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# Linear Programming Approach to Determine Balance Diet with Minimum Cost: A Case Study

Shuhag Islam[1], Mohammad Kamrul Hasan[1], Md. Rakibul Islam[1]

[1]Department of Industrial & Production Engineering, Rajshahi University of Engineering & Technology

*E-mail: shuhag.ruet@gmail.com, kh439570@gmail.com, rbn_khan@yahoo.com*

## *Abstract*

*This paper presents a balance diet planning by using linear programming approach. Not having a properly balanced diet leads the people to disease-related life. So, not having a balanced diet is assumed as one of the most critical problems in the present world. The cause of not having to maintain a balanced diet is lacking education of what to eat and what amount to eat. In this paper, balanced diet planning corresponding of each user to take a variety of foods for a few times per day (5 per day). The planning will help users to obtain nutritional requirements for the human body in daily routine and to prevent chronic disease such as high blood pressure, heart disease, stroke, depression, osteoporosis, diabetes, etc.*

**Keywords:** balance diet, minimum cost, linear programming, nutrition, amount of foods.

## 1. Introduction

A diet is all about that we consume in a day. A balanced diet consisting of a variety of different types of food and providing adequate of the nutrients necessary for good health. A balanced diet includes six main nutrients, i.e. fats, protein, carbohydrates, fiber, vitamins, and minerals. All these nutrients are present in the different food that we eat. Different food items have different properties of nutrients present in them. A balanced diet provides the body with essential nutrition and adequate calories. It is very important because human organs and tissues need proper nutrition to work effectively. Without proper nutrition, the human body is more prone to disease, infection, fatigue and poor performance during work time.

Not maintaining a balanced diet is a serious problem in the entire life course. More than one-third of all deaths are caused by one or more this five chronic disease: heart disease, cancer, stroke, chronic obstructive pulmonary disease, and diabetes. According to a report of WHO, 79% of all deaths worldwide that are attributable to chronic diseases are already occurring in a developing country. The cause of getting chronic disease is not to maintain a balanced diet.

There are many studies which are focused on balance diet and chronic diseases such as diet planning for human using mixed-integer, linear programming, prevention of chronic disease by diet and diet problem and nutrient requirements using linear programming approach.

The research has done about human diet planning using linear programming. A computerized model is applied to planning a diet at minimum cost while supplying all nutritional requirements. The research aims to suggest people have healthy food at the lowest cost as possible.

To prevent chronic disease, it is necessary to obtain a well-balanced diet in our daily life. Thus linear programming approach will be applied to get a better result.

## 2. Literature Review

Mustafa mamat, noor fadzilah zulkifli, siti kamila deraman, noor maizura mohamad noor (2012) attempt to fuzzy linear programming approach in balanced diet planning for eating disorder and disease-related lifestyle. this paper has described a fuzzy linear programming approach based on the variety of foods consumed by users. the fuzzy linear programming approach is used to calculate the amount of nutrient in food taken and it is considered to estimate nutritional requirements for the human body in daily routine. then, balanced diet planning will be produced as a result. this planning will help users to prevent eating disorder and disease-related lifestyles such as anorexia nervosa, diabetes, heart attack and obesity [1]. André Briend, Nicole Darmon, Elaine Ferguson, Juergen G. Erhardt (January 2003 Lippincott Williams & Wilkins, Inc., Philadelphia) was a lot of work was done on balance diet to prevent chronic disease. This paper analyzing and optimizing children's diets during the complementary feeding period by using linear programming. During the complementary feeding period, children require a nutrient-dense diet to meet their high nutritional requirements. This paper used linear programming is much more efficient than the empirical "trial and error" approach used for formulating diets during the complementary feeding period [2] walter *et al*. [3] discussed prevention of chronic disease by diet and lifestyle changes. this study identifies the relationships between dietary and lifestyle factors and chronic diseases and recommended lifestyle changes and the potential supporting evidence to prevent chronic disease. Meanwhile, Sklan and Dariel [4] have done research about human diet planning using mixed-integer linear programming. A computerized model is applied to planning diet at minimum cost while supplying all nutritional requirements; maintain nutrients relationships and preserving eating practices. Ishi Hiroaki [11] attempt to develop by using internet technology, and it provides multi-user service and menu information sharing capacity like SNS (social networking service). The system works on Web server built by Apache, MySQL, PHP. For menu planning, a genetic algorithm is applied. This paper fully focuses on everyday meals close to our life and proposes a well-balanced menu planning system as a preventive measure of lifestyle-related disease.

## 3. Linear Programming Approach

Linear programming is a mathematical method to optimize (minimize or maximize) a linear function of a set of decision variable while respecting multiple linear constraints.

The function Z to be optimized by linear programming is called the objective function. The variables $x_1$, $x_2$, … $x_n$ whose value can be changed to optimize the function Z are called decision variables.

A function Z of serval variables $x_1$, $x_2$, … $x_n$ is linear when it can be expressed in the following way:

$$Z = a_0 + a_1.x_1 + a_2x_2 \dots + a_n \tag{1.1}$$

Where, $a_0, a_1, a_2 \dots a_n$ are constraints.

In the same way, a constraint on serval variable $x_1$, $x_2$ … $x_n$ is linear when it can be expressed in the following way:

$$b_1x_1 + b_2x_2 + \cdots b_nx_n \geq b_0 \tag{1.2}$$

Where, $b_0, b_1, b_2 .. b_n$ are constraints.

our proposed minimize cost balance diet problem model as following below:

$$Minimize\ \ Z = \sum_{j=1}^{n} c_j\, x_j$$

Subject to,

$$\sum_{j=1}^{n} a_{ij}\, x_j \geq\ b_i$$

$$\sum_{j=1}^{n} a_{ij}\, x_j \leq d_i$$

$$\sum_{j=1}^{n} a_{ij}\, x_j = e_i$$

$$i = 1,2,3, \dots m, j = 1,2, ..\ n, x_j \geq 0$$

Where

*j* = food eaten per day,
$c_j$ = amount of cost 1g of food *j*,
$x_j$ = required the amount of food *j* eaten per day,
$a_{ij}$ = the amount of nutrient *i* in 1g of food *j*,
$b_i$ = the minimum required the amount of nutrient *i*,
$d_i$ = the maximum required the amount of nutrient *i*,
$e_i$ = the daily required the amount of nutrient *i*,
*m* = the amount of nutrients,
*n* = the number of foods.

By using our proposed model, anyone can get a balanced diet plan with minimum cost. Anyone can choose as he or she our proposed model will provide him or her required amount of nutrition with minimum cost as possible and the output of this proposed model will provide the users the required amount of food in gram(g).

## 4. Data Collection

| Nutrition ingredients \ Amount of nutrition ingredient | Energy (kcal) | Protein (g) | Fat (g) | Saturated fat (g) | Carbohydrate (g) | Sugar (g) | Sodium (g) | Dietary fiber (g) |
|---|---|---|---|---|---|---|---|---|
| Cooked Rice | 1.31 | 0.024 | 0.021 | 0.00054 | 0.289 | 0 | 0.0000012 | 0.0048 |
| Rahu fish | 0.97 | 0.167 | 0.034 | 0.0023 | 0.032 | 0 | 0.001 | 0 |
| Potato | 0.72 | 0.018 | 0.0008 | 0 | 0.2 | 0.0074 | 0.012 | 0.014 |
| Lentils | 1.16 | 0.089 | 0.003 | 0.0003 | 0.2 | 0.021 | 0.0024 | 0.08 |
| Banana | 0.89 | 0.0085 | 0 | 0 | 0.229 | 0.119 | 0.0000085 | 0.0178 |
| Egg | 1.37 | 0.11 | 0.0877 | 0.028 | 0.011 | 0 | 0 | 0 |
| Apple | 0.52 | 0.003 | 0.002 | 0 | 0.14 | 0.1 | 0.00001 | 0.024 |

The number of sample food that has been chosen is 7 types and the sample number of nutrients is 8 types. The prizes of the foods are collected from the local market (Shahab bazar, Rajshahi, Bangladesh) in November 2018. Each value of nutrient and price of sample food is taken for 1g.

**Table 4.1**: Data collection for nutrition ingredients and their amount.

**Table 4.2**: Data collection for foods and their price

| Foods name | Cooked Rice | Rahu fish | Potato | Lentils | Banana | Egg | Apple |
|---|---|---|---|---|---|---|---|
| Price (BDT Per g) | 0.0167 | 0.2 | 0.03 | 0.12 | 0.05 | 0.12 | 0.13 |

## 5. Data Analysis

Nutrients requirement were 2400kcal for those of a 21 to 40 years old-sedentary man taken from the 2015-2020 dietary guideline (health.gov, Appendix 2). The acceptable macronutrient distribution range for protein, fat, saturate fat, carbohydrate, sugar, dietary fiber is 10% to 35%, 20% to 35%, At most 9 %, 45 % to 65%, At least 7.6%, 6% of total calories, respectively and required amount of sodium is 0.423g per day (www.nhs.uk).

For 1000 kcal of energy required protein, fat, saturated fat, carbohydrate, sugar, dietary fiber is at least 10g, at least 20 g, at most 9g, at least 45g, at least 7.6g, at least 6g respectively.

We calculate 1800 kcal for lunch (1000 kcal) and dinner (800 kcal) and consider 600 kcal for breakfast and snack. we take nutrients of a white-large grain of rice which is increased 3 times than raw rice after cooking.

**A sample model for launch menu**

Here,

$x_1$ = cooked rice
$x_2$ = rohu fish
$x_3$ = potato
$x_4$ = lentils
$x_5$ = banana
$x_6$ = egg
$x_7$ = apple

Objective function, Minimize $z = 0.0167x_1 + 0.2x_2 + 0.03x_3 + 0.12x_4 + 0.05x_5 + 0.12x_6 + 0.13x_7$

Subject to,

$$1.31x_1 + 0.97x_2 + 0.72x_3 + 1.16x_4 + 0.89x_5 + 1.37x_6 + 0.52x_7 = 1000$$
$$0.024x_1 + 0.167x_2 + 0.018x_3 + 0.089x_4 + 0.0085x_5 + 0.11x_6 + 0.003x_7 \geq 25$$
$$0.021x_1 + 0.034x_2 + 0.00083x_3 + 0.003x_4 + 0\,x_5 + 0.0877x_6 + 0.002x_7 \leq 35$$
$$0.021x_1 + 0.034x_2 + 0.00083x_3 + 0.003x_4 + 0\,x_5 + 0.0877x_6 + 0.002x_7 \geq 20$$
$$0.00054x_1 + 0.0023x_2 + 0\,x_3 + 0.0003x_4 + 0\,x_5 + 0.028x_6 + 0\,x_7 \leq 10$$
$$0.289x_1 + 0.032x_2 + 0.2x_3 + 0.2x_4 + 0.229x_5 + 0.011x_6 + 0.14x_7 \geq 104$$
$$0\,x_1 + 0\,x_2 + 0.0074x_3 + 0.021x_4 + 0.119\,x_5 + 0\,x_6 + 0.1x_7 \geq 25.4$$
$$0.000012x_1 + 0.001x_2 + 0.012x_3 + 0.0024x_4 + 0.0000085x_5 + 0\,x_6 + 0.00001x_7 \leq 3$$
$$0.000012x_1 + 0.001x_2 + 0.012x_3 + 0.0024x_4 + 0.0000085x_5 + 0\,x_6 + 0.00001x_7 \geq 0.417$$
$$0.0048x_1 + 0\,x_2 + 0.014x_3 + 0.08x_4 + 0.0178x_5 + 0x_6 + 0.024x_7 \leq 6$$
$$450 \leq x_1 \geq 480$$
$$110 \leq x_2 \geq 220$$
$$23 \leq x_3 \geq 100$$
$$0 \leq x_4 \geq 50$$
$$100 \leq x_5 \geq 120$$
$$50 \leq x_6 \geq 70$$
$$100 \leq x_7 \geq 120$$

1st constraint equation is satisfied with the required energy by the use of a combination of foods. Next 2nd constraint equation is satisfied required protein, 3rd and 4th constraints equations are satisfied required fat, 5th constraint equation is satisfied required saturated fat, 6th constraint equation is satisfied required carbohydrate, 7th constraint equation is satisfied required sugar, 8th and 9th constraint equation is satisfied required sodium,10th constraint equation is satisfied required dietary fiber. Rest of equations are satisfied with the required amount of foods.

## 6. Result Analysis

After solving the sample model for launch (1000 kcal), we get the amount of food in grams a man of 21 to 40 years-old-sedentary have to eat. We also get the minimum cost for the combination of food. Beside "Fig. 1" can be obtained by solving the sample models. By solving our sample model for launch menu with the help of excel solver, we get a result in the feasible region which means it satisfies each and every constraints equation.

After analyzing the sensitivity report provided by excel solver, it was learned that the obtained result was the feasible but not optimal result. Doing the sensitivity analysis, we get an optimal result. Further cost minimization is not possible which is being seen above "Fig. 2".

=SUMPRODUCT(C3:I3,C4:I4)

| B | C | D | E | F | G | H | I | O | P | Q | R |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | x1 | x2 | x3 | x4 | x5 | x6 | x7 | | | Minimize | 59.3139 |
| objective function,z | 469.69 | 110.534 | 24.893 | 0 | 120 | 70 | 109.358 | | | | |
| | 0.0167 | 0.2 | 0.03 | 0.12 | 0.05 | 0.12 | 0.13 | | | | |
| Subject to, | 1.31 | 0.97 | 0.72 | 1.16 | 0.89 | 1.37 | 0.52 | 1000 | 1000 | | |
| | 0.024 | 0.167 | 0.018 | 0.089 | 0.0085 | 0.11 | 0.003 | 39.2278 | 25 | | |
| | 0.021 | 0.034 | 0.00083 | 0.003 | 0 | 0.0877 | 0.002 | 20 | 35 | | |
| | 0.00054 | 0.0023 | 0 | 0.0003 | 0 | 0.028 | 0 | 2.46786 | 10 | | |
| | 0.289 | 0.032 | 0.2 | 0.2 | 0.229 | 0.011 | 0.14 | 187.816 | 104 | | |
| | 0 | 0 | 0.0074 | 0.021 | 0.119 | 0 | 0.1 | 25.4 | 25.4 | | |
| | 1.2E-05 | 0.001 | 0.012 | 0.0024 | 8.5E-06 | 0 | 0.00001 | 0.417 | 3 | | |
| | 0.0048 | 0 | 0.014 | 0.08 | 0.0178 | 0 | 0.024 | 7.3636 | 6 | | |
| | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 469.69 | 450 | | |
| | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 110.534 | 110 | | |
| | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 24.893 | 23 | | |
| | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | | |
| | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 120 | 100 | | |
| | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 70 | 50 | | |
| | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 109.358 | 100 | | |
| | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 469.69 | 480 | | |
| | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 110.534 | 220 | | |
| | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 24.893 | 100 | | |
| | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 50 | | |
| | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 120 | 120 | | |
| | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 70 | 70 | | |
| | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 109.358 | 120 | | |
| | 0.021 | 0.034 | 0.00083 | 0.003 | 0 | 0.0877 | 0.002 | 20 | 20 | | |
| | 1.2E-05 | 0.001 | 0.012 | 0.0024 | 8.5E-06 | 0 | 0.00001 | 0.417 | 0.417 | | |

Fig. 1. The Result of Sample Launch Menu

After the sensitivity test of sample launch menu, there are only two variables ($x_5$, $x_6$) of the amount of foods have shadow price. So, these variables have sensitivity and $x_5$ variable more sensitive than $x_6$ variable because of this "Fig. 3" show that the slope of $x_5$ variable is steeper than the slope of $x_6$ variable. The slope of the variable determines how much effect of cost for change of the amount of foods.

| Cell | Name | Final Value | Reduced Cost | Objective Coefficient | Allowable Increase | Allowable Decrease |
|---|---|---|---|---|---|---|
| $C$3 | objective x1 | 469.6895356 | 0 | 0.0167 | 0.124404613 | 0.095479592 |
| $D$3 | objective x2 | 110.5336087 | 0 | 0.2 | 0.123318626 | 0.156561303 |
| $E$3 | objective x3 | 24.89304481 | 0 | 0.03 | 0.776301489 | 0.115861202 |
| $F$3 | objective x4 | 0 | 0 | 0.12 | 1E+30 | 0.195235136 |
| $G$3 | objective x5 | 120 | 0 | 0.05 | 0.043024743 | 1E+30 |
| $H$3 | objective x6 | 70 | 0 | 0.12 | 0.533266159 | 1E+30 |
| $I$3 | objective x7 | 109.3579147 | 0 | 0.13 | 1.020093526 | 0.03621908 |

Constraints

| Cell | Name | Final Value | Shadow Price | Constraint R.H. Side | Allowable Increase | Allowable Decrease |
|---|---|---|---|---|---|---|
| $O$10 | | 187.8160683 | 0 | 104 | 83.81606829 | 1E+30 |
| $O$11 | | 25.4 | 1.846126425 | 25.4 | 1.062043221 | 0.162633479 |
| $O$12 | | 0.417 | 0 | 3 | 1E+30 | 2.583 |
| $O$13 | | 7.363602351 | 0 | 6 | 1.363602351 | 1E+30 |
| $O$14 | | 469.6895356 | 0 | 450 | 19.68953563 | 1E+30 |
| $O$15 | | 110.5336087 | 0 | 110 | 0.533608681 | 1E+30 |
| $O$16 | | 24.89304481 | 0 | 23 | 1.893044812 | 1E+30 |
| $O$17 | | 0 | 0.195235136 | 0 | 7.52719791 | 0 |
| $O$18 | | 120 | 0 | 100 | 20 | 1E+30 |
| $O$19 | | 70 | 0 | 50 | 20 | 1E+30 |
| $O$20 | | 109.3579147 | 0 | 100 | 9.357914684 | 1E+30 |
| $O$21 | | 469.6895356 | 0 | 480 | 1E+30 | 10.31046437 |
| $O$22 | | 110.5336087 | 0 | 220 | 1E+30 | 109.4663913 |
| $O$23 | | 24.89304481 | 0 | 100 | 1E+30 | 75.10695519 |

Fig. 2. The Sensibility Report of Sample Launch Menu

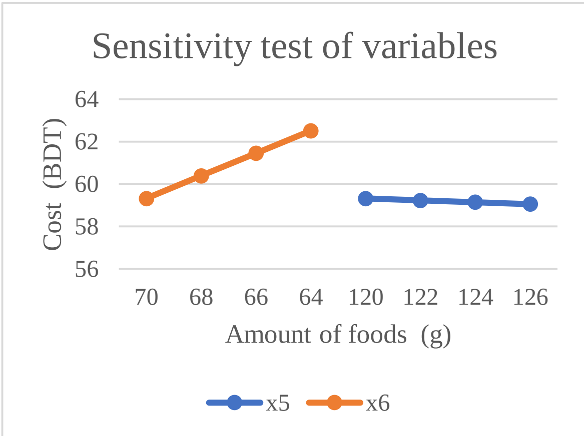


Fig. 3. Sensitivity test of sample launch menu

## 7. Conclusion

This paper has described a linear programming approach based on the variety of foods consumed by users. The linear programming approach is used to calculate the amount of foods to fulfill the required amount of nutrients with minimum cost as possible. Then a balanced diet planning will be produced as a result. This planning will help users to prevent chronic diseases such as heart diseases, cancer, stroke, obesity, and diabetes.

## 8. References

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