	Fat (g)	Carbohydrates (g)	Sodium (mg)	Fiber (g)	Potassium (mg)	Sugar (g)	Cholestrol(mg)
2307	147	73.5	264	2300	38	3500	90	300

Macronutrients by calories:	Protein	Fat	Carbohydrates
	588	662	1057

UserInput | AMPL Input

READY

Model Implementation

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Implement using AMPL

```
# Objective Function
# ##############################################################

minimize fun :
        sum{b in breakfastFoods,t in days} bcost[b]*BX[b,t]
      + sum{l in lunchFoods,t in days} lcost[l]*LX[l,t]
      + sum{d in dinnerFoods,t in days} dcost[d]*DX[d,t]
      + sum{r in restaurants , t in days} (BY[r,t]+LY[r,t]+DY[r,t])
      + sum{n in nutrients , t in days} (nutrSlack[n,t])
;
```

```
set breakfastFoods;
set lunchFoods;
set dinnerFoods;

set restaurants;

set nutrients;

set days;

param bcost{breakfastFoods} >= 0;
param lcost{lunchFoods} >= 0;
param dcost{dinnerFoods} >= 0;

param bnutr{breakfastFoods , nutrients} >= 0;
param lnutr{lunchFoods , nutrients} >= 0;
param dnutr{dinnerFoods , nutrients} >= 0;
param nutrGoal{nutrients,days} >= 0;

param vB{breakfastFoods,restaurants};
param vL{lunchFoods,restaurants};
param vD{dinnerFoods,restaurants};


# Decision Variables
# ##############################################################
var BX{breakfastFoods,days}   binary >= 0;
var LX{lunchFoods,days}       binary >= 0;
var DX{dinnerFoods,days}      binary >= 0;

var nutrSlack{nutrients,days} >= 0 ;

var BY{restaurants , days}  binary >= 0;
var LY{restaurants , days}  binary >= 0;
var DY{restaurants , days}  binary >= 0;
```

```
# Constraints
# ##############################################################

# At least one item per meal
     subject to c1 {t in days}      :     sum{b in breakfastFoods}
     BX[b,t] >= 1;
     subject to c2 {t in days}      :     sum{l in lunchFoods} LX[l,t]
     >= 1;
     subject to c3 {t in days}      :     sum{d in dinnerFoods} DX[d,t]
     >= 1;

# Meet nutrition minimums
     subject to c4 {t in days , n in nutrients} :
               sum{b in breakfastFoods}     (bnutr[b,n]*BX[b,t])
             + sum{l in lunchFoods}         (lnutr[l,n]*LX[l,t])
             + sum{d in dinnerFoods}    (dnutr[d,n]*DX[d,t])
             + nutrSlack[n,t]  = nutrGoal[n,t]
;

# Binary Linking Constraints
     subject to c6 {b in breakfastFoods , t in days , r in restaurants}:
      vB[b,r]*BX[b,t] - 100000*BY[r,t] <= 0;
     subject to c7 {l in lunchFoods     , t in days , r in restaurants}:
     vL[l,r]*LX[l,t] - 100000*LY[r,t] <= 0;
     subject to c8 {d in dinnerFoods    , t in days , r in restaurants}:
     vD[d,r]*DX[d,t] - 100000*DY[r,t] <= 0;

# Cannot go to the same restaurant more than once in a day
     subject to c9 {r in restaurants,t in days}:
          (BY[r,t] + LY[r,t] + DY[r,t]) <= 1
;

# Cannot have the same item more than twice during the plan
     # subject to c10 {b in breakfastFoods} : sum{t in days}(BX[b,t]) <=
     1;
     # subject to c11 {l in lunchFoods} : sum{t in days}(LX[l,t]) <= 1;
     # subject to c12 {d in dinnerFoods} : sum{t in days}(DX[d,t]) <= 1;
```

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Conclusion and Discussion

Sample Meal Plans:

Restaurant	Item	Price	Calories	Protein	Fat	Carbs	Sodium	Fiber	Sugar	Chol.
Breakfast										
Starbucks	Pumpkin Cookie	2.25	330	4	19	37	125	0	18	30
Starbucks	Oatmeal with Fresh Blueberries	3.45	220	5	2.5	43	125	5	13	0
Starbucks	Oatmeal with Fresh Blueberries	3.45	220	5	2.5	43	125	5	13	0
Starbucks	Oatmeal with Fresh Blueberries	3.45	220	5	2.5	43	125	5	13	0
Lunch										
McDonald's	Side Salad	1	20	1	0	4	10	1	2	0
McDonald's	Side Salad	1	20	1	0	4	10	1	2	0
McDonald's	Chicken McNuggets 4 Piece w/ Marinara Sauce	1.99	205	9	12	14	435	1	2	25
Dinner										
Subway	6" Oven Roasted Chicken	4.25	320	23	5	47	610	5	8	40
Subway	6" Oven Roasted Chicken	4.25	320	23	5	47	610	5	8	40
Total		**25.09**	**1875**	**76**	**48.5**	**282**	**2175**	**28**	**79**	**135**
Goals			2400	100	50	350	2200	30	80	250
Difference			525	24	1.5	68	25	2	1	115

Discussion

Future Considerations:

- *More Restaurants/Availability*
- *Personal preferences*
- *Other dietary restrictions (vegetarian)*

Learnings:

- *Importance of model efficiency and solvers as well as data size*