

# Study on Simplex Method and Design & Development of Application for Solving Simplex Problem using Python

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**Abstract:-** The aim of this study is to develop application using python language which solves the simplex problem and this will help the user to understand how each step follows in simplex problem until the optimum solution is reached. Here we can optimize the objective function for minimization as well as maximization and linear constraints with n number of variables. Application developed is user friendly; python code takes input from the user in the console. Every input has a proper labelled question and the user has to enter the values of what is asked, and it shows the solution in excel with all iteration including key column and key row. The simplex algorithm using python can extend to solve real world problems like least cost formulation and maximization of profit.

**Keywords:-** Simplex Problem, Python Application, Optimization, Excel.

## I. INTRODUCTION

The introduction of paper contains the nature of research work, purpose of work, and the contribution of this paper.

Simplex method is one of the approaches to solve linear programming problem. This method invented by George Dantzig in 1947. Simplex is very efficient method [1].

Simplex in one dimension is a line segment connecting two points, in two dimensions it is a triangle formed by the points. A three dimensions simplex is the four-sided pyramid having four corners. Simplex finds the best corner of the feasible region. It usually starts with the corner point which has no values then it moves to neighborhood point which improves the solution simplex repeats the process until gets the optimum solution that is no further more improvements [2]. Standard form of simplex method have three main requirements one is objective function, should be maximization, second all constraints to be linear and, third all variables to be non-negative. The general form is as shown below,

$$Max Z = CX$$

$$\begin{array}{ll} \text{Subject to} & AX = b \\ \text{And} & X \geq 0 \end{array}$$

Where C is the cost matrix, X is variable matrix, A is coefficient matrix, is the right hand side of the constraints [3]. Real world problems like production, sales and management, are solved using simplex algorithm. This study works in two phases' first one, finding appropriate method of solving a LPP, which has different types of constraints ( $\leq$ ,  $\geq$ ,  $=$ ). In the Second phase converting this method into a code using python so that method can be used for all inputs.

Python is a high level programming language used almost everywhere. It was created by Guido van Rossum at Centrum Wiskunde & Informatica (CWI) in Netherlands and was first released in 1991. It supports multi-programming paradigms, which include object oriented, procedural and functional and many more. Python has developed a lot throughout the year since its first release, from being a 'hobby' project to Guido van Rossum to the one of the most useful languages. Python is used in Data Science, Machine Learning, Web servers and many more places. Python is one of the easiest language to learn and it being an open source software anyone in the python community and contribute to its development like 'xlsxwriter', 'flask' etc. making it highly extensible. Today anyone can create useful packages for python so that the other programmers do not have to do the same thing twice but just use it how they want. Python is meant to be an easily readable language and it is possible only due to its formatting. It contains English keywords like 'in', 'as' etc. and the indentation used by python is whitespace indentation where increase or decrease in indentation is used to determine the opening or closing block rather the usually used curly braces in many of the languages. Python can also act as a cross compiler to other languages like Java, R, JavaScript, C/C++, VHDL in the form of JPython, RPython, Pyjs, Cython and MyHDL respectively. Python's design and concept has influenced many other languages which include Cobra, Go, Julia, Kotlin, Ruby, Swift and many more.

**II. MATERIALS & METHODS**

The simplex method can be easily applies to real world problems. The problem is converted into mathematically linear model to keep it into standard form. Simplex method procedure which is been followed in this study is given below with an example

**Example:**  $MIN Z = x_1 + x_2 + 3x_3$

Subject to constraints.

$$\begin{aligned} 3x_1 + 2x_2 + x_3 &\leq 3 \\ 2x_1 + x_2 + 2x_3 &\geq 3 \\ x_1 + x_2 + x_3 &= 3/2 \\ x_1, x_2, x_3 &\geq 0 \end{aligned}$$

**Step 1:** Make sure that objective function is Maximization. If it is minimization then convert it into maximization by multiplying -1 and write  $Max Z = Min(-z)$ .

$$Max Z = -x_1 - x_2 - 3x_3$$

**Step 2:** Convert the inequalities to equalities by employing following rule.

1. If the constraint inequalities is ' $\leq$ ' then add slack variables ( $S$ ) to the left hand side of the inequality and write it as equation.

2. If the constraint inequalities are ' $\geq$ ' then subtract surplus ( $S$ ) variable and add artificial variable( $A$ ) to the left hand side of the inequality and write it as equation.
3. If the constraint inequalities is ' $=$ ' then add artificial variables ( $A$ ) to the left hand side of the inequality and write it as equation.
4. If in case right hand side is negative then multiply the  $-1$  throughout and make it positive and then follow rules(1-3)
5. In the objective function coefficient of slack variable, surplus variable is 0 and artificial variable is -1

$$\begin{aligned} Max Z &= -x_1 - x_2 - 3x_3 + 0S_1 + 0S_2 - A_1 - A_2 \\ 3x_1 + 2x_2 + x_3 + S_1 &= 3 \\ 2x_1 + x_2 + 2x_3 - S_2 + A_1 &= 3 \\ x_1 + x_2 + x_3 + A_2 &= 3/2 \end{aligned}$$

**Step 3:** Non-negativity constraints are  $x_1, x_2, x_3, S_1, S_2, A_1, A_2, \geq 0$

**Step 4:** Initial basic feasible solution can be found by equating  $n - m$  variable to zero ( $n =$  number of variable and  $m =$  number of constraints). That is  $6 - 3 = 3$  variables are equated to zero those are  $x_1 = x_2 = x_3 = 0$ , therefore we Basic variables  $S_1 = 3, A_1 = 3, A_2 = 3/2$ . Write the linear problem in tabular as shown below,

	$C_j$	-1	-1	-3	0	0	-1	-1		
$a_i$	B.V	$x_1$	$x_2$	$x_3$	$S_1$	$S_2$	$A_1$	$A_2$	R.H.S	Ratio
0	$S_1$	3	2	1	1	0	0	0	3	$\frac{3}{3} = 1$
-1	$A_1$	2	1	2	0	-1	1	0	3	$\frac{3}{2} = 1.5$
-1	$A_2$	1	1	1	0	0	0	1	3/2	$\frac{3}{2} = 1.5$
	$Z_j$	-3	-2	-3	0	1	0	0	-9/2	

Table 1:- Table for example input

In the table,  $C_j$  are coefficients of objective function and  $a_i$  are coefficients of basic variable in the objective function.  $Z_j - C_j$  is calculated by the formula  $\sum_{i=1}^3 a_i x_{ij} - C_j = 1, 2 \dots 7$ .

For example,  $[(0X3) + (-1X2) + (-1X1)] = -3$ . Using this formula all the values are calculated and if all the values are positive then optimality is reached. For artificial variable, it is kept zero. If the LPP contain all constraints' less than equal to zero then  $\sum_{i=1}^3 a_i x_{ij} - C_j$  will be found. If a value is less than zero, it means that variable has not reached its optimal value, as we seen in the above table there are two negative values, select the most negative value, the column which consists that value called as pivot column and the variable is entering variable( $x_1$ ). For each value in the

pivot column ratios is found, which is shown in the right hand side. The row, which has, has lowest ratio that will be pivot row, and the variable is departing variable ( $S_1$ ). and coinciding number is called pivot element(3).

**Step 5:** The next iterative table all the pivot row element are divided by the pivot element and remaining rows can be found by using the formula

$$new\ row = \frac{old\ row - (Product\ of\ elemnt\ of\ pivot\ column\ \&\ pivot\ row)}{pivot\ element}$$

The process continues until the optimality condition reached that is all  $Z_j - C_j \geq 0$ .

### III. SIMPLEX APPLICATION USING PYTHON

The application is created using the programming language python. The python code takes input from the user in the console. Every input has a proper-labelled question and the user has to enter the values of what is asked. The input console will look like the figure shown below (The given input is for the above specified example).

```

Enter number of Equations: 3
Enter number of variables: 3
Enter the coefficient of x1 in equation 1: 3
Enter the coefficient of x2 in equation 1: 2
Enter the coefficient of x3 in equation 1: 1
Enter xb of equation1: 3
Enter type of equation (l (<=), g(>=), e(=)): l
Enter the coefficient of x1 in equation 2: 2
Enter the coefficient of x2 in equation 2: 1
Enter the coefficient of x3 in equation 2: 2
Enter xb of equation2: 3
Enter type of equation (l (<=), g(>=), e(=)): g
Enter the coefficient of x1 in equation 3: 1
Enter the coefficient of x2 in equation 3: 1
Enter the coefficient of x3 in equation 3: 1
Enter xb of equation3: 1.5
Enter type of equation (l (<=), g(>=), e(=)): e
Enter the coefficient of x1 of z equation: 1
Enter the coefficient of x2 of z equation: 1
Enter the coefficient of x3 of z equation: 3
Minimization form (y/n): y
Iterations saved in 'Simplex 1' excel file in the documents folder
Press any key to continue...
    
```

Fig 1:- Input example

In the above picture depicts how the program takes the inputs. The program first asks the user the number of equations and number of variables (i.e.  $x_1, x_2, x_3$ , etc.). Then the program asks the user to enter the coefficients of each variable in each question. Then the user enters the R.H.S value of the equation i.e. the “xb” value in the above picture. Then the user is asked if the equation inequality which are l(<=) less than or equal to inequality (or) g(>=) greater than or equal to inequality (or) e(=) equality and the input is case insensitive. After taking all the equation, the user enters the coefficient of variable in the objective function. After entering these values and the code generates the excel file which is stored in the documents folder in the user system.

The excel file contains all the iteration of the above entered equation using simplex method.

#### A. Output

Fig 2:- Excel file

The above picture depicts how the excel sheet looks after doing the operations on the entered equations. The red cells contain the value, which is least in the  $Z_j - C_j$  row, and the yellow cells contain the key values and the green cells contain the values of the variables and Z after doing the simplex method.

#### B. How does it work??

The first thing the code does is, it takes the number of equations and variables as input, so now we know how many equations are there and the number of variables and slack variables. After this, we find out the least value, which is there in the  $Z_j - C_j$  row. That is done by the following code:

```

key_col = equations[-1].index(min(equations[-1]))
key_col_value = equations[-1][key_col]
    
```

Fig 3:- Code to find key column

Now we know which value is least in the  $Z_j - C_j$  row i.e. we know the key column and now we have to find the key row, which is done the following code:

```

for index, equation in enumerate(equations):
    if (equation[key_col]==0):
        continue
    if (equation[-1]/equation[key_col]) < least and index!=(len(equations)-1):
        least = float(equation[-1]/equation[key_col])
        pos = index
    
```

Fig 4:- Code to find key row

From the above code, we have found the least row and the key value. The next step is to generate the next iteration. After generating the next iteration the above steps for the simplex method is followed and when the answer is found the, it is shown in the excel file.

#### C. Examples:

1)

$$\text{Max } Z = 2x_1 + 4x_2 + 3x_3$$

Subject to constraints,

$$3x_1 + 4x_2 + 2x_3 \leq 60$$

$$2x_1 + x_2 + 2x_3 \leq 40$$

$$x_1 + 3x_2 + 2x_3 \leq 80$$

$$x_1, x_2, x_3 \geq 0$$

Fig 5:- Excel output for above example

2)

$$\text{Min } Z = 12x_1 + 20x_2$$

Subject to constraints

$$\begin{aligned} 6x_1 + 8x_2 &\geq 100 \\ 7x_1 + 12x_2 &\geq 120 \\ x_1, x_2 &\geq 0 \end{aligned}$$

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1		x1	x2	s1	s2	a1	a2	kb										
2	a1	6	8	-1	0	1	0	100			8	0.583333	1	0	-0.083333	0	0.083333	10
3	a2	7	12	0	-1	0	1	120		12								
4	Z-Cj	-13	-20	1	1	0	0	0										
5																		
6		x1	a2	s1	s2	a1	a2	kb										
7	a1	1.333336	0	-1	0.666664	1	-0.666666	20		1.333336	1.333336	1	0	-0.75	0.499997	0.749999	-0.5	14.99997
8	x2	0.583333	1	0	-0.083333	0	0.083333	20		1.333336	0.583333							
9	Z-Cj	-1.33334	0	1	-0.66666	0	1.66666	200			-1.33334							
10																		
11		a1	a2	s1	s2	a1	a2	kb										
12	x1	1	0	-0.75	0.499997	0.749999	-0.5	14.99997										
13	x2	0	1	0.437489	-0.375	-0.4375	0.374999	1.250002										
14	Z-Cj	0	0	0	0	1.000004	0.999994	220.0001										
15																		
16	x1																	
17	x2																	
18																		

Fig 6

#### IV. RESULT & DISCUSION

There are many applications available for finding the results for simplex. In this section, we talk about how the developed application is different and simple to analyze the steps of the procedure. In the existing software, there are not many options such as many of them do not compute minimization of the objective function. To overcome this challenge, we have developed this application we can solve all kinds of linear programming problems.

➤ *System Requirements:*

- Any Windows system with Microsoft Excel can be used. No particular
- Requirement for hardware or RAM.

#### V. CONCLUSION

In this paper we have developed a completely functional windows application which works for n no. of equations and variables and shows the output in an excel sheet on the same system. The application can work for any type of equation using less than or equal to or greater than or equal to or equal to equations and it finds the optimal solution using simplex method matrix form. The excel sheet contains each iteration formed during the course of finding the solution and the key column value and key row value are also show in a red and green boxes respectively. The key column coefficient and the key row coefficient are also displayed in the excel for the better understanding for the user and the solution i.e. the optimal solution for the given variables are displayed after all the iteration in green boxes.

#### FUTURE SCOPE

This application can be used for multiple purposes in future. It can use for feed formulation, linear programming and integer programming. The application currently runs on a console, but in future, it can be upgraded with a completely user-friendly interface to make finding solution easier.

#### REFERENCES

- [1]. <https://www.imse.iastate.edu/files/2015/08/Explanation-of-Simplex-Method.docx>
- [2]. J. Reeb., S. Leavengood., operations research, October 1998. Performance excellence in wood products industry
- [3]. S. Kalavathy., 2013. Operations research 4<sup>th</sup> Edition. Vikas publishing house pvt.ltd.
- [4]. <https://maklaboratory.com/>