A Quadratic Model for Budget Planning Related to the Diet Problem

by

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Abstract

This research deals with a variation of the notorious diet problem, which seeks to minimize the budget needed for an individual's diet, subject to nutritional constraints, among others. Here, we address the problem from a different perspective, namely by proposing a model that seeks to maximize the nutritional value of a diet subject to a budgetary constraint. When viewing this problem from this angle, an administrator can determine at which point the money spent in providing nutritional value approaches diminishing returns for the investment. This tool can then be used to plan a reasonable budget for an individual's diet. Here we illustrate its usefulness to the case of the Supplementary Nutritional Assistance Program (SNAP), taking into consideration the fixed budget given to the individuals and the price of every food of the Recommended Basic Food Basket for Puerto Rico. As part of the methodology to achieve this objective, we used two mathematical optimization models. The Linear and Quadratic Programming. The results of this research show those combinations of food that optimize the individual nutritional benefit. These results will allow the Federal Government determine the optimum budget for the SNAP effort, taking into consideration its policies, market prices and other restrictions.

Resumen

Esta investigación atiende una variación del notorio problema de la dieta y busca minimizar el presupuesto necesario para la dieta de un individuo, sujeto a las limitaciones nutricionales, entre otros. Aquí, abordamos el problema desde una perspectiva diferente, es decir al proponer un modelo que busca maximizar el valor nutricional de una dieta sujeto a una restricción presupuestaria. Al ver este problema desde este ángulo, un administrador puede determinar en qué punto el dinero gastado en proveer valor nutritivo alcanza rendimientos decrecientes en la inversión. Esta herramienta puede utilizarse luego para planificar un presupuesto razonable para la dieta de un individuo. Aquí ilustramos su utilidad para el caso del Programa Suplementario de Asistencia Nutricional (SNAP), teniendo en cuenta el presupuesto fijo dado a los individuos y el precio de cada alimento de la canasta básica de alimentos recomienda para Puerto Rico. Como parte de la metodología para lograr este objetivo, se utilizaron varios modelos matemáticos de optimización. Estos modelos son conocidos Programación Linear y Cuadrática. Los resultados de esta investigación muestran aquellas combinaciones de alimentos que optimizan los beneficios nutricionales del individuo. Con estos resultados el Gobierno Federal puede determinar mejor el presupuesto óptimo para el esfuerzo del SNAP, tomando en consideración sus políticas, los precios del mercado y otras restricciones.

This work is dedicated to my Mother and Father which have supported me unconditionally since day one.

Acknowledgements

I want to thank God. God, without your guidance this wouldn't be possible.

I would like to express my gratitude to my family and friends for their support during all this time. Thanks for believing in me.

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List of Abbreviations

PAN	Nutritional Assistance Program
SNAP	Supplemental Nutritional Assistance Program
USDA	United State Department of Agriculture
DACO	Government Consumer Advocacy Agency
UPRM	University of Puerto Rico – Mayagüez Campus
TANF	Temporary Assistance for Needy Families
BMI	Body Mass Index

Chapter 1: Introduction

1.1 Justification

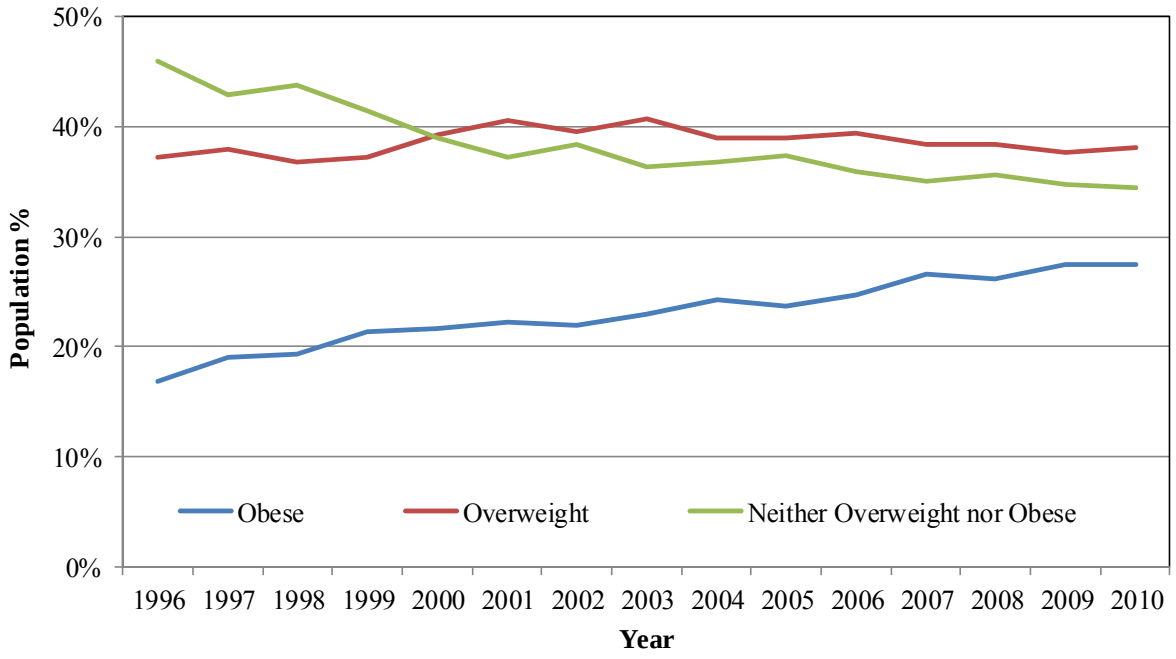
There is a strong link between money and an individual's ability to achieve an adequate nutrition. Thus, when there is an interest to provide the necessary resources for an individual's (or even a population's) nutritional needs, money will probably be the most important topic. This is the case of endeavors as large as a Government Nutritional Program, or as small as a family budget plan for food. This also applies to other fields such as animal husbandry, which are also concerned with budgeting decisions related to feeding livestock. In any case, there is a definite need to develop effective and efficient strategies for the allocation of monetary resources towards the fulfillment of the dietary needs of the individual. The justification for this research is the need to develop a tool that would aid the decision of "nutritional budgeting". Providing too little or too much money would produce undesirable outcomes.

Good nutrition is vital for the development and functioning of every organ in the body. Poor nutrition can lead to serious health complications. Bad nutrition is characterized by a low daily intake of vitamins, minerals and other vital compounds such as antioxidants. Diets high in simple sugars and refined carbohydrates, for example, provide an excess of calories but little or no nutrients, increasing the risk for obesity and nutrient deficiencies. Unhealthy foods might satisfy a person's hunger without providing any nutritional sustenance, creating the false impression that they are nourishing the body. Every unhealthy meal a person eats is harmful because it takes away an opportunity to eat healthy.

In Puerto Rico, good nutritional habits seem to be decreasing. According to The Behavioral Risk Factor Surveillance System, there is an increasing trend in obesity for Puerto Rico since

1996 *(http://apps.nccd.cdc.gov/BRFSS)*. Figure 1.1 shows that from 1996 to 2010 the obesity in Puerto Rico's population has increased more than 10%. Appendix A shows a detailed breakdown of this information.

Figure 1.1. Overweight and Obesity Rate in Puerto Rico since 1996

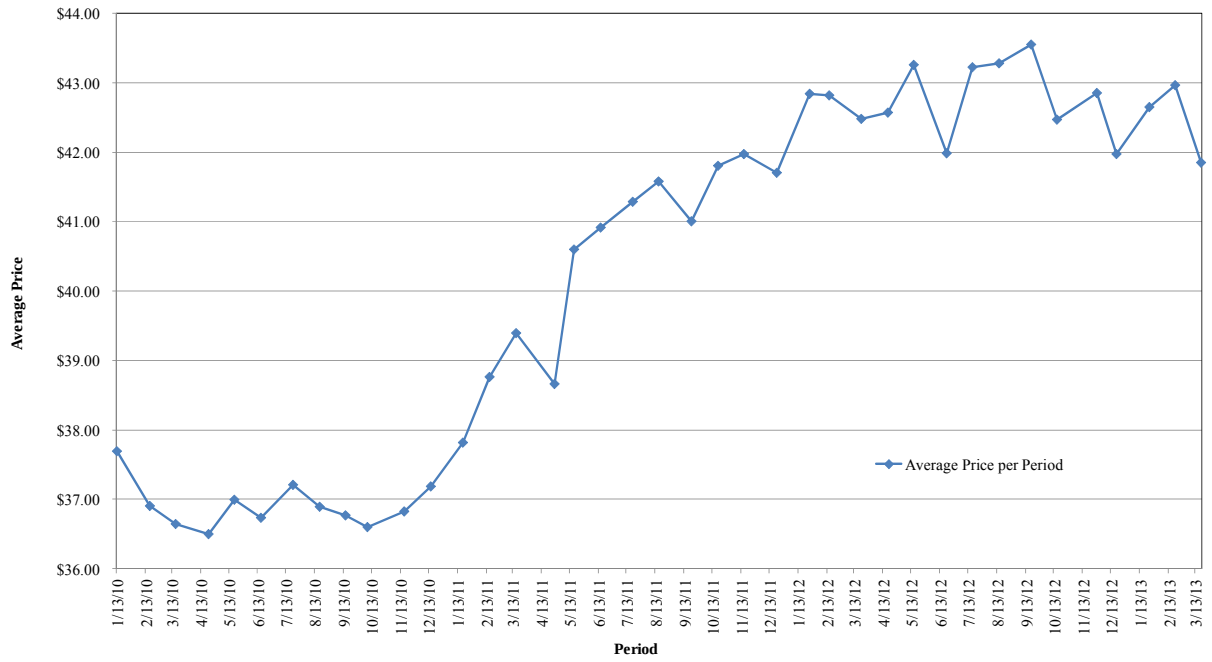


One of the primary causes for this tendency can be poor diet. Factors known to be associated with poor health status are poverty, unemployment, low education, and poor diet (Stoto, 1990, p.52) According to the Government Department of Family, more than 1,300,000 (Appendix B) family members in Puerto Rico are part of the Supplementary Nutritional Assistance Program (SNAP, or PAN in the case of Puerto Rico). In Puerto Rico, this program targets 75% of its use to buying food in certified stores and 25% in cash to buying food in stores that are not certified. This benefit is a fixed amount of money that is transferred electronically to the bank account of the user. One of the biggest restrictions for the PAN user is that this fixed amount of money doesn't take into consideration price fluctuations in the Basic Food Basket. With this restriction,

the user may be unable to achieve a healthy diet. The user may be forced to buy products with less nutritional benefits, or simply less of the right products due to budget constraints.

Figure 1.2 shows the price fluctuation for the current Basic Food Basket in Puerto Rico. According to the government consumer advocacy agency, from 2010 to 2013 prices have increased by approximately 12% (Appendix C).

Figure 1.2. Puerto Rico's Basic Food Basket Average Price per Period (DACO)



This Basic Food Basket is not entirely oriented to provide the best nutritional benefit to the user. It's based on the frequency of consumption within the Puerto Rican society. Due to this, the Basic Food Basket that will be used for this research focuses in the nutritional benefit and well being of every Puerto Rican citizen. This Basket was gathered from the study "Recommended Basic Food Basket" for Puerto Rico by the College of Agricultural Sciences from the University of Puerto Rico, Mayaguez Campus. Food Groups, such as cereals and farinaceous, vegetable and legumes, fruits, oils, milk and meat, are an essential part of this Basket. Table 1.1 shows the Recommended Basic Food Basket for Puerto Rico (College of Agricultural Sciences, 2012).

Table 1.1. Puerto Rico's Recommended Basic Food Basket, 2012

Food Group	Food
Cereals and Farinaceous	Rice
	Starchy Vegetables
	Bread
	Soda Crackers
	Oatmeal
Vegetable and Legumes	Dry Beans
	Pumpkin
	Lettuce
	Tomato
	Cabbage
Fruits	Citric
	Banana
	Mangos
	Papaya
	Watermelon
Oils	Oils
	Butter
	Margarine
	Avocado
Milk and Substitutes	Milk
	Cheese
Meat and Substitutes	Egg
	Chicken
	Beef
	Fish
	Pork
Condiments	Aromatic Herbs
	Sugar
	Salt

The objective of this research is to develop a method, through the application of Mathematical Programming. This will maximize the nutritional value of the average PAN participant taking into consideration their budget limitations. As a result of this research, the PAN user will be able to identify what food products and amounts that will maximize the nutritional value. The nutritional values of the Recommended Basic Food Basket are shown in appendix 7.

As of today (2012), the government of Puerto Rico spends more than 2 billion dollars (Appendix D) in funding for the Nutritional Assistance Program *(http://www.presupuesto.pr.gov)*. The majority of this funding comes from United States Federal Programs. In regards to the United States of America, the Supplemental Nutritional Assistance Program has been significantly increasing their benefits during the last years *(http://www.fns.usda.gov/pd/SNAPsummary.htm)*. The following two figures, Figures 1.3 and 1.4, show an increase of 65% for PAN and 379% for SNAP since 2000. According to the Center on Budget and Policy Priorities Organization, SNAP caseloads increased significantly between late 2007 and 2011 (Appendix E), as the recession and lagging recovery battered the economic circumstances of millions of Americans and dramatically increased the number of low-income households who qualified and applied for help from the program. This can explain the pronounced upward trend showed in the following two Figures during that particular period of time.

Figure 1.3. Total Benefits Granted to Support the PAN Since 2000

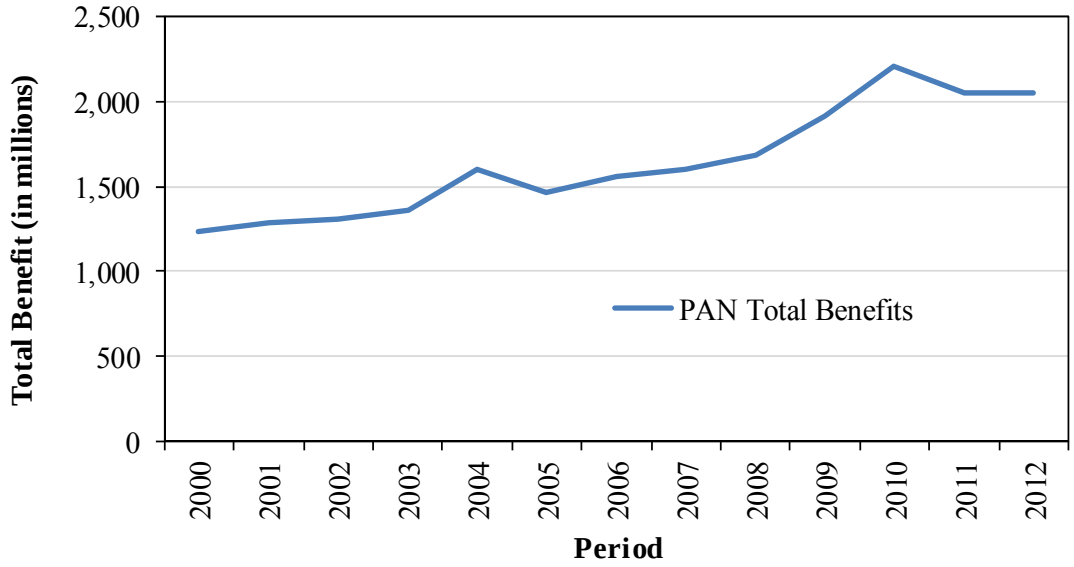
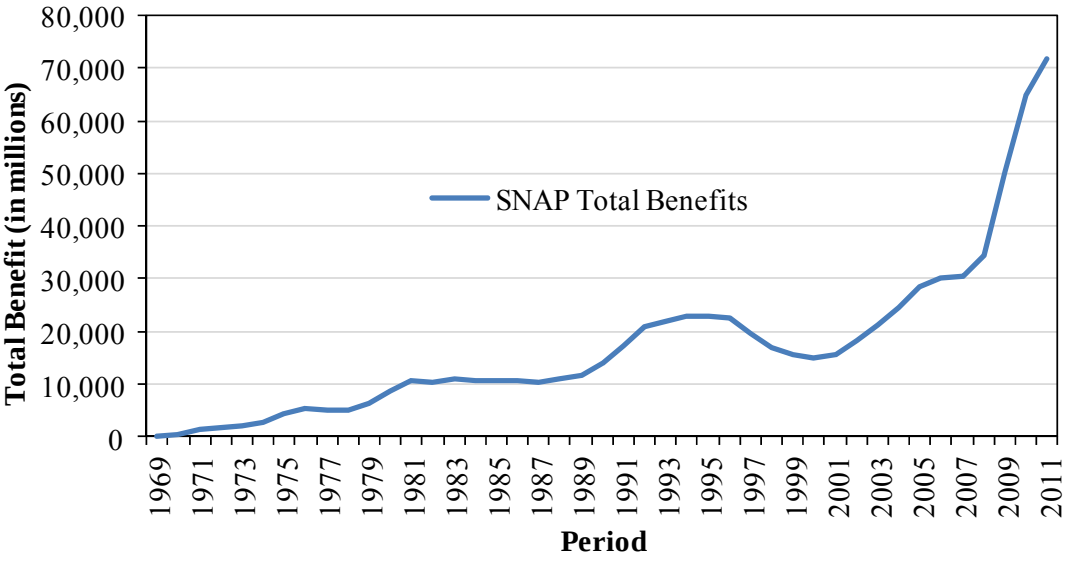


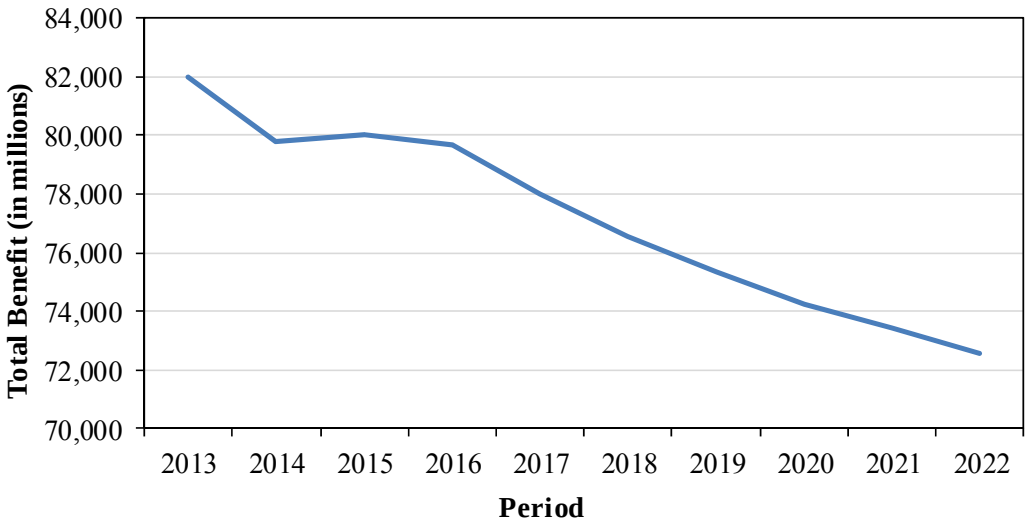
Figure 1.4. Total Benefits Granted to Support the SNAP Since 1969



The 2009 Recovery Act's temporary boost to Supplemental Nutrition Assistance Program (SNAP) benefits was scheduled to end on November 1, 2013, resulting in a benefit cut for nearly every SNAP household. In other words, cuts to the SNAP will be applied during the next 10

years, according to the Congressional Budget Office. Since the PAN is part of the SNAP, its budget will be affected directly and/or indirectly by these cuts. Taking into consideration these cuts, the PAN user needs to be more diligent and responsible with the spending of this benefit. The following figure 1.5 displays the forecasted SNAP budget for the next 10 years (Appendix F) which shows a decreasing trend due to the cuts that took place starting on November 1, 2013.

Figure 1.5. SNAP Forecasted Budget for the Next Ten Years



1.2 Objectives

The main objective of this research is to develop a tool that would help maximize the nutritional benefit of every PAN user, taking into consideration their fixed budget and the price fluctuation of the Basic Food Basket. As a result, the PAN user will be able to identify what products and what amounts will maximize his nutritional benefit.

Chapter 2: Literature Review

Our literature review encompasses the several different fields that are covered in the topic of the present work, namely food security, nutritional science, some political science in the form of the social policies adopted in the current American welfare system, mathematical programming, linear programming and the quality loss function.

2.1 Food Security

According to the UPRM committee that created the recommended Basic Food Basket for Puerto Rico, the creation of this basket rests on the threats to our food security. The Puerto Rican food security is being threatened due to the following factors:

- Increase on population (local and global).
- Loss of agricultural lands.
- Increase in the demand for consumers in emerging countries like India and China.
- Increases in crude oil process costs.
- The use of agricultural crops for biofuel production.
- Natural disasters.
- Wars.
- Climate change (droughts, floods, etc).

Table 1.2 shows the dimensions of food security applied to Puerto Rico which are very important.

Table 1.2. Dimensions of Food Security for Puerto Rico

Dimension	Status of Puerto Rico
Availability	Puerto Rico produces less than 20% of the food consumed. Foods are imported to the island mainly from the United States, this means the food travel approximately 2,800 miles on average from the point of origin to the consumer.
Accessibility	58 % of the population has access to the food by the benefits provided by the governments (Nutritional Assistance Program, WIC and School Meal Program)
Proper Use	Poor nutrition has caused health problems related to consumption of non-nutritious foods (E.g. obesity)
Systems Stability	Risk factors threaten the stability of systems of production and distribution of food: natural disasters, climate change, international trade policies, other.

2.2 Nutritional Science

Nutrition is the science of foods, the nutrients and other substances therein, their action, interaction and balance in relationship to health and disease; the processes by which the organism ingests, digests, absorbs, transports and utilizes nutrients and disposes of their end products (Srilakshmi, 2006, p.1). In addition, nutrition is concerned with social, economic, cultural and psychological implications of food and eating. Nutrition science is the area of knowledge regarding the role of food in the maintenance of health.

The health is defined by the World Health Organization as the “State of complete physical, mental and social well-being and not merely the absence of disease and infirmity” (McCormack,

Thomas & Kotecki, 2002, p.3). A good nutrition is fundamental to maintain a good health state. Due to this, the essential requisites (or dimensions) of health include the following:

- Achievement of optimal growth and development, reflecting the full expression of one's genetic potential.
- Maintenance of the structural integrity and functional efficiency of body tissues necessary for an active and productive life.
- Ability to withstand the inevitable process of ageing with minimal disability and functional impairment, and
- Ability to combat disease.
- Mental health

2.3 United States Welfare System

Federally funded and governed, US welfare began in the 1930's during the Great Depression. The US government responded to the overwhelming number of families and individuals in need of aid by creating a welfare program that would give assistance to those who had little or no income.

The US welfare system stayed in the hands of the federal government for the next sixty-one years. Many Americans were unhappy with the welfare system, claiming that individuals were abusing the welfare program by not applying for jobs, having more children just to get more aid, and staying unmarried so as to qualify for greater benefits. Welfare system reform became a hot topic in the 1990's. Bill Clinton was elected as President with the intention of reforming the federally run US Welfare program. In 1996 the Republican Congress passed a reform law signed by President Clinton that gave the control of the welfare system back to the states.

Eligibility for a Welfare program depends on numerous factors. Eligibility is determined using gross and net income, size of the family, and any crisis situation such as medical emergencies, pregnancy, homelessness or unemployment. A case worker is assigned to those applying for aid. They will gather all the necessary information to determine the amount and type of benefits that an individual is eligible for.

The Federal government provides assistance through the Temporary Assistance for Needy Families (TANF). The TANF is a grant given to each state to run their own welfare program. To help overcome the former problem of unemployment due to reliance on the welfare system, the TANF grant requires that all recipients of welfare aid must find work within two years of receiving aid, including single parents who are required to work at least 30 hours per week opposed to 35 or 55 required by two parent families. Failure to comply with work requirements could result in loss of benefits *(http://www.welfareinfo.org)*.

2.4 Mathematical Programming

Mathematical Programming is a modeling technique that is used as a powerful tool in decision making (Castillo, 2002, p.3). When dealing with a decision problem, the first step consists of identifying the possible decisions to be made; this leads to identifying the problems variables. Usually, decisions are of a quantitative character and we look for the values that optimize our objective. The second step consists of determining which decisions are admissible; this leads to a set of constraints that are determined according to the nature of the problem under consideration. In the third step, the cost/benefit ratio associated with each decision is calculated; this leads to an objective function, assigning to each set of values for the decision variables a given cost/benefit ratio. The set of all these elements is the data set.

Linear Programming, which deals only with linear objective functions and linear constrains, is a part of mathematical programming, and one of the most important areas of applied mathematics. It is used in many fields, as engineering, economics, business administration, and many other areas of science, technology and industry. Any Linear Programming problem requires identifying four basic elements: the set of data, the set of variables involved in the problem (together with their respective domains of definitions), the set of problem linear constrains that define the set of feasible solutions and the linear function to be optimized (minimized or maximized).

2.5 Linear Programming

The pioneering work in applying sophisticated mathematical tools for diet planning was done by George Dantzig (Dantzig, 1990). His objective was to determine a menu of foods that would satisfy nutritional requirements at a minimum cost. During the war, Dantzig was in charge of Air Force Statistical Control's Combat Analysis Branch in the Pentagon. In 1946-47, an opportunity came to Dantzig to mechanize the Air force's planning process. Having formulated a linear program model for this process, next he had to find a way to solve it. At a little bull session at the Pentagon with the Bureau of Labor's input/output team, one person suggested to test the new linear program model on Jerry Confiled's diet problem. Jerry said that he had worked on the problem several years for the Army who wanted a low cost diet that would meet the nutritional needs of a Government Issue soldier. It turned out that Cornfield couldn't find his input data and that it was necessary to reconstruct the diet problem from scratch. Due to this, Dantzig followed up three leads: the cost of foods from the Bureau of Labor Statistics, the nutritional requirements of a person from a brochure issued by the National Research Council of the National Academy of Sciences and the nutritional contents of various foods from the Bureau

of Home Economics of the Department of Agriculture. As a result of this application, a low cost diet was identified.

The modeling and analysis of a linear programming problem in particular evolves through several stages. The *problem formulation phase* stage involves a detailed study of the system, data collection, and the identification of the specific problem that needs to be analyzed, along with the system constrains, restrictions, or limitations and the objective function (Bazaraa, Jarvis & Sherali, 1990, p.7). In any linear programming problem, the decision maker wants to maximize (usually revenue or profit) or minimize (usually cost) some function of the decision variables (Winston, 1993, p.50). The function to be maximized or minimized is called the objective function.

The next stage involves the construction of an abstraction or an idealization of the problem through a *mathematical model*. Care must be taken to ensure that the model satisfactorily represents the system being analyzed, but keeps the model mathematically tractable. This compromise must be made judiciously, and the underlying assumptions inherent in the model must be properly considered. The third step is to *derive a solution*. A proper technique that exploits any special structures (if present) must be chosen or designed. One or more optimal solutions may be sought, or only a heuristic or an approximate solution may be determined along with some assessment of its quality (Bazaraa, Jarvis & Sherali, 1990, p.8).

The fourth stage is *model testing, analysis, and (possibly) restructuring*. One examines the model solution and its sensitivity to various system parameters, and studies its predictions to various types of scenarios. This analysis provides insights into the system. One can also use this analysis to ascertain the reliability of the model by comparing the predicted outcomes with the expected outcomes, using either past experience or conducting the test retroactively using

historical data. At this stage, one may wish to enrich the model further by incorporating other important features of the system that have not been modeled as yet, or, on the other hand, one may choose to simplify the model (Bazaraa, Jarvis & Sherali, 1990, p.8).

The final stage is implementation. The model is set up to interactively aid in the decision-making process. The model should never replace the decision maker. Often a "frank factor" based on judgment and experience needs to be applied to the model solution before making policy decisions (Bazaraa, Jarvis & Sherali, 1990, p.8).

This is the formulation of a particular type of linear programming problem. Any general linear programming problem may be manipulated into this form (Bazaraa, Jarvis & Sherali, 1990, p.2).

$$
\begin{aligned}
\text{Minimize} \quad & c_1x_1 + \ c_2x_2 + \ \ldots + c_nx_n \\
\text{Subject to} \quad & a_{11}x_1 + \ a_{12}x_2 + \cdots + \ a_{1n}x_n \geq b_1 \\
& a_{21}x_1 + \ a_{22}x_2 + \cdots + \ a_{2n}x_n \geq b_2 \\
& \vdots \qquad \vdots \qquad\qquad \vdots \quad \vdots \\
& a_{m1}x_1 + a_{m2}x_2 + \cdots + a_{mn}x_n \geq b_m \\
& x_1, \qquad x_2, \quad \cdots, \qquad x_n \geq 0
\end{aligned}
\qquad \textbf{Equation 2.1}
$$

Here $c_1x_1 + c_2x_2 + \cdots + c_nx_n$ is the *objective function* to be minimized and will be denoted by z. The coefficients $c_1, c_2, \cdots, c_n$ are the (known) *cost coefficients* and $x_1, x_2, \cdots, x_n$ are the *decisions variables* to be determined. The inequality $\sum_{j=1}^{n} a_{ij}x_j \geq b_i$ denotes the ith constraint (or restriction or functional, structural, or technological constraint). The coefficients a_{ij} for $i = 1, 2, \cdots, m, \ \ j = 1, 2, \cdots, n$ are called the technological coefficients. The constraints

$x_1, x_2, \cdots, x_n \geq 0$ are the *nonnegativity constraints*. A set of variables $x_1, \cdots, x_n$ satisfying all the constraints is called a *feasible point* or the *feasible space*.

Using the foregoing terminology, the linear programming problem can be stated as follows: Among all feasible vectors, find one that minimize (or maximizes) the objective function.

2.6 Taguchi Quality Loss Function

The Taguchi quality loss function is a quadratic equation showing increasing cost as a quality characteristic deviates from the target value (Pries, 2009, p.68). It contrasts with the old fashioned tolerance concept, where any value within tolerance is adequate. In short, we are looking at inside tolerance being adequate versus not on target being exponentially and increasingly worse. The function indicates that we lose quality with any deviation from the target value. In some cases, specification limits may be the result of a company policy. In other cases, specification limits may be derived from expected values for random variation. In addition to all this, the concept of worst-case tolerances stackup may enter the discussion if the part is a mechanical piece. In a stackup analysis, the relation of multiple parts can be considered simultaneously to determine if the parts will fit together under the worst-case conditions. A variety of methods exists to accomplish the objective of verifying fit, with root square stackup being perhaps the most sophisticated approach to the problem.

However, the Quality Loss Function effectively says we pay a penalty for any deviation from the target (or nominal) value. It is easy to see this in a plot of the loss function as the deviation increases from the target value. One version of the quality loss function, below, exacts a high penalty for deviations from target:

$m = target\ value$

$y = quality\ characteristic$

$Loss\ Function = L(y) = k(y - m)^2$

$k = (cost\ of\ defective\ product)/(deviation\ from\ target)^2$ **Equation 2.2**

One of the main contributions of this research is our proposal that the Taguchi concept be applied to the diet problem, substituting a nutritional target for the original quality target. Thus, the farther a diet's protein content deviates from the ideal (i.e. nutritionist defined) amount, the diet is less desirable. Such loss in desirability increases with the square of the nutritional deviation. This way, we opt for designing a quadratic linear program for finding the best possible diet given the budget assigned.

Chapter 3: Methodology

The methodology for this work is intended to be quantitative. The series of steps are the followings:

1. *Identify the problem and the objectives to be achieved*. Once it has been determined that a problem exists, the problem must be clearly and concisely defined. Improperly defining a problem can easily result in no solution or an inappropriate solution. Therefore, the limits of the problems and the degree to which it pervades other units of the organization must be included in the problem definition. Because the existence of a problem implies that the objectives of the firm are not being me in some way, the goals (or objectives) of the organization must also be clearly defined. A stated objective helps to focus attention on what the problem actually is.
2. *Identify the variables to be manipulated in order to achieve the best solution.* The variables are symbols used to represent an item that can take on any value.

3. *Define the parameters and data required in order to best satisfy the objectives*. The parameters are constant values that are generally coefficients of the variable (symbols) in an equation. Parameters usually remain constant during the process of solving a specific problem. The parameters values are derived from the data from the problem environment.
4. *Define a model to find the optimal solution for the variables when applied to the objective*. The model is an abstract mathematical representation of a problem situation. Once the model has been constructed, it is solved using a mathematical programming technique. The solution can be either a recommended decision or information that helps to make a decision.
5. *Illustrate the process with a hypothetical situation (Implementation)*. The implementation is the actual use of the model once it has been developed or the solution to the problem the model was developed to solve.

The final model for our problem is shown in detail in Appendix L, where we show our Quadratic Program. The objective function of this mathematical program maximizes the nutritional benefit of the products contained in the proposed Basic Food Basket by minimizing the difference between the nutrients (Appendix G, H & I) of every product and its optimal nutritional value.

Chapter 4: Results

The Mathematical Program proposed in the methodology section was applied to a hypothetical person with an average set of nutritional needs (according to our nutritional literature review). As we defined in our objective function, the higher its final value, the greater the optimal diet's deviation from ideal. We thus optimized the program subject to varying budgets, from $1 to $20 per day, and observed the change in the objective function. We performed the optimization using the popular LINDO software package.

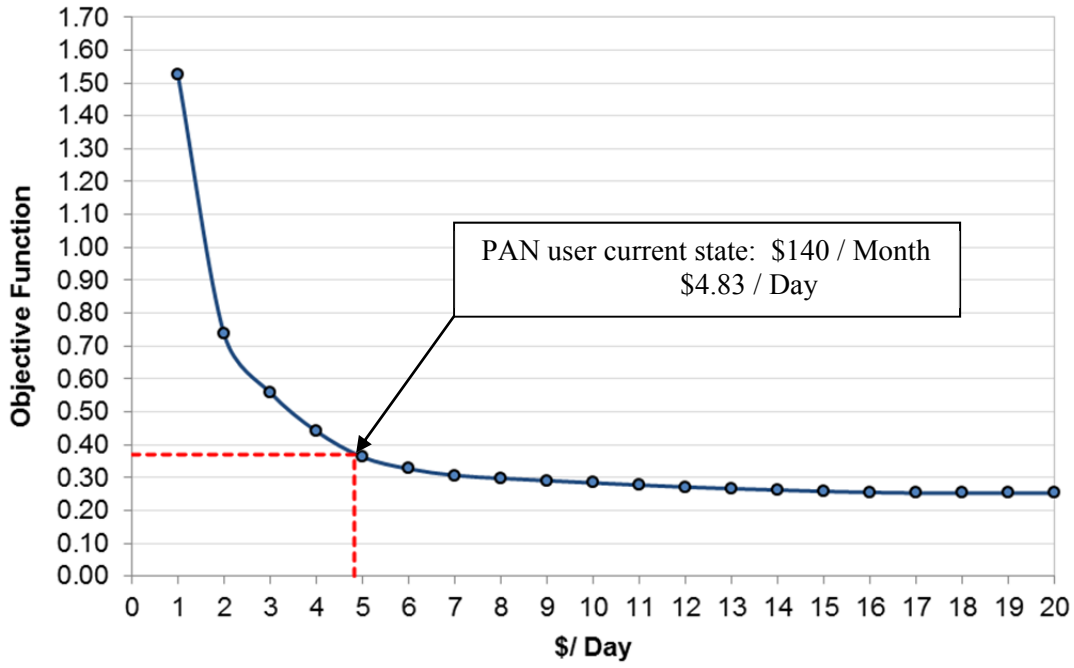
After the compilation and execution of the Mathematical Program, in Table 4.1 are shown the results for the objective function.

Table 4.1. Optimization Results

$ / Day	$ / Month (30 Days)	Objective Function
1	30	1.526
2	60	0.737
3	90	0.559
4	120	0.441
5	150	0.363
6	180	0.327
7	210	0.307
8	240	0.297
9	270	0.291
10	300	0.284
11	330	0.277
12	360	0.271
13	390	0.266
14	420	0.262
15	450	0.258
16	480	0.255
17	510	0.253
18	540	0.253
19	570	0.253
20	600	0.253

Currently, a PAN user gets $140 per month at the most. This represents a consumption of $4.83 per day. This amount of money will minimize our objective function up to 0.375. A graphical representation of this data is shown next.

Figure 4.1. Optimization Results due to an assigned budget.



The graph shown in figure 4.1 can be used by management to plan a budget for PAN. For example, it follows from the graph that for budgets greater than, say $6, the returns have considerably diminished, and thus it would be wasteful to assign more money than that. On the other hand, we see significant returns for budgets less than, say $4, and thus it would not be advisable to assign less than that to the budget. Therefore the program managers should choose a budget somewhere between $4 and $6 dollars, depending on how much we can afford, as well as the policies in place. Table 4.2 shows the combinations of products that optimize the objective function taking in consideration different budgets. These combinations take into consideration

only the nutritional value of every product and does not takes into consideration personal preferences. The combination that best fits the current PAN users' budget is the combination of 5 dollars per day.

Table 4.2. Objective Function Product Combination

Basic Food Basket (Serving 100 g)	$/day																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Rice	1.36	1.08	1.13	1.19	1.39	1.66	1.68	1.52	1.49	1.46	1.43	1.40	1.37	1.43	1.43	1.41	1.39	1.38	1.38	1.38
Sweet Potato	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plantains	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bread	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.08	0.08	0.08	0.12	0.15	0.01	0.00	0.00	0.00	0.01	0.01	0.01
Soda Crackers	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oatmeal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dry Beans	0.76	0.95	0.78	0.57	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pumpkin	0.45	5.94	6.55	5.98	4.98	3.44	2.64	1.66	2.24	2.82	3.38	3.53	3.68	3.81	3.94	4.10	4.16	4.14	4.14	4.14
Lettuce	0.00	0.00	0.00	0.00	0.00	0.00	0.55	1.10	1.19	1.27	1.36	1.41	1.46	1.40	1.40	1.44	1.49	1.51	1.51	1.51
Tomato	0.00	0.00	0.00	4.54	8.50	10.63	11.90	11.68	10.81	9.94	9.09	8.72	8.35	8.44	8.25	7.92	7.71	7.66	7.66	7.66
Cabbage	0.57	0.83	0.91	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mandarin Oranges	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lemon	0.28	0.00	2.70	2.28	1.80	1.56	0.84	1.82	2.05	2.28	2.50	2.61	2.71	2.76	2.83	2.94	3.03	3.05	3.05	3.05
Grapefruit	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bananas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mangos	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Papayas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Watermelon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oil (Canola)	0.51	0.56	0.52	0.47	0.43	0.39	0.34	0.32	0.32	0.32	0.33	0.33	0.34	0.40	0.43	0.45	0.45	0.45	0.45	0.45
Oil (Olive)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Butter	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Margarine	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avocados	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Milk	0.94	0.55	0.31	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cheese	0.00	0.05	0.43	0.85	1.11	1.15	1.16	1.28	1.25	1.22	1.18	1.16	1.13	1.19	1.19	1.18	1.16	1.16	1.16	1.16
Egg	0.00	0.00	0.37	0.63	0.58	0.48	0.35	0.30	0.25	0.20	0.15	0.11	0.08	0.14	0.17	0.14	0.10	0.09	0.09	0.09
Chicken (Breast)	0.00	0.00	0.00	0.00	0.00	0.00	0.70	0.55	0.81	1.08	1.33	1.33	1.31	0.54	0.07	0.00	0.00	0.00	0.00	0.00
Beef (Ground)	0.00	0.20	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fish (Cod)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.66	1.10	1.53	1.95	2.38	3.00	3.53	3.97	4.37	4.49	4.49	4.49
Fish (Tuna)	0.00	0.00	0.00	0.00	0.39	1.25	1.33	1.62	1.23	0.85	0.49	0.39	0.29	0.23	0.16	0.05	0.00	0.00	0.00	0.00
Pork (Chop)	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sugar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salt	0.03	0.03	0.02	0.01	0.01	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Oregano	0.00	0.00	0.00	0.00	0.02	0.07	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cilantro	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Objective Function	1.526	0.737	0.559	0.441	0.363	0.327	0.307	0.297	0.291	0.284	0.277	0.271	0.266	0.262	0.258	0.255	0.253	0.253	0.253	0.253

Chapter 5: Conclusions and Recommendations

5.1 Conclusions

This research developed a tool that can help the PAN participants determine the best diet for their nutrition, taking into consideration the product price fluctuations and the PAN fixed budget. Nutritional Benefit varies according to the amount of budget invested. Since PAN users just had a fixed budget available to address their nutritional needs, the mathematical program offers the user the combinations of products that maximize the nutritional benefit. The output of this mathematical program accomplishes the purpose of this research.

This application can also help other sectors beside the PAN users. Sectors such as the Government and the Livestock Industry can benefit from this mathematical program. This program can help these two organizations to determine the proper amount of budget to be utilized in order to maximize the nutritional benefit of the end goal. Also, the program identifies the point where the objective function provides diminishing returns for the budget the sector is willing to spent. It is extremely important to know the point where the output of the investment is optimized.

We came to the conclusion that this mathematical program can be an effective tool for policy makers to determine the budget intended to supply food support as well as to help those individuals enrolled in such food programs to maximize their nutritional benefits.

5.2 Future Research

There are several areas for future research regarding the topic discussed in this thesis. First, the preferences of food consumption of the PAN users can be incorporated into the Quadratic Linear Program Model. This will require an assessment of our population food consumption.

Another area of opportunity is to incorporate this model into other sectors such as the Livestock Industry. To accomplish this, it will be required to identify the nutritional requirements and the type of food available for these animals.

For the objective function of this Quadratic Linear Model Program there is an area for future research. The objective function can be modified from Quadratic to Linear to see if the optimization of the objective function provides better results.

Chapter 6: Study Limitations

The following are limitations that were present in the execution of this research:

- This study was based strictly on nutritional elements and not on personal preferences.
- The diet choices were limited to 35 products covered by the Recommended Basic Food Basket for Puerto Rico.
- It was presumed that the products included in Appendix G and I were available at any time.
- The prices of every product on the Recommended Basic Food Basket for Puerto Rico are constantly changing. In this study we assumed these prices are static (Appendix K).

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Appendixes

Appendix A: Puerto Rico's Overweight and Obesity (BMI) Data.

Data retrieved from the Behavioral Risk Factor Surveillance System.

Puerto Rico's Overweight and Obesity (BMI)
Prevalence and Trend Data (1996-2009)

Year	Obese	Overweight	Neither overweight nor obese
1996	16.8%	37.2%	46.0%
1997	19.0%	38.0%	42.9%
1998	19.3%	36.8%	43.8%
1999	21.3%	37.2%	41.5%
2000	21.7%	39.3%	39.0%
2001	22.2%	40.6%	37.2%
2002	22.0%	39.6%	38.4%
2003	22.9%	40.7%	36.4%
2004	24.3%	39.0%	36.7%
2005	23.7%	39.0%	37.3%
2006	24.7%	39.4%	35.9%
2007	26.6%	38.3%	35.0%
2008	26.2%	38.3%	35.6%
2009	27.5%	37.7%	34.8%
2010	27.5%	38.1%	34.4%

Appendix B: PAN Family Members Users

PAN Family Members Users			
Period	2009	2010	2011
January	1,173,080	1,294,130	1,345,081
February	1,179,643	1,294,904	1,349,467
March	1,187,574	1,298,986	1,352,614
April	1,194,033	1,303,272	1,356,153
May	1,200,007	1,311,546	1,356,737
June	1,204,789	1,309,687	1,356,802
July	1,215,353	-	
August	1,232,705	1,323,089	
September	1,243,653	1,327,695	
October	1,253,293	1,337,007	
November	1,260,920	1,341,743	
December	1,284,965	1,341,992	

Appendix C: Prices for the Basic Food Basket for Puerto Rico, according to DACO

Canasta Básica de Alimentos de Puerto Rico

Periodo	Artículo																			Total:
	1- Habichuelas Lata 15.5 oz	2- Habichuelas Secas 1 lb	3- Papas Bolsa 5 lb	4- Arroz Grano Mediano 3 lb	5- Arroz Grano Largo 3 lb	6- Arroz Grano Corto 3 lb	7- Pollo Fresco Entero por lb	8- Pollo Fresco Muslos con cadera por lb	9- Pollo Fresco Pechuga lb	10- Chuletas Congeladas Molidas por lb	11- Chuletas Congeladas Centro por lb	12- Corned Beef 12 oz	13- Salsa Tomate 8 oz	14- Leche Evaporada 12 oz	15- Pan Especial Regular 20 oz	16- Aceite Maíz 96 oz	17- Queso Americano Slice 12 Oz	18- Vegetales Lata 8 oz	19- Salchicha Pollo 5 oz	20- Salchicha Carne 5 oz	
10/16/2012	0.75	$1.39	$2.92	$1.64	$1.97	$2.47	$1.44	$2.03	$2.21	$2.35	$2.85	$4.44	$0.32	$1.05	$2.49	$6.95	$2.91	$0.75	$0.72	$0.82	**$42.47**
09/19/2012	0.75	$1.37	$2.94	$1.68	$1.93	$2.51	$1.46	$1.94	$2.22	$2.62	$3.07	$4.88	$0.32	$1.08	$2.52	$7.31	$2.68	$0.75	$0.72	$0.80	**$43.55**
08/15/2012	0.75	$1.39	$2.99	$1.68	$1.91	$2.43	$1.45	$2.01	$2.20	$2.60	$3.09	$4.55	$0.33	$1.04	$2.50	$7.34	$2.75	$0.74	$0.72	$0.81	**$43.28**
07/18/2012	$0.76	$1.35	$2.96	$1.75	$1.97	$2.50	$1.41	$1.94	$2.18	$2.65	$3.10	$4.57	$0.33	$1.06	$2.51	$7.14	$2.78	$0.72	$0.73	$0.82	**$43.23**
06/20/2012	$ 0.74	$1.39	$2.75	$1.72	$1.93	$2.35	$1.43	$1.97	$2.13	$2.57	$2.97	$4.52	$0.34	$1.03	$2.47	$7.49	$2.68	$0.74	$0.71	$0.80	**$41.99**
05/16/2012	$0.75	$1.38	$2.84	$1.73	$2.09	$2.44	$1.42	$1.98	$2.27	$2.23	$2.80	$4.65	$0.33	$1.12	$2.70	$7.33	$2.84	$0.76	$0.72	$0.88	**$43.26**
04/18/2012	$0.72	$1.46	$2.79	$1.75	$1.99	$2.52	$1.37	$1.94	$2.05	$2.60	$2.75	$4.58	$0.31	$1.06	$2.54	$7.22	$2.69	$0.74	$0.71	$0.78	**$42.57**
03/21/2012	$0.71	$1.35	$2.92	$1.75	$1.98	$2.53	$1.35	$1.96	$1.96	$2.58	$3.02	$4.36	$0.32	$1.10	$2.54	$7.14	$2.76	$0.71	$0.71	$0.73	**$42.48**
02/15/2012	$0.71	$1.30	$2.85	$1.75	$1.99	$2.48	$1.38	$1.77	$2.18	$2.76	$3.03	$4.45	$0.32	$1.07	$2.43	$7.30	$2.85	$0.72	$0.69	$0.79	**$42.82**
01/25/2012	$0.71	$1.32	$2.74	$1.78	$1.98	$2.40	$1.31	$1.93	$2.02	$2.71	$3.07	$4.42	$0.32	$1.12	$2.40	$7.59	$2.84	$0.72	$0.70	$0.76	**$42.84**
12/21/2011	$0.69	$1.27	$2.57	$1.75	$2.04	$2.67	$1.30	$1.76	$1.86	$2.62	$3.03	$4.34	$0.32	$1.02	$2.41	$7.13	$2.76	$0.72	$0.70	$0.75	**$41.71**
11/16/2011	$0.66	$1.26	$2.80	$1.78	$2.01	$2.44	$1.35	$1.76	$2.10	$2.66	$3.06	$4.15	$0.33	$1.05	$2.32	$7.40	$2.74	$0.69	$0.69	$0.72	**$41.97**
10/19/2011	$0.67	$1.21	$3.02	$1.78	$1.99	$2.49	$1.31	$1.88	$2.16	$2.76	$2.91	$4.05	$0.31	$1.08	$2.00	$7.43	$2.68	$0.69	$0.69	$0.70	**$41.81**
09/21/2011	$0.64	$1.18	$3.21	$1.75	$2.01	$2.36	$1.31	$1.81	$2.11	$2.21	$2.92	$3.92	$0.32	$1.17	$2.07	$7.21	$2.72	$0.69	$0.67	$0.72	**$41.00**
08/16/2011	$0.65	$1.16	$3.13	$1.77	$2.00	$2.47	$1.33	$1.85	$1.95	$3.11	$2.93	$3.65	$0.32	$1.09	$2.14	$7.25	$2.67	$0.69	$0.69	$0.73	**$41.58**
07/20/2011	$0.66	$1.17	$2.82	$1.85	$2.02	$2.40	$1.40	$1.90	$2.26	$2.09	$2.79	$4.26	$0.32	$1.02	$2.06	$7.56	$2.63	$0.68	$0.69	$0.71	**$41.29**
06/15/2011	$0.64	$1.15	$2.67	$1.79	$2.07	$2.38	$1.28	$1.86	$1.97	$2.42	$2.99	$4.47	$0.31	$1.02	$2.13	$7.15	$2.50	$0.69	$0.68	$0.74	**$40.91**
05/18/2011	$0.65	$1.16	$2.71	$1.86	$2.03	$2.42	$1.29	$1.98	$2.09	$2.48	$2.86	$3.99	$0.32	$1.03	$2.03	$7.12	$2.46	$0.68	$0.68	$0.76	**$40.60**
04/27/2011	$0.66	$1.18	$2.61	$1.85	$2.06	$2.42	$1.21	$1.86	$1.88	$2.39	$2.98	$2.39	$0.32	$0.97	$2.05	$7.22	$2.51	$0.69	$0.68	$0.73	**$38.66**
03/17/2011	$0.65	$1.14	$2.73	$1.88	$2.00	$2.37	$1.28	$1.82	$2.02	$2.22	$2.96	$3.01	$0.32	$1.58	$2.07	$6.68	$2.51	$0.71	$0.69	$0.75	**$39.39**
02/16/2011	$0.68	$1.15	$2.91	$1.82	$2.00	$2.26	$1.17	$1.68	$2.00	$2.42	$2.86	$3.12	$0.32	$1.07	$2.18	$6.47	$2.45	$0.70	$0.72	$0.78	**$38.76**
01/19/2011	$0.67	$1.18	$2.73	$1.67	$1.87	$2.11	$1.27	$1.88	$1.76	$2.37	$2.93	$2.87	$0.32	$1.05	$2.04	$6.44	$2.46	$0.73	$0.70	$0.77	**$37.82**
12/15/2010	$0.66	$1.16	$2.73	$1.60	$1.86	$2.13	$1.29	$1.79	$1.82	$2.39	$2.96	$2.77	$0.32	$0.95	$2.09	$6.03	$2.48	$0.69	$0.69	$0.77	**$37.18**
11/17/2010	$0.65	$1.18	$2.40	$1.64	$1.86	$2.10	$1.21	$1.91	$2.13	$2.38	$2.82	$2.60	$0.32	$1.00	$2.03	$5.93	$2.57	$0.68	$0.68	$0.73	**$36.82**
10/08/2010	$0.66	$1.15	$2.71	$1.65	$1.81	$2.13	$1.25	$1.85	$1.96	$2.34	$2.75	$2.53	$0.35	$1.07	$2.10	$5.65	$2.51	$0.70	$0.69	$0.74	**$36.60**
09/15/2010	$0.66	$1.15	$2.87	$1.75	$1.85	$2.18	$1.23	$1.59	$1.75	$2.23	$2.82	$2.51	$0.32	$1.02	$2.10	$5.95	$2.62	$0.71	$0.69	$0.77	**$36.77**
08/18/2010	$0.65	$1.15	$2.82	$1.75	$1.88	$2.19	$1.35	$1.95	$2.05	$2.21	$2.77	$2.39	$0.32	$1.00	$2.11	$5.70	$2.49	$0.70	$0.69	$0.72	**$36.89**
07/21/2010	$0.66	$1.14	$2.69	$1.80	$1.88	$2.24	$1.36	$1.95	$2.01	$2.26	$2.81	$2.51	$0.32	$1.09	$2.09	$5.71	$2.56	$0.70	$0.69	$0.73	**$37.20**
06/16/2010	$0.68	$1.14	$2.46	$1.83	$1.91	$2.25	$1.32	$1.96	$2.03	$2.12	$2.69	$2.41	$0.35	$1.14	$2.14	$5.67	$2.55	$0.70	$0.68	$0.70	**$36.73**
05/19/2010	$0.67	$1.18	$2.56	$1.84	$1.96	$2.31	$1.30	$1.89	$2.02	$2.03	$2.72	$2.55	$0.32	$1.00	$2.10	$5.73	$2.64	$0.71	$0.69	$0.77	**$36.99**
04/21/2010	$0.66	$1.18	$2.45	$1.84	$1.98	$2.25	$1.26	$1.82	$1.98	$2.07	$2.71	$2.53	$0.32	$0.99	$2.07	$5.58	$2.65	$0.70	$0.69	$0.77	**$36.50**
03/17/2010	$0.66	$1.18	$2.43	$1.93	$1.93	$2.24	$1.31	$1.97	$1.99	$2.01	$2.52	$2.50	$0.32	$1.04	$2.13	$5.58	$2.77	$0.69	$0.68	$0.76	**$36.64**
02/17/2010	$0.66	$1.18	$2.68	$1.85	$1.92	$2.35	$1.30	$1.97	$1.91	$1.94	$2.69	$2.52	$0.32	$1.04	$2.11	$5.68	$2.69	$0.69	$0.68	$0.72	**$36.90**
01/13/2010	$0.66	$1.17	$2.80	$1.93	$1.94	$2.34	$1.29	$1.87	$2.09	$2.04	$2.75	$2.58	$0.32	$1.02	$2.09	$5.85	$2.81	$0.70	$0.68	$0.76	**$37.69**

Appendix D: PR Nutritional Assistance Program Funding (in thousands of dollars)

Nutritional Assistance Program Funding (in thousands of dollars)

Period	Federal Funds	Federal Funds: ARRA	General Budget Resolution	Stabilization Fund	Total Benefits
2000	1,201,810	0	33,449	0	1,235,259
2001	1,249,362	0	32,264	0	1,281,626
2002	1,282,992	0	29,380	0	1,312,372
2003	1,325,626	0	36,498	0	1,362,124
2004	1,515,481	0	80,550	0	1,596,031
2005	1,415,871	0	52,645	0	1,468,516
2006	1,504,159	0	50,970	0	1,555,129
2007	1,550,969	0	50,870	0	1,601,839
2008	1,624,651	59,260	0	0	1,683,911
2009	1,765,288	90,078	57,076	0	1,912,442
2010	1,749,486	409,026	24,061	26,185	2,208,758
2011	1,747,736	256,793	17,388	32,885	2,054,802
2012	2,003,699	0	44,101	0	2,047,800

Appendix E: US Supplemental Nutrition Assistance Program Costs (in millions of dollars)

US Supplemental Nutrition Assistance Program Costs
(in millions of dollars)

Period	Total Benefits	Period	Total Benefits
1969	228.8	1991	17,315.77
1970	549.7	1992	20,905.68
1971	1,522.70	1993	22,006.03
1972	1,797.30	1994	22,748.58
1973	2,131.40	1995	22,764.07
1974	2,718.30	1996	22,440.11
1975	4,385.50	1997	19,548.86
1976	5,326.50	1998	16,890.49
1977	5,067.00	1999	15,769.40
1978	5,139.20	2000	14,983.32
1979	6,480.20	2001	15,547.39
1980	8,720.90	2002	18,256.20
1981	10,629.90	2003	21,404.28
1982	10,208.30	2004	24,618.89
1983	11,152.30	2005	28,567.88
1984	10,696.10	2006	30,187.35
1985	10,743.60	2007	30,373.27
1986	10,605.20	2008	34,608.40
1987	10,500.30	2009	50,359.92
1988	11,149.10	2010	64,702.16
1989	11,669.78	2011	71,810.99
1990	14,142.79		

Appendix F: US Supplemental Nutrition Assistance Program Forecasted Budget (in millions of dollars)

SNAP Forcasted Budget

Period	Forecasted Budget
2013	82,002
2014	79,784
2015	80,043
2016	79,648
2017	78,008
2018	76,564
2019	75,322
2020	74,214
2021	73,449
2022	72,572

Appendix G: Recommended Basic Food Basket Nutrients Matrix (Based on USDA National Nutrient Database) - Part 1

Nutrient	Unit	Cereals and Farinaceous						Vegetable and Grains				
		Rice	Sweet Potato	Plantains	Bread	Soda Crackers	Oatmeal	Dry Beans	Pumpkin	Lettuce	Tomato	Cabbage
Proximates												
Water	g	13.29	77.28	65.28	36.34	3	8.8	10.06	91.6	94.61	94.52	92.18
Energy	kcal	358	86	122	265	414	367	343	26	17	18	25
Protein	g	6.5	1.57	1.3	9.15	5.6	16	20.96	1	1.23	0.88	1.28
Total lipid (fat)	g	0.52	0.05	0.37	3.19	11.5	6.3	1.13	0.1	0.3	0.2	0.1
Carbohydrate	g	79.15	20.12	31.89	49.06	74	67	64.19	6.5	3.29	3.89	5.8
Fiber	g	2.8	3	2.3	2.7	3.3	9.8	12.7	0.5	2.1	1.2	2.5
Sugars	g	0	4.18	15	5.07	2.3	1	2.14	2.76	1.19	2.63	3.2
Minerals												
Calcium, Ca	mg	3	30	3	260	0	52	130	21	33	10	40
Iron, Fe	mg	4.23	0.61	0.6	3.59	4.3	4.2	6.77	0.8	0.97	0.27	0.47
Magnesium, Mg	mg	23	25	37	25	0	148	182	12	14	11	12
Phosphorus, P	mg	95	47	34	103	0	474	415	44	30	24	26
Potassium, K	mg	76	337	499	115	0	350	1464	340	247	237	170
Sodium, Na	mg	1	55	4	491	597	4	8	1	8	5	18
Zinc, Zn	mg	1.1	0.3	0.14	0.84	0	3.07	2.55	0.32	0.23	0.17	0.18
Vitamins												
Vitamin C	mg	0	2.4	18.4	0	0	0	0	9	4	13.7	36.6
Thiamin	mg	0.565	0.078	0.052	0.533	0.62	0.73	0.772	0.05	0.072	0.037	0.061
Riboflavin	mg	0.048	0.061	0.054	0.243	0.39	0.14	0.192	0.11	0.067	0.019	0.04
Niacin	mg	4.113	0.557	0.686	4.78	5.1	0.78	1.892	0.6	0.313	0.594	0.234
Vitamin B-6	mg	0.171	0.209	0.299	0.087	0	0.12	0.527	0.061	0.074	0.08	0.124
Folate	µg	389	11	22	171	0	0	463	16	136	15	43
Vitamin B-12	µg	0	0	0	0	0	0	0	0	0	0	0
Vitamin A, RAE	µg	0	709	56	0	0	0	0	426	436	42	5
Vitamin E	mg	0	0.26	0.14	0.22	0	0.47	0.21	1.06	0.13	0.54	0.15
Vitamin D	µg	0	0	0	0	0	0	0	0	0	0	0
Vitamin K (phylloquinone)	µg	0	1.8	0.7	0.2	0	0	5.7	1.1	102.5	7.9	76
Lipids												
Fatty acids, total polyunsaturated	g	0.138	0.014	0.069	1.602	1.07	2.3	0.487	0.005	0.16	0.083	0.017
Cholesterol	mg	0	0	0	0	0	0	0	0	0	0	0

Appendix H: Recommended Basic Food Basket Nutrients Matrix (Based on USDA National Nutrient Database) - Part 2

Nutrient	Unit	Fruits							Oils				
		Mandarin Oranges	Lemon	Grapefruit	Bananas	Mangos	Papayas	Watermelon	Oil (Canola)	Oil (Olive)	Butter	Margarine	Avocados
Proximates													
Water	g	85.17	88.98	90.89	74.91	83.46	88.06	91.45	0	0	17.94	15.7	73.23
Energy	kcal	53	29	32	89	60	43	30	884	884	717	719	160
Protein	g	0.81	1.1	0.63	1.09	0.82	0.47	0.61	0	0	0.85	0.9	2
Total lipid (fat)	g	0.31	0.3	0.1	0.33	0.38	0.26	0.15	100	100	81.11	80.5	14.66
Carbohydrate	g	13.34	9.32	8.08	22.84	14.98	10.82	7.55	0	0	0.06	0.9	8.53
Fiber	g	1.8	2.8	1.1	2.6	1.6	1.7	0.4	0	0	0	0	6.7
Sugars	g	10.58	2.5	6.98	12.23	13.66	7.82	6.2	0	0	0.06	0	0.66
Minerals													
Calcium, Ca	mg	37	26	12	5	11	20	7	0	1	24	30	12
Iron, Fe	mg	0.15	0.6	0.09	0.26	0.16	0.25	0.24	0	0.56	0.02	0	0.55
Magnesium, Mg	mg	12	8	8	27	10	21	10	0	0	2	3	29
Phosphorus, P	mg	20	16	8	22	14	10	11	0	0	24	23	52
Potassium, K	mg	166	138	139	358	168	182	112	0	1	24	42	485
Sodium, Na	mg	2	2	0	1	1	8	1	0	2	11	943	7
Zinc, Zn	mg	0.07	0.06	0.07	0.15	0.09	0.08	0.1	0	0	0.09	0	0.64
Vitamins													
Vitamin C	mg	26.7	53	34.4	8.7	36.4	60.9	8.1	0	0	0	0.2	10
Thiamin	mg	0.058	0.04	0.036	0.031	0.028	0.023	0.033	0	0	0.005	0.01	0.067
Riboflavin	mg	0.036	0.02	0.02	0.073	0.038	0.027	0.021	0	0	0.034	0.037	0.13
Niacin	mg	0.376	0.1	0.25	0.665	0.669	0.357	0.178	0	0	0.042	0.023	1.738
Vitamin B-6	mg	0.078	0.08	0.042	0.367	0.119	0.038	0.045	0	0	0.003	0.009	0.257
Folate	µg	16	11	10	20	43	37	3	0	0	3	1	81
Vitamin B-12	µg	0	0	0	0	0	0	0	0	0	0.17	0.1	0
Vitamin A, RAE	µg	34	1	46	3	54	47	28	0	0	684	819	7
Vitamin E	mg	0.2	0.15	0.13	0.1	0.9	0.3	0.05	17.46	14.35	2.32	3.1	2.07
Vitamin D	µg	0	0	0	0	0	0	0	0	0	1.5	0	0
Vitamin K (phylloquinone)	µg	0	0	0	0.5	4.2	2.6	0.1	71.3	60.2	7	0	21
Lipids													
Fatty acids, total polyunsaturated	g	0.065	0.089	0.024	0.073	0.071	0.058	0.05	28.142	10.523	3.043	20.9	1.816
Cholesterol	mg	0	0	0	0	0	0	0	0	0	215	0	0

Appendix I: Recommended Basic Food Basket Nutrients Matrix (Based on USDA National Nutrient Database) - Part 3

Nutrient	Unit	Milk and Substitutes		Meat and Substitutes						Condiments			
		Milk	Cheese	Egg	Chicken (Breast)	Beef (Ground)	Fish (Cod)	Fish (Tuna)	Pork (Chop)	Sugar	Salt	Oregano	Cilantro
Proximates													
Water	g	2.47	43.12	76.15	69.46	67.13	81.22	68.09	67.64	0.02	0.2	9.93	92.21
Energy	kcal	496	331	143	172	192	82	144	194	387	0	265	23
Protein	g	26.32	19.66	12.56	20.85	19.42	17.81	23.33	19.56	0	0	9	2.13
Total lipid (fat)	g	26.71	24.46	9.51	9.25	12.73	0.67	4.9	12.27	0	0	4.28	0.52
Carbohydrate	g	38.42	8.32	0.72	0	0	0	0	0	99.98	0	68.92	3.67
Fiber	g	0	0	0	0	0	0	0	0	0	0	42.5	2.8
Sugars	g	38.42	0	0.37	0	0	0	0	0	99.8	0	4.09	0.87
Minerals													
Calcium, Ca	mg	912	497	56	11	12	16	8	35	1	24	1597	67
Iron, Fe	mg	0.47	0.84	1.75	0.74	1.99	0.38	1.02	0.66	0.05	0.33	36.8	1.77
Magnesium, Mg	mg	85	30	12	25	19	32	50	17	0	1	270	26
Phosphorus, P	mg	776	400	198	174	175	203	254	207	0	0	148	48
Potassium, K	mg	1330	363	138	220	289	413	252	288	2	8	1260	521
Sodium, Na	mg	371	966	142	63	68	54	39	69	1	38758	25	46
Zinc, Zn	mg	3.34	3.01	1.29	0.8	4.55	0.45	0.6	2.56	0.01	0.1	2.69	0.5
Vitamins													
Vitamin C	mg	8.6	0	0	0	0	1	0	0	0	0	2.3	27
Thiamin	mg	0.283	0.03	0.04	0.063	0.049	0.076	0.241	0.499	0	0	0.177	0.067
Riboflavin	mg	1.205	0.446	0.457	0.085	0.154	0.065	0.251	0.314	0.019	0	0.528	0.162
Niacin	mg	0.646	0.074	0.075	9.908	4.818	2.063	8.654	6.704	0	0	4.64	1.114
Vitamin B-6	mg	0.302	0.141	0.17	0.53	0.355	0.245	0.455	0.427	0	0	1.044	0.149
Folate	µg	37	5	47	4	6	7	2	0	0	0	237	62
Vitamin B-12	µg	3.25	1.28	0.89	0.34	1.97	0.91	9.43	0.55	0	0	0	0
Vitamin A, RAE	µg	258	159	160	24	0	12	655	6	0	0	85	337
Vitamin E	mg	0.58	0	1.05	0.27	0.35	0.64	1	0.21	0	0	18.26	2.5
Vitamin D	µg	10.5	0	2	0.4		0.9	5.7	0.7	0	0	0	0
Vitamin K (phylloquinone)	µg	2.2	0	0.3	0	1.1	0.1	0	0	0	0	621.7	310
Lipids													
Fatty acids, total polyunsaturated	g	0.665	0.719	1.911	1.96	0.532	0.231	1.433	1.941	0	0	1.369	0.04
Cholesterol	mg	97	64	372	64	62	43	38	63	0	0	0	0

Appendix J: Nutrients Intake Levels

Nutrient	Units	**Intake Level** (Life Stage Group: 19 through 70)		
		Estimated Average Requirement (***Minumum***)	Recommended Dietary Allowance (***Optimum***)	Tolerable Upper Intake (***Maximum***)
Proximates				
Water	g/day	3.7	3.7	
Energy	kcal/day	1800	2000	
Protein	g/day	50	113	175
Total lipid (fat)	g/day	44	61	78
Carbohydrate	g/day	225	275	325
Fiber	g/day	20	23	26
Sugars	g/day		40	40
Minerals				
Calcium, Ca	mg/day	1000	1000	2500
Iron, Fe	mg/day	6	8	45
Magnesium, Mg	mg/day	330	340	350
Phosphorous, P	mg/day	580	700	4000
Potassium, K	mg/day	4700	4700	
Sodium, Na	mg/day	1500	1900	2300
Zinc, Zn	mg/day	9.4	11	40
Vitamins				
Vitamin C	mg/day	75	90	2000
Thiamin	mg/day	1	1.2	
Riboflavin	mg/day	1.1	1.3	
Niacin	mg/day	12	16	35
Vitamin B-6	mg/day	1.1	1.3	100
Folate	µg/day	320	400	1000
Vitamin B-12	µg/day	2	2.4	
Vitamin A	µg/day	625	900	3000
Vitamin E	mg/day	12	15	1000
Vitamin D	µg/day	5	27.5	50
Vitamin K	µg/day	120	120	
Lipids				
Fatty acids, total polyunsaturated	g/day	17	17	
Cholesterol	mg/day		300	300

Appendix K: Recommended Basic Food Basket Prices

Recommended Basic Food Basket	Price	Weight		$ / 100 grams
		Pounds / Grams / Liters / Others	Grams	
Rice	$ 1.69	3 lbs	1360.78	$ 0.12
Sweet Potato	$ 0.99	1 lb	453.59	$ 0.22
Plantains	$ 0.60	1 platano	300.00	$ 0.20
Bread	$ 3.19	1 lb	453.59	$ 0.70
Soda Crackers	$ 3.09	793.8 g	793.80	$ 0.39
Oatmeal	$ 5.19	660 g	660.00	$ 0.79
Dry Beans	$ 1.49	454 g	454.00	$ 0.33
Pumpkin	$ 0.69	1 lb	453.59	$ 0.15
Lettuce	$ 1.69	1 bolsa	187.00	$ 0.90
Tomato	$ 0.85	1 lb	453.59	$ 0.19
Cabbage	$ 1.19	1 lb	453.59	$ 0.26
Mandarin Oranges	$ 0.99	1 lb	453.59	$ 0.22
Lemon	$ 0.79	1 lb	453.59	$ 0.17
Grapefruit	$ 2.59	1 lb	453.59	$ 0.57
Bananas	$ 0.69	1 lb	453.59	$ 0.15
Mangos	$ 1.39	1 lb	453.59	$ 0.31
Papayas	$ 0.99	1 lb	453.59	$ 0.22
Watermelon	$ 0.79	1 lb	453.59	$ 0.17
Oil (Canola)	$ 3.89	1.18 litros	1180.00	$ 0.33
Oil (Olive)	$ 9.19	1 litro	1000.00	$ 0.92
Butter	$ 3.45	425 g	425.00	$ 0.81
Margarine	$ 3.59	454 g	454.00	$ 0.79
Avocados	$ 0.99	1 aguacate	270.00	$ 0.37
Milk	$ 3.00	1.89 litros	1890.00	$ 0.16
Cheese	$ 3.89	340 g	340.00	$ 1.14
Egg	$ 2.59	12 huevos	680.39	$ 0.38
Chicken (Breast)	$ 3.29	1 lb	453.59	$ 0.73
Beef (Ground)	$ 2.59	1 lb	453.59	$ 0.57
Fish (Cod)	$ 11.79	1 lb	453.59	$ 2.60
Fish (Tuna)	$ 1.19	142 g	142.00	$ 0.84
Pork (Chop)	$ 2.79	1 lb	453.59	$ 0.62
Sugar	$ 3.75	4 lbs	1814.37	$ 0.21
Salt	$ 0.75	737 g	737.00	$ 0.10
Oregano	$ 0.69	14.2 g	14.20	$ 4.86
Cilantro	$ 1.69	1 bolsa	79.37	$ 2.13

These prices were gathered from the following supermarkets: Econo, Amigo & Mr. Special.

Appendix L: Mathematical Program

VARIABLES:

Recommended Basic Food Basket

x_1 : Quantity of Rice

x_2 : Quantity of Sweet Potato

x_3 : Quantity of Plantains

x_4 : Quantity of Bread

x_5 : Quantity of Soda Crackers

x_6 : Quantity of Oatmeal

x_7 : Quantity of Dry Beans

x_8 : Quantity of Pumpkin

x_9 : Quantity of Lettuce

x_{10} : Quantity of Tomato

x_{11} : Quantity of Cabbage

x_{12} : Quantity of Mandarin Oranges

x_{13} : Quantity of Lemon

x_{14} : Quantity of Grapefruit

x_{15} : Quantity of Bananas

x_{16} : Quantity of Mangos

x_{17} : Quantity of Papaya

x_{18} : Quantity of Watermelon

x_{19} : Quantity of Oil (Canola)

x_{20} : Quantity of Oil (Olive)

x_{21} : Quantity of Butter

x_{22} : Quantity of Margarine

x_{23} : Quantity of Avocados

x_{24} : Quantity of Milk

x_{25} : Quantity of Cheese

x_{26} : Quantity of Egg

x_{27} : Quantity of Chicken (Breast)

x_{28} : Quantity of Beef (Ground)

x_{29} : Quantity of Fish (Cod)

x_{30} : Quantity of Fish (Tuna)

x_{31} : Quantity of Pork (Chop)

x_{32} : Quantity of Sugar

x_{33} : Quantity of Salt

x_{34} : Quantity of Oregano

x_{35} : Quantity of Cilantro

Nutrients

Y_1 : Quantity of Water (g)

Y_2 : Quantity of Energy (kcal)

Y_3 : Quantity of Protein (g)

Y_4 : Quantity of Total Lipid-Fat (g)

Y_5 : Quantity of Carbohydrate (g)

Y_6 : Quantity of Fiber (g)

Y_7 : Quantity of Sugar (g)

Y_8 : Quantity of Calcium (mg)

Y_9 : Quantity of Iron (mg)

Y_{10} : Quantity of Magnesium (mg)

Y_{11} : Quantity of Phosphorus (mg)

Y_{12} : Quantity of Potassium (mg)

Y_{13} : Quantity of Sodium (mg)

Y_{14} : Quantity of Zinc (mg)

Y_{15} : Quantity of Vitamin C (mg)

x_{16} : Quantity of Thiamin (mg)

Y_{17} : Quantity of Riboflavin (mg)

Y_{18} : Quantity of Niacin (mg)

Y_{19} : Quantity of Vitamin B-6 (mg)

Y_{20} : Quantity of Folate (µg)

Y_{21} : Quantity of Vitamin B-12 (µg)

Y_{22} : Quantity of Vitamin A (µg)

Y_{23} : Quantity of Vitamin E(mg)

Y_{24} : Quantity of Vitamin D (µg)

Y_{25} : Quantity of Vitamin K (µg)

Y_{26} : Quantity of Fatty acids, total polyunsaturated (g)

Y_{27} : Quantity of Cholesterol(mg)

MINIMIZE:

$$\left(\frac{D_1}{AverageY_1}\right)^2 + \left(\frac{D_2}{AverageY_2}\right)^2 + \left(\frac{D_3}{AverageY_3}\right)^2 + \left(\frac{D_4}{AverageY_4}\right)^2 + \left(\frac{D_5}{AverageY_5}\right)^2 + \left(\frac{D_6}{AverageY_6}\right)^2 + \left(\frac{D_7}{AverageY_7}\right)^2 + \left(\frac{D_8}{AverageY_8}\right)^2 + \left(\frac{D_9}{AverageY_9}\right)^2 + \left(\frac{D_{10}}{AverageY_{10}}\right)^2 + \left(\frac{D_{11}}{AverageY_{11}}\right)^2 + \left(\frac{D_{12}}{AverageY_{12}}\right)^2 + \left(\frac{D_{13}}{AverageY_{13}}\right)^2 + \left(\frac{D_{14}}{AverageY_{14}}\right)^2 + \left(\frac{D_{15}}{AverageY_{15}}\right)^2 + \left(\frac{D_{16}}{AverageY_{16}}\right)^2 + \left(\frac{D_{17}}{AverageY_{17}}\right)^2 + \left(\frac{D_{18}}{AverageY_{18}}\right)^2 + \left(\frac{D_{19}}{AverageY_{19}}\right)^2 + \left(\frac{D_{20}}{AverageY_{20}}\right)^2 + \left(\frac{D_{21}}{AverageY_{21}}\right)^2 + \left(\frac{D_{22}}{AverageY_{22}}\right)^2 + \left(\frac{D_{23}}{AverageY_{23}}\right)^2 + \left(\frac{D_{24}}{AverageY_{24}}\right)^2 + \left(\frac{D_{25}}{AverageY_{25}}\right)^2 + \left(\frac{D_{26}}{AverageY_{26}}\right)^2 + \left(\frac{D_{27}}{AverageY_{27}}\right)^2$$

SUBJECT TO:

COST

$.12 X_1 + .22X_2 + .2X_3 + .7X_4 + .39X_5 + .79X_6 + .33X_7 + .15X_8 + .9X_9 + \$ .19X_{10} + .26X_{11} + .22X_{12} + .17X_{13} + .57X_{14} + .15X_{15} + .31X_{16} + .22X_{17} + .17X_{18} + .33X_{19} + .92X_{20} + .81X_{21} + .79X_{22} + .37X_{23} + .16X_{24} + 1.14X_{25} + .38X_{26} + .73X_{27} + .57X_{28} + 2.6X_{29} + .84X_{30} + .62X_{31} + .21X_{32} + .10X_{33} + 4.86X_{34} + 2.13X_{35} \leq$ **BUDGET**

QUANTITY

Total $_{Water}$

$Y_1 = 13.29 X_1 + 77.28 X_2 + 65.28 X_3 + 36.34 X_4 + 3 X_5 + 8.8 X_6 + 10.06 X_7 + 91.6 X_8 + 94.61 X_9 + 94.52 X_{10} + 92.18 X_{11} + 85.17 X_{12} + 88.98 X_{13} + 90.89 X_{14} + 74.91 X_{15} + 83.46 X_{16} + 88.06 X_{17} + 91.45 X_{18} + 0 X_{19} + 0 X_{20} + 17.94 X_{21} +$

$15.7\ X_{22} + 73.23\ X_{23} + 2.47\ X_{24} + 43.12\ X_{25} + 76.15\ X_{26} + 69.46\ X_{27} + 67.13\ X_{28} + 81.22\ X_{29} + 68.09\ X_{30} + 67.64\ X_{31} + 0.02\ X_{32} + 0.2\ X_{33} + 9.93\ X_{34} + 92.21\ X_{35}$

Total $_{\text{Energy}}$

$Y_2 = 358\ X_1 + 86\ X_2 + 122\ X_3 + 265\ X_4 + 414\ X_5 + 367\ X_6 + 343\ X_7 + 26\ X_8 + 17\ X_9 + 18\ X_{10} + 25\ X_{11} + 53\ X_{12} + 29\ X_{13} + 32\ X_{14} + 89\ X_{15} + 60\ X_{16} + 43\ X_{17} + 30\ X_{18} + 884\ X_{19} + 884\ X_{20} + 717\ X_{21} + 719\ X_{22} + 160\ X_{23} + 496\ X_{24} + 331\ X_{25} + 143\ X_{26} + 172\ X_{27} + 192\ X_{28} + 82\ X_{29} + 144\ X_{30} + 194\ X_{31} + 387\ X_{32} + 0\ X_{33} + 265\ X_{34} + 23\ X_{35}$

Total $_{\text{Protein}}$

$Y_3 = 6.5\ X_1 + 1.57\ X_2 + 1.3\ X_3 + 9.15\ X_4 + 5.6\ X_5 + 16\ X_6 + 20.96\ X_7 + 1\ X_8 + 1.23\ X_9 + 0.88\ X_{10} + 1.28\ X_{11} + 0.81\ X_{12} + 1.1\ X_{13} + 0.63\ X_{14} + 1.09\ X_{15} + 0.82\ X_{16} + 0.47\ X_{17} + 0.61\ X_{18} + 0\ X_{19} + 0\ X_{20} + 0.85\ X_{21} + 0.9\ X_{22} + 2\ X_{23} + 26.32\ X_{24} + 19.66\ X_{25} + 12.56\ X_{26} + 20.85\ X_{27} + 19.42\ X_{28} + 17.81\ X_{29} + 23.33\ X_{30} + 19.56\ X_{31} + 0\ X_{32} + 0\ X_{33} + 9\ X_{34} + 2.13\ X_{35}$

Total $_{\text{Lipid}}$

$Y_4 = 0.52\ X_1 + 0.05\ X_2 + 0.37\ X_3 + 3.19\ X_4 + 11.5\ X_5 + 6.3\ X_6 + 1.13\ X_7 + 0.1\ X_8 + 0.3\ X_9 + 0.2\ X_{10} + 0.1\ X_{11} + 0.31\ X_{12} + 0.3\ X_{13} + 0.1\ X_{14} + 0.33\ X_{15} + 0.38\ X_{16} + 0.26\ X_{17} + 0.15\ X_{18} + 100\ X_{19} + 100\ X_{20} + 81.11\ X_{21} + 80.5\ X_{22} + 14.66$

X_{23} + 26.71 X_{24} + 24.46 X_{25} + 9.51 X_{26} + 9.25 X_{27} + 12.73 X_{28} + 0.67 X_{29} + 4.9 X_{30} + 12.27 X_{31} + 0 X_{32} + 0 X_{33} + 4.28 X_{34} + 0.52 X_{35}

Total Carbohydrates

$Y_5 =$ 79.15 X_1 + 20.12 X_2 + 31.89 X_3 + 49.06 X_4 + 74 X_5 + 67 X_6 + 64.19 X_7 + 6.5 X_8 + 3.29 X_9 + 3.89 X_{10} + 5.8 X_{11} + 13.34 X_{12} + 9.32 X_{13} + 8.08 X_{14} + 22.84 X_{15} + 14.98 X_{16} + 10.82 X_{17} + 7.55 X_{18} + 0 X_{19} + 0 X_{20} + 0.06 X_{21} + 0.9 X_{22} + 8.53 X_{23} + 38.42 X_{24} + 8.32 X_{25} + 0.72 X_{26} + 0 X_{27} + 0 X_{28} + 0 X_{29} + 0 X_{30} + 0 X_{31} + 99.98 X_{32} + 0 X_{33} + 68.92 X_{34} + 3.67 X_{35}

Total Fiber

$Y_6 =$ 2.8 X_1 + 3 X_2 + 2.3 X_3 + 2.7 X_4 + 3.3 X_5 + 9.8 X_6 + 12.7 X_7 + 0.5 X_8 + 2.1 X_1 + 1.2 X_{10} + 2.5 X_{11} + 1.8 X_{12} + 2.8 X_{13} + 1.1 X_{14} + 2.6 X_{15} + 1.6 X_{16} + 1.7 X_{17} + 0.4 X_{18} + 0 X_{19} + 0 X_{20} + 0 X_{21} + 0 X_{22} + 6.7 X_{23} + 0 X_{24} + 0 X_{25} + 0 X_{26} + 0 X_{27} + 0 X_{28} + 0 X_{29} + 0 X_{30} + 0 X_{31} + 0 X_{32} + 0 X_{33} + 42.5 X_{34} + 2.8 X_{35}

Total Sugars

$Y_7 =$ 0 X_1 + 4.18 X_2 + 15 X_3 + 5.07 X_4 + 2.3 X_5 + 1 X_6 + 2.14 X_7 + 2.76 X_8 + 1.19 X_9 + 2.63 X_{10} + 3.2 X_{11} + 10.58 X_{12} + 2.5 X_{13} + 6.98 X_{14} + 12.23 X_{15} + 13.66 X_{16} + 7.82 X_{17} + 6.2 X_{18} + 0 X_{19} + 0 X_{20} + 0.06 X_{21} + 0 X_{22} + 0.66 X_{23} + 38.42 X_{24} + 0 X_{25} + 0.37 X_{26} + 0 X_{27} + 0 X_{28} + 0 X_{29} + 0 X_{30} + 0 X_{31} + 99.8 X_{32} + 0 X_{33} + 4.09 X_{34} + 0.87 X_{35}

Total $_{\text{Calcium}}$

$Y_8 = 3\ X_1 + 30\ X_2 + 3\ X_3 + 260\ X_4 + 0\ X_5 + 52\ X_6 + 130\ X_7 + 21\ X_8 + 33\ X_9 + 10\ X_{10} + 40\ X_{11} + 37\ X_{12} + 26\ X_{13} + 12\ X_{14} + 5\ X_{15} + 11\ X_{16} + 20\ X_{17} + 7\ X_{18} + 0\ X_{19} + 1\ X_{20} + 24\ X_{21} + 30\ X_{22} + 12\ X_{23} + 912\ X_{24} + 497\ X_{25} + 56\ X_{26} + 11\ X_{27} + 12\ X_{28} + 16\ X_{29} + 8\ X_{30} + 35\ X_{31} + 1\ X_{32} + 24\ X_{33} + 1597\ X_{34} + 67\ X_{35}$

Total $_{\text{Iron}}$

$Y_9 = 4.23\ X_1 + 0.61\ X_2 + 0.6\ X_3 + 3.59\ X_4 + 4.3\ X_5 + 4.2\ X_6 + 6.77\ X_7 + 0.8\ X_8 + 0.97\ X_9 + 0.27\ X_{10} + 0.47\ X_{11} + 0.15\ X_{12} + 0.6\ X_{13} + 0.09\ X_{14} + 0.26\ X_{15} + 0.16\ X_{16} + 0.25\ X_{17} + 0.24\ X_{18} + 0\ X_{19} + 0.56\ X_{20} + 0.02\ X_{21} + 0\ X_{22} + 0.55\ X_{23} + 0.47\ X_{24} + 0.84\ X_{25} + 1.75\ X_{26} + 0.74\ X_{27} + 1.99\ X_{28} + 0.38\ X_{29} + 1.02\ X_{30} + 0.66\ X_{31} + 0.05\ X_{32} + 0.33\ X_{33} + 36.8\ X_{34} + 1.77\ X_{35}$

Total $_{\text{Magnesium}}$

$Y_{10} = 23\ X_1 + 25\ X_2 + 37\ X_3 + 25\ X_4 + 0\ X_5 + 148\ X_6 + 182\ X_7 + 12\ X_8 + 14\ X_9 + 11\ X_{10} + 12\ X_{11} + 12\ X_{12} + 8\ X_{13} + 8\ X_{14} + 27\ X1_5 + 10\ X_{16} + 21\ X_{17} + 10\ X_{18} + 0\ X_{19} + 0\ X_{20} + 2\ X_{21} + 3\ X_{22} + 29\ X_{23} + 85\ X_{24} + 30\ X_{25} + 12\ X_{26} + 25\ X_{27} + 19\ X_{28} + 32\ X_{29} + 50\ X_{30} + 17\ X_{31} + 0\ X_{32} + 1\ X_{33} + 270\ X_{34} + 26\ X_{35}$

Total $_{\text{Phosphorus}}$

$Y_{11} = 95\ X_1 + 47\ X_2 + 34\ X_3 + 103\ X_4 + 0\ X_5 + 474\ X_6 + 415\ X_7 + 44\ X_8 + 30\ X_9 + 24\ X_{10} + 26\ X_{11} + 20\ X_{12} + 16\ X_{13} + 8\ X_{14} + 22\ X_{15} + 14\ X_{16} + 10\ X_{17} + 11\ X_{18} + 0\ X_{19} + 0\ X_{20} + 24\ X_{21} + 23\ X_{22} + 52\ X_{23} + 776\ X_{24} + 400\ X_{25} + 198\ X_{26} +$

$174\ X_{27} + 175\ X_{28} + 203\ X_{29} + 254\ X_{30} + 207\ X_{31} + 0\ X_{32} + 0\ X_{33} + 148\ X_{34} + 48\ X_{35}$

Total $_{\text{Potassium}}$

$Y_{12} = 76\ X_1 + 337\ X_2 + 499\ X_3 + 115\ X_4 + 0\ X_5 + 350\ X_6 + 1464\ X_7 + 340\ X_8 + 247\ X_9 + 237\ X_{10} + 170\ X_{11} + 166\ X_{12} + 138\ X_{13} + 139\ X_{14} + 358\ X_{15} + 168\ X_{16} + 182\ X_{17} + 112\ X_{18} + 0\ X_{19} + 1\ X_{20} + 24\ X_{21} + 42\ X_{22} + 485\ X_{23} + 1330\ X_{24} + 363\ X_{25} + 138\ X_{26} + 220\ X_{27} + 289\ X_{28} + 413\ X_{29} + 252\ X_{30} + 288\ X_{31} + 2\ X_{32} + 8\ X_{33} + 1260\ X_{34} + 521\ X_{35}$

Total $_{\text{Sodium}}$

$Y_{13} = 1\ X_1 + 55\ X_2 + 4\ X_3 + 491\ X_4 + 597\ X_5 + 4\ X_6 + 8\ X_7 + 1\ X_8 + 8\ X_9 + 5\ X_{10} + 18\ X_{11} + 2\ X_{12} + 2\ X_{13} + 0\ X_{14} + 1\ X_{15} + 1\ X_{16} + 8\ X_{17} + 1\ X_{18} + 0\ X_{19} + 2\ X_{20} + 11\ X_{21} + 943\ X_{22} + 7\ X_{23} + 371\ X_{24} + 966\ X_{25} + 142\ X_{26} + 63\ X_{27} + 68\ X_{28} + 54\ X_{29} + 39\ X_{30} + 69\ X_{31} + 1\ X_{32} + 38758\ X_{33} + 25\ X_{34} + 46\ X_{35}$

Total $_{\text{Zinc}}$

$Y_{14} = 1.1\ X_1 + 0.3\ X_2 + 0.14\ X_3 + 0.84\ X_4 + 0\ X_5 + 3.07\ X_6 + 2.55\ X_7 + 0.32\ X_8 + 0.23\ X_9 + 0.17\ X_{10} + 0.18\ X_{11} + 0.07\ X_{12} + 0.06\ X_{13} + 0.07\ X_{14} + 0.15\ X_{15} + 0.09\ X_{16} + 0.08\ X_{17} + 0.1\ X_{18} + 0\ X_{19} + 0\ X_{20} + 0.09\ X_{21} + 0\ X_{22} + 0.64\ X_{23} + 3.34\ X_{24} + 3.01\ X_{25} + 1.29\ X_{26} + 0.8\ X_{27} + 4.55\ X_{28} + 0.45\ X_{29} + 0.6\ X_{30} + 2.56\ X_{31} + 0.01\ X_{32} + 0.1\ X_{33} + 2.69\ X_{34} + 0.5\ X_{35}$

Total $_{\text{Vitamin C}}$

$Y_{15} = 0\ X_1 + 2.4\ X_2 + 18.4\ X_3 + 0\ X_4 + 0\ X_5 + 0\ X_6 + 0\ X_7 + 9\ X_8 + 4\ X_9 + 13.7\ X_{10} + 36.6\ X_{11} + 26.7\ X_{12} + 53\ X_{13} + 34.4\ X_{14} + 8.7\ X_{15} + 36.4\ X_{16} + 60.9\ X_{17} + 8.1\ X_{18} + 0\ X_{19} + 0\ X_{20} + 0\ X_{21} + 0.2\ X_{22} + 10\ X_{23} + 8.6\ X_{24} + 0\ X_{25} + 0\ X_{26} + 0\ X_{27} + 0\ X_{28} + 1\ X_{29} + 0\ X_{30} + 0\ X_{31} + 0\ X_{32} + 0\ X_{33} + 2.3\ X_{34} + 27\ X_{35}$

Total $_{\text{Thiamin}}$

$Y_{16} = 0.565\ X_1 + 0.078\ X_2 + 0.052\ X_3 + 0.533\ X_4 + 0.62\ X_5 + 0.73\ X_6 + 0.772\ X_7 + 0.05\ X_8 + 0.072\ X_9 + 0.037\ X_{10} + 0.061\ X_{11} + 0.058\ X_{12} + 0.04\ X_{13} + 0.036\ X_{14} + 0.031\ X_{15} + 0.028\ X_{16} + 0.023\ X_{17} + 0.033\ X_{18} + 0\ X_{19} + 0\ X_{20} + 0.005\ X_{21} + 0.01\ X_{22} + 0.067\ X_{23} + 0.283\ X_{24} + 0.03\ X_{25} + 0.04\ X_{26} + 0.063\ X_{27} + 0.049\ X_{28} + 0.076\ X_{29} + 0.241\ X_{30} + 0.499\ X_{31} + 0\ X_{32} + 0\ X_{33} + 0.177\ X_{34} + 0.067\ X_{35}$

Total $_{\text{Riboflavin}}$

$Y_{17} = 0.048\ X_1 + 0.061\ X_2 + 0.054\ X_3 + 0.243\ X_4 + 0.39\ X_5 + 0.14\ X_6 + 0.192\ X_7 + 0.11\ X_8 + 0.067\ X_9 + 0.019\ X_{10} + 0.04\ X_{11} + 0.036\ X_{12} + 0.02\ X_{13} + 0.02\ X_{14} + 0.073\ X_{15} + 0.038\ X_{16} + 0.027\ X_{17} + 0.021\ X_{18} + 0\ X_{19} + 0\ X_{20} + 0.034\ X_{21} + 0.037\ X_{22} + 0.13\ X_{23} + 1.205\ X_{24} + 0.446\ X_{25} + 0.457\ X_{26} + 0.085\ X_{27} + 0.154\ X_{28} + 0.065\ X_{29} + 0.251\ X_{30} + 0.314\ X_{31} + 0.019\ X_{32} + 0\ X_{33} + 0.528\ X_{34} + 0.162\ X_{35}$

Total $_{\text{Niacin}}$

$Y_{18} = 4.113\ X_1 + 0.557\ X_2 + 0.686\ X_3 + 4.78\ X_4 + 5.1\ X_5 + 0.78\ X_6 + 1.892\ X_7 + 0.6\ X_8 + 0.313\ X_9 + 0.594\ X_{10} + 0.234\ X_{11} + 0.376\ X_{12} + 0.1\ X_{13} + 0.25\ X_{14} + 0.665\ X1_5 + 0.669\ X_{16} + 0.357\ X_{17} + 0.178\ X_{18} + 0\ X_{19} + 0\ X_{20} + 0.042\ X_{21} + 0.023\ X_{22} + 1.738\ X_{23} + 0.646\ X_{24} + 0.074\ X_{25} + 0.075\ X_{26} + 9.908\ X_{27} + 4.818\ X_{28} + 2.063\ X_{29} + 8.654\ X_{30} + 6.704\ X_{31} + 0\ X_{32} + 0\ X_{33} + 4.64\ X_{34} + 1.114\ X_{35}$

Total $_{\text{Vitamin B-6}}$

$Y_{19} = 0.171\ X_1 + 0.209\ X_2 + 0.299\ X_3 + 0.087\ X_4 + 0\ X_5 + 0.12\ X_6 + 0.527\ X_7 + 0.061\ X_8 + 0.074\ X_9 + 0.08\ X_{10} + 0.124\ X_{11} + 0.078\ X_{12} + 0.08\ X_{13} + 0.042\ X_{14} + 0.367\ X_{15} + 0.119\ X_{16} + 0.038\ X_{17} + 0.045\ X_{18} + 0\ X_{19} + 0\ X_{20} + 0.003\ X21 + 0.009\ X_{22} + 0.257\ X_{23} + 0.302\ X_{24} + 0.141\ X_{25} + 0.17\ X_{26} + 0.53\ X_{27} + 0.355\ X_{28} + 0.245\ X_{29} + 0.455\ X_{30} + 0.427\ X_{31} + 0\ X_{32} + 0\ X_{33} + 1.044\ X_{34} + 0.149\ X_{35}$

Total $_{\text{Folate}}$

$Y_{20} = 389\ X_1 + 11\ X_2 + 22\ X_3 + 171\ X_4 + 0\ X_5 + 0\ X_6 + 463\ X_7 + 16\ X_8 + 136\ X_9 + 15\ X_{10} + 43\ X_{11} + 16\ X_{12} + 11\ X_{13} + 10\ X_{14} + 20\ X_{15} + 43\ X_{16} + 37\ X_{17} + 3\ X_{18} + 0\ X_{19} + 0\ X_{20} + 3\ X_{21} + 1\ X_{22} + 81\ X_{23} + 37\ X_{24} + 5\ X_{25} + 47\ X_{26} + 4\ X_{27} + 6\ X_{28} + 7\ X_{29} + 2\ X_{30} + 0\ X_{31} + 0\ X_{32} + 0\ X_{33} + 237\ X_{34} + 62\ X_{35}$

Total Vitamin B−12

$Y_{21} = 0\ X_1 + 0\ X_2 + 0\ X_3 + 0\ X_4 + 0\ X_5 + 0\ X_6 + 0\ X_7 + 0\ X_8 + 0\ X_9 + 0\ X_{10} + 0\ X_{11} + 0\ X_{12} + 0\ X_{13} + 0\ X_{14} + 0\ X_{15} + 0\ X_{16} + 0\ X_{17} + 0\ X_{18} + 0\ X_{19} + 0\ X_{20} + 0.17\ X_{21} + 0.1\ X_{22} + 0\ X_{23} + 3.25\ X_{24} + 1.28\ X_{25} + 0.89\ X_{26} + 0.34\ X_{27} + 1.97\ X_{28} + 0.91\ X_{29} + 9.43\ X_{30} + 0.55\ X_{31} + 0\ X_{32} + 0\ X_{33} + 0\ X_{34} + 0\ X_{35}$

Total Vitamin A

$Y_{22} = 0\ X_1 + 709\ X_2 + 56\ X_3 + 0\ X_4 + 0\ X_5 + 0\ X_6 + 0\ X_7 + 426\ X_8 + 436\ X_9 + 42\ X_{10} + 5\ X_{11} + 34\ X_{12} + 1\ X_{13} + 46\ X_{14} + 3\ X_{15} + 54\ X_{16} + 47\ X_{17} + 28\ X_{18} + 0\ X_{19} + 0\ X_{20} + 684\ X_{21} + 819\ X_{22} + 7\ X_{23} + 258\ X_{24} + 159\ X_{25} + 160\ X_{26} + 24\ X_{27} + 0\ X_{28} + 12\ X_{29} + 655\ X_{30} + 6\ X_{31} + 0\ X_{32} + 0\ X_{33} + 85\ X_{34} + 337\ X_{35}$

Total Vitamin E

$Y_{23} = 0\ X_1 + 0.26\ X_2 + 0.14\ X_3 + 0.22\ X_4 + 0\ X_5 + 0.47\ X_6 + 0.21\ X_7 + 1.06\ X_8 + 0.13\ X_9 + 0.54\ X_{10} + 0.15\ X_{11} + 0.2\ X_{12} + 0.15\ X_{13} + 0.13\ X_{14} + 0.1\ X_{15} + 0.9\ X_{16} + 0.3\ X_{17} + 0.05\ X_{18} + 17.46\ X_{19} + 14.35\ X_{20} + 2.32\ X_{21} + 3.1\ X_{22} + 2.07\ X_{23} + 0.58\ X_{24} + 0\ X_{25} + 1.05\ X_{26} + 0.27\ X_{27} + 0.35\ X_{28} + 0.64\ X_{29} + 1\ X_{30} + 0.21\ X_{31} + 0\ X_{32} + 0\ X_{33} + 18.26\ X_{34} + 2.5\ X_{35}$

Total Vitamin D

$Y_{24} = 0\ X_1 + 0\ X_2 + 0\ X_3 + 0\ X_4 + 0\ X_5 + 0\ X_6 + 0\ X_7 + 0\ X_8 + 0\ X_9 + 0\ X_{10} + 0\ X_{11} + 0\ X_{12} + 0\ X_{13} + 0\ X_{14} + 0\ X_{15} + 0\ X_{16} + 0\ X_{17} + 0\ X_{18} + 0\ X_{19} + 0\ X_{20} +$

$1.5\ X_{21} + 0\ X_{22} + 0\ X_{23} + 10.5\ X_{24} + 0\ X_{25} + 2\ X_{26} + 0.4\ X_{27} + 0\ X_{28} + 0.9\ X_{29} + 5.7\ X_{30} + 0.7\ X_{31} + 0\ X_{32} + 0\ X_{33} + 0\ X_{34} + 0\ X_{35}$

Total Vitamin K

$Y_{25} = 0\ X_1 + 1.8\ X_2 + 0.7\ X_3 + 0.2\ X_4 + 0\ X_5 + 0\ X_6 + 5.7\ X_7 + 1.1\ X_8 + 102.5\ X_9 + 7.9\ X_{10} + 76\ X_{11} + 0\ X_{12} + 0\ X_{13} + 0\ X_{14} + 0.5\ X_{15} + 4.2\ X_{16} + 2.6\ X_{17} + 0.1\ X_{18} + 71.3\ X_{19} + 60.2\ X_{20} + 7\ X_{21} + 0\ X_{22} + 21\ X_{23} + 2.2\ X_{24} + 0\ X_{25} + 0.3\ X_{26} + 0\ X_{27} + 1.1\ X_{28} + 0.1\ X_{29} + 0\ X_{30} + 0\ X_{31} + 0\ X_{32} + 0\ X_{33} + 621.7\ X_{34} + 310\ X_{35}$

Total Fatty acids, polyunsaturated

$Y_{28} = 0.138\ X_1 + 0.014\ X_2 + 0.069\ X_3 + 1.602\ X_4 + 1.07\ X_5 + 2.3\ X_6 + 0.487\ X_7 + 0.005\ X_8 + 0.16\ X_9 + 0.083\ X_{10} + 0.017\ X_{11} + 0.065\ X_{12} + 0.089\ X_{13} + 0.024\ X_{14} + 0.073\ X_{15} + 0.071\ X_{16} + 0.058\ X_{17} + 0.05\ X_{18} + 28.142\ X_{19} + 10.523\ X_{20} + 3.043\ X_{21} + 20.9\ X_{22} + 1.816\ X_{23} + 0.665\ X_{24} + 0.719\ X_{25} + 1.911\ X_{26} + 1.96\ X_{27} + 0.532\ X_{28} + 0.231\ X_{29} + 1.433\ X_{30} + 1.941\ X_{31} + 0\ X_{32} + 0\ X_{33} + 1.369\ X_{34} + 0.04\ X_{35}$

Total Cholesterols

$Y_{29} = 0\ X_1 + 0\ X_2 + 0\ X_3 + 0\ X_4 + 0\ X_5 + 0\ X_6 + 0\ X_7 + 0\ X_8 + 0\ X_9 + 0\ X_{10} + 0\ X_{11} + 0\ X_{12} + 0\ X_{13} + 0\ X_{14} + 0\ X_{15} + 0\ X_{16} + 0\ X_{17} + 0\ X_{18} + 0\ X_{19} + 0\ X_{20} + 215\ X_{21} + 0\ X_{22} + 0\ X_{23} + 97\ X_{24} + 64\ X_{25} + 372\ X_{26} + 64\ X_{27} + 62\ X_{28} + 43\ X_{29} + 38\ X_{30} + 63\ X_{31} + 0\ X_{32} + 0\ X_{33} + 0\ X_{34} + 0\ X_{35}$

MAXIMUM AND MINIMUM REQUIREMENTS

Total Water

$$D_1 \geq 3700 - Y_1$$

Total Energy

$$D_2 \geq 1800 - Y_2$$

Total Protein

$$D_3 \geq 50 - Y_3$$

$$D_3 \geq Y_8 - 175$$

Total Lipid

$$D_4 \geq 44 - Y_4$$

$$D_4 \geq Y_4 - 78$$

Total Carbohydrates

$$D_5 \geq 225 - Y_5$$

$$D_5 \geq Y_5 - 325$$

Total Fiber

$$D_6 \geq 20 - Y_6$$

$$D_6 \geq Y_6 - 26$$

Total Sugars

$$D_7 \geq Y_7 - 40$$

Total Calcium

$$D_8 \geq 1000 - Y_8$$

$$D_8 \geq Y_8 - 2500$$

Total $_{\textbf{Iron}}$

$$D_9 \geq 6 - Y_9$$

$$D_9 \geq Y_9 - 45$$

Total $_{\textbf{Magnesium}}$

$$D_{10} \geq 330 - Y_{10}$$

$$D_{10} \geq Y_{10} - 350$$

Total $_{\textbf{Phosphorus}}$

$$D_{11} \geq 580 - Y_{11}$$

$$D_{11} \geq Y_{11} - 4000$$

Total $_{\textbf{Potassium}}$

$$D_{12} \geq 4700 - Y_{12}$$

Total $_{\textbf{Sodium}}$

$$D_{13} \geq 1500 - Y_{13}$$

$$D_{13} \geq Y_{13} - 2300$$

Total **Zinc**

$$D_{14} \geq 9.4 - Y_{14}$$

$$D_{14} \geq Y_{14} - 40$$

Total **Vitamin C**

$$D_{15} \geq 75 - Y_{15}$$

$$D_{15} \geq Y_{15} - 2000$$

Total **Thiamin**

$$D_{16} \geq 1 - Y_{16}$$

Total **Riboflavin**

$$D_{17} \geq 1.1 - Y_{17}$$

Total **Niacin**

$$D_{18} \geq 12 - Y_{18}$$

$$D_{18} \geq Y_{18} - 35$$

Total **Vitamin B−6**

$$D_{19} \geq 1.1 - Y_{19}$$

$$D_{19} \geq Y_{19} - 100$$

Total **Folate**

$$D_{20} \geq 320 - Y_{20}$$

$$D_{20} \geq Y_{20} - 1000$$

Total **Vitamin B−12**

$$D_{21} \geq 2 - Y_{21}$$

Total **Vitamin A**

$D_{22} \geq 625 - Y_{22}$

$D_{22} \geq Y_{22} - 3000$

Total **Vitamin E**

$D_{23} \geq 12 - Y_{23}$

$D_{23} \geq Y_{23} - 1000$

Total **Vitamin D**

$D_{24} \geq 5 - Y_{24}$

$D_{24} \geq Y_{24} - 50$

Total **Vitamin K**

$D_{25} \geq 120 - Y_{25}$

Total **Fatty acids, poldunsaturated**

$D_{26} \geq 17 - Y_{26}$

Total **Cholesterols**

$D_{27} \geq Y_{27} - 300$

BOUNDS

$X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10}, X_{11}, X_{12}, X_{13}, X_{14}, X_{15}, X_{16}, X_{17}, X_{18}, X_{19}, X_{20},$

$X_{21}, X_{22}, X_{23}, X_{24}, X_{25}, X_{26}, X_{27}, X_{28}, X_{29}, X_{30}, X_{31}, X_{32}, X_{33}, X_{34}, X_{35} \geq 0$

$Y_1, Y_2, Y_3, Y_4, Y_5, Y_6, Y_7, Y_8, Y_9, Y_{10}, Y_{11}, Y_{12}, Y_{13}, Y_{14}, Y_{15}, Y_{16}, Y_{17}, Y_{18}, Y_{19}, Y_{20},$

$Y_{21}, Y_{22}, Y_{23}, Y_{24}, Y_{25}, Y_{26}, Y_{27} \geq 0$

$D_1, D_2, D_3, D_4, D_5, D_6, D_7, D_8, D_9, D_{10}, D_{11}, D_{12}, D_{13}, D_{14}, D_{15}, D_{16}, D_{17}, D_{18}, D_{19}, D_{20},$

$D_{21}, D_{22}, D_{23}, D_{24}, D_{25}, D_{26}, D_{27} \geq 0$