Universiti Teknologi MARA
Cawangan Perlis
Jurnal Intelek

Volume 14 Issue 2 (December 2019)

Cost-Minimized Diets For UiTM Perlis Students Using Goal And Linear Programming

Nur Fatihah Fauzi[1*], Nurul Asyiqin Supardi[2], Rohana Alias[3], and Nor Hayati Shafii[4]
[1,2,3,4] Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA Perlis Branch, 02600 Arau, Perlis, Malaysia

*Authors' Email Address: *[1]fatihah@uitm.edu.my, [3]annna@uitm.edu.my, [4]norhayatishafii@uitm.edu.my*
Received Date: 30 September 2019
Accepted Date: 19 November 2019

ABSTRACT

Humans need to eat good and balanced nutritious diet that provides calories for energy requirements and nutrients for proper growth, repair and maintenance of the body tissue. Today, busy lifestyle habits drastically changed the pattern of eating where students are more likely to have irregular meal times and the cost of food may be expensive for them. Therefore, this study is conducted to find the minimum cost that satisfies the daily nutrient requirements. A linear programming (LP) model and goal programming (GP) model are formulated where the objective function is the total cost of food. Food prices were collected from selected cafés in UiTM Perlis and the recommended daily nutrient intakes of 19-29 years old, male and female were obtained from the Ministry of Health Malaysia. The sample used in this research consists of 10 most frequently consumed food items as decision variables. QM for Windows V5 was used to determine minimum cost that satisfies the nutritional requirements. LP results, the minimum cost for male students is RM9.88 and for female students is RM9.10. Based on the GP results, the cost is RM9.00 for both male and female students. It is evident from the results that GP has achieved the minimum cost and the food basket for male students consists of 410g of rice, 140g of chicken, 42.9g of broccoli and 252.7g of mushroom. Meanwhile, the food basket for female students consists of 429g of rice, 113.4g of chicken, 37.44g of broccoli and 321.3g of mushroom.

Keywords: *Linear Programming Model, Goal Programming Model, Minimum Cost, Nutritional requirements, Optimization*

INTRODUCTION

Nutrition is the intake of food that is related to the body's dietary requirements (World Health Organization (WHO), 2018). A good nutrition is an adequate and well-balanced diet that increases immunity, reduces susceptibility to diseases, enhances physical and mental development and also increases productivity. Currently, we are living in an environment that encourages unhealthy eating and less physical activity. According to Sidik & Ahmad (2004) and Poh et al. (2013), many children in developing countries, including Malaysia are facing obesity issue.

Stigler (1945) studied the minimum cost of his chosen 77 food would be consumed by a man weighing 154 pounds so that his intake of nine nutrients would be at least equal to the recommended dietary intake (as suggested by the National Research Council). A similar study by Darko et al. (2013) observed that an average Ghanaian requires $0.36 per day to meet his daily nutritional needs. This would be met with a food basket made up of sorghum, yam, cassava, coconut and milk. Besides, Sufahani and Ismail (2013)

ISSN: 2231-7716
DOI: http://10.24191/ji.v14i2.240

deliberated total cost of diet planning model for boarding schools in Malaysia is less than RM9.00 per day. Furthermore, based on studies of optimization on nutrition by Pasic et al. (2012) found that women need to spend 3.04km and men need to spend 3.39km to obtain all daily nutrient requirements. Meanwhile, Nykänen et al. (2018) created a list of affordable food basket that fulfill all Ghanaian nutrient recommendations while also helping to reduce risk of diet-related non-communicable disease for low-income families of four. Parlesak et al. (2016) designed a range of cost-minimized health promoting food baskets that could both help to prevent micronutrient inadequacies and to be culturally acceptable for a low-income family.

When it was first proposed in 1947 by the author (in connection with the planning activities of the military), LP and its many extensions have come into wide use. In academic settings, decision scientists (operation researchers and management scientists), as well as numerical analysts, mathematicians and economists have written hundreds of books and numerous number of articles on this subject. Moraes et al. (2012) studied that LP plays an important role in optimization such as maximizing profit, minimizing costs and scheduling. Hasan and Arefin (2017) applied LP to the scheduling problem for large organizations and industries. Their main objective is to minimize the number of workers required to meet all shifts. Numerous researches have been conducted with different purposes such as Stamenkovska et al. (2012), Georgakakos (2012), Maurya et al. (2015) and Akpan and Iwok (2016). Stamenkovska et al. (2012) developed an optimization model to maximize the vegetable production in the Republic of Macedonia to help the decision making on Macedonian family farms. In addition, Georgakakos (2012) formulated a model of water allocation in maximizing the water management operation cost. Meanwhile, Maurya et al. (2015) developed LP to optimize the profit of an Ethiopian chemical company in Adama, Ethiopia. They recommended a viable product-mix to ensure optimum profit for the company. Last but not least, Akpan and Iwok (2016) considered the LP to obtain maximum profit so that the bakery production can be optimized.

GP is a branch of multi-criteria decision analysis. It was first introduced by Charnes et al. in 1955, more explicitly defined by the same author in 1961. There are a lot of researches that has been done by using GP. These include the study in maximizing both production and planted areas of rubber in Malaysia (Hassan et al., 2013), optimizing the production planning of clothing company (Anggraeni et al., 2015), reducing the liability, gain earning, profitability, increase asset accumulation, equity wealth and optimum managements items in the financial statement (Halim et al., 2015) and allocating the work force in order to achieve the objectives related to energy, economic and environmental goals of the United Arab Emirates by the year 2030 (Jayaraman et al., 2015).

Motivated by the above-mentioned studies, this study is focused in finding the minimum cost that meets nutrition needs for students in UiTM Perlis and to compare the LP and GP methods to minimize cost. This study will benefit students to minimize costs of food but meet the daily nutritional requirements. The primary data which is price of food per serving were obtained from randomly selected café in UiTM Perlis namely Apple slice, Bachok, Aisyah, D'Durani Rasa and Selera cafes. While, the secondary data which is nutrition facts of each food per serving and the daily nutrient requirement intake for 19 – 29 years old male and female were obtained from the Ministry of Health Malaysia, Putrajaya.

LP MODEL FORMULATION

LP method was developed by Leonid Kantorovich who is a Russian mathematician. The first problem was used during World War II which is to plan expenses and returns in order to reduce costs to the army. In 1947, the latest version of the simplex method was formulated by George B. Dantzig. The objective function and constraints must be linear (Sallan et al., 2015). LP has been used to solve the problem of optimization in the system of industries such as banking, petroleum, education and trucking. From expert

views, LP problem is a mathematical program in optimizing which is to identify the minimum or maximum point of a linear objective function that satisfies a set of constraints.
LP model consists of an objective and constraints functions.

Objective function: Minimize cost

$$Z = \sum_{j=1}^{10} a_j X_j \quad (1)$$

Where X_j is the quantity of the food item j and a_j is the cost of food item j. The food items are rice (X_1), chicken (X_2), beef (X_3), squid (X_4), shrimp (X_5), egg (X_6), broccoli (X_7), cabbage (X_8), salad (X_9) and mushroom (X_{10}).
The above objective function is subjected to the constraints:

$$\sum_{j=1}^{10} b_{ij} X_j \le c_i \quad ; \quad X_j \ge 0 \quad (2)$$

where b_{ij} is the amount of nutrient i in the food item j and c_i is the minimum daily requirement of nutrient i. The constraints are energy, protein, fat, vitamin A, vitamin B1, vitamin B2, vitamin D, vitamin K, calcium, iron, zinc, phosphorus, sodium, potassium and magnesium (refer to Table 1).

An example of the constraint is the energy constraint, shown in equation (3).

$$130X_1 + 307X_2 + 204X_3 + 149X_4 + 84X_5 + 78X_6 + 27X_7 + 18X_8 + 277.5X_9 + 15.8X_{10} \le 2240 \quad (3)$$

Table 1: Price and Nutritional Content of Food Items

	Rice	Chicken	Beef	Squid	Shrimp	Egg	Broccoli	Cabbage	Salad	Mushroom	Constraint
Price	RM1/100g	RM2.50/140g	RM2/85g	RM2/85g	RM2/85g	RM1/50g	RM0.80/78g	RM0.50/70g	RM0.50/70g	RM0.50/70g	
Energy	130kcal	307 kcal	204 kcal	149 kcal	84 kcal	78 kcal	27 kcal	18 kcal	277.5 kcal	15.8 kcal	≤ 2240
Protein	2.4g	43g	21g	15g	20g	6.3g	1.9g	0.9g	0.75g	1.5g	≥ 62
Fat	0.2g	13g	12g	6.4g	0.2g	5.3g	0.3g	0.1g	23.75g	0.25g	≤ 75
Vitamin A	0 µg	82.6 µg	18.7 µg	29.75 µg	0 µg	260 µg	1207.44 µg	68.6 µg	44.65 µg	0 µg	≥ 750
Vitamin B1	0.17mg	0.12mg	0.04mg	0.05mg	0mg	0.03 mg	0.05mg	0.04mg	0.01mg	0.05mg	≥ 1.2
Vitamin B2	0.02mg	0.28mg	0.15mg	0.39mg	0mg	0.23 mg	0.1mg	0.03mg	0.02mg	0.24mg	≥ 1.3
Vitamin D	0 µg	7 µg	6.8 µg	0 µg	129 µg	43.5 µg	0 µg	0 µg	2.13 µg	5.68 µg	≥ 15

Vitamin K	0mcg	3.9mcg	1.4mcg	0mcg	0.33mcg	0.1mcg	110.1mcg	53.2mcg	45.25mcg	0mcg	≤ 90
Calcium	3mg	23.8mg	21.25mg	33.15mg	59.5mg	25mg	31.2mg	28mg	9.93mg	4.25mg	≤ 1000
Iron	1.49mg	1.89mg	2.27mg	0.86mg	0.43mg	0.59mg	0.52mg	0.33mg	0.15mg	1.23mg	≥ 1.37
Zinc	0.42mg	3.14mg	5.26mg	1.48mg	1.39mg	0.53mg	0.35mg	0.13mg	0.13mg	0.63mg	≥ 6.6
Phosphorus	37mg	287mg	181.05mg	213.35mg	201.45mg	86mg	52.26mg	18.2mg	18.43mg	61.65mg	≥ 700
Sodium	0mg	127.4mg	72mg	260mg	94.35mg	62mg	204.36mg	12.6mg	502.5mg	168.68mg	≤ 1500
Potassium	29g	359.8g	300.05g	237.15g	220.15g	63g	228.54g	119g	6.38g	252.3g	≤ 4700
Magnesium	13mg	37.8mg	18.7mg	32.3mg	33.15mg	5mg	16.38mg	8.4mg	1.43mg	7.75mg	≤ 400

The formulated model will be analyzed in QM for Windows V5 software to obtain the optimal solution.

GP MODEL FORMULATION

GP method was introduced in 1955 by A. Charnes, R. O. Ferguson and W. W. Copper. GP is often seen as a multi-objective and multi-decision optimization programming model. GP is a platform of analyzing multiple measures of organizational performance in terms of costs, profitability, productivity and revenue (Charnes and Cooper, 1977).
GP model consists of an objective and the constraints functions.

Objective function: Minimize cost

$$Z = \sum_{i=1}^{16} d_i^+ + d_i^- \quad (4)$$

subjected to the constraints

$$\sum_{i=1}^{16} a_{ij} X_j - d_i^+ + d_i^- = c_i \qquad ;\ d_i^+, d_i^-, X_j \geq 0 \quad (5)$$

where a_{ij} is the coefficient associated with j in goal i-th, d_i^+ is the overachievement in goal i-th, d_i^- is the underachievement in goal i-th and c is the target value.

In equation (3), by subtracting d_i^+ and adding d_i^- results in equation (6).

$$\begin{aligned} 130X_1 + 307X_2 + 204X_3 + 149X_4 + 84X_5 + 78X_6 + 27X_7 + 18X_8 \\ +277.5X_9 + 15.8X_{10} + (0)d_2^- - (1)d_2^+ = 2240 \end{aligned} \quad (6)$$

Then, the GP model will be run in QM for Windows V5 software to obtain optimal solution.

RESULTS AND DISCUSSION

Table 2 represents the results of linear programming technique for male and female students. The lowest cost for male and female students in order to get enough nutrition is RM9.88 and RM9.10, respectively. Meanwhile, the daily meal portion for male (female) students should be 513g (443g) of rice, 141.4g (113.4g) of chicken, 42.9g (37.44g) broccoli and 251.3g (317.8g) of mushroom.

Table 2. Constraints and Output for Male (Female) Students

	Rice X_1	**Chicken** X_2	**Beef** X_3	**Squid** X_4	**Shrimp** X_5	**Egg** X_6	**Broccoli** X_7	**Cabbage** X_8	**Salad** X_9	**Mushroom** X_{10}		**RHS**
Price	1	2.5	2	2	2	1	0.8	0.5	0.5	0.5		
Energy	130	307	204	149	84	78	27	18	277.5	15.8	≤	2240 (1840)
Protein	2.4	43	21	15	20	6.3	1.9	0.9	0.75	1.5	≥	62 (53)
Fat	0.2	13	12	6.4	0.2	5.3	0.3	0.1	23.75	0.25	≤	75 (61)
Vitamin A	0	82.6	18.7	29.75	0	260	1207.44	68.6	44.65	0	≥	750 (650)
Vitamin B1	0.17	0.12	0.04	0.05	0	0.03	0.05	0.04	0.01	0.05	≥	1.2 (1.1)
Vitamin B2	0.02	0.28	0.15	0.39	0	0.23	0.1	0.03	0.02	0.24	≥	1.3 (1.1)
Vitamin D	0	7	6.8	0	129	43.5	0	0	2.13	5.68	≥	15 (15)
Vitamin K	0	3.9	1.4	0	0.33	0.1	110.1	53.2	45.25	0	≤	90 (90)
Calcium	3	23.8	21.25	33.15	59.5	25	31.2	28	9.93	4.25	≤	1000 (1000)
Iron	1.49	1.89	2.27	0.86	0.43	0.59	0.52	0.33	0.15	1.23	≥	1.37 (1.13)
Zinc	0.42	3.14	5.26	1.48	1.39	0.53	0.35	0.13	0.13	0.63	≥	6.6 (4.7)
Phosphorus	37	287	181.05	213.35	201.45	86	52.26	18.2	18.43	61.65	≥	700 (700)
Sodium	0	127.4	72	260	94.35	62	204.36	12.6	502.5	168.68	≤	1500 (1500)
Potassium	29	359.8	300.05	237.15	220.15	63	228.54	119	6.38	252.3	≤	4700 (4700)
Magnesium	13	37.8	18.7	32.3	33.15	5	16.38	8.4	1.43	7.75	≤	400 (310)
Solution	5.13 (4.43)	1.01 (0.81)	0 (0)	0 (0)	0 (0)	0 (0)	0.55 (0.48)	0 (0)	0 (0)	3.59 (4.54)		9.88 (9.1)

Example of calculation for the daily meal portion (male student):
For rice: $5.13 \times 100\text{g} = 513\text{g}$.
For chicken: $1.01 \times 140\text{g} = 141.4\text{g}$.
For broccoli: $0.55 \times 78\text{g} = 42.9\text{g}$.
For mushroom: $3.59 \times 70\text{g} = 251.3\text{g}$.

Example of calculation for the daily meal portion (female student):

For rice: $4.43 \times 100\text{g} = 443\text{g}$.
For chicken: $0.81 \times 140\text{g} = 113.4\text{g}$.
For broccoli: $0.48 \times 78\text{g} = 37.44\text{g}$.
For mushroom: $4.54 \times 70\text{g} = 317.8\text{g}$

Table 3 shows the optimal nutrients for both male and female students which are 1047.52kcal (907.43kcal) of energy, 62g (53g) of protein, 15.17g (12.64g) of fat, 750µg (650µg) of vitamin A, 1.2mg (1.1mg) of vitamin B1, 1.3mg (1.45mg) of vitamin B2, 27.41µg (31.34µg) of vitamin D, 64.73mcg (56.34mcg) of vitamin K, 71.81mg (66.82mg) of calcium, 14.24mg (13.95mg) of iron, 7.77mg (7.42mg) of zinc, 728.48mg (700mg) of phosphorus, 845.8mg (966.73mg) of sodium, 1541.56g (1673.44g) of potassium and 141.57mg (131.07mg) of magnesium.

Table 3. LP Summary of Slack and Surplus for Male (Female) Students

Variable	Value	Available value
Slack 1	1192.48 (932.57)	1047.52 (907.43)
Surplus 2	0 (0)	62 (53)
Slack 3	59.83 (48.36)	15.17 (12.64)
Surplus 4	0 (0)	750 (650)
Surplus 5	0 (0)	1.2 (1.1)
Surplus 6	0 (0.35)	1.3 (1.45)
Surplus 7	12.41 (16.41)	27.41 (31.34)
Slack 8	25.27 (33.66)	64.73 (56.34)
Slack 9	928.19 (933.18)	71.81 (66.82)
Surplus 10	12.87 (12.82)	14.24 (13.95)
Surplus 11	1.17 (2.72)	7.77 (7.42)
Surplus 12	28.48 (0)	728.48 (700)
Slack 13	654.2 (533.27)	845.8 (966.73)
Slack 14	3158.44 (3026.56)	1541.56 (1673.44)
Slack 15	258.43 (178.93)	141.57 (131.07)
Optimal value (Z)	9.88 (9.1)	

The results of goal programming are shown in Table 4. It is indicated that the minimum cost for both male and female students are RM9 with the 410g (429g) of rice, 148.4g (113.4g) of chicken, 42.9g (37.44g) of broccoli and 252.7g (321.3g) of mushroom. Then, the optimal nutrients from the suggested food items for male (female) students are 998.22kcal (892.24kcal) of energy, 62g (53g) of protein, 15.71g (12.7g) of fat, 750.12µg (650µg) of vitamin A, 1.37mg (1.12mg) of vitamin B1, 1.3mg (1.38mg) of vitamin B2, 27.93µg (31.77µg) of vitamin D, 64.52mcg (69.19mcg) of vitamin K, 70.04mg (60.29mg) of calcium, 12.84mg (7.43mg) of iron, 7.52mg (7.41mg) of zinc, 707.84mg (700mg) of phosphorus,

855.89mg (976.83mg) of sodium, 1536.72g (1685.56g) of potassium and 130.43mg (129.93mg) of magnesium.
Example of calculation for the daily meal portion (male student):

For rice: $4.1 \times 100\text{g} = 410\text{g}$.
For chicken: $1.06 \times 140\text{g} = 148.4\text{g}$.
For broccoli: $0.55 \times 78\text{g} = 42.9\text{g}$.
For mushroom: $3.61 \times 70\text{g} = 252.7\text{g}$.

Example of calculation for the daily meal portion (female student):

For rice: $4.29 \times 100\text{g} = 429\text{g}$.
For chicken: $0.81 \times 140\text{g} = 113.4\text{g}$.
For broccoli: $0.48 \times 78\text{g} = 37.44\text{g}$.
For mushroom: $4.59 \times 70\text{g} = 321.3\text{g}$

Table 4. GP Summary for Male (Female) Students

Decision variable analysis	Value
X_1	4.1 (4.29)
X_2	1.06 (0.81)
X_3	0 (0)
X_4	0 (0)
X_5	0 (0)
X_6	0 (0)
X_7	0.55 (0.48)
X_8	0 (0)
X_9	0 (0)
X_{10}	3.61 (4.59)

Constraint Analysis	RHS	d+(row i)	d-(row i)	Available value
Cost	9 (9)	0 (0)	0 (0)	
Energy	2240 (1840)	0 (0)	1241.88 (947.76)	998.22 (892.24)
Protein	62 (53)	0 (0)	0 (0)	62 (53)
Fat	75 (61)	0 (0)	59.3 (48.3)	15.71 (12.7)
Vitamin A	750 (650)	0 (0)	0.28 (0)	750.12 (650)
Vitamin B1	1.2 (1.1)	0 (0)	0.17 (0.02)	1.37 (1.12)
Vitamin B2	1.3 (1.1)	0 (0.28)	0 (0)	1.3 (1.38)
Vitamin D	15 (15)	12.92 (16.77)	0 (0)	27.93 (31.77)
Vitamin K	90 (90)	0 (0)	25.5 (20.81)	64.52 (69.19)
Calcium	1000 (1000)	0 (0)	929.97 (939.71)	70.04 (60.29)
Iron	1.37 (1.13)	11.47 (6.3)	0 (0)	12.84 (7.43)
Zinc	6.6 (4.7)	0.92 (2.71)	0 (0)	7.52 (7.41)
Phosphorus	700 (700)	7.73 (0)	0 (0)	707.84 (700)
Sodium	1500 (1500)	0 (0)	644.31 (523.17)	855.89 (976.83)
Potassium	4700 (4700)	0 (0)	3163.6 (3014.44)	1536.72 (1685.56)
Magnesium	400 (310)	0 (0)	269.59 (180.07)	130.43 (129.93)

Table 5 summarizes the output for cost, nutrients and foods achieved from LP and GP methods. Both methods satisfy all the nutrient requirements. LP results showed the minimum cost for male students is RM9.88 and for female students is RM9.10. While, the GP results demonstrated that the cost is RM9 for

both male and female students. The findings revealed that the GP model achieved a lesser minimum cost for both gender than LP model.

Table 5. Comparison Between LP and GP for Male (Female) Students

	LP	GP
Cost	RM9.88 (RM9.10)	RM9.00 (RM9.00)
Nutrition		
Energy	1047.52kcal (907.43 kcal)	998.22 kcal (892.24 kcal)
Protein	62g (53g)	62g (53g)
Fat	15.17g (12.64g)	15.71g (12.7g)
Vitamin A	750µg (650µg)	750.12µg (650µg)
Vitamin B1	1.2mg (1.1mg)	1.37mg (1.12mg)
Vitamin B2	1.3mg (1.45mg)	1.3mg (1.38mg)
Vitamin D	27.41µg (31.34µg)	27.93µg (31.77µg)
Vitamin K	64.73mcg (56.34mcg)	64.52mcg (69.19mcg)
Calcium	71.81mg (66.82mg)	70.04mg (60.29mg)
Iron	14.24mg (13.95mg)	12.84mg (7.43mg)
Zinc	7.77mg (7.42mg)	7.52mg (7.41mg)
Phosphorus	728.48mg (700mg)	707.84mg (700mg)
Sodium	845.8mg (966.73mg)	855.89mg (976.83mg)
Potassium	1541.56g (1673.44g)	1536.72g (1685.56g)
Magnesium	141.57mg (131.07mg)	130.43mg (129.93mg)
Food		
Rice (X_1)	513g (443g)	410g (429g)
Chicken (X_2)	141.4g (113.4g)	148.4g (113.4g)
Beef (X_3)	0 (0)	0 (0)
Squid (X_4)	0 (0)	0 (0)
Shrimp (X_5)	0 (0)	0 (0)
Egg (X_6)	0 (0)	0 (0)
Broccoli (X_7)	42.9g (37.44g)	42.9g (37.44g)
Cabbage (X_8)	0 (0)	0 (0)
Salad (X_9)	0 (0)	0 (0)
Mushroom (X_{10})	251.3g (317.8g)	252.7g (321.3g)

CONCLUSION AND RECOMMENDATIONS

The purpose of this study is to minimize the cost while meeting the nutrition needs among the students in UiTM Perlis and to compare the LP and GP methods in order to minimize cost. Based on the results the GP method used in this study is an effective tool for designing least cost nutritious food basket. The least cost that meets the nutrition needs will benefit students and parents to plan enough budgets for themselves and their children, respectively. In addition, all the suggested food items such rice, chicken, beef, squid, shrimp, egg, broccoli, cabbage, salad and mushroom are widely accessible in Malaysia. This study only focuses on UiTM Perlis undergraduates and no other specific groups. It would be interesting if future researchers can consider other factors such as the range of age, body weight and habitual physical activities that affect the total requirement nutrient intakes of individuals. Modifications to both

techniques are needed in achieving a better result. The modification can be done by increasing the number of decision variables and constraints.

REFERENCES

Akpan, N. & Iwok, I. (2016). Application of linear programming for optimal use of raw materials in bakery. International Journal of Mathematics and Statistics Invention, 4(8), 51 – 57. https://www.researchgate.net/publication/311038428_Application_of_Linear_Programming_for_Optimal_Use_of_Raw_Materials_in_Bakery

Anggraeni, W., Vinarti, R. A. Tyasnurita, R. & Permatasari, J. (2015). Production planning optimization using goal programming method in Habibah Busana. Journal of Advance Management Science, 3(4), 270 – 275. http://www.joams.com/index.php?m=content&c=index&a=show&catid=43&id=214

Charnes, A., Cooper, W. W. & Ferguson, R. (1955). Optimal estimation of executive compensation by linear programming. Management Science, 1, 138 – 151. https://doi.org/10.1287/mnsc.1.2.138

Charnes, A. & Cooper, W. W. (1961). Management Models and Industrial Applications of Linear Programming. Wiley-New York. https://doi.org/10.1002/nav.3800090109

Charnes, A. & Cooper, W. W. (1977). Goal programming and multiple objective optimizations: Part 1. European Journal of Operational Research, 1(1), 39 – 54. https://doi.org/10.1016/S0377-2217(77)81007-2

Darko, F. A., Allen, B., Mazunda, J., Rahimzai, R. & Dobbins, C. (2013). Cost-minimizing food budgets in Ghana. Journal of Development and Agricultural Economics, 5(4), 135 – 141. https://academicjournals.org/journal/JDAE/article-abstract/99D513A2099

Georgakakos, K. P. (2012). Water supply and demand sensitivities of linear programming solutions to a water allocation problem. Applied Mathematics, 3(10), 1285. https://m.scirp.org/papers/24096

Halim, B. A., Karim, H. A., Fahmi, N. A., Mahad, N. F., Syed Nordin, S. K. & Hassan, N. (2015). Bank financial statement management using a goal programming model. Procedia-Social and Behavioral Sciences, 211, 145 – 150. https://doi.org/10.1016/j.sbspro.2015.11.066

Hasan, M. M. & Arefin, M. R. (2017). Application of linear programming in scheduling problem. Dhaka University Journal of Sciences, 211, 498 – 504. http://journal.library.du.ac.bd/index.php?journal=dujs&page=article&op=view&path%5B%5D=1342

Hassan, N., Hamzah, H. H. M. & Zain, S. M. M. (2013). A Goal Programming Approach for Rubber Production in Malaysia. American-Eurasian Journal of Sustainable Agriculture, 7(2), 50 – 53. https://ukm.pure.elsevier.com/en/publications/a-goal-programming-approach-for-rubber-production-in-malaysia

Jayaraman, R., Torre, D. L., Malik, T., & Pearson, E. (2015). Optimal work force allocation for energy, economic and environmental sustainability in the United Arab Emirates; A goal programming approach. Energy Procedia, 75, 2999 – 3006. https://doi.org/10.1016/j.egypro.2015.07.611

Maurya, V. N., Misra, R. B., Anderson, P. K. & Shukla, K. K. (2015). Profit optimization using linear programming model: A case study of Ethiopian chemical company. America Journal of Biological and Environmental Statistics, 1(2), 51 – 57. http://www.sciencepublishinggroup.com/j/ajbes

Moraes, L. E., Wilen, J. E., Robinson, P. H. & Fadel, J. G. (2012). A linear programming model to optimize diets in environmental policy scenarios. Journal of Dairy Science, 95(3), 1267 – 1282. https://www.ncbi.nlm.nih.gov/pubmed/22365210

Nykänen, E. A., Dunning, H. E., Aryeetey, R. N. O., Robertson, A. & Parlesak, A. (2018). Nutritionally optimized, culturally acceptable, cost-minimized diets for low income Ghanaian families using linear programming. Nutrients, 10(4), 461. https://doi.org/10.3390/nu10040461

Pasic, M., Catovic, A., Bijelonja, I., & Bahtanovic, A. (2012). Goal programming nutrition optimization model. Annals & Proceedings of DAAAM International, 1(23), 0243-0246, ISSN 2304 – 1382.

Parlesak, A., Tetens, I., Jensen, J. D., Smed, S., Blenkuš, M. G., Rayner, M., Darmon, N., & Robertson, A. (2016). Use of linear programming to develop cost-minimized nutritionally adequate health promoting food baskets. PLoS ONE, 11(10), e0163411. https://doi.org/10.1371/journal.pone.0163411

Poh, B. K., Ng, B. K., Siti Haslinda, M. D., Nik Shanita, S., Wong, J. E., Busin, S. T., Ruzita, A. T., Ng, L. O., Khouw, I. & Norimah, A. K. (2013). Nutritional status and dietary intakes of children aged 6 months to 12 years: Finding of the Nutrition Survey of Malaysian Children (SEANUTS Malaysia). British Journal of Nutrition, 110(3), 21 – 35. https://www.ncbi.nlm.nih.gov/pubmed/24016764

Sallan, J. M., Lordan, O. & Fernandez, V. (2015). Modelling and solving linear programming with R. Omnia Publisher SL.

Sidik, S. M. & Ahmad, R. (2004). Childhood obesity: Contributing factors, consequences and intervention. Malaysia Journal of Nutrition, 10(1), 13 – 22.

Stamenkovska, I. J., Dimitrievski, D., Erjavec, E., Zgajnar, J. & Martinovska-Stojcheska, A. (2018). Optimisation of the vegetable production in the Republic of Macedonia: Linear programming approach. Malaysia Journal of Nutrition, 10(1), 139492. https://ideas.repec.org/p/ags/eaa132/139492.html

Stigler, G. J. (1945). The cost of subsistence. J. Farm Econ, 27, 303 – 314.

Sufahani, S. F. & Ismail, Z. (2013). Diet planning model for Malaysian boarding school using zero-one integer programming. Institutional Repository Universiti Tun Hussein Onn Malaysia, http://eprints.uthm.edu.my/id/eprint/4516.