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SOLUTION AND SENSITIVITY ANALYSIS OF DIET PROBLEM OF SEDENTARY AND MODERATE WORKING WOMEN IN INDIA

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Abstract: Diet problem is an application of Linear programming problem (LPP). Linear programming is a technique of Operations Research for determining an optimum schedule of interdependent activities in view of the available resources. The word programming means determining the plan of action from amongst several alternatives and the word linear refers to the fact that the relationships involved are linear.

The various nutrients like carbohydrates, proteins, fats, vitamins and minerals in different food items like wheat, rice, milk, carrot, groundnuts, etc. are helpful for maintenance, growth, reproduction and health of human being.
This paper is the study of determining the optimum solution and analyzing its sensitivity for diet problem of sedentary and moderate working women in India. We solved this problem by using the LPP solver tool in MS-Excel.
In this paper the various food items are taken as decision variables and constrains are designed corresponding to different nutrients. In the construction of constraints we have assumed that any intake of more than the minimum requirement of nutrients is not harmful to the human body. Here the objective is to find the optimum solution that is to find the quantity of food items that should be consumed to minimize the cost of diet which will fulfil the minimum requirement of nutrients for these two types of women. Also we analyzed the sensitivity of this optimum solution.

Index Terms **-** Nutrients, Diet, Solver tool in MS Excel, Reduced cost, Shadow price.

1. INTRODUCTION

Women need a wide range of nutrients to perform various functions in the body and to lead a healthy life. Since women derive all the nutrients they need through the diet they eat, their diet must be well balanced to provide all the vital nutrients in proper proportion [2]. Especially sedentary as well as moderate working women are in the high need of protein, fats, carbohydrates, vitamin A and C, iron, calcium and also dietary fibre to have a good nutritional status which will keep them free from deceases like anaemia, underweight, osteoporosis, etc. Hence their diet must have good accessibility to these nutrients through their regular diet which must be easily available to them. To find optimum nutritional benefits in low cost here we formulate the LPP (Diet Problem) in which we have to specify first, the four things which are,

1.1. Decision Variables:

These are the variables for which we have to take the decision. We have taken 25 vegetarian food items as decision variables (as shown in table 2) which Indian women commonly use in their daily diet as a sustaining food. In this diet problem using LPP we have to find out that how much grams of these food items are necessary for daily requirement of nutrients for women at minimum cost.

1.2. Objective Function:

The linear function which is to be optimized is called the objective function. In this problem, our main objective is to minimize the total cost of daily diet of women which will fulfil the minimum requirement of nutrients. Here we want the cost of food items purchased (as shown in table 2) to be as little as possible and at the same time, we also emphasised on the thing that these food items provide all the necessary nutrients required for the healthy life of women. Some food items can be common for different nutrients. It is beneficial for cost cutting of diet.

1.3. Constraints:

Constraints mean restrictions i.e. food items should provide minimum nutritional requirements necessary for healthy life. There are many nutrients which are available in various food items, but for convenience, for sedentary and moderate working women we considered 8 nutrients which are commonly available in all types of food items and their minimum amounts which are required for sustaining a healthy life recommended by Indian Council of Medical Research (ICMR) are as shown in table 1[1].

Table 1. ICMR Recommended dietary allowances per day for Indians

Nutrients (gm/day)		Protein	Fats	Carbohydrates	Vitamin A	Vitamin C	Iron	Calcium	Dietary Fibre
Women (Body weight 50 Kg.)	Sedentary work	50	20	100	0.0024	0.04	0.03	0.4	50
	Moderate work								

1.4. Non Negative Restrictions:

All the decision variables are restricted to be non negative.

Mathematically, the diet problem can be stated as follows,

$$\text{Min } Z = \sum_{j=1}^{n} c_j x_j \qquad \dots (1)$$

Subject to the constraints,

$$\sum_{j=1}^{n} a_{ij} x_j \geq b_i \qquad ; i = 1, 2, \dots, m \qquad \dots (2)$$

$$x_j \geq 0 \qquad ; j = 1,2, \dots, n \qquad \dots (3)$$

Where x_j's are the quantities of food items, c_j's are the costs of food items per 100 gm, a_{ij}'s are amounts of nutrients per 100 gm of food items and b_i's are daily minimum nutritional requirements.

Our diet problem is to minimize the function (1) subject to the constraints (2) and non negative restrictions (3).

LPPs are usually solved by simplex method, originally developed by Dantzig in 1948. Since diet problem is of minimization and constraints are of greater than or equal to type, we solved it using Charnes method of penalties or the Big M method. In our paper, we proposed a computer-based method using the Solver tool from Microsoft Excel for planning an optimal menu with respect to the daily nutritional requirements of Indian sedentary and moderate working women [5].

Following the formulation of LPP and attainment of an optimum solution of it, it is often desired to study the effect of changes in the different parameters of the problem on the current optimum solution. If slight changes are made in the parameters or the structure of a given LPP after its optimum solution has been attained then the analysis of such post-optimal problems can thus be termed as post-optimality analysis or sensitivity analysis [4].

2. FORMULATION OF DIET PROBLEM

Table 2 provides us the input data for a LPP with 25 decision variables indicating amount of various food items to be consumed and 8 constraints determining minimum nutritional requirement [3].

Table 2. Amount of various nutrients contained in different vegetarian food groups-items with costs

Sr. No.	Food Groups (Food Items in 100 gm)		Costs (in Rs.)*	Nutrients (gm / day)							
				Protein	Fats	Carbo hydrates	Vitamin A	Vitamin C	Iron	Calcium	Dietary Fibre
1	**Cereals, Grains And Products**										
	Wheat	x_1	3	8.2	1.6	77.2	0.000029	0	0.0049	0.037	1.7
	Jawar	x_2	4	10.4	1.9	72.6	0.000047	0	0.0041	0.025	1.6
	Bajra	x_3	4	11.6	5	67.5	0.000132	0	0.008	0.042	1.2
	Rice	x_4	6	7.5	1	76.7	0	0	0.0032	0.01	0.6
	Ragi	x_5	6	7.3	1.3	72	0.000042	0	0.0039	0.344	3.6
2	**Pulses And Legumes**										
	Redgram Dal	x_6	10	22.3	1.7	57.6	0.000132	0	0.0027	0.073	1.5
	Green Gram Dal	x_7	10	24	1.3	56.7	0.000049	0	0.0044	0.124	4.1
	Bengalgram Dal	x_8	8	7	1.4	14.1	0.000189	0.003	0.0238	0.34	2
	Mothbean	x_9	8	23.6	1.1	56.5	0.000009	0.002	0.0095	0.202	4.5
3	**Leafy Vegetables**										
	Shepu	x_{10}	4	3	0.5	5.2	0.007182	0	0.0174	0.19	1.1
4	**Roots And Tubers**										
	Carrot	x_{11}	4	0.9	0.2	10.6	0.00189	0.003	0.00103	0.08	1.2
	Beetroot	x_{12}	8	1.7	0.1	8.8	0	0.01	0.00119	0.0183	0.9
	Onion	x_{13}	6	1.2	0.1	11.1	0	0	0.0006	0.0469	0.6
5	**Condiments And Spices**										
	Green Chillies	x_{14}	7	2.9	0.6	3	0.000175	0.111	0.0044	0.03	6.8
6	**Other Vegetables**										
	Papaya Green	x_{15}	5	0.7	0.2	5.7	0.000666	0.057	0.0009	0.028	0.9
7	**Fruits**										
	Banana	x_{16}	3	1.2	0.3	27.2	0.000078	0.007	0.00036	0.017	0.4
	Amla	x_{17}	6	0.5	0.1	13.7	0.000009	0.6	0.0012	0.05	3.4
	Guava	x_{18}	5	0.9	0.3	11.2	0	0.212	0.00027	0.01	5.2
8	**Nuts And Oil Seeds**										
	Sesame Seeds	x_{19}	16	18.3	43.3	25	0.00006	0	0.0093	1.45	2.9
	Graundnuts	x_{20}	12	25.3	40.1	26.1	0.000037	0	0.0025	0.09	3.1
9	**Milk And Milk Products**										
	Paneer	x_{21}	35	13.4	23	7.9	0	0	0	0.48	0
	Milk(Buffello)	x_{22}	6	4.3	6.5	5	0.000048	0.001	0.0002	0.21	0
10	**Fats And Edible Oils**										
	Sunflower Oil	x_{23}	14	19.8	52.1	17.9	0	0	0.005	0.28	1
	Ghee	x_{24}	64	0	100	0	0	0	0	0	0
11	**Sugars**										
	Sugar	x_{25}	4	0.1	0	99.4	0	0	0.000155	0.012	0

*The prices of food items are found from the grocery shop of Amravati (MS, India) in the month of December 2019 i.e. in the winter season. Here we have taken seasonal leafy vegetable-*Shepu* and fruits- *Amla* and *Guava*.

Thus using all the collected data from tables 1 and 2, the formulated diet problem is as follows:

MIN Z = $3x_1 + 4x_2 + 4x_3 + 6x_4 + 6x_5 + 10x_6 + 10x_7 + 8x_8 + 8x_9 + 4x_{10} + 4x_{11} + 8x_{12} + 6x_{13} + 7x_{14} + 5x_{15} + 3x_{16} + 6x_{17} + 5x_{18} + 16x_{19} + 12x_{20} + 35x_{21} + 6x_{22} + 14x_{23} + 64x_{24} + 4x_{25}$ ...(4)

subject to constraints,

Protein: $8.2x_1 + 10.4x_2 + 11.6x_3 + 7.5x_4 + 7.3x_5 + 22.3x_6 + 24x_7 + 7x_8 + 23.6x_9 + 3x_{10} + 0.9x_{11} + 1.7x_{12} + 1.2x_{13} + 2.9x_{14} + 0.7x_{15} + 1.2x_{16} + 0.5x_{17} + 0.9x_{18} + 18.3x_{19} + 25.3x_{20} + 13.4x_{21} + 4.3x_{22} + 19.8x_{23} + 0.1x_{25} \geq 50$ ...(5)

Fats: $1.6\ x_1 + 1.9\ x_2 + 5\ x_3 + x_4 + 1.3\ x_5 + 1.7\ x_6 + 1.3\ x_7 + 1.4\ x_8 + 1.1\ x_9 + 0.5\ x_{10} + 0.2x_{11} + 0.1x_{12} + 0.1x_{13} + 0.6x_{14} + 0.2x_{15} + 0.3x_{16} + 0.1x_{17} + 0.3x_{18} + 43.3x_{19} + 40.1x_{20} + 23x_{21} + 6.5x_{22} + 52.1x_{23} + 100x_{24} \geq 20$ ...(6)

Carbohydrates: $77.2\ x_1 + 72.6\ x_2 + 67.5\ x_3 + 76.7\ x_4 + 72\ x_5 + 57.6\ x_6 + 56.7\ x_7 + 14.1\ x_8 + 56.5\ x_9 + 5.2\ x_{10} + 10.6x_{11} + 8.8x_{12} + 11.1x_{13} + 3x_{14} + 5.7x_{15} + 27.2x_{16} + 13.7x_{17} + 11.2x_{18} + 25x_{19} + 26.1x_{20} + 7.9x_{21} + 5x_{22} + 17.9x_{23} + 99.4x_{25} \geq 100$ ...(7)

Vitamin A : $0.000029\ x_1 + 0.000047\ x_2 + 0.000132\ x_3 + 0.000042\ x_5 + 0.000132\ x_6 + 0.000049\ x_7 + 0.000189\ x_8 + 0.000009\ x_9 + 0.007182\ x_{10} + 0.00189x_{11} + 0.000175x_{14} + 0.000666x_{15} + 0.000078x_{16} + 0.000009x_{17} + 0.00006x_{19} + 0.000037x_{20} + 0.000048x_{22} \geq 0.0024$ ...(8)

Vitamin C: $0.003\ x_8 + 0.002\ x_9 + 0.003x_{11} + 0.01x_{12} + 0.111x_{14} + 0.057x_{15} + 0.007x_{16} + 0.6x_{17} + 0.212x_{18} + 0.001x_{22} \geq 0.04$ ...(9)

Iron:$0.0049\ x_1 + 0.0041\ x_2 + 0.008\ x_3 + 0.0032\ x_4 + 0.0039\ x_5 + 0.0027\ x_6 + 0.0044\ x_7 + 0.0238\ x_8 + 0.0095\ x_9 + 0.0174\ x_{10} + 0.00103x_{11} + 0.00119x_{12} + 0.0006x_{13} + 0.0044x_{14} + 0.0009x_{15} + 0.00036x_{16} + 0.0012x_{17} + 0.00027x_{18} + 0.0093x_{19} + 0.0025x_{20} + 0.0002x_{22} + 0.005x_{23} + 0.000155x_{25} \geq 0.03$ ...(10)

Calcium: $0.037\ x_1 + 0.025\ x_2 + 0.042\ x_3 + 0.01\ x_4 + 0.344\ x_5, + 0.073\ x_6 + 0.124\ x_7 + 0.34\ x_8 + 0.202\ x_9 + 0.19\ x_{10} + 0.08x_{11} + 0.0183x_{12} + 0.0469x_{13} + 0.03x_{14} + 0.028x_{15} + 0.017x_{16} + 0.05x_{17} + 0.01x_{18} + 1.45x_{19} + 0.09x_{20} + 0.48x_{21} + 0.21x_{22} + 0.28x_{23} + 0.012x_{25} \geq 0.4$ ...(11)

Dietary Fibre: $1.7\ x_1 + 1.6\ x_2 + 1.2\ x_3 + 0.6\ x_4 + 3.6\ x_5 + 1.5\ x_6 + 4.1\ x_7 + 2\ x_8 + 4.5\ x_9 + 1.1\ x_{10} + 1.2x_{11} + 0.9x_{12} + 0.6x_{13} + 6.8x_{14} + 0.9x_{15} + 0.4x_{16} + 3.4x_{17} + 5.2x_{18} + 2.9x_{19} + 3.1x_{20} + x_{23} \geq 50$ ...(12)

and $x_1 \geq 0,\ x_2 \geq 0,\ ---, x_{25} \geq 0$ ...(13)

3. SOLUTION OF DIET PROBLEM

MS-Excel workbook was developed using Solver tool [6]. By using this tool, we can provide a fast way to solve this diet problem and to check whether the daily nutritional requirements of women are satisfied.

Here we get resultant optimum solution which gives the minimum cost of food items satisfying minimum nutritional requirement with values of basic variables as $x_1 = 4.3458$, $x_9 = 0.0053$, $x_{10} = 0.3151$, $x_{18} = 7.9722$, $x_{19} = 0.0554$, $x_{20} = 0.2018$ and Min. Z=57.5095 as shown below in figure 1.

Here x_1, x_9, x_{10}, x_{18}, x_{19} and x_{20} indicates *Wheat*, *Mothbean*, *Shepu*, *Guava*, *Sesame Seeds*, and *Groundnuts* respectively.

Figure 1. Inputs and results of diet problem solved by Solver Tool in MS-EXCEL.

Nutrients		Protein	Fats	Carbohydrates	Vitamin A	Vitamin C	Iron	Calcium	Dietary Fibre	MIN Z = 57.50945705	
Minimum Requirement gm/day		50	20	100	0.0024	0.04	0.03	0.4	50		
X	Food Items (100 gms)	50	20	433.3721	0.0024	1.69012	0.03	0.4	50	Costs	Optimum Solution
x1	Wheat	8.2	1.6	77.2	0.000029	0	0.0049	0.037	1.7	3	4.345771
x2	Jawar	10.4	1.9	72.6	0.000047	0	0.0041	0.025	1.6	4	0
x3	Bajra	11.6	5	67.5	0.000132	0	0.008	0.042	1.2	4	0
x4	Rice	7.5	1	76.7	0	0	0.0032	0.01	0.6	6	0
x5	Ragi	7.3	1.3	72	0.000042	0	0.0039	0.344	3.6	6	0
x6	Redgram Dal	22.3	1.7	57.6	0.000132	0	0.0027	0.073	1.5	10	0
x7	Green Gram Dal	24	1.3	56.7	0.000049	0	0.0044	0.124	4.1	10	0
x8	Bengalgram Dal	7	1.4	14.1	0.000189	0.003	0.0238	0.34	2	8	0
x9	Mothbeen	23.6	1.1	56.5	0.000009	0.002	0.0095	0.202	4.5	8	0.005291
x10	Shepu	3	0.5	5.2	0.007182	0	0.0174	0.19	1.1	4	0.315112
x11	Carrot	0.9	0.2	10.6	0.00189	0.003	0.00103	0.08	1.2	4	0
x12	Beetroot	1.7	0.1	8.8	0	0.01	0.00119	0.0183	0.9	8	0
x13	Onion	1.2	0.1	11.1	0	0	0.0006	0.0469	0.6	6	0
x14	Green Chillies	2.9	0.6	3	0.000175	0.111	0.0044	0.03	6.8	7	0
x15	Papaya Green	0.7	0.2	5.7	0.000666	0.057	0.0009	0.028	0.9	5	0
x16	Banana	1.2	0.3	27.2	0.000078	0.007	0.00036	0.017	0.4	3	0
x17	Amla	0.5	0.1	13.7	0.000009	0.6	0.0012	0.05	3.4	6	0
x18	Guava	0.9	0.3	11.2	0	0.212	0.00027	0.01	5.2	5	7.972207
x19	Sesame Seeds	18.3	43.3	25	0.00006	0	0.0093	1.45	2.9	16	0.055437
x20	Graundnuts	25.3	40.1	26.1	0.000037	0	0.0025	0.09	3.1	12	0.201778
x21	Paneer	13.4	23	7.9	0	0	0	0.48	0	35	0
x22	Milk(Buffello)	4.3	6.5	5	0.000048	0.001	0.0002	0.21	0	6	0
x23	Sunflower Oil	19.8	52.1	17.9	0	0	0.005	0.28	1	14	0
x24	Ghee	0	100	0	0	0	0	0	0	64	0
x25	Sugar	0.1	0	99.4	0	0	0.00016	0.012	0	4	0

4. SENSITIVITY ANALYSIS

Finding the optimum solution to a linear programming model is only the first step. After that we need to perform the sensitivity analysis of the optimum solution.

Sensitivity analysis is called “what-if-analysis” i.e. what happens to the solution if some parameters change.

The sensitivity report obtained from Solver tool of MS Excel is as shown in table 3 which provides classical sensitivity analysis information for LPP (diet problem) including dual values and range information. The dual values for non basic variables are called reduced costs and for binding constraints are called shadow prices.

Table 3. Sensitivity Report

Variables					
Name	**Final Value (Optimum Solution)**	**Reduced Cost**	**Objective Coefficient**	**Allowable Increase**	**Allowable Decrease**
Wheat	4.345771371	0	3	0.043973801	0.029824013
Jawar	0	0.829329631	4	1E+30	0.829329631
Bajra	0	0.478071243	4	1E+30	0.478071243
Rice	0	4.3092075	6	1E+30	4.3092075
Ragi	0	0.396346455	6	1E+30	0.396346455
Redgram Dal	0	5.345590456	10	1E+30	5.345590456
Green Gram Dal	0	2.616340558	10	1E+30	2.616340558
Bengalgram Dal	0	3.581171752	8	1E+30	3.581171752
Mothbeen	0.00529119	0	8	0.098126857	0.170307503
Shepu	0.315111805	0	4	3.470250326	1.617138948
Carrot	0	2.036033624	4	1E+30	2.036033624
Beetroot	0	6.86829339	8	1E+30	6.86829339
Onion	0	5.121392651	6	1E+30	5.121392651
Green Chillies	0	0.065759167	7	1E+30	0.065759167
Papaya Green	0	3.794082241	5	1E+30	3.794082241
Banana	0	2.361843368	3	1E+30	2.361843368
Amla	0	2.59489499	6	1E+30	2.59489499
Guava	7.972206894	0	5	0.055856536	1.941947266
Sesame Seeds	0.055437473	0	16	2.113469724	1.425402175
Graundnuts	0.20177768	0	12	0.554435512	0.864982556
Paneer	0	28.51437523	35	1E+30	28.51437523
Milk(Buffello)	0	3.845990922	6	1E+30	3.845990922
Sunflower Oil	0	2.249120906	14	1E+30	2.249120906
Ghee	0	49.75699659	64	1E+30	49.75699659
Sugar	0	3.946040389	4	1E+30	3.946040389
Constraints					
Name	**Final Value**	**Shadow Price**	**Constraint R.H. Side**	**Allowable Increase**	**Allowable Decrease**
Protein	50	0.1216845	50	5.7310651	0.0552488
Fats	20	0.14243	20	0.0985949	10.947947
Carbohydrates	433.37214	0	100	333.37214	1.00E+30
Vitamin A	0.0024	231.33079	0.0024	0.0014565	1.78E-05
Vitamin C	1.6901184	0	0.04	1.6501184	1.00E+30
Iron	0.03	14.916881	0.03	3.48E-05	0.0052974
Calcium	0.4	3.2899204	0.4	0.3551313	0.0038536
Dietary Fibre	50	0.9251593	50	0.6431614	39.274105

5. RESULTS AND DISCUSSION

5.1. Interpreting Dual Values

Dual values are the most basic form of sensitivity analysis information. The dual value for a variable i. e. Reduced cost is nonzero only when the variable's value is equal to its upper or lower bound at the optimal solution. This variable is called a *nonbasic* variable, and its value was driven to the bound during the optimization process. The reduced costs tell us how much the objective coefficients (costs per 100 gm) can be increased or decreased before the optimal solution changes.

For instance, if we decrease the cost of non basic variable Jawar Rs. 4 by its Allowable Decrease Rs. 0.829329631 we get the cost Rs. 3.170670369, the optimal solution changes as 4.341208 gm of Wheat, 0.0173 gm of Jawar, 0.3150 gm of Shepu, 7.9733gm of Guava, 0.0561 gm of sesame seeds, 0.2006 gm of Groundnuts with minimum cost **Z = 57.50945705.** If we decrease the cost Rs. 3.170670369 by 1 unit the optimum solution changes to 5.2837 gm of Jawar, 0.2984 gm of Shepu, 7.8229 gm of Guava, 0.0859 gm of sesame seeds, 0.0934 gm of Groundnuts with minimum cost **Z = 54.27263776**. If we increase the cost Rs.3.170670369 by 1 or more units, the optimum solution and minimum value of Z remains same.

The dual value for a constraint i. e shadow price is nonzero only when the constraint is equal to its bound i. e. Final Value equal to Constraints R. H. Side as shown in the table 3. This is called a *binding* constraint, and its value was driven to the bound during the optimization process. These shadow prices tell us how much the optimal solution can be increased or decreased if we change the right hand side values (Minimum Requirement) with one unit.

For instance, with 50 gm of dietary fibre the total cost is Rs. **57.50945705** as shown in figure 1.

If we increase 1 gm of dietary fibre i. e to 51 gm, the total cost we obtained is **58.43511628** with optimum solution 4.3406 gm of Wheat, 0.3150 gm of Shepu, 0.0076 gm of Green chillies, 8.1615 gm of Guava, 0.0549 gm of Sesame seeds and 0.2012 gm of Groundnuts.

5.2. Interpreting Range Information

In this diet problem, the dual values are *constant* over a range of possible changes in the objective function coefficients and the constraint right hand sides.

For each decision variable, the report shows its coefficient in the objective function, and the amount by which this coefficient could be increased or decreased without changing the dual value (Allowable Increase and Allowable Decrease).

For each constraint, the report shows the constraint right hand side, and the amount by which the RHS could be increased or decreased without changing the dual value (Allowable Increase and Allowable Decrease).

With a shadow price of 0.925159266 gm for dietary fibre, this is according to our expectations. This shadow price is only valid between [(50 – 0.64316135) to (50 + 39.27410506)] (see sensitivity report for constraints).

6. CONCLUSIONS

The optimum solution with food items Wheat, Mothbean, Shepu, Guava, Sesame seeds and Groundnuts from which the sedentary as well as moderate working women in India can have a sufficient nutritional benefits necessary for sustaining the healthy life by spending **Rs. 57.5095** per day only. This diet may not be tasteful but there is no doubt about the optimality of the solution within the limitations we have formulated.

The costs of food items play very important role in finding the optimum solution of diet problem. It should be noted that as costs always vary according to locations and seasons, the optimum solution changes.

The Sensitivity Report details how changes in the coefficients of the objective function affect the solution and how changes in the constants on the right hand side of the constraints affect the solution. For each variable, we can calculate the range of values that the coefficient can take on by subtracting the allowable decrease from the coefficient or adding the allowable increase to the coefficient. The second part of the Sensitivity Report examines how changes to the right hand side of any constraint affects the optimal solution. A change to the constant on the right hand side of a constraint changes the size of the feasible region. Increasing the right hand side of any constraint with positive coefficients shifts the border matching the constraint up. Decreasing the right hand side of any constraint with positive coefficients shifts the border matching the constraints down. The shadow price indicates how the objective function will change when the constant on the right hand side is changed.

The sensitivity analysis for a nonbinding constraint, like Carbohydrates and Vitamin C, is different. At the optimal solution, changes to the right hand side do not affect the costs as long as the right hand side is not decreased too much. This means that the shadow price is Rs. 0.

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