DECEMBER 2, 2024

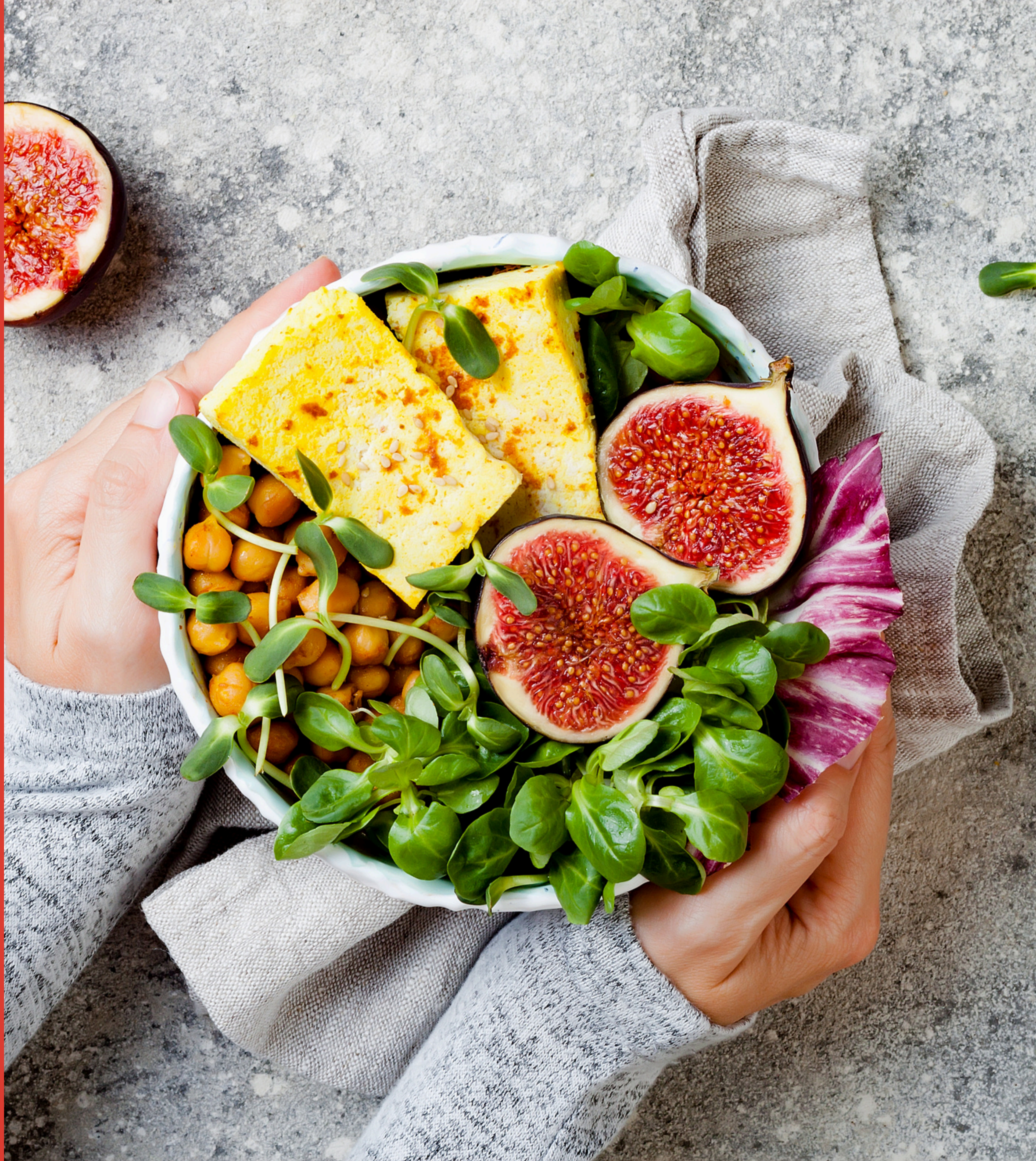
Retirement Home Meal Ordering Optimization

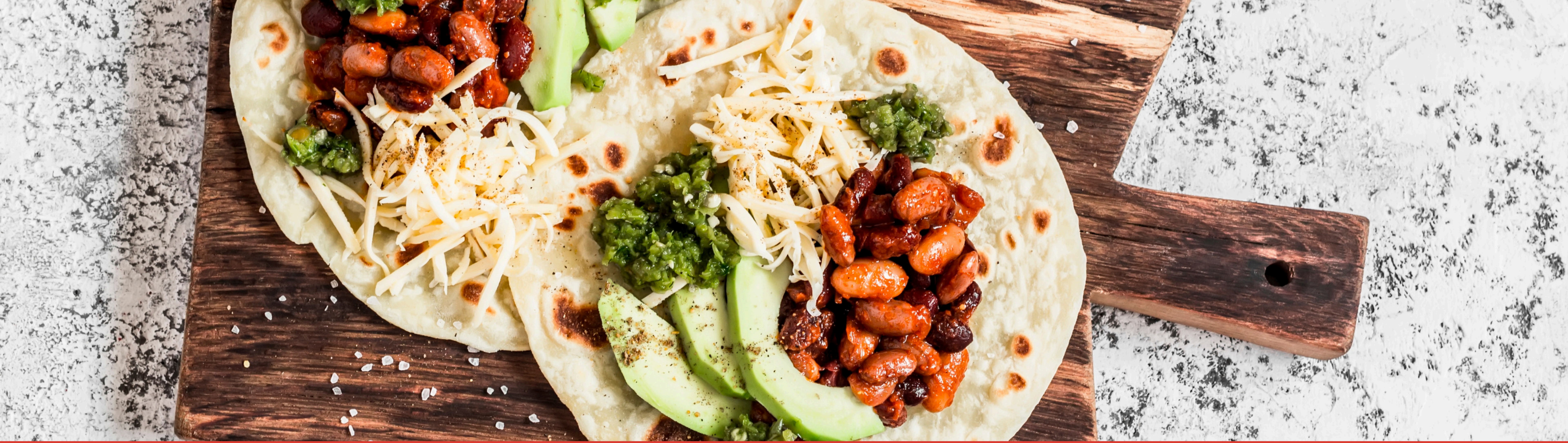
Team 10: Grace, Victor, Ya Ya, Sneha

01

Problem Statement

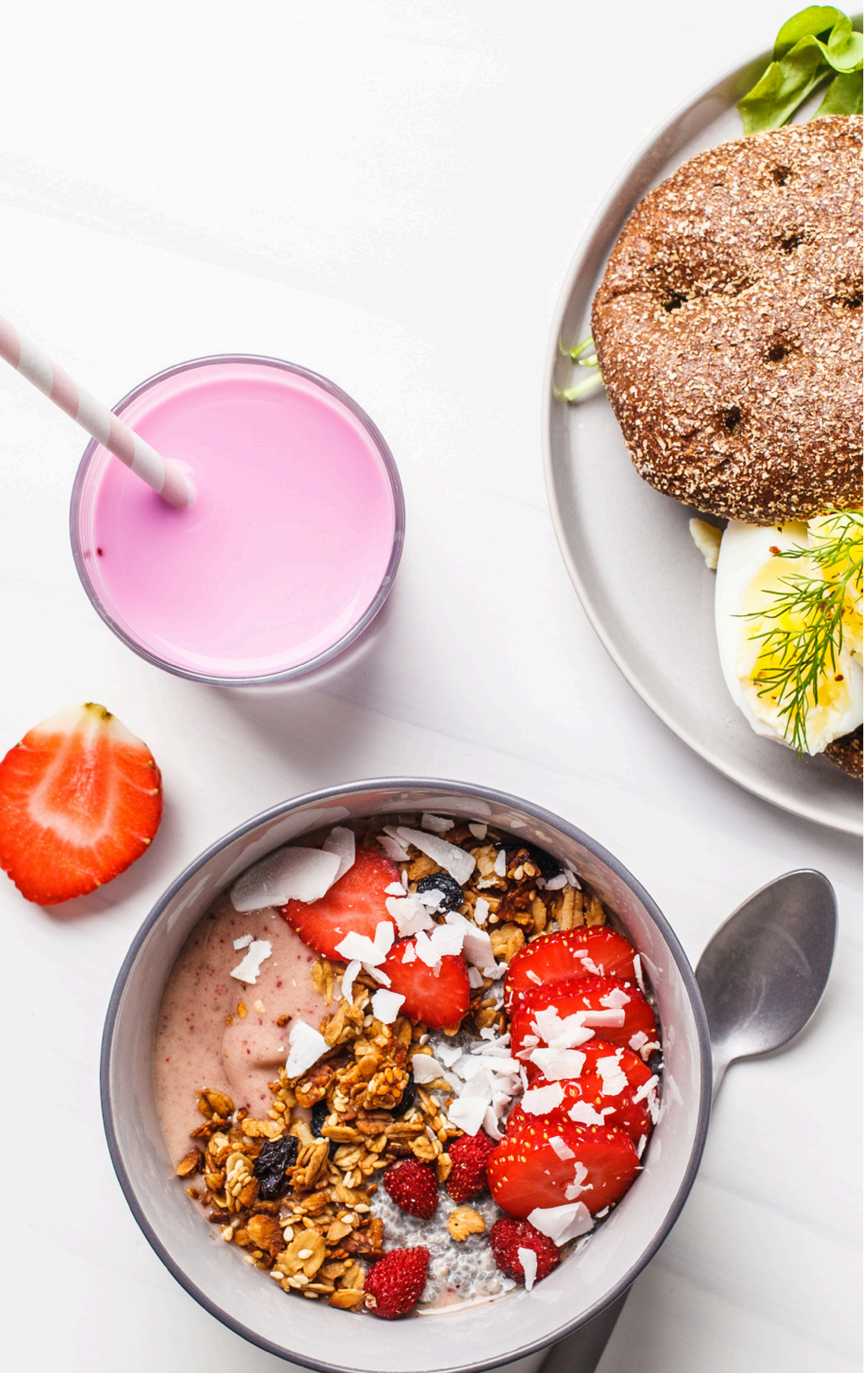
To determine the optimal selection and allocation of food items for a retirement home with 50 residents on a weekly basis, while minimizing cost and balancing nutritional requirements, dietary restrictions, and meal diversity.





Objectives

- *Minimize the total cost of food purchases for 50 retirement home residents over one week.*
- *Meet specific nutritional requirements for each resident based on their body weight.*
- *Adhere to dietary restrictions such as lactose intolerance and gluten sensitivity.*
- *Ensure meal diversity and practicality in food allocation.*



02

Key Stakeholders

01 — ***Retirement Home Administrators*** want to ensure cost-effective meal plannning while meeting diverse nutritional needs.

02 — ***Residents*** must receive balanced meals that cater to individual dietary restrictions and preferences.

03 — ***Healthcare providers*** to promote health through proper nutrition.

03

Case Description

Create 50 Resident Data Using Normal Random Distribution

- Artificial dataset of 50 residents generated using a normal distribution (mean = 73 kg, SD = 10 kg) to reflect realistic variability.

- Nutritional needs scaled for a weekly period based on individual body weight.

ESPEN Guidelines

- Nutritional requirements derived from ESPEN (European Society for Clinical Nutrition and Metabolism) guidelines, specifying nutrient needs per kilogram of body weight.

Amazon Nutritional and Price Data

- Nutritional values and prices for 24 food items sourced from Amazon Business.
- Items categorized into Fruits, Vegetables, Protein Sources, Grains/Starches, and Legumes.

04 Mathematical Models

Scenario 1

Baseline Model

Scenario 2

Encouraging Food Diversity

Scenario 3

Balancing Food Diversity with Daily Serving Limits

Scenario 1
baseline model

01 — **Decision Variables (1200)**

How many portions of food item *i* to assign to resident *j*

$$x_{ij}$$

02 — **Objective Function**

To minimize the total cost of food purchases for the week:

$$Minimize : \sum_i \sum_j p_i \times x_{ij}$$

p_i : Price per serving of food item *i*

Scenario 1
baseline model

03

Constraints

1. Nutritional Constraints: For each nutrient k each patient had a Max and Min value

$$Min_{nutrientk} \leqslant \sum_{i} nutrient_k \times x_{ij} \leqslant Max_{nutrientk}$$

2. Dietary Restrictions: For each resident *j* their **lactose** and **gluten** values had to be below an allowed Max value, and Max = 0 for those with restrictions

$$Lactose_j \leqslant Max_{Lactosej}$$

$$Gluten_j \leqslant Max_{Glutenj}$$

Scenario 1
baseline model

03 — **Constraints**

3. Food Group Requirements: Minimum weekly portions of vegetables and fruits enforced to all residents

$$\sum_{i \in C_k} x_{ij} \geqslant Min_{Ck,j}$$

4. Non-Negative Constraints:

$$x_{ij} \geqslant 0$$

04 — **Outcome**

Scenario 1
baseline model

Minimal Total Cost: $3,059.87 for all residents

Limitation: Lack of diversity in food selection

Resident 1
- *112 Eggs
- 25 Tomatoes
- 60 Bananas

Scenario 1 Sensitivity Analysis

01 Allowable Increase

For food items that were selected the allowable increase was close to 0 - showing that even small changes in price would change our optimal solution

02 Binding Constraints

- Max values for protein constraints were binding (**non-zero shadow price**) for some residents but not for others (**zero shadow price**)
- Min values for lipids and carbohydrates were always binding
- Min vegetable requirement was always binding

Scenario 2
+ food diversity

01 — **Additional Decision Variable**

Binary variable indicating whether food item *i* is assigned to resident *j*

$$y_{ij}$$

where,

y_{ij} = 1 At least one serving of food item *i* is assigned to resident *j*

= 0 Food item *i* is not assigned to resident *j*

Scenario 2
+ food diversity

02 — **Constraints**

1. Linking decision variables: To ensure consistency following constraints were introduced

$$x_{ij} \leqslant y_{ij \times M}$$

$$y_{ij} \leqslant x_{ij}$$

2. Minimum variety per food group: For each resident *j* we enforced a minimum variety constraint within each food group

$$\sum_{i \in C_k} y_{ij} \geqslant Min_{Variety,k}$$

Scenario 2
+ food diversity

03 — **Outcome**

Minimal Total Cost: $3,151.45 for all residents

Limitation: Misalignment with practical dietary needs

Resident 1
protein sources

- *105 portions of eggs
- 1 portion of pork
- 1 portion of whole milk

Scenario 3
+ daily serving limits

01 — **Additional Constraints**

Daily serving limits (Per variety per week)

- Fruits: Max 7 (1 serving per day)
- Vegetables: Max 7 (1 serving per day)
- Protein: Max 14 (2 servings per day)
- Grains and Starches: Max 7 (1 serving per day)
- Legumes: Max 7 (1 serving per day)

$$x_{ij} \leqslant MaxServings_k \quad \text{for all} \quad i \in C_k$$

$MaxServings_k$: Maximum allowed servings per variety for food category k

C_k : Set of food items belonging to category *k*

Scenario 3
+ daily serving limits

02 — Outcome

Minimal Total Cost: $4744.63 for all residents

Resident 1

Protein: 7 Ground Beef, 14 Ground Pork, 14 Whole Milk, 14 Egg

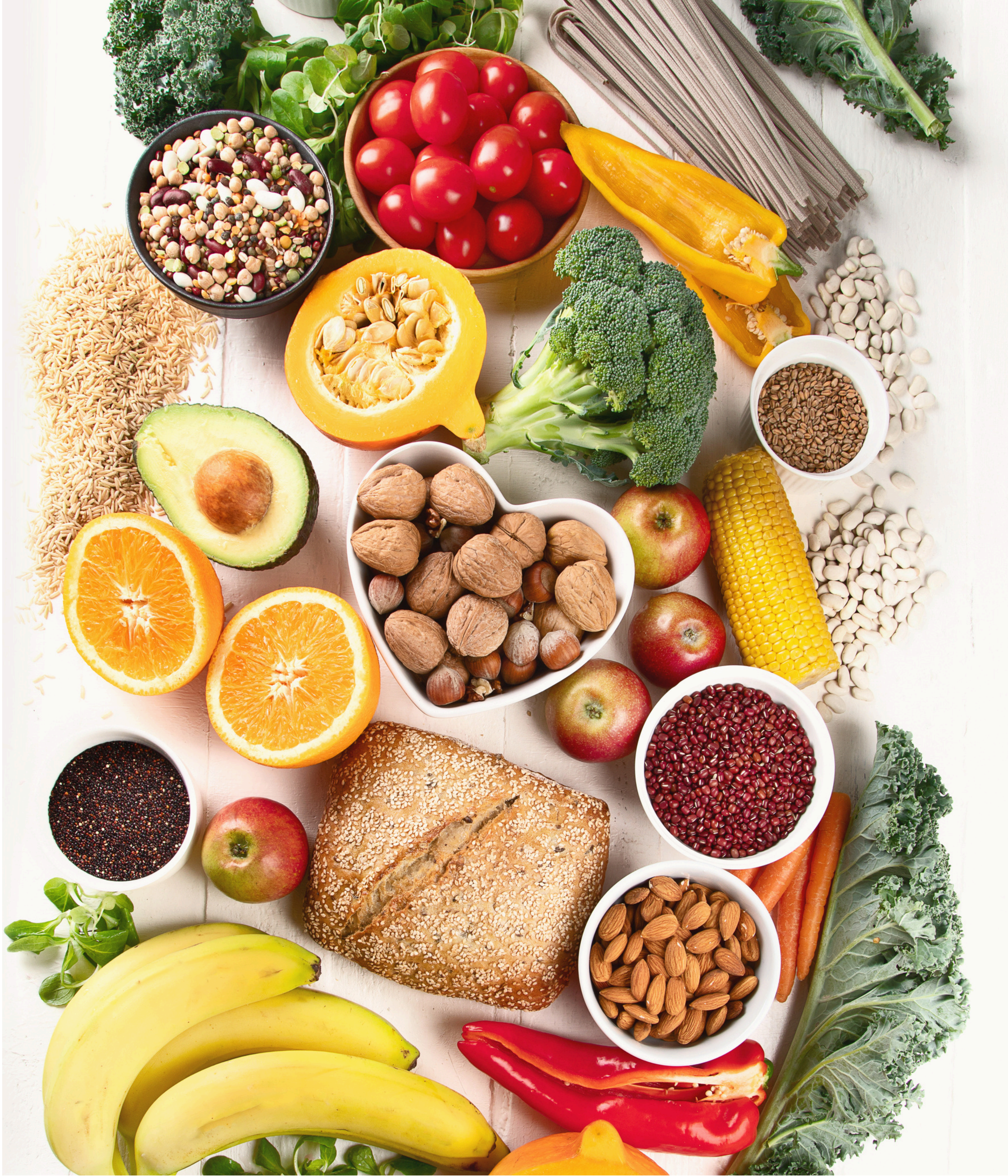
Vegetables: 7 Carrot, 7 Tomatoes, 7 Cauliflower, 4 Bell Peppers

Fruits: 7 Bananas, 7 Oranges, 4 Blueberries

05

Challenges

- Decision Variables: 2400
- Open Solver instead of Excel Solver
- Limited Data Sources
- Per Meal Constraint (Breakfast, Lunch, Dinner)

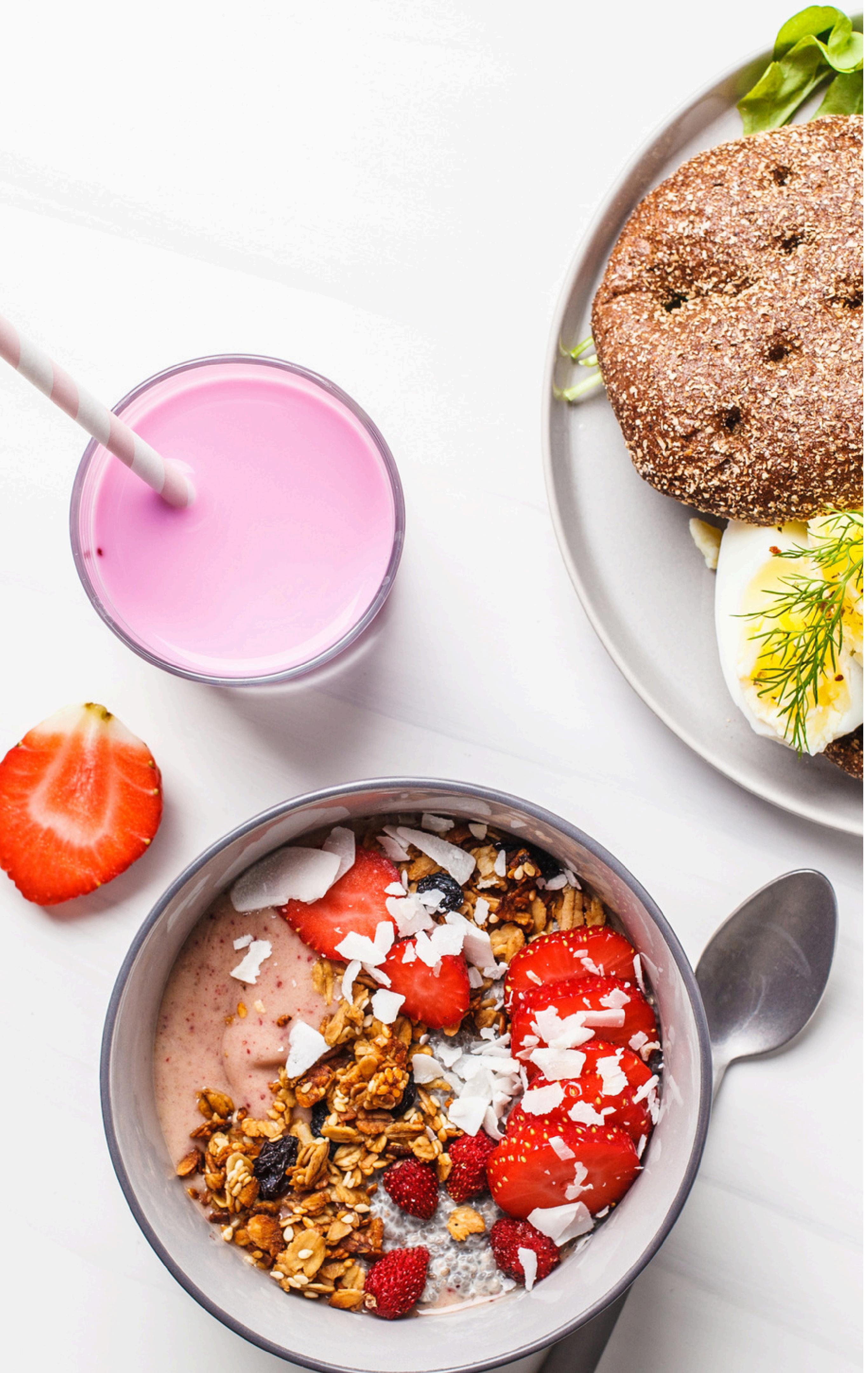


06

Conclusion

Evolution of Model:

- Scenario 1: Basic model ($3,059.87) → lowest cost but impractical
- Scenario 2: Added variety ($3,151.45) → minimal implementation
- Scenario 3: Balanced approach ($4,744.63 or $13.56/resident/day) → most practical, more variance for meal solutions.



Thank you!