Using the Global Criterion Method to Solve Multi-Objective Diet Problem

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Abstract

Healthy diets that help the body maintain its full health is an important matter in our daily lives. Perhaps one of the most important diets that most people need is a low-fat diet, which is important in reducing the risk of heart disease, as well as important in losing weight and other health problems that Most people encounter. Therefore, in this paper, we presented a new multi-objective mathematical model of finding the lowest cost and lowest fat percentage for 19-50 year old females using some low fat foods. Where, the multi-objective linear system was transformed into a non-linear system with a single objective function by using the global criterion method, and then the non-linear system was solved by using the augmented lagrangian method as a tool to find the results that provide the least cost with the least fat percentage.

Keywords: *Global criterion method. Diet problem. The augmented lagrangian method. Multi-objective. Nutritional requirements.*

1. INTRODUCTION

Healthy diets are important in our daily lives, especially if they are accompanied by some exercise that can help the body maintain its health [1, 2]. There are many diets that meet a wide range of goals, such as dieting to lose weight [3] or control diseases such as coronary heart disease [4], kidney disease[5] and diabetes [6].

Many people suffer from some chronic diseases such as high blood pressure and other diseases that are directly related to weight gain and obesity that is caused by the accumulation of fat in the body due to the lack of sports activity in addition to unhealthy diets [7]. In order to reduce these health problems, many researchers presented plans for balanced diets that meet their daily needs by reducing daily costs and also to reduce eating disorders. Therefore, these plans can be considered as a theoretical method that can deal with decision-making problems for multiple objective [8, 9].

Linear programming has the greatest role in solving optimization problems through the use of linear objective functions that are accompanied by a set of linear constraints and finding the best solutions to meet the constraints that can appear in the case of equality or inequality [10, 11].

There are many diets with multiple objective that want to be improved at the same time when the individual objective functions are combined in one function only using some mathematical methods such as weighted-sum method and the global criterion method, which is an important and interesting way through which the multiple linear functions are combined to nonlinear objective function [12, 13].

To find the optimal solution for nonlinear systems and optimization problems, the authors introduced many papers in variety of science fields to discover the best solution including operation research [14- 23] reliability [24- 33] and optimization [34- 53] , but in this paper, a new model is presented for a low-fat diet for females between the ages of 19-50 years, using some nutritional foods that can meet the needs of the proposed diet with nutrients that meet the individual's need, and therefore the model presented has multiple goals that include less cost and less the percentage of fat with a number of restrictions accompanying them. By using the global criterion method, the two linear objective functions were combined and transformed into one non-linear objective function, and with the same constraints, the augmented lagrangian method was used as a tool to find the best solutions for the proposed system.

2. Methodology

The linear programming model of diet problem is given as follows:

$$Min\ z = c_1x_1 + c_2x_2 + \cdots + c_nx_n$$

Subject to,

$$a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n \geq b_1;$$
$$a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n \geq b_2;$$
$$\vdots$$
$$a_{m1}x_1 + a_{m2}x_2 + \cdots + a_{mn}x_n \geq b_m;$$
$$x_1, x_2, \ldots, x_n \geq 0$$

where:

c_j = cost of food j, $j = 1,2, \ldots, n$,

x_j = the number of units of food j in the diet,

a_{ij} = amount of i^{th} nutrient in food type j, $i = 1,2, \ldots, m$,

b_i = the required daily amount of nutrient i,

m = the number of nutrients,

n = the number of food items.

3. Data analysis

Eight types of foods were used in the proposed diet and six nutrients were used. The prices of food samples were collected from grocery stores in dollars. In addition, the nutritional requirements were for females aged between 19-50 years [54].

Table 1 shows the group of foods used in grams and the amount of nutrients per food unit in addition to the daily nutritional requirements of the individual with the cost of foods, as the goal is to find the value of x_j that achieves the least cost and the least amount of fat for the proposed diet.

Table 1. Nutrient requirement per day (Females, 19-50 years old)

Nutritional Requirement									
nutrient	Food Items								daily requirement
	100gms of chicken	100gms of almonds	100gms soya beans	100gms wheat	egg 1	1 class milk	100gms of Orange	100gms of spinach	
fat	3.57	49.42	2.09	1.87	9.94	0.2	0.15	0.39	

calcium	15	264	37	34	53	298.9	43	99	1000 mg
Potassium	256	705	332	405	134	382.2	166	558	4700 mg
Iron	1.04	3.72	2.57	3.88	1.83	0.07	0.13	2.71	18 mg
Protein	31.02	21.22	13.05	13.7	12.57	8.26	0.91	2.86	46 mg
Fiber	0	12.2	0	12.2	0	0	2.2	2.2	28 mg
Magnesium	29	268	130	138	12	26.95	11	79	310 mg
Cost in $	0.25	1	0.20	0.15	0.15	0.25	0.20	0.15	minimization

3.1 Objective function

Total formulation of problem:

$$Min\ z_1 = 0.25x_1 + 1x_2 + 0.20x_3 + 0.15x_4 + 0.15x_5 + 0.25x_6 + 0.20x_7 + 0.15x_8$$

$$Min_f\ z_2 = 3.57x_1 + 49.42\,x_2 + 2.09x_3 + 1.87x_4 + 9.94x_5 + 0.2x_6 + 0.15x_7 + 0.39x_8$$

Subject to,

$$15x_1 + 264x_2 + 37x_3 + 34x_4 + 53x_5 + 298.9x_6 + 43x_7 + 99x_8 \geq 1000;$$

$$256x_1 + 705x_2 + 332x_3 + 405x_4 + 134x_5 + 382.2x_6 + 166x_7 + 558x_8 \geq 4700;$$

$$1.04x_1 + 3.72x_2 + 2.57x_3 + 3.88x_4 + 1.83x_5 + 0.07x_6 + 0.13x_7 + 2.71x_8 \geq 18;$$

$$31.02x_1 + 21.22x_2 + 13.05x_3 + 13.7x_4 + 12.57x_5 + 8.26x_6 + 0.91x_7 + 2.86x_8 \geq 46;$$

$$0x_1 + 12.2x_2 + 0x_3 + 12.2x_4 + 0x_5 + 0x_6 + 2.2x_7 + 2.2x_8 \geq 28;$$

$$29x_1 + 268x_2 + 130x_3 + 138x_4 + 12x_5 + 26.95x_6 + 11x_7 + 79x_8 \geq 310;$$

$$x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8 \geq 0$$

Where :

$Min\ z_1 =$represent the lowest cost.

$Min_f\ z_2 =$represents the least amount of fat.

3.2. Using global criterion technique

Divide the main problem into K of sub-problems:

Divide the main problem into K of sub-problems:

1. When $i = 1 \Rightarrow$ sub-problem 1 :

$$Min\ z_1 = 0.25x_1 + 1x_2 + 0.20x_3 + 0.15x_4 + 0.15x_5 + 0.25x_6 + 0.20x_7 + 0.15x_8$$

Subject to,

$$15x_1 + 264x_2 + 37x_3 + 34x_4 + 53x_5 + 298.9x_6 + 43x_7 + 99x_8 \geq 1000;$$

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$$x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8 \geq 0$$

by using the big M method, a solution to this problem was obtained, where:

$$Min\ z_1 = 1.4589, x_1^* = x_2^* = x_3^* = x_5^* = x_7^* = 0, x_4^* = 1.3733, x_6^* = 0.9438, x_8^* = 6.7797.$$

2. When $i = 2 \Rightarrow$ sub-problem 2 :

$$Min_f\ z_2 = 3.57x_1 + 49.42\ x_2 + 2.09x_3 + 1.87x_4 + 9.94x_5 + 0.2x_6 + 0.15x_7 + 0.39x_8$$

Subject to,

$$15x_1 + 264x_2 + 37x_3 + 34x_4 + 53x_5 + 298.9x_6 + 43x_7 + 99x_8 \geq 1000;$$

$$256x_1 + 705x_2 + 332x_3 + 405x_4 + 134x_5 + 382.2x_6 + 166x_7 + 558x_8 \geq 4700;$$

$$1.04x_1 + 3.72x_2 + 2.57x_3 + 3.88x_4 + 1.83x_5 + 0.07x_6 + 0.13x_7 + 2.71x_8 \geq 18;$$

$$31.02x_1 + 21.22x_2 + 13.05x_3 + 13.7x_4 + 12.57x_5 + 8.26x_6 + 0.91x_7 + 2.86x_8 \geq 46;$$

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$$x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8 \geq 0$$

by using the big M method, a solution to this problem was obtained, where:

$$Min_f\ z_2 = 3.9498, x_1^* = x_2^* = x_3^* = x_4^* = x_5^* = 0, x_6^* = 2.6884, x_7^* = 6.4648, x_8^* = 6.2625$$

Create a table of optimal final solutions for sub-problems

Table 2. optimal solutions for sub-problems

$z_i(x)$ \ $z_i(x^*)$	$z_1(x^*)$	$z_2(x^*)$	x_1^*	x_2^*	x_3^*	x_4^*	x_5^*	x_6^*	x_7^*	x_8^*
$z_1(x)$	1.4589	0	0	0	0	1.3733	0	0.9438	0	6.7797
$z_2(x)$	0	3.9498	0	0	0	0	0	2.6884	6.4648	6.2625

The global criterion method formulation is given by:

$$min\, z = \sum_{i=1}^{k}\left[\frac{z_i(x^*) - z_i(x)}{z_i(x^*)}\right]^2$$

$$= \sum_{i=1}^{2}\left[\frac{z_i(x^*) - z_i(x)}{z_i(x^*)}\right]^2$$

Subject to the constraints.

So our system will be as follows:

$$min\, z = \left[\frac{1.4589 - (0.25x_1 + 1x_2 + 0.20x_3 + 0.15x_4 + 0.15x_5 + 0.25x_6 + 0.20x_7 + 0.15x_8)}{1.4589}\right]^2$$

$$+ \left[\frac{3.9498 - (3.57x_1 + 49.42\, x_2 + 2.09x_3 + 1.87x_4 + 9.94x_5 + 0.2x_6 + 0.15x_7 + 0.39x_8)}{3.9498}\right]^2$$

Subject to,

$$15x_1 + 264x_2 + 37x_3 + 34x_4 + 53x_5 + 298.9x_6 + 43x_7 + 99x_8 \geq 1000;$$

$$256x_1 + 705x_2 + 332x_3 + 405x_4 + 134x_5 + 382.2x_6 + 166x_7 + 558x_8 \geq 4700;$$

$$1.04x_1 + 3.72x_2 + 2.57x_3 + 3.88x_4 + 1.83x_5 + 0.07x_6 + 0.13x_7 + 2.71x_8 \geq 18;$$

$$31.02x_1 + 21.22x_2 + 13.05x_3 + 13.7x_4 + 12.57x_5 + 8.26x_6 + 0.91x_7 + 2.86x_8 \geq 46;$$

$$0x_1 + 12.2x_2 + 0x_3 + 12.2x_4 + 0x_5 + 0x_6 + 2.2x_7 + 2.2x_8 \geq 28;$$

$$29x_1 + 268x_2 + 130x_3 + 138x_4 + 12x_5 + 26.95x_6 + 11x_7 + 79x_8 \geq 310;$$

$$x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8 \geq 0$$

It can be seen that the above model represents a non-linear (quadratic) programming problem that can be solved by relying on some well-known methods or algorithms. Here, the augmented lagrangian method will be used as a tool to find the best solutions. Despite the difficulty of determining the initial basic variables to reach the final optimal solution, and by making many input attempts, it has been The 3 best results are listed in the following table:

Table 3. the best possible solutions with decimals

No.	Decision Variables								Min z	Min z_1	Min$_f$ z_2
	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8			
1	0.231	0.440	0.598	1.663	1.804	1.115	0.039	6	121.53	2.323	47.429
2	0.181	0.391	0.169	1.523	1.678	1	0.375	6.421	96.09	2.238	42.61
3	0.229	0.393	0.152	1.619	1.661	1.035	0.3	6.357	97.168	2.244	42.826

The final solutions that were identified in the previous table using the global criterion method are non-dominant solutions, with the attention that it is possible to adopt solution (No. 2) is an optimal solution among the solutions that have been recorded in the table, taking into account that the mentioned numbers can be approximated in accordance with the elements of the problem under the condition realizing the limitations of the problem.

4. Conclusion

The presented mathematical model was formulated according to the diet problem intended to reduce the daily cost and obtain the lowest possible percentage of fat by using some of the food samples in a linear mathematical model that is restricted and multi-objective. Also, the global criterion method has many non-dominant solutions that the decision maker can choose one of them is to be the best solution so that this solution meets the needs of the problem in terms of reducing the daily cost and reducing the percentage of fat in the proposed diet.

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