MATHEMATICAL MODELLING FOR DIET MANAGEMENT USING LINEAR PROGRAMMING

Thesis Submitted for the Award of the Degree of

DOCTOR OF PHILOSOPHY

in

Mathematics

By

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DECLARATION

I, Monika Sahu, declared that the presented work in the thesis entitled "Mathematical Modelling for Diet Management using Linear Programming" in fulfillment of degree of Doctor of Philosophy (Ph.D.) is outcome of research work carried out by me under the supervision of Dr. Rakesh Yadav working as Professor, in Mathematics Department/ School of Computer Science and Engineering of Lovely Professional University, Punjab, India.

I further declared that the work described here has been founded on the findings of another researcher; appropriate acknowledgements have been made in accordance with standard procedure for reporting scientific observations. No other University or Institute has received this work in whole or in portion for the purpose of awarding a degree.

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CERTIFICATE

Certified that research embodied in this thesis entitled "MATHEMATICAL MODELLING FOR DIET MANAGEMENT USING LINEAR PROGRAMMING" has been done by Miss Monika Sahu at Lovely Professional University, Phagwara for the award of Ph.D. degree. The research work has been carried out under my supervision and is to my satisfaction. To the best of my knowledge and belief the thesis:

1. Reflects the candidate's own efforts
2. Has been properly finished.
3. Meets the requirements of the ordinance guiding the university's Ph.D. degree.
4. Covers the requirements for mention to the examiner in terms of both material and language.

Signature of the Supervisor
Name: Dr. Rakesh Yadav
Designation: Professor
Date: 4 July 2024

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

A real-world issue can be transformed into a mathematical form using mathematical modeling. In today's world, a healthy lifestyle is essential for living a balanced lifestyle. The right nutrition intake is essential for healthy bodily functioning and disease prevention. Various health problems, including obesity, overweight, and a rise in the death rate from malnutrition, are more prevalent in all age groups.

In this research work, I have examined how mathematical models can be used to optimize the daily diet of Indians, including adults, small children, old age, diabetic patients and sports person. This thesis is divided into 6 chapters. Linear programming and integer programming are just two of the methods employed to achieve the research objectives. Lingo is additionally used to optimize the nutritional diet. It helps to do the work in less time.

The three goals of this thesis are to optimize the daily nutritional diet. It attempted to respond to the following queries:

- How much nutrients taken by an infected person?
- Which type of programming is more important for finding minimum cost?
- What is a balanced diet in different stages of life?

Research objectives are:

1. To develop an optimum model for diet planning using Linear Programming Problem.
2. To design food intake pattern to achieve nutritional goals for Indians adults by Linear Programming Optimization technique.
3. To develop a mathematical model for analyzing and optimizing children's diet during feeding period.

The entire work is covered in many chapters, each of which has a corresponding abstract. These chapters are presented below.

Chapter 1- This chapter deals with the discussion of mathematical modeling and the various factors affecting a nutritional diet. Various research papers were studied to gain knowledge about balance diet for different age persons. In this chapter also describes certain fundamental concepts, technical terms, and mathematical principles that are used throughout the course. Some significant studies by many scholars in this field up to this point are highlighted in the section on the review of literature.

Chapter 2- The focus of this chapter is on the dietary choices of students when selecting certain food items to fulfill their daily nutritional requirements, with the goal of minimizing costs. The objective of this study is to create a mathematical model for dietary choice at the Indian Institute of Technology, Mumbai, which can aid students in selecting a diet at the lowest estimated cost. The integer linear programming (ILP) method of food selection, which aids in identifying acceptable food items and lowers the overall cost of the diet to promote the health of all students, forms the basis of this strategy. According to the mathematical model's findings, a nutritious meal should only cost Rs. 58.05 per day.

Chapter 3- In this chapter, we use linear programming from operations research to create a model that is as efficient as possible, reducing the cost of micronutrient supplements, particularly minerals and vitamins to meet the daily nutritional demands of people of a certain age.

Chapter 4- This chapter highlights the importance of providing children with a meal that satisfies their nutritional needs during complementary feeding times. Remember that the diet should be reasonable as well. Diets for complementary feeding are also influenced by the adjacent food supply. In this situation, two inquiries are frequently posed: 1) Is it possible to plan a diet for the supplemental feeding period utilizing locally accessible foods? 2. If this is feasible, what is the least expensive choice that still meets nutritional requirements? Is there a diet plan? The trial and error approach is frequently used to answer these problems. However, there is also a linear programming-based method that is more effective and constrained. Since the development of powerful computer systems, it has become more accessible. The purpose of this study is to inform paediatric specialists and public health professionals therefore, doing so is essential. The foundational ideas of linear programming are briefly presented in relation to this tool, some real-world examples are offered, and its applications for formulating effective nutritional guidance dependent on food in diverse circumstances are described. The important goal of the current investigation was to keep the price of the supplemental feeding period's nutritional food as low as possible to build a mathematical model of nutrition choice for infants aged 6 to 23 months. The goal of this research is to reduce the cost of micronutrient supplements, particularly those containing vitamins and minerals. To determine the ideal diet, we are using Lingo software. The outcome of the mathematical model indicated that the minimum daily price of a nutritious food is Rs. 44.72.

Chapter 5- This chapter provides healthy lifestyle of diabetic patients by using mathematical modeling. In this chapter, we construct a mathematical representation of diabetes meal planning. The mathematical model was created using integer and linear programming. All the requirements and restrictions were fulfilled in the mathematical model which was developed in this paper. An optimal and feasible solution was produced by using linear and integer programming. This optimal solution gives the diet problem of diabetic patients. All the constraints and objective functions are defined in the diet problem. To fulfill the everyday food supplement requirements of diabetic patients in their specific age group.

Chapter 6- The current work achieves its objective of providing a scientific instrument for the service of non-public health, an associate degree-enhanced diet in terms of the cost and amount of supplies required to fulfill the diet of a superior player, as well as energy requirements in terms of the sort of physical activity. The approach was composed of determining a group of players from the United Nations agency to follow a four-hour everyday training routine; the result expressed the execution of the applied mathematics model of research, which is a mathematical matrix model of settled kind for the improvement of assets at a reasonable expense with the most practicality. This framework was utilized to develop a perfect biological procedure formulation that fulfills the technical specifications, resulting in the bare minimum, maximum, or constant dietary needs (restrictions = rows) for the biological procedure food for players. Such necessary nutrients should be compared to or satisfied by combining widely available dietary components or inputs (decision variables = columns), each with its own unique technical features, biological factors, and contents. Because there are so many options for daily formulation for the competitor, this matrix structure of the model and its related process abuse of the problematic simplex approach allow for the development of the optimal biological process diet for the players.

Chapter 7- This paper makes use of publicly available data to anticipate certain Covid-19 trajectories in India. In this using of a mathematical model, to anticipate the number of Covid-19 infected cases every day in the near future. People need to consume nutritious food that is well-balanced and contains the right number of calories, nutrients, as well as vitamins for strong development, bearing in mind that sustaining and repairing bodily tissues is the ultimate goal while preventing unfavorable illnesses and disease. Recent studies have shown that healthy eating can help lower the possibilities of developing cancer, cardiovascular disease and for Covid patients. The purpose of this project is to evolve a computational framework for scheduling meals that maximizes financial constraints while ensuring adequate nutrient intake. Therefore, an optimization strategy, integer programming and Lindo software was used to solve the model.

CHAPTER - 1

GENERAL INTRODUCTION

1.1 INTRODUCTION

In order to maintain the good health, humans must consume food to fulfill their basic needs. For healthy growth and development and maintaining an active lifestyle throughout life, a balanced diet is essential, starting at the very earliest stages. The distribution impacts people's fitness and nutritional status as well as food consumption, which is highly dependent on production. The suggested nutritional limits are nutrient-focused and supported by technology. In addition to providing nutrients, food also contains a variety of additional elements (non-nutrient phytochemicals) that are beneficial to health. Since human beings eat, it is important that we define diet in terms of foods rather than nutrients. The focus has moved from a nutrition approach to a meal-based approach in order to achieve optimal nutritional status. Dietary guidelines are a way for scientists to translate their understanding of nutrients into particular dietary recommendations.
When it comes to prescribed diets for the general public, they stand for the recommended dietary allowances for nutrients. The recommendations advocate for healthy lifestyles and diets that are nutrient-dense from conception until old age.

1.2 MATHEMATICAL MODELING

The Latin word modulus is where the word modeling comes from. It explains common human response to dealing with reality. Numbers were the first models that could be recognized counting and writing numbers have been recorded since about 30.000 BC. The next fields where models were used were astronomy and architecture, which began around 4.000 B.C. It is common knowledge that by the year 2000 B.C., at least three cultures — Babylon, Egypt, and India had a basic understanding of mathematics and was using mathematical models to make their daily lives better.

1.2.1 MATHEMATICAL MODEL

A mathematical representation is an example of a system that involves mathematical concepts and terms. The procedure for developing a mathematical model is called mathematical modeling.

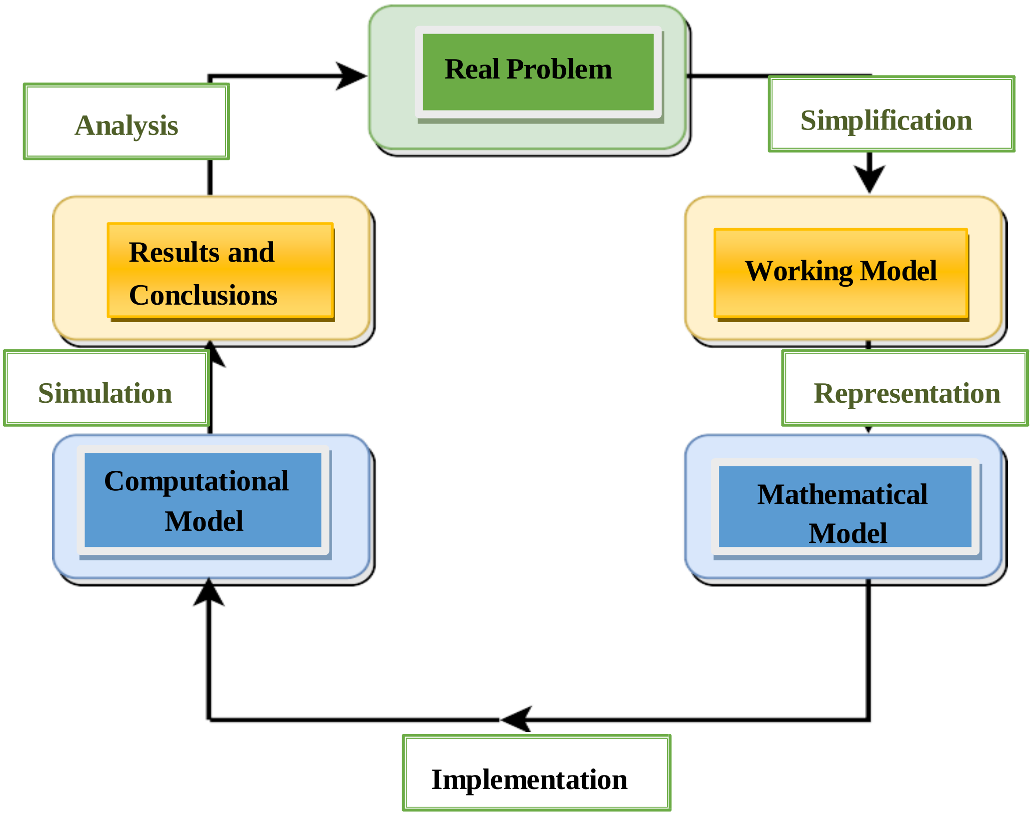


Figure 1.1- *Showing Mathematical Modeling Process*

1.3 LINEAR PROGRAMMING

One of the easiest methods for performing optimization is LP. By adopting a few simplifications and simplifying assumptions, you can solve some really difficult optimization issues. The desire to tackle difficult scheduling issues during military operations provided the initial push for the discipline of linear programming that began in the 1940s. After World War II, it rapidly expanded as many companies discovered the value of linear programming. It is generally accepted that George Dantzig and John von Neumann founded the simplex approach and the theory of duality, respectively, in 1947. The 1975 Nobel Prize in Economics was shared by US economist Tjalling Koopmans and USSR researcher Leonid Kantorovich for their work on the theory of optimal resource allocation, which mainly depended on linear programming.

Linear programming is a technique that is frequently applied in enterprises. It is used, for example, to distribute a finite number of resources in the best possible way. Important application areas include scheduling airline crews, transportation or networks for communication, refinement of oil and blending, and selecting stock and bond allocations.

1.4 INTEGER PROGRAMMING

Programming that only allows integers as variables are known as integer programming. In 1958, Ralph Edward Gomory demonstrated how to methodically generate the cutting planes, In contrast to previous studies by Delbert Ray Fulkerson, Selmer Martin Johnson, and Dantzig on the travelling seller issue. When added to an established set of imbalances, cuts are extra-necessary conditions that guarantee that the optimized approach will resolve in integers. The concepts of Gomory were developed by IBM's Ellis Johnson. For resolving 0-1 coverage issues, Egon Balas and numerous others have devised innovative elimination techniques. Branch and bound has proven to be one of the most effective techniques for resolving real-world integer programs. The methods that combine branch and bound with cutting planes seem to be the most effective.

1.5 THE DIET PROBLEM

This is the example for understanding linear programming: The nutrient composition of a variety of foods is provided here. For instance, we may be aware of how much zinc or sulphur each food has in milligrams per ounce. Each nutrient's suggested daily consumption is also given. Finding the diet that satisfies dietary allowances and costs the least is difficult because we are aware of the price per ounce of food. Determine: -

Quantity of nutritious items is m, count of meals is n.

1 oz of the jth food has a_{ij} milligrams of the ith item.

b_i is milligrams of ith item which advised for consumption. The price per oz of jth meal is c_i.

x_j the quantity of the jth meal to spend in ounces ($x_j \geq 0$).

The whole quantity of ith nutritious item present in every food that has been purchased is provided given below:

$$a_{i1}x_1 + a_{i2}x_2 + \cdots + a_{in}x_n$$

Since the sum of these two amounts must be larger than or equal to the ith, the objective of the linear programming problem is to minimize the cost function.

$$c_1x_1 + c_2x_2 + \cdots + c_nx_n$$

Other conditions are:

$$a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n \geq b_1$$

$$a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n \geq b_2$$

$$\vdots$$

$$a_{m1}x_1 + a_{m2}x_2 + \cdots + a_{mn}x_n \geq b_m$$

and $x_1 \geq 0, x_2 \geq 0, \ \ldots \ x_n \geq 0$

Here is a straightforward numerical illustration of a diet problem. Let's take a look at a diet consisting of only two foods, x_1 and x_2, as well as dietary restrictions concerning potassium, zinc, and sulphur. The table below lists each nutrient's milligrams per ounce content in each of the following foods:

Table 1.1- Containment of Nutrients in milligram per ounce

	x_1	x_2
Potassium	0.16milligram/oz	0.15milligram/oz
Zinc	0.80milligram/oz	0.20milligram/oz
Sulphur	1.15milligram/oz	0.50milligram/oz

We require a diet consuming at least 10 milligram of potassium, 5 milligram of zinc, and 15 milligram of sulphur daily for our straight forward two-food diet. The cost for x_1 is 3 cents per ounce, whereas the cost for x_2 is 4 cents per ounce.

We receive an identical linear program, which follows the predominant diet problem technique mentioned above.

Minimize: $3x_1 + 4x_2$

Subject to: $0.16x_1 + 0.15x_2 \geq 10$

$$0.80x_1 + 0.20x_2 \geq 5$$

$$0.15x_1 + 0.50x_2 \geq 15$$

$$x_1 \geq 0, x_2 \geq 0$$

The most efficient method to overcome this particular problem is to combine x_1 = 20/7 oz and x_2 = 40/7 oz with a price of $ 206.08. With the help of Lingo software, we solve this problem and the solution comes out like this.

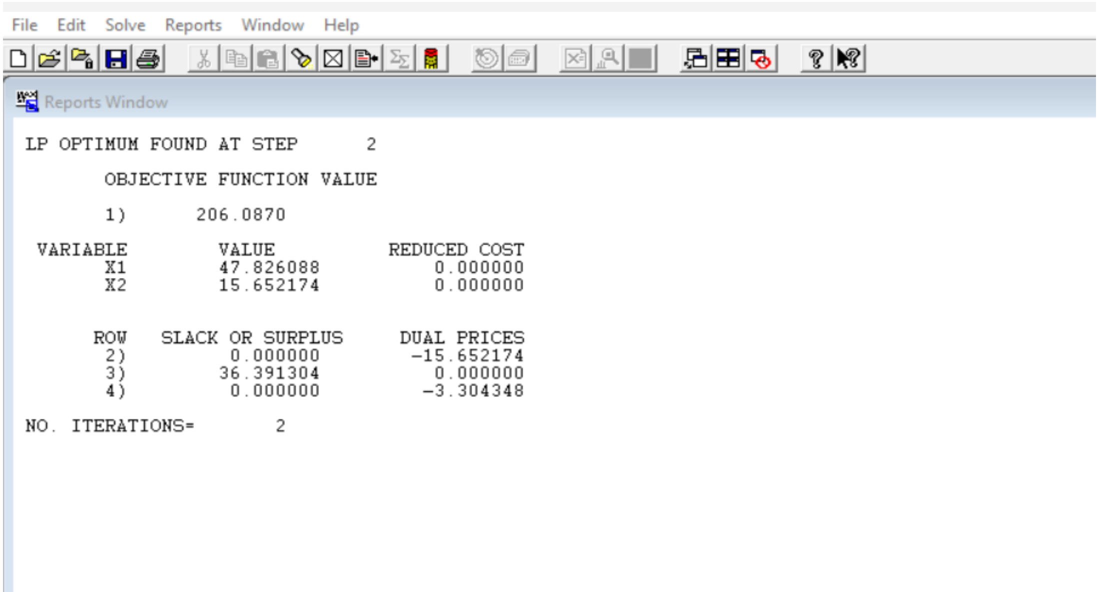


Figure.1.2 – *Solution through Lingo*

1.6 NORMAL DIET

Proteins, lipids, carbs (sugars and starches), fibre, vitamins, and minerals are just a few of the nutrients content in food. Energy comes from proteins, lipids, and carbohydrates. Our body typically uses carbs as its main energy source. A balanced diet provides all the nutrients in the proper ratios and amounts. Combining the four main food groups makes it easier to achieve. Age, gender, physiological condition, and level of physical activity all have an impact on how much food is needed to meet nutrient requirements. A balanced diet should contain about 10–15% of total calories from proteins, 50–60% from carbohydrates, preferably complex carbohydrates, and 20–30% from both visible and unseen fat. A nutritious diet helps avoid malnutrition in all of its forms as well as diseases that are not transmissible, like cancer, diabetes, heart disease, and stroke. The two major health concerns in the world are poor diet and insufficient exercise. Inadequate or unbalanced dietary and nutritional intake is the main cause for concern. The most significant nutritional problems in India that are relevant to public health are premature births, protein-energy deficiency in children, chronic low energy levels in adults, micronutrient deficiencies, and non-communicable illnesses related to diet. Diseases associated with under nutrition and over nutrition, on the other hand, are significant at either extreme of the nutritional continuum. To create diets that are nutrient-dense, a variety of foods that are readily available and affordable might be chosen. There are several food preparation methods and culinary customs in India, despite the fact that there are only four basic food groups that are generally accepted. In addition to a range of cereal/millet/pulse combinations, different grains and millets are consumed as regular meals throughout India. There are numerous varieties of cooking fats and oils. The two most significant determinants of human resource development in the nation are health and nutrition. To ensure a balanced diet, consume a range of foods. Consume a lot of fruits and vegetables. Dietary components like fruits and vegetables offer a wide range of health advantages. Fruits and vegetables not only offer a variety of vital nutrients, but they also help prevent disease. Nutrition science has made considerable gains in the past ten years in pinpointing the precise nutrients that have positive health effects and the processes by which those positive health impacts take place. Make sure to consume ghee, butter, and vanaspati in very small amounts, along with animal products and edible oils, in moderation.

The nutrients we ingest through food play an important role in our physical development, the maintenance of good bodily functioning, physical activity, and general health. A nutrient-rich diet is therefore essential to sustain life and activity. All vital nutrients must be present in our diet at sufficient levels. With respect to age, gender, physiological status, and physical activity, different vital nutrients are required. The macronutrients that are required in large quantities are proteins, lipids, and carbohydrates. The micronutrients, which include vitamins and minerals, are needed in very small amounts. These nutrients are necessary for the physiological and biochemical processes through which the body digests, absorbs, and utilizes food for better health and function.

Figure 1.3 - *Define a Balanced Diet: A picture**

Consumption of fruits and vegetables can be increased by:

- adding veggies to every meal
- consuming food based on fresh fruit and raw vegetables
- having seasonal fresh fruit and vegetables
- taking a range of fruit and vegetables.

1.6.1 CARBOHYDRATES

Both simple and complex carbohydrates are important energy source in the human diet. The energy content per gram is 4 kcal. Simple carbohydrates, including glucose and fructose, are present in fruits, vegetables, honey, sucrose in sugar, and lactose in milk, as opposed to complex polysaccharides, which are starches in grains, millets, pulses, and root vegetables, as well as glycogen in animal products.

1.6.2 PROTEINS

Every live cell's basic structural and functional component is a protein. Muscle makes up over half of the protein in our bodies, with the remaining amounts found in cartilage, bones, and skin. Proteins are intricate molecules made up of many amino acids. Since the human body cannot synthesis some amino acids, those that are considered essential must be acquired from proteins in the diet. Rich sources of protein include both plant-based meals like pulses and legumes and animal products like milk, meat, fish, and eggs. Dietary visible fats are oils and fats like butter, ghee, and vanaspati.

1.6.3 FATS

As a concentrated energy source with 9kcal/g, fats are composed of fatty acids in various ratios. Fats assist fat-soluble vitamins like carotenes and vitamins A, D, E, and K in being digested. Additionally, they provide vital polyunsaturated fatty acids. The type and quantity of fat consumed each day affect blood triglyceride and cholesterol levels.

1.6.4 VITAMINS

Vitamins are chemical substances that the body needs in very small amounts. Since the body cannot synthesize them, they must be consumed through diet. Vitamins are necessary for many bodily functions as well as the preservation of the structure of the blood, mucous membranes, skin, bone, nerves, eye, and brain. They either melt in fat or they don't. The B-complex vitamins, such as thiamin, riboflavin, niacin, pyridoxine, folic acid, and cyanocobalamin, are water-soluble vitamins, whereas vitamins A, D, E, and K are fat-soluble. Vitamin C and the B-complex vitamins are also water-soluble. The body transforms pro-vitamins like beta-carotene into vitamin A. While water- soluble vitamins cannot be kept by the body and are quickly eliminated in urine, fat-soluble vitamins can. The vitamins B-complex and C are heat-labile, meaning they can be quickly destroyed by heat, air, or when food is dried, cooked, or processed.

1.6.5 MINERALS

Inorganic substances called minerals are present in bodily fluids and tissues. Major macro minerals consist of potassium, sodium, phosphorus, calcium, magnesium, and sulphur, whereas micro minerals consist of copper, zinc, selenium, fluorine, cobalt, chromium, and iodine. They are necessary for the blood, connective tissues, skin, hair, and nails to remain healthy and intact.

1.7 LINDO SOFTWARE

Systems create software tools for modeling and optimization. Quickly and simply solve linear, nonlinear, and integer problems. Lindo Systems has committed itself to offering robust, cutting-edge optimization tools that are both adaptable and user-friendly. The first Lindo Systems product to incorporate a fully functional modeling language was Lingo, which debuted in 1988. Users were able to use summations and subscripted variables to succinctly express models using the modeling language. A large-scale nonlinear solver was included in Lingo in 1993. The user didn't have to specify which solver to use, making it special. Following a model analysis, Lingo would automatically select the best linear or nonlinear solver. Support for general and binary integer limitations was another feature that set Lingo's nonlinear solver apart.

An optimization program called Linear Program Solver (Lips) focuses on addressing linear, integer, and goal programming issues. You can use Lips to study and teach linear algebra since it presents a thorough solution procedure as a series of simplex tables. In order to study the behavior of the model when its parameters are changed, sensitivity analysis procedures are provided by Lips. These procedures include the analysis of changes to the right sides of constraints, the analysis of changes to the coefficients of the objective function, and the analysis of changes to the column or row of the technology matrix. Such information might be very helpful for putting LP models into practice.

1.8 LITERATURE REVIEW

The primary research performed in this area was mostly of a theoretical, empirical, and statistical nature. Nutritional diet is very important for good health. Different researcher has their different opinions daily diet. These researches explain the optimization related to health purpose.

Ute Alexy was discussed about the research, Dortmund Nutrient and Anthropometric Longitudinally Designed Study which provides the ability to assess long-term food and nutrient intake data on the basis of 3D weighted dietary records of infants and children [98]. The variations in calorie and macronutrient intake including protein, fat, saturated, monounsaturated, and polyunsaturated fatty acids are examined in this paper. There were no discernible changes in the amount of energy, protein, polyunsaturated fatty acids, or added sugars consumed. Between -0.20 and -0.26 E%/year, the intake of fats declined significantly across all age groups, as did the intake of saturated and monounsaturated fatty acids (between -0.11 and -0.14 E%/year). With the exception of boys between the ages of 14 and 18, there was no discernible change in energy consumption during the 15-year DONALD research period, yet total food intake rose across the board for all age and sex categories.

The main findings of the 15-year time trend (1985–2000) examination of energy and macronutrient consumption in German children and adolescents aged 2–18 are as follows: (1) Energy intake was stable during the study period; (2) Total food intake rose as a result of an increase in beverage consumption; (3) The decrease in consumption of fats, oils, seafood, and eggs and the minor increase in consumption of flour, cereals, potatoes, noodles, and rice were principally responsible for the changes in macronutrient patterns. Although not achieving the nutritional guidelines of 30–35% fat (4). The macronutrient pattern did improve slightly with regard to a decrease in fat intake (E%) compensated for by an increase in carbohydrate intake (E%). We observed no growth in the prevalence of overweight and obesity, body weight, or BMI during the course of the 15-year DONALD research. The recommended fat intake (30–35 E%) was significantly surpassed during this research, which was conducted in 1985.

A further reduction is still required because, after 15 years, despite the large drop, fat consumption (E%) only reached the upper acceptable boundaries. The same is true of saturated fatty acid consumption (E%). Due to an increase in the consumption of bread, cereals, potatoes, pasta, and rice in the final third of the observation period, the recommended intake of carbs (.50 E %) was roughly met. The quality of carbohydrate intake increased as a result of added sugars remaining constant.

Kentaro Murakami, Hitomi Okubo and Santoshi Sasaki [33] used information from the "National Health and Nutrition Survey, Japan, 2003–2015" to evaluate 13-year trends in eating patterns. In 88,527 Japanese adults over the age of 20 who participated in multiple, independent cross-sectional investigations, dietary intake was evaluated using a one-day weighed dietary record. We discovered three dietary patterns using principal component analysis based on the daily consumption of 31 food groups: the plant food and fish, bread and dairy, and animal food and oil patterns. The bread and dairy and animal food and oil pattern scores climbed across the board, whereas the plant food and fish pattern score declined. In all of the subgroups taken into consideration, the plant food and fish pattern showed decreasing tendencies. Regardless of gender or current smoking status, the increasing trends in the bread and dairy pattern were consistent.

Age 50–64 and 65 years, security/transportation/labour occupations, non- workers, normal weight, and overweight participants were the only subgroups where increasing trends in age, occupation, and weight status were visible. With the exception of the youngest age group (20–34 years old), growing trends were seen for the animal food and oil pattern across all categories. According to this report, there has been a steady Westernization of the Japanese cuisine. These findings imply that the Japanese diet is continuously becoming more westernized. Our findings serve as a guide and an indication for additional study as well as for the creation of food-based dietary recommendations. It is necessary to continuously evaluate eating habits in order to improve the diets of people living in Japan.

Neeru Rajendra and Gagan Shridhar were discussed about the modern diet and human health [68]. Along with the intensity of daily activities and the storage of energy substances, nutrition, especially the sense and absorption of energy substances, is essential for regulating ageing and lifespan. Increased activity and rapid growth result in shorter life expectancies, while decreased activity and slower growth result in longer life expectancies. All community members are largely ignorant of the dangers that junk food poses to their health. Eating balanced diet requires effort. The only way to avoid consuming junk food is to promote the following items, which are typically considered to be part of a healthy diet, and to consume more of them. Foods with high fiber content and low fat, saturated fat, and cholesterol, such as whole-grain products, vegetables, and fruits. Calcium-rich meals with only a moderate quantity of salt and sugar can be consumed to meet daily calcium needs. To fulfill your daily iron needs, eat foods high in iron. Future studies will clarify the separate and combined effects of modifiable factors, such as physical activity and nutrition, on human health as nutrition science is continually evolving. Optimizing modern diet and human health can benefit people at all stages of life, but especially during adolescence and old age. Health is more than just the absence of illness or physical fitness. A comprehensive condition of physical, mental, and social well-being could be used to describe it. People perform better at work when they are healthy. He boosts output and promotes economic success. Additionally, good health extends life expectancy and lowers neonatal and maternal mortality. To maintain excellent health, a balanced diet, good personal care, and regular exercise are crucial. Achieving excellent health requires knowledge of illnesses and their effects on various bodily functions, vaccination (immunization) against infectious diseases, efficient waste disposal, control of vectors, and maintenance of clean food and water supplies. In general, diseases can be divided into infectious and non- infectious categories. Infectious conditions are those that can spread quickly from one person to another. Every one of us has experienced an infectious illness at some point in our lives. AIDS is one of many infectious diseases that can be lethal. The leading cause of death from illnesses other than infectious ones is cancer. Abuse of alcohol and drugs has a negative impact on our health. Globalization and modern cuisine have definitely divided the third world.

It is a crucial component of daily life in both industrialized and developing countries and it is associated with a significant increase in obesity and the health problems it causes. The term junk food refers to foods with few nutrients or calories. An empty-calorie food is one that has a lot of calories but is low in micronutrients like fibre, carbs, proteins, vitamins, minerals, or amino acids. These foods don't provide the nutrition your body needs to stay healthy. As a result, this meal, which has poor nutritional properties, is regarded as harmful and may be referred to as junk food.

Norazura Ahmad was explored the use of integer linear programming (ILP) to create a mathematical model of food selection for students at University Utara Malaysia [70]. In order to build a healthy diet for people, the right food products that meet their nutritional needs must be selected. The created model is applied to find the most affordable solution for the student's diet issue. The ILP model is designed to choose appropriate food items while attempting to keep costs to a minimum while still providing the required amounts of nutrients for a healthy student. The best outcome from the ILP model showed that a nutritious diet should only cost RM10.50 per day. The choice of diet or food has become one of people's top priorities in order to maintain a healthy lifestyle. It is essential to consume enough nutrients to keep our bodies healthy and prevent illness and chronic disease. The amount of nutrients consumed can affect how well nutrients are absorbed and stored, and consuming too many nutrients can lead to chronic disorders like diabetes, obesity, and heart disease. On the other side, inadequate or under nutrition can also result in health issues that raise the possibility of passing away. Basically, eating food has a cost or price attached to it. Consuming too much can have negative effects on one's health as well as their finances, as obesity sufferers know all too well. In addition to health problems, obesity has additional financial costs. On the other hand, excessive consumption brought on by a lack of resources could be the root of under consumption. The literature search revealed that proteins, lipids, and carbohydrates along with other minerals like calcium, potassium, and vitamins were the most crucial nutrients that a healthy individual should consume every day. The Ministry of Health Malaysia's report on recommended nutrient intake served as the basis for our study's upper and lower limits, as well as other nutritional data. Reviewing the literature has given us insight into how LP can be used to address the associated diet issue. These studies have encouraged us to investigate the ideal meal preparation for University Utara Malaysia (UUM) students using integer linear programming (ILP).

The model that was created is based on a few particular foods. These foods were chosen based on their accessibility and availability on the UUM campus. Outside of the campus's boundaries, no food was taken into consideration. The human body, which consists of energy, proteins, carbs, lipids, and extra vitamins and minerals like sodium and calcium, would be taken into account in the model together with both macronutrients and micronutrients. These nutrients were regarded as the essential ones that the human body needs to function properly. In this study, the lowest diet cost plan for a student is established using an ILP model created using Lingo 12.0. The decision variables for a linear programming problem known as ILP must be determined using integer values. As a result, the mathematical model of ILP is comparable to that of LP, with the addition that the variables must have integer values. Fundamentally, an ILP mode is made up of three main parts: the goal functions, the restrictions, and the decision variables. The objective function is either maximized or minimized in the general form of an ILP model. In our situation, the objective function, denoted by Z, which is the product of multiplying the cost vector C with the quantity vector for the individual food products X is what we aim to minimize. Equation (2) demonstrates that each and every food item was associated with a constraint coefficient A and was subject to a B restriction. The limit D, as mentioned in equation (3), also placed restrictions on the number of projected servings of food items. The final equation, which resembles a pure integer issue, asserts the non-negativity and integer restriction for the decision variables.

$$Minimize\ Z = C_1X_1 + C_2X_2 + C_3X_3 + \dots + C_nX_n \quad (1)$$

$$Subject\ to: \quad a_{11}X_1 + a_{12}X_2 + a_{13}X_3 + \cdots + a_{1n}X_n \geq b_1$$

$$a_{21}X_1 + a_{22}X_2 + a_{23}X_3 + \cdots + a_{2n}X_n \geq b_2$$

$$\vdots$$

$$a_{m1}X + a_{m2}X_2 + a_{m3}X_3 + \cdots + a_{mn}X_n \geq b_m \quad (2)$$

$$X_1 \geq d_1 , \qquad X_2 \geq d_2$$

$$\vdots$$

$$X_n \geq d_n \quad (3)$$

$$X_n \geq 0 \ and\ integer \quad (4)$$

Low Zhen Sheng talked about using Integer programming to create a mathematical model for diet planning for eczema sufferers [51]. By incorporating appropriate foods that meet the diets nutritional needs, human diet planning is carried out. The proposed methodology is used to address the nutrition issue for young patients with eczema. The integer programming method is a scientific method for choosing appropriate food items that tries to minimize costs while still supplying the required amounts of nutrients, avoiding food allergies, and including certain foods in the diet that relieve eczema problems. This study demonstrates how the integer programming method might result in an ideal and workable solution to an eczema patient's diet. Eczema is a type of skin condition that affects 2–5% of people worldwide, with a prevalence of nearly 10% in children and teenagers. According to The Star Malaysia in 2012, eczema affects between 10 and 20 percent of youngsters and two out of every ten Malaysians. Patients with eczema struggle with selecting a diet that satisfies their nutritional needs. There has never been any investigation done on using an optimization method to help eczema patients with their diet. Techniques for integer programming can be utilized to optimize the cost and nutrient intake for eczema patients.

Monika’s research shows children need a diet that satisfies their nutritional needs throughout complementary feeding time [63]. Remember that the diet should be in budget as well. Diets for complementary feeding are also influenced by the adjacent food supply. In this situation, two inquiries are frequently posed: 1) Can a diet during the supplemental feeding period be planned using foods that are readily available in the area? 2) If this is feasible, what is the least expensive choice that still meets nutritional requirements? Is there a diet plan? The trial-and-error approach is frequently used to answer these problems. However, there is also a linear programming-based method that is more effective and constrained. Since the development of powerful computer systems, it has become more accessible. Because of this, it is essential to notify the public and paediatricians about the purpose of this review. The foundational ideas of linear programming are briefly presented in relation to this tool, some real-world examples are offered and its applications for formulating effective dietary recommendations based on food diverse circumstances are described. The main goal of the current study was to keep the price of the supplemental feeding period's nutritional food as low as possible to build a mathematical model of nutrition choice for infants aged 6 to 23 months. The goal of this research is to reduce the cost of micronutrient supplements, particularly those containing vitamins and minerals. To determine the ideal diet, we are using Lingo software. According to the data gathered from the mathematical model, a daily balanced meal should only cost a minimum of Rs. 44.72.

Perio Soden was examined the best diet for a certain person [78]. There are numerous dietary combinations that could meet certain nutrient needs. Every person will have their own tastes. The current work highlights the tastes of using a diet of foods and serving sizes that the individual has chosen, with as little modification as possible made to it to fulfill nutritional needs. Although the initial meal quantity vector may already be the most favorable outcome for the particular person, it does not typically match the standards of adequate nutrition. The formulation of the LP mentioned in the food quantity vector in the current paper is the one that is closest to the initial vector of choice. The minimal change in food quantity is represented by the distance between these two vectors. The program occasionally made alterations to food quantities that were deemed excessively large. It is vital to introduce new foods or modify some of the foods in the preparatory diet when this happens in real life. The program has proven effective as a teaching tool in this situation. It is simple to use LP to identify a new meal to include in the diet to satisfy the nutrient targets more conveniently while dealing with the issue of foods having unacceptably big increases in volume. There are numerous mathematical methods accessible. It was capable of carrying out the computations required to determine the adjustments to foods, but for the work presented here, linear programming (LP) was used. The LP analysis module is currently a part of the dietary analysis programme. Micro diet and makes use of the same database of nutrient values obtained from nutritional tables. Any food item from these tables may be chosen by the user for inclusion in the LP analysis. The power of the technique used to precisely satisfy nutritional requirements has been illustrated by the example provided in the current research. At every level of the software's development, clinicians and dietitians were involved, and a lively discussion on the advantages of such a precise approach resulted. Some people believe that giving precise food and quantity recommendations is preferable to giving more broad dietetic guidance. Others believe that dietary specificity may increase patient compliance. Clinical trials are currently being conducted to evaluate the viability of this part of the program. Large adjustments in food quantities are occasionally required to satisfy nutrient requirements however, this issue is typically resolved by swapping out existing foods or adding new foods from the database. In the given example, the total amount of fat was decreased by substituting two specific dishes with lower-fat options. The whole milk might have been swapped out for skim milk, and if low-fat spread was closer to the subject's liking, substitute butter for it. The LP analysis would result in a new diet that satisfied the nutrient requirements but addressed various issues preferences for eating.

Allan Anderson and Mary Earle first introduced goal programming and offered a fictitious example to illustrate its use [5]. The outcomes of a challenge involving the selection of 150 food raw materials to satisfy 26 nutrients using linear programming are then shown. Goal-oriented programming was used to improve nutritional balance. Quantitative techniques are increasingly being used to choose diets. Linear programming is the most widely used method. Although linear programming is effective for choosing the least expensive food combinations to meet particular nutritional needs, it is frequently challenging to ensure a healthy balance of nutrients. Nutritionists are increasingly aware of the risks associated with nutrient overdoses and the importance of consuming a variety of nutrients in a balanced diet. When diets are selected through linear programming to satisfy certain nutritional needs, certain nutrients are usually provided in excess. Due to the complicated interactions between the limitations, nutritional balance in meals chosen through linear programming is challenging to attain. A technique for obtaining nutritional balance in certain diets is goal programming. An application of the strategy to the selection of 150 food raw materials to meet the daily nutritional requirements of Thais is described in a study that follows an example illustrating the goal programming approach. The dietary content of the raw materials chosen using goal programming was noticeably better than that chosen through linear programming.

Nicole Darmon, Elaine Ferguron, predicted the dietary preferences of a rational person would try to cut back on food spending while maintaining a diet that was as typical of the general population as possible [69]. The modeling of isoenergetic diets using linear programming so as to these diets were compatible with regular food consumption habits, deviated little from the typical French diet, and included restrictions on portion size and the quantity of energy from different food groups. A cost limitation was established and progressively tightened to evaluate the program's assessment of the impact of cost on food selection. These findings suggest that a simple cost restriction can reduce nutrient densities in diets and have an impact on food choice in ways that mimic the patterns of food intake seen in poor socioeconomic groups. They contend that in order to significantly raise the nutritional value of these population’s diets, economic action will be required. In the current study, a mathematical modeling technique called linear programming (LP) was used to evaluate the effects of food budget (i.e. diet cost) on food selection patterns and dietary quality. The benefit of LP is that it may be used to describe fundamental structures of food choice, independent of social or cultural factors or the declaration bias inherent to dietary surveys, in order to assist in explaining observational studies.

Matthieu Maillot and Adam Drewnowski's analysis from 2010 used databases from the U.S. federal government on nutritional composition and dietary intake to simulate eating patterns for six gender-age groups [59]. As the mean salt content gradually decreased from levels seen in the 2001–2002 National Health and Nutrition Examination Survey (NHANES) down to 1500 mg/day, food patterns were created to meet nutritional criteria for 27 nutrients. The 2300 mg/day salt goal for adults under the age of 50 was consistent with diets that provided adequate amounts of nutrients, although it required significant changes to daily eating habits. It was impossible to achieve the 1500 mg/day target, and no mathematical solution could be found. The theoretically attainable and lowest-sodium food patterns were low amounts of grains and meats and significant amounts of fruit juices, nuts, and seeds.

Nicole Darmon was attempted to forecast for French women the effects of a budgetary restriction on the food selections necessary to ensure a diet that was nutritionally adequate [67]. Our analysis demonstrated that middle- and upper-class women can be encouraged to eat nutritionally appropriate diets that differ just a little from the diet of the typical population and that only marginally raise the average expense of a diet. In comparison to the average dietary patterns seen in a general population of French women, it is recommended that these women promote increased consumption of fish, whole meal bread, fresh fruit, green vegetables, and tomatoes while promoting decreased consumption of animal fats, high-fat dairy products, soft drinks, sugar, and pastries. Such dietary adjustments are in line with food-based recommendations that are widely publicized, especially in France. On the other hand, French ladies on a tight food budget need a different food-based recommendation. To attain a nutritionally balanced diet, it was necessary to encourage higher consumption of reduced-fat milk, offal, canned fish, almonds, dried fruits, fruit juice, and legumes in comparison to the diet generally consumed by French women. Finally, our study showed that a nutritionally balanced diet is not possible with a food budget of €3.18/d, meaning that nutrition education alone will not be sufficient for women in the lowest sectors of the French population. Increasing the nutritional value of currently offered food assistance programs could help ensure that those receiving them eat enough food.

Victor Smith was provided a potent illustration of how little basic diet requirements need the total amount of actual food expenditure [102]. It is unknown how widely Stigler's diet of wheat, flour, leafy greens, evaporated cow's milk, and dried navy beans was adopted. If we want to design diets that people might be likely to follow, we must develop examples that take likes and habits into account. Despite the fact that diet palatability cannot be tested, the three models presented here demonstrate how conventional limitations can be used in programming models to raise it. The issue is to select a set of food proportions that will meet customary and dietary needs while costing the least amount of money. The dietary plan also contains meat items, seafood, fish, eggs, orange juice, juicy fruits, and greens, in addition to ice cream, cake, candy, and nuts. Potatoes, flour, and sugar are merely minimally present. The calculations select among the most reasonably priced sources of the nutritional mixtures that are necessary in addition to those offered by products chosen to adhere to other traditional model restrictions. The calculations determine the groups least common needs.

Monika says in her research analyses how students choose their diets and what they eat to meet their daily nutritional requirements [82]. The current study's goal was to keep costs per day to a minimum and to develop a quantitative nutrition selection model for the Mumbai campus of the Indian Institute of Technology. The student's diet issue is helped by this model at the lowest possible cost. This model is an implementation of ILP for meal choice. The ILP model is set up to select suitable food items and lower the cost of the meals consumed by the students while maintaining their health. The outcome of the mathematical model revealed that a nutritious diet ought to cost no more than Rs 58.05 per day.

1.9 PROPOSED METHODOLOGY OF RESEARCH WORK

During our research work we propose to use the following type of methodology to achieve goals:

- We will use the Linear Programming Problem and some other concepts of operation research to minimize or maximize the optimum diet.
- We will use some software like Lindo and Lips to solve the linear programming problem by using mathematical model.
- We will collect the authentic data of vitamins and minerals for mathematical models.
- We will apply the Integer Programming to formulate some problems.

CHAPTER – 2

FOOD INTAKE PATTEREN TO ACHIEVE NUTRITIONAL GOAL FOR INDIAN ADULTS BY LINEAR PROGRAMMING OPTIMIZATION TECHNIQUES

2.1 INTRODUCTION

In today's world, healthy eating is critical for maintaining an appropriate pace of life. Proper nutritional consumption helps our bodies operate normally and protects them from illness. Many health conditions, such as obesity and overweight, as well as death rates, grow in adulthood as a result of poor nutrition [8]. University students are suffering from hunger as a result of their financial constraints. Students suffered from malnutrition as a result of a lack of funds. Now, a substantial percentage of pupils suffer from being underweight or overweight. This problem occurred among students from various universities, as well as at IIT Mumbai. In certain research, nutritious diets were shown to be more expensive than less healthy ones. Fish, fruits, and lean meat are abundant in nutrients, but they are pricey, so not everyone can afford to consume them [57]. Good and unhealthy foods are the subject of several discussions. Some of them are both healthy and terrible diets, depending on the overall quantity of various foods consumed. Many foods can fit into a healthy eating regimen. Some particular foods promote a healthy life if consumed in moderation. Because of the increased range of food options, people's attention shifts from particular items to the overall quality of their diets. According to the dietary requirements, several daily actions must be taken to attain nutritional goals, such as eating a large number of fruits and vegetables, using less ghee and butter, exercising frequently, drinking lots of water, and using the least amount of salt and sugar. The children of lower and higher- income households get addressed in one of the objectives. A study found significant differences in carbohydrate, calorie, and cholesterol consumption between low- and high-income children [76]. According to statistics from various states in India, 45% of boys and 61% of girls consume enough quantities of protein and energy, whereas 28% of boys and 22% of girls consume insufficient amounts of both nutrients.

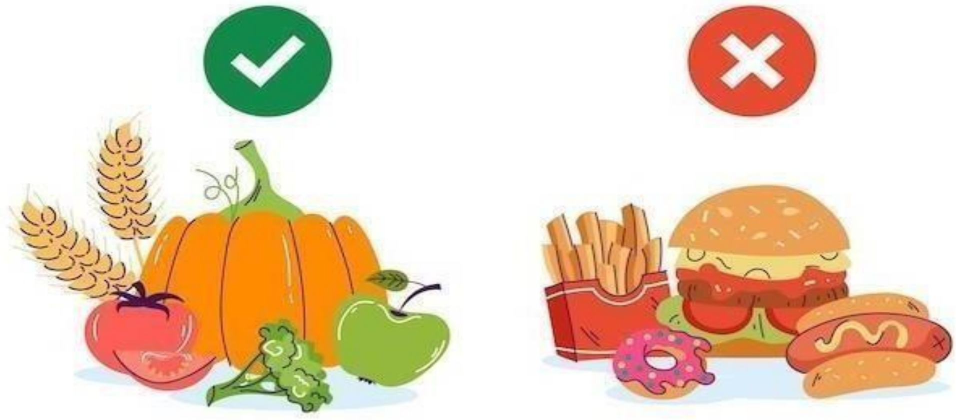


Figure 2.1- *Healthy and Unhealthy things: A picture**

About 51% of boys and 35% of girls were eating insufficient quantities of calories, while approximately 31% of boys and 25% of girls were eating inadequate quantities of proteins [4]. Dietary recommendations for salt, published in 2010, study targets based on linear programming. We used linear programming to create models that displayed sodium levels for all participants. The recommended salt consumption amount for young individuals is less than 2300 mg/day. The sodium dose of 1500 mg/day is considered inadequate for those under 50 and sufficient for those over 50 [59].

This study will specifically examine student's knowledge of healthy eating habits. The results of this study will assist the students in making the best meal decisions to meet their nutritional needs each day at the lowest possible price. A mathematical model is created using integer linear programming This is a very effective strategy that is frequently used for minimization and maximization.

2.2 Formulation of the Model

By consuming certain meals, a mathematical model is created. The availability of these foods on the IIT Mumbai campus fully depends on it. In this model, the external eater was not taken into account. The model specified the amounts of calorie intake, fats, proteins, sodium, calcium, vitamin C, and carbs included in the food consumed for the purposes of the data. By Lindo, to determine the minimum cost plan for a student. The application of Linear Programming is ILP that needs the description of decision variables in integer values. So that the mathematical model of ILP is same as LP. But only one condition is extra in ILP which is the variables must have integer values. An ILP model includes of three main parts which is the objective function, constraints and decision variables.

In the typical form of an ILP model, the objective function is either maximized or minimized. In this concept, Z is the objective function that was minimized. Z is determined by adding the results of multiplying both C and X, where C stands for the price of food and X for its amount. Equation (2) pertains to the limit B and the limitations A that were connected to all food related products. The non-negativeness and integer constraint for the choice variables, which express the pure integer problem are defined in equation (4).

$$Minimize\ Z = C_1X_1 + C_2X_2 + C_3X_3 + \dots + C_nX_n \quad (1)$$

$$\begin{aligned} Subject\ to: \quad & a_{11}X_1 + a_{12}X_2 + a_{13}X_3 + \cdots + a_{1n}X_n \geq b_1 \\ & a_{21}X_1 + a_{22}X_2 + a_{23}X_3 + \cdots + a_{2n}X_n \geq b_2 \\ & \vdots \\ & a_{m1}X + a_{m2}X_2 + a_{m3}X_3 + \cdots + a_{mn}X_n \geq b_m \end{aligned} \quad (2)$$

$$\begin{aligned} & X_1 \geq d_1\ ,\ X_2 \geq d_2 \\ & \vdots \\ & X_n \geq d_n \end{aligned} \quad (3)$$

$$X_n \geq 0\ and\ integer \quad (4)$$

Table 2.1 defines the minimal significance of dietary needs. In this table, the nutrients calorie intake, proteins, fats, sodium, calcium, and carbohydrates are listed. Tables 2.2, 2.3 and 2.4 provide appropriate explanations of breakfast, lunch, and dinner, respectively. The cost of each food item provided to the pupils is adequately disclosed. According to the observation, the daily diet consists of a total of 19 different foods. All of the information in these tables originated from the IIT Mumbai canteen. The internet was used to note certain nutrition information that could not be found.

Table 2.1 The Minimum value of Nutrient Requirements

Nutrients	Minimum Requirements
Calories(kcal)	1600
Protein (gm)	120
Fats (gm)	38
Sodium (mg)	152
Calcium (mg)	140
Vitamin C (mg)	65
Carbohydrates (mg)	190

Table2.2 Ingredients for the breakfast

Food Item	Mix Veg Prantha	Poha	Omlate	Milk	Daliya	Bread	Sambher	Butter
	X1	X2	X3	X4	X5	X6	X7	X8
Per serving	100gm	100gm	1 large	250gm	100gm	2 slices	100gm	5gm
Price (Rs)	17	12	17	15	12	6	5	2
Calories (Kcal)	153	110	93	150	152	133	114	36
Proteins (gm)	3.5	2.34	6.48	8.05	5.03	3.82	4.85	0.04
Fats (gm)	4.1	2.87	7.33	8.12	3.41	1.64	4.08	4.06
Sodium (mg)	35.8	201	96	100	143	340	252	1
Calcium (mg)	30.3	15	29	282	35	76	43	1
Vitamin C (mg)	9.1	6.4	0	0	0	0	13.9	0
Carbohydrates (mg)	25.9	18.8	0.42	12.87	27.7	25	15.86	0

Table2.3 Ingredients for the lunch

Food Item	Roti	Rice	Raita/ Curd	Salad	Rajma (Dal)	Chicken Biryani
	X9	X10	X11	X12	X13	X14
Per serving	2	100g	100g	1cup	100g	1cup
Price (Rs)	3	10	10	15	10	40
Calories(kcal)	208	364	61	9	165	348
Proteins(gm)	9.99	3.54	4.1	0.84	7.04	15.9
Fats(gm)	0.8	0.3	3.3	0.13	7.08	9.82
Sodium(mg)	506	1	61	16	286	805
Calcium(mg)	20.8	10	83	26	143	53
Vitamin C (mg)	0	0	0	8.7	4.5	5.1
Carbohydrates (mg)	58.04	28	4.4	11	19.77	48.07

Table2.4 Ingredients for the dinner

Food Item	Veg Pulao	Egg Curry	Shahi Paneer	Moong Dal	Chicken Fry
	X15	X16	X17	X18	X19
Per serving	200g	100g	100g	100g	1medium
Price (Rs)	30	25	15	8	30
Calories(kcal)	198	114	131	347	119
Proteins(gm)	5.08	5.95	6.35	24	13.6
Fats(gm)	2.74	7.11	9.44	1.2	6.79
Sodium(mg)	620	253	311	15	211
Calcium(mg)	34	55	208	132	17
Vitamin C (mg)	10.6	9	4	4.8	0
Carbohydrates (mg)	38.28	7.54	5.98	18.38	0

2.3 Total formulation of the problem

Min Z= $\mathbf{17X_1 + 12X_2 + 17X_3 + 15X_4 + 12X_5 + 6X_6 + 5X_7 + 2X_8 + 3X_9 + 10X_{10} + 10X_{11} + 15X_{12} + 10X_{13} + 40X_{14} + 30X_{15} + 25X_{16} + 15X_{17} + 8X_{18} + 30X_{19}}$

Subject to

$$153X_1 + 110X_2 + 93X_3 + 150X_4 + 152X_5 + 133X_6 + 114X_7 + 36X_8 + 208X_9 + 364X_{10} + 61X_{11} + 9X_{12} + 165X_{13} + 348X_{14} + 198X_{15} + 114X_{16} + 131X_{17} + 347X_{18} + 119X_{19} \geq 1600$$

$3.5X_1 + 2.3X_2 + 6.48X_3 + 8.05X_4 + 5.03X_5 + 3.82X_6 + 4.85X_7 + 0.04X_8 +$
$9.99X_9 + 3.54X_{10} + 4.1X_{11} + 0.84X_{12} + 7.04X_{13}$+$7.04X_{13} + 15.9X_{14} + 5.08X_{15} +$
$5.95X_{16} + 6.35X_{17}$+$24X_{18} + 13.6X_{19} \geq 120$

$4.1X_1 + 2.87X_2 + 7.33X_3 + 8.12X_4 + 3.41X_5 + 1.64X_6 + 4.08X_7 + 4.06X_8 +$
$0.8X_9 + 0.3X_{10} + 3.3X_{11} + 0.13X_{12} + 7.08X_{13}$+$7.08X_{13} + 9.82X_{14} + 2.74X_{15} +$
$7.11X_{16} + 9.44X_{17}$+$1.2X_{18} + 6.79X_{19} \geq 38.$

$35.8X_1 + 201X_2 + 96X_3 + 100X_4 + 143X_5 + 340X_6 + 252X_7 + 1X_8 + 506X_9 +$
$X_{10} + 61X_{11} + 16X_{12} + 286X_{13}$+$805X_{14} + 620X_{15} + 253X_{16} + 311X_{17} +$
$15X_{18}$+$2.11X_{19} \geq 152$

$303X_1 + 15X_2 + 29X_3 + 282X_4 + 35X_5 + 76X_6 + 43X_7 + X_8 + 20.8X_9 + 10X_{10} +$
$83X_{11} + 26X_{12} + 143X_{13}$+$53X_{14}$+ $34X_{15} + 55X_{16} + 208X_{17} + 132X_{18} + 17X_{19} \geq$
140

$9.1X_1 + 6.4X_2 + 13.9X_7 + 8.7X_{12} + 4.5X_{13} + 5.1X_{14} + 10.6X_{15} + 9X_{16}$+$4X_{17} +$
$4.8X_{18} \geq 65.$

$25.9X_1 + 18.8X_2 + 0.42X_3 + 12.87X_4 + 27.7X_5 + 25X_6 + 15.86X_7 + 58.04X_8 +$
$28X_9 + 4.4X_{10} + 4.4X_{11} + 19.77X_{12} + 48.07X_{13}$+$38.28X_{14} + 7.54X_{15} +$
$5.98X_{17}$+$18.38X_{18} \geq 190.$

2.4 Lingo Formulation

Min= $17*X_1$ + $12*X_2$ +$17*X_3$ +$15*X_4$ +$12*X_5$ +$6*X_6$ +$5*X_7$ +$2*X_8$ +$3*X_9$ +$10*X_{10}$
+$10*X_{11}$ +$15*X_{12}$ +$10*X_{13}$ +$40*X_{14}$ +$30*X_{15}$ +$25*X_{16}$ +$15*X_{17}$ +$8*X_{18}$ +$30*X_{19}$

$153*X_1$ + $110*X_2$ +$93*X_3$ +$150*X_4$ +$152*X_5$ +$133*X_6$ +$114*X_7$ +$36*X_8$ +$208*X_9$
+$364*X_{10}$ +$61*X_{11}$ +$9*X_{12}$ +$165*X_{13}$ +$348*X_{14}$ +$198*X_{15}$ +$114*X_{16}$ +$131X_{17}$
+$347*X_{18}$ +$119*X_{19}$ $>= 1600$

$3.5*X_1$ + $2.34*X_2$ +$6.48*X_3$ +$8.05*X_4$ +$5.03*X_5$ +$3.82*X_6$ +$4.85*X_7$ +$0.04*X_8$
+$9.99*X_9$ +$3.54X_{10}$ +$4.1*X_{11}$ +$0.84*X_{12}$ +$7.04*X_{13}$ +$15.9*X_{14}$ +$5.08*X_{15}$ +$5.95*X_{16}$
+$6.35X_{17}$ +$24*X_{18}$ +$13.6*X_{19}$ $>= 120$

$4.1*X_1$ + $2.87*X_2$ $+7.33*X_3$ $+8.12*X_4$ $+3.41*X_5$ $+1.64*X_6$ $+4.08*X_7$ $+4.06*X_8$ $+0.8*X_9$ $+0.3X_{10}$ $+3.3*X_{11}$ $+0.13*X_{12}$ $+7.08*X_{13}$ $+9.82*X_{14}$ $+2.74*X_{15}$ $+7.11*X_{16}$ $+9.44*X_{17}$ $+1.2*X_{18}$ $+6.79*X_{19}$ $>= 38$

$35.8*X_1$ + $201*X_2$ $+96*X_3$ $+100*X_4$ $+143*X_5$ $+340*X_6$ $+252*X_7$ $+1*X_8$ $+509*X_9$ $+1*X_{10}$ $+61*X_{11}$ $+16*X_{12}$ $+286*X_{13}$ $+805*X_{14}$ $+620*X_{15}$ $+253*X_{16}$ $+311*X_{17}$ $+15*X_{18}$ $+211*X_{19}$ $>= 152$

$303*X_1$ + $15*X_2$ $+29*X_3$ $+ 282*X_4$ $+ 35*X_5$ $+ 76*X_6$ $+ 43*X_7$ $+ 1*X_8$ $+ 20.8*X_9$ $+10*X_{10}$ $+83*X_{11}$ $+ 26*X_{12}$ $+ 143*X_{13}$ $+ 53*X_{14}$ $+ 34*X_{15}$ $+ 55*X_{16}$ $+ 208*X_{17}$ $+132*X_{18}$ $+17*X_{19}$ $>= 140$

$9.1*X_1$ + $6.4*X_2$ $+13.9*X_7$ $+8.7*X_{12}$ $+4.5*X_{13}$ $+5.1*X_{14}$ $+10.6*X_{15}$ $+9*X_{16}$ $+4*X_{17}$ $+ 4.8*X_{18}$ $>= 65$

$25.9*X_1$ + $18.8*X_2$ + $0.42*X_3$ + $12.87*X_4$ + $27.7*X_5$ + $25*X_6$ + $15.86*X_7$ + $58.04*X_9$ + $28*X_{10}$ + $4.4X_{11}$ + $19.77*X_{12}$ + $48.07*X_{13}$ + $38.28*X_{14}$ + $7.54*X_{15}$ + $5.98*X_{17}$ + $18.38*X_{18}$ $>= 190$

2.5 Lingo Solution:

Global optimal solution

Objective Value: 58.05945

Infeasibilities: 0.000000

Total solver iterations: 4

Elapsed solver seconds: 0.08

Model Class: LP

Total variables: 19

Nonlinear variables: 0

Integer variables: 0

Total constraints: 8

Nonlinear constraints: 0

Total nonzero: 140

Nonlinear nonzero: 0

Table 2.5 Reduced cost comes from the Lingo

Variable	Reduced Cost	Value
X1	12.94160	0.000000
X2	9.184089	0.000000

X3	11.71636	0.000000
X4	8.919368	0.000000
X5	9.015846	0.000000
X6	4.199095	0.000000
X7	0.000000	4.676259
X8	0.000000	2.742917
X9	0.000000	9.730773
X10	8.928843	0.000000
X11	7.312534	0.000000
X12	13.63138	0.000000
X13	4.131145	0.000000
X14	30.40059	0.000000
X15	26.00840	0.000000
X16	18.83946	0.000000
X17	8.217176	0.000000
X18	0.5475949	0.000000
X19	23.12225	0.000000

Table 2.6 Slack or Surplus from Lingo

Row	Slack or Surplus	Dual Price
1	58.05945	-1.000000
2	1055.839	0.000000
3	0.000000	-0.2610580
4	0.000000	-0.4900388
5	5952.932	0.000000
6	266.2221	0.000000
7	0.000000	-0.1247849
8	448.9396	0.000000

Tables 2.5 and 2.6 define the solution that comes out through lingo. These tables describe the reduced cost and slack or surplus variables.

Conclusion

The ILP model offers a cost-effective option for nutrition planning suited to student needs. This approach successfully balances cost and nutrition using integer linear programming, providing realistic guidance for students dealing with budgetary and nutritional issues. The study demonstrates ILP's value for diet planning, but further validation through testing and comparison with literature would improve the model's applicability. The ILP model is prepared to pick suitable food items and minimize the cost of the diet taking by the students which makes all students are healthy. The result obtained from the mathematical model disclosed the minimum cost of a balanced diet is Rs 58.05 per day.

CHAPTER – 3

AN OPTIMUM MATHEMATICAL MODEL FOR DIET PLANNING USING LINEAR PROGRAMMING

3.1 INTRODUCTION

Linear programming is very important part of Operation Research. Mathematics has various branches and mathematical modeling can be done in several branches of mathematics. Linear Programming places an important role to frame the optimum model that is to minimize the expenditure and increase the profit. In this article we apply the linear programming to find decrease price and increase the daily needs of nutritional supplements like vitamins and minerals. Most important vitamins are Vitamin A which is also known as Retinol, Vitamin B, Vitamin C etc. The important minerals are magnesium (mg), calcium (ca), potassium (k), phosphorus (p), chromium (cr), iodine (i), zinc (zn), selenium (se), iron (fe) etc. Vitamins are very important because it place an important role to stimulate the human cells. So, body needs vitamins and minerals for energy point of view. Human body fulfils the daily requirements of vitamins and minerals that we take in the form of vegetables, pulses, milk, egg, fruits etc. The nutrients in plants depending on plants grew up and which nutrients and fertilizers supplied. Minerals are also present in drinking water and differs according geographic situation. The detail of vitamins and minerals present in various sources are given in table no (3.1). calcium, phosphorus place important role to provide the strength to our bones and teeth while fluorine is important for the normal mineralization of bones as 96% fluoride in the human body is found and fluorine is also essential for formation of dental enamel.

3.2 METHOD AND FORMULATION OF THE MODEL

In this model we are going to examine only important vitamins and minerals essential for the human body at the age of 20-50years. The examination of ingredients are Vitamin-A, Vitamin-B1, Vitamin- B2, Vitamin-B3, Vitamin-B5, Vitamin-B6, Vitamin-B7, Vitamin-B9, Vitamin-B12, Vitamin-C, Vitamin-

D, Vitamin-E, Vitamin-K, Calcium, Potassium and Minerals. We are considering here oranges, tomatoes, peanuts, barley, egg, broccoli, papaya, turnip greens, green beans, carrots, cow’s milk (grass-fed) and chicken. Vitamins will be measured in micrograms minerals in milligrams and nutritional supplement in calorie and analyze in each vitamin and mineral in foods and their daily needs for good health conditions. We also measure expenditure on the food in Indian currency. The model's goal is to reduce overall food prices. The quantity of each vitamin and mineral found in foods, as well as their daily needs for good health, as well as the combined pricing of these items. The objective is to minimize the overall food price.

Table 3.1 Daily needs ofvitamins and minerals

	Papaya 275 gm	Peanuts 36.48 gm	Broccli chopped 155 gm	Oranges 130 gm	Tomatoes sliced 180 gm	Turnip Greens 145 gm	Barley 59.35 gm	Green beans 123 gm	Carrot Sliced raw 120 gm	Egg per 100 gm	Cow’s Milk, 125 Gm	Chicken 112.80 gm	Requirement Daily
Vitamin A	131.12 mcg	0.00 mcg	120.72 mcg	13.98 mcg	73.94 mcg	548.32 mcg	0.65 mcg	44.23 mcg	1019.0 6mcg	147 mcg	55.93 Mcg	7.16 mcg	848 mcg
Different types of Vitamin B													
Vitamin B1 Thiamin	1.07 milli gram	1.22 milli gram	1.11 milli gram	1.12 milli gram	1.08 milli gram	1.05 milli gram	1.42 milli gram	1.08 milli gram	1.09 milli gram	1.07 milli gram	1.07 milli gram	1.09 milli gram	2.4 milli gram
Vitamin B2 Riboflavin	1.06 milli gram	1.06 milli gram	1.18 milli gram	1.04 milli gram	1.04 milli gram	1.11 milli gram	1.18 milli gram	1.13 milli gram	1.09 milli gram	1.3 milli gram	1.22 milli gram	1.15 milli gram	2.8 milli gram
Vitamin B3 Niacin	1.02 milli gram	5.02 milli gram	1.88 milli gram	1.36 milli gram	2.08 milli gram	1.58 milli gram	1.83 milli gram	1.76 milli gram	2.22 milli gram	5.2 milli gram	1.12 milli gram	16.53 milli gram	19 milli gram
Vitamin B5 Pantothenic Acid	1.52 milli gram	1.62 milli gram	1.94 milli gram	1.32 milli gram	1.17 milli gram	1.38 milli gram	1.16 milli gram	1.08 milli gram	1.32 milli gram	2.2 milli gram	1.47 milli gram	2.092 milli gram	6.25 milli gram
Vitamin B6 Pyridoxine	0.12 milli gram	1.12 milli gram	1.32 milli gram	1.07 milli gram	1.13 milli gram	1.25 milli gram	1.19 milli gram	1.06 milli gram	1.16 milli gram	1.03 milli gram	1.03 milli gram	1.69 milli gram	3 milli gram
Vitamin B7 Biotin	0.01 micro gram	5.39 micro gram	0.01 micro gram	2.32 micro gram	6.22 micro gram	1.59 micro gram	2.28 micro gram	2.02 micro gram	5.12 micro gram	17 micro gram	3.34 micro gram	0.01 micro gram	26 micro gram
Vitamin B9 Folate	101.11 micro grams	86.62 micro grams	167.44 micro grams	38.32 micro grams	28 micro grams	168.91 micro grams	22.32 micro grams	85.76 micro grams	22.16 micro grams	45 micro grams	5.12 micro grams	5.56 micro gram	501 micro gram
Vitamin B12 Cobalamin	0 micro gram	0 micro gram	0 micro gram	0 micro gram	0 micro gram	0 micro gram	0 micro gram	0 Micro Gram	0 micro gram	2.6 micro gram	1.54 micro gram	1.38 micro Gram	3 micro gram

Vitamin C	167.09 milli gram	0 milli gram	102.22 milli gram	68.68 milli gram	23.67 milli gram	40.47 milli gram	0 milli gram	11.14 milli gram	6.22 milli gram	.001 milli gram	.002 milli gram	.003 milli gram	82 milli gram
Vitamin D	0 micro gram	0 micro gram	0 micro gram	0 micro gram	0 micro gram	0 micro gram	0 micro gram	0 micro gram	0 micro gram	2.6 micro gram	2.58 micro gram	1.13 micro gram	12 micro gram
Vitamin E	1.84 milli gram	2.06 milli gram	3.28 milli gram	1.26 milli gram	1.96 milli gram	3.72 milli gram	1.34 milli gram	1.57 milli gram	1.82 milli gram	2.62 milli gram	1.12 milli gram	1.33 milli gram	16 milli gram
Vitamin K	8.19 micro gram	0.01 micro gram	219.13 micro gram	.001 micro gram	13.24 micro gram	530.36 micro gram	2.36 micro gram	19.10 micro gram	17.12 micro gram	1.32 micro gram	1.36 micro gram	1.32 micro gram	136 micro gram
Choline	17.85 milli gram	20.17 milli gram	63.57 milli gram	10 milli gram	13.04 milli gram	1.44 milli gram	24.64 milli gram	22.12 milli gram	11.72 milli gram	284 milli gram	16.44 milli gram	95.72 milli gram	551 milli gram
Calcium	55.23 milli gram	32.59 milli gram	61.41 milli gram	53.42 milli gram	19.02 milli gram	198.26 milli gram	21.23 milli gram	54.02 milli gram	41.25 milli gram	50 milli gram	136.85 milli gram	18.10 milli gram	1001 milli gram
Magnesium	56.8 milli gram	62.33 milli gram	33.75 milli gram	14.11 milli gram	20.82 milli gram	32.66 milli gram	80.55 milli gram	21.51 milli gram	15.62 milli gram	11.01 milli gram	13.21 milli gram	33.88 milli gram	352 milli gram
Phosphorus	27.58 milli gram	137.25 milli gram	104.51 milli gram	18.32 milli gram	43.22 milli gram	41.75 milli gram	161.91 milli gram	36.24 milli g ram	42.72 milli gram	192 milli gram	102.44 milli gram	258.52 milli gram	701 milli gram
Potassium	502.33 milli gram	257.31 milli gram	457.06 milli gram	237.12 milli gram	426.62 milli gram	292.34 milli gram	277.25 milli gram	182.6 milli gram	390.5 milli gram	142 milli gram	162.03 milli gram	291.2 milli gram	4511 milli gram
Chromium	0.01 micro gram	0.01 micro gram	19.54 micro gram	1.38 micro gram	2.25 micro gram	0.10 micro gram	9.15 micro gram	3.05 micro gram	1.48 micro gram	1.42 micro gram	1.05 micro gram	1.65 micro gram	36 micro gram
Copper	1.10 milli gram	1.43 milli gram	1.12 milli gram	1.08 milli gram	1.12 milli gram	1.35 milli gram	1.32 milli gram	1.06 milli gram	1.04 milli gram	1.03 milli gram	1.02 milli gram	1.05 milli gram	1.5 milli gram
Iodine	.001 micro gram	7.32 micro gram	3.14 micro gram	0 micro gram	0 micro gram	.001 micro gram	4.42 micro gram	0 micro gram	0 micro gram	44 micro gram	28.04 micro gram	0 micro gram	151 micro gram
Iron	1.68 milli gram	2.66 milli gram	1.04 milli gram	1.12 milli gram	1.48 milli gram	1.14 milli gram	2.20 milli gram	1.82 milli gram	1.36 milli gram	1.8 milli gram	1.05 milli gram	1.19 milli gram	16 milli gram
Selenium	2.65 micro gram	3.62 micro gram	3.49 micro gram	1.66 micro gram	.001 micro gram	2.29 micro gram	24.13 micro gram	1.26 micro gram	1.13 micro gram	24 micro gram	5.52 micro gram	32.29 micro gram	46 micro gram
Zinc	1.21 milli gram	1.20 milli gram	1.69 milli gram	1.08 milli gram	1.32 milli gram	.001 milli gram	1.69 milli gram	1.32 milli gram	1.28 milli gram	1.1 milli gram	1.5 milli gram	1.12 milli gram	16 milli gram
Calorie	120	205	56	60	30	30	218	45	51	155	75	188	2500 Calorie
Cost	8	5.5	22	6	2.5	5.55	1.75	12	4	4.8	6	12.5	

Vitamins	Daily Requirements	Primary Natural sources		Functions	Problems
		Products vegetables/ Fruits	Products Animals		
Vitamin-A (Retinol)	More than 848mcg	Spinach , carrots, Melon	Egg, liver, product of milk	It is very during The pregnancy	Vision problem in Night
Vitamin-B1 (Thiamin)	More than 2.4mg	Fruits, mixed nuts, almonds	Meat, offal, Fish	It is very muscular	Enlarged heart
Vitamin-B2 (Riboflavin)	More than 2.8mg	Almonds, all types of grains	Meat	It plays a role in clear useful of energy	Growth failure, Dermatitis, blurred vision
Vitamin-B3 (Niacin)	More than 19mg	Avocados, sunflower seeds, peanuts, all type of grain	Fish, milk, meat, eggs	Energy Neuro-logical	Mental disorders, Diarrhea
Vitamin-B5 (Pantothenic-acid)	More than 6.25mg	Broccoli, mushroom, tomato	Fish, milk, Meat	Blood	Insomnia
Vitamin-B6 (Pyridoxine)	More than 3mg	Gram seed, corns, banana, mixed nuts	Chicken, liver, seafood, fish	Nerve blood DNA	Muscular weakness
Vitamin-B7 (Biotin)	More than 26mcg	Vegetables, Nuts, Peanuts	Non vegetarian item, liver, egg, products of milk	Nails, Skin	Hair loss, muscle pain, dermati tis, confusi on
Vitamin-B9 (Folic-acid)	More than 501mcg	Orange, Leafy vegetables, broccoli	Yolk of egg, products of milk, liver	DNA	Spina bifida, Megalo blastic anemia
Vitamin-B12 Cobalamin	More than 3mcg	Milk products	Shellfish, meat,	Nerve	Pernicious anemia

Vitamin-C Ascorbic-acid	More than 82mg	Citrus fruits, tomato, green vegetables.	Liver, milk Product	Protection against infections, iron	Infections, kidney Stones
Vitamin-D Calciferol	More than 12mcg	Sunlight, Mushroom	Fish oil, yolk of egg	Bones skin kidney Intestine	Infection and kidney stones
Vitamin-E Tocopheol	More than 16mg	Green vegetables, fruits, nuts and oils of vegetable	Egg and by milk product	Stored in the liver, cells of blood, antioxidant	Weakness in muscle, Headaches, nausea, diarrhea
Vitamins-K Phylloquinone	More than 136mcg	Oil of vegetable, vegetable green leaves, cauliflower	Meat, non-vegetarian item liver, by products of milk	Clotting of blood	It can interface with anticoagulant medication
Choline	More than 551mg	Peanuts	Eggs, milk	Nerve gene	It is an existent nutritious, strictly Speaking
Calorie	More than 2500	Green beans, barley, carrots, peanuts, papaya	Chicken, egg, cow's milk	It is very important to maintain health	Increase the risk for human health by more quantity
Minerals	Daily requirements	Products vegetables/ fruits	Product animals	Functions	Use in the body and risks
Calcium (Ca) Atomic No – 20	More than 1001mg	Green vegetables	Fish, products of milk	Teeth and bones	Teeth and bones contain almost 99% of calcium. It is very important during the time of pregnancy and helps to control blood pressure.
Magnesium (Mg) Atomic No – 12	More than 352mg	All types of grain, mixed nuts, green vegetables	Seafood fish	Bones and efficiency metabolism	Magnesium acts an essential part in the body growth and strength to the bones
Phosphorus (P) Atomic No – 15	More than 701mg	Seeds of Sunflower	Fish, milk, meat, eggs	Efficiency metabolism, bones and teeth	Approx. 85% of Phosphorus merges with the calcium in the teeth

					and bones. It is also part of DNA and RNA
Potassium(K) Atomic No – 19	More than 4511mg	Pumpkins, green vegetables, grains, tomatoes	Nonvegetarian Food	Human muscle activity and blood pressure	Potassium increased the risk of stones and stroke. It pumped the cell membrane.
Chromium (Cr) Atomic No – 24	More than 36mcg	Green beans, broccoli, all types of grains, nuts	Yolk of egg	It supports defends blood sugar level and rich insulin activity	High doses create side effects like blood disorders.
Copper (Cu) Atomic No – 29	More than 15mg	All types of grain, legumes, nuts	Offal, seafood	Blood formation, activity metabolism.	Insufficient quantity of copper is very dangerous.
Iodine(I) Atomic No – 53	More than 151mcg	Iodized salt	Seafood	Function like thyroid	Imperfection of iodine is very harmful for human health.
Iron (Fe) Atomic No – 26	More than 16mg	Legumes, grains	Red meats, fish, poultry	Blood production	Kids want additional iron to maintain their brain development.
Selenium (Se) Atomic No– 34	More than 46mcg	Mushrooms, fruits, all grains, nuts, vegetables.	Seafood, meat, dairy products	Antioxidant	Brittleness of hair
Zinc (Zn) Atomic No – 30	More than 16mg	Mushrooms, legumes, types of all grain.	Poultry, Shellfish, meat	Gene declaration and immune activity	Zinc is very useful in periods.

3.3 OBJECTIVE FUNCTION AND CONSTRAINT

To reduce the overall cost of mineral and vitamin content in foods, as well as the price per gram. The price function (Z) for the one papaya price 275gm X1, peanuts price 36.48gm X2, one broccoli price 155gm X3, one medium orange price 130gm X4, tomatoes price 180gm X5, turnips greens price 145gm X6, barley price 61.35gm X7, green beans price 125gm X8, carrot price 120gm X9, one egg price 100gm X10, cow's milk price 125gm X11, chicken price 113.40gm X12. The quantity for Vitamin A in this diet content more than 848mcg, Vitamin B1(thiamine) content more than 1.4gm, Vitamin B2(riboflavin) content more than 1.8mcg, Vitamin B3(niacin) content more than 19mg, Vitamin B5(pantothenic acid) content more than 5.25mg, Vitamin B6(pyridoxine) content more than 2mg, Vitamin B7(biotin) content more than 26mcg, Vitamin B9(foliate) content more than 500mcg, Vitamin B12(cobalamin) content more than 3mcg, Vitamin C content more than 82mg, Vitamin D content more than 12mcg, Vitamin E content more than 16mg, Vitamin K content more than 136mcg, choline content more than 551mg, calorie content more than 2500 calories, calcium (ca) content more than 1001 mg, magnesium (mg) content more than 352mg, phosphorus (p) content more than 701mg, potassium (k) content more than 4500mg, chromium (cr) content more than 36mcg, copper (cu) content more than 2.5mg, iodine (i) content more than 151mcg, iron (fe) content more than 16mg, selenium (se) content more than 46mcg, zinc (zn) content more than 16mg.

3.4 TOTAL FORMULATION OF THE PROBLEM

Min Z = $8X_1 + 5.5X_2 + 22X_3 + 6X_4 + 2.5X_5 + 5.55X_6 + 1.75X_7 + 12X_8 + 4X_9 + 4.8X_{10} + 6X_{11} + 12.5X_{12}$

Subject to,

$$131.12X_1 + 120.72X_3 + 13.98X_4 + 73.94X_5 + 548.32X_6 + 0.65X_7 + 44.23X_8 + 1019.06X_9 + 147X_{10} + 55.93X_{11} + 7.16X_{12} \geq 848,$$

$$1.07X_1 + 1.22X_2 + 1.11X_3 + 1.12X_4 + 1.08X_5 + 1.05X_6 + 1.42X_7 + 1.08X_8 + 1.09X_9 + 1.07X_{10} + 1.07X_{11} + 1.09X_{12} \geq 2.4$$

$$1.06X_1 + 1.06X_2 + 1.18X_3 + 1.04X_4 + 1.04X_5 + 1.11X_6 + 1.18X_7 + 1.13X_8 + 1.09X_9 + 2.3X_{10} + 1.22X_{11} + 1.15X_{12} \geq 2.8$$

$$1.02X_1 + 5.02X_2 + 1.88X_3 + 1.36X_4 + 2.08X_5 + 1.58X_6 + 1.83X_7 + 1.76X_8 + 2.22X_9 + 5.2X_{10} + 1.12X_{11} + 16.53X_{12} \geq 19$$

$$1.52X_1 + 1.62X_2 + 1.94X_3 + 1.32X_4 + 1.17X_5 + 1.38X_6 + 1.16X_7 + 1.08X_8 + 1.32X_9 + 2.2X_{10} + 1.47X_{11} + 2.092X_{12} \geq 6.25$$

$$0.12X_1 + 1.12X_2 + 1.32X_3 + 1.07X_4 + 1.13X_5 + 1.25X_6 + 1.19X_7 + 1.06X_8 + 1.16X_9 + 1.03X_{10} + 1.03X_{11} + 1.69X_{12} \geq 3$$

$$0.01X_1 + 5.39X_2 + 0.01X_3 + 2.32X_4 + 6.22X_5 + 1.59X_6 + 2.28X_7 + 2.02X_8 + 5.12X_9 + 17X_{10} + 3.34X_{11} + 0.01X_{12} \geq 26$$

$$101.11X_1 + 86.62X_2 + 1.67.44X_3 + 38.32X_4 + 28X_5 + 168.91X_6 + 22.32X_7 + 85.76X_8 + 22.16X_9 + 45X_{10} + 5.12X_{11} + 5.56X_{12} \geq 501$$

$$2.6X_{10} + 1.54X_{11} + 1.38X_{12} \geq 3$$

$$167.09X_1 + 102.22X_3 + 68.68X_4 + 23.67X_5 + 40.47X_6 + 11.14X_8 + 6.22X_9 +.001X_{10} +.002X_{11} +.003X_{12} \geq 82$$

$$2.6X_{10} + 2.58X_{11} + 1.13X_{12} \geq 12$$

$$1.84X_1 + 2.06X_2 + 3.28X_3 + 1.26X_4 + 1.96X_5 + 3.72X_6 + 1.34X_7 + 1.57X_8 + 1.82X_9 + 2.62X_{10} + 1.12X_{11} + 1.33X_{12} \geq 16$$

$$8.19X_1 + 219.13X_3 + 13.24X_5 + 530.36X_6 + 2.36X_7 + 19.10X_8 + 17.12X_9 + 1.32X_{10} + 1.36X_{11} + 1.32X_{12} \geq 136$$

$$17.85X_1 + 20.17X_2 + 63.57X_3 + 10X_4 + 13.04X_5 + 1.44X_6 + 24.64X_7 + 22.12X_8 + 11.72X_9 + 284X_{10} + 16.44X_{11} + 95.72X_{12} \geq 551$$

$$55.23X_1 + 32.59X_2 + 61.41X_3 + 53.42X_4 + 19.02X_5 + 198.26X_6 + 21.23X_7 + 54.02X_8 + 41.25X_9 + 50X_{10} + 136.85X_{11} + 18.10X_{12} \geq 1001$$

$$56.8X_1 + 62.33X_2 + 33.75X_3 + 14.11X_4 + 20.82X_5 + 32.66X_6 + 80.55X_7 + 21.51X_8 + 15.62X_9 + 11.01X_{10} + 13.21X_{11} + 33.88X_{12} \geq 352$$

$$27.58X_1 + 137.25X_2 + 104.51X_3 + 18.32X_4 + 43.22X_5 + 41.75X_6 + 161.91X_7 + 36.24X_8 + 42.72X_9 + 192X_{10} + 102.44X_{11} + 258.52X_{12} \geq 701$$

$$502.33X_1 + 257.31X_2 + 457.06X_3 + 237.12X_4 + 426.62X_5 + 292.34X_6 + 277.25X_7 + 182.6X_8 + 390.5X_9 + 142X_{10} + 162.03X_{11} + 291.2X_{12} \geq 4511$$

$$.01X_1 + .01X_2 + 19.54X_3 + 1.38X_4 + 2.25X_5 + 0.10X_6 + 9.15X_7 + 3.05X_8 + 1.48X_9 + 1.42X_{10} + 1.05X_{11} + 1.65X_{12} \geq 36$$

$$1.10X_1 + 1.43X_2 + 1.12X_3 + 1.08X_4 + 1.12X_5 + 1.35X_6 + 1.32X_7 + 1.06X_8 + 1.04X_9 + 1.03X_{10} + 1.02X_{11} + 1.05X_{12} \geq 1.5$$

$$.001X_1 + 7.32X_2 + 3.14X_3 + 4.42X_7 + 44X_9 + 28.04X_{10} \geq 151$$

$$1.68X_1 + 2.66X_2 + 1.04X_3 + 1.12X_4 + 1.48X_5 + 1.14X_6 + 2.20X_7 + 1.82X_8 + 1.36X_9 + 1.8X_{10} + 1.05X_{11} + 1.19X_{12} \geq 16$$

$$2.65X_1 + 3.62X_2 + 3.49X_3 + 1.66X_4 + .001X_5 + 2.29X_6 + 24.13X_7 + 1.26X_8 + 1.13X_9 + 24X_{10} + 5.52X_{11} + 32.29X_{12} \geq 46$$

$$1.21X_1 + 1.20X_2 + 1.69X_3 + 1.08X_4 + 1.32X_5 + .001X_6 + 1.69X_7 + 1.32X_8 + 1.28X_9 + 1.1X_{10} + 1.5X_{11} + 1.12X_{12} \geq 16$$

$$120X_1 + 205X_2 + 56X_3 + 60X_4 + 30X_5 + 30X_6 + 218X_7 + 45X_8 + 51X_9 + 155X_{10} + 75X_{11} + 188X_{12} \geq 2500$$

$X1 \geq 0,\ X2 \geq 0,\ X3 \geq 0,\ X4 \geq 0,\ X5 \geq 0,\ X6 \geq 0,\ X7 \geq 0,\ X8 \geq 0,\ X9 \geq 0,$

$X10 \geq 0,\ X11 \geq 0,\ X12 \geq 0.$

3.5 RESULTS AND DISCUSSIONS

Global optimal solution found.

Objective value: 53.66342

Infeasibilities: 0.000000

Total solver iterations: 5

Elapsed runtime seconds: 1.69

Model class: LP

Total variables: 12

Nonlinear variables: 0

Integer variables: 0

Total constraints: 38

Nonlinear constraints: 0

Table 3.2 Reduced cost, Slack, Surplus and dual prices from Lingo

Variable	Value	Reduced Cost
X_1	0.000000	4.215713
X_2	0.000000	1.678922
X_3	0.000000	16.40654
X_4	0.000000	3.368036
X_5	2.711736	0.000000
X_6	1.222622	0.000000
X_7	7.283082	0.000000
X_8	0.000000	8.288752
X_9	0.000000	0.8265912
X_{10}	3.851212	0.000000
X_{11}	2.656089	0.000000
X_{12}	0.000000	10.41989

Row	Slackor Surplus	Dual price
1	53.68342	-1.000000
2	752.7042	0.000000
3	2.266850	0.000000
4	4.635850	0.000000
5	21.85821	0.000000

6	3.762322	0.000000
7	0.4144332	0.000000
8	72.26466	0.000000
9	136.3161	0.000000
10	5.237667	0.000000
11	35.11608	0.000000
12	0.000000	-1.446312
13	0.000000	-0.6240084
14	562.7140	0.000000
15	799.4184	0.000000
16	0.000000	-0.1537987E-01
17	407.4224	0.000000
18	1651.261	0.000000
19	0.000000	-0.2527172E-02
20	29.546558	0.000000
21	1.152897	0.000000
22	129.8800	0.000000
23	10.48368	0.000000
24	225.5311	0.000000
25	3.135525	0.000000
26	0.000000	-0.1243209E-02
27	0.000000	0.000000
28	0.000000	0.000000
29	0.000000	0.000000
30	0.000000	0.000000
31	2.711736	0.000000
32	1.222622	0.000000
33	7.283082	0.000000
34	0.000000	0.000000
35	0.000000	0.000000
36	3.851212	0.000000
37	2.656089	0.000000
38	0.000000	0.000000

Lingo program is used to find a solution because this model comprises 12 variables, and the outcomes are verified by NCSS and Lingo software. This is the global best possible result of linear programming. The minimum solution for a balanced diet is Rs. 53.66.

Tomatoes (sliced raw) 488grams required per day.

Turnip Greens175grams required per day.

Barley (dry) 445gramsrequired per day.

Egg Required Three to Four per day.

Cow's Milk (grass-fed) 325 grams required per day.

Conclusion

The linear programming methodology efficiently generates a low-cost meal plan that covers daily nutritional requirements for people aged 20 to 50. By optimizing food selections within financial limits, it assures vital nutrient consumption, making it a useful tool for economical and balanced nutrition. The optimum value is Rs. 53.66 and also find the daily requirements with the help of Lingo software.

CHAPTER - 4

A MATHEMATICAL MODEL FOR ANALYZING AND OPTIMIZING CHILDREN'S DIET DURING FEEDING PERIOD

4.1 INTRODUCTION

According to available data, breastfeeding alone is not enough to meet the nutritional requirements of children aged between 6 and 23 months. In order to ensure proper growth and development, it is crucial to supplement their diet with nutrient-dense foods that are rich in key minerals such as zinc, iron, copper, calcium, and vitamins A, B, and C. Once infants reach the six-month mark, it is recommended that they receive additional nutritional supplements in addition to breast milk. While local nutrient-rich foods may seem like a viable substitute for a well-balanced diet in developing nations, recent LP modeling has shown that serving sizes based on real-life scenarios may increase nutritional value but still fail to provide enough of certain important nutrients, notably thiamin, folate, and iron. As such, it is imperative to ensure that children in this age group receive a variety of nutrient-dense foods that are sufficient in quantity to meet their daily needs for optimal growth and development [41]. This study highlights the importance of awareness regarding nutrient-boosting food items and problem nutrients in dietary intake data, criteria, energy and fat requirements using linear programming [46]. One-fourth of all children, approximately 28.7%, still receive prelacteal feedings, which challenge the WHO's 90% EBF recommendation. Introducing optimal early breastfeeding and avoiding prelacteal feeding can improve effective breastfeeding by 65.7%. The year 2001 marks the establishment of the initial base percentage at 27.1% [30]. Inadequate nutrition education and the consumption of low-nutrient dense complementary foods contribute significantly to the prevalence of childhood malnutrition. To address this issue, many developing nations are considering the implementation of complementary feeding programs. However, the insufficiency in food quality and quantity poses a significant risk for nutritional inadequacies during the latter half of infancy. Usually, in developing nations, unfortified cereal-based complementary foods are the 1main source of sustenance. Gruels are a common food preference, but they have low nutrient and energy density, and may lack essential nutrients in certain populations. While iron, zinc, and pyridoxine are present in adequate levels, vitamins such as riboflavin, niacin, calcium, thiamine, folate, ascorbic acid, and vitamin A may be deficient [101]. Our analysis revealed that the CFR program improved the diets of children aged 9-16 months by enhancing knowledge and addressing key problem nutrients such as calcium, iron, niacin, and zinc. Following a 6-month intervention, nutrient densities in the CFR group were significantly higher, with most nutrients being relatively higher in the CFR group compared to the non-CFR group [96].

In Australia, many children between the ages of 6 and 23 months suffer from a condition known as anemia, which is caused by a lack of iron. When the level of hemoglobin drops too low within red blood cells, the body becomes susceptible to this disease. According to a recent study, infants aged between6 and 12 months should receive a daily dose of 5.8mg of iron, while breastfed toddlers aged between 13 and 23 months should receive a dose of 4.4mg [25]. Malnutrition and poor neurobehavioral development pose a significant threat to millions of young children living in low- and middle-income countries around the world. In 2019, global data indicated that 144 million children under the age of five, or 21.3 percent, experienced stunted growth, while 47 million, or 6.9 percent, suffered from malnourishment caused by a deficiency in important micronutrients like zinc, iron, vitamin B12, and vitamin A. Due to inadequate nutrient stores at birth and insufficient dietary intake, children less than two years old face a heightened risk of malabsorption and infection, with roughly 250 million affected. Furthermore, undernourishment in childhood, linked to 43 percent of cases, can impede children less than five years of age from attaining their full developmental potential [48].

The main objective of this document is to furnish the necessary context to craft well-founded dietary advice and suitable educational schemes that augment kid’s nutrient absorption and nutritional well-being. The evaluation is chiefly intended for healthcare practitioners and other stakeholders in child health, sustenance, and welfare in emerging nations. Although the majority of the data might apply to youths in prosperous economies, the manuscript spotlights the particular requirements of underprivileged children, and the proposals were developed with financial and ecological constraints that are prevalent in developing nations.

Assuming the reader is familiar with fundamental concepts of nutritional science [18], the benchmark for linear growth has two components: length-for- age (0 to 24 months) and height-for-age (2 to 5 years), where both components were developed using the same model, yet the average difference between recumbent length and standing height is exhibited in the final curves [62]. Breast milk plays a critical role in providing energy, macro nutrients and nine out of eleven micronutrients in the model diet, emphasizing the importance of continued breastfeeding. Initial food introduction for babies incorporated meals derived from animals, protein foods with added nutrients (such as baby cereal and margarine), and starchy plant meals like butternut which stood out as a primary nutrient source, contributing 71% of the calories consumed from breast milk in the diet's simulation [66].

Using information from local food sources, this research demonstrated that both linear and nonlinear programming can be utilized to formulate nutritional recommendations. In underprivileged African regions, Malawi's findings revealed that there are pervasive issues related to low intakes of riboflavin, zinc, and phytate. The outcomes of this study suggest that increasing the consumption of fruits, vegetables, and animal-derived nutrients significantly improves the nutrient content of food during and after harvest, thus providing positive impacts. Nevertheless, meeting the nutritional needs of everyone during these stages of development is challenging. To fulfill the dietary requirements of young children (below 2 years old), it is highly recommended that one should exercise caution while consuming sugar in order to maintain a healthy lifestyle. Additionally, it is crucial that we conduct and delve into more research to develop reference profiles for the composition of human breast milk. It is imperative that the DRI values for various age groups are updated and reinforced as well. Lastly, it is advisable to consider optimization models that combine with FPM and identify food combinations to fully meet all nutritional objectives [44].

For parents of growing children, it is recommended to: 1. Continue frequent breastfeeding, 2. Serve larger meal portions and actively encourage the child to eat as much as they want, 3. Gradually introduce complementary foods, starting at 6-7 months with three meals per day and increasing to at least five times per day (three meals and three snacks) by 12 months, 4. Initially offer soft foods, and then progress to chopped or mashed pieces, 5. Encourage and support the child's feeding efforts [104]. Scientists analyzed data on breastfeeding, nutrition, and body measurements from the Cebu Longitudinal Health and Nutrition Survey by utilizing fixed-effects longitudinal regression models which were stratified by sex. The researchers assessed the scores for dietary diversity scores (DDS) by categorizing seven food groups as low (<4) or high (≥4). The study examined complementary feeding practices, where low dietary diversity scores (DDS) were found to be common in non-breastfed infants. The optimal DDS was achieved through breastfeeding and high DDS. The objective of the research was to utilize a procedure based on linear and goal programming to create suggestions for complementary feeding (CFR) for Indonesian infants between the ages of 9 to 11 months. The CFR was created by focusing on nutrients that were likely to be insufficient, based on gathered dietary information from a cross-sectional study of 100 children. The study found local foods were inadequate in nutrients such as iron, niacin, zinc, and calcium, despite fortified options such as meatballs, chicken liver, eggs, bananas, and spinach being the best sources of nutrients. As a result, iron requirements could not be met solely through local food consumption (with the best possible level only reaching 63% of suggested intake) [75].

According to the analysis, offering multiple meals that are sourced locally can meet the protein needs of infants between 6 to 23 months old. Nonetheless, the insufficiencies of specific vitamins and nutrients such as zinc, iron, calcium, as well as energy, thiamin, riboflavin, niacin, and vitamin A, persist. Additionally, folate and vitamin C intake was inadequate in some cases. Local foods can be used to address these deficiencies. Improving food preparation methods, such as soaking maize to reduce phytate levels or processing local foods for easier consumption by infants, and increasing dietary options can address most nutritional needs. Nonetheless, iron, zinc, and calcium requirements may still remain unsatisfied even with improved feeding regimens and nutrient- dense meals [87].

We noticed a significant rise in nutrient-related problems in our study after fortified foods were removed from the diet models. The highest difference was observed in infants between the ages of 6 and 8 months, but no data was available to support this. Surprisingly, we identified more malnutrition concerns in rural Filipino kids compared to those earlier studied in the same region who were in the age group of 12 to 23 months. The deficiency of specific nutritional elements in the older age group might be attributed to the lower intake of fortified infant foods and breast milk dietary formula, which play an indispensable role in the overall nutritional consumptions in young ones. This decrease could be attributed to the lack of availability of fortified items, which has contributed in part to the reduced nutritional intake of children. [42].

We've created best diet formulas that satisfy the dietary reference intakes (DRIs) for 20 nutrients recommended for children aged 6-11 months and 12-23 months. However, the cost of these optimal formulations was twice the actual food expenditure observed across various age groups. The perfect formulas included a combination of fish, whole-grain cereals, legumes, Irish potatoes, poultry meat, seeds, and locally grown fruits and vegetables. Our findings indicate that a balanced diet can be provided to rural children aged between 6 to 23 months without compromising on nutritional value. However, doubling the child's diet budget may not be feasible under these circumstances. Therefore, alternative efforts are required to enhance households' access to nutrient-rich foods to overcome nutritional deficiencies, as suggested by our results [40].

Nutritional worth of complementary feeding (CF) meals consumed by rural Eastern Ugandan children aged 12 to 23 years is inadequate, as demonstrated by this study. Twelve nutrients were analyzed, and nutrient densities in seven of them were below the recommended levels. A large proportion, 45%, of children was at risk of receiving insufficient levels of eight of the twelve nutrients. In contrast to the US, where over 90% of the population meets the calcium, iron, and niacin requirements as well as energy, the dietary intake of these children seems futile. The lower quality of CF diets is related to the limited portions of nutrient-dense foods and lack of dietary diversity. Slightly over 50% of the children consume less than four nutrient-dense food groups per day and their intake of animal-source meals that contain 2-4g of small dry fish, 4g of eggs, and 52g of milk per serving are minimal. It should be emphasized that eggs are consumed by only 4% of children. Additionally, nutrient-rich vegetables like pumpkin, green leafy vegetables and carrots are also rarely consumed. Therefore, improving the variety and serving sizes of food is necessary to enhance the quality of children's CF diets [73].

The national complementary feeding guidelines (CFGs) for infants between 6 to 12 months of age were informed through the application of mathematical modeling. The Optifood linear programming approach was employed, utilizing model parameters that were derived from dietary data, nationally representative, and examined for 11 micronutrients concerning the infant’s age group. The modeling exercise selectively identified micronutrients that local food sources could not provide at the required levels. Reference levels for nutrient intake were thereby determined, and existing CFGs were assessed. Problem nutrients were highlighted, such that the nutritional benefits of enhancing food supplements could be predicted. This investigation was primarily based on the 2012 Thai CFGs.

Upon conducting an investigation, it was discovered that a group of three nutrients - iron, zinc, and calcium, posed a recurring issue. For infants ranging from 9 to 11 months, the concentration of these nutrients was reduced to a solitary level, particularly in situations where fortified food was present. As a result of devising nutritionally-optimized diets, it was brought to light that augmenting the frequency of vegetable consumption along with meat, fish, or eggs (medians) was observed, which was quite the contrary to the dietary, where the number of servings of fruit and oil per week experienced a decline. The Thai CFGs' original iteration, including a weekly recommendation for the intake of oil and fruit, became impractical due to the exceeding energy constraint. Thus, modifications were made to the recommended number of servings per week for the two food groups. The study demonstrates the benefits of the use of mathematical modeling in assessing and enhancing national CFGs. [97].

4.2 DIET PLANNING WITH AND WITHOUT THE AID OF LINEAR PROGRAMMING

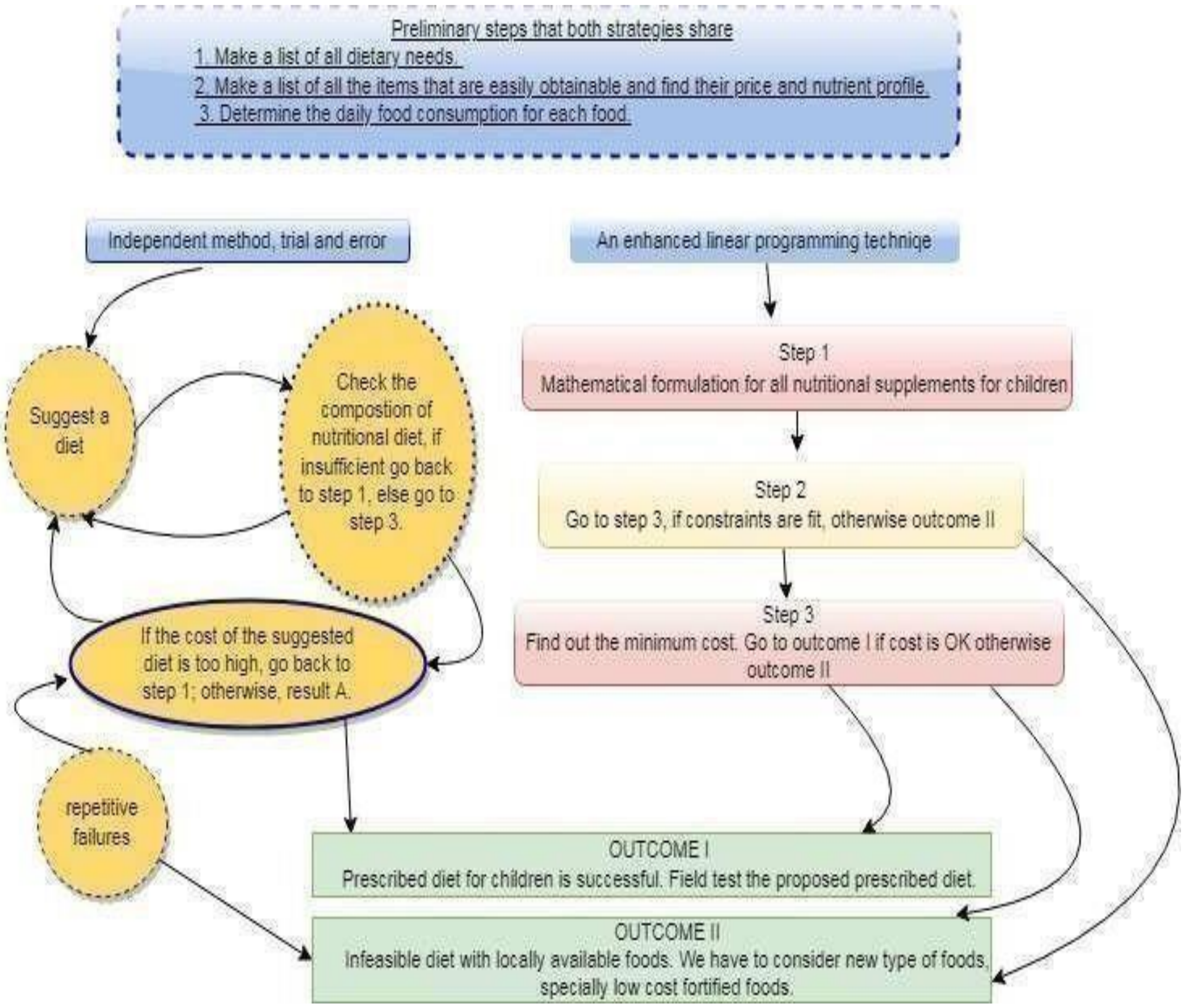


Figure-4.1- *Diet planning with and without the aid Linear Programming*

In order to comprehend the justification for utilizing linear programming in diet formulation, it's imperative to examine the presently employed method for diet design during its formation. The complementary feeding stage, commonly called trial and error period strategy (depicted in Fig. 4.1), comes prior to the onset of trial-and-error initiatives. In this approach, pertinent details about available food options along with their cost, energy, and nutritional values are presented as part of the trial-and-error method. Based on this information, an approximate recommended maximum daily portion size is suggested for children. The traditional trial and error practice is iterative and inefficient, where various food combinations are experimented with based on conjectured assumptions and repeated attempts.

In this method, multiple iterative steps are taken to design a diet plan which may or may not yield an optimal and feasible solution. Moreover, if repeated attempts to develop a low-cost diet prove insufficient, explicit instructions should be given for diet modification, such as the inclusion of fruits and vegetables, without any provision for fortified foods. Conversely, upon gathering and formulating background information, a feasible diet can be swiftly derived by means of linear programming, which provides the most optimal solution efficiently (Fig. 4.1). In cases where the creation of a viable diet is unattainable as determined by the analysis, it is unequivocally evident that new food items must be introduced to the diet.

LP is a powerful tool that can be used to determine the ideal combination of food items that can be incorporated into a diet to achieve a balanced nutrition. However, it can be a challenging task to create a proper diet plan during the complementary feeding phase. This is due to the complex nature of nutrients' absorption levels and their interactions with enhancers and inhibitors, which is compounded by the uncertainty surrounding nutritional requirements. Moreover, in diverse settings, estimating the optimal intake quantity of each food item is a daunting task. Despite these challenges, once the necessary parameters have been obtained through reasonable approximations, linear programming provides a straight forward solution that takes into account the feasibility and costs of developing a well-rounded diet. In contrast, the current trial-and-error approach is not only time-consuming but also prone to errors, which can introduce significant uncertainties in the process. To mitigate this, we use Lingo software, which streamlines the process and provides quick and efficient results.

4.3 LINEAR PROGRAMMING AND SOME OTHER DEFINITIONS

To achieve optimal results in a decision-making process that involves several factors, linear programming can be employed. With this method, a linear function of decision variables can be optimized, whereby various linear constraints must be taken into account. A collection of parallel lines or a planar surface can be used to graphically describe the objective function, which is the linear function to be optimized. The values that contribute to the objective function are the choice variables, indicated by the letters X_1, X_2, ..., and X_n. which is identified as Y. Y is a function of multiple variables X_1, X_2, ..., X_n, and this function is expressed linearly.

$$Y = a_0 + a_1X_1 + a_2X_2 + ... + a_nX_n$$

and the constants a_0, a_1, a_2, ..., an. In a similar manner, a constraint on multiple X_1, X_2 variables... X_n is linear and has the following expression:

$$b_1X_1 + b_2X_2 + ... + b_nX_n \geq b_0$$

and b_0, b_1, b_2 ... b_n are constants. The inclusion of a supplementary section in the form of an appendix serves the purpose of furnishing readers with an enhanced grasp of the principles of linear programming. This material comprises a basic yet effective visual representation of the underlying theory, coupled with an elucidation of its core mathematical tenets.

4.3.1 OPTIMIZING DIET THROUGH LINEAR PROGRAMMING MODEL DEVELOPMENT

In order to devise an effective model for optimizing one's diet through linear programming, it is imperative that the problem itself be articulated with utmost clarity beforehand. Subsequently, the best possible answers can be obtained by means of an objective function. One must verily ensure that this query is framed specifically as a linear function of the decision variables. Ultimately, it is crucial to adhere to both the nutritional as well as palatability constraints dictated by the diet optimization procedure. To discern the optimal outcome, a thorough analysis of all the pertinent details must be carried out, all of which shall be elucidated upon in the ensuing discourse.

4.3.2 DECISION VARIABLES AND THE OBJECTIVE FUNCTION

The mathematical representation of the criteria utilized to select the optimal solution from a pool of multiple solutions is referred to as the objective function. The appropriate formulation of this objective function is contingent upon the specific question that has been posed. Depending on the purpose, the objective function could be the energy content of a diet, or the total cost of the diet. Regardless, the objective function must be minimized and expressed as a linear function of decision variables X_1, X_2… X_n, expressing the weights of each food item in linear programming form as individual units. If one seeks to design a well-balanced diet, the total energy content that fulfills all constraints represents the optimal objective function in the first scenario, with the importance given to the energy requirements of the child. On the other hand, a cost-optimal diet can only be achieved in the second scenario when cost is minimized as the objective function and it remains within the budgetary limitations of a low-income household.

When we talk about a food related table, we are referring to a comprehensive list of all the food items that are readily available locally and can potentially be integrated into the diet of children. This list includes not only the prices but also the nutritional value of these food items. These food items are taken as decision variables in a specific environment to determine their appropriate weight for feeding young children. The combination of food items selected during this analysis is referred to as the food basket. In an optimized diet, all the food items included must have an optimized nutritional value, but not necessarily a weight greater than zero grams. This implies that the food items in the basket don't have to be eaten in exact amounts as analyzed daily, but instead, they indicate the approximate amounts of various foods that should be consumed during a brief period, like a week.

4.3.3 NUTRITIONAL AND PALATABILITY CONSTRAINTS IN COMPLEMENTARY FEEDING DIET

The limits of the optimization process for developing an ideal complementary feeding diet are established by linear constraints. These constraints play a crucial role in ensuring the diet meets specific nutritional demands while complying with given energy restrictions. Nutrient constraints are essential to ensure that the diet not only satisfies but exceeds the recommended dietary intake for 97% of children. In cases where the objective is to achieve a nutrient level higher than a particular value, a linear constraint is exemplified as an inequality (≥). However, when targeting an energy content equivalent to the average requirements, a linear constraint is represented in the form of equality.

The importance of such constraints cannot be overstated as they are critical in crafting a healthy and balanced diet for children.

It's common for optimization algorithms to exhibit a preference for foods that are abundant in various nutrients, especially those that contain uncommon nutrients. When said nutrients are present within the system, a sizable amount of liver, legumes, dried fish, and dark leafy greens tend to be chosen with noticeable frequency. However, to avoid impractical food choices, new constraints should be added to confirm that the selected diet is both palatable and socially acceptable. By enforcing a set of simple inequality constraints which limit the portion sizes of each food item in the database, unrealistic diets can be eliminated. Additionally, upper limits on food groups should be set when there is a diverse range of food options available.

To illustrate, when a vast array of legumes or fruits are present, including all the distinct foods in the highest amounts can cause impractical diets. Establishing a cap on the total amount of energy that any food in a food group can supply will prevent this result. Ideally, previous surveys on food consumption should have provided the basis for these restrictions on portion sizes and food types. If the necessary information is not accessible, those residing in the vicinity should state the maximum quantity of every meal product appropriate for a child of the corresponding age. Whenever feasible, it is recommended to validate these assertions by means of direct observation. In doing so, one can ensure the accuracy and reliability of the information provided.

4.4 INTERPRETATION OF RESULTS

During supplementary feeding, linear programming can help discover nutrients that may be lacking in a child's diet. By identifying these limiting or problematic nutrients, local diets can be enriched with foods that are rich in or fortified with these nutrients, leading to better outcomes for nutrition intervention programs. Identification of these nutrients is straightforward as the optimized diet selected through linear programming includes them at their absolute minimum. In addition, elimination of the nutrient restrictions results in a decrease in the objective function. When the objective function pertains to energy, these nutrients will be categorized as problematic only if the optimized diet's energy content meets or exceeds the energy requirements of the specific population being considered. In general, children aged 6 to 23 months are likely to be in short supply of iron, hence the challenge of eradicating iron deficiency without iron-fortified foods specifically for infants. The deficiency of other nutrients, in addition to iron, will differ depending on the location and seasonal fluctuations in local markets that impact food availability and pricing.

4.4.1 WHEN CONSTRAINTS CANNOT BE COME THEN WHAT TO DO

There are instances wherein creating a balanced diet through linear programming analysis is unattainable or would lead to an unfavorably costly or energetic outcome. In such cases, deficiencies in nutrients must be determined, and additional foods need to be inserted into the food storage. Depending on the desired outcome, these foods must possess more of the lacking nutrients concerning their energy or cost. In situations where a suitable option is not feasible, utilizing an affordable fortified food or dietary supplement is a viable solution so long as it decreases the objective function and facilitates a cost-effective optimization of the diet.

4.4.2 ADDING NON-LINEAR LIMITATIONS: ENERGY DENSITY AND IRON ABSORPTION INCLUDED

In certain situations, nonlinear nutritional restrictions can be beneficial. For instance, establishing a minimum limit for the energy density of a complete diet is a sound approach. This results in a nonlinear constraint when expressed as a ratio. The mathematical expression for the constraint is as follows:

$$(X1.E1 + X2.E2 + Xn.En)/(X1 + X2 + ...Xn) > ED$$

Here, E_1... E_n stands for the required energy density (ED), and 100 g of food has energy content (E_n) ranging from 1 to n optimizing such nonlinear models is often impractical, and it is preferable to find simple equations or algorithms through iterative methods. However, this approach carries the risk of selecting a local optimum rather than a global one. Therefore, nonlinear functions should be avoided, and nonlinear constraints should be expressed as linear constraints. For example, the energy density constraint can be rewritten as:

$$X1\ (E1 - ED) + X2\ (E2 - ED) + Xn\ (En - ED) \geq 0$$

These linear inequalities can be incorporated into a linear programming model. Similarly, the nonlinear phytate zinc molar ratio constraint can be transformed into a linear constraint while maintaining the phytate zinc ratio. In some cases, a predetermined level may need to be established to ensure an acceptable level of zinc absorption. However, not all nonlinear constraints can be expressed as linear constraints. An algorithm utilizes logarithmic and exponential functions of vitamin C, phytate, and other iron absorption inhibitors to estimate the quantity of iron that can be absorbed from a diet.

4.4.3 A LINEAR APPLICATION OF DIET OPTIMIZATION

By utilizing recommendations from the Food Safety and Standards Authority of India (FSSAI), we can create a nutritional diet plan for Indian infants between the ages of 6 and 23 months using linear programming techniques. Our goal is to identify the optimal diet through the use of Lingo software, which will help us to construct a mathematical model based on collected data. Table 4.1 illustrates the necessary nutritional requirements for this age group, and we aim to meet all of these constraints through the addition of complementary foods. As a child grows older, they require additional foods, and we will incorporate these into our model accordingly. Lingo software isa useful tool for addressing linear programming, non-linear programming, and integer programming issues, which makes it well-suited for our application. For Indian children aged between 6 to 23 months, certain essential complementary foods are chapatti, rice, lentils, ghee, milk, carrot, amaranth leaves, and yogurt. The food quantity needs to be scaled-down for younger infants and scaled-up for older ones based on the given guidelines. As per Table 4.2, the recommended food items are provided for infants that are breastfed aged between 6-23 months old. We will compute the min daily cost.

Table 4.1 RDA for protein, vitamins, and minerals in Indian children (6-23 months) as per FSSAI's nutritional requirements.

Vitamins Vitamin B1 (Thiamin)	≥ 0.3mg
Vitamin B2 (Riboflavin)	≥ 0.4mg
Vitamin B3 (Niacin)	≥ 650ug
Vitamin B6	≥ 0.4mg
Vitamin B9 (Folate)	≥ 30ug
Vitamin A	≥ 300ug
Vitamin C	≥ 50mg
Vitamin D	≥ 10mg
Minerals Calcium	≥ 500mg
Copper	≥ 0.5mg
Iron	≥ 5mg
Magnesium	≥ 45mg
Phosphorus	≥ 500mg
Potassium	≥1000mg
Zinc	≥ 3mg
Chloride	≥ 1000mg
Sodium	≥ 500mg
Calories	≥ 600
Protein	≥ 7g

Table 4.2 Selection of food-item for breastfed child aged 6-23 months

Food stuffs Per serving	Roti Half (50g)	Rice 3spoons (84g)	Yoghurt 3spoons (50g)	Banana Half (60g)	Carrot 1.5spoons (25g)	Ghee 1spoon (5g)	Milk Half cup(50g)	Lentils 1spoon (30g)	Amaranths Handful of leaves(30g)
Price-(Rs.)	5	5	5	3	4	2	3	2	2
Calories-(kcal)	101	115.92	31.50	57	6	44.9	33	49.5	112.2
Protein-(g)	3.65	2.184	2.65	0.7	0.14	0	1.6	2.51	4.33
Vitamin- A(ug)	0	0	7	2	315	37.9	27.5	0	0
Vitamin-B1(mg)	0.22	0.15	0.03	0.01	0.01	0	0.02	0.26	0.03
Vitamin-B2(mg)	0.09	0.07	0.01	0.04	0.01	0	0.08	0.06	1.32
Vitamin-C(mg)	3.55	0	0.40	5.22	1.47	0	0	0.42	1.26
Iron- (mg)	1.05	0.168	0.04	0.009	0.1	0	0.03	0.93	2.27
Calcium- (mg)	1.8	8.4	92.60	3	8.25	0	56.50	5.4	45.9
Zinc- (mg)	0.77	1	0.44	9	0.06	0	0.18	1.43	1.74
Potassium-(mg)	98	29.40	127	214.80	80	0.23	71.50	102.90	109.80

4.5 TOTAL FORMULATION OF THE PROBLEM

$$Min\,Z = 5X_1 + 5X_2 + 5X_3 + 3X_4 + 4X_5 + 2X_6 + 3X_7 + 2X_8 + 2X_9$$

Subject to

$$101X_1 + 115.92X_2 + 31.50X_3 + 57X_4 + 6X_5 + 44.5X_6 + 33X_7 + 49.5X_8 + 112.2X_9 \geq 600$$

$$3.65X_1 + 2.184X_2 + 2.65X_3 + 0.7X_4 + 0.14X_5 + 1.6X_7 + 2.51X_8 + 4.33X_9 \geq 7$$

$$7X_3 + 2X_4 + 315X_5 + 37.9X_6 + 27.5X_7 \geq 300$$

$$0.22X_1 + 0.15X_2 + 0.03 + 0.01X_4 + 0.01X_5 + 0.02X_7 + 0.26X_8 + 0.03X_9 \geq 0.3$$

$$0.09X_1 + 0.07X_2 + 0.04X_4 + 0.01X_5 + 0.08X_7 + 0.06X_8 + 1.32X_9 \geq 0.4$$

$$3.55X_1 + 0.40X_3 + 5.22X_4 + 1.47X_5 + 0.42X_8 + 1.26X_9 \geq 50$$

$$1.05X_1 + 0.168X_3 + 0.04X_3 + 0.009X_4 + 0.1X_5 + 0.03X_7 + 0.93X_8 + 2.27X_9 \geq 5$$

$$1.8X_1 + 8.4X_2 + 92.60X_3 + 3X_4 + 8.25X_5 + 56.50X_7 + 5.4X_8 + 45.90X_9 \geq 500$$

$$98X_1 + 29.40X_2 + 127X_3 + 214.80X_4 + 80X_5 + 0.23X_6 + 71.50X_7 + 102.90X_8 + 109.80X_8 \geq 1000$$

4.6 LINGO Formulation

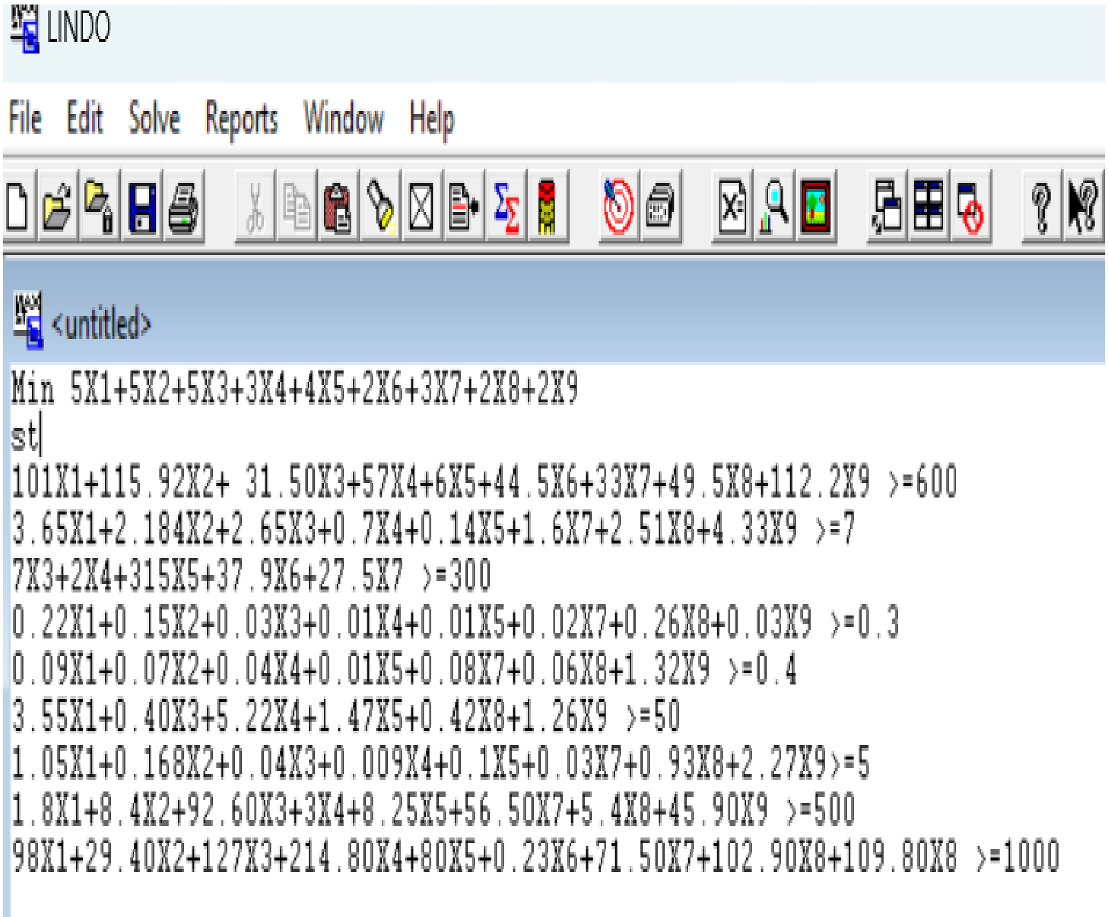


Figure 4.2 – *Representation of Lingo Formulation*

4.7 LINGO Solution

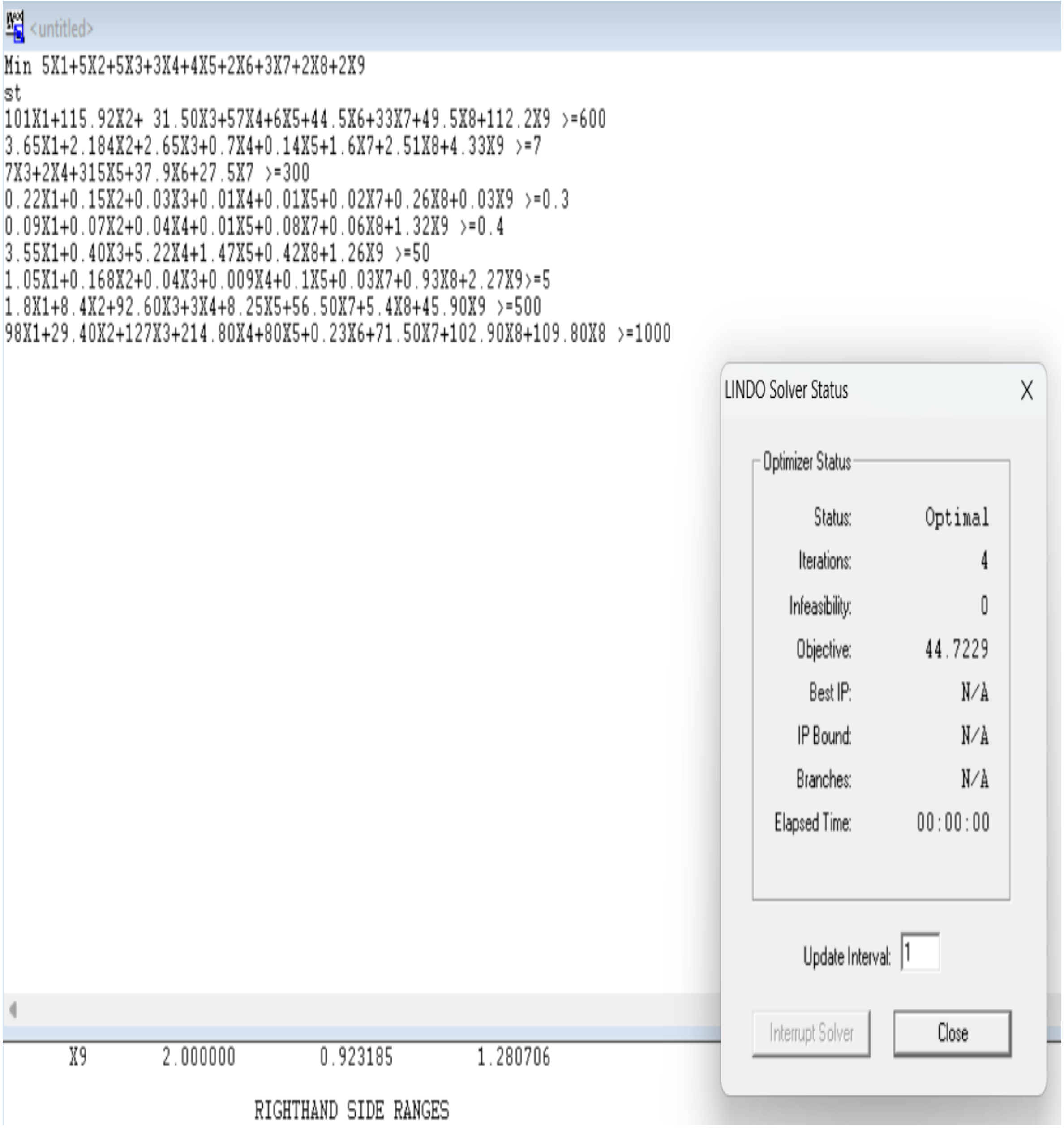
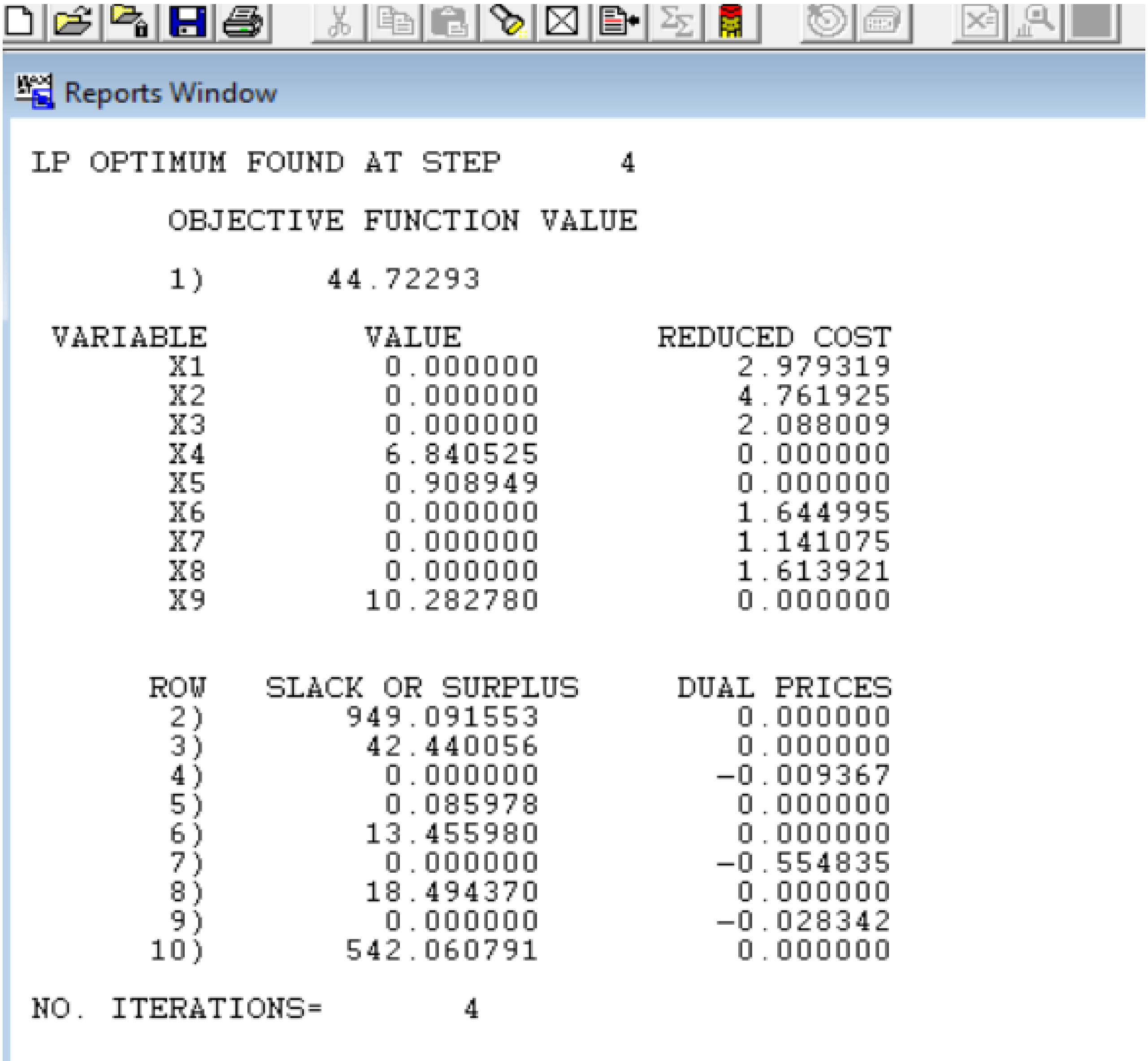


Figure 4.3 - *Working process of Lingo software*



Reports Window

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LP OPTIMUM FOUND AT STEP        4

        OBJECTIVE FUNCTION VALUE

        1)      44.72293

 VARIABLE        VALUE          REDUCED COST
       X1         0.000000          2.979319
       X2         0.000000          4.761925
       X3         0.000000          2.088009
       X4         6.840525          0.000000
       X5         0.908949          0.000000
       X6         0.000000          1.644995
       X7         0.000000          1.141075
       X8         0.000000          1.613921
       X9        10.282780          0.000000


      ROW   SLACK OR SURPLUS     DUAL PRICES
       2)       949.091553          0.000000
       3)        42.440056          0.000000
       4)         0.000000         -0.009367
       5)         0.085978          0.000000
       6)        13.455980          0.000000
       7)         0.000000         -0.554835
       8)        18.494370          0.000000
       9)         0.000000         -0.028342
      10)       542.060791          0.000000

NO. ITERATIONS=        4
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Figure 4.4 - *Working process of Lingo*

RANGES IN WHICH THE BASIS IS UNCHANGED:

OBJ COEFFICIENT RANGES

VARIABLE	CURRENT COEF	ALLOWABLE INCREASE	ALLOWABLE DECREASE
X1	5.000000	INFINITY	2.979319
X2	5.000000	INFINITY	4.761925
X3	5.000000	INFINITY	2.088009
X4	3.000000	4.365886	2.846167
X5	4.000000	12.770044	2.946035
X6	2.000000	INFINITY	1.644995
X7	3.000000	INFINITY	1.141075
X8	2.000000	INFINITY	1.613921
X9	2.000000	0.923185	1.280706

RIGHTHAND SIDE RANGES

ROW	CURRENT RHS	ALLOWABLE INCREASE	ALLOWABLE DECREASE
2	600.000000	949.091553	INFINITY
3	7.000000	42.440056	INFINITY
4	300.000000	8888.741211	285.878937
5	0.300000	0.085978	INFINITY
6	0.400000	13.455980	INFINITY
7	50.000000	690.424500	12.975924
8	5.000000	18.494370	INFINITY
9	500.000000	472.694336	140.779099
10	1000.000000	542.060791	INFINITY

Figure 4.5 - *Result from Lingo*

In above figures 4.3, 4.4, 4.5 show the process of Lingo software. In fig 4.3 there are some starting equations that can be written through Lingo and after that process of solution is started. In fig 4.4, that defines the optimum solution and fig 4.5, determines the reduced cost and slack or surplus variables.

Global optimal solution

Objective value: 44.72293

Infeasibilities: 0.000000

Total solver iterations: 3

Model Class: LP

Total variables: 9

Nonlinear variables: 0

Total constraints: 10

4.8 CONCLUSIONS

Linear programming is a beneficial approach to creating optimal diets for infants and toddlers during the supplementary feeding stage. By utilizing regional food availability and market prices, this practical mathematical technique can rapidly convert global dietary guidance into sound dietary recommendations. Linear programming is particularly adept at optimization, employing tool. Lingo is utilized to determine the most favorable outcome, resulting in a minimal cost of Rs 44.72 for the nutritional diet.

CHAPTER – 5

DIET PLANNING PROBLEMS FOR DIABETIC PATIENTS BY USING MATHEMATICAL MODELING TECHNIQUE

5.1 INTRODUCTION

A balanced diet is good for our daily routine. In this diet a lot of nutrients are present like carbohydrates, proteins, vitamins, minerals, fats and fiber etc. Diet and nutrition play an important role in maintenance of good health. Proper nutritional consumption helps our bodies operate normally and protects them from illness. Chronic diseases are arising in developing country. Some factors of daily life may cause chronic diseases like unhealthy diet, physical inactivity, smoking, hypertension and obesity etc [17]. Cancer and diabetes are the common disease that occurring in most of the country. When blood glucose is very high in our body then the body gets affected by a disease named Diabetes. A hormone called insulin that controls the level of blood sugar in the body. This is a chronic disease. Mainly Diabetes is of two types. Type1 is commonly found in children and adolescents. This happens when the pancreas is not to produce insulin. Type2 is found in adulthood, this takes place when pancreas does not generate insulin and when the body does not effectively use the insulin that is generated. Basically, diabetes is a non-communicable disease (NCDs). In 2008, 63% deaths were due to non-communicable diseases. Mostly 80% of NCDs deaths place in low- and middle-income countries. Health promotion done a magical thing in human life. To educate people, make banners for health care, doing health camps, these are some important works for awareness through chronic diseases. A diabetic patient can easily suffer from some diseases like heart disease, kidney disease, eye problems, food problems and dental problems etc. Give some key messages to the people which are increase intake of healthy food, manage stress, include physical activity in daily life, avoid alcohol and tobacco, time to time health check-up etc [9]. Sign of diabetes increases when the age of individual increases. It means that level of glucose increases with age. According to study, India has largest rate of diabetes than other countries.

Diabetes is increases day by day in rural area as compared to urban area. There are many risk factors by which diabetes happens in rural area most. Education and health care facility are very less in rural area [94]. Eating disorder is a big problem in today's life. Some studies defined the balanced diet and chronic disease. Around 80% of people are affected by chronic disease. Eating disorder and disease-related lifestyle is due to westernization of eating habit, improper nutrition and stress [65].

Vitamins and minerals are the micronutrients of the body. Our body needs small amount of these nutrients. These are very important nutrients for body health. It makes body very strong and disease free. Its deficiency can cause life-threatening conditions. If proper requirement of these micronutrients is not fulfilled then it can cause dangerous health conditions and increases the risk of some diseases. 45% of child deaths is due to under nutrition [20]. According to a study an experiment was conducted in which sixteen sheep were divided on the basis of their weight. It was found that as their weight is increasing, in the same way there has been a change in the nutrients [31]. In animals, the amount of nutrients was measured with nitrogen. By some result we find that if the amount of carbohydrate and protein increases in body then also shows some difference in amount of nitrogen. Animals need carbohydrate and protein like humans. In the same way animals also should have their need of whole food with good and increasing diet [52]. In last fifty years, linear programming is used for animal diet formulation. But there are some drawbacks of linear programming for accuracy of objective function. We can remove those drawbacks by using nonlinear programming. By nonlinear programming we can detect the milk of animals. In this study, we can see that Nonlinear programming is more important than linear programming. By this we can identify the best use of nutrients. Linear and nonlinear both are compared with same data. By this we can understand the animal diet formulation properly [1]. Some early symptoms by which we can know about diabetes. These are weight loss, dehydration, frequent urination, vomiting etc. There are a lot of factors by which production of type2 diabetes happens in our body. Some are overweight, history of family, static lifestyle, high blood pressure, increasing age, during pregnancy etc. Some foods must be avoided by diabetic patients which are trans fats, fruit flavored yogurt, flavored coffee drinks, honey, sugar related things, pasta, white bread and rice etc [64]. In India, rate of diabetic patient is increasing day by day. This is mainly found in rural area as compared with urban area. The reason for increasing rate of diabetic patient in rural area is lack knowledge about food nutrients. The rural area is very backward in all fields. There are no gyms, no proper checkup facilities etc. The chances of diabetes get more with the increasing age. Diabetes usually starts happening in old age. It happens due to not taking the right diet. We can avoid this by introducing some rules in life.

5.2 LITERATURE REVIEW

The application of Linear Programming Technique is used in many studies and fields. It is basically helps in business problem, economic problem like transportation, agriculture problem and diet problem etc. Iterative linear programming is very useful for diet formulation. By using this method UK energy and proteins system for ruminants has been defined. In this study, two nonlinear optimization problems are related with animal feed formulation. To solve this formulation, we use iterative sequence of linear programming problems [3]. Linear programming problems have been solved by two methods. One is boundary methods and another is interior point methods. Primal and dual simplex methods are the part of boundary methods. The primal affine scaling method is most common method of interior point methods. One of the most important methods to solve the linear programming problem is the simplex method. One basic feasible solution is including in this method. We reduce the objective function until we reach its minimum value [53]. All aged people get affected by the habit eating disorder. This habit is starts from the childhood and day by day it is increasing. Eating disorder is very dangerous habit in our daily life. This is of many types includes anoreseia nervosa, bulimia nervosa, avoidant/ restrictive food intake disorder and binge eating disorder [6]. Lifestyle disease is a disease which related to a person or group of people lives. This includes stroke, obesity, type2 diabetes, diseases related with smoke and alcohol, heart disease and atherosclerosis. Good daily routine helps to control obesity, diabetes, heart disease and hypertension [65]. Around 1.77 million people are diabetic in whole world. This number is increasing day by day and it must be double in 2030. More than 80% diabetes deaths related with low and middle-income countries. The reason of one death out of 20 deaths is diabetes. Due to this disease, a lot of complications come in human life. Approx 4 million deaths in a year happened because of diabetes. In India, the rate of diabetes patients is increases very rapidly. India has been called the diabetes capital of the world. There are following steps to control diabetes are exercise daily, take foods of lower fat, slowly eating etc [12]. According to the report, rate of diabetic female patients (9.8%) are more than diabetic male patients (6.1%). In 1995, diabetic adults are 135 million but this ratio is increasing day by day and in 2025, it will be 300 million diabetic adults. In urban Haryana, diffusion of diabetes is less as compared to other states. This is controlled by some factors like education, age, occupation and marital status [99]. Sugar is the most popular sweetener in the world was invented in India. In 327 BC, sugar known to the world when the army of Alexander the Great came to India. Calorie intake and obesity both are related to each other. 1 gram of sugar gives 4 kcal. In 2013, 65 million diabetics were found in India [89]. In this paper, linear programming was solved by using Microsoft excel. In this problem, the objective function was minimized. If solution produced negative values for some items, then those items were not counted in the model and some other items were placed in the model to fulfill the requirements of nutrients [13]. There are many foods which satisfy the daily needs of nutrients for an individual. Any random person will have their own choices but those choices will not fulfill their daily needs of nutrients. With the help of linear programming, it is easy to choose a proper diet or to choose a food which has all the nutrients. A new food will search by LP and that diet satisfies the nutrients targets [78]. Nutritional knowledge and health awareness among diabetic patients was investigated at AIIMS Delhi. A mathematical model of 132 peoples (62 men and 70 women) was formed with two categories one was adults (30-69 years old) and other one was elderly (60 years and above). In this research the involvement of first category was 50.8% and the involvement of second category was 49.2%. Some questions were asked to all the peoples who were related to nutrition knowledge and health awareness. 37.1% of peoples were having less knowledge, 31.8% moderate and only 31.1% were good in the nutrition knowledge. Adults have sharp knowledge about nutrition than elderly [21].

For detected with the help of plasma glucose criteria either the fasting plasma glucose (FPG) or 2-h value in the 75g oral glucose tolerance test (OGTT) [102]. According to the 2020 National Diabetes Statistics Report published that around 34.2 million people have diabetes. More than a million or 26.8% people were diabetic and their age was above 65 years [100].

5.3 DATA REPERSENTATION

The nutritionist from AIIMS Delhi provided the pertinent information pertaining to the issue. This data contained the lower bound and upper bound of the nutrients. With the help of table 5.1 it relates with the knowledge of minimum and maximum of nutrients. The diet for diabetic patients is not so much hard and it is easy to include this diet in daily routine. It is same a diet of a healthy person. For a diabetic patient only one thing should be in mind and that is sugar. A person should away from the sugar compounds otherwise it will close to diabetes conditions. The patients have differed needs of nutrients at different age levels. In this study a patient of 20-year-old with height 170 cm and weight of 55kg. After dietician's consultation, manage the nutritional requirement per day of that patient. The food items that place into the table selected from the whole 100 items.

TABLE 5.1 Lower bound and Upper bound of 11 Nutrients

Nutrients (UB)	Lower Bound (LB)	Upper Bound
Energy (kcal)	2120	2441
Fat (g)	44	70.6
Protein- (g)	78.5	-
Carbohydrates- (g)	181	291.5
Calcium- (g)	801	2000
Vitamin -A(mg)	599	2800
Vitamin- B1 (mg)	1 .3	-
Vitamin- B2 (mg)	1.2	-
Vitamin- C (mg)	71	1800
Iron(mg)	15	45
Copper (mg)	8	10

5.4 DEVELOPMENT OF MODEL

This paper helps the diabetic patients to make a model which is full of nutrients fulfill the requirement of nutrients and also minimize the cost. Optimal solution is solving with the help of operation research approach. In this study minimize the cost of diet with the help of some tools which are used in this. According to their daily demands, diabetes individuals consume 18 foods from 10 dietary groups.

Table 5.2 Essential Food per day

Food Type	Needs per day (n)
Liquor	6
Vegetables	2
Fruits	2
Cereal based Meal	2
Eggs	1
Cereal Flour Based	1
Rice Flour Based	1
Seafood	1
Multigrain's	1
Various	1
Total Foods per day	18

This problem is solved by Linear Programming (LP) and Integer Programming (IP) and makes a model of 100 variables.

Minimize the cost function = $\sum_{i=1}^{100} c_i \ x_i$ (1)

Subject to;

11 nutrient requirements according to table I

Lower Bound $\leq \sum_{i=1}^{100}$ Nutrient value xi $\leq$ Upper Bound (2)

Using 10 food groups based on table II

$\sum_{i=1}^{10} x_i$ Each Food Group = a (3)

xi $\geq$ 0 (LP), xi $\geq$ 0 and integer (IP).

Where,

xi = decision variables of food items i

a= the number of food groups requirement

So that food is placed according to morning tea, breakfast, lunch, evening tea and dinner in the following tables.

Table 5.3 The Menu of Food per Day

Meal	Type of Food	Amount
Morning Tea	Liquor	1
	Rice Flour Based	1
Breakfast	Liquor	1
	Cereal Flour Based	1
Lunch	Liquor	1
	Cereal Based Meal	1
	Vegetables	1
	Fruits	1
	Eggs/Seafood	1
Evening tea	Liquor	1
	Multigrain's	1
Dinner	Various	1
	Cereal Meal Based	1
	Vegetables	1
	Fruits	1
	Eggs/Seafood	1
Dinner Drink	Liquor	1
	Various	1
	Total	18

5.5 RESULT AND DISCUSSION

The mathematical modeling is described the optimal solution of diet problem for diabetic patients. Linear programming (LP) and Integer programming (IP) are used in this study to minimize the cost. It is very easy to work. The results for menu planning per day come out with the help of linear programming and integer programming. The table shown their results which are given below:

Table 5.4 Type of Meal per day by using Linear programming

Meals	Food Item, i	Amount
Morning Tea	Green Tea	1
	Oatmeal	0.71
Breakfast	Butter milk	1
	Muesli	1
Lunch	Multigrain chappati	0.451
	Coconut water	1
	Bindi sbji	0.612
	Strawberries	1
	Wholegrains	1.921
Evening Tea	Lemon tea	1.391
	Hardboiled egg	0.761
Dinner	Guava	0.097
	Coconut water	1
	Fish	1
	Oats	1
Dinner drink	Milk without sugar	1
	Chia seed pudding	1
	Total no of food per day	18
	Total cost (In Rs.)	93.68

Table 5.5 Type of Meal per day by using Integer Programming

Meals	Food Item, i	Amount
Morning Tea	Coconut Water	1
	Beef Sticks	1
Breakfast	Muesli	1
	Juice	1
Lunch	Fish	1
	Avocado	1
	Karela sbji	1
	Oatmeal	1
	Coconut Water	1
Evening Tea	Green tea	1
	Veggies	1
Dinner	Moong dal	1
	Apple	1
	Wholegrain	1
	Juice	1

	Fish	1
Dinner Drink	Milk without sugar	1
	Nuts	1
	Total number of foods per day	18
	Total cost (In Rs.)	96.17

Table 5.4 and Table 5.5 show the result comes out with the help of linear programming and integer programming approaches. In LP approach, the prices are lesser as compared to IP approaches, yet the amount of food made by IP approach can be observed and served. It is very difficult to serve a food which comes out in decimal numbers. So, the amount of food which produced by LP approach is in decimal and that cannot be served. The total number of food groups is 18 but it produced or served more than 18 by LP approach. Therefore, this solution does not complete the food group requirements. So that for meeting all the food group requirements and constraints, IP approach is the better technique to solve the menu problem.

5.6 CONCLUSION

The menu planning of food per day can be minimized with the help of linear programming approaches and integer programming approaches. A mathematical model is constructed for diet plan of diabetic patients. This diet plan contained all the nutrients which are required for healthy person same as diabetic patient. A good result is clearly seen in the tables. Linear programming and Integer programming are used to solve the problem of minimization and maximization. Basically, they are useful to solve the optimal solution. Table IV and Table V contained the result which comes out with the help of linear programming and integer programming respectively. The best result is getting from IP approaches because this provides a more feasible solution in which food items are served in whole units (integer value). The cost is minimum in case of LP approaches but food cannot be served in this case because food is in the decimal form. So the optimal solution of IP approaches is considered. Using integer programming, the expenditure is slightly increased from Rs. 93.68 to Rs. 96.17. This study defined the nutritional diet for diabetic patients and also helped in choosing the solution of linear programming and integer programming. Total cost of meal per day by using linear programming is Rs. 93.68 and the total cost of meal by using integer programming is Rs.96.17. Some other important points that are related to diabetic patients also mentioned in this study. The knowledge of food choice and their respective nutritional value has been explored by conducting this research. Knowledge of choosing food, regular checkup and daily exercise are the most important points for a healthy lifestyle.

CHAPTER - 6

AN OPTIMUM NUTRITIONAL DIET FOR ATHLETES BY USING LINEAR PROGRAMMING MODEL

6.1 INTRODUCTION

Proper nutrition is critical for athletes to maintain good physical health, avoid muscle injuries, and improve performance and job quality. To put it simply, an athlete's diet should differ from that of the average person. In addition to the needs of practicing and competing, sportspersons require sustenance for everyday lives. All sportsperson should follow this common guideline while attempting to maintain a great level of strength, which demands a decent diet. For a system to sustain a perfect weight, the input and output energy must be equal. Therefore, a sportsperson's power and balance are dependent on a carbohydrate-rich diet that allows the body to retain carbs optimally. In this study, we aimed to create an optimum diet for athletes based on calorie maximization and fat consumption. Furthermore, the athlete who follows this diet will acquire a range of nutrients, including vitamins, minerals, and macronutrients, to meet their physical needs. We used a linear programming method with many target choice criteria to do this.

Vegetarianism improves strength and recovery while also minimizing the possibility of chronic illnesses. However, the research on vegetarians is contested and ambiguous. This study raises the topic of whether a vegetarian diet is more advantageous to athletes than non-vegetarian diets. Is this true or false? The study employed both a literature research strategy and an empirical research method. Vegetarianism can benefit people's health. The vegetarian lifestyle acts to reduce the demand for animals by reducing the fast population growth and development of modern civilization. The number of individuals is anticipated to rise in the future; nevertheless, they may not receive enough SHAO protein [32]. It is essential for everyone to eat and drink appropriately. Active sports can have an influence on their performance, so it's crucial to recognize this. For example, the average individual eats more calories than they need. So, if you only have one option—become a sportsperson or begin working out regularly a good diet plan should not be last on your list of objectives. Protein, fat, and carbs provide your body with the energy it requires to function properly. Working muscles mostly use carbs as fuel. Intake must be adequate to avoid muscular weariness. While keeping track of your fat intake, just eliminate it from your diet. Fat provides essential fatty acids, which can be used as an energy source throughout an exercise session lasting more than an hour, particularly if. Furthermore, fat contains the ingredient required to produce hormones and cell membranes. Protein's role in building new muscle tissue and as an energy source cannot be overemphasized. When you exercise with resistance, your body demands extra protein [91].

According to expert Matt Dwyer, the fundamental difference between Indian and Australian sportsmen's diets is that Indian athletes consume more fat, carbs, and protein. These are his observations after working with several Indian athletes. Unfortunately, there has been little scientific study on Indian athletes' nutrition. However, the research performed thus far suggests that Indian athletes have a poor understanding of nutrition, with inadequate protein, iron, calcium, and B-complex vitamin consumption [72]. To summarize, younger age group teams' greater calorie consumption and more well-balanced macronutrient intake might be attributed to physiological growth adaptations or the fact that young athletes eat at home or school, where their diet is more controlled and coordinated. Our data suggest that sportsmen's diets degrade after they enroll in college or begin working. Because it has been demonstrated that a sports nutrition education program may boost nutrition knowledge and practices, we believe the data reported here can be used to generate an initial basis from which a nutrition program can be created [27].

For instance, the formulation of an ideal breakfast diet, followed by the utilization of online resources resulting in accurate outcomes, which are obtained as well as displayed via connection with a software system and an applied mathematics application employed for diet enhancement. These findings are then examined and validated before being implemented in practice. Athletes in team sports have several physiological obstacles and dietary necessities. Nutrition can improve team sports performance by optimizing body composition, providing nutritional support during training, managing fluid and fuel requirements during competition, and utilizing supplements and cryogenic aids [35]. The only acceptable avenues to advancement are those maintained by business via ethical business practices and appropriate government regulations on supplement generation and marketing. Users must be aware of any food items advertised as nutritional products or nutraceuticals, which must satisfy safety and quality criteria and be administered under the guidance of medical experts. In terms of nutrition, the term supplement is self-explanatory; it refers to the administration of additional food material in line with a doctor's or dietician's prescription. Vitamins and minerals (DSs) are often necessary to fulfill the body's normal physical requirements and therapeutic objectives. In addition, athletes and fitness enthusiasts periodically utilize supplements to boost muscle growth and performance[92].

Nutrients may offer harmless methods for athletes to boost their performance, while additional exploration is necessary to evaluate the utility of specific supplements. Before trying to utilize any new vitamins, visit a doctor. These chemicals can be mixed with any other medicine that a person is taking. Certain supplements, like iron, can lead to adverse consequences if taken excessively. In addition, unless a person has deficits, multiple vitamins might be useless. A doctor can test for vitamin deficiencies and, if required, provide recommendations on how to treat them. Before using some another nutrition, those who work out regularly but still feel tired should consider other aspects of their lifestyle.

A diet that is well-rounded and provides sufficient sleep can assist as well as enhance the performance of athletes. It's especially crucial for athletes who follow a vegan or vegetarian diet to make sure they acquire enough of the vitamins and minerals mentioned above [10]. Nutrition is vital for any kind of athletic activity or fitness program. The primary nutrition goal for active people is to eat enough to maximize their performance in sports or physical fitness. These are not only important for improving performance but also for promoting long-term healthy eating. As a result, a suitable fitness and training routine, as well as a healthy diet, must be pushed as a sensible alternative to a rushed, dangerous attitude [77]

6.2 LITERATURE REVIEW

The study of optimization is to finding optimal solutions to mathematically established problems, which might be models of physical reality, human behaviour, or industrial and management systems. It requires the following elements: a required goal function that determines whether a numerical scalar piece measurement should be lowered or raised. These processes can result in system profits, yields, prices, and so forth. To describe the efficiency of the system. These limits cover a reasonable percentage of the search region. It outlines the programmer's performance restrictions. Certain variables must be adjusted to meet the constraints. These are often obtained by multiple occurrences of varied values, generating a workable zone that influences variables [14]. After comparing the energy intake of male and female participants in various sports, female players' energy consumption, expressed relative to body mass, is around 70% of that of their male counterparts. The bulk of female competitors' training schedules are lower in intensity, frequency, and length, which might help explain this. Nevertheless, lots of investigations show that certain athletes appear to be in a state of negative balance; these findings tend to be more common among female athletes than male competitors. Examine the findings and probable causes in considerable detail [84]. The study’s principal result was that experienced youth soccer players who played for a championship team based in the United Kingdom did not have adequate dietary habits to meet the demands of their training and competition. There was a significant difference between mean daily energy intake and expenditure, and the quantity of energy obtained from carbohydrate sources decreased as fat consumption increased. Furthermore, despite the fact that a lot of constituents were ingested in accordance with guidelines, fiber intake [55]. This research gave a thorough overview of sportsmen's perspectives about dietary awareness. It was discovered that players in Aligarh Muslim University's Physical Education Department are better knowledgeable about sports nutrition than players from other areas of study. The professional instructors from the Department of Physical Education are teaching the students an athletic diet, which is the reason for this [28]. This study emphasized the range of observed eating behaviours between sports and cultures, emphasizing the importance of specialized cuisine and proper nutrition aid in this situation. Although there are some scientifically supported recommendations for consuming beforehand, throughout, and following competition, it is obvious that sportsmen occasionally prefer meals that are politically known to them and align with their individual dietary and spiritual convictions. While the great majority of the meals detailed in the present investigation were nutrient-based, it is obvious that an increasing proportion follow certain diets based on spirituality (most typically Halal), animal avoidance, or specific allergies [39].

There is little question that the meals and dietary components that we ingest have an influence on our DNA, either directly or indirectly. Hereditary and regulatory events can both have a big impact on how people react to dietary components. This can occur by affecting the activity of the molecular target or by changing how the food ingredient gets into the body, metabolized, transformed, and removed. The recognition of people who could gain the greatest from approaches to intervention is going to get simpler as genetic understanding advances [49].

6.3 EXAMPLE AND METHOD

The quantity of calories required is determined by your level of energy. Age, sex, physical activity, and other factors all influence the body's nutritional requirements. As a consequence, we concluded that an examination of a 24-year-old young guy who spends around 2 hours per day swimming in a pool and has a body mass index of 22.27 kg/m (74 kg, 180 cm tall) was necessary. Let's start by identifying the dos and don'ts of this athlete's healthy diet plan, utilizing library resources, medical record data and other figures. After giving the required energy (at least 3000 kcal), it is time to distribute it among the macronutrients. Carbohydrates should provide 70% of your energy needs. It is advised that athletes consume at least 50% of their total daily energy from carbs. Fat should account for 30% of your energy. If you want to research fat tissue, reduce this ratio to 15% of total energy, but not below that. The protein content required for each people depends upon their weight. An athlete's body requires between 1.2 and 1.7 grams of protein per kilogram of body weight. According to view points on other vitamins and minerals, a balanced diet can meet all of these needs. Table 6.1 shows the quantity of RDA required by the human body as well as the maximum allowable UL nutritional consumption. The meal plan recommended by the linear programming model solution must account for these limits. Table 6.1 shows the quantity of RDA required by the body as well as the maximum allowable UL nutritional consumption. These limits must be considered while developing the proposed meal plan for the linear programming paradigm. For example, a balanced diet should contain 20 to 35 grams of fiber per day and 47 to 124 grams of sugar. The sportsman's body receives all of the nutrients it needs by following the diet described above. Using the facts in Table 6.1, establish the LP problem and consider the decision factors connected with the dietary program's meal selections.

TABLE 6.1 Daily dietary needs

Sr. No.	Nutrient	Maximum Limit	Minimum Limit
1.	Carbohydrate (g)	525	375
2.	Energy (Kcal)	4000	3000
3.	Protein (g)	133.2	88.8
4.	Fat (g)	100	66.6
5.	Fiber (g)	35	20
6.	Calcium (mg)	2500	1000
7.	Iron (mg)	200	150

TABLE 6.2 Ingredients of the Planned Diet

Sr. No.	Food stuff	Serving (gm)	Price (Rs)	Carbohydrate (gm)	Energy (Kcal)	Protein (gm)	Fat (gm)	Calcium (mg)	Iron (mg)
1.	Low fat milk/X1	165	6.60	8.23	69	5.56	1.6	196	0.05
2.	Egg/X2	60	15	0.46	88	7.55	5.96	32	1.1
3.	Rice/X3	80	3.20	22.11	108	2.11	0.86	8	0.94
4.	Chicken breast/X4	525	210	0	578	121.22	6.51	58	3.78
5.	Bread/X5	25	2.5	12.65	66	1.91	0.82	38	0.94
6.	Low fat cheese/X6	145	58	1.86	584	36.1	48.05	1045	0.99
7.	Spinach/X7	10	0.5	0.36	2	0.29	0.04	10	0.27
8.	Apple/X8	35	2.45	4.83	18	0.09	0.06	2	0.04
9.	Honey/X9	600	125	494.4	1824	1.8	0	36	2.52
10.	Sugar/X10	130	5.2	129.9	503	0	0	1	0.01

6.4 FORMULATION OF THE PROBLEM

$$Min\ Z = 6.60X_1 + 15X_2 + 3.20X_3 + 210X_4 + 2.5X_5 + 58X_6 + 0.5X_7 + 2.45X_8 + 125X_9 + 5.2X_{10}$$

Subject to,

$$8.23X_1 + 0.46X_2 + 22.11X_3 + 12.65X_5 + 1.86X_6 + 0.36X_7 + 4.83X_8 + 494.4X_9 + 129.9X_{10} \geq 375$$

$$69X_1 + 88X_2 + 103X_3 + 578X_4 + 66X_5 + 584X_6 + 2X_7 + 18X_8 + 1824X_9 + 503X_{10} \geq 3000$$

$$5.56X_1 + 7.55X_2 + 2.11X_3 + 121.22X_4 + 1.91X_5 + 36.1X_6 + 0.29X_7 + 0.09X_8 + 1.8X_9 \geq 88.8$$

$$1.6X_1 + 5.96X_2 + 0.86X_3 + 6.51X_4 + 0.82X_5 + 48.05X_6 + 0.04X_7 + 0.06X_8 \geq 66.6$$

$$196X_1 + 32X_2 + 8X_3 + 58X_4 + 38X_5 + 1045X_6 + 10X_7 + 2X_8 \ + 36X_9 + X_{10} \geq 1000$$

$$0.05X_1 + 1.1X_2 + 0.94X_3 + 3.78X_4 + 0.94X_5 + 0.99X_6 + 0.27X_7 + 0.04X_8 + 2.52X_9 + 0.01X_{10} \geq 150$$

6.5 LINGO FORMULATION

Min = 6.60*X1 + 15*X2 +3.20*X3 + 210*X4 + 2.5*X5 + 58*X6 + 0.5*X7 +2.45*X8 + 125*X9 + 5.2*X10

8.23*X1 + 0.46*X2 + 22.11*X3 + 12.65*X5 + 1.86*X6 + 0.36*X7 + 4.83*X8 + 494.4*X9 + 129.9*X10 >= 375

69*X1 + 88*X2 + 108*X3 + 578*X4 + 66*X5 + 584*X6 + 2*X7 + 18*X8 + 1824*X9 + 503*X10 >= 3000

5.56*X1 +7.55*X2 + 2.11*X3 + 121.22*X4 + 1.91*X5 + 36.1*X6 + 0.29*X7+ 0.09*X8 + 1.8X9 >= 88.8

1.6*X1 + 5.96*X2 + 0.86*X3 + 6.51*X4 + 0.82*X5 + 48.05*X6 + 0.04*X7 + 0.06*X8 >= 66.6

196*X1 + 32*X2 + 8*X3 + 58*X4 + 38*X5 + 1045*X6 + 10*X7 + 2*X8 +36*X9 + X10 >= 1000

0.05*X1 + 1.1*X2 + 0.94*X3 + 3.78*X4 + 0.94*X5 + 0.99*X6 + 0.27*X7 + 0.04*X8 + 2.52*X9 + 0.01*X10 >= 150

6.6 LINGO SOLUTION

Global optimal solution

Objective value: 327.2742

Model Class: LP

Total Variables: 10

Non linear variables:0

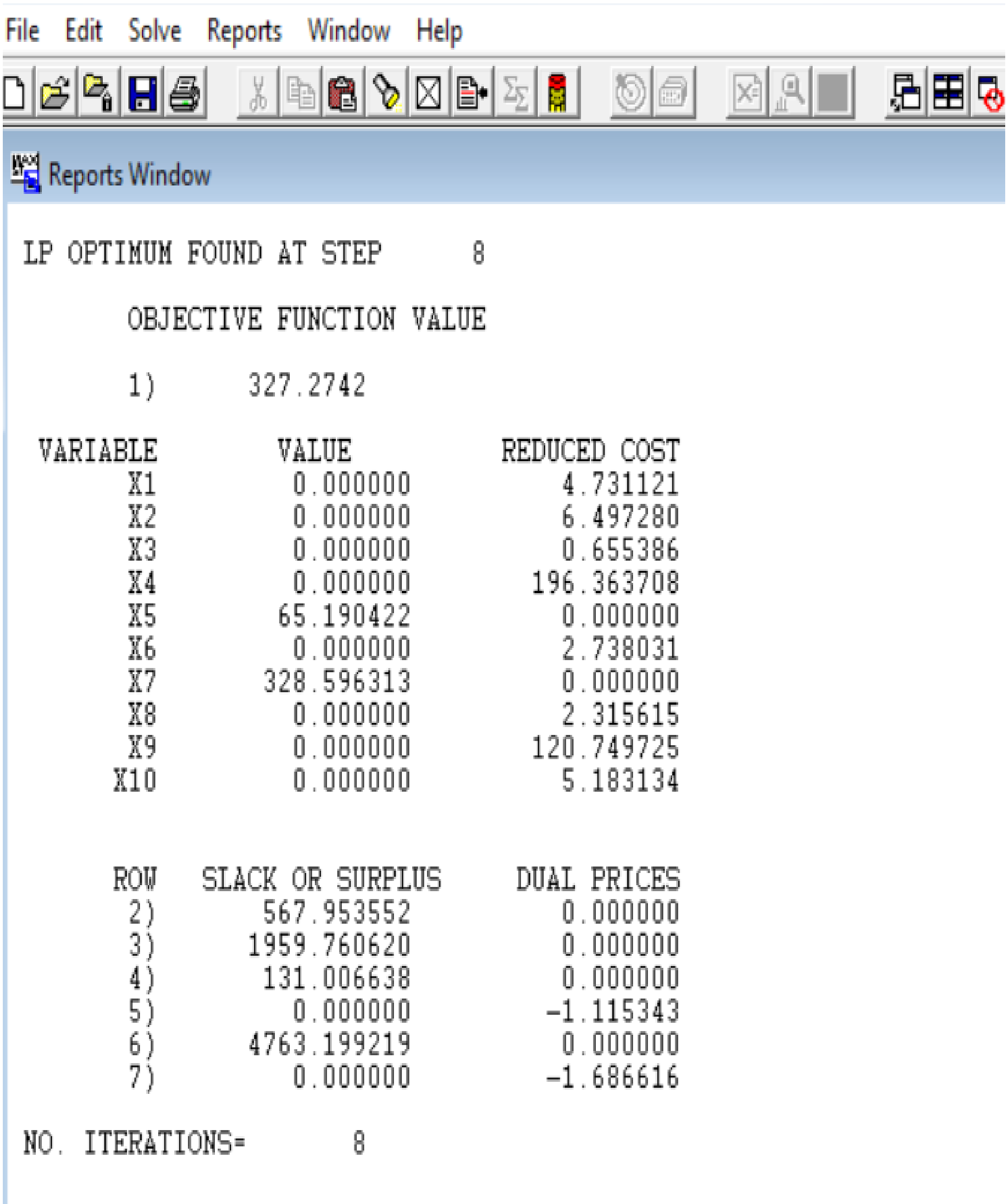

Figure 6.1- *Result through Lingo*

Table 6.3 Reduced cost from Lingo

Variable	Value	Reduced Cost
Z	0.000000	1.000000
X1	0.000000	4.731121
X2	0.000000	6.497280
X3	0.000000	0.655386
X4	0.000000	196.363708
X5	65.190422	0.000000
X6	0.000000	2.738031
X7	328.596313	0.000000
X8	0.000000	2.315615
X9	0.000000	120.749725
X10	0.000000	5.18134
Row	Slack or Surplus	Dual prices
2)	567.953552	0.000000
3)	1959.760620	0.000000
4)	131.006638	0.000000
5)	0.000000	-1.115343
6)	4763.199219	0.000000
7)	0.000000	-1.686616

6.7 CONCLUSION

Exercise has a hugely beneficial effect on a person's quality of life, but to achieve the desired outcomes, we must exercise properly. Eating properly before and after exercise is one of the most essential components of exercise. Linear diet modeling, like any other optimization approach based on the intended aims, necessitates programming and then solving it with Lingo software also, the dietary limits of the various types of nutrients must be addressed. Linear programming is a very efficient method of optimization. Lingo is used to navigate here. The optimal solution and lowest price for a nutritious diet are Rs 327.2742.

CHAPTER-7

FOOD DESIGNING FOR COVID-19 PATIENTS WITH THE HELP OF APPLIED MATHEMATICAL OPTIMIZATION TECHNIQUE IN LINDO SOFTWARE

7.1 INTRODUCTION

Nutrition is very important in this lifestyle. Numerous socioeconomic and environmental factors have an impact on nutrition. Even if the world's diet crisis was acute during World War II, the task of supplying food for everyone in a sustainable and nutritious way will only get worse. Between 1950 and 1960, the initial analysis incorporating LP into diets was released. Jerry Cornfield developed The Diet Problem for the Army during World War II (1941–1955) in an effort to find a cheap diet that would satisfy a soldier's nutritional requirements. This was the beginning of the hunt for diet solutions. The COVID-19 pandemic, which started rapidly and extensively spreading in late 2019, had a significant impact on food security and nutrition. Therefore, utilize operational research and judgement to create a mathematical model to study menu planning. The issue was solved using Lindo and LP Solve programming language. LP problem can be addressed using a variety of techniques, including the graphical and simplex methods. These techniques take a long time to manually solve the LP model. The LP model is solved using the Lindo programme in this paper's application to calculate the patient minimum meal cost. By using computer assisted menu planning and data control, for institutional feeding programmes, a multiple-phase system was created to lower the price of food. Assembling meal items for a series of days that meet the necessary structural, nutritional, compatibility requirements, and variety restrictions at fewer prices was the basis for the formulation of food management objectives, a problem that is commonly encountered by each and every individual and volume feeding agency. The answer was found by solving big integer programmes and linear programmes sequentially using a newly created truncated block enumeration technique [21].

The correlation in both palatable meals and satisfying nutrients is mathematically modelled and analyzed. The standard minimal-cost dietary issue is inappropriate for many uses in the pursuit of the least financial cost that leads to meals that are undesirable to individuals as well as to groups of people. This research presents a unique thought that utilizes a goal value dependent on each person food preferences. Based on this research, a computational technique for using linear programming to create individually appropriate diets is described [26]. Scientific proof is still required to determine which foods constitute a healthy diet in terms of the primary prevention of serious chronic diseases. We therefore sought to provide a thorough review of foods associated with health based on the eight years data from the EPIC-Potsdam research [59]. It is generally known that poor nutrition has an adverse effect on critically ill patients, contributing to higher mortality, longer stays in intensive care units (ICUs), impairment and general morbidity following hospitalization. Guidelines for nutritional therapy for people with SARS-CoV-2 infection were just released by European Society for Clinical Nutrition and Metabolism (ESPEN), and they include suggestions for patients being treated in the intensive care unit (ICU). The main goal of these suggestions is to use promotility drugs to promote gastric emptying, initiating proximal nutrition (PN) if enteral food (EN) is not tolerated, providing early EN where feasible and utilizing EN Post Extubation if oral feeding is not tolerated [102]. The article addresses how students choose their diets, consuming certain foods to meet their daily nutritional requirements. The goal of the current investigation was to reduce the daily. Every patient was getting supportive treatment at the outset, such as anti-inflammatory and antiviral medications, and all patients were receiving oxygen assistance. By day 7 after receiving convalescent plasma, nine patients had improved by at least one point on the clinical scale, and seven had been released. On day 14 after the transfusion, 11 patients were discharged, and 19 (76%) showed at least a one-point improvement in their clinical condition.

No unfavourable effects of the plasma transfusion were noted. There was no association between strain genotype and disease severity found in the whole genome sequencing data [22, 82]. According to the World Health Organization, as of November 14, 2020, there were more than 54 million COVID-19 cases globally, and more than 1,323,196 individuals died as a result. As a result, several countries had to declare an illness or impose a period of isolation, which had a negative effect on society, the economy, and public health in addition to slowing the COVID-19 pandemic progress. Therefore, before focusing on the negative impacts of quarantine on diabetics' health, we present a mathematical model for the dynamics of COVID-19 disease transmission and a quantitative model for the dynamics of diabetes. According to a Chinese meta-analysis of 1,527 individuals, the two most prevalent cardiovascular metabolic comorbidities with COVID-19 were diabetes (9.7%, 95% CI 6.9 -12.5%) and cardio-cerebrovascular disease (16.4%, 95% CI 6.6-26.1%). According to this study, patients with diabetes or high blood pressure had a 2 -fold increased chance of developing a serious illness or needing admission to an intensive care unit (ICU), but patients with cardio-cerebrovascular disease had a 3-fold increased risk. In a subset of 355 COVID-19 patients in Italy who passed away, the mean number of underlying diseases was 2.7, and only 3 people were co morbidity-free [85]. At the time of corona-virus incidents, the condition damaged a large number of people. When someone tests positive for corona-virus, they should adhere to the nutrition to boost their immunity. Therefore, the Health Department is in charge of creating patient diets that take food prices into account. Hospital caterers who provide the whole day food according to the given menu lists. Patients are not given the option to select their favorite dishes from the non-selective menu that is offered. This research paper main goal is to create a framework that might enable the construction of the whole day meal. We made an effort to meet the needs of COVID-19 patients while keeping government funding to a minimum. Additionally, we aimed to maximize variety and satisfy consumer preferences. Therefore, it is imperative to conduct investigation into meal preparation using computational frameworks that incorporate logistic study and scientific decision-making approaches to help caterers serve healthy meals for extended periods of time while adhering to financial restrictions. A healthy diet helps ensure that the body is in the best condition to fight the infection. Researchers have discovered that there is no source of viral transmission via food or food packaging, so that to stop the virus from spreading, the system for managing food safety needs to provide staff and food safety officials with appropriate respiratory protection. However, adopting safe food practices is always advised to reduce the possibility of getting infected.

7.1.1 Mathematical Model: This model represents an effort to investigate a portion of the real-life problem mathematically. Mathematical transformation of a physical situation under certain conditions

7.1.2 Linear Programming: The method of optimizing a problem that is subject to restrictions is known as linear programming. It denotes the process of maximizing or minimizing linear functions under limits imposed by linear inequality. The easiest problem to solve is the one using linear programmes.

7.1.3 Lindo Software: Systems creates software tools for modelling and optimization. Quickly and simply solve linear, nonlinear, and integer problems. LINDO Systems has committed itself to offering robust, cutting-edge optimization tools that are both adaptable and user-friendly. In 1988, LINGO, the company's first product with a full-featured modelling capability, was released. Users were able to use summations and subscripted variables to succinctly express models using the modelling language. A large-scale nonlinear solver was implemented in LINGO in 1993. The user didn't have to specify which solver to use, making it special. Following a model analysis, LINGO would automatically select the best linear or nonlinear solver. The ability to support both general and binary integer limitations was another feature exclusive to LINGO's nonlinear solver.

7.2 DATA INTERPRETATION

A menu-displaying model requires different types of information. The institutionalized cost is included in the Recommended Daily Allowance (RDA), which includes the recommended daily requirement of nutritional diet for hospitalized individuals and the national budget for nutrition suppliers for each menu item. A number of six supplements were taken into consideration, as indicated in TABLE 1, carbs, protein, fat, calories, fiber and iron. Also, fourteen different types of meals, Egg, papaya, lentils, idly, cardamom, banana, milk, ragi porridge, fresh dates, dosa, almond, cottage cheese, curd and muskmelon were all taken into consideration in this study.

Table 7.1 Everyday Consumption

Food Ingredient	Everyday Consumption
Carbohydrates	185
Protein	60
Fats	50
Calories	1800
Fiber	35
Iron	20

So that based on above table, forms a mathematical model as follows: -

Minimization $Y = d_1q_1 + d_2q_2 + d_3q_3 + \dots + d_nq_n$

Subject to:

$$p_{11}q_1 + p_{12}q_2 + p_{13}q_3 + \dots + p_{1n}q_n \geq 185$$

$$p_{21}q_1 + p_{22}q_2 + p_{23}q_3 + \dots + p_{2n}q_n \geq 60$$

$$p_{31}q_1 + p_{32}q_2 + p_{33}q_3 + \dots + p_{3n}q_n \geq 50$$

$$p_{41}q_2 + a_{42}q_2 + p_{43}q_3 + \dots + p_{4n}q_n \geq 1800$$

$$p_{51}q_1 + p_{52}q_2 + p_{53}q_3 + \dots + p_{5n}q_n \geq 35$$

$$p_{61}q_1 + p_{62}q_2 + p_{63}q_3 + \dots + p_{6n}q_n \geq 20$$

$$q_1 + q_2 + q + \cdots + q_n \geq 1$$

Since the information is reliant on the menu supplied by the hospital administration, the LP model will be configured in accordance with the meal prices determined by the management. Here are some examples of foods for COVID sufferers that are nutrient rich.

Table 7.2 Different Type of Food

	Food item	Cost
X_1	Cottage cheese	25
X_2	Curd	10
X_3	Papaya	10
X_4	Egg	7
X_5	Idly	5
X_6	Milk	20
X_7	Cardamom, Banana	7
X_8	Ragi Porridge	15
X_9	Almond	20
X_{10}	Lentils	10
X_{11}	Spinach Soup	10
X_{12}	Dosa	10
X_{13}	Fresh Dates	20
X_{14}	Muskmelon	15

7.3 FORMULATION OF THE EQUATION

Minimize Y = $25x_1 + 10x_2 + 10x_3 + 7x_4 + 5x_5 + 20x_6 + 7x_7 + 15x_8 + 20x_9 + 10x_{10} + 10x_{11} + 10x_{12} + 20x_{13} + 15x_{14}$

Table 7.3 Menu Contained the nutrients of the patients

Variable	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}
Carbohydrates	6	4.7	30	1.1	12	12	18	32	6.1	8	7.1	15.6	5.33	8
Protein	18.3	3.5	2	13	3	8.14	1	13	6	25	7.2	2	0.17	0.8

Fat	27	3.3	0.5	11	0.1	8	0	1	14.2	1.2	2.4	5.1	0.03	0.2
Calories	265	4.7	119	72	58	122	105	354	164	147	37	133	20	34
Fiber	0	0	5	0	0.3	0	3.07	3	3.5	12	2	0.8	0.6	0.9
Iron	216	0.1	0.2	1.89	5	0	0.1	0.1	10	7.57	2.7	0	0.07	0.1

Subject to:

$6x_1 + 4.7x_2 + 30x_3 + 1.1x_4 + 12x_5 + 12x_6 + 18x_7 + 32x_8 + 6.1x_9 + 8x_{10} + 7.1x_{11} + 15.6x_{12} + 5.33x_{13} + 8x_{14} \geq 185$

$18.3x_1 + 3.5x_2 + 2x_3 + 13x_4 + 3x_5 + 8.14x_6 + x_7 + 13x_8 + 6x_9 + 25x_{10} + 7.2x_{11} + 2x_{12} + 0.17x_{13} + 0.8x_{14} \geq 60$

$27x_1 + 3.3x_2 + 0.5x_3 + 11x_4 + 0.1x_5 + 8x_6 + x_8 + 14.2x_9 + 1.2x_{10} + 2.4x_{11} + 5.1x_{12} + 0.03x_{13} + 0.2x_{14} \geq 50$

$265x_1 + 4.7x_2 + 119x_3 + 72x_4 + 58x_5 + 122x_6 + 105x_7 + 354x_8 + 164x_9 + 147x_{10} + 37x_{11} + 133x_{12} + 20x_{13} + 34x_{14} \geq 1800$

$5x_3 + 0.3x_5 + 3.07x_7 + 3x_8 + 3.5x_9 + 12x_{10} + 2x_{11} + 0.8x_{12} + 0.6x_{13} + 0.9x_{14} \geq 35$

$216x_1 + 0.1x_2 + 0.2x_3 + 1.89x_4 + 5x_5 + 0.1x_7 + 0.1x_8 + 10x_9 + 7.57x_{10} + 2.7x_{11} + 0.07x_{13} + 0.1x_{14} \geq 20$

$q_1, q_2, q_3, ..., q_n$ & $x_1, x_2, x_3, ..., x_n$ represents same elements.

A single serving of each dish was allowed per day. The decision variables, restrictions, and parameters used in this investigation were numerous. This program was created in Lingo using LP Solve, and it took just one second to find the best solution for a one-day menu. Comparing this to alternative methods that would have required more than 4 hours or even a day, this is incredibly quick. Investigations carried out in the past have illustrated the effectiveness of the strategies in resolving this menu planning issue. These are a few sample problems that is resolved using the Lindo software.

7.4 LINDO FORMULATION


```
min 25x1 + 10x2 + 10x3 + 7x4 + 5x5 + 20x6 + 7x7 + 15x8 + 20x9 + 10x10 + 10x11 +10x12 + 20x13 + 15x14
st
6x1+4.7x2 + 30x3 + 1.1x4 + 12x5 + 12x6 + 18x7 + 32x8+ 6.1x9+ 8x10+ 7.1x11+ 15.6x12 + 5.33x13 + 8x14 >=185
18.3x1 + 3.5x2 + 2x3 + 13x4 + 3x5 + 8.14x6 + x7 + 13x8+ 6x9+ 25x10 + 7.2x11+ 2x12 + 0.17x13 + 0.8x14 >=60
27x1 + 3.3x2 + 0.5x3 + 11x4 + 0.1x5 + 8x6+ x8+ 14.2x9+ 1.2x10+ 2.4x11+ 5.1x12 + 0.03x13+ 0.2x14  >=50
265x1 + 4.7x2 + 119x3 + 72x4 + 58x5 + 122x6 + 105x7 + 354x8+ 164x9+ 147x10+ 37x11+ 133x12 + 20x13+ 34x14 >=1800
5x3 + 0.3x5 + 3.07x7 + 3x8+ 3.5x9+ 12x10+ 2x11+ 0.8x12 + 0.6x13+ 0.9x14 >=35
216x1 + 0.1x2 + 0.2x3 + 1.89x4 + 5x5 + 0.1x7 + 0.1x8+ 10x9+ 7.57x10+ 2.7x11+ 0.07x13 + 0.1x14>=20
x1>=0
x2>=0
x3>=0
x4>=0
X5>=0
x6>=0
x7>=0
x8>=0
x9>=0
x10>=0
x11>=0
x12>=0
x13>=0
x14>=0
end
```

Figure 7.1 – *Representation of Lingo formulation*

7.5 LINDO SOLUTION

Global optimal solution

Objective value: 109.3363

Infeasibilities: 0.000000

Total solver iterations: 6

Model class: LP

Total variables: 14

Nonlinear variables: 0

Total constraints: 20

LP OPTIMUM FOUND AT STEP 6

OBJECTIVE FUNCTION VALUE

1) 109.3363

VARIABLE	VALUE	REDUCED COST
X1	0.015202	0.000000
X2	0.000000	7.525709
X3	2.600355	0.000000
X4	4.003656	0.000000
X5	0.000000	1.347327
X6	0.000000	11.460486
X7	0.000000	0.372815
X8	2.927621	0.000000
X9	0.000000	7.047612
X10	1.101280	0.000000
X11	0.000000	5.985193
X12	0.000000	1.648369
X13	0.000000	18.386141
X14	0.000000	12.417277

ROW	SLACK OR SURPLUS	DUAL PRICES
2)	0.000000	−0.173712
3)	63.117512	0.000000
4)	0.000000	−0.470173
5)	0.000000	−0.022079
6)	0.000000	−0.384239
7)	0.000000	−0.025057
8)	0.015202	0.000000
9)	0.000000	0.000000
10)	2.600355	0.000000
11)	4.003656	0.000000
12)	0.000000	0.000000
13)	0.000000	0.000000
14)	0.000000	0.000000
15)	2.927621	0.000000
16)	0.000000	0.000000
17)	1.101280	0.000000
18)	0.000000	0.000000
19)	0.000000	0.000000
20)	0.000000	0.000000
21)	0.000000	0.000000

NO. ITERATIONS= 6

RANGES IN WHICH THE BASIS IS UNCHANGED:

		OBJ COEFFICIENT RANGES	
VARIABLE	CURRENT COEF	ALLOWABLE INCREASE	ALLOWABLE DECREASE
X1	25.000000	47.881336	5.293648
X2	10.000000	INFINITY	7.525709
X3	10.000000	0.844178	3.661041
X4	7.000000	2.175130	4.989720
X5	5.000000	INFINITY	1.347327
X6	20.000000	INFINITY	11.460486
X7	7.000000	INFINITY	0.372815
X8	15.000000	2.650131	5.460338
X9	20.000000	INFINITY	7.047612
X10	10.000000	9.904737	4.535483
X11	10.000000	INFINITY	5.985193
X12	10.000000	INFINITY	1.648369
X13	20.000000	INFINITY	18.386141
X14	15.000000	INFINITY	12.417277

		RIGHTHAND SIDE RANGES	
ROW	CURRENT RHS	ALLOWABLE INCREASE	ALLOWABLE DECREASE
2	185.000000	62.793018	26.102392
3	60.000000	63.117512	INFINITY
4	50.000000	21.836929	42.488907
5	1800.000000	567.394531	724.040222
6	35.000000	5.107429	12.999310
7	20.000000	347.551483	3.211621
8	0.000000	0.015202	INFINITY
9	0.000000	0.000000	INFINITY
10	0.000000	2.600355	INFINITY
11	0.000000	4.003656	INFINITY
12	0.000000	0.000000	INFINITY
13	0.000000	0.000000	INFINITY
14	0.000000	0.000000	INFINITY
15	0.000000	2.927621	INFINITY
16	0.000000	0.000000	INFINITY
17	0.000000	1.101280	INFINITY
18	0.000000	0.000000	INFINITY
19	0.000000	0.000000	INFINITY
20	0.000000	0.000000	INFINITY
21	0.000000	0.000000	INFINITY

7.6 RESULT

The findings are shown in Table 7.4. It lists the meals that the hospital administration will give the patients each day. Table 7.4 shows a variety of beverages and foods given in various forms for a single day, which covers six different meals. All of these provide hospital patients with the daily nutrition they need at a low cost. Therefore, it can be said that every meal picked is healthy and is suggested to be given to the patients. The whole cost is less than the management's allocated budget. Therefore, the hospital's administration will only pay around 200 rupees each day.

Table 7.4 Menu of per day

Food	Time
Papaya, milk and idly	Breakfast
Muskmelon	Morning tea
Egg, curd, lentils and ragi	Lunch
Spinach soup, almond	Evening tea
Dosa, cottage cheese	Dinner
Cardamom, banana, fresh dates	Supper

7.7 CONCLUSION

This article includes a useful per day diet that can serve as a manual for school administration. The foods provided in diverse ways for six separate meals in a single day. These all affordably supply hospital patients with the daily nutrients they require. Consequently, it can be concluded that each meal chosen is healthful and should be served to the patients. The entire expenditure is less than the budget that the management set aside. LINDO software was used to solve the model. When compared to other methods of heuristics like biological algorithms, it yields a better result and satisfies all the study limitations. The participants in this study were hospital patients. Rs109.34 is the total cost for the day. As a result, we are able to provide the patients with slightly more expensive and higher-quality meals.

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LIST OF PUBLICATIONS

[1] Rakesh Yadav and Monika Sahu, *Food intake pattern to achieve nutritional goals for Indian adults by linear programming optimization techniques. International Journal of Health Sciences,* 2022, no. 6(S2), 7346–7352. https://doi.org/10.53730/ijhs.v6nS2.6858

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[4] Rakesh Yadav and Monika Sahu, *An Optimum Mathematical Model for Diet Planning Using Linear Programming, Journal of Physics: Conference Series.*

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LIST OF CONFERENCES

[1] Presented paper entitled "An Optimum Mathematical Model for Diet Planning using Linear Programming" in the International Conference on "Recent Advances in Fundamental and Applied Sciences" (RAFAS-2021) held on June 25-26, 2021, organized by School of Chemical Engineering and Physical Sciences, Lovely Professional University, Punjab.

[2] Presented paper on "Diet Planning Problems for Diabetic Patients by using Mathematical Modeling Technique" in the International Conference on Materials for Emerging Technologies (ICMET-21) held on February 18-19, 2022, organized by Department of Research Impact and Outcome, Division of Research and Development, Lovely Professional University, Punjab.

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in the International Conference on "Recent Advances in Fundamental and Applied Sciences" (RAFAS 2021) held on June 25-26, 2021, organized by School of Chemical Engineering and Physical Sciences, Lovely Faculty of Technology and Sciences, Lovely Professional University, Punjab.

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