Menu Planning System for Young Pregnant Women

Nikola Surjanovic
Student Number: 301289816

Justin Byfield
Student Number: 301224030

Ebrahim Adeeb
Student Number: 301056620

Menu Planning System for Young Pregnant Women

Nikola Surjanovic, Ebrahim Adeeb, Justin Byfield

***Abstract*—We analyze the Stigler diet problem in the context of the Surrey Central City mall food court. Comparisons are made between pregnant and non-pregnant young women, and comments are made on the feasibility of such diets, while meeting necessary dietary constraints and minimizing costs. We also discuss possible future work pertaining to diets for young pregnant women and diet problems which incorporate diminishing marginal returns.**

I. Introduction

THE typical Stigler diet problem consists of finding a minimum-cost diet, while meeting a subjects certain dietary needs. In this report, we consider only foods coming from the Surrey Central City mall food court. A common question may be whether or not it is possible to have meals three to five times each day at the food court and meet all of the dietary needs; we analyze whether it is possible to do so for a young pregnant woman to meet the different dietary needs, and how the change in nutritional constraints affects the optimal weekly diet.

The main test subject is a 19-30 year old pregnant woman. Our subject is between 5 feet 2 inches and 5 feet 6 inches, weighing approximately 80 kilograms (15 kilograms heavier than an average woman), doing a moderate workload (in the office or staying at home during pregnancy). The comparison subject is a 19-30 year old non-pregnant woman, also between 5 feet 2 inches and 5 feet 6 inches, but weighing approximately 65 kilograms, and also doing a moderate workload.

Since it is natural that a pregnant woman has to consume higher amounts of certain types of foods in order to support the baby, while avoiding alcoholic beverages and potentially hazardous foods, results can differ greatly from the optimal diet for a non-pregnant woman. Because of this, we compare the two optimal diet results and see how different they are when eating at a food court and make appropriate conclusions.

We also comment on the possible infeasibility of a completely balanced diet for a pregnant woman at the food court, if constraints are added to the model in order to have an increased variety of foods, due to a lack of healthy foods in the food court. We also note potential future work to be done, for researchers interested in the diets of young pregnant women, and those wishing to implement a concept of diminishing marginal returns in a menu planning system.

II. Model Development

Our linear program has an objective of minimizing costs, while meeting specific dietary constraints. Constraints added were upper and lower bounds for nutrients, vitamins, food groups, and other relevant nutritional constraints for both pregnant and non-pregnant 19 to 30 year old women, as specified by the RDIs (Recommended Daily Intakes) given by the US Department of Health and Services.

Variables for quantities of food were set to integer values. Also, since food groups were measured as binary values (represented by 1s if there were appropriate amounts of the given food group present), lower bounds were added to make sure that certain food groups were met. Additional constraints involved avoiding repetition of foods throughout the week, and having three to five meals each day, where each meal could involve purchasing multiple items. We also made sure that certain meal types, such as breakfast meals, were present at least once each day (these could be at any time of day, but they were indicated by "breakfast" since they contained eggs or had high energy content).

The Mixed Integer Linear Program (MIP) was solved using Gurobi through MATLAB by importing nutritional information for foods as a matrix, and adding constraints as an array. Output was exported into CSV files.

The main nutritional data set contains 599 rows which represents each unique food item, and 41 columns which represent variables that are descriptors of the food item. Definitions of the variables found in the dietMasterSheetFinal(Binary).csv are found in Table 1.

The restrictions for avoiding repetitiveness of vendors and food items are not present in the Gurobi LP file, since these were added as additional constraints directly in the MATLAB code. This is because the seven-day meal plan was created by repeating the same linear program each day, but adding new constraints as the week progressed. This does not violate the nature of a linear program, since the same could be done by introducing variables which force certain constraints to appear only on particular days.

The linear programming model files for the pregnant and non-pregnant woman models, as well as the constraints fragment of the MATLAB code can be found under "Section 4: Experimental Results". (All other source files can be found in digital format).

III. Data Collection and Cleaning

Nutritional information for the majority of vendors was found in PDFs posted online by the vendors themselves, or by Healthy Families BC. In order to extract the information from the PDFs, Tabula, a tool for data extraction from PDF files into CSV files, was used. In rare cases that Tabula was unable to interpret data, nutritional information was copied manually.

Due to the high volume of data collected, manual forms of data entry were initially avoided, but were used as a final resort in rare circumstances. It was immediately apparent that the corporate food establishments had more accessible nutrition

TABLE I: Variable Descriptions

ID	numeric unique identifier for each food item.
Food Item Name	character string with the name of the item.
Vendor	character string containing the vendor that is providing the food item.
Vendor#	numeric representation of the vendor.
Class	character string containing the type of meal.
*Class Binary	a binary variable to represent each class of food item.
Cost	numeric cost of food item in Canadian dollars.
Serving Size	numeric count of grams in each serving of food item.
Calories	numeric count of calories in Kcal for each serving of food item
Total Fat	numeric count of total fat in grams for each serving of food item
Saturated Fat	numeric count of saturated fat in grams for each serving of food item
Trans Fat	numeric count of trans fat in grams for each serving of food item.
Cholesterol	numeric count of cholesterol in milligrams for each serving of food item.
Sodium	numeric count of sodium in milligrams for each serving of food item.
Total Carbs	numeric count of total carbohydrates in grams for each serving of food item.
Dietary Fibre	numeric count of total dietary fibre in grams for each serving of food item.
Total Sugars	numeric count of total sugars in grams for each serving of food item.
Protein	numeric count of total protein in grams for each serving of food item.
Calcium	percentage of daily total calcium based on an average womans daily intake.
Iron	percentage of daily total iron based on an average womans daily intake.
Vitamin A	percentage of daily total vitamin A based on an average womans daily intake.
Vitamin C	percentage of daily total vitamin C based on an average womans daily intake.
Vegetable	binary representation of whether item contains vegetables.
Fruit	binary representation of whether item contains fruit.
Dairy	binary representation of whether item contains dairy.
Poultry/Egg	binary representation of whether item contains poultry or egg.
Fish	binary representation of whether item contains seafood.
Meat	binary representation of whether item contains red meat.
Grains	binary representation of whether item contains grains.
Beans/Lentils	binary representation of whether item contains beans or lentils.

TABLE II: Gurobi Model Descriptions

C n	Amount of a food item ordered in a day (integer-value), with id $(n+1)$ After C588, these correspond to nutritional constraint variables, as outlined in the MATLAB file
R n	The $(n+1)$-th dietary restriction, as outlined in the MATLAB file

data but were disjoint from the price data. The price data was input manually after visiting the locations at the Surrey Central City mall food court. Some restaurants did not provide complete data, and this data was either manually researched or imputed.

Although errors were to be expected during the transformation with Tabula, the time required and cost of quality control and spot checking were far lower than for manual data input. As the data was moved into a comma separated values file format, a master sheet was created.

During the process of data collection, some vendors were repeated. As an example, Cultures nutritional information was collected twice, thus verifying the accuracy of the Tabula software, as well as manual data collection. In cases where there were mix-and-match options for choosing meals, in order to avoid having a maximum of 2^{35} meal plans, the most important and realistic choices were used (not more than 100 combinations were used for each vendor).

Since groupings of nutritional information had missing data for certain vendors or meals, if the number of missing entries was relatively low, data was estimated by taking the average of the corresponding nutritional information pertaining to that food class. For example, the average sugar content of salads per gram was multiplied by the serving size corresponding to the missing sugar field. Once the data was complete, quality control was conducted by examining outliers and extreme cases. Also, it was the case that some vendors had seemingly inaccurate information posted on their website (17300% daily vitamin intake, as an example), and so a similar technique was used in these rare circumstances.

During data cleaning certain patterns were observed, as can be seen in the three corresponding figures below, produced using Tableau software.

The histograms in Figure 1 for all variables exhibit a right skewness except for cost. The peak in calories towards the end of the distribution at 900 calories is alarming and required further investigation. This investigation revealed that those high calories belong to Philly Cheese Steak sandwiches, that also provide a higher value of protein. As for cost, it is an apparent bimodal distribution that indicates peaks at just below \$5 and \$10.

Figure 2 shows that many of our variables are linearly correlated. As sugar, protein, and fat are increased, calories are also increasing with an apparently linear trend. The colors in the plots represent vendors and food items. An example of the information that can be gained is the top left Sugar vs. Calories plot. It shows a count of sugar per gram that increases drastically for Orange Julius smoothies. This would lead us to believe that Orange Julius smoothies will not make an appearance in our optimized diet.

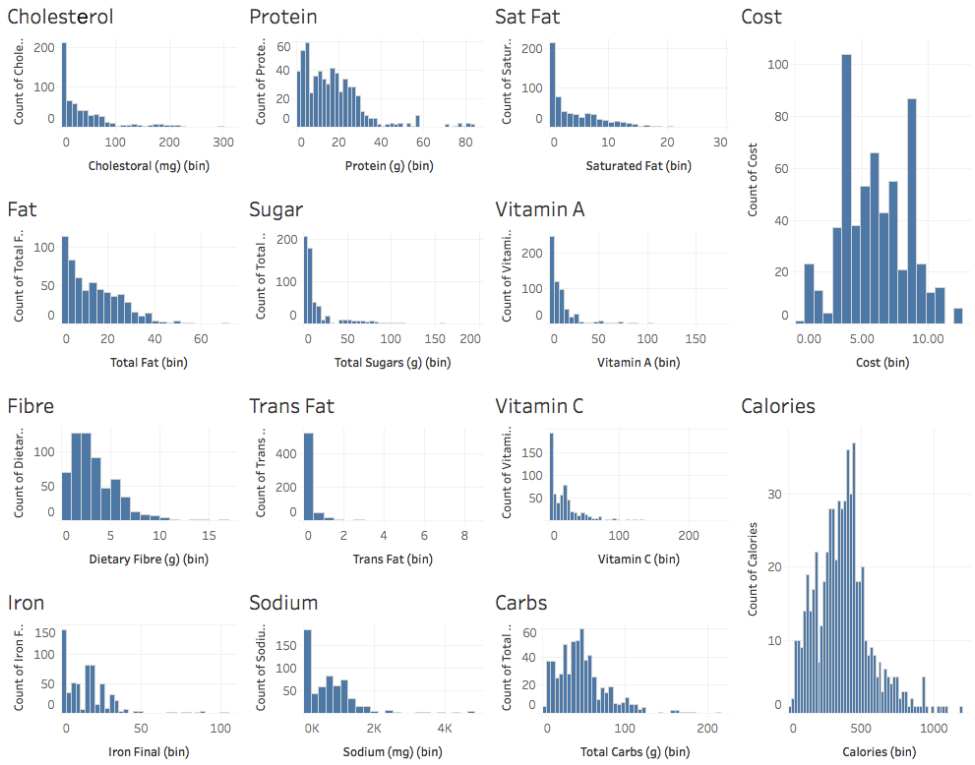

Fig. 1: Distributions of various nutritional content variables

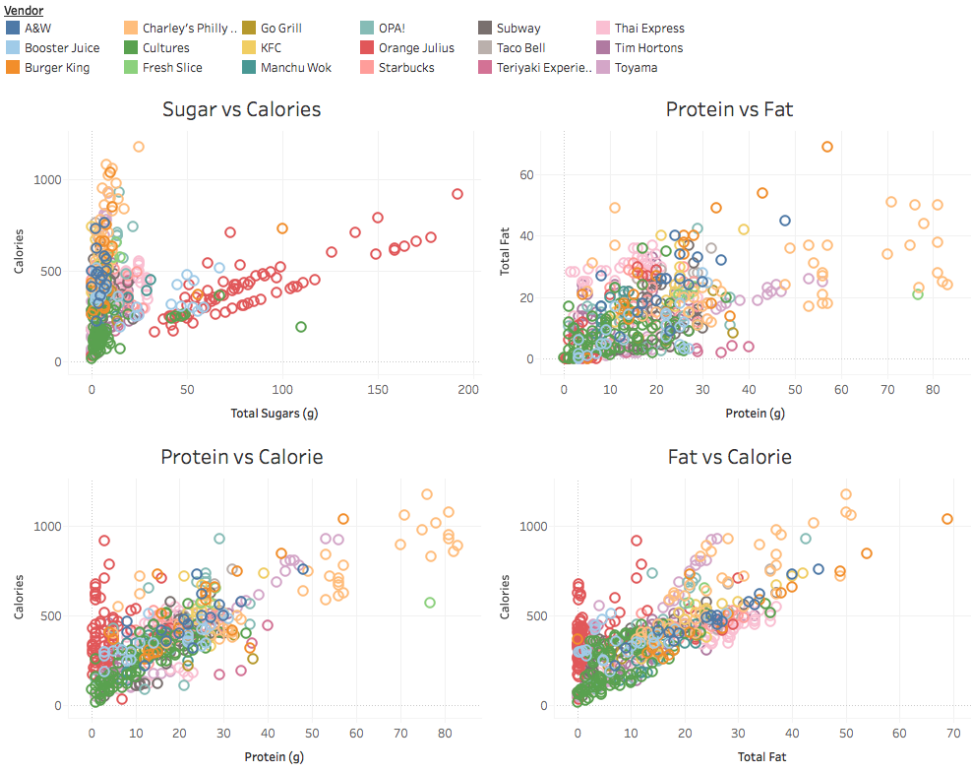

Fig. 2: Relationships between various nutritional variables

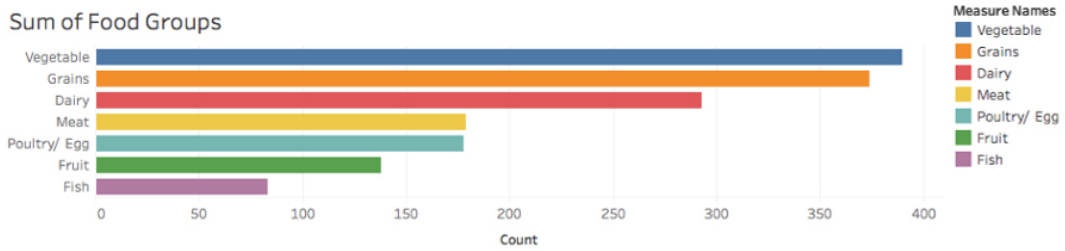

Fig. 3: Frequency of Food Groups

Figure 3 shows that vegetables and grains are about twice as common in the food court as meat and egg-containing foods. Dairy is the third most common food item, with fruits and fish being the least common items.

Finally, after analyzing various plots, we can see that our data collected seems to represent accurate data.

IV. Experimental Results

Attempts with the initial constraints were not successful. For both pregnant and non-pregnant women, the results returned by Gurobi were that both linear programs were infeasible. This could be due to the fact that the food is coming from a food court, and our original constraints forced a very healthy diet. After relaxing a few constraints, in particular, by raising the upper bound on daily sugar intake, and slightly lowering vitamin A requirements, an optimal solution was found, as seen in the provided output.

For both the pregnant and non-pregnant woman, the first day seemed to be the least healthy. However, as constraints were added throughout the week to avoid purchasing the same food item many times, the meals seemed to become more healthy. The sugar intake for Day 1 is not alarming, even though the names of the food items seem to indicate otherwise. Certain other results were also surprising; the daily cost for the pregnant woman was lower than that for the non-pregnant woman. One possible reason for this is because the pregnant woman has to consume more throughout the day, she can buy larger meals which often have a lower price per gram. However, these meals are also sometimes less healthy.

Another interesting result is that poutine shows up as a snack in both of the diets. This was also slightly unexpected, but after further inspection, poutine has plenty of calories for a relatively low price, thus being used likely as a filler to meet the necessary daily calorie and other intake requirements.

The full weekly plan for both the pregnant and non-pregnant woman can be found in the pages below (as part of Section IV). Vendor locations for food items can be found in ”dietMasterSheetFinal(binary).csv”. The linear programming model files are also attached below, as indicated previously in Section III.

V. Conclusion

From the outputs, we can tell that there are obvious differences between diets for pregnant and non-pregnant women. Also, it seems that certain vendors such as Subway are fairly successful in producing foods that rank highly in terms of nutritional quality while maintaining a relatively low price.

Compared to the regular ”Stigler” diet problem, where most meals are unrealistic or unappealing, unless there are an abundance of constraints, this version of the diet problem produces meals which are already pre-made, and are thus realistic options ready to be implemented.

Future work could involve setting different objectives, such as losing or gaining weight during pregnancy, depending on advice given by a doctor. Also, the list of vendors could be expanded to include the dining restaurants in the Surrey Central City mall not found in the food court. If this is done, then it may be possible to tighten some constraints, such as having a greater variety of foods throughout the week. Finally, one might be interested in comparing the diet offered in Central City with the optimal diet offered at the Metrotown food court or a shopping centre located in another area or even country, in order to determine whether there are differences in quality of foods offered. Analysis can be done not only by comparing the objective costs, but also the daily or weekly calorie intakes along with overall perceived healthiness of the diet.

Also, an interesting idea instead of restricting foods or vendors from appearing multiple times within the week, is to set the objective function to maximize ”benefit”, which would mean that due to decreasing marginal benefits of repeating foods, the model output would naturally result in a non-repetitive diet. However, the difficulty here lies in quantifying ”benefit” and creating an accurate scale for benefits obtained between food items.

ModelPregnant.lp

```
Minimize
  3.89 C0 + 5.89 C1 + 5.19 C2 + 5.89 C3 + ... +6.99 C596 + 5.99 C597 +
8.99 C598

Subject To
 R0: C0 + C1 + C2 + C3 + C4 + C5 + C6 + C7 + C8 + C9 + C10 + C11 + C12
   + C13 + C14 + C15 + C16 + C17 + C18 + C19 + C20 + C21 + C22 + C23 + C24
   + C25 + C26 + C27 + C28 + C29 + C30 + C31 + C32 + C33 + C34 + C35 + C36
   + C37 + C38 + C39 + C40 + C41 + C42 + C43 + C44 + C45 + C46 + C47 + C48
   + C49 - C599 = 0
.
.
.
R48: C7 + C18 + C27 + C31 + C54 + C58 + C66 + C67 + C73 + C79 + C85 + C96
   + C102 + C108 + C114 + C132 + C135 + C200 + C233 + C235 + C237 + C254
   + C261 + C262 + C264 + C272 + C292 + C404 + C517 + C518 + C520 + C591
   - C647 = 0

Bounds
 C599 <= 2
 C600 <= 2
 .
 .
 .
 C644 <= 2
 1 <= C645 <= 7
 C646 >= 2

Generals
 C0 C1 C2 C3 C4 C5 C6 C7 C8 ... C647
End
```

NonPregnantModel.lp

```
Minimize
  3.89 C0 + 5.89 C1 + 5.19 C2 + 5.89 C3 +  ... + 5.99 C597 + 8.99 C598

Subject To
 R0: C0 + C1 + C2 + C3 + C4 + C5 + C6 + C7 + C8 + C9 + C10 + C11 + C12
   + C13 + C14 + C15 + C16 + C17 + C18 + C19 + C20 + C21 + C22 + C23 + C24
   + C25 + C26 + C27 + C28 + C29 + C30 + C31 + C32 + C33 + C34 + C35 + C36
   + C37 + C38 + C39 + C40 + C41 + C42 + C43 + C44 + C45 + C46 + C47 + C48
   + C49 - C599 = 0
.
.
.
 R48: C7 + C18 + C27 + C31 + C54 + C58 + C66 + C67 + C73 + C79 + C85 + C96
   + C102 + C108 + C114 + C132 + C135 + C200 + C233 + C235 + C237 + C254
   + C261 + C262 + C264 + C272 + C292 + C404 + C517 + C518 + C520 + C591
   - C647 = 0

Bounds
 C599 = 0
 C600 <= 2
 C601 <= 2
 .
 .
 .
 1 <= C642 <= 7
 1 <= C643 <= 7
 C644 <= 7
 1 <= C645 <= 7
 C646 >= 2

Generals
 C0 C1 C2 C3 C4 C5 C6 ... C646 C647

End
```

```
%Constraints for 19-30 yr old non-pregnant woman
%NOTE: Snacks/deserts are not included in limit on meals per day
%                    min      max      No limit on vendor visits in one day
categoryBounds1 = [ 0          2;       %Subway
                    0          2;       %OPA!
                    0          2;       %Thai Express
                    0          2;       %Starbucks
                    0          2;       %Booster Juice
                    0          2;       %KFC
                    0          2;       %Taco Bell
                    0          2;       %Fresh Slice
                    0          2;       %Cultures
                    0          2;       %Burger King
                    0          2;       %Orange Julius
                    0          2;       %Toyama
                    0          2;       %Charley's
                    0          2;       %Tim Hortons
                    0          2;       %Manchu Wok
                    0          2;       %A&W
                    0          2;       %Go Grill
                    0          2;       %Teriyaki Experience
                    1        inf;       %Breakfast
                    0        inf;       %Sandwich
                    0        inf;       %Smoothie
                    0        inf;       %Desert
                    0        inf;       %Soup
                    0        inf;       %Salad
                    0        inf;       %Entree
                    0        inf;       %Snack
                    2        inf;       %Total Meals
                    1500    2400;       %Calories
                    12       inf;       %Total Fat
                    0        inf;       %Saturated Fat
                    0          6;       %Trans Fat
                    100      350;       %Cholesterol
                    1650    4500;       %Sodium
                    115      250;       %Carbohydrates
                    10        50;       %Fibre
                    0        inf;       %Sugar
                    35       120;       %Protein
                    50       250;       %Calcium
                    12        40;       %Iron
                    0        389;       %Vit A*
```

```
                        Constraining makes infeasible
                    0       235;        %Vit C
                    2       inf;        %Vegetable
                    1       inf;        %Fruit
                    1         7;        %Dairy
                    1         7;        %Poultry
                    0         7;        %Fish
                    1         7;        %Meat
                    2       inf;        %Grains
                    0       inf;];      %Beans/Lentils

%Constraints for 19-30 yr old pregnant woman
%NOTE: Snacks are not included in limit on meals per day
%                   min     max     No limit on vendor visits in one day
categoryBounds2 = [ 0         2;        %Subway
                    0         2;        %OPA!
                    0         2;        %Thai Express
                    0         2;        %Starbucks
                    0         2;        %Booster Juice
                    0         2;        %KFC
                    0         2;        %Taco Bell
                    0         2;        %Fresh Slice
                    0         2;        %Cultures
                    0         2;        %Burger King
                    0         2;        %Orange Julius
                    0         2;        %Toyama
                    0         2;        %Charley's
                    0         2;        %Tim Hortons
                    0         2;        %Manchu Wok
                    0         2;        %A&W
                    0         2;        %Go Grill
                    0         2;        %Teriyaki
                        Experience
                    1       inf;        %Breakfast
                    0       inf;        %Sandwich
                    0       inf;        %Smoothie
                    0       inf;        %Desert
                    0       inf;        %Soup
                    0       inf;        %Salad
                    0       inf;        %Entree
                    0       inf;        %Snack
                    2       inf;        %Total Meals
                    1700    2500;       %Calories
                    15      inf;        %Total Fat
                    8.5     inf;        %Saturated Fat
```

```
0.9       6.1;      %Trans Fat
120       310;      %Cholesterol
1500      4000;     %Sodium
150       250;      %Carbohydrates
15        41;       %Fibre
0         inf;      %Sugar
50        140;      %Protein
60        250;      %Calcium
15        80;       %Iron
0         389;      %Vit A
0         235;      %Vit C
2         inf;      %Vegetable
0         inf;      %Fruit
2         7;        %Dairy
1         7;        %Poultry
0         2;        %Fish
1         7;        %Meat
2         inf;      %Grains
0         inf;];    %Beans/Lentils
```

Pregnant Woman Weekly Diet

Day 1
Buy:
Poutine (A&W) 2
Original Fries (Charley's Philly Steaks) 1
Chocolate Dip (Tim Hortons) 60 g 1
Strudel Strawberry Cheese (Tim Hortons) 1

Day 2
Buy:
Veggie Patty Sandwich 1
Egg & Cheese Breakfast 1
Chocolate Coated Waffle Cone w/ Soft Serve 1
Classica Cookies Chocolate Toasted Coconut 80 g 1
15Cinnamon Sugar 60 g 1

Day 3
Buy:
Booster Bake 1
Plain Waffle Cone with Soft Serve 1
Cheese & Bacon Gourmet Fries 1
Bacon Grilled Breakfast Wrap 1
Homestyle Biscuit 1

Day 4
Buy:
Egg White & Cheese Breakfast 1
Bacon, Egg & Cheese Breakfast 1
Peanut Buster? Parfait 1
A&W Fries _ regular 1

Day 5
Buy:
Meatball Marinara Sandwich 1
Sausage, Egg White & Cheese Breakfast 1
English Muffin, Egg, Cheese 1
Cinnamon Roll-Glazed 1

Day 6
Buy:
Philly Cheesesteak - Small 1
Ultimate Gourmet Fries 1
Sausage Grilled Breakfast Wrap 1
Cinnamon Roll-Frosted 1

Day 7
Buy:
Pizza Sub Melt Sandwich 1
Buffalo Chicken Sandwich 1
Bagel B.E.L.T. 1
Danish-Cherry Cheese 1

Non-Pregnant Woman Weekly Diet

Day 1
Buy:
Poutine 2
Orange Sat Small 1
Chocolate Dip 60 g 1
Strudel-Strawberry Cheese 1

Day 2
Buy:
Bacon, Egg & Cheese Breakfast 1
Chocolate Coated Waffle Cone w/ Soft Serve 1
Original Fries 1
Hearty Potato Bacon Soup 284 mL 1

Day 3
Buy:
Egg & Cheese Breakfast 1
Pina Colada Small 1
Sundae, Cherry - Medium 1
Cheese & Bacon Gourmet Fries 1

Day 4
Buy:
Booster Bake 1
Cheese Gourmet Fries 1
Chubby Chicken? Burger 1
Poutine 1

Day 5
Buy:
Pizza Sub Melt Sandwich 1
Soups Red Thai Chicken Curry 250 1
Tripleberry Medium 1
Sausage Grilled Breakfast Wrap 1

Day 6
Buy:
Greek Yogurt Mixed Berry 2
Berry Pomegranate Small 1
Chicken California - Small 1
Veggie Delight - Small 1

Day 7
Buy:
Ham, Egg & Cheese Breakfast 1
Soups Cream of Vegetable 250 1
Pina Colada Large 1
Bistro French Onion Soup 284 mL 1

	19-30 Yr Old Woman	19-30 Yr Old Pregnant Woman
Vendor #	Items Bought from Vendor	Items Bought from Vendor
1	3	3
2	0	0
3	0	0
4	0	0
5	2	1
6	2	2
7	0	0
8	0	0
9	1	0
10	0	0
11	5	3
12	0	0
13	4	3
14	4	6
15	0	0
16	1	1
17	0	0
18	0	0
Class #	Types of Meals Bought	Types of Meals Bought
1	7	12
2	4	3
3	4	0
4	4	6
5	1	0
6	0	0
7	3	2
8	3	4
Total	19	17
Nutrition Info	Total Consumption	Total Consumption
1	10516	11580
2	444	544
3	168	210
4	7	7
5	1103	1345
6	17820	19360
7	1375	1348
8	92	104
9	545	342
10	297	358
11	381	412
12	211	406
13	140	138
14	360	202
15	14	14
16	10	3
17	19	18
18	7	13
19	1	2
20	8	10
21	15	22
22	0	1
	Total Cost	Total Cost
	105.72	92.53

REFERENCES

[1] A and W Nutrition Information. http://www.awrestaurants.com/sites/all/themes/aw/pdf/A&W_Nutrition_Guide_10_2014.pdf. Accessed: 2016-11-20.

[2] Booster Juice Nutrition Information. https://www.healthyfamiliesbc.ca/sites/hfbcprox-prod.health.gov.bc.ca/files/restaurant_info/945_BoosterJ_Nutritional_InformedDining_32x42_Nov7.pdf. Accessed: 2016-11-20.

[3] Burger King Nutrition Information. http://burgerking.ca/pdfs/CA/nutrition.pdf. Accessed: 2016-11-20.

[4] Charleys Philly Steaks Nutrition Information. http://charleys.com/Data/Sites/1/skins/Charleys/pdf/Nutritional%20Guide_1-16.pdf. Accessed: 2016-11-20.

[5] Cultures Nutrition Information. http://www.cultures-restaurants.com/menu/Cultures_Nutritional_Info_June2014.pdf. Accessed: 2016-11-20.

[6] Fresh Slice Nutrition Information. http://www.freshslice.com/nutrition-chart/. Accessed: 2016-11-20.

[7] KFC Nutrition Information. https://www.kfc.ca/NutritionAllergen.aspx. Accessed: 2016-11-20.

[8] Manchu Wok Nutrition Information. https://manchuwok.com/wp-content/uploads/2014/08/Manchu_Nutritional_Canada_RD21.pdf. Accessed: 2016-11-20.

[9] OPA! Nutrition Information. http://www.opasouvlaki.ca/assets/pdfs/nutrition/western.pdf. Accessed: 2016-11-20.

[10] Orange Julius Nutrition Information. http://www.orangejulius.com/Documents/OJ%20Nutrition%202013%20US_October.pdf. Accessed: 2016-11-20.

[11] Starbucks Nutrition Information. https://www.starbucks.ca/menu/nutrition-info. Accessed: 2016-11-20.

[12] Subway Nutrition Information. http://www.pr.com/upload/presskit_1214_1111255579.pdf. Accessed: 2016-11-20.

[13] Taco Bell Nutrition Information. https://www.tacobell.com/food/nutrition/info. Accessed: 2016-11-20.

[14] Teriyaki Experience Nutrition Information. http://www.teriyakiexperience.com/nutrition-calculator/. Accessed: 2016-11-20.

[15] Thai Express Nutrition Information. https://www.thaiexpress.ca/wp-content/uploads/2012/08/Nutrition_en.pdf. Accessed: 2016-11-20.

[16] Tim Hortons Nutrition Information. https://www.timhortons.com/ca/en/pdf/TH_Nutrition_Guide_CE_2013_-_FINAL.pdf. Accessed: 2016-11-20.

[17] G. Dantzig. The diet problem. *Interfaces*, 20(4):43–47, 1990.

[18] D.Sklan and I.Dariel. Diet planning for humans using mixed-integer linear programming. *British Journal of Nutrition*, 70(4):27–35, 1993.

[19] P.Calkins. Nutritional adaptations of linear programming for planning rural development. *American Journal of Agricultural Economics*, 63(2):247–254, May 1981.

[20] P.Conforti and A.DAmicis. What is the cost of a healthy diet in terms of achieving rdas? *Public Health Nutrition*, 3:367–373, 2000.

[21] P.Leung, K.Wanitprapha, and L.Quinn. A recipe-based, diet-planning modelling system. *British Journal of Nutrition*, 74:151–162, 1995.

[22] R.Armstrong and P.Sinha. Application of quasi-integer programming to the solution of menu planning problems with variable portion size. *Management Science*, 21(4):474–482, 1974.

[23] S.Garille and S.Gass. Stiglers diet problem revisited. *Operations Research*, 49(1):1–13, 2001.