Original Article

# A Mathematical Model For Analyzing And Optimizing Children's Diet During Feeding Period

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## Abstract

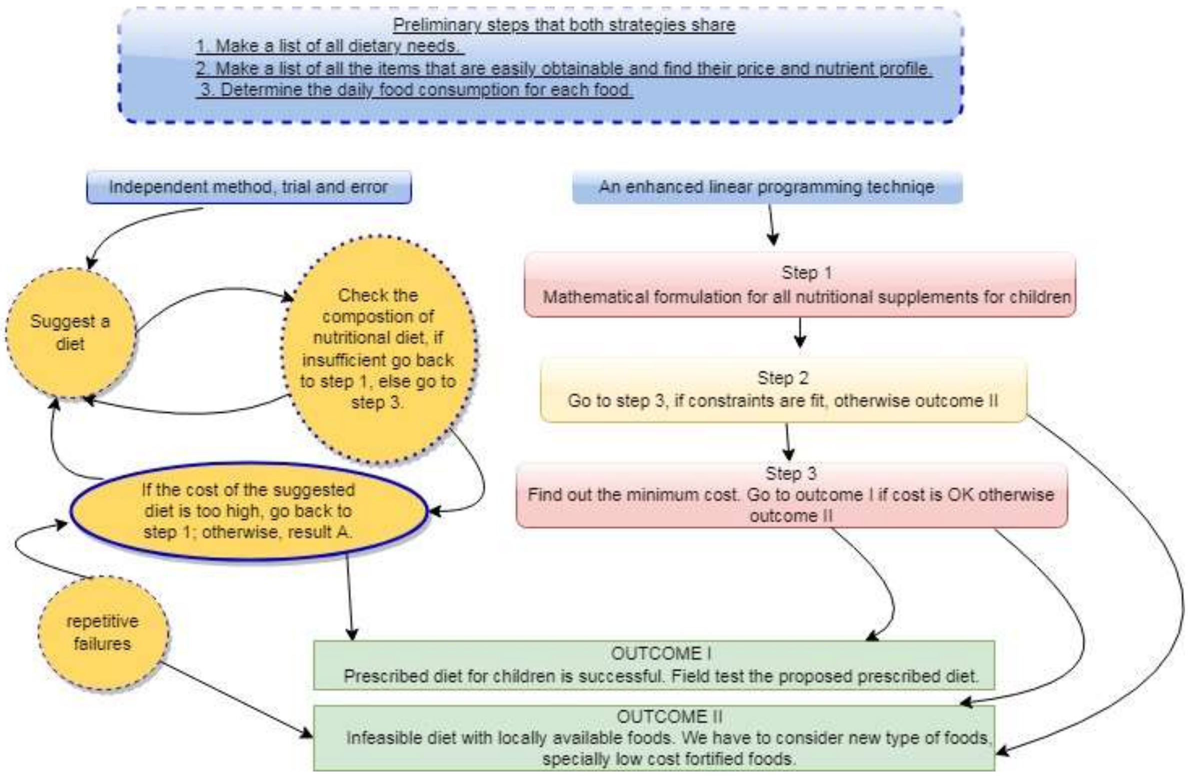
This paper demonstrates that at the time of complementary feeding period, children need a diet that meets the nutritional requirements. One thing also keep in mind that the diet should be affordable. Complementary feeding diets are also related to nearby available foods. Two questions are frequently raised in this context: 1) Can a diet suitable for the complementary feeding period be designed using locally available food? and 2) if this is possible, what is the most affordable, nutritionally adequate option? Is a diet available? These questions are typically addressed with a "trial and error" method. However, a more efficient and restrictive linear programming-based technique is also available. It has become more accessible since the introduction of strong computer systems. The goal of this review is as a result, it is necessary to inform paediatricians and public health professionals. In relation to this tool, the fundamental principles of linear programming are briefly discussed, and some practical examples are provided and its applications for developing sound dietary recommendations based on food in various contexts are explained. The main aim of the present study was to minimize the cost of nutritional diet given in complementary feeding period. To construct a mathematical model of diet selection for 6 to 23 months old children. In this paper an optimum data is made to minimize the expenditure on micronutrients supplements specially vitamins and minerals. We are using Lingo software to find the optimum diet. The result collected from the mathematical model declared the minimum cost of nutritional diet is Rs. 44.72 per day.

**Keywords:** Complementary feeding, kids, nutrients, diet planning, optimization, linear programming.

## Introduction

It has been observed with available data that breastfeeding is not sufficient for 6 to 23 months old children so we have to add some extra things which contain several micronutrients like iron, zinc, copper calcium, vitamin A, vitamin B and vitamin C etc. After six months of age, In addition to breastfeeding milk, we have to give some extra nutritional supplements to infants for proper growth. These micronutrients provide some kind of energy which is needed by the children after first six months. Even in developing countries, it is assumed that suitable nutrient-dense foods are locally available to provide a nutritionally adequate complementary diet. According to the LP modelling, the products provided in realistic servings would improve the nutritional quality of the diet but would not ensure adequate intakes of all nutrients, micronutrients. Iron, thiamin, and folate continued to be problematic nutrients in all simulated diets [1]. This is the first study to consider further awareness of FBR and recognised problem nutrients to dietary intake data, criteria, energy and fat requirements using linear programming. The sensitivity of linear programming results to model input data is commonly discussed but rarely quantified [2]. One in every four children (28.7 percent) is still provided prelacteal feeds, posing a substantial challenge to satisfying the WHO's 90% EBF recommendation. Obtaining EIBF while avoiding prelacteal feeding from a low baseline, optimal early breastfeeding improved by 65.7%. In 2001, the initial base was set at 27.1% [3]. Poor quality complementary foods with low nutrient density, as well as inappropriate nutrition education, have been identified as major causes of childhood malnutrition. Many developing countries are now planning to introduce complementary foods. Food quality and quantity are insufficient; resulting in during the second half of infancy, there is a high risk of nutritional deficiencies. The majority of the unfortified cereal-based complementary foods are usually consumed in developing countries. Gruels are distinguished by their low energy and nutrient density and are frequently consumed. Adequate in iron, zinc, and pyridoxine, and may be deficient in some populations. Riboflavin, niacin, calcium, thiamine, folate, ascorbic acid, and vitamin A are all essential nutrients [4]. The CFR intervention improved mothers' knowledge and children's diets regarding the key problem nutrients calcium, iron, niacin, and zinc, according to our analyses improved nutrient intake in children aged 9–16 months. Following the nutrient densities were significantly higher after a 6-month intervention. Most nutrients are relatively higher in the CFR group than in the non-CFR group [5]. In Australia, lots of children aged 6 to 23 months having a disease called Anaemia. This is due to iron deficiency. When the level of haemoglobin is very low in the red blood cells then body gets a disease named anaemia. With the help of a study finds that 5.8mg of iron given to the infants of aged 6-12 months in a day and 4.4mg of iron given to the breastfed toddlers aged 13-23 months [6]. Millions of infants and young children in low- and middle-income countries are at risk of malnutrition and poor neurobehavioral development. Globally, 21.3 percent (144 million) of children under the age of five were stunted in 2019, while 6.9 percent (47 million) were wasted. Micronutrient deficiencies, such as iron, zinc, vitamin A, and vitamin B12, are common. As a result of low micronutrient stores at birth, children under the age of 2 are highly susceptible. Birth insufficient dietary intake of bio available micronutrients and increased micronutrient requirements needs as a result of infection or malabsorption. It is estimated that 250 million children are affected. Children under the age of 5 are at risk of not reaching their full developmental potential (43 percent) is linked to a lack of nutrients in childhood [8]. The ultimate target of this paper is to provide the background information needed to create scientifically sound food recommendations and appropriate training programmes to enhance children's dietary intake and nutritional status. The review is primarily aimed at healthcare workers and others concerned with children's nutrition, health, and well-being in developing countries. Although much of the information may be appropriate for young children in advanced economies, the document focuses on the individual needs of children in low-income situations, and the recommendations have been formed with financial and environmental limitations that are common in developing countries in mind. The presentation assumes that the reader is familiar with basic nutrition science concepts [9]. The benchmark for linear growth has two components: one based on height and the other on length (length-for-age, 0 to 24 months) (height-for-age, 2 to 5 years). The same model was used to build both components, but the final curves show the average difference between the recumbent length and standing elevation [10]. Breast milk remains the primary source of energy, macronutrients, and nine out of the model diet's eleven micronutrients; underlining the critical role that ongoing breastfeeding plays. When foods are first incorporated into a baby's diet, 71% of the calories came from breast milk and meals derived from animals, consuming protein foods with added nutrients (baby cereal, margarine), and butternut stood out as one of the key suppliers of starchy plant meals to the nutrient intakes in this diet's simulation [11]. The findings of this study demonstrated that, using information from local food sources. Linear and nonlinear programming can be used to develop nutritional recommendations. Malawi's findings supported that, low intakes of riboflavin, zinc, and phytate are prevalent issues in underdeveloped African areas. More significantly the results suggest that a rise in consumption of fruits, vegetables, and nutrients derived from animals considerably enhances the nutrient content of the feed both during and after harvest [17]. It is difficult to satisfy everyone's nutritional needs at these stages of development. Avoiding added sugars is advised for young children (less than 2 years of age). Additional study is required to provide a reference profile for the composition of human milk. The DRI values for these age groups should be updated and strengthened, and optimization models should be combined with FPM, which identifies food combinations that satisfy all nutritional objectives [18]. As the child ages, advise parents to: 1. Continue to breastfed frequently, 2. Increase the amount of food served at meals and give as much as the child will eat while actively encouraging them to do so, 3. Increase the number of meals gradually at 6-7 months feed complementary foods three times per day by 12 months, at least five times per day (three meals, and three snacks), 4. Make the meal soft at first, then mash it or chop it into little pieces, 5. Support and push the kid to eat [25]. Using sex-stratified fixed-effects longitudinal regression models, breastfeeding, nutritional, and anthropometric data from the Cebu Longitudinal Health and Nutrition Survey were analysed. A score for dietary diversity (DDS) based on Seven food groups were given a low (<4) or high (≥4) classification. Complementary feeding habits were as follows: I. Low DDS, non-breastfed (referent); II. Breastfed a low DDS, a high DDS if not breastfed, a high DDS if breastfed, and a low DDS if not breastfed DDS (optimal). Complementary effects of age, energy intake, and feeding habits were covered [13]. In order to construct complementary feeding recommendations (CFR) for Indonesian infants aged 9 to 11 months using this method and identify nutrients that will likely continue to be under consumed, these nutrients were the focus of this study. A 4-phase process based on linear and goal programming was used to create the CFR. A model's parameters were established using dietary information gathered in a cross-sectional study of 100 children aged 9 to 11 months who resided in the Bogor District of West Java, Indonesia, and visited a market analysis of three local markets. The findings demonstrated that theoretical iron requirements could not be satisfied by eating only local foods. (Best possible level, 63% of suggestions), and it was challenging to maintain proper quantities of iron, niacin, zinc, and calcium. The greatest local food sources were fortified foods such as meatballs, chicken liver, eggs, tempe-tofu, bananas, and spinach [14]. The results of the studies on observed intake included in this analysis show that diets consisting primarily of several complementing meals that are accessible locally alone satisfy the protein needs of babies aged 6 to 23 months. The vitamins most frequently insufficient and having the biggest gaps were zinc, iron, and calcium as well energy, thiamin, riboflavin, niacin, vitamin A. Children did not always get enough folate and vitamin C. Local foods can help you meet your daily needs. Only two of the observed consumption studies on vitamin D were published. Improving the methods used to prepare food, such as encouraging the use of soaking methods to lower the phytate level of a maize diet or encouraging local foods to be processed so that infants could swallow them, and better dietary options intakes, but needs for iron, zinc, and in certain instances, calcium needs weren't met. When diets are improved by modelling and raising feeding regimens or nutrient dense feeding volumes meals often meet most nutritional needs with the exception of iron and zinc, can be satisfied [23]. In our study, the number of nutrient issues significantly increased when fortified foods were eliminated from diet models, with the greatest difference observed in infants aged 6 to 8 months. (Data not present.) Surprisingly, more issues nutrition for rural Filipino children was identified. Compared to children, those aged 12 to 23 months of the same age group from earlier research in the region. The nutritional gaps here are an older age group has been observed (12-23 months) may be related to the reduced consumption of lack of fortified infant foods and breast milk dietary formula milk, both of which contributed to partly because of their general nutritional intakes the youngsters [24]. For children aged 6 to 11 months and for those aged 12 to 23 months, optimal formulations that met dietary recommended intakes (DRIs) for 20 nutrients were successfully created at a cost that was double that of the observed food expenditure across age groups. The optimal formulations contained a concoction of components including fish, wholegrain cereals, Irish potatoes, legumes, and seeds poultry meat as well as locally sourced fruits and veggies. Our research showed that, given the variety of meal options, it is possible to ideal formulations that can increase the nutritional sufficiency of rural 6-to 23 month-old children. The child's diet's budget has been doubled. These results suggest the need for alternate initiatives that can boost household access to nutrient-dense foods that can meet the outlined nutritional deficiencies [21]. This study demonstrates the inadequate nutritional quality of complementary feeding (CF) diets taken by children aged between 12 and 23 in rural Eastern Uganda. The nutrient densities in seven of the twelve nutrients in CF diets were not at the desired levels examined. More than 45% of children were at danger of receiving inadequate intakes for 8 of the 12 nutrients looked at were insufficient. Over 90% of Americans get enough calcium, iron, and niacin contrasted with energy. Given the small percentage, intakes of these kids seem to be appropriate of squandered children. Low dietary variety and limited portions of nutrient-dense foods are involved with poor CF diet quality. Just over half of the less than four nutrient-dense food categories were ingested daily by children and median serving sizes of meals made from nutrient-dense animal sources including there were just 2, 4, and 52 g of little dry fish, eggs, and milk in each dish respectively. Small portions of dry fish and eggs were served because they are frequently eaten as a sauce ingredient. Eggs likewise, they were infrequently ingested (just 4% of kids). Likewise nutrient-dense veggies, such as green leafy vegetables, pumpkins, or carrots were hardly eaten. Consequently, to enhance CF quality diets will see an increase in food variety as well as their serving sizes [27]. Mathematical modelling was utilised to guide decisions in the current national complementary feeding guidelines (CFGs) for infants aged 6 to 12 months. Using Optifood's linear programming approach, model parameters were produced from nationally representative dietary data and examined for 11 micronutrients according to age group. Models were conducted to identify micronutrients for which local foods could not provide the nutrient reference levels. Examine the original 2012 Thai CFGs, assess the nutrients consumed (problem nutrients), and forecast the nutritional advantages of a particular food supplements are enriched. Three problematic nutrients (iron, calcium, and zinc) were identified by the results when the fortified food was modelled, were lowered to one for infants aged 9 to 11 months. In the modelled nutritionally best diets rather than the observed diets, the number of servings/week of vegetables and meat, fish, or eggs were greater, and the number of servings/week of oil and fruit were lower (medians). The original Thai CFGs were not practical when they were developed because the energy constraint was surpassed, hence the suggested amount of servings of oil and fruit per week were revised. When modifying national CFGs, this study highlights the benefits of employing mathematical modelling to assess and enhance them [28].

## Diet Design With and Without the Assistance of Linear Programming



(Figure 1)

To better understand the rationale for using linear programming for diet formulation, we must first examine the method currently used to design diets during the design process. The complementary feeding period also known as the "trial and error" period strategy (Fig. 1). Before beginning the "trial and error, “Some background information is provided as part of the "trial and error" approach. A list of available foods with their energy and nutrient content composition, cost, and an estimated maximum daily portion size that is reasonable to recommend intended for children. The traditional "trial and error" method is ineffective then iterative, in which different food combinations are tried. Attempts were made repeatedly, based on educated guesses. This strategy multiple backwards steps must be taken and repeated. Diet plans to arrive at a solution that may or may not be feasible optimal. Furthermore, in the case of repeated failures to improve a sufficient low-cost diet, a clear directive for diet modification (i.e., the introduction of new foods, particularly fruits and vegetables) should be given. There is no provision for fortified foods. Alternatively, once Background information is gathered and formulated. A diet is feasible, and linear programming can be completed quickly. It efficiently provides the best solution (Fig. 1). When creating a suitable diet is clearly not possible shown by the analysis, indicating unequivocally that new Foods must be added to the diet. Linear programming also specifies the types of foods that should be consumed introduced in order to balance the diet. Even with linear programming, diet design during the complementary feeding period remains a difficult exercise due to nutritional uncertainties requirements during this time period, as well as the level of absorption of various micronutrients, which vary depending on potential enhancers and inhibitors' interactions. In addition, the amount of each food that a child can reasonably consume may be difficult to estimate in different contexts. Yet, once reasonable estimates for defining these parameters have been made, linear programming provides a clear answer in this regard. The feasibility and the cost of developing a nutritionally balanced diet. This is in contrast to the current situation. Use of the "trial and error" method, which is not only time-consuming but also error-prone and introduces a significant by attempting to add another source of uncertainty. This method is time consuming so that we use a software name Lingo. With the help of this software we can work easily and very fastly.

## Linear Programming and Some Other Definitions

Linear programming is a mathematical tool that is used to optimise (minimise or maximise) a linear function of a group of decision variables while taking into account multiple linear constraints. Linear programming will be used to optimise the function Y. This is known as the "objective function." It can be represented by a graph (parallel series of lines or plane surface areas). The variables $X_1$, $X_2$... $X_n$ the values of which can be the letter Y stands for choice called the decision variables. A function Y is made up of multiple variables $X_1$, $X_2$ ... Xn can be expressed as follows, it is linear:

$$Y = a_0 + a_1 X_1 + a_2 X_2 + \ldots + a_n X_n$$

and $a_0$, $a_1$, $a_2$ ...$a_n$ are constants. Similarly, a constraint on multiple variables $X_1$, $X_2$... $X_n$ can be expressed as follows, it is linear:

$$b_1 X_1 + b_2 X_2 + \ldots + b_n X_n \geq b_0$$

and $b_0$, $b_1$, $b_2$ ... $b_n$ are constants. In order to provide a conceptual understanding of linear programming, an appendix contains a simple graphic illustration of the theory underlying it the mathematical fundamentals.

## Development of a Diet Optimization Plan: A Linear Programming Model

To create a linear programming model for diet optimization, the question must first be clearly stated. Then comes out the objective function that provides the best answers. This question must be phrased and expressed as follows: A decision variable's linear function. Finally, there is to govern the nutritional and palatability constraints must be met. The process of diet optimization must be identified. The latter are required to establish the actual outcome and all the details are described below.

## Decision Variables and the Objective Function

The objective function mathematically describes the criteria used to select the optimal solution from among all alternative solutions. The objective function chosen is it will therefore, depend on the question posed. In relation the goal is the function will be the energy content of a diet for the first whereas it will be the total cost of the diet for the second. Minimization of objective function will be held in both the cases and expressed the linear function of X1, X2,... Xn, these are the individual food weights and decision variables in terms of linear programming. In the first case, designing a balanced diet is only possible if all of the constraints can be met with a total energy content chosen as the objective. The function is less important than the child's energy requirements. In the second case, developing a diet at a reasonable cost. This will only be possible if the lowest cost is obtained with cost, as an objective function, is within acceptable bounds with a low-income family's budget. The term "food database" will refer to a list of all locally available foods that can, in theory, be incorporated into children's diets, as well as their prices as well as nutritional value. The sum of all locally available weights foods that are appropriate for feeding young children are used as decision variables in a specific environment. The phrase "food basket" will be used to describe a combination of foods chosen during the analysis. In the optimised diet (i.e., all foods with an optimised nutritional value) greater than 0 gram weight).This is not the case. It implies that all of the foods in the food basket must be eaten in the precise amount specified by the analysis each and every day. Instead, it represents the average amounts of different foods that should be consumed over a short period of time (e.g., a week).

## Use of Nutritional Constraints and Palatability Constraints in a Complementary Feeding Diet Problem

Nutritional Constraints: The boundaries of the optimization process are defined by linear constraints. The diet chosen for the optimised complementary feeding diet problem must meet specific nutrient requirements at a given energy level. As a result, nutrient constraints must be applied to ensure that its nutrient content exceeds or equals known recommended nutrient intake levels (i.e., meets 97 percent of children's needs). This linear constraint is represented by an inequality (≥) if we want the nutrient content of the diet to be greater than a certain value. This linear constraint will be represented by equality if we want the energy content of the diet to be just equal to average requirements.

Palatability Constraints: Optimization models typically choose combinations of nutrient-dense foods that contain high levels of several rare nutrients. If they are included in the food database, liver, legumes, dried fish, and dark green leafy vegetables are examples of foods that have been systematically selected in large quantities. To avoid selecting unrealistic diets, a new set of constraints must be included to ensure that the diet chosen is palatable and culturally acceptable. Limiting portion sizes by introducing maximum quantity constraints for each food in the database using a simple inequality constraint will reject unrealistic diets. When there are a variety of foods available, it is also important to set upper limits on food groups. For example, in situations where many different types of legumes or fruit are available, incorporating all of these individual foods at their highest level can lead to unrealistic diets. This can be avoided by setting a maximum amount of energy contributed by all foods in the same food group. These portion size and food group restrictions should ideally be obtained from previous food consumption surveys. If such data is not available, local key informants can specify the maximum amount of each food that a child of this age can consume. These should be confirmed by direct observation whenever possible.

## Result Interpretation

Identifying Limiting Nutrients: Linear programming can be used to predict which nutrients are likely to be deficient in a child's diet during the complementary feeding period. Because it suggests that foods rich in (or fortified with) these limiting or problematic nutrients should be introduced into local diets, this information can be used to direct nutrition intervention programme initiatives. These nutrients are easily identified because the optimised diet chosen by linear programming will contain these nutrients at the bare minimum. Furthermore, when the nutrient constraint is removed, the objective function decreases. If the objective function is energy, these nutrients will be identified as problem nutrients only if the energy content of the optimised diet is equal to or greater than the energy requirements of the population of interest. Iron will be a limiting nutrient in most cases for 6- to 23-month-old children, which may explain why iron deficiency is difficult to eliminate without iron fortified infant foods. Aside from iron the limiting nutrients will vary by region and frequently by season, depending on food availability and price fluctuations in the local market.

## When Constraints cannot be come then what to do

In some cases, the linear programming analysis reveals that designing a balanced diet is either impossible or results in an unacceptably high cost or energy level. Limiting nutrients must be identified in these cases, and new foods must be added to the food database. Depending on the objective function, these foods should be chosen based on their high content of limiting nutrients in relation to energy or cost. If no suitable food can be identified, there is a strong case for using a low-cost fortified food or food supplement, provided this lowers the objective function and allows for lower-cost diet optimization.

## Including Nonlinear Constraints: Energy Density and Absorbed Iron

Nonlinear nutritional constraints may be desirable in some situations. Setting a lower limit on the energy density of the entire diet is a good example. When expressed as a ratio, a nonlinear constraint exists: the constraint's nonlinear mathematical expression is

$$(X_1.E_1 + X_2.E_2 + X_n.E_n)/(X_1 + X_2 + ...X_n) > ED$$

Where $E_1$... $E_n$ denotes the energy content of 100 g of food from 1 to n, and ED denotes the desired energy density. The optimization of these nonlinear models is frequently impossible. Figure out simple equations or algorithms. Instead, solutions are discovered through an iterative process, posing the risk of Instead of an overall general, a local optimum is chosen. Ideal solution as a result, nonlinear functions should be avoided. In the first instance, avoid to accomplish this; nonlinear Constraints should be rewritten as linear constraints. Consider the constraint on whenever possible. As a linear constraint, energy density can be expressed as follows

$$X_1(E_1 - ED) + X_2(E_2 - ED) + X_n(E_n - ED) \geq 0$$

These inequalities are linear, so a linear programming model is appropriate. A similar transformation has described to transform the converting nonlinear phytate zinc molar ratio constraint into a linear constraint maintaining a phytate zinc ratio. To ensure a reasonable level, a predetermined level may be required degree of zinc absorption. Some nonlinear constraints cannot be transformed into linear constraints. For example, an algorithm exists to estimate the amount of absorbable iron in a diet using logarithmic and exponential functions of vitamin C, phytate, and other iron absorption inhibitors.

## A Linear Programming application of diet optimization

With the help of FSSAI (Food Safety and Standards Authority of India) recommendations, we will explain the nutritional diet for 6 to 23 months old Indian infants by using some application of linear programming. We will find out the optimum diet by use of a software name LINGO. In this study, we take some data and make a mathematical model. Table I. was represented the nutritional requirements helpful for this age group. In this model, we fulfil all the nutritional constraints by adding some complementary foods. After 6 month of age a child also need some extra foods. We will use LINGO software for the calculation of the mathematical model because this is the software which helps to find out the problem related to linear programming, non-linear programming and integer programming. This is used for solving bigger problems. Some essential complementary foods for Indian children aged 6 to 23 months contains chapatti, rice, lentils, ghee, milk, carrot, amaranth leaves and yogurt. For younger children these foods will give in lesser quantity according to the guidelines and the quantity of food must increase with age. Table II was represented the food items for breastfed child aged 6-23 months old. After that we find the minimum cost for that nutritional diet for children per day.

**TABLE1. Recommended Dietary Allowances (RDA) for Protein, Vitamins and Minerals for Indian children (Based on FSSAI estimated nutritional requirements for a child aged 6 to 23 months)**

| **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 II. Selection of food-item for breastfed child aged 6-23 months**

| Food item 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 |

**Total formulation of the problem**

$$\text{MIN } Z = 5X_1 + 5X_2 + 5X_3 + 3X_4 + 4X_5 + 2X_6 + 3X_7 + 2X_8 + 2X_9$$

Subject to;

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

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

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

$$0.22X_1 + 0.15X_2 + 0.03X_3 + 0.01X_4 + 0.01X_5 + 0.02X_7 + 0.26X_8 + 0.03X_9 \geq 0.3$$

$0.09X_1 + 0.07X_2 + 0.01X_3 + 0.04X_4 + 0.01X_5 + 0.08X_7 + 0.06X_8 + 1.32X_9 \geq 0.4$

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

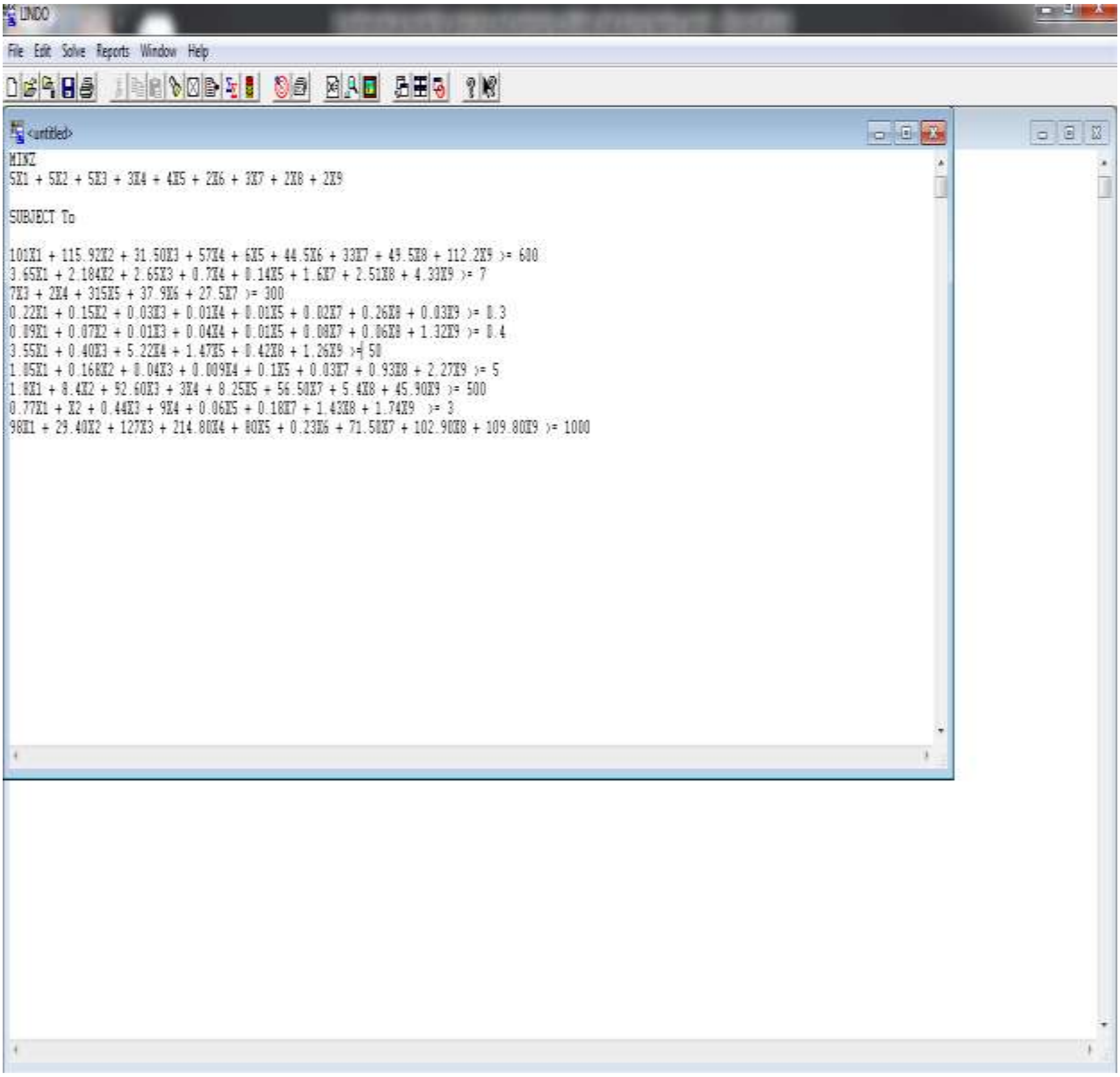
$1.05X_1 + 0.168X_2 + 0.04X_3 + 0.009X_4 + 0.1X_5 + 0.03X_7 + 0.93X_8 + 2.27X_9 \geq 5$

$1.8X_1 + 8.4X_{2s} + 92.60X_3 + 3X_4 + 8.25X_5 + 56.50X_7 + 5.4X_8 + 45.90X_9 \geq 500$

$0.77X_1 + X_2 + 0.44X_3 + 9X_4 + 0.06X_5 + 0.18X_7 + 1.43X_8 + 1.74X_9 \geq 3$

$98X_1 + 29.40X_2 + 127X_3 + 214.80X_4 + 80X_5 + 0.23X_6 + 71.50X_7 + 102.90X_8 + 109.80X_9 \quad \geq 1000$

**LINGO Formulation**



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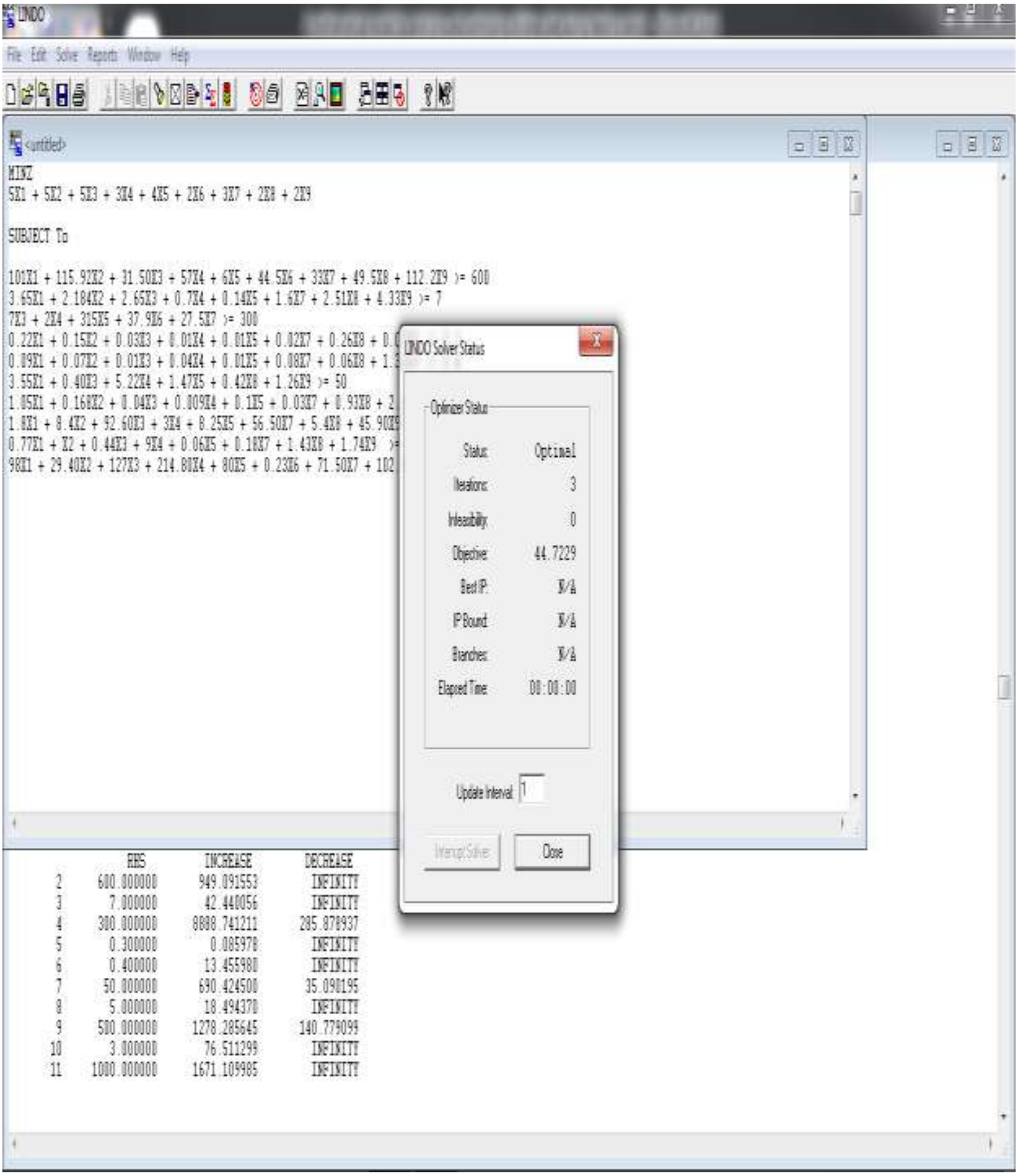
MINZ
5X1 + 5X2 + 5X3 + 3X4 + 4X5 + 2X6 + 3X7 + 2X8 + 2X9

SUBJECT To

101X1 + 115.92X2 + 31.50X3 + 57X4 + 6X5 + 44.5X6 + 33X7 + 49.5X8 + 112.2X9 >= 600
3.65X1 + 2.184X2 + 2.65X3 + 0.7X4 + 0.14X5 + 1.6X7 + 2.51X8 + 4.33X9 >= 7
7X3 + 2X4 + 315X5 + 37.9X6 + 27.5X7 >= 300
0.22X1 + 0.15X2 + 0.03X3 + 0.01X4 + 0.01X5 + 0.02X7 + 0.26X8 + 0.03X9 >= 0.3
0.09X1 + 0.07X2 + 0.01X3 + 0.04X4 + 0.01X5 + 0.08X7 + 0.06X8 + 1.32X9 >= 0.4
3.55X1 + 0.40X3 + 5.22X4 + 1.47X5 + 0.42X8 + 1.26X9 >= 50
1.05X1 + 0.168X2 + 0.04X3 + 0.009X4 + 0.1X5 + 0.03X7 + 0.93X8 + 2.27X9 >= 5
1.8X1 + 8.4X2 + 92.60X3 + 3X4 + 8.25X5 + 56.50X7 + 5.4X8 + 45.90X9 >= 500
0.77X1 + X2 + 0.44X3 + 9X4 + 0.06X5 + 0.18X7 + 1.43X8 + 1.74X9  >= 3
98X1 + 29.40X2 + 127X3 + 214.80X4 + 80X5 + 0.23X6 + 71.50X7 + 102.90X8 + 109.80X9 >= 1000
```

**LINGO Solution**



```
MINZ
5X1 + 5X2 + 5X3 + 3X4 + 4X5 + 2X6 + 3X7 + 2X8 + 2X9

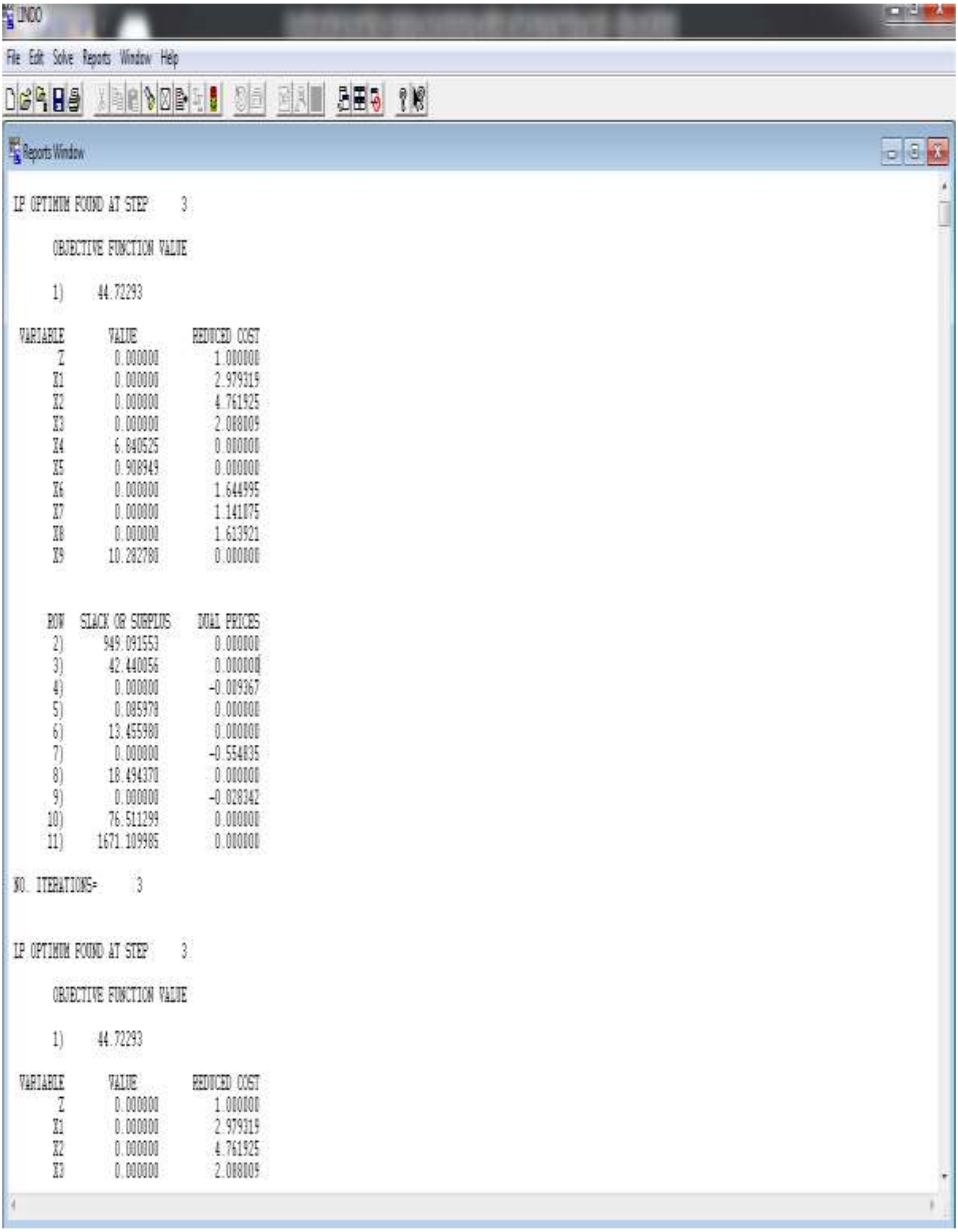
SUBJECT To

101X1 + 115.92X2 + 31.50X3 + 57X4 + 6X5 + 44.5X6 + 33X7 + 49.5X8 + 112.2X9 >= 600
3.65X1 + 2.184X2 + 2.65X3 + 0.7X4 + 0.14X5 + 1.6X7 + 2.51X8 + 4.33X9 >= 7
7X3 + 2X4 + 315X5 + 37.9X6 + 27.5X7 >= 300
0.22X1 + 0.15X2 + 0.03X3 + 0.01X4 + 0.01X5 + 0.02X7 + 0.26X8 + 0.
0.09X1 + 0.07X2 + 0.01X3 + 0.04X4 + 0.01X5 + 0.08X7 + 0.06X8 + 1.
3.55X1 + 0.40X3 + 5.22X4 + 1.47X5 + 0.42X8 + 1.26X9 >= 50
1.05X1 + 0.168X2 + 0.04X3 + 0.009X4 + 0.1X5 + 0.03X7 + 0.93X8 + 2
1.8X1 + 8.4X2 + 92.60X3 + 3X4 + 8.25X5 + 56.50X7 + 5.4X8 + 45.90X
0.77X1 + X2 + 0.44X3 + 9X4 + 0.06X5 + 0.18X7 + 1.43X8 + 1.74X9  >
98X1 + 29.40X2 + 127X3 + 214.80X4 + 80X5 + 0.23X6 + 71.50X7 + 102
```

```
Status:          Optimal
Iterations:            3
Infeasibility:         0
Objective:       44.7229
Best IP:             N/A
IP Bound:            N/A
Branches:            N/A
Elapsed Time:   00:00:00

Update Interval: 1
```

```
              RHS        INCREASE        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       35.098195
  8      5.000000       18.494370        INFINITY
  9    500.000000     1278.285645      140.779099
 10      3.000000       76.511299        INFINITY
 11   1000.000000     1671.109985        INFINITY
```



```
LP OPTIMUM FOUND AT STEP      3

      OBJECTIVE FUNCTION VALUE

      1)      44.72293

 VARIABLE        VALUE          REDUCED COST
        Z         0.000000          1.000000
       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)        76.511299          0.000000
      11)      1671.109985          0.000000

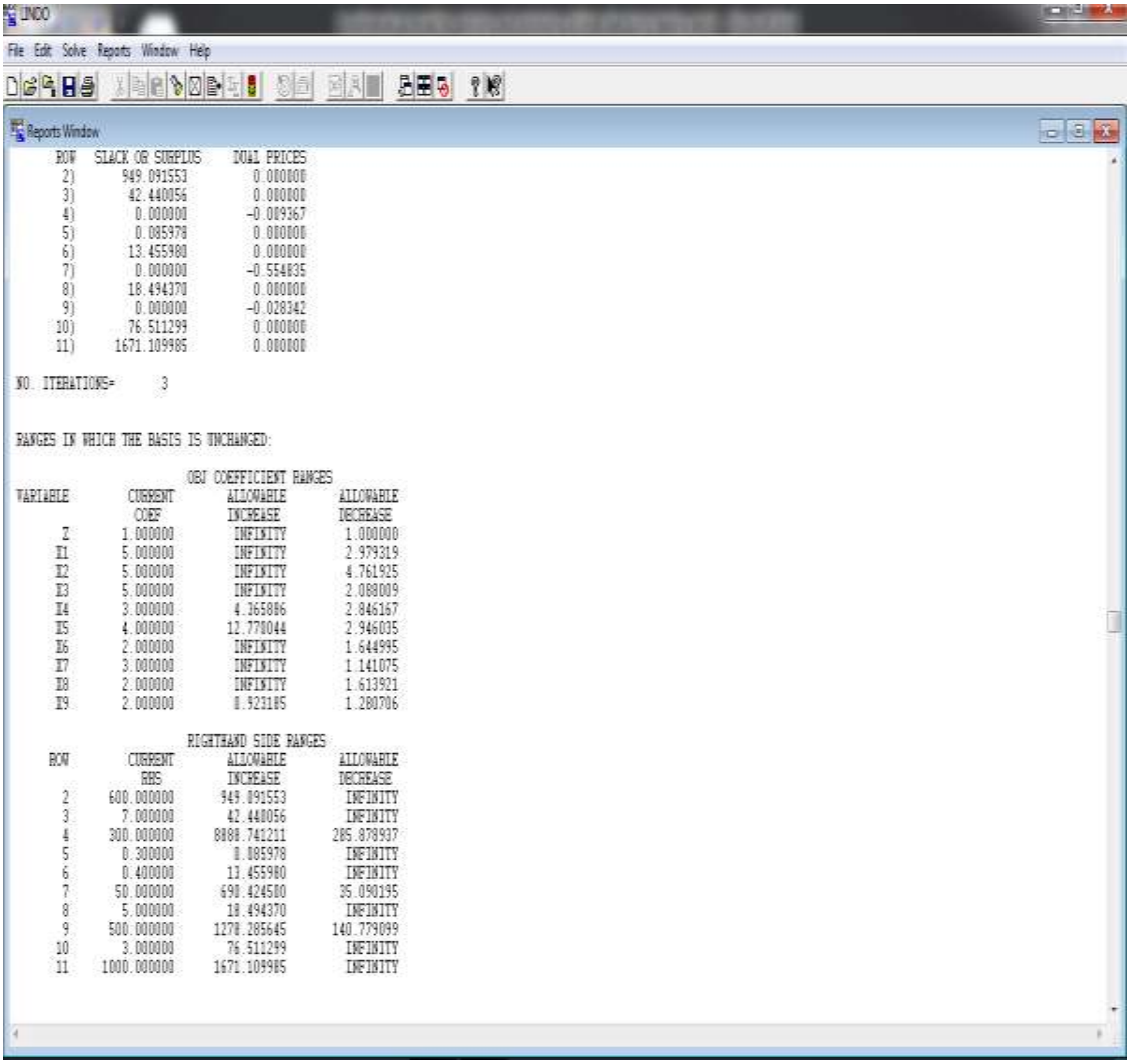
NO. ITERATIONS=       3


LP OPTIMUM FOUND AT STEP      3

      OBJECTIVE FUNCTION VALUE

      1)      44.72293

 VARIABLE        VALUE          REDUCED COST
        Z         0.000000          1.000000
       X1         0.000000          2.979319
       X2         0.000000          4.761925
       X3         0.000000          2.088009
```



```
      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)        76.511299         0.000000
      11)      1671.109985         0.000000

 NO. ITERATIONS=       3


 RANGES IN WHICH THE BASIS IS UNCHANGED:

                           OBJ COEFFICIENT RANGES
 VARIABLE         CURRENT         ALLOWABLE         ALLOWABLE
                   COEF           INCREASE          DECREASE
        Z        1.000000         INFINITY          1.000000
       X1        5.000000         INFINITY          2.979319
       X2        5.000000         INFINITY          4.761925
       X3        5.000000         INFINITY          2.088009
       X4        3.000000         4.365806          2.846167
       X5        4.000000        12.778044          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         ALLOWABLE         ALLOWABLE
                    RHS           INCREASE          DECREASE
        2      600.000000       949.091553          INFINITY
        3        7.000000        42.440056          INFINITY
        4      300.000000      8808.741211        285.878937
        5        0.300000         0.085978          INFINITY
        6        0.400000        13.455980          INFINITY
        7       50.000000       690.424500         35.090195
        8        5.000000        18.494370          INFINITY
        9      500.000000      1270.285645        140.779099
       10        3.000000        76.511299          INFINITY
       11     1000.000000      1671.109985          INFINITY
```

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

## Conclusions

A useful method for developing optimum diets for young children throughout the supplementary feeding period is linear programming. It is a practical mathematical technique for quickly translating globally included dietary suggestions into good dietary recommendations based on regionally accessible foods and market prices in the area. Linear programming is very effective for optimization. Here Lingo is used for finding the optimum solution and the minimum cost of the nutritional diet comes out to be Rs 44.72.

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