FOOD DISTRIBUTION MODEL USING THE GOAL PROGRAMMING APPROACH

Letícia Ferreira Godoi[1], Flávia Queiroga Aranha[2], Daniela Renata Cantane[2]

[1]São Paulo State University (Unesp), Institute of Biosciences, Postgraduate Program in Biometrics, Botucatu, Brazil

[2]São Paulo State University (Unesp), Institute of Biosciences, Botucatu, Brazil

Introduction

Food insecurity represents the situation where people do not have physical or economic access to sufficient food to cover their dietary needs. This situation is seen worldwide and with the negative impact of the Covid-19 pandemic on the world economy, millions of people have experienced hunger or difficulty in accessing food. In 2020 there was an increase in moderate and severe food insecurity and the situation have been persisting [1]. To reduce this problem, Food Banks are responsible for distributing food that normally no longer has commercial value but still has nutritional properties [2]. Therefore, the distribution process is able to reduce waste, redirecting surplus food for people who are in a food insecurity situation. The process must be carried out under conditions of equity, effectiveness, and efficiency in order to reach the greatest number of those in need [3]. The challenge is that often the total amount of food may not be sufficient to cover all the existing demands of the population. This work aims to propose an optimization model applied to the problem of food distribution using the goal programming approach.

Optimization Model

The goal programming approach is used for multi-objective problems and consists of setting goals for the objectives, thereby minimizing the deviations associated with these goals [4]. There are several philosophies for modeling, among them is Chebyshev goal programming, which corresponds to minimizing a maximum deviation λ for the set of goals and it was used to build the model proposed. The optimization model is given by

$$
\begin{aligned}
&\text{minimize} && \lambda && && (1)\\
&\text{subject to} && x_{abi} + n_{ai} - p_{ai} = D_i g_{ai}, && i \in I_b, b \in B, a \in A, && (2)\\
& && \sum_{a \in A} x_{abi} \leq C_i, && i \in I, b \in B, && (3)\\
& && f_k y_k = \sum_{a \in A} x_{abk}, && k \in I_f \subset I, b \in B, && (4)\\
& && \mu_i \frac{\sum_{a \in A} n_{ai}}{D_i} \leq \lambda, && i \in I, && (5)\\
& && \sum_{i \in I_b} x_{abi} = Q_{ab} + \sum_{\substack{b' \in B \\ b' \neq b}} z_{abb'} - \sum_{\substack{b' \in B \\ b' \neq b}} z_{ab'b}, && b \in B, && (6)\\
& && (\lambda, x_{abi}, n_{ai}, p_{ai}) \geq 0, && i \in I, a \in A, b \in B, && (7)\\
& && y_k \geq 0, && k \in I_f \subset I, && (8)\\
& && z_{ab'b} \geq 0, && a \in A, b, b' \in B, b' \neq b. && (9)
\end{aligned}
$$

Set A represents the types of food, set B represents the Food Banks, and I represents the set of Beneficiary Institutions attended. The decision variable x represents the amount of food distributed, where n and p are the missing or surplus deviations, respectively, from the demand (D), which is related to the proportion of each type of food (g). The weights associated with the deviations are represented by μ. The food receiving capacity is represented by C, and Q represents the total amount of food available for distribution. The variable y represents the amount of food sent to each family attended, where f is the total number of families attended by the institution. The variable z represents the amount of food exchanged between food banks.

Instances

In order to analyze the behavior of the model, different instances were built. Figure 1 shows a schematic of the constructed scenario: two Food Banks were considered, where the Food Bank 1 is responsible for distributing food to Beneficiary Institutions 1 to 10 and the Food Bank 2 is responsible for distribution to Institutions 11 to 21. Three different types of food were considered: vegetables, fruits and foods of animal origin. Each institution presents its own preference regarding the food received.

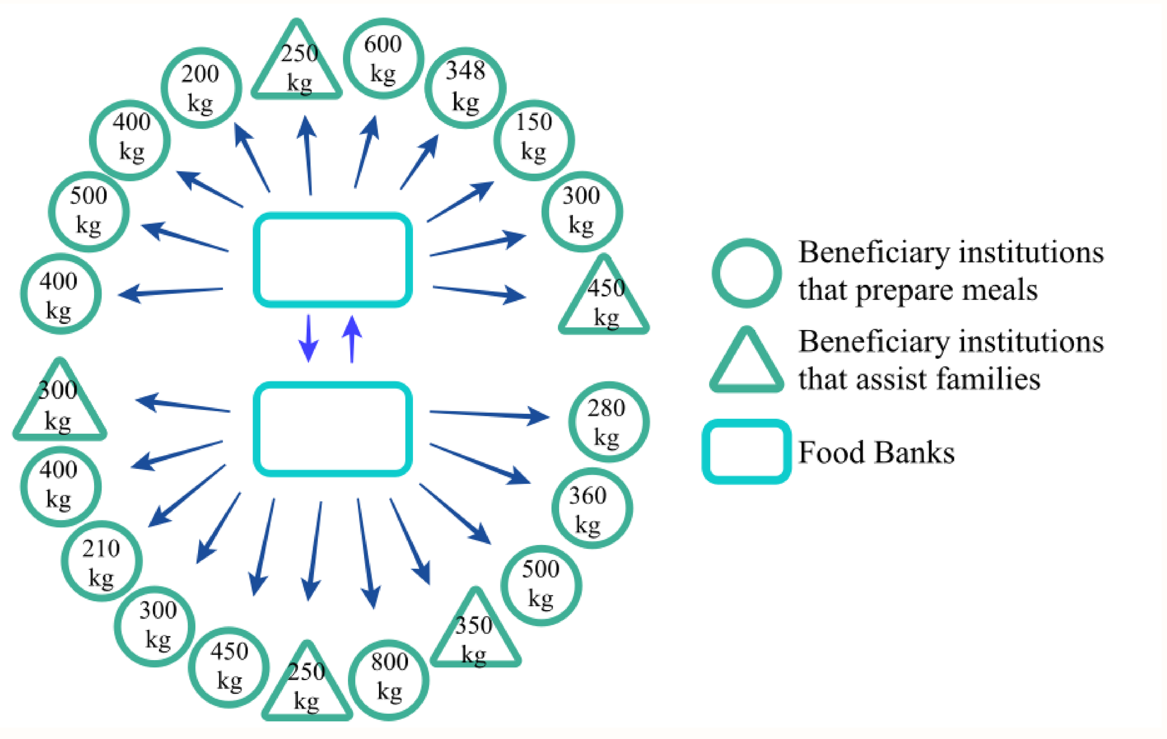

Figure 1: Schematic of the built scenario.

Table 1 presents the built Instances 1, 2 and 3, considering different total amounts (in kg) of food available at each Food Bank (FB). We can notice that the amount of food available for distribution varies between lower, higher or optimal values to supply the demands of Beneficiary Institutions attended.

Table 1: Total amount of food available in each Instance (kg).

	Instance 1		Instance 2		Instance 3	
	FB 1	FB 2	FB 1	FB 2	FB 1	FB 2
Vegetables	1441	1210	1000	1500	1500	1300
Fruits	891	1555	1000	1200	900	1600
Foods of animal origin	1266	1435	1266	1435	1300	1500

The food receiving capacity of each institution was considered to be 5% greater than its demand and the number of families attended by the Beneficiary Institutions 5, 10, 11, 16 and 18 are respectively 50, 90, 60, 50 and 70.

Results and Discussion

No prioritization was considered in the attendance of the institutions, then the weights μ_i were considered equal. The results for each instance are shown in Figure 2.

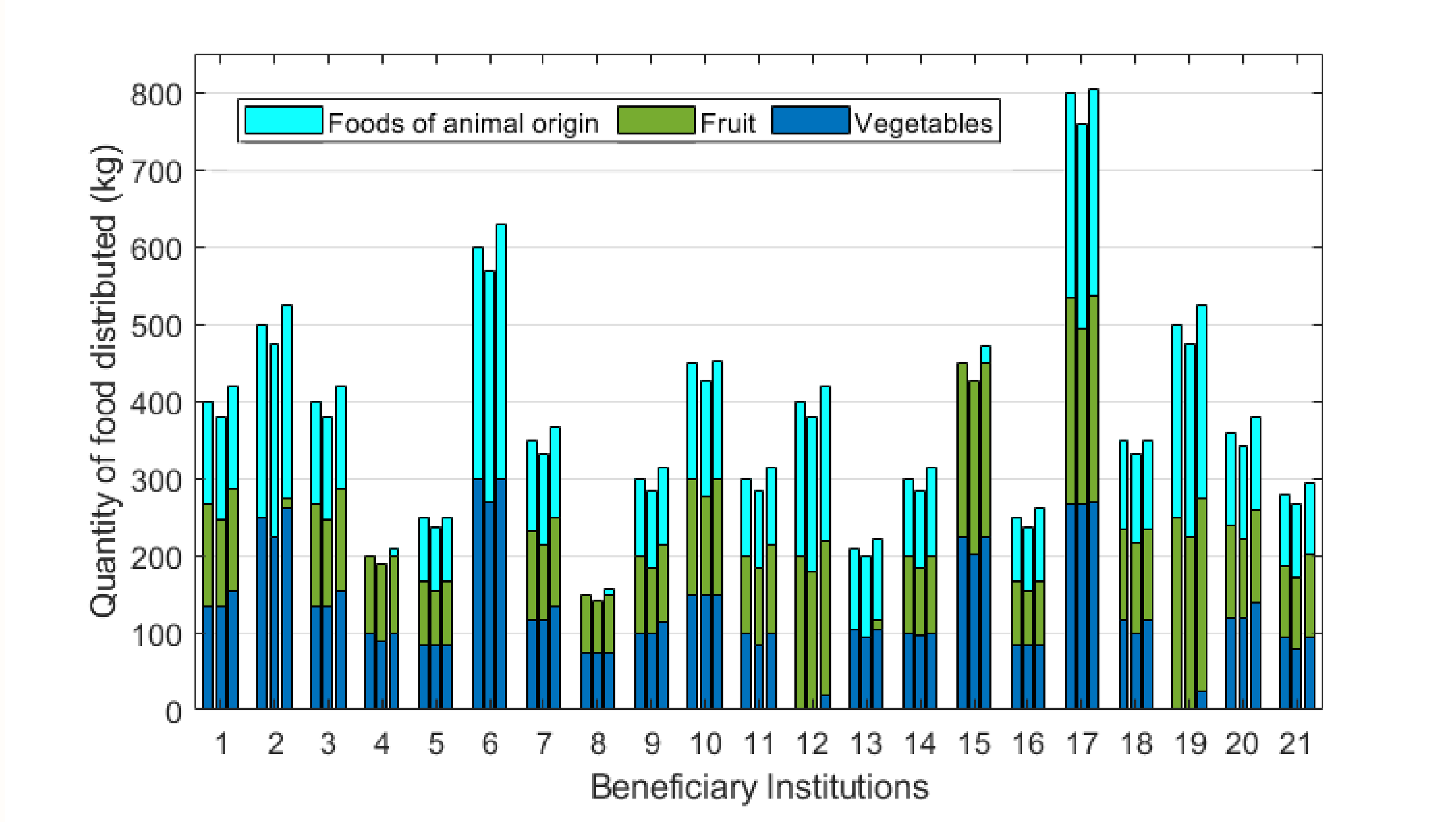

Figure 2: Results of the optimization model for Instances 1, 2 and 3.

Considering the results, the distribution of food considers equity, since the amount of food available, even if insufficient to supply all demands, was distributed to all institutions according to their demand. In Instances 1 and 3, the value of λ was equal to 0, and in Instance 2, $\lambda = 0.0024$. The amount of food distributed to each family attended by the Beneficiary Institutions was 5 kg in Instance 1 and 4.74 kg in Instance 2. In Instance 3 the values found were about 5 kg. In Instance 1 there was no exchange of food between Food Banks. In Instance 2, FB 1 sends about 226 kg of fruits to FB 2 and receives 374.81 kg of vegetables. In Instance 3, FB 2 sends 23.9kg of vegetables, 5.5kg of fruits and 15kg of animal food to FB 1.

Conclusions

The goal programming methodology used was efficient since it indicated a food distribution considering equity. As future perspectives we intend to add other variables involved in the process, and simulation with instances and data from Brazilian Food Banks for better analysis and adaptations of the model, in order to attend the largest number of those in need and reduce food waste.

Acknowledgements

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Finance Code 001 and Projeto Universal CNPq/MCTI/FNDCT 405716/2021-4.

Bibliography

[1] FAO, IFAD, UNICEF, WFP and WHO. 2022. *The State of Food Security and Nutrition in the World 2022. Repurposing food and agricultural policies to make healthy diets more affordable.* Rome, FAO. https://doi.org/10.4060/cc0639en

[2] Ministerio da Cidadania, Brasil. *Guia Operacional e de Gestão para Bancos de Alimentos.* 2020.

[3] I. S. Orgut, J. Ivy, R. Uzsoy, and J. R. Wilson. *Modeling for the equitable and effective distribution of donated food under capacity constraints.* IIE Transactions, vol. 48, no. 3, 2016.

[4] D. Jones and M. Tamiz. *Practical Goal Programming.* Springer, 2010.