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Department of Mathematics**



Solving and Analysing a model: the diet problem (Decision Optimization)

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By

Sajjad Ali mzher shamhood

Supervised by

Asst. Prof. Dr. Ahmed Sabah Aljilawi

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1442 A. H.

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

(وَلَقَدْ آتَيْنَا دَاوُدَ وَسُلَيْمَانَ عِلْمًا وَقَالَا الْحَمْدُ لِلَّهِ الَّذِي

فَضَّلَنَا عَلَى كَثِيرٍ مِّنْ عِبَادِهِ الْمُؤْمِنِينَ)

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Supervisor Certification

I certify that the thesis entitled the **“Solving and Analysing a model: the diet problem(Decision Optimization)”** by **"Sajjad ali mzher shamhood”** has been prepared under my supervision in Babylon University/ College of Education for Pure Sciences as a partial requirement for the degree of Higher Diploma Education / Mathematics.

Signature:

Name: Asst. Prof. Dr. Ahmed Sabah Aljilawi

Title: Professor

Date: / / 2022

In view of the available recommendation, I forward this thesis for debate by the examining committee.

Signature:

Name: Dr. Azal Jaafar Musa

Head of Mathematics Department

Title: Assistant Professor

Date: / / 2022

Examining Committee Certification

We certify that we have read the thesis entitled the “**Solving and Analysing a model: the diet problem(Decision Optimization)**” by “**Sajjad ali mzher shamhood**” and as a committee examined the student in its contents and, according to our opinion, it is accepted as a thesis for the degree of Higher Diploma Education / Mathematics.

Signature:

Name: Dr.Audia Sabri Abd al Razzak

Title:

Date: / / 2022

Chairman

Signature:

Name:Asst.Prof.Mustafa Hasan Hadi

Title:

Date: / / 2022

Member

Signature:

Name: Dr. Ahmed Sabah Aljilawi

Title:

Date: / / 2022

Member

I hereby certify the decision of the examining committee.

Signature:

Name: Dr. Bahaa Hussien Salih Rabee

Title: Professor

Address: Dean of the College of Education for Pure Sciences

Date: / / 2022

Linguistic Supervisor's Certification

This is to certify that I have read this thesis entitled "**Solving and Analysing a model: the diet problem (Decision Optimization)**" and I found that this thesis is qualified for debate.

Signature:

Name: Asst.Prof.Hasnaa Hasan Shahid

Title: Asst.Prof.

Address: Department of, College Mathematics of Education for pure
Sciences, University of Babylon

Date: / / 2022

Scientific Supervisor's Certification

This is to certify that I have read this thesis entitled "**Solving and Analysing a model: the diet problem (Decision Optimization)**" and I found that this thesis is qualified for debate.

Signature:

Name:Dr.Zahir Abd al Haddi Hassan

Title:Proof.

Address:

Date: / / 2022

Dedication

Give this humble effort

To my family

To everyone who supported me and

Gave me support

Acknowledgments

Praise be to Allah, the Lord of the Worlds, and peace and blessings be upon the noblest creation and messengers of our Prophet Muhammad and on the house of the good and pure and his companions.

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Abstract

The aim of the study is to introduce the application of linear programming problem to optimize diets with economic, nutritional, and environmental constraints, Diet is normally the sum of food you consume, providing what the body needs and greatly affecting how an individual functions physically, rationally, and even socially, There are t main reasons for studying the application of LP to diets in greater depth, This research involves a few nutrients, such as calcium, iron, cholesterol, and vitamin A, in this study, we focus on one of most important method which called simplex method to find a solution that is at the intersection, The results are compared to determine which ways are the best. The results obtained are the optimal solutions.

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List of Abbreviations:

ON.		
1	LP	Linear programming

Chapter One

Introduction

1.1. INTRODUCTION

The diet problem was one of the first optimization problems studied in the 1930s and 1940s. The problem was motivated by the Army's desire to minimize the cost of feeding in the field while still providing a healthy diet. One of the early researchers to study the problem was Georg. In the late 1930's and early 1940's the diet problem was formulated. It was motivated by the desire of the U.S. Army to feed its troops in World War II at a minimal cost, while maintaining the basic nutritional guidelines. Using a heuristic method, George Stigler, an early researcher of the problem, made an educated guess of \$39.93 per year[1].

In the modern world, people have variant nutrition requirements depending on different positions they have. After providing individuals with appropriate foods and a desirable diet, some priorities also emerge for selection of optimal nutrition regime for them. Examples of these priorities are taste and final cost of the eaten food. The higher quality of taste and flavor of the eaten food and the lower final price would contribute to more desirability for selecting a special diet [2].

In addition to two above - mentioned factors, any of the limitations related to macro and micro nutrients could be minimized or maximized or stabilized to a certain amount depending on people's various requirements. In summary it can be stated that, under the current circumstances, it seems vital to have an optimal diet in which the goals pursued by people and nutrition - science experts are met and also different economical conditions are taken into account. Generally, a problem exists regarding the inaccurate values of nutrients in foods because the approximate amounts of nutrients available in a certain food

are normally known but there is always a question of their exact amounts. If presence of a certain nutrient is doubted, its amount is assumed to be negligible which makes the problem of inaccurate near - zero amounts appear again. In addition, the exact price of foods cannot be determined due to imbalance in market and price fluctuations. Thus, the price of foods should be considered as a fuzzy number [4].

A Linear Programming Problem is an optimization problem for which the following are true: There is a linear function of decision variables called the objective function that must be maximized or minimized. The maximization or minimization takes place subject to a set of constraints defined by linear functions of decision variables, x including restrictions on the sign of the variables. There are several basic assumptions which hold true in any linear program in Problem:

Proportionality - the linear function is proportional to each of the decision variables.

Additivity - the contribution of each variable to the function is independent of each other.

Divisibility - the variables can assume non-integer values.

Certainty Assumption - each parameter is known with certainty.

The goal of the diet problem is to find the cheapest combination of foods that will meet the minimal daily nutritional requirements of an individual. To solve the problem the complete nutritional information for each food product must be known as well as the dietary constraints for the individual in question. The objective function is the sum of the cost per serving of each food product and the constraints are the minimal

dietary guidelines (such as calories, fat, vitamins, carbohydrates) to be met [5].

The simplex method had not yet been created, and computers not having been developed, so finding optimal solutions for linear programming models at this time was done solely by hand calculations. The first large scale computation in optimization took place during the fall of 1947. Jack Laderman of the Mathematical Tables Project of the National Bureau of Standards solved Stigler's model with the newly developed simplex method. The program consisted of nine equations in 77 unknowns. It took nine clerks using hand-operated desk calculators 120 man days to solve for the optimal solution of Stigler's guess of \$39.93 was only off by 24 cents per year \$39.69 [6].

In 1947, Dantzig needed to go on a diet and used the diet problem to help him fashion a diet that would help him lose weight. He was less interested in saving money than in feeling full. He calculated the difference between weight (per unit amount) of a food and the weight of its water content. Then he maximized the resulting weights of the foods. He used information for 500 food products to create his optimal diet. The optimal solution was not what he expected because the constraints had a few flaws in them. Due to the fact that vinegar was listed as having a water content of zero, the model called for him to consume 500 gallons of vinegar a day. The optimal solution also called for him to eat 200 billion cubes a day due to its low water content. Thus he had to put upper bounds on many parameters, which had never been done before. Dantzig, in using the diet problem to formulate his own optimal diet, claimed that he invented the use of upper bounds in linear programming [7,8].

1.2 Literature Review.

Linear programming is mathematical model used to improve management decision and capable for production planning, resource allocation, inventory control and advertising. Method considers objective function as which is optimization element and decision variable as constraint [9].The method was extended to minimize transportation cost with 3 plants and 14 depots across India. Vogel approximation method, Big M Method, Two phase method and Dual simplex method of linear programming were used to get optimal cost comparison [10].

The method was also used to maximize profit of cola manufacturing company considering production constraint of different products [11]. Further operation research tools were used to optimal utilization of rooms and scheduling to maximize patient satisfaction and minimize total operating cost in health care unit [12]. Problem of nurse shifts and nurse allocation on day basis was considered and solved using linear programming to get optimal allocation that minimizes cost in health unit[13]. The literature review signifies the wide application of linear programming in service and also manufacturing domain.

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Chapter Two

Mathematical Background

2.1 Linear programming (LP).

Linear programming (LP) is a technique for solving optimization problems which involves the optimization of a linear objective function, subject to the linear equality or inequality constraints of decision variables. A mathematical optimization model consists of an objective function and a set of constraints in the form of a system of equations or inequalities. The process of variable selection requires multiple reiteration before a satisfactory objective function is developed. Linear programming deals with a class of optimization problems, where both the objective function to be optimized and all the constraints, are linear in terms of the decision variables [19].

LP problems are usually solved by the Simplex method, originally developed by Dantzig in 1948, using methods from numerical linear algebra. Linear programming is being successfully applied to problems of design of diets, conservation of resources, economic growth prediction, transportation systems. The first computer-based menu planner, optimizing menu for nutritional adequacy and budgeted food cost was built in 1964 by Balintfy who applied linear programming Techniques [14]. Today there is a variety of software packages to solve optimization problems such as: LINDO, WinQSB, and What's Best for solving nonlinear and linear problems. Also, Microsoft Excel can provide a fast way to solve linear problems, using Solver. In our paper, we propose a computer-based method using the Solver tool from Microsoft Excel for planning an optimal menu with respect to the daily nutritional requirements of a person.

2.2 History of Linear Programming.

Linear Programming has its origins in the 1940's, when complex planning problems needed to be solved to contribute to the wartime operations. The period directly following the war saw the most rapid development of linear programming, as many industries found valuable uses for it. Transportation firms use linear programming to choose the cheapest way to coordinate shipments of products from suppliers to markets subject to capacity constraints [20].

The petroleum industry has many uses for it such as the blending and distribution of oils and production scheduling. The iron and steel industry uses it to evaluate iron ores, explore the addition of coke ovens and select products_Paper mills use it to reduce trim loss. Governments use it to evaluate policy alternatives.If not for George Danzig's original formulation of the simplex algorithm as well as the development of the computer, the field of linear programming would not be what it is today [20].

2.3 Food Management / Menu Planning.

Food management deals with the decision problems of feeding a given population by converting raw food into edible products - called menu items - as well as delivering meals which meet the preferences of the population. Those menu items must meet basic standards such as being nutritionally adequate and can be produced with the facilities and budget available [6].

My project deals more with menu planning than the diet problem due to the fact that my variables are prepared foods and considered whole meals, not necessarily the food items that are used in the diet problem [6].

2.4 Formulation Of The Problem.

The initial goal of the project was to find the minimal cost for a college student, myself, to eat for one week, while maintaining the minimum daily nutritional standards such as a minimum level for calories, fats, carbohydrates, vitamin A and vitamin C. To begin formulating the problem, the nutritional facts for each of the food products included in the model needed to be researched. The labels on the back of the food products were used to gather information the basic nutritional guidelines for a 23 year old male [3].

The goal was to minimize the amount of money spent on food for a week. The foods were broken into three categories breakfast, lunch, and dinner. A constraint was created which mandated that at least five breakfast, lunch, and dinner. A constraint was created which mandated that at least five servings of "breakfast" would be eaten, at least seven "servings" of lunch would be eaten and at least seven servings of "dinner" would be eaten. The remaining constraints would then be based on getting the minimum daily requirements (over the course of a seven day week) for the following nutritional items: calories, fats, carbohydrates, iron, calcium vitamin A, vitamin C, and the minimum daily requirements for the five food groups (grain, vegetables, fruits, dairy, and meat/beans). Some diets can be set as follows:

Breakfast

- PopTarts - Chocolate Chip Cookie Dough Pop Tarts
- Yogurt - Vanilla Yogurt
- Cereal - Honey Nut Cheerios and Skim Milk
- Orange - Clementine Orange
- Apple - Granny Smith Apple

Lunch

- Soup - Campbell's Chicken with Egg Noodles
- Chili - Campbell's Chunky Chili
- Turkey - Turkey Sandwich on White Bread with 1 slice cheese
- TunaSand - Tuna Fish Sandwich on White Bread with 1 slice cheese
- PBJSand - Chunky Peanut Butter and Grape Jelly on White Bread
- Bologna - Fat Free Bologna Sandwich with 1 slice cheese
- Caesar- Light Caesar Salad kit
- Salad- Garden Salad with Fat Free Thousand Island dressing

Dinner

- M Cheese - Kraft Macaroni and Cheese
- Pizza - Lean Cuisine Pizza
- Pasta - Spaghetti and Meat Sauce
- Fish - Frozen Fish and Vegetables
- StirFry - Stir Fry and White Rice
- PSide - Tomato Parmesan Pasta Sides
- Patty - Chicken Patty on bun with 1 slice cheese and ketchup
- LoMein - Dragon Shrimp Lo Mein
- SpicyVeg - Spicy Vegetables and Chicken
- Rad –Radiator Romano
- Adobo - Southwest Style Adobo Chicken
- HotDog- Nathan's Best Hot Dog on bun with ketchup

- Tort- Cheese Tortellini
- HChili - Homemade Chili
- Taco - Homemade Taco
- Ham - Ham and Mashed Potatoes

The nutritional information and cost per serving of each variable The objective function then became a simple sum of the cost per serving of each item multiplied by the number of servings that specific item would be eaten over the course of the week. The resulting solution could then be applied by choosing which foods to eat on which days of the week.

The objective function is listed below:

Minimize

.6 PopTarts + .4 Yogurt + .5 Cereal + .3 Orange + .15 Apple + 3.78 Soup + 1.89 Chili + 65 Turkey + 1.29 TunaSand + .8 PBJSand + .75 Bologna + 2 Caesar + .8 Salad + .33 MCheese + 1.66 Pizza + .4 Pasta + 3.1 Fish + 3.3 StirFry + 1.19 PSide + .75 Patty + 2.25 LoMein + 2.25 SpicyVeg + 2.25 Rad + 2.25 Adobo + .7 HotDog + 3.49 Tort + 2.33 HChili + 1 .25 Taco + 3 Ham

Constraints:

- PopTarts + Yogurt + Cereal + Orange + Apple > 5 (breakfast constraint)
- Soup + Chili + Turkey + TunaSand + PBJSand + Bologna + Caesar + Salad > 7 (lunch constraint)
- MCheese + Pizza + Pasta + Fish + StirFry + PSide + Patty + LoMein + SpicyVeg + Rad + Adobo+
- HotDog + Tort + HChili + Taco + Ham \geq 7 (dinner constraint)
- 400 PopTarts + 170 Yogurt + 300 Cereal + 80 Orange + 80 Apple + 110 Soup + 220 Chili + 330 Turkey + 310 TunaSand + 400 PBJSand + 240

Bologna + 180 Caesar + 110 Salad + 380 Mcheese ,380 Pizza + 450 Pasta + 170 Fish + 1360 StirFry + 320 PSide + 490 Patty + 240 LoMein + 240 SpicyVeg + 290 Rad + 280 Adobo + 530 HotDog + 840 Tort + 407.5 HChili + 360 Taco + 520 Ham ≤ 17066 (calorie constant)

- .16PopTarts + .02 Yogurt + .03 Cereal + .02 Apple + .05 Soup + .12 Chili + .2 Turkey + .19TunaSand + .22 PBJSand + .1 Bologna + .18 Caesar + .23 Mcheese + .14 Pizza +.08Pasta + .1 Fish+ .34 StirFry + .15 PSide + .28 Patty + .06 LoMein + .08 SpicyVeg + .11 Rad + .07 Adobo + .36 HotDog +.34Tort + .06 Chili + .24 Taco + .3 Ham < 7 (fat constraint)
- 24 PopTarts + .11 Yogurt + .09 Cereal + .07 Orange + .07 Apple + .05 Soup + .08 Chili + .12 Turkey +.11 TunaSand + .19 PBJSand + .12 Bologna + .06 Caesar + .08 Salad + .16 Mcheese + .18 Pizza+ .33 Pasta + .03 Fish + .64 StirFry + .15 PSide + .19 Patty + .12 LoMein + .12 SpicyVeg + .14 Rad+ .13Adobo + .16 HotDog + .42 Tort + .05 HChili + .08 Taco + .15 Ham ≤ 7 (carbohydrate constraint)
- .2PopTarts + .25 Cereal + .02 Soup + .1 Chili + .12 Turkey + .12 TunaSand + .12 PBJSand + .12Bologna + .12 Caesar + .04 Salad + .1 Mcheese + .1 Pizza + .28 Pasta + .05 Fish + .03 StirFry +.35 PSide + .15 Patty + .2 LoMein + .08 SpicyVeg + .1 Rad + .04 Adobo + .24 HotDog + .36 Tort + .15HChili + .06 Taco + .2 Ham ≥ 5.25 (lower limit iron constraint)
- .2 PopTarts + .25 Cereal + .02 Soup + .1 Chili + .12 Turkey + .12 TunaSand + .12 PBJSand + .12Bologna + .12 Caesar + .04 Salad + .1 Mcheese + .1 Pizza + .28 Pasta + .05 Fish + .03 StirFry + .35PSide + .15 Patty + .2 LoMein + .08 SpicyVeg + .1 Rad + .04 Adobo + .24 HotDog + .36 Tort + .15HChili + .06 Taco + .2 Ham ≤ 7.5 (upper limit iron constraint)

- .2 Yogurt + .25 Cereal + .04 Orange + .02 Soup + .04 Chili + .14 Turkey + .14 TunaSand + .08PBJSand + .2 Bologna + .12 Caesar + .1 MChese + .2 Pizza + .04 Pasta + .02 Fish + .04 StirFry + .15PSide + .1 Patty + .04 LoMein + .04 SpicyVeg + .2 Rad + .04 Adobo + .38 Tort + .01 HChili + .26Taco + .04 Ham ≥ 5.25 (lower limit calcium constraint)
- .2 Yogurt + .25 Cereal + .04 Orange + .02 Soup + .04 Chili + .14 Turkey + .14 TunaSand + .08PBJSand + .2 Bologna + .12 Caesar + .1 MChese + .2 Pizza + .04 Pasta + .02 Fish + .04 StirFry + .15PSide + .1 Patty + .04 LoMein + .04 SpicyVeg + .2 Rad + .04 Adobo + .38 Tort + .01 HChili + .26Taco + .04 Ham ≤ 7.5 (upper limit calcium constraint)
- .2 PopTarts + .15 Cereal + .5 Soup + .15 Chili + .06 Turkey + .06 TunaSand + .06 Bologna + .8 Caesar +.4 Salad + .15 MChese + .04 Pizza + .25 Pasta + .02 Fish + .07 StirFry + .15 PSide + .12 Patty + .1LoMein + .1 SpicyVeg + .15 Rad + .02 Adobo + .58 Tort + .14 HChili + .06 Taco + .12 Ham ≥ 5.25 (lower limit vitamin A constraint)
- .2 PopTarts + .15 Cereal + .5 Soup + .15 Chili + .06 Turkey + .06 TunaSand + .06 Bologna + .8 Caesar +.4 Salad + .15 MChese + .04 Pizza + .25 Pasta + .02 Fish + .07 StirFry + .15 PSide + .12 Patty + .1LoMein + .1 SpicyVeg + .15 Rad + .02 Adobo + .58 Tort + .14 HChili + .06 Taco + .12 Ham ≤ 7.5 (upper limit vitamin A constraint)
- .02 Yogurt + .1 Cereal + 1.2 Orange + .06 Apple + .02 Chili + .6 Caesar + .2 Salad + .05 Fish + 1.7StirFry + .02 PSide + .06 LoMein + .02 SpicyVeg + .04 Rad + .08 Adobo + .07 HChili ≥ 5.75 (lower limit vitamin C constraint)
- Yogurt + .1 Cereal + 1.2 Orange + .06 Apple + .02 Chili + .6 Caesar + .2 Salad + .05 Fish + 1.7StirFry + .02 PSide + .06 LoMein + .02 SpicyVeg + .04 Rad + .08 Adobo + .07 Chili ≤ 7.5 (upper limit vitamin C constraint)

- 2 PopTarts + 2 Cereal + Soup + 2 Turkey + 2 TunaSand + 2 PBJSand + 2 Bologna + 4 MChese + 3Pizza + 4 Pasta + 4 StirFry + 4 PSide + 2 Patty + 3 LoMein + 3 SpicyVeg + 4 Rad + 3 Adobo + 2HotDog + 4 Tort + 2 Taco ≥ 10 (servings of grains constraint)
- Soup + 3 Caesar + 3 Salad + 1 Pasta + 3 Fish + 3 StirFry + 2 LoMein + 2 SpicyVeg + Rad + Adob + 3HChili + 2 Taco + 3 Ham ≥ 3.5 (servings of vegetables constraint)
- Orange + 2 Apple + PBJSand ≥ 2.5 (servings of fruit constraint)
- Yogurt + Cereal + Turkey + Tuna Sand + Bologna + MChese + PSide + Patty + Tort + Taco > 3 (servings of dairy constraint)
- Soup + 2 Chili + 2 Turkey + 2 TunaSand + PBJSand + 2 Bologna + Pizza + 3 Fish + 2 StirFry + 2 Patty + 2 LoMein + 2 SpicyVeg + Rad + 2 Adobo + 2 HotDog + 3 HChili + 3 Taco + 3 Ham > 7 (servings of meat/beans constraint)

Chapter Three

3.1 Simplex Method.

The Simplex method is an approach for determining the optimal value of a linear program by hand. The method produces an optimal solution to satisfy the given constraints and produce a maximum zeta value. To use the Simplex method, a given linear programming model needs to be in standard form, where slack variables can then be introduced. Using the table and pivot variables, an optimal solution can be reached [21].

3.1 .1.Slack Variable.

Slack variables are additional variables that are introduced into the linear constraints of a linear program to transform them from inequality constraints to equality constraints [21].

3.1 .2.Surplus Variable.

Surplus variables are variables subtracted into the linear constraints of a linear program to transform them from inequality constraints to equality constraints.

If the inequality is \leq (less than or equal), then we add a slack variable + S to change \leq to $=$.

For example: $2x_1 + x_2 \leq 3$ is an inequality.

Then, $2x_1 + x_2 + s = 3$; s is the slack variable

If the inequality is \geq (greater than or equal), then we subtract a *surplus* variable - S to change \geq to $=$.

For example: $2x_1 + 3x_2 \geq 5$ is an inequality.

Then, $2x_1 + 3x_2 - s = 5$; s is the surplus variable [6].

3.2.1. Standard Form of a maximization problem in two variables.

Standard form is the baseline format for all linear programs before solving for the optimal solution and has three requirements: (1) must be a maximization problem, (2) all linear constraints must be in a less-than-or-equal-to inequality, (3) all variables are non-negative [6].

Example:

$$Z = 7x_1 + 5x_2$$

Subject to

$$x_1 + 2x_2 \leq 6$$

$$4x_1 + 3x_2 \leq 12$$

$$x_1, x_2 \geq 0$$

3.2.2. Basic Solution.

Given a system of m linear equations with n variables ($m < n$). Any solution which is obtained by solving for m variables keeping the remaining $(n - m)$ variables zero is called a basic solution[21].

3.2.3. Basic feasible Solution.

A basic solution, which also satisfies the non-negative constraints, is called a basic feasible solution[21].

3.2.3. Bounded, Unbounded, Empty Solutions.

If the value of objective function Z has both a maximum value and minimum value, such a solution is a bounded solution. If the value of the objective function Z can be increased or decreased indefinitely, such solutions are called unbounded solutions. An unbounded solution has minimum values but no maximum value.

An empty solution will have no maximum or minimum value[21].

3.3.1. Fundamental Theorem of LP.

The fundamental theorem of linear programming says that if there is a solution, it occurs on the boundary of the feasible region, not inside the region [22].

3.3.2. Basic Variables.

Basic variables are variables that are non-negative in terms of the optimal solution [22].

3.3.3. Non-Basic Variables.

Non-basic variables are variables that are zero in terms of the optimal solution. [22].

3.3.4. Simplex Table.

Simplex table is used to perform row operations on the linear programming model as well as for checking optimality[23].

3.3.5. Optimality Check.

Optimal solutions of a maximization linear programming model are the values assigned to the variables in the objective function to give the largest zeta value. The optimal solution would exist on the corner points of the graph of the entire model [23].

Example 1 (Step-wise explanation)

Use the simplex method to find the optimal solutions of the following LP Problem.

$$\text{Max. } Z = 7x_1 + 5x_2$$

$$\begin{aligned} &\text{Subject to} \\ &x_1 + 2x_2 \leq 6 \\ &4x_1 + 3x_2 \leq 12 \\ &x_1, x_2 \geq 0 \end{aligned}$$

Solution:

Step 1: Standard form

Standard form is necessary because it creates an ideal starting point for solving the Simplex method as efficiently as possible.

$$\begin{aligned} \text{Max. } P &= 7x_1 + 5x_2 \\ &\text{Subject to} \\ &x_1 + 2x_2 \leq 6 \\ &4x_1 + 3x_2 \leq 12 \\ &x_1, x_2 \geq 0 \end{aligned}$$

Note:

To transform a minimization linear program model into a maximization linear program model, simply multiply both the left and the right sides of the objective function by -1.

$$\begin{aligned} -1 \times [-Z &= -8x_1 - 10x_2 - 7x_3] \\ Z &= 8x_1 + 10x_2 + 7x_3 \\ \text{Maximize: } Z &= 8x_1 + 10x_2 + 7x_3 \end{aligned}$$

Transforming linear constraints from a greater-than-or-equal-to inequality to a less-than-or-equal-to inequality can be done similarly as what was done to the objective function. By multiplying by -1 on both sides, the inequality can be changed to less-than-or-equal-to.

$$\begin{aligned} -1 \times [x_1 - 5x_2 - x_3 &\geq -8] \\ x_1 + 5x_2 + x_3 &\leq 8 \end{aligned}$$

Step 2: Determine Slack Variables

Let x_3 and x_4 be non-negative slack variables,

$$x_1 + 2x_2 + x_3 = 6$$

$$4x_1 + 3x_2 + x_4 = 12$$

$$7x_1 + 5x_2 = P$$

Now, the given LP problem in its standard form is,

$$1.x_1 + 2.x_2 + 1.x_3 + 0.x_4 + 0.P = 6$$

$$4.x_1 + 3.x_2 + 0.x_3 + 1.x_4 + 0.P = 12$$

$$-7.x_1 + -5.x_2 + 0.x_3 + 0.x_4 + 1.P = 0$$

Step 3: Setting up the Table

The table consists of the coefficient corresponding to the linear constraint variables and the coefficients of the objective function.

The equations in initial simplex table are as follows:

Basic Variables	x_1	x_2	x_3	x_4	P	RHS(b)
x_3	1	2	1	0	0	6
x_4	4	3	0	1	0	12
	-7	-5	0	0	1	0

Step 4: Check Optimality

To check optimality using the table, all values in the last row must contain values greater than or equal to zero. If a value is less than zero, it means that variable has not reached its optimal value. As seen in the previous table, two negative values exist in the bottom row indicating that this solution is not optimal. If a table is not optimal, the next step is to identify the pivot element to base a new table on.

Step 5: Identify Pivot Element

The pivot element can be identified by looking at the bottom row of the table and the indicator. Pick the smallest negative value in the bottom row. That column containing the smallest negative value would be the pivot column. One of the values lying in the pivot column will be the pivot element. To find the indicator, divide the beta values of the linear constraints by their corresponding values from the pivot column.

Basic Variables	x_1	x_2	x_3	x_4	P	RHS (b)
x_3	1	2	1	0	0	6
x_4	4	3	0	1	0	12
	$-7 \uparrow$	-5	0	0	1	0

$\therefore -7$ is the most -ve value (smallest value), so, the first column is the pivot column.

$$\therefore \frac{6}{1} = 6 \text{ and } \frac{12}{4} = 3(\text{min}) [3 < 6]$$

$\therefore 4$ is the pivot element.

Step 6: Create the New Table

1) To optimize the pivot variable, it will need to be transformed into a unit value (value of 1). To transform the value, multiply the row containing the pivot variable by the reciprocal of the pivot value. In the example below, the pivot variable is originally 4, so multiply the entire row by 1/4.

$$R_2 \rightarrow R_2/4$$

Basic Variables	x_1	x_2	x_3	x_4	P	RHS (b)
x_3	1	2	1	0	0	6
x_2	1	$\frac{3}{4}$	0	$\frac{1}{4}$	0	3
	-7	-5	0	0	1	0

2) After the unit value has been determined, the other values in the column containing the unit value will become zero. This is because the x_2 in the second constraint is being optimized, which requires x_2 in the other equations to be zero.

$$R_1 \rightarrow R_1 - R_2$$

Basic Variables	x_1	x_2	x_3	x_4	P	RHS (b)
x_1	0	$\frac{5}{4}$	1	$\frac{-1}{4}$	0	3
x_2	1	$\frac{3}{4}$	0	$\frac{1}{4}$	0	3
	-7	-5	0	0	1	0

$$R_3 \rightarrow 7R_2 + R_3$$

Basic Variables	x_1	x_2	x_3	x_4	P	RHS (b)
x_1	0	$\frac{5}{4}$	1	$-\frac{1}{4}$	0	3
x_2	1	$\frac{3}{4}$	0	$\frac{1}{4}$	0	3
	0	$\frac{1}{4}$	0	$\frac{7}{4}$	1	21

Once the new table has been completed, the model can be checked for an optimal solution.

∴ All the entries in the last row are non-negative.

So, the optimal solution is obtained.

So, maximum $P=21$ when $x_1=3$ and $x_2=0$

Finally, $\text{Max } P = 7x_1 + 5x_2 = 7.3 + 0 = 21$

Step 8: Identify New Pivot Variable.

If the solution has been identified as not optimal, a new pivot element will need to be determined. Steps are repeated from Step 5 and optimality is checked until optimal values can be obtained.

Example 2

Use the simplex method to find the optimal solutions of the following LP Problem.

$$\text{Max. } Z = 3x_1 + 5x_2$$

Subject to

$$3x_1 + 2x_2 \leq 18$$

$$x_1 \leq 4$$

$$x_2 \leq 6$$

$$x_1, x_2 \geq 0$$

Solution:

Let x_3, x_4 and x_5 be non-negative slack variables,

$$3x_1 + 2x_2 + x_3 = 18$$

$$x_1 + x_4 = 4$$

$$x_2 + x_5 = 6$$

$$3x_1 + 5x_2 = Z$$

Now, the given LP problem in its standard form is,

$$3.x_1 + 2.x_2 + 1.x_3 + 0.x_4 + 0.x_5 + 0.Z = 18$$

$$1.x_1 + 0.x_2 + 0.x_3 + 1.x_4 + 0.x_5 + 0.Z = 4$$

$$0.x_1 + 1.x_2 + 0.x_3 + 0.x_4 + 1.x_5 + 0.Z = 6$$

$$3.x_1 + 5.x_2 + 1.x_3 + 0.x_4 + 0.x_5 + 0.Z = 0$$

The equations in initial simplex table are as follows:

Basic Variables	x_1	x_2	x_3	x_4	x_5	Z	RHS (b)
x_3	3	2	1	0	0	0	18
x_4	1	0	0	1	0	0	4
x_5	0	1	0	0	1	0	6
	-3	-5	0	0	0	1	0

$\therefore -5$ is the most -ve value (smallest value), so, the second column is the pivot column.

$$\therefore \frac{18}{2} = 9 \text{ and } \frac{5}{1} = 5(\text{min}) [5 < 18]$$

$\therefore 1$ is the pivot element.

$$R_1 \rightarrow R_1 - 2R_3$$

$$R_4 \rightarrow R_4 + 5R_3$$

Basic Variables	x_1	x_2	x_3	x_4	x_5	Z	RHS (b)
x_3	3	0	1	0	-2	0	6
x_4	1	0	0	1	0	0	4
x_2	0	1	0	0	1	0	6
	$-3 \uparrow$	0	0	0	0	1	30

$\therefore -3$ is the most -ve value (smallest value), so, the first column is the pivot column.

$$6/3=2\text{min and } 4/1=4 [2 < 4]$$

$\therefore 3$ is the pivot element.

$$R_1 \rightarrow R_1/3$$

Basic Variables	x_1	x_2	x_3	x_4	x_5	Z	RHS (b)
x_1	1	0	$\frac{1}{3}$	0	$-\frac{2}{3}$	0	2
x_4	1	0	0	1	0	0	4

x_2	0	1	0	0	1	0	6
	-3	0	0	0	0	1	30

$$R_2 \rightarrow R_2 - R_1$$

$$R_4 \rightarrow R_4 + 3R_1$$

Basic Variables	x_1	x_2	x_3	x_4	x_5	Z	RHS (b)
x_1	1	0	$\frac{1}{3}$	0	$-\frac{2}{3}$	0	2
x_4	0	0	$-\frac{1}{3}$	1	$\frac{2}{3}$	0	2
x_2	0	1	0	0	1	0	6
	0	0	1	0	-2	1	36

\therefore All the entries in the last row are non-negative.

So, the optimal solution is obtained.

So, maximum $Z=36$ when $x_1=2$ and $x_2=6$

Finally, $\text{Max } Z = 3x_1 + 5x_2 = 3 \cdot 2 + 5 \cdot 6 = 36$.

3.4. Methodology.

3.4.1. Collecting data and formulation.

A simple survey is distributed to 100 students of University Technology MARA Cavanagh Terengganu Kampus Kuala Terengganu (UiTMCTKKT). The purpose of the survey is to discover each student's diet pattern. The survey requires student to answer what they most prefer to eat for breakfast, lunch and dinner. Additionally, the survey also aims to discover students' attitude toward healthy eating habits.

The choice of menu and suggested in the survey was obtained through a short interview carried out on a staff of the cafe. While, the nutritional content of each menu is obtained from the website of Ministry of Health. Is very important in setting up the LP model. In order to obtain feasible solution for this diet problem, this study only considered 6 nutrients which are protein, fat, carbohydrate, calcium, phosphorus and vitamin C. Furthermore, fulfilling all nutrients at once is realistically not possible.

The LP model for each student is difference, since each student have different preferred menus. Hence, the objective function and constraints for each student will also be different. The formula tedconstraints are subjected to their commended daily intake (Table3–1) of the following nutrient

(Table 3–1): Recommended Daily Intake

Nutrient	Recommended daily intake
Protein	55g

Fat	46g
Carbohydrate(CHO)	180g
Phosphorus (P)	700mg
Vitamin C	70mg
Calcium	800mg

Hence, based on the recommended daily nutrient above, the linear programming models are setup as follows:

$$\text{Minimize} = c_1x_1 + c_2x_2 + \dots + c_nx_n$$

Subject to:

$$a_{11}x_1 + a_{12}x_2 + \dots + c_{1n}x_n \geq 55g$$

$$a_{21}x_1 + a_{22}x_2 + \dots + c_{2n}x_n \geq 46g$$

$$a_{31}x_1 + a_{32}x_2 + \dots + c_{3n}x_n \geq 180g$$

$$a_{41}x_1 + a_{42}x_2 + \dots + c_{4n}x_n \geq 700mg$$

$$a_{51}x_1 + a_{52}x_2 + \dots + c_{5n}x_n \geq 70mg$$

$$a_{61}x_1 + a_{62}x_2 + \dots + c_{6n}x_n \geq 800mg$$

$$x_1, x_2, x_3, x_4 \geq 1$$

Where,

c_n = cost of menu n

x_n = menu of type n

a_{mn} = amount of nutrient type m in menu type n

Since the data collected is based on the menu provided by the café in UiTM Kuala Terengganu, hence the LP model will be set up

based on the price of food determined by the café. The following are the example of common choices of menus old at the café (Table2).

(Table 3–2): Choice of common food sold at the café.

Menu label	Menu name	Price(U.S.)
x ₁	Plain rice	0.22
x ₂	Fried Noodle	0.9
x ₃	Fried Rice	0.79
x ₄	Nasi Lemak	0.56
x ₅	Fried Chicken	0.56
x ₆	Fried Egg	0.22
x ₇	Nugget	0.22
x ₈	Curry Puff	0.22
x ₉	Donut	0.22
x ₁₀	White Bread	0.56
x ₁₁	Who lemeal Bread	0.13
x ₁₂	Cream Cracker Biscuit	0.067
x ₁₃	Cereal	0.2
x ₁₄	Fried Eel(Ikan Keli)	0.67
x ₁₅	“Kentang Masak Sambal”	0.22
x ₁₆	“Sayur Campur”	0.22
x ₁₇	Chicken Rice	1.01
x ₁₈	Fried Maggie	0.9
x ₁₉	FriedMeeHoon	0.9
x ₂₀	Mee Soup	0.79
x ₂₁	Mee Hoon Soup	0.79
x ₂₂	Chicken Soup	0.79

x_{23}	Chicken Burger	0.63
x_{24}	Beef Burger	0.63
x_{25}	Egg Banjo	0.56
x_{26}	Plain Water	0.00
x_{27}	Iced Tea	0.22
x_{28}	Iced Tea with Milk	0.34
x_{29}	Iced Syrup	0.22
x_{30}	Orange Juice	0.22
x_{31}	Iced Milo	0.34

3.5. Implementation

The following are the choice of menu for 3 meals session in a day choose by Student 26 (Table 3) and the nutrient contenting

(Table 3–3) Nutritional content of menu choose by Student 26.

Menu	x_1	x_{15}	x_3	x_{25}
Protein(g)	2.3	6.2	6.7	7.6
Fat(g)	0.1	15	5.3	9.4
Carbohydrate(g)	30	53	26	23
Phosphorus(mg)	26	0	203	145
Vitamin C(mg)	0	7.6	0.5	4
Calcium(mg)	3	36	16	42

Hence, based on the information collected from Student 26, the LP model for student 26 is as follow:

$$\text{Minimize } Z = x_1 + x_2 + 3.5x_3 + 2.5x_4$$

Subject to:

$$2.3x_1 + 6.2x_2 + 6.7x_3 + 7.6x_4 \geq 55\text{g}$$

$$0.1x_1 + 15x_2 + 5.3x_3 + 9.4x_4 \geq 46\text{g}$$

$$30x_1+53x_2+26x_3+23x_4\geq 180g$$

$$26x_1+0x_2+203x_3+145x_4\geq 700mg$$

$$0x_1+7.6x_2+0.5x_3+4x_4\geq 70mg$$

$$3x_1+36x_2+16x_3+42x_4\geq 800mg$$

$$x_1, x_2, x_3, x_4\geq 1$$

The Solver is specialized to solve linear programming problems and the chosen solving method is the Simplex method. Through this Solver, the values of x will be calculated such that all the constraints are satisfied, and Z is minimized.

In case that no solution is found for any one model, the menu of diet for that student is neglected. The solutions found are discussed based on various factors such as price, quantity and feasibility. The many possible diets are then suggested to all students.

	campur”
3.91	2bottles of plain water, 2 servings of “sayur campur”, 9 pieces of cream cracker biscuits, and 5 pieces of fried chicken
4.00	1 bottle of plain water, 1 glass of orange juice, iced tea, 1 piece of fried chicken, 1 serving of beefburger, eggbanjo, and 26 pieces of white Bread
4.02	1 bottle of plain water, 1 glass of iced tea, 1 plate of plain rice, fried chicken, mee hoon soup, 2 servings of “sayur campur”, 9 pieces of cream cracker biscuit, and 4 glasses of iced tea with Milk

If all available menus are considered in the LP model, a minimum diet of u.s 1.77 is obtained which consists of 2 pieces of white bread, 18 pieces of cream crackers, 4 bowls of cereals and 2 servings of “sayur

campur”. However, this menu might not satisfy the preferences of many students because of the repeated choice of menu for 3 meals. By observation, most of the diets under u.s 4.49 have menu choices with high Calcium or Vitamin C to cost ratio such as whole meal bread, white bread, cereal, ice tea with milk, fried chicken and especially “ sayur campur”.

Some students choose the wrong type of food, hence it is difficult to fulfill all recommended nutrient intake with low cost. Some of the diets cost more than u.s 22.47, which is unreasonable. This is caused by the student’s menu choice shaving too little content of certain nutrients

3.6.Model Description.

The work diet is exceptionally essential for human being so to keep fit and healthy. Consuming dry or junk food is reason for early ageing and falling immune system of human being. Deciding balanced diet is multi-dimensional problem as it constitutes numerous ingredients which are in turn necessary for growth of different body. The decision becomes more complex if it is appended by cost constraint. Model considers only important justified nutritional ingredient required by human body at age of 40-45 years. Some of the ingredients that help create a balanced diet will be mentioned as calcium, iron, protein, vitamin A, vitamin B1, vitamin C, and vitamin E. Foods readily available include oranges, beans, wheat, milk, eggs, soybeans, and broccoli. , tomatoes, and potato. We know that nutritional requirements will be expressed in milligrams.

This is all summarized in a table that includes the amount of each nutrient available in the foods and their daily requirements for the

individual's good health conditions, as well as the standardized cost of these foods. The goal is to reduce the overall cost of the diet and to comply with dietary restrictions

Nutritional Requirement									
Nutrient	Food Items								daily requirement
	Orange	Cup of beans	100gms wheat	1 class milk	2 eggs	100gms soya beans	1 cup of cauliflower	tomato or patato	
<i>Calcium</i>	52	112	32	276	87	138	10	12	800 mg
<i>Iron</i>	0.13	1.91	4.56	0.07	1.46	3.9	0.2	0.33	15 mg
<i>Protein</i>	1.23	12.48	11.31	7.69	13.5 3	35.22	1.14	1.08	50 mg
<i>Vitamin A</i>	295	0	9	395	642	0	7	1025	8000IU
<i>Vitamin B1</i>	0.114	0.23	0.387	0.11 2	0.06 3	0.1	0.26	0.046	1.2 mg
<i>Vitamin C</i>	69.7	2.1	0	0	0.2	2.2	0.26	15.6	60 mg
<i>Vitamin E</i>	0.24	0	1.01	0.17	1.33	0	0.04	0.66	0.25 mg
<i>Cost in u.s.</i>	4.5	5	2.5	7.5	8	8	6	2	Minimization

3.7.Objective function.

To minimize the total diet cost and is defined by the food and unit cost respectively. The cost function (Z) is linear function of cost of one orange

(X1), Cost of cup of bean (X2), cost of 100gms of wheat (X3), cost of one glass of milk (X4), cost of two eggs (X5), cost of 100gms of soya (X6), cost of one cup of cauliflower (X7), cost of one tomato or potato (X8).

Total formulation of problem

$$\text{Min } Z = X1 + X2 + X3 + X4 + X5 + X6 + X7 + X8$$

Subject to,

$$52*X1 + 112*X2 + 32*X3 + 276*X4 + 87*X5 + 138*X6 + 10*X7 + 12*X8 \geq 800;$$

$$0.13*X1 + 1.91*X2 + 4.56*X3 + 0.07*X4 + 1.46*X5 + 3.9*X6 + 0.2*X7 + 0.33*X8 \geq 15;$$

$$1.23*X1 + 12.48*X2 + 11.31*X3 + 7.69*X4 + 13.53*X5 + 35.22*X6 + 1.14*X7 + 1.08*X8 \geq 50;$$

$$295*X1 + 9*X3 + 395*X4 + 642*X5 + 7*X7 + 1025*X8 \geq 8000;$$

$$0.114*X1 + 0.23*X2 + 0.387*X3 + 0.112*X4 + 0.063*X5 + 0.1*X6 + 0.26*X7 + 0.046*X8 \geq 1.2;$$

$$69.7*X1 + 2.1*X2 + 0.2*X5 + 2.2*X6 + 0.26*X7 + 15.6*X8 \geq 60;$$

$$0.24*X1 + 1.01*X3 + 0.17*X4 + 1.33*X5 + 0.04*X7 + 0.66*X8 \geq 0.25;$$

This mathematical model contains z variables and h equations, so it can be solved and reach the optimal solution and this mathematical model can enables the optimum diet expenditure per day considering readily available food. The paper helped to understand the major human body requirement at age of 40-45 years and application of linear programming to get optimal diet. The further it can extended to the all age groups and also all season foods. The methodology can also be implemented to patient groups including diabetic, cardiac for those where diet control is important issue.

In general, a table can be drawn up that can include all nutrients, the amount of nutrients, their cost, and their restrictions, as shown below.

Nutritional Requirement									
Nutrient	Food Items								daily requirement
	Orange	Beans	Wheat	Milk	Eggs	soya beans	Cauliflower	tomato or potato	
<i>Calcium</i>	a_{11}	a_{12}	a_{13}	a_{14}	a_{15}	a_{16}	a_{17}	a_{18}	b_1
<i>Iron</i>	a_{21}	a_{22}	a_{23}	a_{24}	a_{25}	a_{26}	a_{27}	a_{28}	b_2
<i>Protein</i>	a_{31}	a_{32}	a_{33}	a_{34}	a_{35}	a_{36}	a_{37}	a_{38}	b_3
<i>Vitamin A</i>	a_{41}	a_{42}	a_{43}	a_{44}	a_{45}	a_{46}	a_{47}	a_{48}	b_4
<i>Vitamin B1</i>	a_{51}	a_{52}	a_{53}	a_{54}	a_{55}	a_{56}	a_{57}	a_{58}	b_5
<i>Vitamin C</i>	a_{61}	a_{62}	a_{63}	a_{64}	a_{65}	a_{66}	a_{67}	a_{68}	b_6
<i>Vitamin E</i>	a_{71}	a_{72}	a_{73}	a_{74}	a_{75}	a_{76}	a_{77}	a_{78}	b_7
<i>Cost</i>	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	minimization

Objective function to minimize the total diet cost and is defined by the food and unit cost respectively. The cost function (Z) is linear function of cost of one orange (x_1), Cost of cup of bean (x_2), cost of 100gms of wheat (x_3), cost of one glass of milk (x_4), cost of two eggs (x_5), cost of 100gms of soya (x_6), cost of one cup of cauliflower (x_7), cost of one tomato or potato (x_8).

Total formulation of problem

$$\text{Min } z = c_1x_1 + c_2x_2 + c_3x_3 + c_4x_4 + c_5x_5 + c_6x_6 + c_7x_7 + c_8x_8$$

Subject to,

$$a_{11}x_1 + a_{12}x_2 + a_{13}x_3 + a_{14}x_4 + a_{15}x_5 + a_{16}x_6 + a_{17}x_7 + a_{18}x_8 \geq b_1;$$

$$a_{21}x_1 + a_{22}x_2 + a_{23}x_3 + a_{24}x_4 + a_{25}x_5 + a_{26}x_6 + a_{27}x_7 + a_{28}x_8 \geq b_2;$$

$$a_{31}x_1 + a_{32}x_2 + a_{33}x_3 + a_{34}x_4 + a_{35}x_5 + a_{36}x_6 + a_{37}x_7 + a_{38}x_8 \geq b_3;$$

$$a_{41}x_1 + a_{42}x_2 + a_{43}x_3 + a_{44}x_4 + a_{45}x_5 + a_{46}x_6 + a_{47}x_7 + a_{48}x_8 \geq b_4;$$

$$a_{51}x_1 + a_{52}x_2 + a_{53}x_3 + a_{54}x_4 + a_{55}x_5 + a_{56}x_6 + a_{57}x_7 + a_{58}x_8 \geq b_5;$$

$$a_{61}x_1 + a_{62}x_2 + a_{63}x_3 + a_{64}x_4 + a_{65}x_5 + a_{66}x_6 + a_{67}x_7 + a_{68}x_8 \\ \geq b_6; a_{71}x_1 + a_{72}x_2 + a_{73}x_3 + a_{74}x_4 + a_{75}x_5 + a_{77}x_7 + a_{76}x_6 + a_{78}x_8 \geq b_7;$$

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

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الخلاصة

الهدف من الدراسة هو تقديم تطبيق مشكلة البرمجة الخطية لتحسين النظم الغذائية مع القيود الاقتصادية والتغذية والبيئية ، والنظام الغذائي هو عادة مجموع الطعام الذي تستهلكه ويوفر ما يحتاجه الجسم ويؤثر بشكل كبير على كيفية عمل الفرد جسدياً ، بشكل منطقي وحتى اجتماعياً ، هناك أسباب رئيسية لدراسة تطبيق LP على الأنظمة الغذائية بتعمق أكبر ، يتضمن هذا البحث بعض العناصر الغذائية ، مثل الكالسيوم والحديد و الكولسترول وفيتامين A ، في هذه الدراسة ، نركز على واحد من أهم الطرق التي تسمى طريقة (simplex) لإيجاد حل عند التقاطع ، تتم مقارنة النتائج لتحديد الطرق الأفضل. النتائج التي تم الحصول عليها هي الحلول المثلى



جمهورية العراق
وزارة التعليم العالي والبحث العلمي
جامعة بابل كلية
التربية للعلوم الصرفة
قسم الرياضيات

حلول وتحليل نموذج: مشكلة النظام الغذائي (تحسين القرار)

بحث مقدم إلى
قسم الرياضيات - كلية التربية للعلوم الصرفة - جامعة بابل وهو جزء من متطلبات نيل
درجة الدبلوم العالي تربية / الرياضيات

من قبل

سجاد علي مزهر شمهود

بإشراف

ا.م.د. احمد صباح الجيلوي

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