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An Integer Linear Programming Model For A Diet Problem Of Mcdonald’s Sets Menu In Malaysia

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Abstract: In this paper, we solve a diet problem of McDonald’s sets menu in order to find the optimal costs and satisfied the daily calories and nutritional requirements for a person. The nutrient contents and price for each set menu of McDonald’s need to be found. After that, by using the integer linear programming technique, we search the sets menu of McDonald’s with the minimum costs while satisfying the calories intake by a person is not exceeded 2500 Kcal / a day or 2200 Kcal / day. The mathematical model of the problem is formulated as linear integer programming where the total cost for the proposed set menu is the objective function. The constraints involved are the amounts of calories, carbohydrates, protein, fats, salt and sugar. By using the Solver tools in MS Excel, we solve this problem.

Keywords: Linear programming, integer linear programming, diet problem, McDonald’s menu.

1. INTRODUCTION

Integer linear programming problem is a mathematical method for solving optimization problem with a linear objective function and sets of linear constraints of equality or inequalities of decision variables. Integer linear programming provides optimal solutions to meet several limitations [1]. Usually, the simplex method is used in solving the integer linear programming. Simplex method was developed by Dantzig in 1948 [2] which is the method from numerical linear algebra. In real life problems, there are many problems were solved by using the integer linear programming model such as production planning, vehicle scheduling, telecommunications networks and cellular networks.

[3] proposed mixed integer linear programming model in solving the vehicle routing problem which is to deliver and pick up the goods from one location to the other location in a systematic way. While [4] used the mixed integer linear programming in the car parts manufacturing company. In manufacturing the car parts, there are three steps involved which

are separating the operations in its critical departments, establish the second shift and lastly provide newly machines. Then, [5] has explained the relationship between linear system and principle of steady-state analysis and stability theory. [6] had used linear program boosting technique in forecasting the weather.

In the diet problems, the first research that had been using linear programming were in the year 1955 and 1970 [7]. [8] obtained the minimal costs of diets that fulfil the requirements of energy, proteins, vitamins and minerals by using the optimization methods. During the World War II, the Air Force had been hiring mathematicians in order to solve the diet problem for planning affordable meals [1]. One of the mathematicians that hired is George Dantzig. He is the first one that proposed a correct method in solving the diet problem. In 1950s, the development of the solutions of diet problems was reliant to the computers with high computational capacity [9]. Initially, past researchers modelled the diet problem without acceptable constraints. The diet problem was then modelled by taking into account the restrictions on food prices, energy consumption and macronutrients and micronutrients [10]-[18]. [19] found 55% increased of costs in order to obtained the nutritious diet. In addition,[20] found that when optimising the size of the servings and energy density, the cost increased. [21] proposed linear programming method in solving the impact of cost constraints on food choices for French women has been assessed in [22], so that a healthy diet is reached. [23] used the Food-Based Dietary Guidelines (FBDGs) in their work. However, the healthy diet could not be achieved because of the increasing price of the foods. The contribution for this paper are (i) a model formulation for the diet problem by using integer linear programming and (ii) recommended diet plan for McDonalds's sets menu. In the final section, results and discussion including the conclusion of our study will be discussed.

2. RESEARCH METHOD

An integer linear programming problem is defined as an optimization problem with minimizing or maximizing of a linear function subject to linear constraints [24]. In this section, we describe the model formulation of the diet problem for McDonald's sets menu in Malaysia.

Model Formulation

The integer linear programming consists of the objective function, a set of constraints, a set of decision variables and the parameters. In order to solve the integer linear programming, we must determine the objective function that minimizes or maximizes while satisfy the set of the constraints of the model. In this paper, the objective function is to minimize the intake of calories for the given diet but restrict the minimum requirement of calories intake. While satisfied the nutritional requirements by a person, we determine the menu that will be chosen by solving the mathematical modelling. The formulation of the diet problem of McDonald's sets menu in Malaysia is demonstrated in this section. In Table 1, the notations used in the model are summarised.

Table 1: The notations in the diet problem of McDonald's sets menu in Malaysia

Notation	Explanation
x_i	Sets menu of McDonald's in Malaysia

c_i	Calories for the sets menu x_i
t_1	Calories intake for a person for the sets menu x_i
t_2	Carbohydrates for the sets menu x_i
t_3	Protein for the sets menu x_i
t_4	Fats for the sets menu x_i
t_5	Salt for the sets menu x_i
t_6	Sugar for the sets menu x_i

The integer linear programming for the diet problem of McDonald's sets menu in Malaysia is shown as follows:

$$\text{Min } c_1x_1 + c_2x_2 + ... + c_ix_j \quad (1)$$

$$\text{subject to } t_1x_1 + t_1x_2 + ... + t_1x_j \le 2500/2200 \quad (2)$$

$$t_2x_1 + t_2x_2 + ... + t_2x_j \le 375 \quad (3)$$

$$t_3x_1 + t_3x_2 + ... + t_3x_j \le 63 \quad (4)$$

$$t_4x_1 + t_4x_2 + ... + t_4x_j \le 80 \quad (5)$$

$$t_5x_1 + t_5x_2 + ... + t_5x_j \le 6 \quad (6)$$

$$t_6x_1 + t_6x_2 + ... + t_6x_j \le 50 \quad (7)$$

The objective function (1) aims to get the minimal calories intake by a person. While equation (2) restricts that calorie intake by a person for man is 2500 kcal and woman is 2200 kcal. Equation (3) restricts that carbohydrates need to be taken by a person at most 375 gram. Equation (4) makes sure that the protein intake by a person is 63 gram. Equation (5) guarantees that the fats taken by a person is at most as 80 gram. Equation (6) restricts the intake of salt at most as 6 gram only while equation (7) makes sure that the intake of sugar at most as 50 gram only. Tables 2, 3 and 4 shows the nutrients for each McDonald's sets menu in Malaysia, x_i.

Table 2: The nutrients for each McDonald's sets menu in Malaysia, x_i

	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}
Calories (kcal)	361	265	303	325	229	558	526	449	409	506	1042
Carbohydrate (g)	27	25.4	26.5	38.6	38.8	43.1	33.6	33	35.8	37.4	129.4
Protein (g)	24.8	16.4	20.3	14.5	5.6	25.6	30	22	16.7	25.1	33.9
Fats (g)	16.6	10.3	12.3	12.5	5.8	29.2	31	26	21.6	27.9	42.1
Salt (g)	1.9	1.8	1.6	1.4	0.9	2.7	0.9	0.9	2.1	2.2	3.2
Sugar (g)	1.8	1.7	2.1	5	9	1.8	5.5	5.3	3.3	3.4	47.3

Table 3: The nutrients for each McDonald's sets menu in Malaysia, x_i

							x_{18}	x_{19}	x_{20}	x_{21}	x_{22}
Calories (kcal)	1032	1262	774	819	963	913	1163	929	703	764	845
Carbohydrat	122.0	122.1	117.	116.	117.	128.	161.	123.	96.	96.	124

e (g)	2	8	5	8	4	9	5	6	8	6	.9
Protein (g)	37.42	57.4	19.2	22.2	33.8	19.5	24.4	26.6	15	24.7	19.5
Fats (g)	42.7	59.35	24.2	28.1	38.5	34.4	44	35.4	27.3	29.8	28.6
Salt (g)	3.35	3.76	2.2	2.6	3.4	2.6	3.6	3.4	1.6	2.1	2.3
Sugar (g)	47.8	47.88	46.2	45.7	46.1	45.8	44.3	46.7	39.2	39.2	44.2

Table 4: The nutrients for each McDonald’s sets menu in Malaysia, x_i

	x_{23}	x_{24}	x_{25}	x_{26}	x_{27}	x_{28}	x_{29}	x_{30}	x_{31}	x_{32}	x_{33}	x_{34}
Calories (kcal)	1198	1188	1418	930	975	1119	1069	1319	1085	859	920	1001
Carbohydrate (g)	158.6	151.22	151.38	146.7	146	146.6	158.1	190.7	152.8	126	125.8	154.1
Protein (g)	35.4	38.92	58.9	20.7	23.7	35.3	21	25.9	28.1	16.5	26.2	21
Fats (g)	47	47.6	64.25	29.1	33	43.4	39.3	48.9	40.3	32.2	34.7	33.5
Salt (g)	3.4	3.55	3.96	2.4	2.8	3.6	2.8	3.8	3.6	1.8	2.3	2.5
Sugar (g)	62	62.5	62.58	60.9	60.4	60.8	60.5	59	61.4	53.9	53.9	58.9

While Table 5 represents the recommended daily nutrients for a diet of 2500 Kcal per day and 2200 Kcal per day.

Table 5: Recommended daily values of carbohydrates, protein, fats, salt and sugar

Number of nutrients	Nutrients	Recommended for	Quantity of calories	
			2500 Kcal	2200 Kcal
1.	Carbohydrate (g)	Less than	375	330
2.	Protein (g)	Less than	63	50
3.	Fats (g)	Less than	80	80
4.	Salt (g)	Less than	6	6
5.	Sugar (g)	Less than	50	50

Based on the Table 5, quantity of calories 2500 Kcal is for men (20-60 years old), teenager boys and active women. While the quantity of calories 2200 Kcal per day is for women (20-60 years old) and teenager girls. The mathematical model of our proposed diet problem is formulated as an integer linear programming in which the minimum cost for McDonald's set menu for a day is the objective function is:

$$f(x_1,...,x_{34}) = 9.15x_1 + 7.75x_2 + 7.9x_3 + 10x_4 + 9.45x_5 + 10.4x_6 + 9.9x_7 + 8.5x_8 + 8.5x_9 + 9.9x_{10} + 11.85x_{11} + 12.3x_{12} + 18.35x_{13} + 9.6x_{14} + 8.3x_{15} + 8.95x_{16} + 9.95x_{17} + 12.15x_{18} + 12.75x_{19} + 6.5x_{20} + 12.15x_{21} + 7.95x_{22} + 13.25x_{23} + 13.7x_{24} + 19.75x_{25} + 11x_{26} + 9.7x_{27} + 10.35x_{28} + 11.35x_{29} + 13.55x_{30} + 14.15x_{31} + 7.9x_{32} + 13.55x_{33} + 9.35x_{34} \tag{8}$$

For this diet problem, there are constraints that need to be satisfied which are:

Calories (Kcal):

$$361x_1 + 2655x_2 + 303x_3 + 325x_4 + 229x_5 + 558x_6 + 526x_7 + 449x_8 + 409x_9 + 506x_{10} + 1042x_{11} + 1032x_{12} + 1262x_{13} + 774x_{14} + 819x_{15} + 963x_{16} + 913x_{17} + 1163x_{18} + 929x_{19} + 703x_{20} + 764x_{21} + 845x_{22} + 1198x_{23} + 1188x_{24} + 1418x_{25} + 930x_{26} + 975x_{27} + 1119x_{28} + 1069x_{29} + 1319x_{30} + 1085x_{31} + 859x_{32} + 920x_{33} + 1001x_{34} \le 2500/2200 \tag{9}$$

Carbohydrate (g):

$$27x_1 + 25.4x_2 + 26.5x_3 + 38.6x_4 + 38.8x_5 + 43.1x_6 + 33.6x_7 + 33x_8 + 35.8x_9 + 37.4x_{10} + 129.4x_{11} + 122.02x_{12} + 122.18x_{13} + 117.5x_{14} + 116.8x_{15} + 117.4x_{16} + 128.9x_{17} + 161.5x_{18} + 123.6x_{19} + 96.8x_{20} + 96.6x_{21} + 124.9x_{22} + 158.6x_{23} + 151.22x_{24} + 151.38x_{25} + 146.7x_{26} + 146x_{27} + 146.6x_{28} + 158.1x_{29} + 190.7x_{30} + 152.8x_{31} + 126x_{32} + 125.8x_{33} + 154.1x_{34} \le 375 \tag{10}$$

Protein (g):

$$24.8x_1 + 16.84x_2 + 20.3x_3 + 14.5x_4 + 5.6x_5 + 25.6x_6 + 30x_7 + 22x_8 + 16.7x_9 + 25.1x_{10} + 33.9x_{11} + 37.42x_{12} + 57.4x_{13} + 19.2x_{14} + 22.2x_{15} + 33.8x_{16} + 19.5x_{17} + 24.4x_{18} + 26.6x_{19} + 15x_{20} + 24.7x_{21} + 19.5x_{22} + 35.4x_{23} + 38.92x_{24} + 58.9x_{25} + 20.7x_{26} + 23.7x_{27} + 35.3x_{28} + 21x_{29} + 25.9x_{30} + 28.1x_{31} + 16.5x_{32} + 26.2x_{33} + 21x_{34} \le 63 \tag{11}$$

Fats (g):

$$16.6x_1 + 10.3x_2 + 12.3x_3 + 12.5x_4 + 5.8x_5 + 29.2x_6 + 31x_7 + 26x_8 + 21.6x_9 + 27.9x_{10} + 42.1x_{11} + 42.7x_{12} + 59.35x_{13} + 24.2x_{14} + 28.1x_{15} + 38.5x_{16} + 34.4x_{17} + 44x_{18} + 35.4x_{19} + 27.3x_{20} + 29.8x_{21} + 28.6x_{22} + 47x_{23} + 47.6x_{24} + 64.25x_{25} + 29.1x_{26} + 33x_{27} + 43.4x_{28} + 39.3x_{29} + 48.9x_{30} + 40.3x_{31} + 32.2x_{32} + 34.7x_{33} + 33.5x_{34} \le 80 \tag{12}$$

Salt (g):

$$1.9x_1 + 1.8x_2 + 1.6x_3 + 1.4x_4 + 0.9x_5 + 2.7x_6 + 0.9x_7 + 0.9x_8 + 2.1x_9 + 2.2x_{10} + 3.2x_{11} + 3.35x_{12} + 3.76x_{13} + 2.2x_{14} + 2.6x_{15} + 3.4x_{16} + 2.6x_{17} + 3.6x_{18} + 3.4x_{19} + 1.6x_{20} + 2.1x_{21} + 2.3x_{22} + 3.4x_{23} + 3.55x_{24} + 3.96x_{25} + 2.4x_{26} + 2.8x_{27} + 3.6x_{28} + 2.8x_{29} + 3.8x_{30} + 3.6x_{31} + 1.8x_{32} + 2.3x_{33} + 2.5x_{34} \le 6 \tag{13}$$

Sugar (g):

$$1.8x_1 + 1.7x_2 + 2.1x_3 + 5x_4 + 9x_5 + 1.8x_6 + 5.5x_7 + 5.3x_8 + 3.3x_9 + 3.4x_{10} + 47.3x_{11} + 47.8x_{12} + 47.88x_{13} + 46.2x_{14} + 45.7x_{15} + 46.1x_{16} + 45.8x_{17} + 44.3x_{18} + 46.7x_{19} + 39.2x_{20} + 39.2x_{21} + 44.2x_{22} + 62x_{23} + 62.5x_{24} + 62.58x_{25} + 60.9x_{26} + 60.4x_{27} + 60.8x_{28} + 60.5x_{29} + 59x_{30} + 61.4x_{31} + 53.9x_{32} + 53.9x_{33} + 58.9x_{34} \leq 50 \quad (14)$$

$x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{10}, x_{11}, x_{12}, x_{13}, x_{14}, x_{15}, x_{16}, x_{17}, x_{18}, x_{19}, x_{20}, x_{21}, x_{22}, x_{23}, x_{24}, x_{25}, x_{26}, x_{27}, x_{28}, x_{29}, x_{30}, x_{31}, x_{32}, x_{33}, x_{34} \geq 0$ which are integer only where $x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{10}, x_{11}, x_{12}, x_{13}, x_{14}, x_{15}, x_{16}, x_{17}, x_{18}, x_{19}, x_{20}, x_{21}, x_{22}, x_{23}, x_{24}, x_{25}, x_{26}, x_{27}, x_{28}, x_{29}, x_{30}, x_{31}, x_{32}, x_{33}, x_{34}$ are the menu sets of McDonalds in Malaysia. (15)

3. RESULTS AND DISCUSSION

A mathematical model for a diet problem of McDonald's sets menu in Malaysia is formulated as an integer linear programming in which the objective function is the minimum costs involved for menu sets of McDonalds consumed for a person per day while satisfying all the nutrients requirements needed. In this proposed mathematical model, all daily sets menu are satisfying all the constraints involved, which are the total amounts of calories, carbohydrate, protein, fats, salt and sugar. Using the Solver method, an integer linear Excel workbook system was built and then solved it. Table 6 represents the results of the diet problem of McDonald's sets menu by using integer linear programming.

The solution for the type of Diet 1 (2500 Kcal), the minimum costs involved is RM57.25 with suggestion menu are one set of Filet-O-Fish and five sets of Hotcakes (2 pieces) for a person per day. While for the type of Diet 2 (2200 Kcal), the minimum costs involved is also RM57.25 with suggestion menu are also same which are one set of Filet-O-Fish and five sets of Hotcakes (2 pieces) for a person per day. As both diets consist of same sets menu of McDonald's, hence the obtained amount calories for both diets are 1470 Kcal.

4. CONCLUSIONS

A realistic model of integer linear programming was developed which applied to a dietary situation for menu sets of McDonalds. The variables involved are the menu sets of McDonalds while the constraints are the nutrients requirement for a person for a day and the objective function is the minimum costs obtained from the diet. By using the Solver tool in Microsoft Excel, the costs obtained are minimal and the nutrients requirement is satisfied. It is showed that the optimal solution was obtained. One conceivable future research is to solve the proposed mathematical model in this research by using a heuristic approach and then compare both solutions in terms of optimality solution.

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