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Analysis of Suitability of Poverty Line Measures using Nutritional Requirements

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Abstract - *The significance of the impact that poverty and nutrition have on each other are well researched and documented. The Planning Commission has considered calorie requirement as the primary basis for consumption led poverty and these are also the first and second Millenium Development Goals due to them being highly intertwined with each other. Due to the high capacity of Operations Research for being helpful with public policy making LPP shall be used to determine the optimal mix of food that should be consumed by a vegetarian adult in order to minimize their food expenses can be determined. This will in turn help us understand where does the actual food expenditure against hypothesized food expenditure stand and if the existing standards for consumption based poverty are actually poverty lines or starvation lines.*

***Key Words*: Poverty Line, Nutrition, Diet Problems, Policy, Linear Programming**

1. INTRODUCTION

In the second quarter of 2018, Nigeria managed to knock India off its undesirable perch as the home to the largest number of "poor" people in the world as per a report by the Brookings Institution.[1] However, India ranks 102 out of 119 countries on the 2019 Global Hunger Index with a high score of 30.3 which signifies a serious level of hunger in India.[2] Although food grain production has increased almost 2 times, and India indeed does produce sufficient food to feed its population, it is unable to provide access to food to a large number of people, especially women and children. According to FAO estimates in 'The State of Food Security and Nutrition in the World, 2019' report, 194.4 million people are undernourished in India which means that nearly 14.5% of India's population is undernourished.[3]

According to the World Poverty Clock India is winning its battle against extreme poverty. There is a downwards trend in the extreme poverty population while it is being seen otherwise in countries like Nigeria and Congo. It is expected by job creations and developing industries India will reduce its extreme poverty population to 3% by 2022. In Nigeria approximately in 6 people add to the extremely poor population while India pulled out almost 50 million out of the extremely poor category in just 2 years.

The facts above signify that India is well on course to meet its' Sustainable Development Goal 2 - Zero Hunger, which is also resultant of India playing an important role in the formulation of SDGs and much of the country's development programmes is mirrored in them. In its first iteration, the Index gives as a whole picture of India's inclusive growth trajectory, and the condition of both national and state-level economic, environmental and social parameters. It helps in evaluating success, by measuring the impact of government programmes, helping identify effective models and trends for future interventions.[4]

Operations Research is a science intended to give quantitative answers for decision making roles. It includes a lot of numerical enhancement and recreation strategies and models, for example, Linear Programming, Non-direct Programming, Theory of Queues, Dynamic Programming, Theory of Decisions, and so forth. Applications of linear programming include uses in engineering, food and agriculture, transportation, energy and manufacturing. It has exhibited to be an elective answer for planning brachytherapy, overthrowing the conventional methods dependent on experimentation.

Linear programming has been in use for a long time now to create a balanced diet in accordance with the nutritional requirements. Linear programming is a very efficient method in planning for dietary needs and in order to do the calculations unprocessed food data and prices are required. It is used to provide low cost yet healthy food baskets by nutritionists.

The concept of poverty is quite relevant in the context of policy formulation, its process and outcome evaluation. It matters most in a country low-income developing country like India, which has been pursuing development strategies for 'Growth with Poverty Reduction'. Operations Research can be utilized to deliver a cost-effective diet plan to ensure that the maximum.

The principal target of this case is to utilize linear programming technique, to analyze whether individuals in India can satisfy their nutritional needs using the poverty line as a basis of reference. We have tried to find the optimal diet plan for a single adult with a vegetarian diet by ensuring that their basic minimum dietary requirements for sustenance are met within budget with regards to the Poverty Line. This research will also help us in identifying the best possible combination of food products that will help minimize the cost while ensuring that the dietary requirements for an active male are met.

2. OVERVIEW OF THE INDUSTRY

'Poverty means not being able to heat your home, pay your rent, or buy the essentials for your children. It means waking up every day facing insecurity, uncertainty, and impossible decisions about money. It means facing marginalisation – and even discrimination – because of your financial circumstances. The constant stress it causes can lead to problems that deprive people of the chance to play a full part in society.'[5]

According to a 2012 report by the World Bank, India accounted for the single largest contribution to population of the impoverished. In 1950, the poverty was estimated at 59%. In 1970's survey conducted found out that 40% of rural and 50% of urban residents are below Poverty Line. In the 1990's the method was changed, and various poverty indices were set for each state. Global Hunger Index (GHI) is an index that is used to find the proportion of the population that is undernourished. Over the course of years, India has improved its performance by 22% in a 20 year span, from 30.4 to 23.7 over 1990 to 2011 period.

The National Planning Committee of 1936 under the guidance of Pt. Nehru remarked that "there was a lack of food, of clothing, of housing and of every other essential requirement of human existence". It then defined goals for the alleviation poverty by setting targets in terms of nutrition (2400 to 2800 kilocalories per adult worker), clothing (30 yards per capita per annum) and housing (100 sq. ft per capita).[6] This method of linking poverty as a function of nutrition, clothing and housing continued in India after it became independent from British colonial empire. As a part of one of the legacies left behind by the Britishers, the practice of using such multi-dimensional measures of poverty has stuck.

However, one of the main ways in which these things are defined are is to start by identifying a basic minimum level of nutrition one must get everyday in order to sustain themselves which is done by looking at the consumption expenditure related data from the National Sample Survey Office. From this data, the quantity of food consumed in each of these categories can be assumed and coupled with an estimate of the calorie value of these foods to arrive at the number of calories required for individuals to sustain themselves. However, care is taken to ensure that the differences arising in calorie consumption due to consumption expenditure being a function of consumer income are accounted for as well.

Despite the aforementioned process, defining a poverty line has been a controversial issue, starting from the mid-1970s when the first such poverty line created by the Dandekar and Rath led Planning Commission of 1971 was based on minimum daily requirement of 2,250 kilocalories per day for adults in both rural and urban areas. This sparked a large debate about how minimum calorie consumption requirements were calculated as per gender and age. In 1979, the Planning Commission formed a task force headed by YK Alagh which finally determined 2,400 and 2,100 kilocalories to be the appropriate amount of nutrition required for an adult in rural and urban areas respectively.[7]

As per the then existing methods of defining nourishment, calorie requirement seemed to be the only criteria that mattered whereas it is well known that in order for a body to healthily subsist, it also needs minimum amount of other macronutrients, minerals and vitamins. In addition to it, calorie requirements depend not only on one's age, gender and lifestyle but also other factors such as body mass related goals, and in the case of women, stages of pregnancy to greatly affect their nutritional requirements. This perspective was brought into consideration in the attempts by future task forces appointed by the National Planning Commission.

Through the report of the Tendulkar Committee (2009) some modifications were made considering other basic requirements of the poor, such as housing, clothing, education, health, sanitation, conveyance, fuel, entertainment, etc, thus making the poverty line more realistic. The Tendulkar committee set down Rs 27 and Rs 33 as the benchmark daily per capita expenditure for rural and urban areas respectively which resulted in designating 22% of the population as 'below the poverty line'. The committee had defined the poor based on a normative living standard — it has moved away from calorie intake as the criterion and considered per capita consumption expenditure on commodities and services.[8]

Rangarajan Committee (2014) raised the benchmark amounts previously set by the Tendulkar Committee to Rs 32 and Rs 47 daily per capita expenditure for rural and urban areas respectively which resulted in nearly 30% of the nation's then population being determined as below the poverty line. The committee report stated its recommendation that the poverty line should be based on certain normative levels of adequate nourishment, clothing, house rent, conveyance and education, and a behaviorally determined level of other non-food expenses. It also considered average requirements of calories, protein and fats based on ICMR norms differentiated by age and gender.[9]

Thus, since the 1950s, the Government of India has initiated various plans to reduce and poverty and increase the capacity for nutrition-based consumption. They have done so by initiating several programs including subsidizing food, introduction of Ration Cards, improved agriculture techniques, and easier availability of loans. The Mahatma Gandhi National Rural Employment Guarantee Act, for instance, has generated over 2 billion person-days of employment during 2016-17 alone, largely for the disadvantaged sections of society. Additionally, initiatives have been launched for providing pension and insurance to workers in the unorganised sector, widows and the differently abled. Over 130 million people have accessed life

and accident insurance under these programmes.[10] These measures have helped the government by cutting the poverty rate to half, tackling famine, reducing malnutrition and literacy.

Meanwhile on a global scale, in 1990, The World Bank released a paper where it first proposed the "$1 a day" poverty line for measuring absolute poverty by the standards of the world's economically weakest countries. However, when the macroeconomic data for 2005 was observed, a marked economic gradient for national poverty line was observed when the consumption per person was above about $2.00 a day at 2005 purchasing power parity. Below that, the average poverty line was $1.25, which was proposed as the new international poverty line.[11] As per the Purchasing Power Parity (PPP) for 2011, the new international poverty line was adjudged to be $1.90.

In 2017, The World Poverty Clock had been introduced which is a real-time global poverty tracking model. It makes use of publicly available data on income distribution, production, and consumption from institutions like WorldBank, UN and IMF on peer reviewed models to forecast the speed of poverty reduction of each region and country against the average speed needed to achieve the first SDG by 2030.[12] On the basis of the difference, they are classified into the following 4 categories: No Extreme Poverty, On-Track, Off-Track, and Poverty is Rising.

3. RESEARCH OBJECTIVES

1. To *understand* whether a vegetarian adult can meet their minimum required basic nutritional needs within the poverty line amount

2. To *find* the food combination and minimum amount needed to be spent on food for an adult to be able to meet their minimum required basic nutritional needs

3. To *elaborate* on the suitability of the domestic and international benchmarks defined as the poverty line amount.

4. LITERATURE REVIEW

As a scientific approach to decision making, designing and operating systems under situation requiring allocation of scarce resources, Operations Research finds numerous uses for itself in the public sector issues, problems and systems (Pollock, Rothkopf, & Barnett, 1994).[13] The usage of scientifically established methods reduces the requirement for human judgement only to places where it is needed and is necessary. The computer revolution which has enabled the existence of high-powered personal computing devices, communication systems and data, has resulted in the availability of user-friendly software at every public official's desk which has made it easy to use mathematical models from Operations Research to solve nearly all types of problems (Pollock, Rothkopf, & Barnett, 1994).[13]

The economist George Stigler had posed a famous question in the early 1940s: 'For a moderately active man (economist) weighing 154 pounds, how much of each of 77 foods should be eaten on a daily basis so that the man's intake of nine nutrients (including calories) will be at least equal to the recommended dietary allowances (RDAs) suggested by the National Research Council in 1943, with the cost of the diet being minimal' (Garille & Gass, 1999)[14]. It was one of the first problems solved by the simplex method. Stigler's nonoptimal solution cost $39.93, with a diet consisting of wheat flour, evaporated milk, cabbage, spinach, and dried navy beans. The optimal, linear-programming solution cost $39.69 and included wheat flour, cabbage, spinach, beef liver, and dried navy beans (Gass & Harris, 2001).[15]

In 1999, Susan Garner Garille and Saul Gass applied Linear Programming Method to solve the aforementioned famous problem posed by the economist George Stigler but with updated nutritional content values and prices for those foods in 1998, unlike the 1939 prices and 1943 nutritional values taken by Stigler. In addition to updating the data, Garille & Gass (1999) also looked at satisfying the different requirements for individuals belonging to different demographics such as gender and age. Through the paper, they explore the significance of Stigler's handwritten solution on the field of Operations Research since Stigler made first use of greater than or smaller than linear inequalities to define constraints for his minimisation type objective, and he was able to solve the inequalities after a tedious process of trial and error. The inadequacy of Stigler's answer of 15 products and their respective quantities for the diet problem to produce a nutritious and palatable human diet caused researchers to extend the approach to menu plan-ning, which in turn raised new research questions in integer and goal programming (Garille & Gass, 1999).[14]

Linear Programming Problems with an objective of matching the total calories required while satisfying other daily nutritional requirements can be solved easily and quickly using the Solver tool on MS Excel (Hretcanu & Hretcanu, 2010)[16]. This also helped in finding out the nutrient composition of different diets of different target calorie amounts to understand the viability of each of the diets.

As demonstrated in the aforementioned paper Hretcanu & Hretcanu, 2010, the Solver tool in MS Excel is used to identify personal diets for individuals in real life as well in the Healthcare industry by Dieticians. However, it isn't as straightforward in real life due to the different nutritional requirements for each individuals which are dependant upon various personal behavioural and genetic factors. One such example is minimizing the cost objective function on the condition that the constraints regarding the amounts of protein, vitamins, minerals, fats, dietary fiber consumed throughout an entire day are satisfied. For an average adult male of 40-45 years of age (Patil & Kasturi, 2016).[17]

The usage of only cost constraints and nutritional constraints as the primary objective functions in the analysis of dietary problems and solutions, results in a fallibility under situations featuring a small number of food items and/or nutritional constraints (Dooren, 2018)[18]. While Dooren (2018) argued that introducing acceptability constraints is recommended, no study has provided the ultimate solution to calculating acceptability. Only 12 studies applied and introduced ecological constraints (and of these, only two also included cost constraints) and these studies showed that the environmental impacts of diets can be halved, staying within the existing nutritional constraints by using Linear Programming makes it possible to propose diets with lower impacts than diet scenario studies (Dooren, 2018)[18]. Due to Linear Programming's potential as a tool for environmental optimization, future possibilities lie in finding LP solutions for complex diets by combining nutritional, cost, ecological, and acceptability constraints.

5. RESEARCH METHODOLOGY

Proper diet is needed to ensure a person is healthy and fit. Decision regarding balanced diet is multi dimensional as it constitutes various food items carrying different amounts of nutrients which are necessary for proper growth. The decision becomes more complex when constraint of cost is considered.

5.1 Linear Programming Model

Linear Programming Program (LPP) is a mathematical technique used for optimizing (maximizing or minimizing) a linear function subject to linear constraints. A feasible solution which the objective function gets the value is called optimal. A feasible optimal problem is said to be unbounded if the objective function can assume arbitrarily large positive (resp. negative) values at feasible solutions otherwise, it is said to be bounded. The value of a bounded feasible minimum

(resp, maximum) problem is the minimum (resp. maximum) value of the objective function as the variables range over the constraint set.[16] Any linear program consists of four parts: a set of decision variables, the parameters, the objective function, and a set of constraints (Hretcanu & Hretcanu, 2010). LPP is at the heart of Operations Research and a classic public policy application is the "diet problem" that played a central role in defining the poverty level. In this paper, we are seeking to minimize the cost of a given dietary preferences on the basis of satisfying all nutritional requirement criteria and also help identify the appropriate relevant combination of food. We shall use the nutrient content of a proposed diet, as the condition that the daily nutritional requirements of a person (the amounts of protein, vitamins, minerals, fats and dietary fiber) are being satisfied.

5.2 Objective function

To minimize the total diet cost and is defined by the food and unit cost respectively. The cost function (Z) is a linear function giving the total sum of cost of cereals, pulses, vegetables(includes roots & tubers , green leafy vegetables ,others), fruits , sugars , fats & oils each and one milliliter of milk multiplied by the number of grams consumed for each food item respectively.

Food Items		Energy (kcal)	Protein (g)	Carbohydrates (g)	Fat (g)	Cost (per gm)
x_1	Cereals and Millets	3.333	0.1	0.6667	0.0267	0.0075
x_2	Pulses	3.333	0.2	0.5	0.0233	0.0035
x_3	Milk(ml) & milk products	0.7	0.03	0.05	0.03	0.005
x_4	Roots and Tubers	0.8	0.013	0.18	-	0.0015
x_5	Green Leafy Vegetables	0.46	0.036	-	0.004	0.01
x_6	Other Vegetables	0.28	0.017	-	0.002	0.009
x_7	Fruits	0.40	-	0.10	-	0.012
x_8	Sugars	4	-	1	-	0.025
x_9	Fats & Oils (visible)	9	-	-	1	0.045
Total Requirement		2500	56	225	44	

5.3 Constraint

The total quantity of calcium in this diet should be equal or greater than. Energy content should be greater than 2500 gms, Protein 56 gms, Fats 44 gms, Carbohydrate 225 gms.

5.4 Total formulation of problem

Min Z = $0.0075x_1 + 0.0035x_2 + 0.005x_3 + 0.0015 x_4 + 0.01x_5 + 0.009x_6 + 0.012x_7 + 0.025x_8 + 0.045x_9$

Subject to,

$3.3333*x_1 + 3.3333*x_2 + 0.7*x_3 + 0.8*x_4 + 0.46*x_5 + 0.28*x_6 + 0.40*x_7 + 4*x_8 + 9*x_9 >= 2500$

$0.1*x_1 + 0.2*x_2 + 0.03*x_3 + 0.013*x_4 + 0.036*x_5 + 0.017*x_6 >= 56$

$0.6667*x_1 + 0.5*x_2 + 0.05*x_3 + 0.18*x_4 + 0.10*x_7 + 1*x_8 >= 225$

$0.0267*x_1 + 0.0233*x_2 + 0.03*x_3 + 0.004*x_5 + 0.002*x_6 + 1*x_9 >= 44$

Also,

$x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8$ and $x_9 >= 0$;

5.5 Findings

The objective is a minimization type of problem. However the coefficients of the objective function are variable and keep on changing due to fluctuation in the price of the commodity and the non-homogeneity in the prices of the commodities across all geographies, qualities of commodity and time of the year. Additionally, different groups of people on the basis of age and gender too would have different nutritional requirements for their survival. Due to the large number of constraints and food requirements it is advisable to solve the problem using Excel solver.

Once the minimum possible price and the diet mix has been identified, the value should be compared against the food expenditure component of the various benchmarks for poverty line to understand whether the benchmark takes the minimum required nutritional amount into account sufficiently or not.

6. CONCLUSIONS

A practical model of a linear programming applied to a dietary situation was constructed. The demand for efficient decisions in deciding adult food requirement in rural areas gives opportunity to application of optimization techniques in problems related to resource allocation, which could be a complementary tool to economic evaluation models. The methodology can be implemented for the ones who have diabetic, cardiac or other health issues for whom diet control is an important aspect of healthcare by changing the constraint values accordingly.

If the acquired value minimum cost of the optimal diet plan exceeds the benchmark, a revision of these benchmarks, especially for the nutritional component is advised because poverty takes a multi-dimensional approach by not solely focusing on nutrition but by also considering shelter, clothing, healthcare and other bare necessities into account.

"I have learnt to seek my happiness by limiting my desires rather than in attempting to satisfy them." - John Stuart Mill

7. LIMITATIONS

. OR techniques provide a solution only when all the elements related to a problem can be quantified. Other qualitative factors are not taken into consideration. In our case, the OR technique is concerned with just minimising the cost of basic nutrients needed by a person. However other factors like a person's tastes and preferences for food are not considered.

· It is an assumption while using OR technique that the food products required for basic nutrients are available to the poor. However, it is not necessary that all the food products are readily available in rural and backward areas and it is of good quality.

· People in different regions consume different types of food products. For example, people from south India consume more rice than people from north. Also the cost of food products is different in different regions. OR does not take these regional differences into consideration.

· The basic nutrients which are required can be consumed by a variety of food products. However, our method takes into account only a specific set of food products consumed by the person. A change in the set of food products will also change the cost of consuming those basic nutrients.

· A person's basic nutritional requirements depend on the age, weight, gender and various other characteristics of the person. For example, a person looking for gaining muscle will require more amount of proteins than a person who wants to lose weight. The OR technique does not take these factors into consideration.

· There are some assumptions made while using the OR technique. Therefore, our solution is not 100% accurate. For example, for the cost of vegetables, we have taken an average of the price of a wide variety of vegetables. However, a person consumes only a few of them which varies from person to person.

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