Feeding CMU Orientation Using Optimization Techniques

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1 Introduction

Each August, just before the semester begins, Carnegie Mellon's incoming freshmen arrive on campus for their first taste of college life. Many of these students, nervous and inexperienced in managing life on their own, require nutritious meals during orientation to fuel them. However, coordinating meals for 900 students with varying dietary restrictions is a challenging task that can easily lead to overspending and providing unhealthy meal options.

The goal of our project is to create a list of meals to prepare and the corresponding ingredients to buy from local grocers to feed these 900 students during the orientation. This meal plan must meet the nutritional constraints while minimizing the cost of the ingredients and ensuring that all students are adequately fed. Additionally, our work takes into account students' dietary restrictions, such as vegan, dairy-free, and vegetarian preferences, curating the meal list accordingly.

To achieve this, we produced datasets we produced datasets that are an amalgamation of Trader Joe's and Whole Foods products, as well as MealDB database recipes. Using these datasets, we developed two Integer Programming models to optimize the meal plan. The first model treats dietary restrictions as discrete sets, while the second model considers the overlap of dietary restrictions, offering a more nuanced solution.

Our findings indicate that the first model resulted in a meal plan costing \$69,385.63, while the second model costed \$27,016.50 and \$36,813.50 for the two iterations of it. These models not only make sure that each student's dietary needs are met, but also guarantee a cost-effective and efficient meal plan. By providing a practical, scalable solution, our work helps Carnegie Mellon improve the orientation meal experience for incoming freshmen that accounts for dietary restrictions and nutrition.

2 The Datasets

To address the challenge of feeding 900 Carnegie Mellon students nutritious and cost-effective meals during orientation, we focused on constructing meals from individual ingredients rather than purchasing pre-made options. This decision required us to gather and process two key datasets:

1. **Recipe Data:** Information about recipes, specifically the list of ingredients and the quantity of each ingredient required to construct meals.

2. **Product Data:** Information about individual food items available at a local grocery store. This data set must include the following attributes:

    - Product name

- Price per unit
- Nutritional information (e.g., calories, protein, fats, carbohydrates, etc.)
- Serving size and number of servings per unit
- Is the product vegan, vegetarian, dairy-free?

2.1 Data Collection

2.1.1 MealsDB Recipe Data:

Recipe data was obtained from MealsDB, a publicly available online recipe database. This data set contains 301 distinct recipes, each listing the required ingredients and their respective quantities. These recipes act as templates for assembling meals that meet our nutritional and dietary restrictions.

2.1.2 Walmart Product Data

At first, we attempted to scrape product data from Walmart's website. However, due to strict CAPTCHA protections that prevented us from scraping data, we decided to try to scrape product data from other grocers.

2.1.3 Trader Joe's Product Data:

After failing to scrape product data from Walmart's website, We scraped product data from Trader Joe's website. We successfully scraped 986 products from their website. Many of their products and seasonal items, including most of their basic ingredients (e.g., fruits and vegetables), lacked nutritional information. We filled the missing nutrition information by mapping those products to foods from the USDA's product and food nutrition databases. We labelled each product as vegan, vegetarian, and dairy-free by finding the products with keywords (e.g. milk, cheese, etc.). We then mapped the products to ingredients in our recipe data set and ran our IP results (shown in Model 1). However, it produced unrealistic and unreasonable results, so we restarted our analysis by scraping data from Whole Foods instead.

2.1.4 Whole Foods Product Data:

Finally, we collected product data from the Whole Foods website because Whole Foods is close to Carnegie Mellon University and because the website provided the most comprehensive nutritional information and was the most accessible for data collection. Whole Foods offers detailed product attributes, including serving sizes, calories, and macronutrient breakdowns, as well as indicating whether each product is vegan, vegetarian, dairy-free, and so on. The scraping process resulted in a data set of 8,673 unique products. We cleaned this data, mapped it to the recipes in the recipes dataset, and solved an IP based on it (results in Model 2).

2.2 Data Integration: Mapping Ingredients to Products

A significant challenge we faced was matching the ingredients listed in the recipes with the corresponding products from the products data sets. Ingredient names often differ in format, plurality, and specific wording, which required an automated solution for accurate mapping.

To address this, we implemented a similarity-based mapping algorithm that operates as follows:

- **Text Normalization:** Both ingredient names and product names were normalized to improve comparability:
  - Converted all text to lowercase
  - Removed extra spaces
  - Singularized words using the `inflect` library (e.g., "apples" becomes "apple")
- **Similarity Matching:** We calculated the similarity between normalized ingredient names and product names using TF-IDF vectorization and cosine similarity. The process works as follows:
  1. Ingredient names and product names were converted into TF-IDF vectors.
  2. The cosine similarity score between each ingredient and all products was calculated.
  3. The product with the highest similarity score was chosen as the best match for the given ingredient.

To ensure compatibility between the product and recipe datasets, all units of measurement were converted to a standardized format (e.g., grams, liters) when applicable. This step was crucial for accurately comparing quantities and calculating the cost and nutritional values of meals.
The resulting mapping aligns recipe ingredients with specific products in the Whole Foods dataset, allowing accurate cost and nutrition calculations. An example of the mapping process is shown below.

Ingredient: "green apples"
Normalized Ingredient: "green apple"
Matched Product: "Whole Foods Organic Granny Smith Apples"

The final mappings were saved in a structured JSON format for use in our optimization models, ensuring a seamless connection between the recipe data set and the Whole Foods product data.

3 Model 1

Model 1 was based on products from Trader Joe's and recipes from MealDB.

First, we set an Integer Program that focuses on minimizing cost of meals for students with three dietary restrictions: Vegan, Vegetarian, and Unrestricted. This model serves as the foundation for creating a meal plan that meets the nutritional needs of students while minimizing costs. By considering these dietary preferences, the model makes sure that each group receives meals tailored to their needs. This Integer Program is set up to be the basic foundation, so that we can add additional constraints later on easily, such as ingredient availability or more specific dietary requirements.

3.1 Model Assumptions

3.2 The variables

- x_m denote the number of times meal m is selected.
- q_i denote the amount of ingredient i purchased.
- $p_{m,i}$ is the amount of ingredient i used in meal m.
- c_i is the cost of ingredient i

3.3 Objective Function

Minimize the total cost of ingredients:

$$\text{Minimize:} \quad \sum_{i \in \text{Ingredients}} c_i \cdot q_i$$

3.4 Constraints

Nutritional Constraints (scaled by number of students):

These constraints make sure that each student's daily nutrition are met according to their dietary preferences (Vegan, Vegetarian, or Unrestricted). The constraints are scaled by the number of students, certifying that the total nutritional intake is sufficient for the entire group. The nutritional data are sourced from the FDA, with gaps filled with additional sources cited in Section 7.

- **Caloric Intake Constraint:**

$$\sum_{m \in \text{diet}} \text{calories}_m \cdot x_m \geq 2000 \cdot |students|$$

  This constraint ensures that the total number of calories consumed by the students in each dietary group is at least 2000 calories per student.

- **Protein Intake Constraint:**

$$\sum_{m \in \text{diet}} \text{Protein}_m \cdot x_m \geq 50 \cdot |students|$$

  This constraint ensures that the total protein intake for each dietary group is at least 50 grams per student.

- **Total Fat Intake Constraint:**

$$\sum_{m \in \text{diet}} \text{TotalFat}_m \cdot x_m \geq 78 \cdot |students|$$

  This constraint guarantees that the total fat intake per student in each dietary group is at least 78 grams.

- **Total Sugar Intake Constraint:**

$$\sum_{m \in \text{diet}} \text{TotalSugars}_m \cdot x_m \geq 90 \cdot |students|$$

  This constraint ensures that the total sugar intake for each dietary group is at least 90 grams per student.

- **Added Sugars Intake Constraint:**

$$\sum_{m \in \text{diet}} \text{AddedSugars}_m \cdot x_m \leq 50 \cdot |students|$$

  This constraint limits the total amount of added sugars per student in each dietary group to a maximum of 50 grams.

- **Meal Selection Constraint:**

$$\sum_{m \in \text{diet}} 1_{\{x_m > 0\}} = 3$$

  This constraint ensures that at least three different meals are selected for each dietary group.

Ingredient Constraints:

$$\sum_{m \in \text{Meals}} p_{m,i} \cdot x_m \leq q_i.$$

This constraint ensures that the total amount of ingredient i used across all selected meals does not exceed the amount of ingredient i purchased.

Variable Constraints:

- **Ingredient Cost Constraint:**

$$c_i \in \mathbb{R} \text{ and } c_i \geq 0$$

  This means the cost of each ingredient, c_i, is a non-negative real number (it can be zero, but not negative. For example, water has cost 0 in the dataset).

- **Ingredient Quantity Constraint:**

$$q_i \in \mathbb{N}$$

  This constraint ensures that the quantity of each ingredient, q_i, is a natural number. You cannot purchase a fractional ingredient.

- **Meal Selection Constraint:**

$$x_m \in \mathbb{N}$$

  This means that the number of times meal m is selected, x_m, must be a natural number. You cannot make a fraction of a meal.

- **Ingredient Usage Constraint:**

$$p_{mi} \in \mathbb{R} \text{ and } p_{mi} \geq 0$$

  This means the amount of ingredient i used in meal m, p_{mi}, is a non-negative real number. You can use non-fractional portions of ingredients when making meals.

3.5 Solving the IP

The IP was solved Python PuLP. The implementation details are in Section 8.1.

3.6 Results

The optimal meal plan cost $69,385.63 and its details are shown in Tables 1 and 2:

Dish	**Times Served**
Beetroot Soup (Borscht)	2031.0
Tamiya (Egyptian Falafel)	101.0
Vegan Chocolate Cake	568.0

Table 1: Frequency of Dishes Served

Nutrient	**Average Value**
Calories	2021.76
Total Sugars	91.85g
Added Sugars	13.32g
Protein	50.12g
Total Fat	552.95g

Table 2: Average Nutrition Per Student

The meal plan generated by our model, which costs $69,385.63 meets the nutritional needs of the students and does have meals that are acceptable for each dietary restriction. One notable feature of the plan is the prominent inclusion of Borscht, which is selected 2,031 times. Borscht is categorized as a vegan meal in our dataset and, while it provides a substantial portion of the required nutrients, it is also relatively expensive. This higher cost of one of the prominent meals results in the overall cost being high, something that we look to decrease in further iterations.

In terms of nutritional content, the meal plan provides an average of 2021.76 calories per student, which is very close to the minimum daily requirement of 2,000 calories. The average protein intake is 50.12 grams, which also aligns closely with the recommended minimum of 50 grams. Total sugars are calculated at 91.85 grams, which is slightly above the required intake of 90 grams, with 13.32 grams coming from added sugars, well within the acceptable limit of 50 grams.

However, the total fat intake is 552.95 grams, which is significantly higher than the minimum requirement of 78 grams. This could be explained by the presence of certain meals, particularly the Vegan Chocolate Cake and the Tamiya, which have high fat content, but are choose by the model due to be high in calories, something Borscht is not. This large amount of total fat, while common is cheap food such as fast food, should be a focus of minimizing, as it is unhealthy and not balanced choice.

Something to note is that the model choose vegan meals for each of the dishes, which, while fits under all of the dietary restrictions, is not preferable in a real-world scenario. This is something to consider for future iterations.

4 Model 2

Model 2 was based on products from Whole Foods and recipes from MealDB.

In this model, we aim to estimate the minimum cost of feeding all the students in the orientation for a single day according to their possible dietary restrictions. We first classified all the students into five groups: vegan group, vegetarian and dairy-free but not vegan group, dairy-free but not vegetarian group, vegetarian but not dairy-free group, and no restriction group. We also classified the meals and snacks into five groups each according to similar rules as we did on students. In addition, we assume that the appropriate lower bounds for a college student's need per day for calories, sugar, protein, and fat are 2500 calories, 20g, 50g, and 70g, respectively. This standard comes from the average values of the nutrition required by men and women per day.

We also present an upgraded version of Model 2. This version not only satisfies the nutritional requirements and students' dietary restrictions but also ensures that each student can have at least one share of snack. Admittedly, the optimal cost of the upgraded version would be higher than the original one, leading to trade-offs between the total cost and the diversity of food provided.

4.1 The Variables

- x_m: Quantities of meal $m \in M$, where M is the set of meals.
- y_s: Quantities of snack $s \in S$, where S is the set of snacks.
- M_1, M_2, M_3, M_4, M_5: Subsets of M representing meals for the five student groups (vegan, vegetarian and dairy-free, dairy-free but not vegetarian, vegetarian but not dairy-free, and unrestricted) (visualized in Figure 1).
- n_1, n_2, n_3, n_4, n_5: Number of students in each group (visualized in Figure 2).
- S_1, S_2, S_3, S_4, S_5: Subsets of S representing snacks for the five student groups.
- c_m: Cost of meal m.
- c_s: Cost of snack s.
- a_{mj}: Amount of nutrition j in meal m.
- a_{sj}: Amount of nutrition j in snack s.
- $p_{m,i}$: Amount of ingredient i used in meal m.
- q_i: Quantity of ingredient i purchased.
- d_j: Daily nutritional requirement for nutrient j.

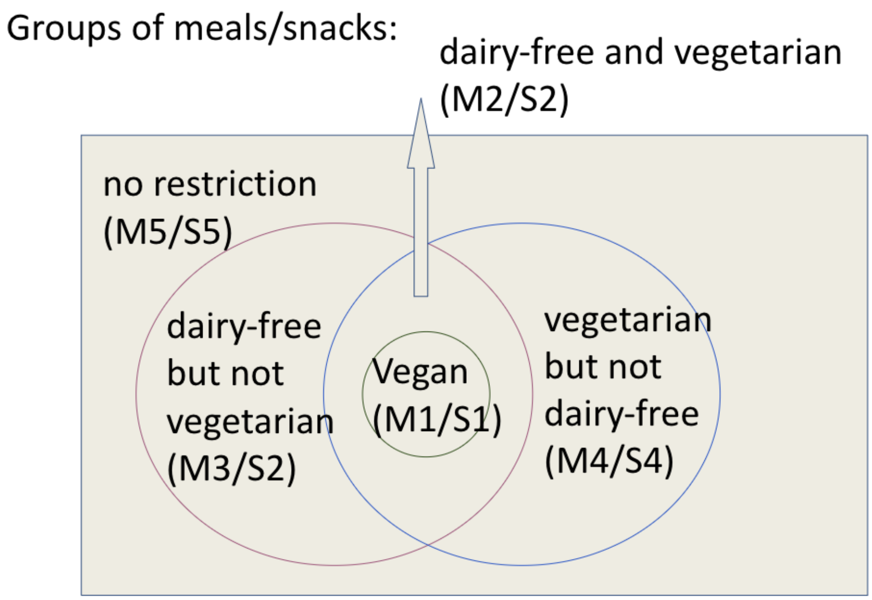

Figure 1: Five groups of meals and five groups of snacks.

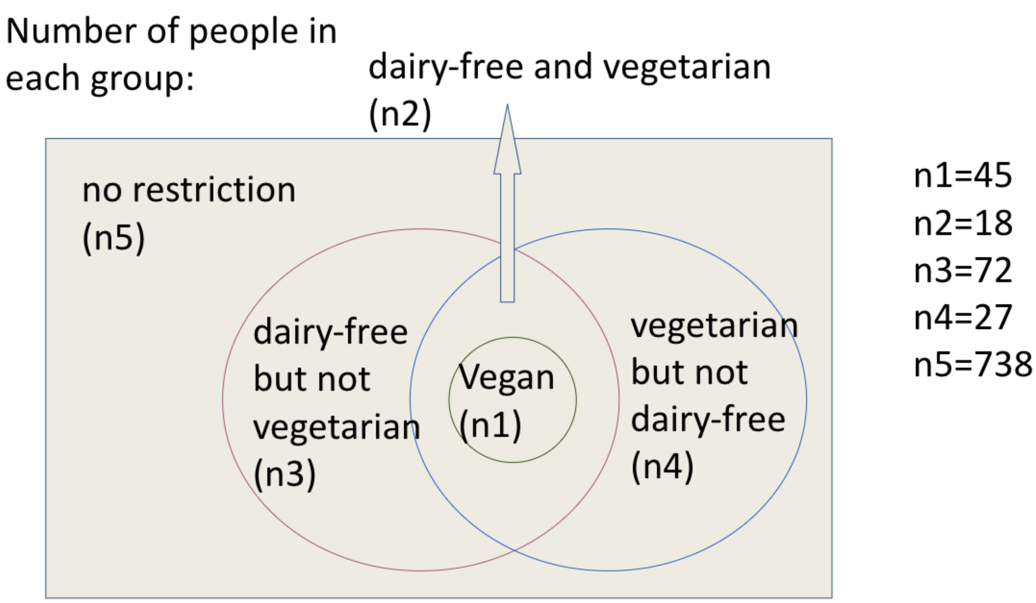

Figure 2: Five groups of students and the number of students in each group.

4.2 Objective Function

Minimize the total cost of all meals and snacks:

$$\text{Minimize:} \quad \sum_{m \in M} c_m \cdot x_m + \sum_{s \in S} c_s \cdot y_s.$$

4.3 Constraints

Total Nutritional Requirements: The meals and snacks selected must meet the nutritional needs for each student group:

$$\sum_{m \in M_1} a_{mj} x_m + \sum_{s \in S_1} a_{sj} y_s \geq d_j \cdot n_1 \qquad \forall j,$$

$$\sum_{m \in M_1 \cup M_2} a_{mj} x_m + \sum_{s \in S_1 \cup S_2} a_{sj} y_s \geq d_j \cdot (n_1 + n_2) \qquad \forall j,$$

$$\sum_{m \in M_1 \cup M_2 \cup M_3} a_{mj} x_m + \sum_{s \in S_1 \cup S_2 \cup S_3} a_{sj} y_s \geq d_j \cdot (n_1 + n_2 + n_3) \qquad \forall j,$$

$$\sum_{m \in M_1 \cup M_2 \cup M_4} a_{mj} x_m + \sum_{s \in S_1 \cup S_2 \cup S_4} a_{sj} y_s \geq d_j \cdot (n_1 + n_2 + n_4) \qquad \forall j,$$

$$\sum_{m \in M} a_{mj} x_m + \sum_{s \in S} a_{sj} y_s \geq d_j \cdot (n_1 + n_2 + n_3 + n_4 + n_5) \qquad \forall j.$$

Ingredient Linking Constraint: Ensure that ingredient usage for meals does not exceed the purchased quantity:

$$\sum_{m \in M} p_{m,i} x_m \leq q_i \quad \forall i \in \text{Ingredients}.$$

Snack Constraints (Upgraded Version of Model 2 Only): Ensure each student receives at least one share of snack:

$$\sum_{s \in S_1} y_s \geq n_1,$$

$$\sum_{s \in S_1 \cup S_2} y_s \geq n_1 + n_2,$$

$$\sum_{s \in S_1 \cup S_2 \cup S_3} y_s \geq n_1 + n_2 + n_3,$$

$$\sum_{s \in S_1 \cup S_2 \cup S_4} y_s \geq n_1 + n_2 + n_4,$$

$$\sum_{s \in S} y_s \geq n_1 + n_2 + n_3 + n_4 + n_5.$$

Non-Negativity Constraints:

$$x_m, y_s, q_i \geq 0 \quad \text{and integer}.$$

4.4 Model Summary

Model 2 considers a more detailed categorization of students and food, ensuring that the nutritional requirements and dietary preferences of each group are satisfied while minimizing costs. The upgraded version introduces an additional constraint to ensure snack distribution, balancing cost-efficiency with diversity and inclusiveness. The inclusion of the ingredient-meal linking constraint further ensures that ingredient usage remains within purchased quantities.

4.5 Dataset

The data set included meals from the recipe dataset and Whole Foods products as snacks. Some of the meals are shown in Figure 3, while some of the snacks are shown in Figure 4.

Name	Calories	Protein (g)	Fat (g)	Sugar (g)	Price ($)	Group
Vegan Mushroom Risotto	350	10	8	5	10.0	M1
Chickpea and Spinach Curry	400	15	12	8	12.5	M1
Vegan Tofu Stir Fry	450	12	10	6	8.0	M1
Vegan Lentil Stew	380	20	14	4	9.5	M1
Vegan Cauliflower Tacos	320	8	6	3	7.0	M1
Vegetarian Pasta Primavera	500	15	12	10	3.0	M2
Quinoa Salad with Avocado	550	18	15	12	2.5	M2
Vegetarian Chili	600	20	14	15	4.0	M2
Sweet Potato and Black Bean Tacos	500	12	16	10	2.8	M2
Vegetarian Mushroom Stroganoff	550	17	14	13	3.5	M2
Grilled Chicken Salad	600	20	18	8	10.0	M3
Beef Stir Fry with Vegetables	700	25	20	7	9.0	M3
Chicken and Vegetable Soup	750	30	24	6	11.0	M3
Lamb Kofta with Couscous	650	28	22	4	8.5	M3
BBQ Grilled Shrimp	500	22	25	9	10.5	M3
Caprese Salad	300	7	7	6	12.0	M4
Eggplant Parmesan	450	9	10	5	15.0	M4
Vegetarian Pizza	500	11	8	3	13.0	M4
Vegetarian Paella	600	14	7	2	14.0	M4
Vegetarian Burger	700	20	10	1	12.5	M4
Grilled Salmon with Asparagus	650	25	28	12	7.5	M5
Beef Steak with Mashed Potatoes	750	30	35	9	8.0	M5

Figure 3: Meal cost and nutritional information

Chicken Alfredo	800	35	30	10	10.0	M5
Pork Tenderloin with Roasted Veggies	900	40	25	5	9.5	M5
Shrimp Scampi with Linguine	1000	45	22	4	13.0	M5
Hummus with Veggies	150	5	8	3	14.5	S1
Vegan Granola Bars	250	6	9	5	12.0	S1
Chia Pudding	180	3	6	7	11.0	S1
Vegan Banana Bread	220	4	7	8	13.5	S1
Hummus with Veggies	150	5	8	3	14.5	S2
Vegan Granola Bars	250	6	9	5	12.0	S2
Chia Pudding	180	3	6	7	11.0	S2
Vegan Banana Bread	220	4	7	8	13.5	S2
Hummus with Veggies	150	5	8	3	14.5	S3
Vegan Granola Bars	250	6	9	5	12.0	S3
Chia Pudding	180	3	6	7	11.0	S3
Vegan Banana Bread	220	4	7	8	13.5	S3
Hummus with Veggies	150	5	8	3	14.5	S4
Vegan Granola Bars	250	6	9	5	12.0	S4
Chia Pudding	180	3	6	7	11.0	S4
Vegan Banana Bread	220	4	7	8	13.5	S4
Hummus with Veggies	150	5	8	3	14.5	S5
Vegan Granola Bars	250	6	9	5	12.0	S5
Chia Pudding	180	3	6	7	11.0	S5
Vegan Banana Bread	220	4	7	8	13.5	S5

Figure 4: Snack cost and nutritional information

4.6 Results

We found that for the original version of the model 2, the optimal solution is to cook the following number of each meal: 152 Vegan Tofu Stir Fry, 117 vegan Lentil Stew, 84 Quinoa Salad with Vegetables, 258 Beef Stir Fry with Vegetables, 67 Caprese Salad, 143 Vegetarian Burger, 934 Beef Steak with Mashed Potatoes, and 1273 Pork Tenderloin with Roasted Veggies. The total cost for this optimal solution is \$27016.5. The nutritional and price information is shown in Figure 5.

Remember that we also have the upgraded version that requires that each student should have one share of snack. For this version, the optimal solution is shown in figure 6. The total cost for this solution is 36813.5

We observed that the the solution 2 has a higher cost than solution 1 probably due to the nature of snacks being high in price and low in nutrition. With all the nutritional constraints satisfied, we can anticipate that containing more snacks in the meal plan results in higher total cost, which means the cost of including more types of meals or snacks is the higher total cost of the food. So there are reasonable trade-offs between the diversity of the food and the total cost.

Solution 1

Name	Type	Group	Calories	Protein (g)	Sugar (g)	Fat (g)	Price ($)	Meal Quantity	Snack Quantity	Quantity
Vegan Tofu Stir Fry	Meal	M1	450	12	6	10	8.0	0	0	152
Vegan Lentil Stew	Meal	M1	380	20	4	14	9.5	0	0	117
Quinoa Salad with Avocado	Meal	M2	550	18	12	15	2.5	0	0	84
Beef Stir Fry with Vegetables	Meal	M3	700	25	7	20	9.0	0	0	258
Caprese Salad	Meal	M4	300	7	6	7	12.0	0	0	67
Vegetarian Burger	Meal	M4	700	20	1	10	12.5	0	0	143
Beef Steak with Mashed Potatoes	Meal	M5	750	30	9	35	8.0	0	0	934
Pork Tenderloin with Roasted Veggies	Meal	M5	900	40	5	25	9.5	0	0	1273

Figure 5: The optimal solution for the original version of model 2.

Solution 2

Name	Calories	Protein (g)	Fat (g)	Sugar (g)	Price ($)	Group	Quantity	Total Cost
Vegan Tofu Stir Fry	450	12	10	6	8.0	M1	152	1216.0
Vegan Lentil Stew	380	20	14	4	9.5	M1	115	1092.5
Hummus with Veggies	150	5	8	3	14.5	S1	0	0.0
Vegan Granola Bars	250	6	9	5	12.0	S1	0	0.0
Chia Pudding	180	3	6	7	11.0	S1	45	495.0
Vegan Banana Bread	220	4	7	8	13.5	S1	0	0.0
Quinoa Salad with Avocado	550	18	15	12	2.5	M2	82	205.0
Hummus with Veggies	150	5	8	3	14.5	S2	0	0.0
Vegan Granola Bars	250	6	9	5	12.0	S2	0	0.0
Chia Pudding	180	3	6	7	11.0	S2	18	198.0
Vegan Banana Bread	220	4	7	8	13.5	S2	0	0.0
Beef Stir Fry with Vegetables	700	25	20	7	9.0	M3	256	2304.0
Hummus with Veggies	150	5	8	3	14.5	S3	0	0.0
Vegan Granola Bars	250	6	9	5	12.0	S3	0	0.0
Chia Pudding	180	3	6	7	11.0	S3	72	792.0
Vegan Banana Bread	220	4	7	8	13.5	S3	0	0.0
Caprese Salad	300	7	7	6	12.0	M4	63	756.0
Vegetarian Burger	700	20	10	1	12.5	M4	143	1787.5
Hummus with Veggies	150	5	8	3	14.5	S4	0	0.0
Vegan Granola Bars	250	6	9	5	12.0	S4	0	0.0
Chia Pudding	180	3	6	7	11.0	S4	27	297.0
Vegan Banana Bread	220	4	7	8	13.5	S4	0	0.0
Beef Steak with Mashed Potatoes	750	30	35	9	8.0	M5	930	7440.0
Pork Tenderloin with Roasted Veggies	900	40	25	5	9.5	M5	1275	12112.5
Hummus with Veggies	150	5	8	3	14.5	S5	0	0.0
Vegan Granola Bars	250	6	9	5	12.0	S5	0	0.0
Chia Pudding	180	3	6	7	11.0	S5	738	8118.0
Vegan Banana Bread	220	4	7	8	13.5	S5	0	0.0

Figure 6: The optimal solution for the upgraded version of model 2.

4.7 Limitations of the Model

- Limited variety: The dataset includes only a few meals and snacks per group, limiting the model's flexibility to satisfy constraints efficiently.

- Nutritional thresholds: Setting hard constraints for 2500 calories, 50g protein, etc., per person may not align with real-world flexibility. Some individuals may require less/more nutrition depending on age, gender, or activity level.

5 Conclusion

In conclusion, we set up two Integer Programs with the goal of curating a meal plan for Carnegie Mellon freshman at their orientation. The Integer Programs aimed to meet their daily nutrition while minimizing cost. The first model, which accounted for vegan, vegetarian, and unrestricted diets resulted in a meal plan costing \$69,385.63. This plan included Borscht, Vegan Chocolate Cake, and Tamiya. It met the nutritional requirements, but was high in cost and very high in total fat.

We had two iterations of the second model, which focused on having separate meals for each of the dietary restrictions. Without the added snack constraint, the model resulted in a optimal solution that cost \$27016.5, which is vastly cheaper than the first model. The results also had higher diversity of meals chosen. We also ran the second model with an additional constraint of requiring that each student to receive a snack. The resulting cost was, as expected, higher, being \$36,813.50. Even with the snack, the meal plan is cheaper than model 1. While the inclusion of the snack leads to more exciting and more diverse options, it increases cost and does not increase nutritional value by a significant amount. Overall, both our models' results successfully met nutritional requirements, with the second more complex model having a lower cost and more diverse meal plan.

6 Future Work

Our work can be expanded upon and improved in various directions. First, we can refine our dataset so that it has higher data quality and include data from more stores, such as Costco or another bulk store. Second, we could add more constraints to make the problem more in line with the real world by considering more dietary restrictions or more nutrition constraints. Third, another option is to consider student feedback to personalize the meal choices. Moreover, scaling up the model for larger groups of students or dividing the meals into times of day such as breakfast, lunch, and dinner could be beneficial.

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8 Implementation

8.1 Trader Joe's Data Collection and Model 1 Code

GitHub repo

https://github.com/DominickRobinson/OR2-Final-Project–Whole-Foods

8.2 Whole Foods Data Collection

GitHub repo

https://github.com/DominickRobinson/OR2-Final-Whole-Foods

8.3 Model 2 Code

GitHub repo

https://github.com/Sherylw/Final-project-model2