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Student Learning Time Analysis during COVID'19 Using Linear Programming - Simplex Method

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Abstract: Corona Virus has a great impact in some other ways of everybody's life. It greatly affected the education sector in India. All of the sudden changes from traditional teaching-learning to online teaching-learning have made it difficult to manage students as well as faculties. Academic activities were inactive due to the novel coronavirus - SARS-CoV-2 (COVID-19). During this time it is necessary to examine the student's learning habits during a pandemic when all schools and colleges closed because of the spread of COVID'19. Data has been collected to understand Indian (Maharashtra) student's learning time spent throughout the epidemic. The data is collected using the survey research tool to understand the possible effects of the COVID'19 through WhatsApp, Facebook, and the Network of an educational group from September 30 to October 20, 2020. This research focuses on optimizing the role of instructor and finding the required number of hours period the learner needs to spend on online learning during COVID'19. With the help of a linear programming (LP) model and the Simplex method, results are presented here.

Keywords: Learning Time, Online Learning, COVID'19, Simplex Method, Linear Programming.

1. Introduction

1.1. Motivation and Need

The pandemic situation happened because of COVID'19, suddenly several transformations have been observed across the different sectors. Most of the transformations are also observed across the education sector which is happening through the changes in offline traditional teaching and learning to the online teaching and learning process. As the sudden change happened that gave birth to the necessities of adoption for the instructors and students with such transformations. This research focuses to understand and analyse the learning time of the students that will be spent during the online learning mode during the COVID'19 situation. For this purpose, the survey is conducted through online mode with the help of WhatsApp and Facebook groups in which the questionnaires circulated among the student community.

It is always necessary to consider the number of hours students will prefer and feel comfortable during the online learning mode and according to this, the research equipment is designed. This equipment has a questionnaire tool that is used to collect the responses of the student's community. Afterward, the researchers have used the data to analyze the learning time in the number of hours of the students and the effect of the instructor during the online learning mode during the COVID'19 situation.

1.2 Objectives

The main focus of this paper is to optimize the online learning time either with the instructor or without instructor during the pandemic situation and the following objectives are defined:

I. To analyze the applicable online learning time for the learners.
II. To examine the effect of online learning with the instructor or without the instructor.

2 Literature Review and Hypothesis Development

The literature review is mainly done to identify the past research done in the area of impact of COVID'19 on student learning time and effectiveness of online learning mode. It is observed that many factors are affecting online learning due to pandemic situations and with regards to this, the following review is done to find out the further scope and to formulate the hypothesis.

Sushopti Gawade, Umesh Kulkarni, Hemant Palivela, Swati Chopade, Sandeep Chopade [1], the authors have collected the data from the student's community and stated that it is always better to have online learning of the students with the instructor effectively and students prefer the learning time

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spent near about 4 to 7 hours. The authors have shown the result analysis using the standard graphs and it gives further scopes to optimize the perfect number of hours students may need to spend for online learning by considering the impact of the instructor factor.

Kesavan Vadakalur et al.[2] have examined the relationship between different independent factors which are always playing a major role in the teaching-learning process and their impact on online learning during COVID'19. In their work, the researchers have considered the factors such as the support of the administrative part, the effect of course design and contents, the characteristics of instructors and learners, and social and technical support and its impact on e-learning during COVID'19 in the higher education sector. It is identified that there is further scope to analyze essential aspects about optimizing the number of hours the learner may prefer during e-learning and the impact of it on the quality of e-learning. The authors have studied the characteristics of the instructors and it is specified that the characteristics of instructors need to be taken and the institute has to adopt it as an important strategy in e-learning. This finding also gives further scope to study the impact of online learning with the instructor and without the instructor.

Pinaki Chakraborty, Prabhat Mittal, Manu Sheel Gupta, Savita Yadav, Anshika Arora [3], the authors have studied the opinions of the students on online learning during COVI'19 and stated that in future to have a better impact of the online learning, it is necessary to personalize the online teaching-learning process from the student's perspective point of view. To personalize online learning, it is necessary to consider the number of hours that learners may be ready to spend based on the availability of required resources. Therefore, it gives further scope to examine the opinion and preference of the learning time in terms of the number of hours the learners may spend on online learning before or during COVID'19.

Lokanath Mishra, Tushar Gupta, Abha Shree [4], the authors have addressed the required essential factors of the online teaching-learning process in education during COVID'19 by collecting the data of Mizoram University. One of the findings the authors have mentioned is the development of a time-suited gap mechanism to meet the demands of the online teaching-learning process during COVID'19 and it is necessary to consider the time limit. This finding gives the further scope to collect and analyze the data about the learning period time that the learner may prefer to have effective learning.

Tran Trung et al. [5] work is reviewed to design the survey type research equipment to collect and construct the dataset effectively. In this case, the author has constructed the dataset to observe the learning habits of Vietnamese students of the different schools that were suspended because of a pandemic situation that occurs because of COVID'19. This dataset is divided into two parts as A and B to collect the demographic data of the students and students' learning habits, including the number of hours they can prefer for online learning before and during the COVID'19, with and without the support of an instructor. With the help of this review, to analyze the students learning during the online mode, the genders and students learning habits as the number of hours they can spend are defined as the major parameters for the result analysis purpose.

Depending on the literature review [1][2][3][4][5] done, the research work is hypothesized as follows:

H_1: There is a positive relationship between the impact of learning with the instructor and understanding the content by the students during online learning mode.

H_2: There is a positive relationship between the learner's preference for the number of hours they may spend and the impact of the learning period on online learning.

3 Methodology

3.1 Dataset Collection

The survey was conducted between September 30 and October 20, 2020, after the second month of nationwide online academic opening due to COVID-19. The research equipment is designed with the help of a survey tool that involves different variables like genders, the number of hours spent, and the effect of the instructor during the online and offline learning mode before COVID'19 as well as during COVID'19 [5]. The number of hours variable is defined as the learning time factor and that is further divided into three categories as less than 4 hours, 4 to 7 hours, and 7 hours. The collection methodology is shown in figure 1. Based on the data collection, the independent and dependent variables are defined and it is observed that the total number of students is playing the role of the independent variable. The different categories of the learning time which are depending on the number of students are defined as dependent variables to analyze the required result. In the next step, total responses have been collected and it is observed that the 866 respondents have responded and out of that, 859 have given valid responses and these are used for further processing. The respondent data is shown in Table No. 1.

Table 1: Data Collection

Learning Time of students(before covid/during covid/ online/offline)	Duration in hours	Number of students
Learning Time before COVID-19	less than 4hrs	581
	4-7hrs	249

	< 7 hrs	28
Total Learning Time online during COVID-19	less than 4hrs	142
	4-7hrs	558
	< 7 hrs	106
Learning Time online with the instructor during COVID-19	less than 4hrs	214
	4-7hrs	589
	< 7 hrs	55
ONLINE Learning Time without instructor during COVID-19	less than 4hrs	616
	4-7hrs	209
	above 7 hrs	33
OFFLINE Learning time with the instructor during COVID-19	less than 4hrs	666
	4-7hrs	160
	above 7 hrs	32

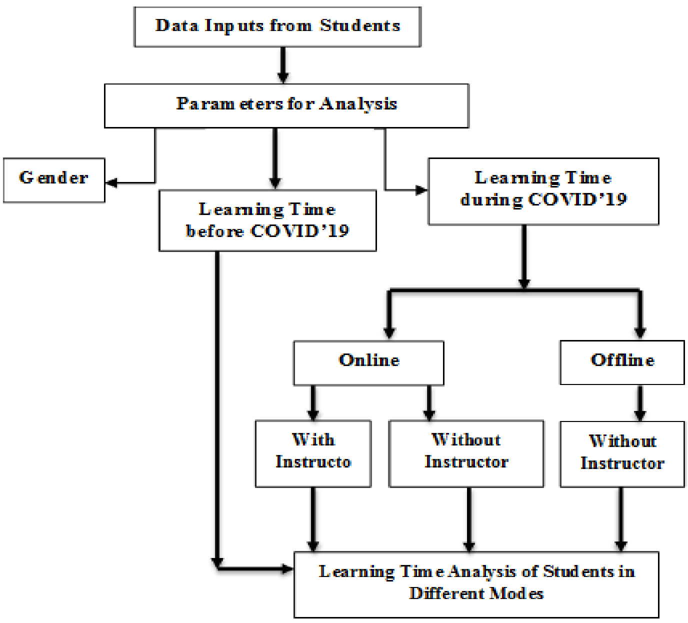

Fig 1- Data Collection Methodology

3.2 LP Model and Simplex Method:

To analyze the result, the Linear Programming [LP] model is used since most of the real-life problems which are needed to optimize are formulated as an LP model. The linear programming model is solved using either the general graphical method or the simplex method. To optimize the problem using a linear programming model, the problem is formed in terms of the equation that contains the number of the variables. It is difficult to solve any equation that involves more than two variables with the help of the graphical method. So, to provide an optimal solution for such types of large problems, the simplex method is used. The term simplex is an important term in mathematics that is used to represent an object in n-dimensional space containing n+1 points.

In the graphical method, to find out the optimal solution, the space of the extreme points of the feasible solution is examined and any one of a point from this space gives the optimal solution. Sometimes, it is not possible to draw a graph for the feasible region even if it involves the optimal solution in the n-dimensional polyhedron region of the feasible solution. So, the simplex method of linear programming is used to overcome these limitations. As the simplex is a line segment connecting two points in one dimension and if three points are there in three dimensions then it forms a triangle. Afterward, the triangle is used to examine the extreme points systematically by repeating the same set of finite number steps of the simplex algorithm to find out the optimal solution. The following general steps specified by the author [7] are used to find out the optimized solution using the simplex method.

Step 1: Formulation of the function Z to optimize the given problem.

$$Z = C_1X_1 + C_2X_2 + C_3X_3 + \dots\dots\dots + C_nX_n \quad . \quad (1)$$

The linear constraints defined and the function Z subjected to them

$$\begin{matrix} a_{11}x_{11+} & \cdots & +a_{1n}x_{1n} + S_1 = b_1 \\ \vdots & \ddots & \vdots \\ a_{m1}x_1 + & \cdots & +a_{mn}x_n + S_m = b_m \end{matrix}$$

In matrix notation, the following standard form is used to express the LP model: Optimize $Z = C_1X_1 + 0S$ that will be subjected to linear constraints $A_x + S = b$, where X, S ≥0 along with a row vector − $C = (C_1C_2C_3 \dots C_m)$ and following column vectors

$X = (X_1X_2X_3 \dots X_n)^T$

$b = (b_1b_2b_3 \dots b_m)^T$

$$S = (S_1S_2S_3 \dots S_m)$$

Step 2: Formulation of the matrix of coefficients of constraints.

Based on the above data, a matrix a[m][n] is formed with the coefficients of decision variables $(X_1X_2X_3 \dots X_n)$ Those are constrained.

In the simplex method, three types of additional variables are used:

1) Slack variables are denoted as S which is used to represent unused variables either in the form of resources used to optimize the given function.

2) Surplus variables are denoted as (-S) and can carry zero coefficient like slack variables in the objective function. These variables are used to express the quantity by which the resources are utilized to provide the solution value.

3) Artificial variables, denoted as (A) - These variables are used as a tool for generating an initial LP problem solution.

The above variables are added to the LP problem for the following reasons:

1) To convert the given LP problem into a form that is amenable to algebraic solutions, so these variables allow to convert inequalities into inequalities.

2) To make a better comprehensive economic representation of the final solution with the help of these variables.

3) To get an initial feasible solution as the identity matrix with the help of these variables. These variables and their values are mentioned in the columns of the initial feasible solution.

The slack variables are used when the LP problem needs to maximize the optimization function Z, otherwise, the surplus and artificial variables are used to minimize the optimization function. The role of different variables is shown in Table No. 2.

Table 2: Standard form of LP Model - Simplex Method

Extra Variable Required	Coefficients of Extra Variables in the objective function		Presence of Extra Variables in the initial solution
	Max - Z	Min - Z	
Slack Variable is added.	0	0	Yes
Surplus variable is subtracted	0	0	No
Artificial variable is added	-M	+M	Yes
Only artificial variable is added	-M	+M	Yes

4. Result Analysis

Use Case of Student Learning Time Analysis Using Simplex Method

The research done in [1] is stated that the students preferred the 4 to 7 hours of the period during online learning and with the instructor so that the learning process is very much effective. The work done by [1] [2] [3] [4] [5] gives further scope to identify the exact number of hours students need to spend during online learning so that, teaching community will identify effective, applicable, and executable learning methodologies within the stipulated period. The survey research equipment constructed by [1] is used to examine the hypothesis formulated in section 2. The analysis is done using the simplex algorithm and the following steps are implemented in a mathematical LP model to generate the optimal solution.

Step 1: Defining Decision Variables and Constraints

Table 3: Learning Time Activities of Students

Activity	Duration in hours	No of Students
Learning time online with instructor during COVID-19	Less than 4 hrs.	214
	4-7 hrs.	589
	Above 7 hrs.	55
Learning time online without instructor during COVID-19	Less than 4 hrs.	616
	4-7 hrs.	209
	Above 7 hrs.	33

Two activities are only considered to analyze the hypothesis during the implementation of the simplex algorithm and these are shown in Table No.2. The X_1 and X_2 Decision variables are defined to examine hypotheses 1 and 2. The constraints are defined for the duration in the number of hours the students spend during online learning which are:

1) The learning time is less than four hours - In this case, the first constraint is taken as the constant period of four hours.

2) The learning time from four to seven hours - In this case, the second constraint is taken as 5.5 hours as a mean of four to seven hours.

3) The learning time of more than seven hours - In this case, the third constraint is taken as the constant period of seven hours because it is not possible for the human being to spend more than seven hours.

Based on the decision variables and constraints, the well-formed tabular structure of the LP model is shown in Table No. 4.

Table 4: Well-Formed Tabular Structure of the LP Model

Resource		Online Learning Activity	
Learning Time	Constraint	With Instructor (X_1)	Without Instructor (X_2)
Less than 4 Hrs.	4 Hrs	214	616
4 to 7 Hrs.	5.5 Hrs	589	209
More than 7 Hrs.	7 Hrs	55	33

Step 2: Formulation of Mathematical Structure of LP Model

Using the well-formed tabular structure of the LP model, the optimization function Z is defined to find out the optimal solution. To form the function Z using the decision variables and constraints, the following assumptions are made as per the off-line teaching that had taken place before lockdown:

1) Students spent 3 hours of their learning time with the instructor.

2) Students spent 5 hours of their learning time without the instructor.

The above assumptions are made by considering the practice followed usually specified in the evaluation structure of the course that needs to be spent on theory and laboratory components. Mostly, 3 hours per week of learning time is spent for the theory component and 2 hours per week will be spent for the laboratory component. Therefore, the LP Model to optimize the function Z to assess the learning activity with the instructor and without an instructor is as structured follows:

$$Z = 3X_1 + 5X_2 \quad (2)$$

The following constraints are defined to optimize the function Z

$$214X_1 + 616X_2 \leq 4 \quad (3)$$
$$589X_1 + 209X_2 \leq 5.5 \quad (4)$$
$$55X_1 + 33X_2 \leq 7 \quad (5)$$

Where $X_1, X_2 \geq 0$

Three non-negative variables S_1, S_2 and S_3 are defined [7] as the slack variables and used for each constraint. These slack variables are required to convert the inequality to equality involved in constraint equations that are shown in (3), (4), and (5). Afterward, these slack variables are added to a function Z because all the values of time resources which are 4 hours, 5.5 hours, and 7 hours are positive. To find out optimal learning activity which will be effective either with the instructor or without the instructor, the following equations are formed:

$$Z \geq 3X_1 + 5X_2 + 0S_1 + 0S_2 + 0S_3 \quad (6)$$

The following constraints are defined to optimize the function Z

$$214X_1 + 616X_2 + S_1 = 4 \quad (7)$$
$$589X_1 + 209X_2 + S_2 = 5.5 \quad (8)$$
$$55X_1 + 33X_2 + S_3 = 7 \quad (9)$$

Where $X_1, X_2, S_1, S_2, S_3 \geq 0$

Step 3: Formation of Initial Simplex Table

The initial simplex table is formed using the equations 6, 7, 8, and 9 and the initial simplex table is shown in Table No. 5.

Where

$Z = \sum C_{Bi} X_{Bi}$ = (B. V. coefficients) X (Values in Basic Variables)

$Zj = \sum C_{Bi} X_j = \sum$ (B. V. coefficients) X (j[th] column of data matrix)

Step 4: Calculation of Zj and $C_j - Z_j$ and Iteration Number 1.

The value of the function Zj and $C_j - Z_j$ are calculated by considering the values of column j that it is shown in Table 6.

From the above step, it is observed that, the values of $C_j - Z_j$ are (3, 5, 0, 0, 0) which are greater than or equal to zero "0" which indicates that there is further scope to iterate the simplex algorithm.

To iterate the simplex algorithm there is a need to add outgoing and incoming variables to the simplex table using the concept of the key column and key row. For this purpose, the data mentioned in Table No. 6 is used. The following steps are used:

1) To identify a key column, the maximum function is applied to the values of $C_j - Z_j$. So a maximum of from a set of values (3, 5, 0, 0, 0) is 5 and this value belongs to the column named X_2. Therefore, the column named X_2 is declared as a key column.

2) To identify a key row, the minimum ratio is calculated using equation 10.

$$\text{Minimum Ratio} = \frac{X_B}{X_2} \quad (10)$$

Equation 10 is applied for the data mentioned in rows number 1, 2, and 3, and values are calculated as minimum ratio= (0.006494, 0.026316, 4.714286). The minimum function is applied to the minimum ratio to find out the minimum value. Hence, a minimum value is 0.006494, and it belongs to the basis variable S_1 and it is defined as a key row and declared as the outgoing variable.

The key column X_2 and key row S_1 are shown in Table no. 6 which are used in the next step of the simplex algorithm.

Step 5: Iteration Number 2

After completion of Iteration Number 1, it is observed that column X_2 is the incoming variable and S1 is the outgoing variable. According to this, to iterate the simplex algorithm the key elementary row operations are performed. The value of a key column X_2= 616 is made to "1" other values of a key column X_2 are made to "0" by performing the key elementary row operations receptive to the key row. The result of iteration number 2 is as follows:

After completion of Iteration Number 2, the values of $C_j - Z_j \geq 0$ are greater than or equal to zero "0" which indicates that there is further scope to iterate the simplex algorithm. To iterate the simplex algorithm, similar steps are followed as performed in step number 4. By following those steps, it is declared that a X_1 is an incoming variable and basis variable S_2 is an outgoing variable and these are used in the next iteration of the simplex algorithm.

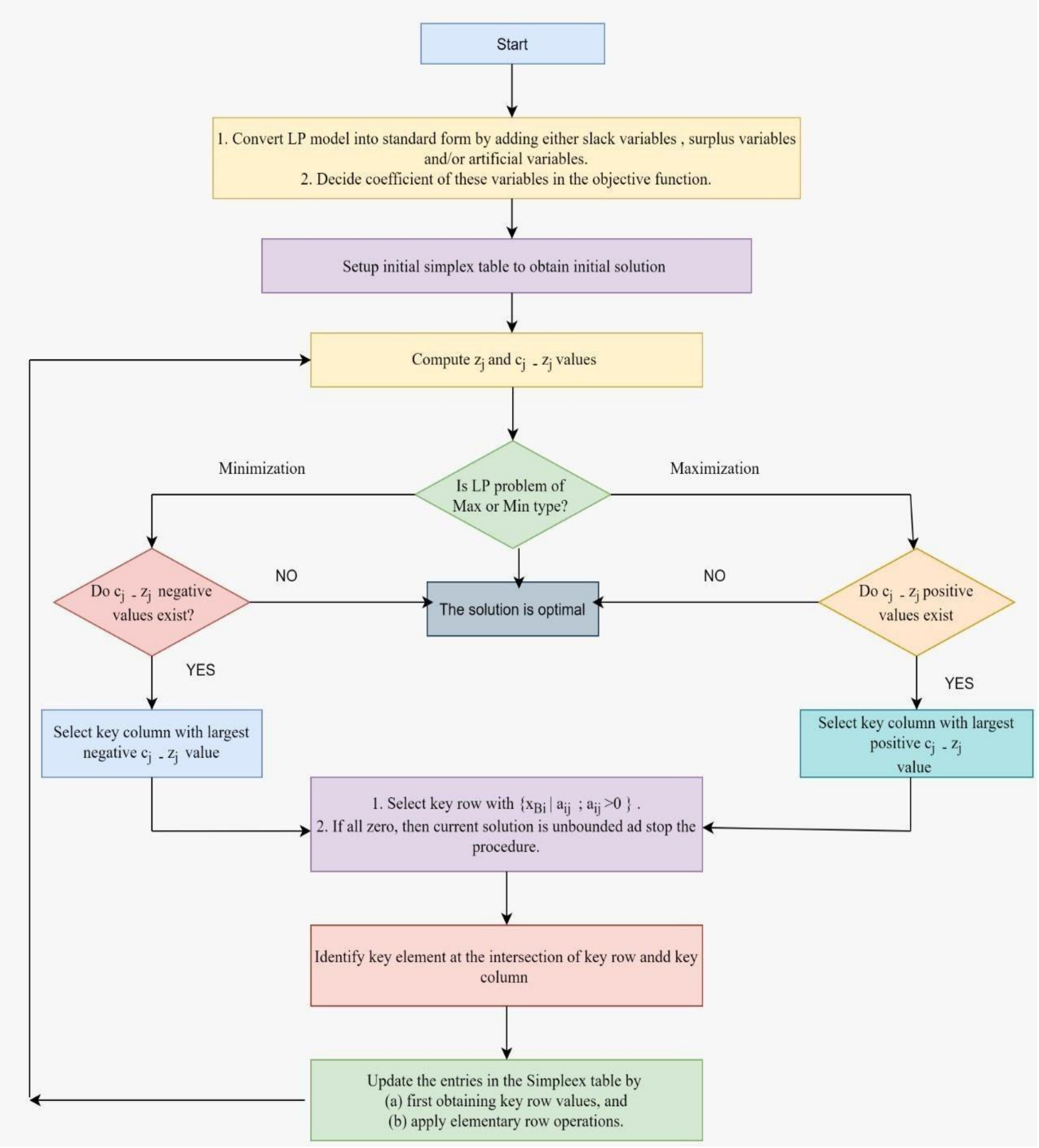

Fig. 2.- LP Model Flow

Table 5: Initial Simplex Table

	C_j	3	5	0	0	0	b
Time Constraints (C_B)	**Variables in Basis (B)**	X_1	X_2	S_1	S_2	S_3	
0	S_1	214	616	1	0	0	4
0	S_2	589	209	0	1	0	5.5
0	S_3	55	33	0	0	1	7
$Z = \sum C_{Bi} X_{Bi}$	$Zj = \sum C_{Bi} X_j$	Z_1	Z_2	Z_3	Z_4	Z_5	
$C_j - Z_j$							

Table 6: Calculations of Zj and Iteration Number 1

R. No.	Time Constraints (C_B)	Variables in Basis (B)	X_1	X_2	S_1	S_2	S_3	B (= XB)	Min Ratio (XB/X2)
		C_j	3	5	0	0	0		
R1	0	S_1	214	616 Key Element	1	0	0	4	0.006494 Key Row
R2	0	S_2	589	209	0	1	0	5.5	0.026316
R3	0	S_3	55	33	0	0	1	7	4.714286
R4	$Z = \sum C_{Bi} X_{Bi}$	$Zj = \sum C_{Bi} X_j$	Z_1	Z_2	Z_3	Z_4	Z_5		
R5			0	0	0	0	0		
R6	$C_j - Z_j$		3	5	0	0	0		
R7				Key Column					

Table 7: Iteration Number 2

R. No.	Time Constraints (C_B)	Variables in Basis (B)	X_1	X_2	S_1	S_2	S_3	B (= XB)	Min Ratio (XB/X2)
		C_j	3	5	0	0	0		
R1	5	X_2	0.347403	1	0.001623	0	0	0.006493506	0.018691589
R2	0	S_2	588.653 Key Element	0	-0.00162	1	0	5.493506494	0.009332341 Key Row
R3	0	S_3	54.6526	0	-0.00162	0	1	6.993506494	0.12796293
R4	Zj		Z_1	Z_2	Z_3	Z_4	Z_5		
R5			1.737012987	5	0.008116883	0	0		
R6	$C_j - Z_j$		1.262987013	0	-0.008116883	0	0		
R7			Key Column						

Table 8: Iteration Number 3

R. No.	Time Constraints (C_B)	Variables in Basis (B)	X_1	X_2	S_1	S_2	S_3	B (= XB)
		C_j	3	5	0	0	0	
R1	5	X_2	0	1	0.0016234	0	0	0.006432907
R2	3	X_1	0.99996	0	-2.75778E-06	0.001698	0	0.009332341
R3	0	S_3	0	0	-0.001623381	0	1	0.032164534
R4	Zj		Z_1	Z_2	Z_3	Z_4	Z_5	
R5			3	5	0	0	0	
R6	$C_j - Z_j$		0	0	0	0	0	

Step 6: Iteration Number 3

After completion of Iteration Number 2, it is observed that, a X_1 is an incoming variable and basis variable S_2 is an outgoing variable. According to this, to iterate the simplex algorithm again the key elementary row operations are performed. The value of key column X1 = 588.653 is made to 1 and other values of a key column are made to “0” by performing the key elementary row operations receptive to the key row. The result of iteration number 3 is shown in Table 8.

After iteration Number 3, it is observed that the values of $C_j - Z_j$ <=0, which indicates that there is no chance for further improvement to iterate the simplex algorithm. Hence the iteration process of the simplex method is stopped.

Analysis of the LP Model:

1) From LP Model that is solved using the simplex method**,** the result of X_1 and X_2 decision variables are 0.009332341, 0.006432907 which indicates that the learning analysis of the students with the instructor is always good as comparative to the learning of analysis of students without an instructor. Hence, hypothesis H_1 is achieved.

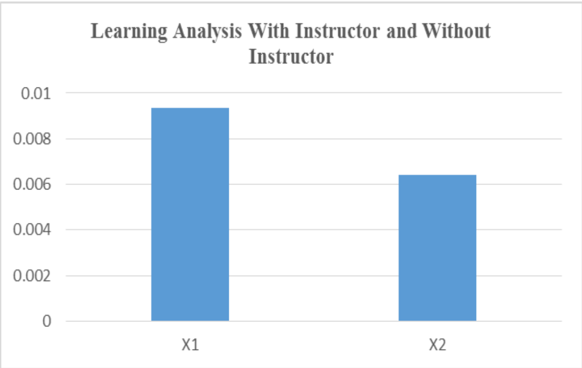

Fig. 3 - Result Analysis Part – I

2) The result analysis shown in Table No. 9 indicates that, as learning time goes on increasing from 4 Hrs. to 7 Hrs. , the maximum number of students are comfortable with the instructor and preferred 5.5 Hrs. period on online learning. Therefore, 550 students have preferred the 5.5 Hrs. of the period effectively during the online learning process and it shows the satisfaction of hypothesis 2. The analysis is shown in the following figure 4.

Table 9: Result Analysis – I

Resource		Online Learning Activity	
Learning Time	Constraint	With Instructor (X_1)	Without Instructor (X_2)
Less than 4 Hrs.	4 Hrs	199.7120874	396.2670638
4 to 7 Hrs.	5.5 Hrs.	549.6748573	134.4477538
More than 7 Hrs.	7 Hrs.is	51.32787292	21.2285927

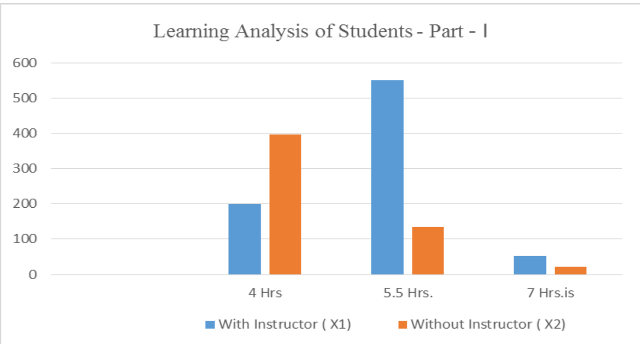

Fig. 4 - Result Analysis Part - II

5. Conclusion

During COVID'19, the transformations happened in the education sector from offline learning to online learning and suddenly online learning is so important. The online learning process is effective with regards to different factors such as the delivery of contents, use of learning methodologies, use of different pedagogies, and involvement of the learners, and impact of instructors [2], etc. To apply these factors effectively, the number of hours students can spend plays a major role during online learning. Therefore, in this paper the simplex method of linear programming [LP] is used, in the first stage, to optimize the impact of the learning with the instructor. In the second step, the actual number of hours are identified that learners can prefer to have effective online learning. The result analysis part shows that most of the students prefer online learning with an instructor instead of without the instructor and 550 students preferred the learning period of 5.5. hours.

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