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Linear Programming Techniques and Its Application in Optimizing Lecture Room in an Institution

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Abstract

This paper deals with linear programming techniques and their application in optimizing lecture rooms in an institution. This linear programming formulated based on the available secondary data obtained from the information Technology units of an institution as the secondary data as well as the primary data source obtained by the researchers, which includes measuring the classroom dimension, lecture current seating capacity, number of registered students in each of department within the eight (8) schools in the institution, number of registered students per programme in each department in the schools totaling 3249. Maximizing the current available classroom space using AMPL software revealed that in all the available 32 lecture rooms with a current seating capacity of 2023 to accommodate a total student population of 3249, the finding revealed three (3) important solutions, which were categorized as: 1) For the calculated current good seating capacity can accommodate 9234 students and 2) the calculated current seating capacity of both good and bad seating can accommodate 10,431 students and 3) the projected seating capacity as indicated by the AMPL software can accommodate 13,300 students with current and existing 32 lecture rooms for all departments in the eight (8) schools provided that the seating capacities is fully maximize and this will help the school management to have more internal revenue.as school fees using the same and current classroom facility assuming each students pays GH₵1500.00 as academic fees yearly, the institution could generate an additional GH₵ 8977, 500.00 in revenue for the good sitting capacity only if it is fully maximized, *i.e.* (5985 × GHc1500.00); GHc.10,773,000.00 (7182 × GH₵1500) for the current sitting capacity, and GHc.15,076,500.00 as internal revenue, *i.e.* (10,051 students × GH₵1500.00) from the projected seating capacity respectively while maintaining the same lecture room and seating capacity were fully maximized.

Keywords

Optimize, Maximize, Linear Programming, Capacity, Classroom Facility

1. Introduction

Optimizing lecture room in educational Institutions is crucial for maximizing resource utilization and enhancing the learning environment by applying linear programming technique which is a powerful tool to address issues of over-allocation and under-allocation of lecture room spaces.

C.K. Tedam University of Technology and Applied Sciences is one of the Universities in Ghana established and became autonomous in 2020 with a student population of 3249 students, both undergraduates and post-graduate students and runs 45 regular programs in its 8 schools and 18 departments with only 32 lecture rooms and laboratories. It has been observed that allocating lecture room for an effective teaching and learning process currently becomes worrisome and makes teaching and learning ineffective. This posed the question of how the institution can manage the current lecture room capacity so that more space can be created for the institution to admit more students over 2000 and improve the internally generated revenue. This has prompted researchers to apply linear programming optimization techniques to find an optimal solution to this problem by maximizing the objective function subject to a set of constraints as it was fully applied by [1] and [2].

In this case, our aim is to maximize the current seating capacity in the lecture room of the institution, the constraints and the number of students with the available lecture space in the lecture hall to determine the optimal value of the lecture room in the institution

[3] studied and applied linear programming techniques in allocating classroom space in Premier Nurses Training College, Kumasi, where he adopted linear programming to solve the problem of over-allocation and under-allocation of the scarce classroom space was considered with particular reference and data collected from the Premier Nurse's Training College, Kumasi. The authors apply POM-QM for Windows 4 (Software for Quantitative Methods, Production and Operation Management by Howard J. Weiss) to run and analyze results which show that six (50%) of the twelve classrooms could be used to obtain a maximum classroom space of six hundred and forty while the two hundred and eighty (280) surplus spaces can be used to increase its student's intake from three hundred and sixty (360) to six hundred and forty (640) students, an increase to about 77.78% with only 50% of the total number of classrooms.

[4] Modelled classroom space allocation at the University of Rwanda using linear programming approach where he emphasized that education and training play

a key role in the human capital function. Their research seeks to assess the Rwandan education system using linear programming model formulated to assess the level of usage of the available classroom space at the College. The model adopted the Dual Simplex algorithm via the Cplex solver implemented in AMPL. It was revealed that out of the 68 classrooms available on the Nyarugenge campus, only 18 classrooms with seating capacity of 2147 are being used to facilitate the teaching and learning process of approximately 4088 students, and that 50 classrooms with a seating capacity of 1506 are being underutilized or not being used at all. It was then recommended that the college explore the usage of virtual laboratory platforms to overcome space and material limitations associated with physical laboratories.

In this paper, we apply linear programming technique to optimize the lecture rooms in C.K. Tedam University of Technology and Applied Sciences to minimize conflicts and challenges being faced and maximize lecture room facility and resource management as there is a growing need for the University management to maximize the resources, especially lecture rooms as an effective lecture room allocation can result in better learning outcomes for students and achieve higher academic results all around.

2. Design and Methodology Approach

According to [5], research methodology provides the effective principle for planning, arranging, designing and conducting fruitful research. Hence, it can be considered as a pioneer path with the application of science and philosophy to perform all research confidently.

2.1. Data Collection

The current seating capacity, dimensions of the lecture rooms, dimensions of the desks in the lecture rooms and the total number of lecture rooms in the institution were determined by the researcher through measurement, as shown in **Table 1** below. Likewise, the total number of registered students in each academic level of the programmes in each department of all 8 schools was also collected through the information Technology units of the school, all serve as the secondary data of this research, as shown in **Table 2**.

2.2. Formulation of Linear Programming Model

Here, we formulate the Linear programming model as proposed by [6] and well applied by [7] to determine how to adequately allocate class spaces to each course in the department, which consists of types of classrooms, seating capacities, number of such classrooms according to the departments and programs in each of the schools as well as the total number of the students in each of the departments according to the levels, which was collected from the director of the Information Technology (IT) unit of the University and examination time table committee for the attainment of our stated aims and objective.

Table 1. Below is the summary of class types and respective capacities, expected capacities after taking dimensions of the classrooms, differences in capacities of current and expected capacities, and dimensions of the classrooms.

Available Classroom	Number of Current Desk	Good Seating Capacity	Bad Seating Capacity	Bad Seating Capacity	Classroom Dimension	Projected. Seating Capacity	Difference
32	2023	1867	156	2113	3113	-	1248

Source: Researcher 2024.

Table 2. Below shows summary of the registered students in each program in the Department, of each School according to the academic level.

School	Department	Programme	Level						Grand ToT.
			Dip.	100	200	300	400	PG	
SCBCS	2	6	0	106	61	46	52	50	315
SELS	2	3	0	30	23	21	34	36	149
SMS	4	6	12	44	65	66	86	136	410
SPH	2	2	0	310	114	0	0	31	465
SCIS	3	6	140	240	188	173	247	99	1373
SPS	2	5	0	23	20	17	11	7	78
SMEDS	1	3	0	25	0	0	0	64	88
SMES	2	3	23	0	15	35	21	214	371
ToT. 8	**18**	**34**	**183**	**778**	**642**	**448**	**502**	**696**	**3249**

Source: IT unit 2024.

We then consider a standard form of linear programming as:

$$\text{Max} : F = \sum_{i=1}^{n} c_i x_j \tag{1}$$

subject to

$$\sum_{j=1}^{n} a_{i,j} = b_i,\ i = 1, 2, \cdots, n$$

$$i_j \le x \le u_j,\ j = 1, 2, \cdots, m$$

where,

c_i is the n objects function coefficients a_{ij} and b are parameters in them linear inequality constraints i_j and u_j are lower and upper bound with $i_j \le u_j$ Both i_j and u_j maybe positive or negative.

Thus we have:

$$\text{Maximize} : Z = \sum_{j=1}^{n} c_i x_j \tag{2}$$

Subject to

$$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 = b_1$$

$$a_{11}x_1 + a_{12}x_2 + a_{13}x_3 + a_{14}x_4 + a_{15}x_5 + a_{16}x_6 + a_{17}x_7 + a_{18}x_8 \le b_2$$
$$a_{21}x_1 + a_{22}x_2 + a_{23}x_3 + a_{24}x_4 + a_{25}x_5 + a_{26}x_6 + a_{27}x_7 + a_{28}x_8 \le b_3$$
$$a_{31}x_1 + a_{32}x_2 + a_{33}x_3 + a_{34}x_4 + a_{35}x_5 + a_{36}x_6 + a_{37}x_7 + a_{38}x_8 \le b_4$$
$$a_{41}x_1 + a_{42}x_2 + a_{43}x_3 + a_{44}x_4 + a_{45}x_5 + a_{46}x_6 + a_{47}x_7 + a_{48}x_8 \le b_5$$
$$a_{51}x_1 + a_{52}x_2 + a_{53}x_3 + a_{54}x_4 + a_{55}x_5 + a_{56}x_6 + a_{57}x_7 + a_{58}x_8 \le b_6$$
$$a_{61}x_1 + a_{62}x_2 + a_{63}x_3 + a_{64}x_4 + a_{65}x_5 + a_{66}x_6 + a_{67}x_7 + a_{68}x_8 \le b_7$$
$$a_{71}x_1 + a_{72}x_2 + a_{73}x_3 + a_{74}x_4 + a_{75}x_5 + a_{76}x_6 + a_{77}x_7 + a_{78}x_8 \le b_8$$
$$a_{81}x_1 + a_{82}x_2 + a_{83}x_3 + a_{84}x_4 + a_{85}x_5 + a_{86}x_6 + a_{87}x_7 + a_{88}x_8 \le b_9$$
$$a_{91}x_1 + a_{92}x_2 + a_{93}x_3 + a_{94}x_4 + a_{95}x_5 + a_{96}x_6 + a_{97}x_7 + a_{98}x_8 \le b_{10}$$
$$a_{101}x_1 + a_{102}x_2 + a_{103}x_3 + a_{104}x_4 + a_{105}x_5 + a_{106}x_6 + a_{107}x_7 + a_{108}x_8 \le b_{11} \quad (3)$$

2.3. Modelling Technique

The University lecture room space allocation problem is considered as a linear programming problem and was categorized according to the number of seat available, and the type of sitting, equipment and capacity available. The students were classified and considered according to the level in the classes based on the program and the class level of the students as follows:

1) We let the capacity of each category (type) of a lecture room be:
$C_i = C_1, C_2, C_3, C_4, \cdots, C_n$ for $i = 1, 2, 3, \cdots, n$
where:

$$\left.\begin{array}{l} c_1 \text{ is the capacity of lectureroom type } 1 \\ c_2 \text{ is the capacity of lectureroom type } 2 \\ c_3 \text{ is the capacity of lectureroom type } 3 \\ c_4 \text{ is the capacity of lectureroom type } 4 \\ \quad\vdots \\ c_n \text{ is the capacity of lectureroom type } n \end{array}\right\} \quad (4)$$

2) We let the lecture rooms be categorized into types as:

$$X_i = x_1, x_2, x_3, x_4, \cdots, x_n$$

For $i = 1, 2, 3, 4, \cdots, n$ based on the capacities of the,
where

$$\left.\begin{array}{l} x_1 \text{ is the lectureroom type 1 with seating capacity of } c_1 \\ x_2 \text{ is the lectureroom type 1 with seating capacity of } c_2 \\ x_3 \text{ is the lectureroom type 1 with seating capacity of } c_3 \\ x_4 \text{ is the lectureroom type 1 with seating capacity of } c_4 \\ \quad\vdots \\ x_n \text{ is the lectureroom type 1 with seating capacity of } c_n \end{array}\right\} \quad (5)$$

3) We let the number of classrooms of each type be:

$$a_1, a_2, a_3, \cdots, a_n$$

where,

$$\left.\begin{array}{l} a_1 \text{ is the number of room of classroom type 1} \\ a_2 \text{ is the number of room of classroom type 2} \\ a_3 \text{ is the number of room of classroom type 3} \\ a_4 \text{ is the number of room of classroom type 4} \\ \vdots \\ a_n \text{ is the number of room of classroom type } n \end{array}\right\} \tag{6}$$

4) We let the total available lecture room space of all the types of classrooms denoted by d.

Thus,

$$d = \sum_{i=1}^{n} a_i c_i \tag{7}$$

where:

$$\left.\begin{array}{l} a_1, \cdots, a_n \text{ is the number of lecturroom of each type} \\ d \text{ is the total available lectureroom space of all type} \\ c_3, \cdots, c_n \text{ is the capacity of each category of lectureroom} \end{array}\right\}$$

Then the linear programming is applied to determine the objective function as we consider the following assumptions

$$\text{Max} : \sum_{i=1}^{n} c_i x_j$$

Subject to constraints:

$$\sum_{i=1}^{n} a_i c_j \le d, \ i = 1, 2, 3, \cdots, n$$

With the assumptions that:

1) The total number of students assigned to certain categories of lecture rooms cannot exceed the total classroom space available in each of the classrooms.

2) Given that $x_i \ge 0 : \left(i = 1, 2, 3, \cdots, n\right)$ is non-negative since a number of students can be assigned to a room cannot be a negative number

2.4. Objective Function and the Constraints

In this paper, we considered the following three categories of objective functions:

1) The current capacity of good desks in the various lecture rooms

2) The current capacity of desks (good and Bad) in the various lecture rooms

3) The capacity of projected desks in each of the lecture rooms after taking the dimensions of the lecture rooms

Thus:

We considered the current capacity of the good desk/sitting in various lecture rooms as:

$$\text{Maximize}: P = 285x_1 + 166x_2 + 72x_3 + 48x_4 + 13x_5 + 30x_6 + 87x_7 + 132x_8 + 30x_9 + 23x_{10} + 33x_{11} + 24x_{12} + 27x_{13} + 75x_{14} + 16x_{15} + 13x_{16} + 33x_{17} + 339x_{18} + 87x_{19} + 30x_{20} + 31x_{21} + 14x_{22} + 20x_{23} + 56x_{24} + 19x_{25} + 6x_{26} + 39x_{27} + 22x_{28} + 33x_{29} + 30x_{30} + 34x_{31}$$

Subject to:

$$a_2x_1 + a_2x_2 + a_2x_3 + a_2x_4 + a_2x_5 + a_2x_6 + a_2x_7 + a_2x_8 + a_2x_9 + a_2x_{10} + a_2x_{11} + a_2x_{12} + a_2x_{13} + a_2x_{14} + a_2x_{15} + a_2x_{16} + a_2x_{17} + a_2x_{18} + a_2x_{19} + a_2x_{20} + a_2x_{21} + a_2x_{22} + a_2x_{23} + a_2x_{24} \le T_2$$

$$a_3x_1 + a_3x_2 + a_3x_3 + a_3x_4 + a_3x_5 + a_3x_6 + a_3x_7 + a_3x_8 + a_3x_9 + a_3x_{10} + a_3x_{11} + a_3x_{12} + a_3x_{13} + a_3x_{14} + a_3x_{15} + a_3x_{16} + a_3x_{17} + a_3x_{18} + a_3x_{19} + a_3x_{20} + a_3x_{21} + a_3x_{22} + a_3x_{23} + a_3x_{24} \le T_3$$

$$a_4x_1 + a_4x_2 + a_4x_3 + a_4x_4 + a_4x_5 + a_4x_6 + a_4x_7 + a_4x_8 + a_4x_9 + a_4x_{10} + a_4x_{11} + a_4x_{12} + a_4x_{13} + a_4x_{14} + a_4x_{15} + a_4x_{16} + a_4x_{17} + a_4x_{18} + a_4x_{19} + a_4x_{20} + a_4x_{21} + a_4x_{22} + a_4x_{23} + a_4x_{24} \le T_4$$

$$a_5x_1 + a_5x_2 + a_5x_3 + a_5x_4 + a_5x_5 + a_5x_6 + a_5x_7 + a_5x_8 + a_5x_9 + a_5x_{10} + a_5x_{11} + a_5x_{12} + a_5x_{13} + a_5x_{14} + a_5x_{15} + a_5x_{16} + a_5x_{17} + a_5x_{18} + a_5x_{19} + a_5x_{20} + a_5x_{21} + a_5x_{22} + a_5x_{23} + a_5x_{24} \le T_5$$

$$a_6x_1 + a_6x_2 + a_6x_3 + a_6x_4 + a_6x_5 + a_6x_6 + a_6x_7 + a_6x_8 + a_6x_9 + a_6x_{10} + a_6x_{11} + a_6x_{12} + a_6x_{13} + a_6x_{14} + a_6x_{15} + a_6x_{16} + a_6x_{17} + a_6x_{18} + a_6x_{19} + a_6x_{20} + a_6x_{21} + a_6x_{22} + a_6x_{23} + a_6x_{24} \le T_6$$

$$a_7x_1 + a_7x_2 + a_7x_3 + a_7x_4 + a_7x_5 + a_7x_6 + a_7x_7 + a_7x_8 + a_7x_9 + a_7x_{10} + a_7x_{11} + a_7x_{12} + a_7x_{13} + a_7x_{14} + a_7x_{15} + a_7x_{16} + a_7x_{17} + a_7x_{18} + a_7x_{19} + a_7x_{20} + a_7x_{21} + a_7x_{22} + a_7x_{23} + a_7x_{24} \le T_7$$

$$a_8x_1 + a_8x_2 + a_8x_3 + a_8x_4 + a_8x_5 + a_8x_6 + a_8x_7 + a_8x_8 + a_8x_9 + a_8x_{10} + a_8x_{11} + a_8x_{12} + a_8x_{13} + a_8x_{14} + a_8x_{15} + a_8x_{16} + a_8x_{17} + a_8x_{18} + a_8x_{19} + a_8x_{20} + a_8x_{21} + a_8x_{22} + a_8x_{23} + a_8x_{24} \le T_8$$

Thus we have:

$$\text{Maximize}: P = 285x_1 + 166x_2 + 72x_3 + 48x_4 + 13x_5 + 30x_6 + 87x_7 + 132x_8 + 30x_9 + 23x_{10} + 33x_{11} + 24x_{12} + 27x_{13} + 75x_{14} + 16x_{15} + 13x_{16} + 33x_{17} + 339x_{18} + 87x_{19} + 30x_{20} + 31x_{21} + 14x_{22} + 20x_{23} + 56x_{24} + 19x_{25} + 6x_{26} + 39x_{27} + 22x_{28} + 33x_{29} + 30x_{30} + 34x_{31}$$

Subject to:

$$10x_1 + 56x_2 + 15x_3 + 22x_4 + 3x_5 + 16x_6 + 14x_7 + 13x_8 + 16x_9 + x_{10} + 5x_{11} + 9x_{12} + 85x_{13} + 225x_{14} + 33x_{15} + 12x_{16} + 73x_{17} + 3x_{18} + 94x_{19} + 25x_{20} + 2x_{21} + 13x_{22} + 8x_{23} + 25x_{24} \le 778$$

$$14x_1 + 32x_2 + 16x_3 + 5x_4 + 21x_5 + 15x_6 + 3x_7 + 16x_8 + 11x_9 + 24x_{10} + 6x_{11} + 109x_{12} + 3x_{13} + 98x_{14} + 23x_{15} + 4x_{16} + 6x_{17} + 7x_{18} + 35x_{19} \le 448$$

$$41x_1 + 23x_2 + 13x_3 + 19x_4 + 2x_5 + 14x_6 + 6x_7 + 8x_8 + 22x_9 + 23x_{10} + x_{11} + 11x_{12} + 8x_{13} + 29x_{14} + 95x_{15} + 17x_{16} + 9x_{17} + 111x_{18} + x_{19} + 3x_{20} + 137x_{21} + 48x_{22} + 6x_{23} + 5x_{24} + 9x_{25} + 18x_{26} \le 642$$

$$9x_1 + 43x_2 + 29x_3 + 5x_4 + 19x_5 + 23x_6 + 7x_7 + 25x_8 + 13x_9 + 167x_{10} + 86x_{11} + 44x_{12} + 5x_{13} + 6x_{14} + 21x_{15} \le 502$$

$$5x_1 + 7x_2 + 9x_3 + 2x_4 + 44x_5 + 85x_6 + 8x_7 + 17x_8 + 6x_9 \le 183$$

$$18x_1 + 32x_2 + 27x_3 + 9x_4 + 29x_5 + 10x_6 + 26x_7 + 65x_8 + 6x_9 + 19x_{10} + 12x_{11} + 30x_{12} + 69x_{13} + 7x_{14} + 29x_{15} + 34x_{16} + 199x_{17} + 75x_{18} \le 696$$

$$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 + x_9 + x_{10} + x_{11} + x_{12} + x_{13} + x_{14} + x_{15} + x_{16} + x_{17} + x_{18} + x_{19} + x_{20} + x_{21} + x_{22} + x_{23} + x_{24} + x_{25} + x_{26} + x_{27} + x_{28} + x_{29} + x_{30} + x_{31} + x_{32} \le 32$$

$$x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{10}, x_{11}, x_{12}, x_{13}, x_{14}, x_{15}, x_{16}, x_{17}, x_{18}, x_{19}, x_{20}, x_{21}, x_{22}, x_{23}, x_{24}, x_{25}, x_{26}, x_{27}, x_{28}, x_{29}, x_{30}, x_{31}, x_{32} \ge 0$$

where:

x_1 represents the lecture room type 1 with seating capacity of 285
x_2 represents the lecture room type 2 with seating capacity of 166
x_3 represents the lecture room type 3 with seating capacity of 72
x_4 represents the lecture room type 4 with seating capacity of 48
x_5 represents the lecture room type 5 with seating capacity of 13
x_6 represents the lecture room type 6 with seating capacity of 30
x_7 represents the lecture room type 7 with seating capacity of 87
x_8 represents the lecture room type 8 with seating capacity of 132
x_9 represents the lecture room type 9 with seating capacity of 30
x_{10} represents the lecture room type 10 with seating capacity of 23
x_{11} represents the lecture room type 11 with seating capacity of 33
x_{12} represents the lecture room type 12 with seating capacity of 24
x_{13} represents the lecture room type 13 with seating capacity of 27
x_{14} represents the lecture room type 14 with seating capacity of 75
x_{15} represents the lecture room type 15 with seating capacity of 16
x_{16} represents the lecture room type 16 with seating capacity of 13
x_{17} represents the lecture room type 17 with seating capacity of 33
x_{18} represents the lecture room type 18 with seating capacity of 339
x_{19} represents the lecture room type 19 with seating capacity of 97
x_{20} represents the lecture room type 20 with seating capacity of 30
x_{21} represents the lecture room type 21 with seating capacity of 31
x_{22} represents the lecture room type 22 with seating capacity of 14
x_{23} represents the lecture room type 23 with seating capacity of 20
x_{24} represents the lecture room type 24 with seating capacity of 56
x_{25} represents the lecture room type 25 with seating capacity of 19
x_{26} represents the lecture room type 26 with seating capacity of 6
x_{27} represents the lecture room type 27 with seating capacity of 39
x_{28} represents the lecture room type 28 with seating capacity of 22
x_{29} represents the lecture room type 29 with seating capacity of 33
x_{30} represents the lecture room type 30 with seating capacity of 30
x_{31} represents the lecture room type 31 with seating capacity of 34

2.5. Development of AMPL Software for Good Desks as Objective Functions

We then develop and run the above data using AMPL. Software to obtain an optimal solution for the current good desks or seating only as objective functions which gives the following optimal solutions:

$$x_1 = 29.8947; x_{18} = 2.10526;$$
$$x_2 = x_3 = x_4 = x_{17} = x_{18} = x_{20} = x_{21} = \cdots = x_{32} = 0;$$
$$P_{\max} = 9234$$

1) Current capacity of good and bad seating.

We consider the current capacity of good and bad seating in various lecture rooms.

Thus, we formulate the L.P as follows:

Subject to:

$$\begin{aligned}&10x_1 + 56x_2 + 15x_3 + 22x_4 + 3x_5 + 16x_6 + 14x_7 + 13x_8 + 16x_9 + x_{10} + 5x_{11}\\&+ 9x_{12} + 85x_{13} + 225x_{14} + 33x_{15} + 12x_{16} + 73x_{17} + 3x_{18} + 94x_{19} + 25x_{20}\\&+ 2x_{21} + 13x_{22} + 8x_{23} + 25x_{24} \le 778\end{aligned}$$

$$\begin{aligned}&41x_1 + 23x_2 + 13x_3 + 19x_4 + 2x_5 + 14x_6 + 6x_7 + 8x_8 + 22x_9 + 23x_{10} + x_{11}\\&+ 11x_{12} + 8x_{13} + 29x_{14} + 95x_{15} + 17x_{16} + 9x_{17} + 111x_{18} + x_{19} + 3x_{20} + 137x_{21}\\&+ 48x_{22} + 6x_{23} + 5x_{24} + 9x_{25} + 18x_{26} \le 642\end{aligned}$$

$$\begin{aligned}&14x_1 + 32x_2 + 16x_3 + 5x_4 + 21x_5 + 15x_6 + 3x_7 + 16x_8 + 11x_9 + 24x_{10} + 6x_{11}\\&+ 109x_{12} + 3x_{13} + 98x_{14} + 23x_{15} + 4x_{16} + 6x_{17} + 7x_{18} + 35x_{19} \le 448\end{aligned}$$

$$\begin{aligned}&9x_1 + 43x_2 + 29x_3 + 5x_4 + 19x_5 + 23x_6 + 7x_7 + 25x_8 + 13x_9 + 167x_{10} + 86x_{11}\\&+ 44x_{12} + 5x_{13} + 6x_{14} + 21x_{15} \le 502\end{aligned}$$

$$5x_1 + 7x_2 + 9x_3 + 2x_4 + 44x_5 + 85x_6 + 8x_7 + 17x_8 + 6x_9 \le 183$$

$$\begin{aligned}&18x_1 + 32x_2 + 27x_3 + 9x_4 + 29x_5 + 10x_6 + 26x_7 + 65x_8 + 6x_9 + 19x_{10} + 12x_{11}\\&+ 30x_{12} + 69x_{13} + 7x_{14} + 29x_{15} + 34x_{16} + 199x_{17} + 75x_{18} \le 696\end{aligned}$$

$$\begin{aligned}&x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 + x_9 + x_{10} + x_{11} + x_{12} + x_{13} + x_{14} + x_{15}\\&+ x_{16} + x_{17} + x_{18} + x_{19} + x_{20} + x_{21} + x_{22} + x_{23} + x_{24} + x_{25} + x_{26} + x_{27} + x_{28}\\&+ x_{29} + x_{30} + x_{31} + x_{32} \le 32\end{aligned}$$

$$\begin{aligned}&x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{10}, x_{11}, x_{12}, x_{13}, x_{14}, x_{15}, x_{16}, x_{17}, x_{18}, x_{19}, x_{20},\\&x_{21}, x_{22}, x_{23}, x_{24}, x_{25}, x_{26}, x_{27}, x_{28}, x_{29}, x_{30}, x_{31}, x_{32} \ge 0\end{aligned}$$

where:

x_1 represents the lecture room type 1 with seating capacity of 318

x_2 represents the lecture room type 2 with seating capacity of 100

x_3 represents the lecture room type 3 with seating capacity of 78

x_4 represents the lecture room type 4 with seating capacity of 54

x_5 represents the lecture room type 5 with seating capacity of 13

x_6 represents the lecture room type 6 with seating capacity of 30

x_7 represents the lecture room type 7 with seating capacity of 100

x_8 represents the lecture room type 8 with seating capacity of 33
x_9 represents the lecture room type 9 with seating capacity of 30
x_{10} represents the lecture room type 10 with seating capacity of 34
x_{11} represents the lecture room type 11 with seating capacity of 147
x_{12} represents the lecture room type 12 with seating capacity of 33
x_{13} represents the lecture room type 13 with seating capacity of 27
x_{14} represents the lecture room type 14 with seating capacity of 33
x_{15} represents the lecture room type 15 with seating capacity of 24
x_{16} represents the lecture room type 16 with seating capacity of 27
x_{17} represents the lecture room type 17 with seating capacity of 75
x_{18} represents the lecture room type 18 with seating capacity of 16
x_{19} represents the lecture room type 19 with seating capacity of 13
x_{20} represents the lecture room type 20 with seating capacity of 33
x_{21} represents the lecture room type 21 with seating capacity of 384
x_{22} represents the lecture room type 22 with seating capacity of 93
x_{23} represents the lecture room type 23 with seating capacity of 30
x_{24} represents the lecture room type 24 with seating capacity of 31
x_{25} represents the lecture room type 25 with seating capacity of 20
x_{26} represents the lecture room type 26 with seating capacity of 20
x_{27} represents the lecture room type 27 with seating capacity of 57
x_{28} represents the lecture room type 28 with seating capacity of 21
x_{29} represents the lecture room type 29 with seating capacity of 8
x_{30} represents the lecture room type 30 with seating capacity of 39
x_{31} represents the lecture room type 31 with seating capacity of 22
Then

AMPL Software was run using the above given data to obtain optimal solution for the current good and bad desks/seating as objective functions which gives the following optimal solutions:

$$\begin{aligned}
&x_1 = 28.1354; x_{21} = 3.86466;\\
&x_2 = x_3 = x_4 = x_{20} = x_{22} = x_{24} = x_{25} = \cdots = x_{32} = 0;\\
&P_{\max} = 10431
\end{aligned}$$

2) Expected seating/desks capacity in each of the lecture rooms after measuring its dimensions and formulating as follows.

$$\begin{aligned}
\text{Maximize}: P = {} & 351x_1 + 210x_2 + 90x_3 + 90x_4 + 36x_5 + 36x_6 + 100x_7 + 70x_8\\
& + 80x_9 + 80x_{10} + 186x_{11} + 48x_{12} + 90x_{13} + 54x_{14} + 36x_{15} + 36x_{16}\\
& + 36x_{17} + 75x_{18} + 16x_{19} + 33x_{20} + 33x_{21} + 528x_{22} + 219x_{23} + 73x_{24}\\
& + 73x_{25} + 73x_{26} + 73x_{27} + 73x_{28} + 73x_{29} + 73x_{30} + 39x_{31} + 30x_{32}
\end{aligned}$$

Subject to:

$$\begin{aligned}
& 10x_1 + 56x_2 + 15x_3 + 22x_4 + 3x_5 + 16x_6 + 14x_7 + 13x_8 + 16x_9 + x_{10} + 5x_{11}\\
& + 9x_{12} + 85x_{13} + 225x_{14} + 33x_{15} + 12x_{16} + 73x_{17} + 3x_{18} + 94x_{19} + 25x_{20}\\
& + 2x_{21} + 13x_{22} + 8x_{23} + 25x_{24} \le 778
\end{aligned}$$

$$41x_1 + 23x_2 + 13x_3 + 19x_4 + 2x_5 + 14x_6 + 6x_7 + 8x_8 + 22x_9 + 23x_{10} + x_{11} + 11x_{12} + 8x_{13} + 29x_{14} + 95x_{15} + 17x_{16} + 9x_{17} + 111x_{18} + x_{19} + 3x_{20} + 137x_{21} + 48x_{22} + 6x_{23} + 5x_{24} + 9x_{25} + 18x_{26} \le 642$$

$$14x_1 + 32x_2 + 16x_3 + 5x_4 + 21x_5 + 15x_6 + 3x_7 + 16x_8 + 11x_9 + 24x_{10} + 6x_{11} + 109x_{12} + 3x_{13} + 98x_{14} + 23x_{15} + 4x_{16} + 6x_{17} + 7x_{18} + 35x_{19} \le 448$$

$$9x_1 + 43x_2 + 29x_3 + 5x_4 + 19x_5 + 23x_6 + 7x_7 + 25x_8 + 13x_9 + 167x_{10} + 86x_{11} + 44x_{12} + 5x_{13} + 6x_{14} + 21x_{15} \le 502$$

$$5x_1 + 7x_2 + 9x_3 + 2x_4 + 44x_5 + 85x_6 + 8x_7 + 17x_8 + 6x_9 \le 183$$

$$18x_1 + 32x_2 + 27x_3 + 9x_4 + 29x_5 + 10x_6 + 26x_7 + 65x_8 + 6x_9 + 19x_{10} + 12x_{11} + 30x_{12} + 69x_{13} + 7x_{14} + 29x_{15} + 34x_{16} + 199x_{17} + 75x_{18} \le 696$$

$$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 + x_9 + x_{10} + x_{11} + x_{12} + x_{13} + x_{14} + x_{15} + x_{16} + x_{17} + x_{18} + x_{19} + x_{20} + x_{21} + x_{22} + x_{23} + x_{24} + x_{25} + x_{26} + x_{27} + x_{28} + x_{29} + x_{30} + x_{31} + x_{32} \le 32$$

$$x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{10}, x_{11}, x_{12}, x_{13}, x_{14}, x_{15}, x_{16}, x_{17}, x_{18}, x_{19}, x_{20}, x_{21}, x_{22}, x_{23}, x_{24}, x_{25}, x_{26}, x_{27}, x_{28}, x_{29}, x_{30}, x_{31}, x_{32} \ge 0$$

We also run the AMPL Software using the given data to obtain optimal solution for the projected desks/seating capacity as objective functions which gives the following optimal solutions:

$$x_1 = 20.3182; x_{22} = 11.6818;$$
$$x_2 = x_3 = x_4 = x_{21} = x_{23} = x_{24} = x_{25} = \cdots = x_{32} = 0$$
$$P_{\max} = 13300$$

3. Discussion of Results

Here, we present the analysis of data and discuss the results obtained from the AMPL software system as related to our main aims and objective of this paper as categories into three (3) main results.

1) Results generated by the AMPL. Software with current good seating capacity only

Results and analysis of linear programming model using the Cplex method in AMPL software system estimated the value of the objective function to be 9234 students.

With the current registered student population of the university as 3249, the model indicated that the institution can still admit and accommodate an additional 5985 students with the existing good seating desks. This suggests that the institution has the capacity to admit 5985 more students using the current and existing seating capacity if it is well and fully maximized. Assuming each student pays GHc1500.00 as academic fees yearly, the institution could generate an additional GHc 8,977,500.00 in revenue, *i.e.* (5985 students × GH₵1500.00 = GHc.8,977,500.00) while maintaining the same classroom and seating capacity.

2) Results generated by the AMPL. Software with Current Seating Capacity (Both Good and Bad)

The results and analysis from AMPL software estimated the optimal value of 10,431 students. The current student population is 3249, and the maximum student capacity based on available current desks (both good and bad) is 10,431. This represents an additional capacity of 7182 students with the current seating capacity (both good and bad) arrangement. If a student pays GHc.1500.00 as annual school fees, the institution would have generated an additional GHc.10,773,000.00, *i.e.* (7182 × GH₵1500) as internally generated revenue from tuition fees while utilizing the existing classroom facilities and seating capacity.

3) Projected capacity after taking the full dimensions of the Lecture Rooms

From the analysis of the linear programming model using Cplex in AMPL, the objective function's value is 13,300 students. Given the current student population of 3249, the model indicates that the institution can accommodate an additional 10,051 students based on the expected capacity after measuring the full dimensions of each lecture room. This suggests that the institution has the capacity to admit 10,051 more students, taking into consideration the dimensions of the lecture rooms and the expected seating capacity. If each student pays GHc.1500.00 as academic fees yearly, the institution could generate an additional GHc. 15,076,500.00 in revenue, *i.e.* (10,051 students × GH₵1500.00) while maintaining the same lecture rooms and maximizing the projected capacity based on the lecture room dimensions

4. Conclusions

In this paper, we have fully determined the total seating capacity in each of the available lecture rooms at C.K. Tedam University of Technology and Applied Sciences and proposed appropriate solutions and recommendations to the lecture room allocation problem using linear programming by maximizing the existing 32 lecture room available to accommodate about 9234, 10,431 and 13,300 additional students respectively taking into consideration the objective function using the same and existing lecture rooms this probably will earn the institution management an additional revenue of GHc.8,977,500 (GH₵1500 × 5985), GHc 10,773,000 (GH₵1500 × 7182) and GHc.15,076,500 (1500 × 10,051) as school fees respectfully using the same lecture room facility and as well as the existing seating capacity, working on the broken desks and furnishing the lecture rooms with the expected capacities.

It is recommended that the institution's management consider the following suggestion: even without constructing new lecture rooms, the institution should admit more students in the upcoming academic years, as the current lecture rooms can accommodate them conveniently.

1) The Institution should take into consideration the three maximized optimal values. This would aid them in deciding on which model could generate more revenue as school fees mobilization.

2) The management should fully utilize lecture rooms labelled as JA2 and KB5 and should be well furnished with more seating desks.

3) Lecture rooms with regular dimensions should be furnished with good desks (three per dual desk), and lecture rooms with irregular dimensions should be furnished with single tables and chairs desks.

4) Courses with highly populated students should be assigned to lecture rooms with large capacity. Or be divided into two or more to be taken by different lecturers, and courses with less populated students should be assigned to lecture rooms with lower capacity.

5) The management should partition large lecture rooms to facilitate easy interactions between students and lecturers.

6) The broken desks should be repaired to accommodate more students in the institution.

7) All old science laboratories and the old library should be renovated to convert to a lecture room with well-furnished seating or desks.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Appendix 1. Classroom Measurement and Dimension

Available Classroom	Number of current Desk	Good Seating Capacity	Bad Seating Capacity	Classroom Dimension	Projected. Seating capacity	Difference
SA1 (1)	(106 × 3) 318	285	33	922 × 552	(117 × 3) 351	66
SA2 (1)	(60 × 3) 180	166	14	465 × 710	(70 × 3) 210	44
SA3 (1)	(26 × 3) 78	72	6	457 × 350	(30 × 3) 90	18
SA4 (1)	(18 × 3) 54	48	6	457 × 350	(30 × 3) 90	42
SB1 (1)	(13 × 1) 13	13	0	210 × 251	(36 × 1) 36	23
SB2 (1)	(30 × 1) 30	30	0	210 × 251	(36 × 1) 36	6
SB3 (1)	(25 × 4) 100	87	13	277 × 767	(25 × 4) 100	13
SC1 (1)	(33 × 1) 33	33	0	75 × 223	(70 × 1) 70	37
SC2 (1)	(30 × 1) 30	30	0	75 × 223	(80 × 1) 80	50
SC3 (1)	(34 × 1) 34	34	0	75 × 223	(80 × 1) 80	46
JA1 (1)	(49 × 3) 147	132	15	307 × 916	(62 × 3) 186	54
JA2 (1)	(0 0) 0	0	0	307 × 417	(24 × 2) 48	48
JA3 (1)	(11 × 3) 33	30	3	307 × 421	(30 × 3) 90	60
JA4 (1)	(9 × 3) 27	23	4	307 × 276	(18 × 3) 54	31
JB1 (1)	(11 × 3) 33	33	0	190 × 283	(12 × 3) 36	3
JB2 (1)	(8 × 3) 24	24	0	190 × 283	(12 × 3) 36	12
JB3 (1)	9 × 3) 27	27	0	190 × 283	(12 × 3) 36	9
JB4 (1)	(25 × 3) 75	75	0	518 × 243	(25 × 3) 75	0
JB5 (1)	(16 × 1) 16	16	0	190 × 283	(16 × 1) 16	0
JB6 (1)	(13 × 1) 13	13	0	190 × 283	(33 × 1) 33	20
JB7 (1)	(33 × 1) 33	33	0	190 × 28	(33 × 1) 33	0
KA1 (1)	(128 × 3) 384	339	45	845 × 940	(176 × 3) 528	189
KA2 (1)	(31 × 3) 93	87	6	463 × 654	(73 × 3) 219	132
KB1 (1)	(30 × 1) 30	30	0	379 × 146/107 × 347/72 × 207	(73 × 1) 73	43
KB2 (1)	(31 × 1) 31	31	0	379 × 146/107 × 347/72 × 207	(73 × 1) 73	42
KB3 (1)	(20 × 1) 20	14	6	379 × 146/107 × 347/72 × 207	(73 × 1) 73	59
KB4 (1)	(20 × 1) 20	20	0	379 × 146/107 × 347/72 × 207	(73 × 1) 73	53
KB5 (1)	(57 × 1) 57	56	1	379 × 146/107 × 347/72 × 207	(73 × 1) 73	17
KB6 (1)	(21 × 1) 21	19	2	379 × 146/107 × 347/72 × 207	(73 × 1) 73	54
KB7 (1)	(8 × 1) 8	6	2	379 × 146/107 × 347/72 × 207	(73 × 1) 73	67
KB8 (1)	(39 × 1) 39	39	0	-	(39 × 1) 39	0
KB9 (1)	(22 × 1) 22	22	0	250 × 215	(30 × 1) 30	8
TOTAL. 32	**2023**	**1867**	**156**	**3113**		1248

Source: IT unit 2024.

Appendix 2. Number of Registered Students

School	Department	Programme	LEVELS 100	200	300	400	DIP	P G	TOT.	Grand. Total.
SCBCS	Applied Chemistry	Applied Chemistry	10	4	14	9	0	18	55	162
		Industrial Chemistry	0	0	0	0	0	0	0	
		Pharmaceutical Tech	56	23	0	0	0	0	79	
		Dip in Lab Tech	15	13	0	0	0	0	28	
		Total	**81**	**40**	**14**	**9**	**0**	**18**	**162**	
	Biochemistry & Forensic Sc.	Biochem	22	19	32	43	0	32	148	153
		Forensic Science	3	2	0	0	0	0	5	
		Total	**25**	**21**	**32**	**43**	**0**	**32**	**153**	
SELS	Applied Biology	Applied Biology	16	14	16	29	0	27	102	102
		Total	**16**	**14**	**16**	**29**	**0**	**27**	**102**	
	Environmental science	Environmental Science	0	6	5	5	0	9	25	47
		Environment and Sustainable Development	14	8	0	0	0	0	22	
		Total	**14**	**14**	**5**	**5**	**0**	**9**	**47**	
SMS.	Mathematics	Mathematics	13	22	21	19	5	29	109	119
		Computational Mathematics	0	0	0	0	0	10	10	
		Total	**13**	**22**	**21**	**19**	**5**	**39**	**119**	
	Industrial Mathematics	Mathematics with Economics	16	23	15	23	0	0	77	89
		Mathematics with Finance	1	1	3	7	0	0	12	
		TOTAL	**17**	**24**	**18**	**30**	**0**	**0**	**89**	
	Statistics & Actuarial Sc.	Statistics	5	11	16	25	7	26	90	196
		Actuarial Science	9	8	11	13	0	0	41	
		Applied statistic	0	0	0	0	0	65	65	
		TOTAL	**14**	**19**	**27**	**38**	**7**	**91**	**196**	
	Biometry	Biometry	0	0	0	0	0	6	6	6
		TOTAL	**0**	**0**	**0**	**0**	**0**	**6**	**6**	
SPH	Public Health and control	Public Health in Health Control	85	29	0	0	0	19	133	465
		TOTAL	**85**	**29**	**0**	**0**	**0**	**19**	**133**	
	Epidemiology & Biostats	Public Health in Disease Control	225	95	0	0	0	12	332	
		TOTAL	**225**	**95**	**0**	**0**	**0**	**12**	**332**	
SCIS	Cyber Security and Computer. Engineering.	Cyber Security	33	17	24	0	9	0	83	112
		Software Engineering.	12	9	6	0	2	0	29	
		Total	**45**	**26**	**30**	**0**	**11**	**0**	**112**	

Continued

	Computer Science	Computer Science	73	111	109	167	44	30	534	**544**
		Data Science	3	1	3	0	0	0	7	
		Network Science	0	3	0	0	0	0	3	
		Total	**76**	**115**	**112**	**167**	**44**	**30**	**544**	
	Info. System & Technology	Information Tech	94	137	98	86	85	69	569	**569**
		Total	**94**	**137**	**98**	**86**	**85**	**69**	**569**	
	Business Computing	Computing-with-Acct.	25	48	23	44	0	0	140	**148**
		Dip in Business Computing	0	0	0	0	8	0	8	
		Total	**25**	**48**	**23**	**44**	**0**	**0**	**148**	
SPS	Applied Physics	Applied Physics	2	6	4	5	0	0	17	**48**
		Medical Physics	13	5	6	0	0	0	24	
		Geophysics	0	0	0	0	0	0	0	
		Industrial Physics	0	0	0	0	0	7	7	
		Total	**15**	**11**	**10**	**5**	**0**	**7**	**48**	
	Geological Science	Geological Science	8	9	7	6	0	0	30	**30**
		Total	**8**	**9**	**7**	**6**	**0**	**0**	**30**	
SMEDS	Anesthesia & Critical Care	Medical Laboratory Science	25	0	0	0	0	0	25	**88**
		Anesthesia and Critical care	0	0	0	0	0	29	29	
		Infectious disease and immunology	0	0	0	0	0	34	34	
		TOTAL	**25**	**0**	**0**	**0**	**0**	**63**	**88**	
SMES.	Mathematics & ICT Education.	Diploma in ICT Education	0	0	0	0	17		17	**371**
		Mathematics Education	0	0	0	0	0	199	199	
		TOTAL	**0**	**0**	**0**	**0**	**17**	**199**	**216**	
	Science Education	Science Education	0	18	35	21	6	75	155	
		TOTAL	**0**	**18**	**35**	**21**	**6**	**75**	**155**	
Grand TOTAL			**778**	**642**	**448**	**502**	**183**	**696**	**3249**	**3249**

Sources: IT unit 2024.

Appendix 3. Keys to the Table

1. SA (1-4) NHA BLOCK, SB (1-3) C-BLOCK & COMPUTER LAB and SC (1-3) SCIENCE LABS (Chemistry, Biology and physics)
2. JA (1-4) NGF & NTF BLOCK, JB (1-7) SPANISH LAB BOTH LECTURE ROOMS AND LABS
3. KA (1-2) NH BLOCK, KB (1-9) LECTURE ROOM AT SCH, PUB.H AND SCH.MED SC. & ALLIED BIOLOGY LABS

Appendix 4. AMPL Software

1. Develop AMPL Software Programme (USING GOOD SEATING CAPACITY)

```
# PART 1: DECISION VARIABLES
var x1>= 0;var x2>= 0;var x3>= 0;var x4>= 0;var x5>= 0;var x6>= 0;var x7>= 0;var x8>= 0;
var x9>= 0;var x10>= 0;var x11>= 0;var x12>= 0;var x13>= 0;var x14>= 0;var x15>= 0;
var x16>= 0;var x17>= 0;var x18>= 0;var x19>= 0;var x20>= 0;var x21>= 0;var x22>= 0;
var x23>= 0;var x24>= 0;var x25>= 0;var x26>= 0;var x27>= 0;var x28>= 0;var x29>= 0;
var x30>= 0;var x31>= 0;var x32>= 0;
# PART 2: OBJECTIVE FUNCTION
maximize P: 285*x1 + 166*x2 + 72*x3 + 48*x4 + 13*x5 + 30*x6 + 87*x7 + 132*x8 + 30*x9 + 23*x10 + 33*x11 + 24*x12 + 27*x13 + 75*x14 + 16*x15 + 13*x16 + 33*x17 + 339*x18 + 87*x19 + 30*x20 + 31*x21 + 14*x22 + 20*x23 + 56*x24 + 19*x25 + 6*x26 + 39*x27 + 22*x28 + 33*x29 + 30*x30 + 34*x31; #Capacity of each class type
# PART 3: CONSTRAINTS
s.t. M1: 10*x1 + 56*x2 + 15*x3 + 22*x4 + 3*x5 + 16*x6 + 14*x7 + 13*x8 + 16*x9 + x10 + 5*x11 + 9*x12 + 85*x13 + 225*x14 + 33*x15 + 12*x16 + 73*x17 + 3*x18 + 94*x19 + 25*x20 + 2*x21 + 13*x22 + 8*x23 + 25*x24<= 778; #Total of students in 100level
s.t. M2: 4*x1 + 23*x2 + 13*x3 + 19*x4 + 2*x5 + 14*x6 + 6*x7 + 8*x8 + 22*x9 + 23*x10 + x11 + 11*x12 + 8*x13 + 29*x14 + 95*x15 + 17*x16 + 9*x17 + 111*x18 + x19 + 3*x20 + 137*x21 + 48*x22 + 6*x23 + 5*x24+ 9*x25+ 18*x26<= 642; #Total of students in 200level
s.t. M3: 14*x1 + 32*x2 + 16*x3 + 5*x4 + 21*x5 + 15*x6 + 3*x7 + 16*x8 + 11*x9 + 24*x10 + 6*x11 + 109*x12 + 3*x13 + 98*x14 + 23*x15 + 4*x16 + 6*x17 + 7*x18 + 35*x19<= 448; #Total of students in 300level
s.t. M4: 9*x1 + 43*x2 + 29*x3 + 5*x4 + 19*x5 + 23*x6 + 7*x7 + 25*x8 + 13*x9 + 167*x10 + 86*x11 + 44*x12 + 5*x13 + 6*x14 + 21*x15<= 502; #Total of students in 400level
s.t. M5: 5*x1 + 7*x2 + 9*x3 + 2*x4 + 44*x5 + 85*x6 + 8*x7 + 17*x8 + 6*x9<= 183; #Total of students in diploma level
s.t. M6: 18*x1 + 32*x2 + 27*x3 + 9*x4 + 29*x5 + 10*x6 + 26*x7 + 65*x8 + 6*x9 + 19*x10 + 12*x11 + 30*x12 + 69*x13 + 7*x14 + 29*x15 + 34*x16 + 199*x17 + 75*x18<= 696; #Total of students in postgraduate level
s.t. M7: x1 + x2 + x3 + x4 + x5 + x6 + x7 + x8 + x9 + x10 + x11 + x12 + x13 + x14 + x15 + x16 + x17 + x18 + x19 + x20 + x21 + x22 + x23 + x24 + x25 + x26 + x27 + x28 + x29 + x30 + x31 + x32<= 32; # No of available classrooms
```

The part that was run for the result is (example2.run);

```
#RESET THE AMPL ENVIRONMENT
reset;
#LOAD THE MODEL
model example1.mod;
#CHANGE THE SOLVER (optional)
option solver cplex;
#SOLVE
solve;
#SHOW RESULTS
display x1, x2, x3, x4, x5, x6, x7, x8, x9, x10, x11, x12, x13, x14, x15, x16, x17, x18, x19, x20, x21, x22, x23, x24, x25, x26, x27, x28, x29, x30, x31, x32, P;
```

The AMPL Software Results

```
ampl: include wumpini2.run;
CPLEX 22.1.1: optimal solution; objective 9233.684211
1 simplex iterations
x1 = 29.8947
x2, x3, x4……., x17 = 0
x18 = 2.10526
x19, x20, x21……., x32 = 0 and
Pmax = 9233.68
```

Appendix 5

2. Develop AMPL Software Programme (USING CURRENT CAPACITY)# PART 1: DECISION VARIABLES

```
var x1>= 0;var x2>= 0;var x3>= 0;var x4>= 0;var x5>= 0;var x6>= 0;var x7>= 0;var x8>= 0;
var x9>= 0;var x10>= 0;var x11>= 0;var x12>= 0;var x13>= 0;var x14>= 0;var x15>= 0;
var x16>= 0;var x17>= 0;var x18>= 0;var x19>= 0;var x20>= 0;var x21>= 0;var x22>= 0;
var x23>= 0;var x24>= 0;var x25>= 0;var x26>= 0;var x27>= 0;var x28>= 0;var x29>= 0;
var x30>= 0;var x31>= 0;var x32>= 0;
# PART 2: OBJECTIVE FUNCTION
maximize P: 318*x1 + 180*x2 + 78*x3 + 54*x4 + 13*x5 + 30*x6 + 100*x7 + 33*x8 + 30*x9 + 34*x10 + 147*x11 + 33*x12 + 27*x13 + 33*x14 + 24*x15 + 27*x16 + 75*x17 + 16*x18 + 13*x19 + 33*x20 + 384*x21 + 93*x22 + 30*x23 + 31*x24 + 20*x25 + 20*x26 + 57*x27 + 21*x28 + 8*x29 + 39*x30 + 22*x31; #Capacity of each class type
# PART 3: CONSTRAINTS
s.t. M1: 10*x1 + 56*x2 + 15*x3 + 22*x4 + 3*x5 + 16*x6 + 14*x7 + 13*x8 + 16*x9 + x10 + 5*x11 + 9*x12 + 85*x13 + 225*x14 + 33*x15 + 12*x16 + 73*x17 + 3*x18 + 94*x19 + 25*x20 + 2*x21 + 13*x22 + 8*x23 + 25*x24<= 778; #Total of students in 100level
s.t. M2: 4*x1 + 23*x2 + 13*x3 + 19*x4 + 2*x5 + 14*x6 + 6*x7 + 8*x8 + 22*x9 + 23*x10 + x11 + 11*x12 + 8*x13 + 29*x14 + 95*x15 + 17*x16 + 9*x17 + 111*x18 + x19 + 3*x20 + 137*x21 + 48*x22 + 6*x23 + 5*x24+ 9*x25+ 18*x26<= 642; #Total of students in 200level
s.t. M3: 14*x1 + 32*x2 + 16*x3 + 5*x4 + 21*x5 + 15*x6 + 3*x7 + 16*x8 + 11*x9 + 24*x10 + 6*x11 + 109*x12 + 3*x13 + 98*x14 + 23*x15 + 4*x16 + 6*x17 + 7*x18 + 35*x19<= 448; #Total of students in 300level
s.t. M4: 9*x1 + 43*x2 + 29*x3 + 5*x4 + 19*x5 + 23*x6 + 7*x7 + 25*x8 + 13*x9 + 167*x10 + 86*x11 + 44*x12 + 5*x13 + 6*x14 + 21*x15<= 502; #Total of students in 400level
s.t. M5: 5*x1 + 7*x2 + 9*x3 + 2*x4 + 44*x5 + 85*x6 + 8*x7 + 17*x8 + 6*x9<= 183; #Total of students in diploma level
s.t. M6: 18*x1 + 32*x2 + 27*x3 + 9*x4 + 29*x5 + 10*x6 + 26*x7 + 65*x8 + 6*x9 + 19*x10 + 12*x11 + 30*x12 + 69*x13 + 7*x14 + 29*x15 + 34*x16 + 199*x17 + 75*x18<= 696; #Total of students in postgraduate level
s.t. M7: x1 + x2 + x3 + x4 + x5 + x6 + x7 + x8 + x9 + x10 + x11 + x12 + x13 + x14 + x15 + x16 + x17 + x18 + x19 + x20 + x21 + x22 + x23 + x24 + x25 + x26 + x27 + x28 + x29 + x30 + x31 + x32<= 32; # No of available classrooms
```

The part that was run for the result is (example2.run);

```
#RESET THE AMPL ENVIRONMENT
reset;
#LOAD THE MODEL
model example1.mod;
#CHANGE THE SOLVER (optional)
option solver cplex;
#SOLVE
solve;
#SHOW RESULTS
display x1, x2, x3, x4, x5, x6, x7, x8, x9, x10, x11, x12, x13, x14, x15, x16, x17, x18, x19, x20, x21, x22, x23, x24, x25, x26, x27, x28, x29, x30, x31, x32, P;
```

The AMPL Software Results

ampl: include example2.run;
CPLEX 22.1.1: optimal solution; objective 10431.06767
1 simplex iterations
x1 = 28.1353,
x2, x3, x4 ……., x20 = 0,
x21 = 3.86466,
x22, x23, x24……, x32 = 0 and
Pmax = 10431.1

Appendix 6

3. Develop AMPL Software Programme (USING PROJECTED SEATING CAPACITY)

```
# PART 1: DECISION VARIABLES
var x1>= 0;var x2>= 0;var x3>= 0;var x4>= 0;var x5>= 0var x6>= 0;var x7>= 0;
var x8>= 0;var x9>= 0;var x10>= 0var x11>= 0;var x12>= 0;var x13>= 0;var x14>= 0;
var x15>= 0;var x16>= 0;var x17>= 0var x18>= 0;var x19>= 0;var x20>= 0;var x21>= 0;
var x22>= 0;var x23>= 0;var x24>= 0;var x25>= 0;var x26>= 0;var x27>= 0var x28>= 0;
var x29>= 0;var x30>= 0;var x31>= 0;var x32>= 0;
# PART 2: OBJECTIVE FUNCTION
maximize P: 351*x1 + 210*x2 + 90*x3 + 90*x4 + 36*x5 + 36*x6 + 100*x7 + 70*x8 + 80*x9 + 80*x10 + 186*x11 + 48*x12 + 90*x13 + 54*x14 + 36*x15 + 36*x16 + 36*x17 + 75*x18 + 16*x19 + 33*x20 + 33*x21 + 528*x22 + 219*x23 + 73*x24 + 73*x25 + 73*x26 + 73*x27 + 73*x28 + 73*x29 + 73*x30 + 39*x31 + 30*x32; #Capacity of each class type
# PART 3: CONSTRAINTS
s.t. M1: 10*x1 + 56*x2 + 15*x3 + 22*x4 + 3*x5 + 16*x6 + 14*x7 + 13*x8 + 16*x9 + x10 + 5*x11 + 9*x12 + 85*x13 + 225*x14 + 33*x15 + 12*x16 + 73*x17 + 3*x18 + 94*x19 + 25*x20 + 2*x21 + 13*x22 + 8*x23 + 25*x24<= 778; #Total of students in 100level
s.t. M2: 4*x1 + 23*x2 + 13*x3 + 19*x4 + 2*x5 + 14*x6 + 6*x7 + 8*x8 + 22*x9 + 23*x10 + x11 + 11*x12 + 8*x13 + 29*x14 + 95*x15 + 17*x16 + 9*x17 + 111*x18 + x19 + 3*x20 + 137*x21 + 48*x22 + 6*x23 + 5*x24+ 9*x25+ 18*x26<= 642; #Total of students in 200level
s.t. M3: 14*x1 + 32*x2 + 16*x3 + 5*x4 + 21*x5 + 15*x6 + 3*x7 + 16*x8 + 11*x9 + 24*x10 + 6*x11 + 109*x12 + 3*x13 + 98*x14 + 23*x15 + 4*x16 + 6*x17 + 7*x18 + 35*x19<= 448; #Total of students in 300level
s.t. M4: 9*x1 + 43*x2 + 29*x3 + 5*x4 + 19*x5 + 23*x6 + 7*x7 + 25*x8 + 13*x9 + 167*x10 + 86*x11 + 44*x12 + 5*x13 + 6*x14 + 21*x15<= 502; #Total of students in 400level

s.t. M5: 5*x1 + 7*x2 + 9*x3 + 2*x4 + 44*x5 + 85*x6 + 8*x7 + 17*x8 + 6*x9<= 183; #Total of students in diploma level
s.t. M6: 18*x1 + 32*x2 + 27*x3 + 9*x4 + 29*x5 + 10*x6 + 26*x7 + 65*x8 + 6*x9 + 19*x10 + 12*x11 + 30*x12 + 69*x13 + 7*x14 + 29*x15 + 34*x16 + 199*x17 + 75*x18<= 696; #Total of students in postgraduate level
s.t. M7: x1 + x2 + x3 + x4 + x5 + x6 + x7 + x8 + x9 + x10 + x11 + x12 + x13 + x14 + x15 + x16 + x17 + x18 + x19 + x20 + x21 + x22 + x23 + x24 + x25 + x26 + x27 + x28 + x29 + x30 + x31 + x32<= 32; # No of available classrooms
```

The part that was run for the result is (example2.run);

```
#RESET THE AMPL ENVIRONMENT

reset;
#LOAD THE MODEL
model example1.mod;
#CHANGE THE SOLVER (optional)
option solver cplex;
#SOLVE
solve;
#SHOW RESULTS
display x1, x2, x3, x4, x5, x6, x7, x8, x9, x10, x11, x12, x13, x14, x15, x16, x17, x18, x19, x20, x21, x22, x23, x24, x25, x26, x27, x28, x29, x30, x31, x32, P;
```

The AMPL Software Results

ampl: include example2.run;
CPLEX 22.1.1: optimal solution; objective 13299.68182
1 simplex iterations
x1 = 20.3182,
x2, x3, x4 ……., x21 = 0,
x22 = 11.6818,
x23, x24, x25…….,32 = 0 and
Pmax: = 13299.7