

A Comprehensive Approach to the Menu Planning Problem

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The **Menu Planning Problem (MPP)** is a critical challenge in food management, balancing multiple, often conflicting objectives to create meal plans that are nutritionally adequate, cost-effective, and sustainable. Effective menu planning plays a crucial role in various settings, including schools, hospitals, restaurants, and large-scale catering, where dietary needs, budget constraints, and consumer preferences must be carefully considered. Beyond its practical implications, MPP has gained increasing attention due to its impact on public health, environmental sustainability, and food security.

The MPP is examined through the lens of the **SHARP framework**, which integrates these perspectives. This comprehensive methodology seeks to tackle the complex nature of menu planning, fostering responsible and balanced food choices. Sustainability is addressed by designing menus that reduce environmental impact, incorporating locally sourced, seasonal, and eco-friendly ingredients. Health considerations guide the creation of nutritionally balanced meals aligned with dietary recommendations. Cost-effectiveness is ensured by optimizing expenses while formulating meal plans. Reliability is maintained by guaranteeing consistent access to a diverse selection of food options, factoring in supply chain stability and availability. Finally, palatability remains essential, ensuring that meals are both appealing and culturally relevant to support adherence to sustainable and healthy eating habits.

Our work integrates all five SHARP dimensions into the problem. A key innovation is the introduction of a novel Similarity Function to enhance palatability. We propose a Multi-Objective Combinatorial Optimization model that considers three main objectives—sustainability, palatability, and cost—while incorporating constraints related to nutrition, Mediterranean diet guidelines, meal variety, balance, and scheduling. To simultaneously account for all objectives, we employ an **Extended Wierzbicki Achievement Function**, which enables the exploration of different regions of the Pareto Front.



Ingredients: (MAPA, Information per gram)

Nutritional (Moreiras et al. 2017)

Cost

Energy

GHGE

Labels related to group and subgroup classification



Recipes:

Percentage of each ingredient to include in the recipe.

Suggested quantity, depending of the intake position of the recipe.

Labels related to intake position and principal ingredient.

Decision variables:

For each intake $k = 1 \dots K$ on a given day -within the range of days $d = 1 \dots D$

$$x_{A,p}^{k,d} = \begin{cases} 1 & \text{if the recipe } p \text{ is suggested in menu } A \text{ on day } d \text{ for the } k\text{-th intake} \\ 0 & \text{otherwise} \end{cases}$$

INITIAL MENU (matrix form)

Meal\Day	Day 1	...	Day D
BF Drink			
BF Main			
BF Fruit			
Lunch Drink			
Lunch Bread			
Lunch 1st			
Lunch 2nd			
Lunch Dessert			
Dinner Drink			
Dinner Main			
Dinner Dessert			
Break Nuts			
Lunch Bread			

CONSTRAINTS

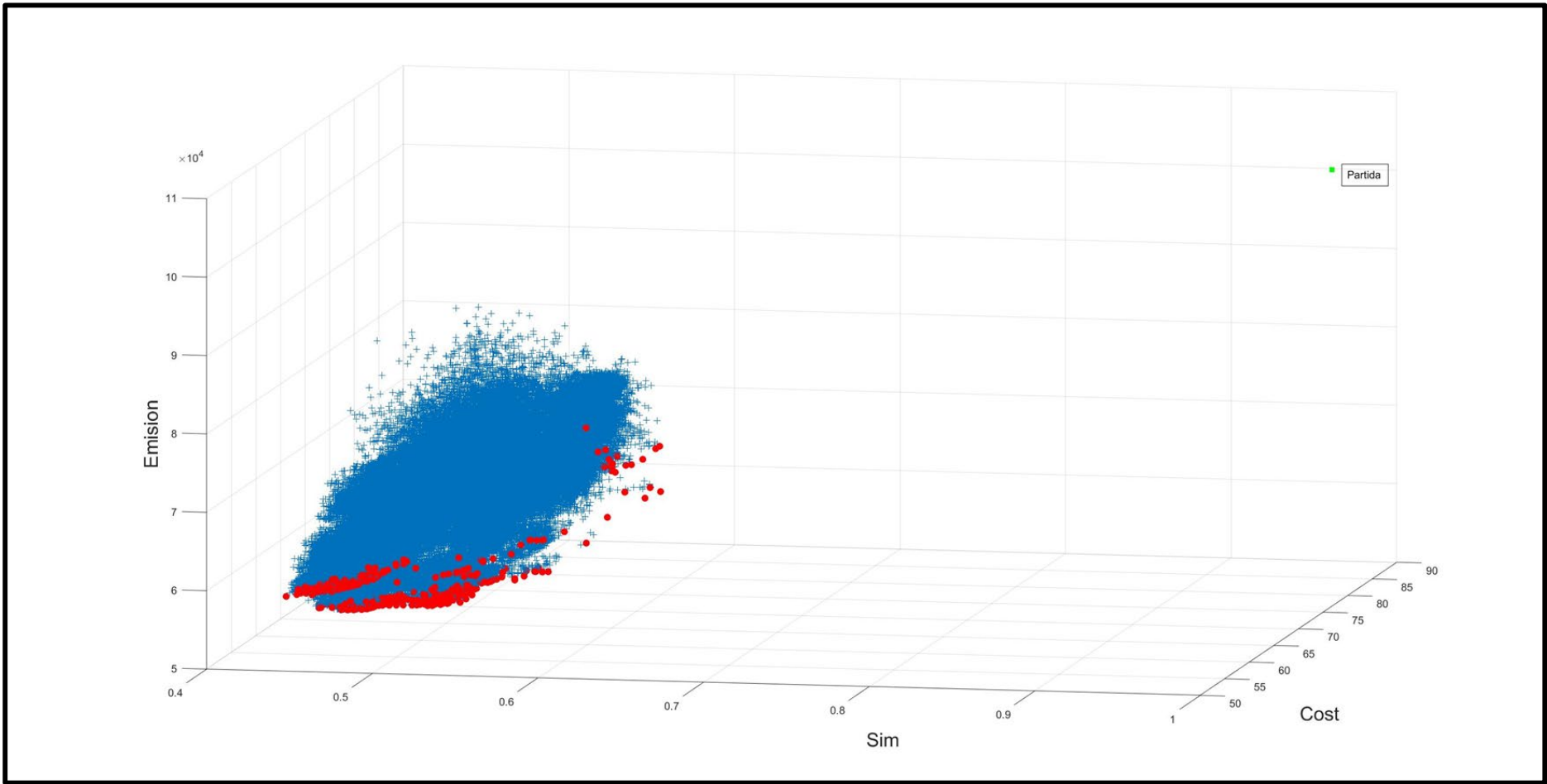
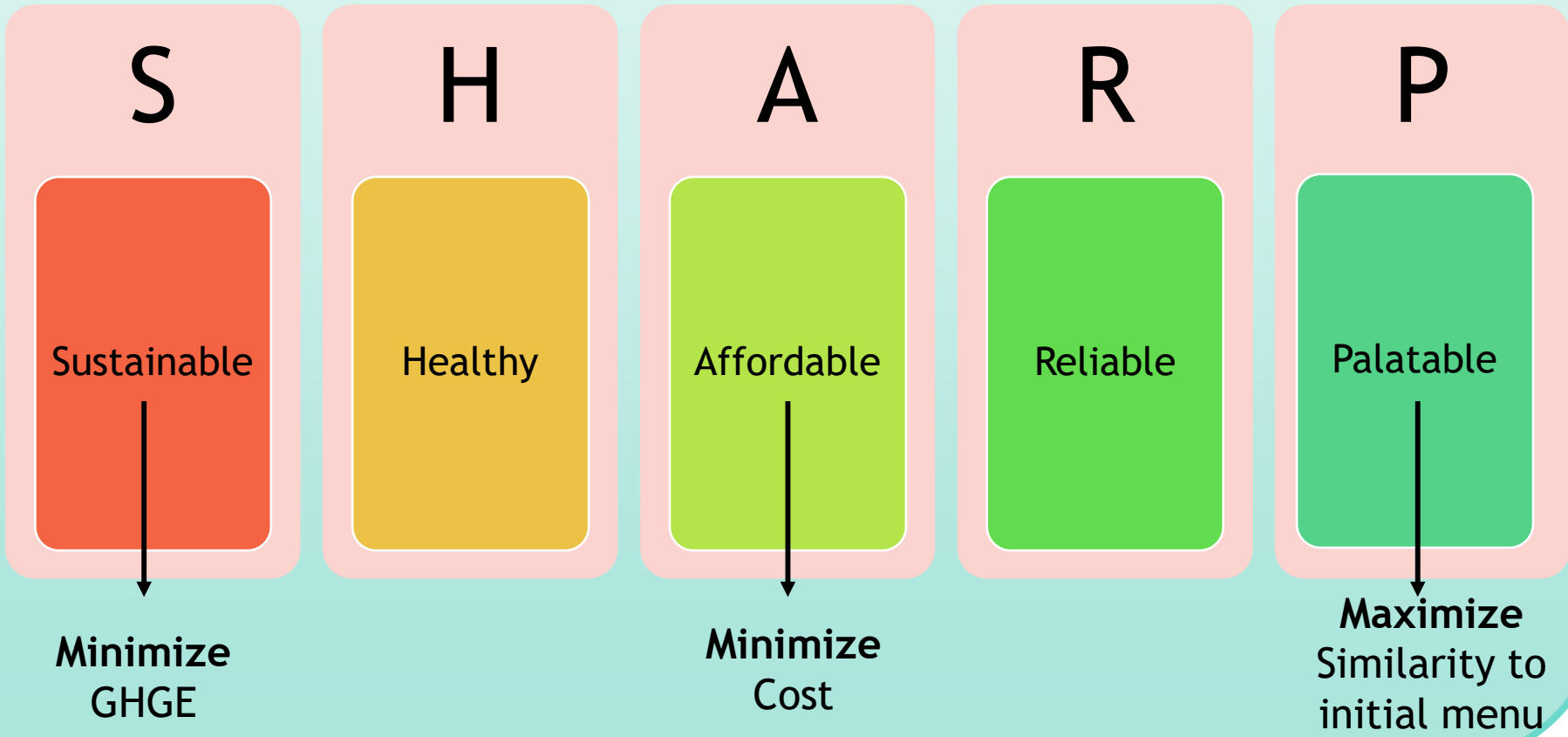
- Nutritional requirements (Moreiras et al. 2017)

Mediterranean Diet
 - Quantity of foods depending of their group (Sociedad Española de Nutrición Comunitaria, 2011).
 - Fat quality.
 - Increase fish intake over meat.

Daily structure: Breakfast-Lunch-Dinner + snack (following Spain standards)

Variety
 - Limit the frequency of a particular recipe within a period of time.
 - Do not repeat the same animal protein in the same day (lunch-dinner)
 - Allow energy flexibility (±25%)

OBJECTIVES



References:

- Martos-Barrachina, F., Delgado-Antequera, L., Hernández, M., Caballero, R. (2022) “An extensive search algorithm to find feasible healthy menus for humans” Operational Research International Journal, 22, pp.5231-5267 <https://doi.org/10.1007/s12351-022-00702-4>
- Martos-Barrachina, F., Delgado-Antequera, L., Hernández, M. (2024) “A novel cost-palatability bi-objective approach to the menu planning problem with an innovative similarity metric using a path relinking algorithm” Journal of the Operational Research Society, 76(1), 73-85. <https://doi.org/10.1080/01605682.2024.2326188>