Optimized Weekly Meal Planner using MIP Optimization

Cost Minimization and Nutritional Balance

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Overview

- **Goal**: Develop a Mixed-Integer Programming (MIP) model to optimize weekly meal planning.
- **Objective**: Minimize the total cost of meals while satisfying daily nutritional requirements (calories, protein, carbs, fats).
- **Target**: Individuals or organizations interested in optimizing meal plans based on cost and nutrition.

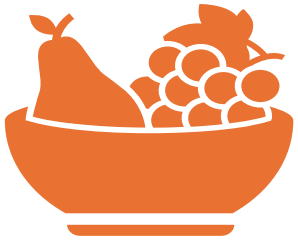
Problem Description

- **Challenge**: Plan meals for the week (7 days) that meet specific nutritional goals, ensure meal variety, and minimize costs.
- **Constraints**:Each day needs exactly one breakfast and two meals (lunch and dinner).
- Ensure at least 4 unique breakfast options and 8 unique lunch/dinner options throughout the week.
- Ensure variety: no breakfast should repeat more than twice in the week; no lunch/dinner option should repeat more than 4 times.
- Meet nutritional goals (e.g., 2000 calories, 100g protein, etc.) while minimizing meal costs.

Optimization Approach

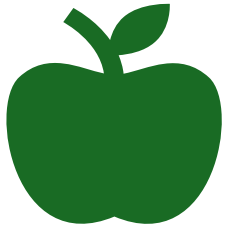
- **Optimization Type**: Mixed-Integer Programming (MIP)
- **Key Elements**:**Objective**: Minimize total meal cost (sum of costs for breakfast, lunch, dinner, and fruit).
- **Decision Variables**:
  - x1[day,breakfast]: Binary variable representing whether a specific breakfast is chosen on a given day.
  - x2[day,meal,lunch/dinner] : Binary variable representing whether a specific lunch/dinner meal is chosen on a given day.
  - y[day,fruit]: Binary variable representing whether a specific fruit is selected on a given day.

Objective Function and Constraints



Objective Function: Minimize the total cost

Total Cost = Sum of (Cost of breakfast + cost of lunch/dinner + cost of fruit) for the entire week.



Key Constraints:

Nutritional Requirements: Each day's meals must satisfy the daily nutritional goals:

- Total Calories ≥ 2000
- Protein ≥ 100g
- Carbohydrates ≥ 250g
- Fats ≥ 70g

Meal Assignment: Each day must have one breakfast and two meals (lunch and dinner).

Objective Function and Constraints

- **Variety Constraints**:
  - **Breakfast Options**: At least 4 different breakfast options selected over the week.
  - **Lunch/Dinner Options**: At least 8 different lunch/dinner options selected over the week.
- **Repetition Constraints**:
  - **Breakfast**: No more than 2 repetitions of the same breakfast in a week.
  - **Lunch/Dinner**: No more than 4 repetitions of the same meal per week.
  - **Fruit Selection:** Each day should have exactly one fruit selected.

Example Inputs & Data

- **Breakfast Meals** (with nutritional values):
- Oatmeal with fruit: 300 calories, 5g protein, 50g carbs, 8g fats, $2
- Eggs and toast: 350 calories, 20g protein, 30g carbs, 15g fats, $3
- Yogurt with granola: 250 calories, 15g protein, 40g carbs, 8g fats, $2.5 etc.
- **Lunch/Dinner Meals** (with nutritional values):
- Chicken Bowl: 600 calories, 40g protein, 50g carbs, 20g fats, $5
- Pizza: 800 calories, 30g protein, 90g carbs, 30g fats, $7
- Spaghetti: 700 calories, 25g protein, 90g carbs, 15g fats, $6 etc.
- **Fruits** (with nutritional values):
- Apple: 95 calories, 0g protein, 25g carbs, 0g fats, $1
- Banana: 105 calories, 1g protein, 27g carbs, 0g fats, $1 etc.

Optimization Output (Example)

Example Output (Day 1):

- **Breakfast**: Yogurt with granola
- **Lunch**: Chicken Bowl
- **Dinner**: Spaghetti
- **Fruit**: Apple

Cost Breakdown for Day 1:

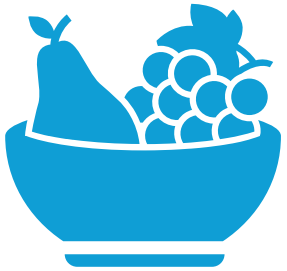
- Breakfast: $2.5
- Lunch: $5
- Dinner: $6
- Fruit: $1

Total Cost for Day 1: $14.5

Weekly Cost Optimization Output

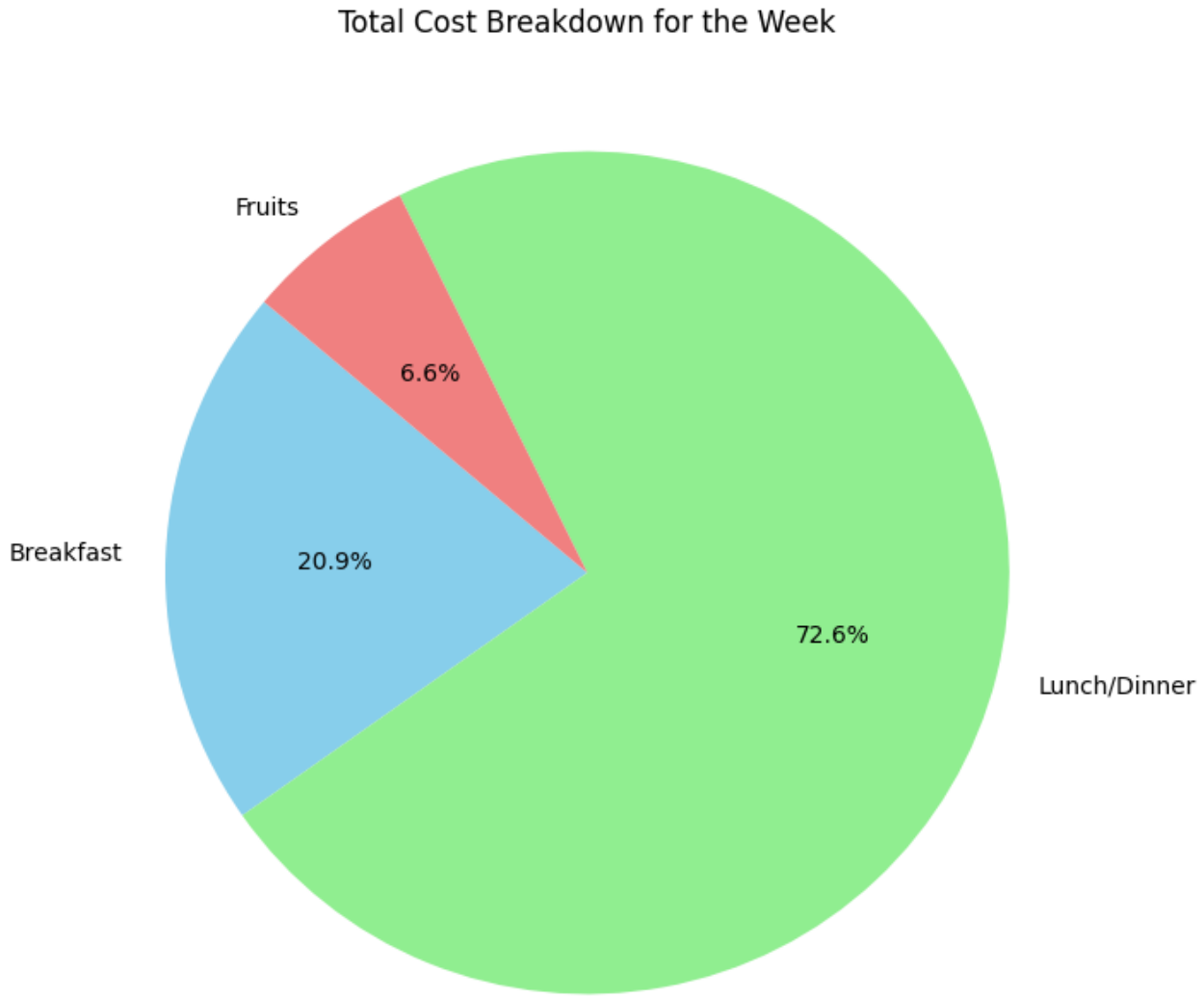
Total Weekly Cost: After solving the optimization, the model selects meals that satisfy all constraints and minimize the overall cost while ensuring nutritional requirements are met.

Weekly Meal Plan: Each day's meals and their associated costs.



Total Cost for the Week: Calculated total cost based on the selected meals and fruit.

Total Cost Breakdown for the Week



Output of the Optimization Model

Day	Breakfast	Lunch	Dinner	Fruit
Day 1	Eggs and toast	Black Bean Bowl	Quinoa Salad	Strawberry
Day 2	Pancakes	Spaghetti	Soup	Orange
Day 3	Yogurt with granola	Pizza	Taco Bowl	Banana
Day 4	Avocado toast with egg	Quinoa Salad	Veggie Burger	Apple
Day 5	Granola with milk	Veggie Stir Fry	Grilled Chicken Salad	Orange
Day 6	Smoothie (Banana, Spinach, Protein)	Cauliflower Rice Bowl	Quinoa Salad	Banana
Day 7	Oatmeal with fruit	Chicken Bowl	Grilled Salmon	Grapes

Performance and Feasibility

Solver Performance: The optimization solver (CBC) was able to find an optimal solution within a reasonable time

Feasibility: The model respects all constraints, ensuring nutritional balance, meal variety, and cost minimization.

Scalability: The model can easily scale to larger datasets with more meals, dietary restrictions, or changing requirements.

Key Takeaways

Value of the Model:

- **Cost Efficiency**: Minimizes meal costs while ensuring balanced nutrition.
- **Variety**: Prevents meal repetition, ensuring diverse options.
- **Nutritional Balance**: Meets required daily intake for calories, protein, carbs, and fats.

Impact: Ideal for organizations or individuals looking for cost-effective and healthy meal planning solutions.