Journal of Economics and Sustainable Development www.iiste.org
ISSN 2222-1700 (Paper) ISSN 2222-2855 (Online)
Vol.6, No.2, 2015

Allocation of Classroom Space Using Linear Programming (A Case Study: Premier Nurses Training College, Kumasi)

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Abstract
The use of linear programming to solve the problem of over-allocation and under-allocation of the scarce classroom space was considered with particular reference to the Premier Nurse's Training College, Kumasi. Data was collected from the College on the classroom facilities and the number of students per programme. A linear programming model was formulated based on the data collected to maximize the usage of the limited classroom space. POM-QM for Windows 4 (Software for Quantitative Methods, Production and Operation Management by *Howard J. Weiss*) was used based on the simplex algorithm to obtain optimal solution.Analysis of the results showed that six (50%) of the twelve classrooms could be used to create a maximum classroom space of six hundred and forty. It was also observed that the management could use two hundred and eighty (280) surplus spaces to increase its student's intake from three hundred and sixty (360) to six hundred and forty (640) students, an increase of about 77.78% with only 50% of the total number of classrooms. Again management could cut down the number of classrooms used from twelve to six and reduce the cost of maintaining the classrooms by 50% and still have as many as six extra classrooms for other equally important purposes, hence maximize its profit margin.
Keywords: Linear programming, Allocation, Optimal solution, Simplex Algorithm, Premier Nurse's Training College.

Introduction

The problem of allocation of scarce resource to satisfy unlimited human needs has been and continuous to be a global phenomenon confronting managers, administrators, entrepreneurs, heads of institutions and individuals alike.

Space allocation can be defined as the allocation of resources to areas of space such as rooms, satisfying as many requirements and constraints as possible. D. B. Varley (1998) defines space allocation as a process of allocating rooms or areas of space for specific functionality. Thus, since it is limited it must in well manage by the faculties towards availability and suitable with the user required.

In this study, Classroom Space Allocation refers to the distribution of the available areas of classroom space among a number of courses with different sizes of student population so as to ensure the optimal space utilization and the satisfaction of additional requirements and/or constraints. In this generic case, an important condition exists: the areas of space that can be used and the space required by the entities are not subject to modification. The ideal solution in the space allocation problem is one where all the entities are allocated, no space is wasted or overused and every additional requirements and constraints have been satisfied.

Gosselin and Truchon (1986) presented a procedure for allocating classrooms in an educational institution. It 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 real rooms to the requests as possible. It also seeks to do so with the most preferred rooms. Finally, when it is necessary to depart from the most preferred rooms to satisfy the first objective, the model attempts to spread this departure uniformly among requests. By altering the default values in the penalty function, the user may also favor some requests in the attribution of rooms. Constraints are concerned with the availability of rooms at various hours of the day, and with the requests for these rooms. They stated emphatically that since this approach implicitly explores all possible assignments, it should produce better results than manual allocation. Results of empirical applications confirmed these expectations, taking the number of demands that can be met as the main criterion. Moreover, an automated procedure to prepare the problem and decode its solution has made it possible to decrease substantially the time spent on this task.

In accordance with the mission of the Premier Nurses Training College (P.T.C), classroom resources are primarily for use by students, and staff for educational activities and programs that are directly related to the functions of teaching, research, and scholarly production. Every effort is always made by the College to ensure that classrooms are assigned fairly, used appropriately, and accommodate the College's academic and instructional needs.

According to Bougie P. (2012), 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.

Oladokun and Badmus (2008) studied about assigning a number of courses to classrooms taking into consideration constraints like classroom capacities.

Asharm (2009) 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. Linear programming deals with optimization problems where both the objective function to be optimized and all constrains are linear in terms of decision variables.

An optimization problem, the objective is to minimize a linear cost function. With this objective, it is possible to consider the satisfaction of expressed preferences regarding teaching periods or days of the week or even classrooms for specified courses.

According to Wikimedia Foundation Inc. (2009), linear programming (LP) is a technique for optimization of a linear objective function, subject to linear equality and linear inequality constraints. Informally, linear programming determines the way to achieve the best outcome (such as maximum profit or lowest cost) in a given mathematical model and given some list of requirements represented as linear equations.

The objectives of undertaking this study on "allocation of classroom space by linear programming" at the Premier Nurse's Training College are to find out how classroom space is allocated to the students of the College based on the various programmes and courses offered by the students and to develop a linear programming model to allocate classroom space to the students in the College based on the various programmes and courses offered by the students to ensure optimal use of the classrooms available to the College.

Methodology

The data needed for the study was collected from the Premier Nurses' Training College (P.N.T.C) Kumasi. A questionnaire was designed to elicit for the required data from the management of the college on the number of classrooms the college has and the capacities of each of the classrooms. Also information was sort for on the number of programmes the college offers and the number of students enrolled on each of the programmes. Table 1 depicts the information on classroom facilities. Table 2 also shows the number of students per programme.

The students were assigned to the eight hundred and sixty (860) classroom spaces that were available in the twelve classrooms of different sizes. At the beginning of each academic year new students are admitted into the college and as a result the college must plan how to allocate these new students and the continuing students to the available classrooms so as to avoid over-allocation and under-allocation of the limited classrooms.

Within a period, the number of times classroom type 1 could be assigned cannot exceed four, classroom type 2 cannot be assigned more than three times, classroom type 3 cannot be assigned more than two times, classroom type 4 cannot be assigned more than two and the room type 5 cannot be allocated more than once.

We therefore formulate the linear programming problem based on the above information to maximize the usage of the limited classroom space.

Modeling technique

The classroom space allocation problem can be considered as a linear programming problem. The classroom space was categorized into types according to the number of seats, and the type of equipments available. The students were put into groups termed as the classes based on the programme and the level of the students.

Let the capacity of each category (type) of a classroom be $C_i = C_1, C_2, C_3 \ldots C_n$ for i =1, 2, 3…n where

C_1= the capacity of a room of type1

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 five, etc.

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 . . . . 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 of C_2

x_3 = classroom type 3 with a seating capacity of C_3

x_4 = classroom type 4 with a seating capacity of C_4

x_5 = classroom type 5 with a seating capacity of C_5

Again, 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
a_3 = number of rooms of classrooms type 3 in that order.
Also let the total available classroom space of all the types of classrooms denoted by **d**. $\boldsymbol{d = \sum_{i=1}^{n} a_i c_i}$

The general formulation of the allocation problem is as follows:
The objective function is
Maximize $\sum_{i=1}^{n} C_i X_i$
Subject to the constraints;
$\sum_{i=1}^{n} a_i x_i \leq d$ (i = 1, 2, 3….n)
Since the total number of students that could be assigned to a number of categories of the rooms cannot exceed the total classroom space available in each of the classrooms.
Again $x_i \geq 0$ for (i = 1, 2, 3…) since a number of students to be assigned to a room cannot be a negative number.
The objective function was set up as;
Maximize $z = 30x_1 + 50x_2 + 100x_3 + 120x_4 + 150x_5$
Subject to the constraints;
$4x_1 + 3x_2 + 2x_3 + 2x_4 + x_5 \leq 12$
$30x_1 + 50x_2 + 100x_3 + 120x_4 + 150x_5 \leq 860$
$x_1 \leq 4, x_2 \leq 3, x_3 \leq 2, x_4 \leq 2, x_5 \leq 1$
$x_1, x_2, x_3, x_4, x_5 \geq 0$
Where: x_1 = classroom type 1 with a seating capacity of 30
x_2 = classroom type 2 with a seating capacity of 50
x_3 = classroom type 3 with a seating capacity of 100
x_4 = classroom type 4 with a seating capacity of 120
x_5 = classroom type 5 with a seating capacity of 150
POM-QM for Windows 4 (Software for Quantitative Methods, Production and Operation Management by *Howard J. Weiss*) was used based on the simplex algorithm to obtain optimal solution.

Results
The classroom allocation problem formulated above was transferred onto the POM-QM for Windows 4 for windows model by first selecting the linear programming option from the module, create data set was then used to select the number of variables (five variables) and the number of constraints(eight constraints) as displayed in Table 3. Solve problem icon was then used to display the problem results including linear programming results, ranging, solution list, as well as the iterations.

Tables 4 and 5 represent the results of the eighth iteration (the final tableau) which shows the optimal solution of the problem and the linear programming results of the problem respectively.

In Table 4, x_1, x_2, x_3, x_4, and x_5, represent room type 1, type 2, type 3, type 4, and type 5 respectively, whiles, slack 1, slack 2, slack 3, slack 4, slack 5, slack 6, slack 7, slack 8, artificial 3, and surplus 3, that were used to convert the inequality constraints to the standard form, are respectively represented by; s_1, s_2, s_3, s_4, s_5, s_6, s_7, s_8, A_3, and spl_3.

Discussion
Gosselin and Truchon (1986) presented a procedure for allocating classrooms in an educational institution. It was based on a linear programming model in which a penalty function is minimized. According to Bougie P. (2012), a better way to consistently and effectively allocate classrooms is to use a computer-assisted system that will keep track of all classrooms; the efficiency will be judged based on many factors, most importantly being that the size of each room is used effectively. Again, Asharm (2009) stated that linear programming is the Mathematical programming that solves the problem of determining the optimal allocation of limited resources required to meet a given objective. An optimization problem, the objective is to minimize a linear cost function. With this objective, it is possible to consider the satisfaction of expressed preferences regarding teaching periods or days of the week or even classrooms for specified courses.

Analysis of results generated from the POM- QM for Windows 4 is presented; the problem went through eight iterations before an optimal solution was found. Whiles none of the four classrooms of type 1 with the seating capacities of thirty (30) each was allocated to a class, one of the three classrooms of type 2 with the capacities of fifty (50) each, all the two classrooms of type 3 with the capacities of hundred each, all the two rooms of type 4 with the capacities of one hundred and twenty each, and the one classroom of type5 with the capacity of one hundred and fifty seats were allocated to the Students.

We observed that six(6) out of the twelve(12) classrooms were used to provide a seating capacity of six hundred and forty (640) to accommodate the student population of three hundred and sixty students. The maximum classroom space (optimal solution) of six hundred and forty was thus obtained by:

(0*30) + (1*50) + (2*100) + (2*120) + (1*150) = 640

It was realized that six out of the twelve classrooms available representing 50% of the classrooms were utilized to provide a space of six hundred and forty for the three hundred and sixty students leaving a surplus of two hundred and eighty spaces which could be assigned to two hundred and eighty additional students.

There were four (4) classrooms of type 1 with the seating capacities of thirty (30) each and two (2) classrooms of type 2 with the capacities of fifty (50) each which were not assigned to students. There were a total of two hundred and twenty available classroom spaces that were not assigned to students thus (4*30) + (2*50) = 220

The implication of our findings is that the management of the College could use the two hundred and eighty (280) surplus spaces to increase its student's intake from three hundred and sixty to six hundred and forty students (about 77.78%). Again management could cut down the number of classrooms used from twelve to six and reduce the cost of maintaining the classrooms by 50% and still have as many as six extra classrooms for other equally important purposes, hence maximize its profit margin.

Conclusion

The problem of allocation of scarce resource to satisfy unlimited human needs has been and continuous to be a global phenomenon confronting managers, administrators, entrepreneurs, heads of institutions and individuals alike. The use of linear programming to solve the problem of over-allocation and under-allocation of the scarce classroom space was considered with particular reference to the Premier Nurse's Training College. Data was collected from the College on the classroom facilities and the number of students per programme.

A linear programming model was formulated based on the data collected to maximize the usage of the limited classroom space using POM-Q M model for windows based on the simplex algorithm.

Analysis of the results showed that six (50%) of the twelve classrooms could be used to create a maximum classroom space of six hundred and forty. It was also observed that the management could use the two hundred and eighty (280) surplus spaces to increase its student's intake from three hundred and sixty (360) to six hundred and forty (640) students, an increase of about 77.78% with only 50% of the total number of classrooms.

It is evidently clear from the above summary that linear programming is an effective tool that can be utilized by managers of Educational Institutions to avoid over-allocation and under- allocation of scarce resources, particularly classroom space.

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Journal of Economics and Sustainable Development www.iiste.org
ISSN 2222-1700 (Paper) ISSN 2222-2855 (Online)
Vol.6, No.2, 2015

Table 1. Data on classroom facilities

Types of classroom (T_i)	Seating capacity (C_i)	Number of classrooms available (a_i)
T_1	30	4
T_2	50	3
T_3	100	2
T_4	120	2
T_5	150	1

Table 2 . Number of students per programme

	Programme	Level	Number of students
1.	Registered	100	20
	General Nurse	200	40
		300	60
2.	Health		110
	Attendant	100	130
	Clinical	200	

Source: Premier Nurses Training College, Kumasi.

Table 3 The initial tableau for the classroom problem on the QM for windows

	X1	X2	X3	X4	X5		RHS
		Maximize	30	50	100	120	150
Constraint 1	20	40	60	110	130	<=	860
Constraint 2	4	3	2	2	1	<=	12
Constraint 3	1	1	1	1	1	>=	0
Constraint 4	1	0	0	0	0	<=	4
Constraint 5	0	1	0	0	0	<=	3
Constraint 6	0	0	1	0	0	<=	2
Constraint 7	0	0	0	1	0	<=	2
Constraint 8	0	0	0	0	1	<=	1

Table 4. The optimal solution (iteration8) of the classroom allocation problem

	C_j	30	50	100	120	150	0	0	0	0	0	0	0	0	0	
C_B	Basic vari-able	x_1	x_2	x_3	x_4	x_5	s_1	s_2	A_3	surpls3	s_4	s_5	s_6	s_7	s_8	Qnty
0	s_1	-33.33	0	0	0	0	1	-13.33	0	0	0	0	-33.33	-83.33	116.67	350
50	x_2	1.33	1	0	0	0	0	0.33	0	0	0	0	-0.67	-0.67	-0.33	1
150	x_5	0	0	1	0	1	0	0	0	0	0	0	0	0	1	1
0	s_4	1	0	0	0	0	0	0	0	0	1	0	0	0	0	4
0	s_5	-3.33	0	0	0	0	0	-0.33	0	0	0	1	0.67	0.67	0.33	2
100	x_3	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2
120	x_4	0	0	0	1	0	0	0	0	0	0	0	0	1	0	2
0	spl3	0.33	0	0	0	0	0	0.33	-1	1	0	0	0.33	0.33	0.67	6
	Z_j	66.67	50	100	120	150	0	16.67	0	0	0	0	66.67	86.67	133.33	640
	Cj-Zj	-36.67	0	0	0	0	0	-16.67	0	0	0	0	-66.67	-86.67	-133.33	

Table 5 the linear programming results

	X1	X2	X3	X4	X5		RHS	Dual
Maximize	30	50	100	120	150			
Constraint 1	20	40	60	110	130	<=	860	0
Constraint 2	4	3	2	2	1	<=	12	1.66667
Constraint 3	1	1	1	1	1	>=	0	0
Constraint 4	1	0	0	0	0	<=	4	0
Constraint 5	0	1	0	0	0	<=	3	0
Constraint 6	0	0	1	0	0	<=	2	66.6666
Constraint 7	0	0	0	1	0	<=	2	86.66666
Constraint 8	0	0	0	0	1	<=	1	133.3333
Solution	0	1	2	2	1		640	

APPENDIX

QUESTIONNAIRES

The purpose of this study is to develop a linear programming model to be used to allocate classroom space to the various student groups in the best possible way.

You are kindly requested to complete this questionnaire as frankly as possible; your response will be kept confidential and shall be used only for this thesis.

1) What programmes do you offer in the college?
2) What is the duration for each of the programmes you offer?
3) How many students were enrolled for each of the programmes?
4) How many classrooms (lecture halls) are available to the College?
5) What are the seating capacities of each of the rooms?

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