Application of optimization principles in classroom allocation using linear programming

Article - January 2019

6 authors, including:

- Nathaniel Kayode Oladejo
  University for Development Studies
  17 PUBLICATIONS 9 CITATIONS
  SEE PROFILE

- Nathaniel Kayode Oladejo
  University for Development Studies
  17 PUBLICATIONS 9 CITATIONS
  SEE PROFILE

- Salawu Sulyman
  Landmark University
  34 PUBLICATIONS 27 CITATIONS
  SEE PROFILE

- Nathaniel Kayode Oladejo
  University for Development Studies
  17 PUBLICATIONS 9 CITATIONS
  SEE PROFILE

- Salawu Sulyman
  Landmark University
  34 PUBLICATIONS 27 CITATIONS
  SEE PROFILE

Some of the authors of this publication are also working on these related projects:

- Handy type inequalities on Riemannian manifolds View project

- Statistical modelling View project
APPLICATION OF OPTIMIZATION PRINCIPLES IN CLASSROOM ALLOCATION USING LINEAR PROGRAMMING

N. K Oladejo*, A. Abolarinwa, S.O Salawu, M.O Bamiro and A.F Lukman

Physical Sciences Department, Landmark University, Kwara State, Nigeria

H.I Bukari

Mathematics Department, Bagabaga College of Education, Tamale, Ghana

*corresponding author

ABSTRACT

This paper deal with the application of optimization principle in solving the problem of over-allocation and under-allocation of the classroom space using linear programming in Landmark University, Nigeria. A linear programming model was formulated based on the data obtained from the examination and lecture timetable committee on the classroom facilities, capacities and the number of students per programme in all the three (3) Colleges to maximize the usage of the available classroom space and minimizes the congestion and overcrowding in a particular lecture room using AMPL software which revealed that 16 out of 32 classrooms available with a seating capacity of 2066 has always been used to accommodate the current student population of 2522 which always causes overflow and congestion in those concentrated classroom because the remaining 16 classroom of the seating capacity of 805 were underutilized. Meanwhile if the projected seating capacity of 3544 as revealed by the AMPL software in all these 32 classroom were fully utilized, this indicated that an additional 1022 i.e.(3544-2522) students can be fully absorbed comfortably with the existing 32 classrooms in both of the three (3) colleges if the seating capacities are fully managed and maximized. This will helps the school management to generate additional income of N 585,606,000.00 i.e. (1022 × 573,000) as school fees using the same classroom facility and as well as the existing seating capacity.

Keywords: Allocation, classroom, linear, optimization, programming, maximize


http://www.iaeme.com/IJMET/issues.asp?JType=IJMET&VType=10&IType=01
1. INTRODUCTION
The problem of allocating scarce resource to satisfy unlimited human needs has been and continues to be a global phenomenon confronting both the managers, administrators, entrepreneurs, heads of institutions and individuals alike. Allocation of resources to areas of space such as rooms, satisfying as many requirements and constraints as possible can be called a space allocation. Arsham (1998) presented a procedure for allocating classrooms in an educational institution which was based on a linear programming model in which a penalty function is minimized. With the default values of some parameters provided by the procedure, the model first assigns as many rooms to the requests as possible.

The ideal solution in the space allocation problem is one where all the entities were optimally allocated, no space is wasted or overused and every additional requirements and constraints have been satisfied. Classroom allocation has been an issue affecting many organisations, companies and schools such as Landmark University of which the paper try to find a lasting solution to the problem using Linear programming method which was developed as a discipline by George Danzig (1947) always refers to the founder who devised the simplex method in 1947 which was motivated initially by the need to solve complex planning problems in wartime operations. Its’ development accelerated rapidly in the post-war period as many industries found valuable uses for linear programming and George Danzig who established the theory of duality also in 1947.

Karmarkar (1984) opined that a better way to consistently and effectively allocate classrooms is to use a computer-assisted system that will keep track of all classrooms on campus along with specific details about those rooms that can automatically suggest efficient pairings with the courses offered for a given semester. The efficiency will be judged based on many factors, most importantly being that the size of each room is used effectively. Rajgopal and Bricker (1990) stated that Mathematical programming that solves the problem of determining the optimal allocation of limited resources required to meet a given objective, is the linear programming, a method of allocating limited resources to competing needs in the best way in order to ensure optimality.

Raz, and Bricker (1990) presented the ellipsoid method, guaranteed to solve any linear program in a number of steps which is a polynomial function of the amount of data defining the linear program. Consequently, the ellipsoid method is faster than the simplex method in contrived cases where the simplex method performs poorly. In practice, however, the simplex method is far superior to the ellipsoid method. Abad and Banks (1993) introduced an interior-point method for linear programming, combining the desirable theoretical properties of the ellipsoid method with practical advantages of the simplex method. Its success initiated an explosion in the development of interior-point methods. These do not pass from vertex to vertex, but pass only through the interior of the feasible region. Though this property is very easy to state, the analysis of interior-point methods is a subtle subject which is much less easily understood than the behaviour of the simplex method. Interior-point methods are now generally considered competitive with the simplex method in most cases, though not all, applications, and sophisticated software packages implementing them are now available.

2. LINEAR PROGRAMMING PROBLEM
A Linear programming (LP) is one of the most widely used optimization techniques and perhaps the most effective method. The term linear programming was coined by George Dantzig in 1947 to refer to problems in which both the objective function and constraints are provided. It is a problem of optimizing linear objective in the decision variables $x_1, x_2, \ldots, x_n$ subject to linear inequality or inequality constraints on the $X$.

We then give our standard form of linear programming as:
Application of Optimization Principles in Classroom Allocation Using Linear Programming

Maximize \[ F = \sum_{j=1}^{n} C_j X_j \] 

Subject to \[ \sum_{j=1}^{n} a(i,j)X_j = b_i, i = 12...n \] 

\[ l_j \leq X \leq u_j, j = 12...n \] 

Where \( C_j \) are then objective function coefficients \( a(i,j) \) and \( b \) are parameters in the linear inequality constraints and \( l \) and \( u \) are lower and upper bounds with \( l_j \leq u_j \). Both \( l \) and \( u \) may be positive or negative.

### 2.1. Formulation of LP Model

Mathematical linear programming models were formulated to determine how to adequately allocate class spaces to each department which consist of types of classroom, seating capacities, number of such classroom according to the departments and programmes in each of the three (3) colleges as well as the total number of the students in each of the departments according to the levels which was collected from the Chairman of the University lecture and examination time table committee.

The specified LP model for the attainment of the objective function is as follows:

Minimize \[ Z = \sum C_j X_j \]

Subject to \[ x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 = b_1 \]

\[ a_{11} x_1 + a_{12} x_2 + a_{13} x_3 + a_{14} x_4 + a_{15} x_5 + a_{16} x_6 + a_{17} x_7 + a_{18} x_8 \leq b_2 \]

\[ a_{21} x_1 + a_{22} x_2 + a_{23} x_3 + a_{24} x_4 + a_{25} x_5 + a_{26} x_6 + a_{27} x_7 + a_{28} x_8 \leq b_3 \]

\[ a_{31} x_1 + a_{32} x_2 + a_{33} x_3 + a_{34} x_4 + a_{35} x_5 + a_{36} x_6 + a_{37} x_7 + a_{38} x_8 \leq b_4 \]

\[ a_{41} x_1 + a_{42} x_2 + a_{43} x_3 + a_{44} x_4 + a_{45} x_5 + a_{46} x_6 + a_{47} x_7 + a_{48} x_8 \leq b_5 \]

\[ a_{51} x_1 + a_{52} x_2 + a_{53} x_3 + a_{54} x_4 + a_{55} x_5 + a_{56} x_6 + a_{57} x_7 + a_{58} x_8 \leq b_6 \]

\[ a_{61} x_1 + a_{62} x_2 + a_{63} x_3 + a_{64} x_4 + a_{65} x_5 + a_{66} x_6 + a_{67} x_7 + a_{68} x_8 \leq b_7 \]

\[ a_{71} x_1 + a_{72} x_2 + a_{73} x_3 + a_{74} x_4 + a_{75} x_5 + a_{76} x_6 + a_{77} x_7 + a_{78} x_8 \leq b_8 \]

\[ a_{81} x_1 + a_{82} x_2 + a_{83} x_3 + a_{84} x_4 + a_{85} x_5 + a_{86} x_6 + a_{87} x_7 + a_{88} x_8 \leq b_9 \]

\[ a_{91} x_1 + a_{92} x_2 + a_{93} x_3 + a_{94} x_4 + a_{95} x_5 + a_{96} x_6 + a_{97} x_7 + a_{98} x_8 \leq b_{10} \]

\[ a_{101} x_1 + a_{102} x_2 + a_{103} x_3 + a_{104} x_4 + a_{105} x_5 + a_{106} x_6 + a_{107} x_7 + a_{108} x_8 \leq b_{11} \]

\[ x_1 \geq 0, \ i = 1,2,3,...,n \]  

(3)

This which can be transformed into the following
Minimize \( Z = \sum C_i X_i \)

Subject to

\[
x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 + x_9 + x_{10} + x_{11} = b_1 \\
+ x_2 + x_3 + x_4 + x_5 + x_6 + x_7 = b_2 \\
+ x_3 + x_4 + x_5 + x_6 + x_7 + x_8 = b_3 \\
+ x_4 + x_5 + x_6 + x_7 + x_8 + x_9 = b_4 \\
+ x_5 + x_6 + x_7 + x_8 + x_9 + x_{10} = b_5 \\
+ x_6 + x_7 + x_8 + x_9 + x_{10} + x_{11} = b_6 \\
+ x_7 + x_8 + x_9 + x_{10} + x_{11} = b_7 \\
+ x_8 + x_9 + x_{10} + x_{11} = b_8 \\
+ x_9 + x_{10} + x_{11} = b_9 \\
+ x_{10} + x_{11} = b_{10} \\
\]

\( x_i \geq 0, i = 1,2,3,\ldots,n \) \hspace{1cm} (4)

### 2.2. Modelling Technique:

This classroom space allocation problem is considered as a linear programming problem and this classroom space was categorized into types according to the number of seats, and the type of sitting/equipment/capacity available. The students were considered according to the level in the classes based on the programme and the level of the students as follows.

(i). We let the capacity of each category (type) of a classroom be: \( C_i = C_1, C_2, C_3, C_4, \ldots, C_n \) 

For \( i = 1, 2, 3 \ldots n \)

Where

\( C_1 = \) the capacity of a room of type 1  
\( C_2 = \) the capacity of a room of type 2  
\( C_3 = \) the capacity of a room of type 3  
\( C_4 = \) the capacity of a room of type 4  
\( C_5 = \) the capacity of a room of type 5

(ii). We let the classrooms be categorized into types as: \( x_i = x_1, x_2, x_3, x_4, \ldots, x_n \) 

For \( i = 1, 2, 3, 4 \ldots n \) based on the capacities of the rooms, where

\( x_1 = \) classroom type 1 with a seating capacity \( C_1 \)  
\( x_2 = \) classroom type 2 with a seating capacity \( C_2 \)  
\( x_3 = \) classroom type 3 with a seating capacity \( C_3 \)  
\( x_4 = \) classroom type 4 with a seating capacity \( C_4 \)  
\( x_5 = \) classroom type 5 with a seating capacity \( C_5 \) \hspace{1cm} (3)

We let the number of classrooms of each type be: \( a_1, a_2, a_3, \ldots, a_n \)

Where;

\( a_1 = \) number of rooms of classroom type 1  
\( a_2 = \) number of rooms of classroom type 2

(iii) We let the total available classroom space of all the types of classrooms denoted by \( d \). 

Then

\( d = \sum_{i=1}^{n} a_i c_i \) \hspace{1cm} (5)

Where: \( a_1, \ldots, a_n \) is the number of classrooms of each type,
$d$ is the total available classroom space of all the types of classrooms

c$_1, \ldots, c_n$ is the capacity of each category (type) of a classroom

3. DATA COLLECTION AND ANALYSIS OF RESULTS

The primary data collected from the Landmark University Chairman examination committee which consist of types of classroom, seating capacities, number of available classroom by category, list of the Departments and programmes in each of the three (3) colleges as well as the total number of the students in the Departments according to the levels which was collected from the chairman of the University time table committee. The list of classroom types currently utilized in the school is as follows:

1. Wing A, we have A01, A02, A03, A04, A11, A12, A13, A14, A21, A22, A23, A24 in NCB and A215, A315, A316 in FCB
2. Wing B, we have: B01, B02, B03, B04, B12, B13, B14, B21, B22, B23, and B24 in NCB
3. Wing C, we have: C02, C12, C13, C14 in NCB

Where NCB= New College Building and FCB= First College Building. The tables of all the class types and their respective capacities as well as their availability are given table 1 below.

**Table 1:** Shows the classes available and their respective seating capacities

<table>
<thead>
<tr>
<th>Classroom Type</th>
<th>Seating Capacity</th>
<th>No of available Classrooms</th>
</tr>
</thead>
<tbody>
<tr>
<td>A01</td>
<td>92</td>
<td>1</td>
</tr>
<tr>
<td>A02</td>
<td>36</td>
<td>1</td>
</tr>
<tr>
<td>A13</td>
<td>38</td>
<td>1</td>
</tr>
<tr>
<td>A12</td>
<td>40</td>
<td>1</td>
</tr>
<tr>
<td>A22, A23</td>
<td>42</td>
<td>2</td>
</tr>
<tr>
<td>A03</td>
<td>45</td>
<td>1</td>
</tr>
<tr>
<td>B12, B13, B22, B23</td>
<td>48</td>
<td>4</td>
</tr>
<tr>
<td>B02, B03</td>
<td>55</td>
<td>2</td>
</tr>
<tr>
<td>C02, C12, C13</td>
<td>60</td>
<td>3</td>
</tr>
<tr>
<td>C14</td>
<td>70</td>
<td>1</td>
</tr>
<tr>
<td>A11, A14</td>
<td>72</td>
<td>2</td>
</tr>
<tr>
<td>B04, B14, B24</td>
<td>91</td>
<td>3</td>
</tr>
<tr>
<td>A315</td>
<td>96</td>
<td>1</td>
</tr>
<tr>
<td>A04, A21, A24</td>
<td>98</td>
<td>3</td>
</tr>
<tr>
<td>B01, A215</td>
<td>100</td>
<td>2</td>
</tr>
<tr>
<td>A316</td>
<td>104</td>
<td>1</td>
</tr>
<tr>
<td>B21</td>
<td>119</td>
<td>1</td>
</tr>
<tr>
<td>LT2 Ground Floor</td>
<td>350</td>
<td>1</td>
</tr>
<tr>
<td>LT1 First Floor</td>
<td>394</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>2861</td>
<td>32</td>
</tr>
</tbody>
</table>
Table 2 shows number of students in each College, Department and Programme per level

<table>
<thead>
<tr>
<th>COLLEGE</th>
<th>DEPT</th>
<th>LEVEL 100</th>
<th>LEVEL 200</th>
<th>LEVEL 300</th>
<th>LEVEL 400</th>
<th>LEVEL 500</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAS</td>
<td>Agric. Econs.</td>
<td>15</td>
<td>12</td>
<td>18</td>
<td>4</td>
<td>7</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td>Crop Sc.</td>
<td>9</td>
<td>7</td>
<td>5</td>
<td>4</td>
<td>-</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Animal Sc.</td>
<td>10</td>
<td>14</td>
<td>6</td>
<td>4</td>
<td>4</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>Agric. Eng. Ext.</td>
<td>5</td>
<td>8</td>
<td>5</td>
<td>7</td>
<td>2</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>Soil Sc.</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>CSE</td>
<td>Computer Sc.</td>
<td>114</td>
<td>52</td>
<td>36</td>
<td>25</td>
<td>-</td>
<td>227</td>
</tr>
<tr>
<td></td>
<td>Biological Sc.</td>
<td>68</td>
<td>66</td>
<td>54</td>
<td>39</td>
<td>-</td>
<td>227</td>
</tr>
<tr>
<td></td>
<td>Physical Sc.</td>
<td>12</td>
<td>9</td>
<td>17</td>
<td>18</td>
<td>-</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td>Civil Eng.</td>
<td>86</td>
<td>45</td>
<td>46</td>
<td>47</td>
<td>27</td>
<td>251</td>
</tr>
<tr>
<td></td>
<td>Chem. Eng.</td>
<td>30</td>
<td>30</td>
<td>20</td>
<td>25</td>
<td>28</td>
<td>133</td>
</tr>
<tr>
<td></td>
<td>Mech. Eng.</td>
<td>97</td>
<td>72</td>
<td>48</td>
<td>36</td>
<td>35</td>
<td>288</td>
</tr>
<tr>
<td></td>
<td>EIE</td>
<td>86</td>
<td>57</td>
<td>58</td>
<td>65</td>
<td>50</td>
<td>316</td>
</tr>
<tr>
<td></td>
<td>ABE</td>
<td>8</td>
<td>23</td>
<td>14</td>
<td>12</td>
<td>8</td>
<td>65</td>
</tr>
<tr>
<td>CBS</td>
<td>Accounting</td>
<td>61</td>
<td>69</td>
<td>52</td>
<td>37</td>
<td>-</td>
<td>219</td>
</tr>
<tr>
<td></td>
<td>Bus. Admin.</td>
<td>21</td>
<td>27</td>
<td>30</td>
<td>27</td>
<td>-</td>
<td>105</td>
</tr>
<tr>
<td></td>
<td>Economics</td>
<td>45</td>
<td>33</td>
<td>22</td>
<td>32</td>
<td>-</td>
<td>132</td>
</tr>
<tr>
<td></td>
<td>Sociology</td>
<td>31</td>
<td>23</td>
<td>18</td>
<td>14</td>
<td>-</td>
<td>86</td>
</tr>
<tr>
<td></td>
<td>BFN</td>
<td>5</td>
<td>8</td>
<td>6</td>
<td>14</td>
<td>-</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Pol. Sc. &amp; Int. Rel.</td>
<td>76</td>
<td>52</td>
<td>60</td>
<td>37</td>
<td>-</td>
<td>225</td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td>781</td>
<td>611</td>
<td>518</td>
<td>449</td>
<td>163</td>
<td>2522</td>
</tr>
</tbody>
</table>

3.1. Formulation of Linear programming

The linear Programming is hereby formulated and determines the objective function as:

\[
Max : \sum_{i=1}^{n} C_i X_i \quad (6)
\]

Subject to constraints:

\[
\sum_{i=1}^{n} a_i c_j \leq d \quad (i = 1, 2, \ldots, n) \quad (7)
\]

**Assumption:**

We assumed that

I. The total number of students assigned to a number of categories of the rooms cannot exceed the total classroom space available in each of the classrooms.

II. \( x_i \geq 0 \) for \( i = 1, 2, 3, \ldots \) is non-negative since a number of students to be assigned to a room cannot be a negative number.

Then we set up the objective function as follows:

\[
Max \quad P = 36x_1 + 38x_2 + 40x_3 + 34x_4 + 45x_5 + 192x_6 + 110x_7 + 180x_8 + 70x_9 + 144x_{10} + 273x_{11} + 92x_{12} + 96x_{13} + 294x_{14} + 200x_{15} + 104x_{16} + 119x_{17} + 350x_{18} + 294x_{19}
\]

Subject to
Application of Optimization Principles in Classroom Allocation Using Linear Programming

\[\begin{align*}
19x_1 + 9x_2 + 10x_3 + 5x_4 + 2x_5 + 114x_6 + 68x_7 + 12x_8 + 86x_9 + 30x_{10} + 97x_{11} + 86x_{12} + 8x_{13} + 61x_{14} + 21x_{15} + 45x_{16} + 31x_{17} + 5x_{18} + 76x_{19} & \leq 781 \\
12x_1 + 7x_2 + 14x_3 + 18x_4 + 4x_5 + 52x_6 + 66x_7 + 9x_8 + 45x_9 + 30x_{10} + 72x_{11} + 57x_{12} + 23x_{13} + 69x_{14} + 27x_{15} + 33x_{16} + 23x_{17} + 8x_{18} + 52x_{19} & \leq 611 \\
18x_1 + 5x_2 + 6x_3 + 5x_4 + 3x_5 + 36x_6 + 54x_7 + 17x_8 + 46x_9 + 20x_{10} + 48x_{11} + 58x_{12} + 14x_{13} + 52x_{14} + 30x_{15} + 22x_{16} + 18x_{17} + 6x_{18} + 60x_{19} & \leq 518 \\
4x_1 + 4x_2 + 4x_3 + 7x_4 + 2x_5 + 25x_6 + 39x_7 + 18x_8 + 47x_9 + 25x_{10} + 36x_{11} + 65x_{12} + 12x_{13} + 37x_{14} + 27x_{15} + 32x_{16} + 14x_{17} + 14x_{18} + 37x_{19} & \leq 449 \\
7x_1 + 4x_2 + 2x_3 + 2x_4 + 27x_5 + 28x_6 + 35x_7 + 50x_8 + 8x_9 & \leq 163 \\
x_1 + x_2 + x_3 + 2x_4 + 8x_7 + 4x_8 + 2x_9 + 3x_{10} + x_{11} + x_{12} + x_{13} + 3x_{14} + 21x_{15} + x_{16} + x_{17} + x_{18} + x_{19} & \leq 32 \\
92x_1 + 36x_2 + 38x_3 + 40x_4 + 45x_5 + 48x_6 + 55x_7 + 60x_8 + 70x_9 + 72x_{10} + 91x_{11} + 96x_{12} + 98x_{13} + 100x_{14} + 104x_{15} + 119x_{16} + 350x_{17} + 394x_{18} & \leq 2861
\end{align*}\]

\[\begin{align*}
x_1 & \leq 1 \\
x_2 & \leq 2 \\
x_3 & \leq 4 \\
x_4 & \leq 2 \\
x_5 & \leq 3 \\
x_6 & \leq 1 \\
x_7 & \leq 2 \\
x_8 & \leq 3 \\
x_9 & \leq 1 \\
x_{10} & \leq 1 \\
x_{11} & \leq 1 \\
x_{12} & \leq 1 \\
x_{13} & \leq 3 \\
x_{14} & \leq 2 \\
x_{15} & \leq 1 \\
x_{16} & \leq 1 \\
x_{17} & \leq 1 \\
x_{18} & \leq 1 \\
x_{19} & \geq 0
\end{align*}\]

Where

- \(x_1\) = Classroom type 1 with seating capacity of 36
- \(x_2\) = Classroom type 2 with seating capacity of 38
- \(x_3\) = Classroom type 3 with seating capacity of 40
- \(x_4\) = Classroom type 4 with seating capacity of 84
- \(x_5\) = Classroom type 5 with seating capacity of 45
- \(x_6\) = Classroom type 6 with seating capacity of 192
- \(x_7\) = Classroom type 7 with seating capacity of 110
- \(x_8\) = Classroom type 8 with seating capacity of 180
- \(x_9\) = Classroom type 9 with seating capacity of 70
- \(x_{10}\) = Classroom type 10 with seating capacity of 114
- \(x_{11}\) = Classroom type 11 with seating capacity of 273
- \(x_{12}\) = Classroom type 12 with seating capacity of 92
- \(x_{13}\) = Classroom type 13 with seating capacity of 96
- \(x_{14}\) = Classroom type 12 with seating capacity of 294
- \(x_{15}\) = Classroom type 15 with seating capacity of 200

http://www.iaeme.com/IJMET/index.asp 880  editor@iaeme.com
3.2. Develop AMPL Software Programme

# 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;

# PART 2: OBJECTIVE FUNCTION

maximize P: 36*x1 + 38*x2 + 40*x3 + 84*x4 + 45*x5 + 192*x6 + 110*x7 + 180*x8 + 70*x9 + 144*x10 + 273*x11 + 92*x12 + 96*x13 + 294*x14 + 200*x15 + 104*x16 + 119*x17 + 350*x18 + 394*x19; # Capacity of each class type

# PART 3: CONSTRAINTS

s.t. M1: 15*x1 + 9*x2 + 10*x3 + 5*x4 + 2*x5 + 114*x6 + 68*x7 + 12*x8 + 86*x9 + 30*x10 + 97*x11 + 86*x12 + 8*x13 + 61*x14 + 21*x15 + 45*x16 + 31*x17 + 5*x18 + 76*x19 <= 2861; # Total of students in 100level
s.t. M2: 12*x1 + 7*x2 + 14*x3 + 8*x4 + 4*x5 + 52*x6 + 66*x7 + 9*x8 + 45*x9 + 30*x10 + 72*x11 + 57*x12 + 23*x13 + 69*x14 + 27*x15 + 33*x16 + 23*x17 + 8*x18 + 52*x19 <= 2861; # Total of students in 200level
s.t. M3: 18*x1 + 5*x2 + 6*x3 + 5*x4 + 3*x5 + 36*x6 + 54*x7 + 17*x8 + 46*x9 + 20*x10 + 48*x11 + 58*x12 + 14*x13 + 52*x14 + 30*x15 + 22*x16 + 18*x17 + 6*x18 + 60*x19 <= 2861; # Total of students in 300level
s.t. M4: 4*x1 + 4*x2 + 4*x3 + 7*x4 + 2*x5 + 25*x6 + 39*x7 + 18*x8 + 47*x9 + 25*x10 + 36*x11 + 65*x12 + 12*x13 + 37*x14 + 27*x15 + 32*x16 + 14*x17 + 14*x18 + 37*x19 <= 2861; # Total of students in 400level
Application of Optimization Principles in Classroom Allocation Using Linear Programming

\[ s.t. \ M5: \ 7*x1 + 4*x2 + 4*x3 + 2*x4 + 2*x5 + 27*x9 + 28*x10 + 35*x11 + 50*x12 + 8*x13 <= 2861; \ # \ Total \ of \ students \ in \ 500level \]

\[ s.t. \ M6: \ x1 + x2 + x3 + 2*x4 + x5 + 4*x6 + 2*x7 + 3*x8 + x9 + 2*x10 + 3*x11 + x12 + x13 + 3*x14 + 2*x15 + x16 + x17 + x18 + x19 <= 32; \ # \ No \ of \ available \ classrooms \]

\[ s.t. \ M7: \ x1 + x2 + x3 + x4 + x5 + x6 + x7 + x8 + x9 + x10 + x11 + x12 + x13 + x14 + x15 + x16 + x17 + x18 + x19 >= 0; \]

\[ s.t. \ M8: \ x1 <= 1; \]
\[ s.t. \ M9: \ x2 <= 1; \]
\[ s.t. \ M10: \ x3 <= 1; \]
\[ s.t. \ M11: \ x4 <= 2; \]
\[ s.t. \ M12: \ x5 <= 1; \]
\[ s.t. \ M13: \ x6 <= 4; \]
\[ s.t. \ M14: \ x7 <= 2; \]
\[ s.t. \ M15: \ x8 <= 3; \]
\[ s.t. \ M16: \ x9 <= 1; \]
\[ s.t. \ M17: \ x10 <= 2; \]
\[ s.t. \ M18: \ x11 <= 3; \]
\[ s.t. \ M19: \ x12 <= 1; \]
\[ s.t. \ M20: \ x13 <= 1; \]
\[ s.t. \ M21: \ x14 <= 3; \]
\[ s.t. \ M22: \ x15 <= 2; \]
\[ s.t. \ M23: \ x16 <= 1; \]
\[ s.t. \ M24: \ x17 <= 1; \]
\[ s.t. \ M25: \ x18 <= 1; \]
\[ s.t. \ M26: \ x19 <= 1; \]

The part that was run for results is (example1.run);

```
reset;
model example1.mod;
solve;
display x1, x2, x3, x4, x5, x6, x7, x8, x9, x10, x11, x12, x13, x14, x15, x16, x17, x18, x19, P;
```

3.3. The AMPL Software Results

```
ampl: include example1.run
MINOS 5.51: optimal solution found.
10 iterations, objective 3544
```

\[ x1 = 0 \]
\[ x2 = 0 \]
\[ x3 = 0 \]
\[ x4 = 0 \]
\[ x5 = 0 \]
\[ x_6 = 0 \]
\[ x_7 = 0 \]
\[ x_8 = 0 \]
\[ x_9 = 0 \]
\[ x_{10} = 2 \]
\[ x_{11} = 3 \]
\[ x_{12} = 1 \]
\[ x_{13} = 1 \]
\[ x_{14} = 3 \]
\[ x_{15} = 2 \]
\[ x_{16} = 1 \]
\[ x_{17} = 1 \]
\[ x_{18} = 1 \]
\[ x_{19} = 1 \]

\[ P = 3544 \]
That implies

\[ P_{\text{max}} = 3544 \]

4. ANALYSES OF RESULTS
Analysis of the result generated from the AMPL software is presented in the table 3 below. The table shows the classes that are being utilized and those not being utilized currently as indicated in the AMPL software.

<table>
<thead>
<tr>
<th>Classroom Type</th>
<th>Seating Capacity</th>
<th>Available classrooms</th>
<th>No of classes utilized</th>
</tr>
</thead>
<tbody>
<tr>
<td>A01</td>
<td>92</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>A02</td>
<td>36</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>A13</td>
<td>38</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>A12</td>
<td>40</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>A22, A23</td>
<td>42</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>A03</td>
<td>45</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>B12, B13, B22, B23</td>
<td>48</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>B02, B03</td>
<td>55</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>C02, C12, C13</td>
<td>60</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>C14</td>
<td>70</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>A11, A14</td>
<td>72</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>B04, B14, B24</td>
<td>91</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>A315</td>
<td>96</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>A04, A21, A24</td>
<td>98</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>B01, A215</td>
<td>100</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>A316</td>
<td>104</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>B21</td>
<td>119</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>LT2 Grd Flr</td>
<td>350</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>LT2 First Flr</td>
<td>394</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2861</strong></td>
<td><strong>32</strong></td>
<td><strong>16</strong></td>
</tr>
</tbody>
</table>
From the results of the AMPL software, it is observed that 16 out of 32 classrooms available with a seating capacity of 2066 had been used to accommodate the current student population of 2522 students and this always causes overflow and congestion in the classroom because the remaining 16 classroom of the seating capacity of 805 were underutilized and were not always taken notice of as tabulated as fully utilized classroom and unused classroom in the table 5 and table 6 below respectively.

Meanwhile the projected seating capacity of 3544 as given by the AMPL software if all the 32 classroom were fully utilized and this indicated that an additional 1022 students can be fully absorbed comfortably with the existing 32 classrooms in all of the three (3) colleges if the seating capacity is fully utilized and maximized and this will help the school to generate additional (1022 × 573,000) = N 585,606,000.00 as school fees using the same classroom facility and as well as the existing seating capacity.

Table 4 shows the fully utilized classroom with its seating capacity

<table>
<thead>
<tr>
<th>Classroom Type</th>
<th>Available classroom</th>
<th>Seating Capacity</th>
<th>No of classes utilized</th>
<th>Total No of seating capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>A01</td>
<td>1</td>
<td>92</td>
<td>1</td>
<td>92</td>
</tr>
<tr>
<td>A11, A14</td>
<td>2</td>
<td>72</td>
<td>2</td>
<td>144</td>
</tr>
<tr>
<td>B04, B14, B24</td>
<td>3</td>
<td>91</td>
<td>3</td>
<td>273</td>
</tr>
<tr>
<td>A315</td>
<td>1</td>
<td>96</td>
<td>1</td>
<td>96</td>
</tr>
<tr>
<td>A04, A21, A24</td>
<td>3</td>
<td>98</td>
<td>3</td>
<td>294</td>
</tr>
<tr>
<td>B01, A215</td>
<td>2</td>
<td>100</td>
<td>2</td>
<td>200</td>
</tr>
<tr>
<td>A316</td>
<td>1</td>
<td>104</td>
<td>1</td>
<td>104</td>
</tr>
<tr>
<td>B21</td>
<td>1</td>
<td>119</td>
<td>1</td>
<td>119</td>
</tr>
<tr>
<td>LT2 Grd. Floor</td>
<td>1</td>
<td>350</td>
<td>1</td>
<td>350</td>
</tr>
<tr>
<td>LT1 First Floor</td>
<td>1</td>
<td>394</td>
<td>1</td>
<td>394</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>16</strong></td>
<td><strong>2066</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5 shows not utilized classroom with its seating capacity

<table>
<thead>
<tr>
<th>Classroom Type</th>
<th>Available classroom</th>
<th>Seating Capacity</th>
<th>No of classes not utilized</th>
<th>Total No of seating capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>A02</td>
<td>1</td>
<td>36</td>
<td>0</td>
<td>36</td>
</tr>
<tr>
<td>A13</td>
<td>1</td>
<td>38</td>
<td>0</td>
<td>38</td>
</tr>
<tr>
<td>A12</td>
<td>1</td>
<td>40</td>
<td>0</td>
<td>40</td>
</tr>
<tr>
<td>A22, A23</td>
<td>2</td>
<td>42</td>
<td>0</td>
<td>94</td>
</tr>
<tr>
<td>A03</td>
<td>1</td>
<td>45</td>
<td>0</td>
<td>45</td>
</tr>
<tr>
<td>B12, B13, B22, B23</td>
<td>4</td>
<td>48</td>
<td>0</td>
<td>192</td>
</tr>
<tr>
<td>B02, B03</td>
<td>2</td>
<td>55</td>
<td>0</td>
<td>110</td>
</tr>
<tr>
<td>C02, C12, C13</td>
<td>3</td>
<td>60</td>
<td>0</td>
<td>180</td>
</tr>
<tr>
<td>C14</td>
<td>1</td>
<td>70</td>
<td>0</td>
<td>70</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>16</strong></td>
<td><strong>805</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5. CONCLUSION
In this paper, we have fully determine the total number of seating capacity in each of the available classroom in Landmark University and proposed appropriate solution to the classroom allocation problem using linear programming by maximizing the existing 32 classroom available to accommodate about 3544 additional students using the same and existing classroom capacity and
this probably will earn the school management an additional $585,606,000.00 (1022 \times 573,000) as school fees using the same classroom facility and as well as the existing seating capacity.

REFERENCES


