UNIVERSITY OF SOUTHERN CALIFORNIA
DEPARTMENT OF INDUSTRIAL AND SYSTEMS ENGINEERING

ISE 533-Integrative Analytics

MEAL PLANNING FOR THE NEW MILLENNIUM (MnM)

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1. Introduction-Revisiting the Diet Problem

"The Stigler diet" is a famous optimization problem devised and solved after Nobel Laureate George Stigler. The problem scopes an active man weighing 154 pounds. How much of the seventy-seven foods this person should eat daily so that his intake of nine nutrients will at least satisfy the recommended dietary allowances (RDAs) suggested by the National Research Council in 1943, with a minimum diet cost? The nutrient RDAs to be met in this problem were calories, protein, calcium, iron, vitamin A, thiamine, riboflavin, niacin, and ascorbic acid. The result of this problem with the specified constraints was an annual budget allocated to foods (e.g., evaporated milk, cabbage, dried navy beans, and beef liver at a cost around $0.11 with 1939 U.S. currency).

Praised as one of the earliest efforts in linear programming, this experiment had its own limitations: lack of variety and palatability. Stigler used heuristic methods to solve this problem, reduced his food list to fifteen, from seventy-seven through trial and error, mathematical insight and agility. With a cost-minimizing approach, he estimated the solution as $39.93 in 1939 (inflated to 2016 as $690.13). Seven years after Stigler's initial estimates, George Danzig's Simplex algorithm enabled the solution without relying on the heuristics and made 'The Diet Problem' one of the essentials of introductory optimization education. The exact solution was found to be $39.69 (with 1939 U.S. currency).

Briefly highlighting the limitations of the problem, "No one recommends, these diets for anyone, let alone everyone." said Stigler once. Today, our higher-level objective is to revisit the diet problem by bringing it to the context of our lives today. We will refer to this effort as Meal Planning in the New Millennium (MnM). In this study, we focus on maximizing the recipe ratings of two female graduate students' weekly meal plan.

2. Problem Statement

In this scenario-based case study we focus on two female graduate students' (friendly roommates who do the groceries, meal decision and cooking together) weekly meal plan. Graduate students are contextually exposed to external pressures such as course-load, research deliverables, job hunting, and financial stresses while sustaining themselves as socially functional entities. Thus, these external factors could substantially influence the graduate students' food preferences and nutrition management and brings another question to the busy day; "What are we eating tonight?", which built our *study motivation*.

In this specific case study, being inactive (i.e., not being involved in habitual physical activities) female graduate students concerned with their weights adds up on the stress. This leads to using simpler recipes, however, not to compromise from the food satisfaction. In this context, we do not necessarily focus on the high rating recipes, but we would like to maximize the recipe ratings of our choice for self-motivational reasons, as well as inspiring the other inactive female engineering graduate students to choose from 'low-key high rated food recipes' with low cost. This brings the world-famous 'diet problem' to the millennial context of stressful female engineering students' weekly meal plan.

3. Methodology

As mentioned earlier, the objective of this study is **to maximize the low-key recipes' ratings** which require low number of inexpensive foods (i.e., milk, bread, rice, egg, cheese, chicken, beef, apple, carrot, tomato, potato, onion, leafy green). The constraints of our problem are crafted to address the life-styles (i.e., **calories, budget, time,** making sure to **have five meals** to get through the busy week days), nutrition content (i.e., **protein, fat, sodium**), personal food preferences of these two meat-lovers (i.e., including **either chicken or beef** in every recipe).

We developed a linear programming (LP) model using R language to accommodate our objective function and the constraints. We chose thirty out of twenty thousand fifty-two recipes from Epicurious (https://www.kaggle.com/hugodarwood/epirecipes). The constraints for daily intakes are got from healthline (https://www.healthline.com/nutrition), which we compared with other websites and those websites all have the same conclusion. We also chose the following ingredients to be used in these recipes and the prices are from Food Prices in Los Angeles, CA, United States (https://www.numbeo.com/food-prices/in/Los-Angeles).

Ingredient	Price ($-USD)
milk	0.26
bread	0.76
rice	0.49
egg	0.63
cheese	1.08
chicken	1.47
beef	2.05
apple	1.18
carrot	0.63
mango	1.04
tomato	0.85
potato	0.6
onion	0.26
leafy green	0.28

Table 1: Food ingredients to be used in recipes

Recipe	Rating	Calories (kCal)	Protein (g)	Fat (g)	Sodium (g)	Time (hour)
Chili and Honey Chicken Legs	3.75	698	52	50	959	0.75
Blueberry Cheesecake	5	954	14	66	767	0.58
3-Ingredient Peanut Butter Cookies	5	100	3	6	5	0.58
Eggnog Ice Cream	5	205	3	13	84	0.5
Microwave Chicken Piccata	1.25	1307	145	75	1456	0.2
Mango Coconut Ice Cream	5	240	3	13	33	0.5
Grilled Brined Chicken with Chimichurri Sauce	5	1511	96	118	3097	1.5
Broiled Mustard Chicken Wings	4.375	782	62	56	550	0.75
Beef Tenderloin with Red Wine Sauce, Creamed Spinach, and Truffled French Fries	5	703	37	43	422	1.25
Char-Grilled Beef Tenderloin with Three-Herb Chimichurri	4.375	745	41	60	1146	1.25
Steak Salad with Pickled Vegetables	4.375	682	47	50	150	1.75
Beef Tenderloin Steaks with Chili Sauce	4.375	708	38	52	340	1.25
Roast Beef Sandwiches with Lemon-Basil Mayonnaise and Roasted Red Onions	4.375	795	22	55	290	1.5
Korean Barbecued Beef	4.375	60	5	2	137	1.5
Veal Meatballs with Braised Vegetables	3.75	636	31	41	1774	1.5
Thai-Style Beef and Asparagus Curry	3.125	555	26	49	84	1.5
Chunky Beef and Vegetable Soup	3.125	372	44	11	798	0.75
Grass-Fed Beef Meatloaf in a Bacon Blanket	3.125	880	55	62	1487	1.17
Chicken Curry with Sweet Potatoes	5	591	54	21	1735	0.5
Braised Rotisserie Chicken With Bacon, Tomatoes, and Kale	5	370	20	29	502	0.5

Tropical Chicken Salad	4.375	644	41	40	150	0.5
Country Bread Stuffing with Smoked Ham, Goat Cheese, and Dried Cherries	4.375	425	18	24	706	1.25
Roasted Chicken, Ramps, and Potatoes	4.375	462	26	27	200	1
Chicken and Apple Curry	3.75	295	17	16	458	0.5
Roasted Chicken Breast and Vegetables with Prunes	3.75	361	22	15	127	0.75
Roast Chicken with Mushroom Stuffing and Sauce	3.75	1100	159	32	1292	2.5
Colombian Chicken, Corn, and Potato Stew	3.75	1228	68	74	1364	1.25
Chicken, Ham, and Tarragon Pie	3.125	736	12	50	413	1.5
Chicken and Couscous with a Punchy Relish	2.5	1419	97	87	728	1.75
Broiled Chicken with Bacon Over Egg Fried Rice	2.5	1016	53	67	480	0.25

Table 2: Rating, calories, protein, fat, sodium of the recipes

Please see the following section for further details of mathematical modeling and model execution through R.

3.1. Mathematical Model: objective function & constraints

In this mathematical model for Meal Planning in the New Millennium (MnM), we use the rating as the object and maximize the low-key recipes' ratings. With each receipt (indexed by i), we associate a binary allocation Xi which denotes which receipt we are choosing and allocated to receipt i. With each receipt we also associate the rating of this receipt, denoted Ri. The lifestyle restrictions calories, budget, time associated with receipt i are Ci, Bi and Ti. The vector of available calories and budget capacities are defined by daily recommended calories and minimum amount of money for daily nutrition that mentioned in previous section. Another constraint is for picking out five receipts for each day in weekday, and constraint for the number must be five. As for nutrition content restrictions protein, fat, sodium associated with receipt i are Pi, Fi and Si. The vector of available protein, fat, sodium capacities are defined by daily recommended protein, fat, sodium in healthline website. With daily food intake, we preferred at least one protein for each day and beef, chicken associated with receipt i are Bi, Ci. Letting five to be the adding number of the receipts and the formulation is down below.

$$\text{Max} \sum_{i=1}^{N} R_i \cdot X_i$$

$$\text{s.t.} \quad \sum_{i=1}^{N} X_i = 5$$

$$\sum_{i=1}^{N} C_i \cdot X_i \leq 2000 \times 5$$

$$\sum_{i=1}^{N} B_i \cdot X_i \leq 11.58 \times 5$$

$$\sum_{i=1}^{N} T_i \cdot X_i \leq 5$$

$$\sum_{i=1}^{N} P_i \cdot X_i \leq 5 \times 46$$

$$5 \times 46 \leq \sum_{i=1}^{N} F_i \cdot X_i \leq 5 \times 78$$

$$\sum_{i=1}^{N} S_i \cdot X_i \leq 5 \times 2300$$

$$\sum_{i=1}^{N} B_i \cdot X_i + \sum_{i=1}^{N} C_i \cdot X_i = 5$$

The Mathematical model above provided all the lifestyle constraints and health constraints to get the fit able receipts and best reviews from data in epicurious. With this model we can easy come up with weekly receipts and could fits in our life easily.

3.2. Assumptions

It is worth mentioning, we made certain case-specific assumptions to derive our problem's constraints. The *first assumption* we made was even if we are busy, we should have fresh meal at home during the weekdays. The *second assumption* is interrelated to the first one; we either go out for dinner or eat the leftover food during the weekends. As we said, we are inactive (number of days we are involved in sportive activities is not more than four days in a month), so thirdly we *assumed* we try to keep our current shape (roughly). With this regard, we mainly focused on our protein, fat, and sodium intake. We chose to track these, as two meat-lovers, we were aware of protein diets' positive influence on weight tracking, and bad influence of fat and sodium on our health. And, we weren't considering all ingredients in the receipts, instead we use the ingredients are most commonly find in local grocery store and can find daily updated price on the websites. It's possible to find all the ingredients in the receipts and figure out the renew budget but based on daily lifestyle we prefer to choose those ingredients instead because we count shopping time in those and limited it to smaller range.

4. Results and discussion

As we compute all those data in our model, we come out with those five receipts: Grilled Brined Chicken with Chimichurri Sauce; Beef Tenderloin with Red Wine Sauce, Creamed Spinach, and Truffle French Fries; Chicken Curry with Sweet Potatoes; Braised Rotisserie Chicken with Bacon, Tomatoes, and Kale; Country Bread Stuffing with Smoked Ham, Goat Cheese, and Dried Cherries. Those receipts all fits our request and the optimum outcome for the sum up of the five-day receipts rate is 24.375. As for all those constraints, we summed up each of them for five days and weekly calories is 3600.00; weekly food budget is 11.87; weekly protein intake is 225.00; weekly fat intake is 235.00; weekly sodium intake is 6462.00. Those requires fits basic requirement for two female student's weekly meal plan and the budget for this weekly plan is also attractive. For this meal plan we can skipped all the process of how to pick all those receipts and come out with the solution in a short amount of time. It's an easier way for daily decision making and will benefit us as in real life weekly receipts searching.

5. Limitations and Future Studies

Although our study gives a perspective to carry the conventional diet problem to a millennium context, there are some limitations to this study. We considered eight constraints based on our lifestyles and personal food preferences, and the nutrient content. More constraints could be added to our model based on health considerations, vitamin richness, other personal food preferences. Another limitation is the number of recipes in our mode. We chose thirty recipes from twenty thousand and fifty-two, since the semester is fourteen weeks long, and we do not mind repeating these recipes we like couple of times during this period. We also chose a limited number of ingredients (i.e., fourteen) based on our preferences and budget. Future studies can elaborate on our diet problem model by increasing the number of recipes, ingredients, and constraints.

6. Appendix

R script

```
install.packages("Rglpk")
library(Rglpk)
setwd("/Users/apple/Desktop")
d0=read.csv("/Users/apple/Desktop/receipt_data.csv")
d1=read.csv("/Users/apple/Desktop/prices.csv")

#calculate the prices
milk=d1$X...milk[c(1)]
bread=d1$bread[c(1)]
rice=d1$rice[c(1)]
egg=d1$egg[c(1)]
cheese=d1$cheese[c(1)]
chicken=d1$chicken[c(1)]
beef=d1$beef[c(1)]
apple=d1$apple[c(1)]
carrot=d1$carrot[c(1)]
mango=d1$mango[c(1)]
tomato=d1$tomato[c(1)]
potato=d1$potato[c(1)]
onion=d1$onion[c(1)]
leafy.green=d1$leafy.green[c(1)]
d0$budget=((d0$apple)*apple+(d0$milk)*milk+(d0$bread)*bread+(d0$rice)*rice+(d0$egg)*egg+
(d0$cheese)*cheese+(d0$chicken)*chicken+(d0$beef)*beef+(d0$apple)*apple+(d0$carrot)*carr
ot+(d0$mango)*mango+(d0$tomato)*tomato+(d0$potato)*potato+(d0$onion)*onion+(d0$leafy.g
reen)*leafy.green)

#the LP solve model
mat1 = c(1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1)
obj=d0$rating
mat=rbind(mat1,d0$calories,d0$budget,d0$Time,d0$protein,d0$fat,d0$fat,d0$sodium,d0$chick
en+d0$beef)
dir=c("==","<=", "<=", "<=","<=",">=","<=","<=","==")
rhs=c(5,10000,57.9,5,230,230,390,11500,5)
types=c("B","B","B","B","B","B","B","B","B","B",
        "B","B","B","B","B","B","B","B","B","B",
        "B","B","B","B","B","B","B","B","B","B")
max=TRUE
Rglpk_solve_LP(obj, mat, dir, rhs, types = types, max = max)
```

Outcomes

```
$optimum
[1] 24.375
$solution
 [1] 0 0 0 0 0 0 1 0 1 0 0 0 0 0 0 0 0 1 1 0 1 0 0 0 0 0 0 0
$status
[1] 0
$solution_dual
[1] NA
$auxiliary
$auxiliary$primal
[1]    5.00 3600.00   11.87    5.00  225.00  235.00  235.00 6462.00    5.00
$auxiliary$dual
[1] NA
```

The receipts are: Grilled Brined Chicken with Chimichurri Sauce; Beef Tenderloin with Red Wine Sauce, Creamed Spinach, and Truffled French Fries; Chicken Curry with Sweet Potatoes; Braised Rotisserie Chicken With Bacon, Tomatoes, and Kale; Country Bread Stuffing with Smoked Ham, Goat Cheese, and Dried Cherries.

7. References

[1] Receipts and data in Epicurious: https://www.epicurious.com/
[2] Epicurious Recipes with Rating and Nutrition:
https://www.kaggle.com/hugodarwood/epirecipes
[3] Food Prices in Los Angeles, CA: https://www.numbeo.com/food-prices/in/Los-Angeles
[4] Daily calories, protein, fat, sodium intake: https://www.healthline.com/nutrition
[5] Food Prices in local groceries store: https://www.ralphs.com/products