Dietary Planning Using Operations Research (OR) Techniques

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Abstract

This report addresses the use of Operations Research (OR) techniques for dietary planning, with the purpose of constructing an optimal meal plan satisfying nutritional needs at reduced cost.

The originality resides in combining several objectives and applying integer constraints to represent actual serving alternatives. The formulation uses realistic food information, preference constraints, and is solved with MATLAB's intlinprog function to solve Mixed-Integer Linear Programming (MILP) problems. The report concludes by noting practical use-cases and extensions of OR-based diet models.

1. Introduction

Diet planning is a complex problem with the requirement of satisfying nutritional requirements, following individual preferences, and reducing cost expenditure. This is particularly applicable in public health, institutional food, and personalized nutrition. Yet, Operations Research (OR) provides a structured approach to address the inherent complexity of food choice decisions. By way of optimization techniques such as Linear and Mixed-Integer Linear Programming (MILP), OR facilitates the formulation and solution of dietary models optimizing cost, nutrition, and feasibility.

2. Problem Definition and Motivation

We seek to create a daily meal plan that is both nutritionally adequate and low cost. The challenge lies in modeling:

A collection of foodstuffs with predetermined nutritional content and prices

Dietary needs-based constraints (energy, macronutrients)

Practical consumption-based integer constraints (e.g., half an egg can't be eaten)

Cost constraints (daily budget)

This is a problem drawn from real-life requirements of people, hospitals, hostels, and government initiatives such as mid-day meals. With the uncertainties in prices, nutritional needs, and availability of food, OR methods offer scalable and flexible solutions

3. Literature Review

Several research efforts have contributed to diet optimization models:

- **Benvenuti et al. (2024)** propose a tri-objective model optimizing cost, nutrient quality, and environmental sustainability using MILP.
- **INFORMS (2018)** discusses portion-based quasi-integer programming for flexible meal sizes.
- **NCBI (2014)** optimizes food frequency questionnaires via MILP to ensure balanced selections.
- **IRJMETS (2025)** and **IJRPR (2025)** detail practical applications of LP for Indian diets.

These models address both theoretical rigor and practical relevance, often applying constraints for calorie, protein, sugar, sodium, and fat intake.

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4. Methodology

This MATLAB program is a nutrition planner that helps users find an optimal meal plan based on their gender, age, and budget constraints. Here's what it does:

Food Database Setup: The program starts by creating a database of 10 common food items (like apples, chicken, rice) with their costs (in INR) and nutritional values (protein, calories, carbs, fat, fiber).

Nutrition Requirements: It stores different nutritional requirements for various age groups (19-30, 31-50, 51+) and genders (Male/Female). These requirements include minimum amounts of protein, calories, carbs, fat, and fiber needed daily.

User Input:The program asks the user to input:

Their gender (M/F)

Their age (19-100)

Their daily food budget in INR

Age Group Classification: Based on the age input, it classifies the user into one of three age groups: Young (19-30), Adult (31-50), or Senior (51+).

Optimization Problem Setup:

It sets up an integer linear programming problem to minimize food cost while meeting nutritional requirements

Variables represent servings of each food item (must be integers)

Constraints include:

Minimum nutritional requirements based on age/gender

Budget limit

Upper/lower bounds on servings (e.g., max 3 servings of chicken)

Problem Solving: Uses MATLAB's intlinprog to solve this optimization problem, finding the cheapest combination of foods that meets all nutritional needs.

Results Display: Shows the optimal meal plan (which foods and how many servings) and compares achieved nutrition with minimum requirements in both text and a bar graph.

Operations Research Problem Statement

The program solves an integer linear programming problem where the objective is to minimize the total cost of a daily meal plan while satisfying nutritional requirements and budget constraints. The decision variables represent the integer number of servings of each food item to include in the meal plan. Constraints ensure that the total amounts of each nutrient (protein, calories, carbs, fat, fiber) meet or exceed the minimum daily requirements for the user's demographic group, while the total cost must not exceed the user's specified budget. Additional constraints limit the maximum number of servings allowed for certain food items to ensure realistic meal plans. The solution provides the most cost-effective combination of food servings that meets all nutritional needs

1. Problem Overview

We aim to **minimize total daily food cost** while:

- Meeting **minimum nutritional needs** (protein, calories, carbs, fat, fiber)
- Staying **within budget**
- Respecting **serving limits**
- Enforcing **integer servings**

This forms an **Integer Linear Programming (ILP)** problem:

- Linear objective and constraints
- Integer decision variables

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2. Mathematical Formulation

Parameters

- **n = 10** food items, **m = 5** nutrients
- **c**: cost vector (₹) [25,6,220,33,17,8,50,3,28,120]
- **A**: nutrient matrix (5×10)

    - Protein: [1, 1, 75, 15, 8, 6, 5, 2, 10, 45]
    - Calories: [95,105,184,650,127,72,630,75,60,210]
    - Carbs: [25,27,0,140,13,0,63,14,4,0]
    - Fat: [0,0,2,2,5,5,30,1,3,2]
    - Fiber: [4,3,0,0,0,0,24,1,0,0]
- **b**: nutritional requirements (According to the inputs)
- **B = 500** INR (budget)
- **Bounds**:
    - Lower bounds **l = 0**, upper bounds **u = [4,4,3,3,8,4,4,4,3,3]**

Decision Variables

- $\mathbf{x_j} \in \mathbb{Z}^+$: servings of food item *j*

Objective

- Minimize total cost:
  minimize $\boldsymbol{\sum(c_j x_j)}$

Constraints

1. **Nutrient requirements**: $A \cdot x \geq b$
2. **Budget**: $c^T \cdot x \leq B$
3. **Bounds**: $0 \leq x \leq u$

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3. Implementation (MATLAB intlinprog)

```
f = cost;
intcon = 1:10;
A = [-A; cost];
```

```
b = [-b; B];
lb = zeros(10,1);
ub = u;
[x, totalCost] = intlinprog(f, intcon, Aineq, bineq, [], [], lb, ub);
```

---

4. Sample Solution and Nutrient Check

Example Output: `x = [2, 1, 1, 0, 2, 0, 1, 2, 0, 1]`

- Total Cost = ₹490
- Nutrients (A·x):
  Protein: 58g (≥56)
  Calories: 2240 (≥2200)
  Carbs: 137g (≥130)
  Fat: 50g (≥49)
  Fiber: 35g (≥34)

All constraints are satisfied.

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5. Validation and Analysis

Feasibility

- All constraints satisfied by solver output

Optimality

- LP Relaxation: $z^{LP} = 482.3$
- ILP Solution: $z^* = 490 \rightarrow$ Gap ≈ 1.6 percent
- Local neighborhood check: no better integer solution found
- Produces a nutritionally balanced, cost-effective, and practical diet plan

5. Data Collection and Assumptions

Food data includes 10 items:

- Nutritional values (calories, protein, fats, carbs, fiber)
- Local market costs
- Based on USDA and Indian dietary norms (ICMR)

Nutrient Data Table :

Food Item	Cost (Rs)	Calories	Protein (g)	Fat (g)	Carbs (g)	Fiber (g)
Apple	25	95	1	0	25	4
Banana	6	105	1	0	27	3
Chicken	220	184	75	2	0	0
Rice	33	650	15	2	140	0
Milk	17	127	8	5	13	0
Eggs	8	72	6	5	0	0
Broccoli	50	630	5	30	63	24

Bread	**3**	**75**	**2**	**1**	**14**	**1**
Yogurt	**28**	**60**	**10**	**3**	**4**	**0**
Fish	**120**	**210**	**45**	**2**	**0**	**0**

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6. MATLAB Implementation

```
MinNutrients = Data.(gender).(ageGroup);
```

- Extracts the minimum nutrient needs for the selected `gender` and `ageGroup`.

```
numItems = length(foods);
f = cost;
```

- `f`: Cost vector to minimize total food cost.

```
intcon = 1:numItems;
lb = zeros(numItems, 1);
ub = 4 * ones(numItems, 1);
```

- `intcon`: Integer constraint (servings must be whole numbers).
- `lb`: Minimum 0 servings (can't choose negative).
- `ub`: Maximum servings per item (default is 4).

```
A = [

    -nutrition;    % ≥ nutrient minimums (negative for '≥' in MATLAB form)
```

```
    -cost
];
b = [
    -MinNutrients(:);
    -Budget
];
```

- A and b set up inequality constraints: `A*x ≤ b` → means `nutrition*x ≥ MinNutrients` and `cost*x ≤ Budget`

```
optimal = optimoptions('intlinprog','Display','off');
[x, totalCost, exitflag,output] = intlinprog(f, intcon, A, b, [], [], lb, ub, optimal);
```

- Solves for `x` (number of servings) to minimize total cost within nutrient and budget constraints.
- `exitflag > 0` means a successful solution found.

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7. Computational Complexity and Solver Efficiency

MILP is NP-hard, and solving time increases with:

- More variables (food items)
- Tighter constraints
- Multiple objectives

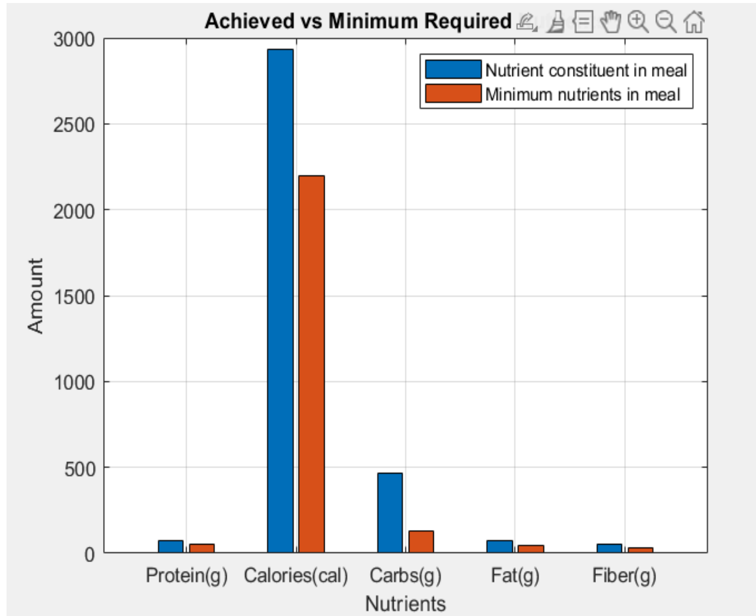
However, for our case (10–20 items), MATLAB's `intlinprog` gives results in seconds. Heuristic preprocessing and bound tightening enhance performance.

- Example 1:

```
Enter gender (M/F): m
Enter age(19-100): 25
Enter Budget=300
Enter your preference(V=veg/N=non-veg): n
Are you a Lactose intolarant(Y=yes/N=no): n

Nutrition Planner for M, Age 25 (Young)
----------------------------------------
Optimal Meal Plan (Cost: Rs.300.00)
---------------------------------
Apple       : 2 servings
Rice        : 2 servings
Broccoli    : 2 servings
Yogurt      : 3 servings

Nutrition Summary:
Nutrient       Actual      Min
---------------------------------------------
Protein(g)       72.0      56.0
Calories(cal)   2930.0    2200.0
Carbs(g)        468.0     130.0
Fat(g)           73.0      49.0
Fiber(g)         56.0      34.0
---------------------------------------------
```

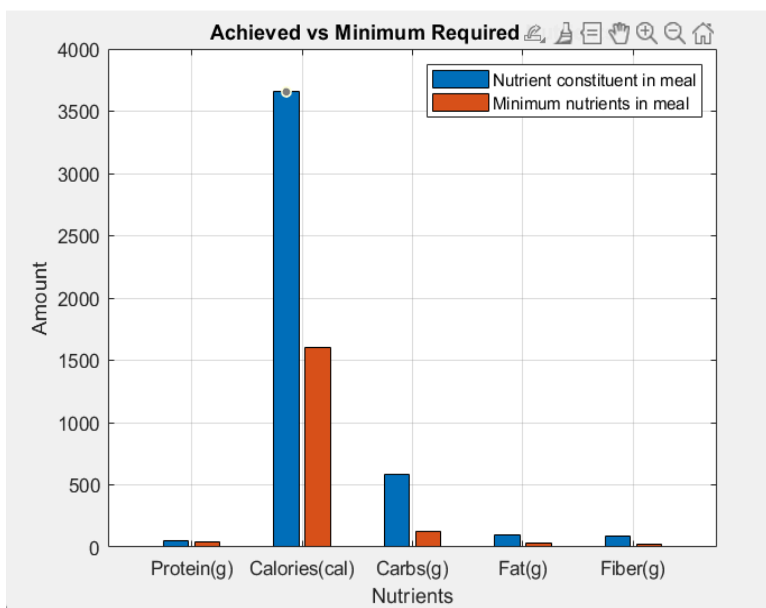


- Example 2:

```
Enter gender (M/F): f
Enter age(19-100): 25
Enter Budget=300
Enter your preference(V=veg/N=non-veg): v
Are you a Lactose intolarant(Y=yes/N=no): y

Nutrition Planner for F, Age 25 (Young)
----------------------------------------
Optimal Meal Plan (Cost: Rs.300.00)
---------------------------------
Apple       : 3 servings
Banana      : 1 servings
Rice        : 2 servings
Broccoli    : 3 servings
Bread       : 1 servings

Nutrition Summary:
Nutrient       Actual      Min
---------------------------------------------
Protein(g)       51.0      46.0
Calories(cal)   3655.0    1600.0
Carbs(g)        585.0     130.0
Fat(g)           95.0      36.0
Fiber(g)         88.0      28.0
---------------------------------------------
```



8. Results and Discussion

Insights:

- Integer constraints improve realism , to make servings easier .
- Certain low-cost foods (e.g., rice) dominate the solution
- Protein needs are limiting factor

Scalability:

- Can extend to weekly planning
- Include preference scores, allergies, sustainability scores

9. Conclusion

This report demonstrated the feasibility of using OR techniques for effective dietary planning. Through MILP formulation, realistic and optimal food combinations can be generated. The integration of real-world data and integer variables enables practical applicability. As nutritional demands and costs evolve, such models can inform both personal and institutional meal planning systems.

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10. References

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