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Assignment problem and its application in Nigerian institutions: Hungarian method approach

O. Solaja*, J. Abiodun, J. Ekpudu, M. Abioro, O. Akinbola

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Abstract Assignment model is a powerful operations research techniques that can be used to solve assignment or allocation problem. This study applies the assignment model to the course allocation problem in Nigeria tertiary institution in order to maximize lecturers' effectiveness. A well-structured questionnaire was used to obtain data from lecturers and solved with Hungarian method. The study revealed that adoption of the assignment model in course allocation will help the institution to experience 13.20% increment in lecturers' effectiveness in taking each topic in analysis for business decision. This will lead to increase in the quality of education students get. The study concluded that assignment model is a unique model that can be used to solve course allocation problems in tertiary institutions. The study then recommends that institutions should endeavor to adopt the assignment model in course allocation for optimal benefit and to improve the quality of education in the country.

Keyword: Allocation, Hungarian, Assignment, Education, Lecturers.

1 Introduction

It is generally believed that no country can achieve sustainable development without paying attention to the intellectual capacity of its citizens. Education is the bedrock of nation's economic, political, technology, and scientific development. Education is expected to increase individual knowledge, improve social and economic life which translates to national development. It is a powerful weapon that can be deployed to fight poverty, increase the standard of living and bring everyone in the country from darkness to light. National

* **Corresponding Author. (✉)**
E-mail: Oluwasegunsolaja@gmail.com (O. Solaja)

O. Solaja
Department of Business Administration, College of Management Sciences, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria

J. Abiodun
Department of Business Administration, College of Management Sciences, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria

J. Ekpudu
Department of Business Administration, College of Management Sciences, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria

M. Abioro
Department of Business Administration, College of Management Sciences, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria

O. Akinbola
Department of Business Administration, College of Management Sciences, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria

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development starts from the individual; that is, national development is a function of individual development in the country, meanwhile individual development is the level of education individual gets.

In Nigeria, the education system is 6-3-3-4, starting from primary school in which individual is expected to spend 6 years getting elementary knowledge after which they move to Junior secondary school to spend 3 years and another 3 years in Senior Secondary school. The final stage is higher institution where an individual is expected to spend a minimum of 4 year or more depending on the demand of the course of study. At this stage, individual in higher institutions is expected to be trained by experts called lecturers in their course of study. These experts impact their students with their knowledge in order to increase their intellectual capacity. Fenster [1] opined that the level of these professionals' effectiveness affects the quality of education students get into the institution. Omo [2] on the other hand, argues that the impact of these professionals called lecturers on students is indisputable in the society.

It is the responsibility of the head of department or course coordinator to assign courses to lecturers based on their expertise and their level of effectiveness at the beginning of each semester or academic session. Most of these head of departments or course coordinators are not aware that assignment model which is a special tool of operations research has the capacity to help them to determine the optimal assignment that will maximize lecturer's effectiveness and minimize lecture preparation time. Rather, they make a decision on the allocation of lectures to courses based on their intuition, lecturers' experiences and their own understanding of lecturers' capacity with no regards to scientific techniques of job assignment. Although different researchers have applied the assignment model to different assignment problems in education sector [3, 6, 7, 8, 9] but there are a limited number of studies that demonstrate the relevance of the assignment model in educational institutions in Nigeria. As at the time of this study, only one of these studies [3] was found in Nigeria. Kabiru et al. [3] applied assignment model to allocate teachers to subjects in Nigeria but the considered case seems not realistic because it is impossible for a teacher to be able to teach all subjects in a school including those that are outside the field of such teacher. Generalization of studies like this might not be reliable for assignment purpose in educational institutions in Nigeria.

The present study set to demonstrate the usefulness of assignment model techniques in allocating lecturers to course in educational institution in Nigeria, maximize effectiveness in course allocation and determine optimal course allocation.

2 Literature review

2.1 Concept of assignment model

The assignment problem arises as a result of different decision making situations relating to job or task assignment in our day-to-day activities. Assignment model is a special class of the linear programming which has to do with allocation of jobs to machines, personnel to location. Basically, assignment model has two objectives either to minimize or maximize. In assignment model, all tasks to be performed must be assigned on one-on-one basis, two tasks or jobs cannot be assigned to a machine or personnel.

Sigh et al. [13] believe that assignment problem is one of the combinatorial optimization problems in mathematics that is fundamental. Sigh et al. [13] also viewed the assignment

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model as a technique that answer the question how we can assign n number of objects to m number of objects in the best possible way.
Kabiru et al. [3] posited that assignment problem plays a significant role in solving real life problems and it is acceptable and well utilized tool around the world. Srinivas and Ganesan [4] believe assignment problem is a management science tool that can be deployed to achieve optimization in both manufacturing and service system. Assignment problem is a technique in operations research that can be used to derive the optimization, it has capacity to minimize and maximize depending on the objective of the model. According to [14], the major objective of assignment problem is minimization of cost, time, space and maximization of profit, effectiveness, efficiency and others. It can be used in allocating jobs to machine, operators to machine, sales-personnel to territories, workers to supervisor, courses to lectures, engineers to construction sites among other with focus to minimize or maximize.
Assignment model is a class of linear programming that is similar to the transportation problem; it assumes that a job can only be assigned to one man or one machine in order to determine optimality.

2.2 Empirical framework

Kabiru et al. [3] utilized assignment model in assigning teachers to science subjects in Nigeria. The model was solved with the help of Hungarian method and LINGO. Optimal solution was discovered in the two techniques used. However, the two techniques produced the same result.
Idris and Hussein [5] applied assignment model to Alhram Plaza Centre in Saudi Arabia who specializes in the sales of clothes. Optimality was discovered in the allocation of workers to a different section in the store.
Frimpong and Owusu [6] used linear programming to solve under allocation and over allocation of classroom in Premier Nurse's Training College, Kumasi. Optimal solution was determined when solved with the help of POM-QM for Windows 4.
Thongsanit [7] developed a mathematical model to solve course – classroom assignment problem in Faculty of Engineering and Industrial Technology at Silpakorn University in the First Semester, 2012. Excel's Premium Solver was employed to solve the model in order to reduce classroom cost. Optimal solution was determined and total cost of classroom was reduced.
Simon [8] used assignment problem to solve staff-subject allocation with the aim of maximizing quality of knowledge teachers' impact to students' lives. Optimal solution was obtained at the end of the analysis.
Xian-Ying [9] employed assignment model in solving teachers' allocation problem in order to minimum time to be spent in preparing for lecturers. Four teachers who are capable of taking four different courses were selected for the study. Optimum solution was discovered with the help of the Hungarian method employed to solve the assignment problem.

3 Model building

Assignment model is a branch of linear programming that requires n persons to perform m tasks/course
Where;

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n = Number of persons to take (teach) the task/course
m = Number of tasks/course to perform (teach)
C = Lecturer's effectiveness
i= Row number representing task/course
j = Column number representing lecturers
X = 1 if task/course is assigned to a lecturer, 0 if not assigned
Cij = Lecturer i effectiveness taking course j
Xij = 1 if Lecturer i will be taking course j
(0 if Lecturer i will not be taking course j)
Z = Objective Function (Maximize)
$Z = C_{11}X_{11} + C_{12}X_{12}$
The problem can be formulated in this canonical form

$$Z = \sum_{j=1}^{n}\sum_{i=1}^{m} C_{ij}X_{ij}$$

$$s.t. \sum_{i=1}^{m} X_{ij} = 1,\ j = 1,...,n,\ \left(A\ lecturer\ take\ a\ course\right),$$

$$\sum_{j=1}^{n} X_{ij} = 1,\ i = 1,...,m,\left(A\ course\ must\ be\ taken\ by\ a\ lecturer\right),$$

$$X_{ij} = 1\ or\ 0, \left(1\ =\ Course\ assigned;\ 0\ =\ Course\ not\ assigned\right).$$

3.1 Techniques for solving assignment model

Hungarian method is one of the widely used techniques for solving assignment model. In 1955, Kuhn [10] developed a method called Hungarian method, he combined the idea of [11] and [12] that can be used to solve assignment model. Hungarian method can be deployed to solve the assignment problem by taking the following steps
Step 1: Formulate the problem in a square matrix form (Introduce dummy row or column if the problem is no balanced to make it balance and form square matrix, the cost of the dummy row/column is zero (0))
Step 2: Convert the problem to a minimization problem in case of maximization problem by subtracting the maximum entry in the matrix from all the entries in the matrix. In case of minimization problem, move to step 3
Step 3: Perform row reduction by subtracting the smallest entry in each row from all the entries in that same row.
Step 4: Perform column reduction by subtracting the smallest entry in each column from all the entries in that same row.
Step 5: Inspect each row in the new matrix table to identify a row with a zero, (leave any row with more than a zero and move to the next row) once, exactly one zero is found, make a small square box around that entry with zero and draw a straight line to cover all other entries in the column and repeat this for all the rows
Step 6: Inspect each column in the new matrix table to identify a column with a zero, (leave any column with more than a zero and move to the next column) once, exactly one zero is found, make a small square box around that entry with zero and draw a straight line to cover all other entries in the row and repeat this for all the columns.

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Step 7: Count the number of small square you have in the matrix, if it is equal to the number of rows I the matrix, then the result is optimal if not, revise the table by moving to the next step. (Optimal Solution = Total number of square boxes equate number of rows in the matrix)
Step 8: Look for the minimum uncovered number in the matrix and subtract it from all uncovered entries in the matrix and add it to the entries in the matrix covered by two lines (Intersection of two lines). All other entries in the matrix remain unchanged
Step 9: Repeat step 5 – 7 until the optimal solution is derived.
Step 10: Allocate Course/Job/Task

4 Materials and methods

Data used for the study was obtained from four lecturers in the case school with the help of a well-structured questionnaire administered to the lecturers. Courses available for final year students are derived from the 2018/2019 university first semester timetable. Out of six (6) courses that students are to be taken in the semester, four (4) are core courses that are mandatory for students in the department while other two (2) courses are elective. The study focused on one (1) of the four (4) core courses that are available for students during the semester. A well-structured questionnaire was administered to four (4) lecturers who are Ph.D. holder in the department. All of them are specialized in operations research and have capacity required to take any of the four (4) topics that are embedded in analysis for business decision. Each lecturer is to rate himself on a 100% scale on their level of effectiveness in taking any of the four (4) topic in analysis for business decision.

5 Data presentation and analyses

Table 1 Lecturers' effectiveness rating

Course Title	Course Code	Rating (100%)
DR. JOACHIM		
Linear Programming Techniques	Topic 1	80
Marcov Chain Analysis	Topic 2	90
Transportation Model	Topic 3	85
Simulation	Topic 4	92
DR. JONATHAN		
Linear Programming Techniques	Topic 1	65
Marcov Chain Analysis	Topic 2	85
Transportation Model	Topic 3	75
Simulation	Topic 4	88
DR. MATTHEW		
Linear Programming Techniques	Topic 1	92
Marcov Chain Analysis	Topic 2	95
Transportation Model	Topic 3	96
Simulation	Topic 4	75
DR. AMOS		
Linear Programming Techniques	Topic 1	100
Marcov Chain Analysis	Topic 2	95
Transportation Model	Topic 3	95
Simulation	Topic 4	60

Source: Authors, 2019

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Entries in Table 1 show lecturers'self-rating on a 100% Scale. Entries in the first column are the topic title to be allocated; the second column is the segmentation of the topics.
Dr. Joachim rated himself 80% in taking Linear Programming Techniques (Topic 1), 90% in taking Marcov Chain Analysis (Topic 2), 85% in Transportation Model (Topic 3) and 92% in taking Simulation (Topic 4).
Dr. Jonathan rated himself 65% in taking Linear Programming Techniques (Topic 1), 85% in taking Marcov Chain Analysis (Topic 2), 75% in Transportation Model (Topic 3) and 88% in taking Simulation (TOPIC 4).
Dr. Matthew rated himself 92% in taking Linear Programming Techniques (Topic 1), 95% in taking Marcov Chain Analysis (Topic 2), 96% in Transportation Model (Topic 3) and 75% in taking Simulation (Topic 4).
Dr. Amos rated himself 100% in taking Linear Programming Techniques (Topic 1), 95% in taking Marcov Chain Analysis (Topic 2), 95% in Transportation Model (Topic 3) and 60% in taking Simulation (Topic 4).

5.1 Data analysis

Table 2 Assignment model table formulation

Courses / **Lecturers**	**Topic 1**	**Topic 2**	**Topic 3**	**Topic 4**
Dr. Joachim	80	90	85	92
Dr. Jonathan	65	85	75	88
Dr. Matthew	92	95	96	75
Dr. Amos	100	95	95	60

Source: Authors, 2019.

Conversion to minimization problem

100 is the highest entry in the table, it will be subtracted from all entries in the table.

Table 3 Regret table

Courses / **Lecturers**	**Topic 1**	**Topic 2**	**Topic 3**	**Topic 4**
Dr. Joachim	20	10	15	08
Dr. Jonathan	35	15	25	12
Dr. Matthew	08	15	04	25
Dr. Amos	0	05	05	40

Source: Authors, 2019.

Table 4 Row reduction table

Courses / **Lecturers**	**Topic 1**	**Topic 2**	**Topic 3**	**Topic 4**	**Minimum Row Entry**
Dr. Joachim	20	10	15	8	**8**
Dr. Jonathan	35	15	25	12	**12**
Dr. Matthew	8	15	4	25	**4**
Dr. Amos	0	5	05	40	**0**

Source: Authors, 2019.

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The minimum row entry in each row will be subtracted from each row.

Table 5 Row minimization

Courses / Lecturers	**Topic 1**	**Topic 2**	**Topic 3**	**Topic 4**
Dr. Joachim	12	02	07	0
Dr. Jonathan	23	03	13	0
Dr. Matthew	04	11	0	21
Dr. Amos	0	05	05	40

Source: Authors, 2019.

Table 6 Column minimization

Courses / Lecturers	**Topic 1**	**Topic 2**	**Topic 3**	**Topic 4**
Dr. Joachim	12	2	7	0
Dr. Jonathan	23	3	13	0
Dr. Matthew	4	11	0	21
Dr. Amos	0	05	5	40
Minimum Entry in columns	**0**	**2**	**0**	**0**

Source: Authors, 2019.

The minimum column entry in each row will be subtracted from each column.

Table 7 Column minimization

Courses / Lecturers	**Topic 1**	**Topic 2**	**Topic 3**	**Topic 4**
Dr. Joachim	12	0	07	0
Dr. Jonathan	23	1	13	0
Dr. Matthew	04	9	0	21
Dr. Amos	0	3	05	40

Source: Authors, 2019.

Table 8 Row inspection

Courses / Lecturers	**Topic 1**	**Topic 2**	**Topic 3**	**Topic 4**
Dr. Joachim	12	0	7	0
Dr. Jonathan	23	1	13	0
Dr. Matthew	04	9	0	21
Dr. Amos	0	3	05	40

Source: Authors, 2019.

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Table 9 Column inspection

Courses / **Lecturers**	**Topic 1**	**Topic 2**	**Topic 3**	**Topic 4**
Dr. Joachim	12	0	7	0
Dr. Jonathan	23	1	13	0
Dr. Matthew	04	9	0	21
Dr. Amos	0	3	05	40

Source: Authors, 2019.

Total number of allocation = Total number of rows, the assignment is optimal. Since the result is optimal, we can allocate lecturers to courses. Allocation will be made for each cell with a squared zero.

Table 10 Optimum allocation table

Topic	Topic Segmentation	Lecturer	Effectiveness
Linear Programming Techniques	Topic 1	Dr. Amos	100
Marcov Chain Analysis	Topic 2	Dr. Joachim	90
Transportation Model	Topic 3	Dr. Matthew	96
Simulation	Topic 4	Dr. Jonathan	88
Total Effectiveness			**374**

Source: Authors, 2019.

5.2 Discussion

Table 10 above shows the result of courses allocation obtained with the help of Hungarian method. The results suggest that the university should allocate linear programming techniques (Topic 1) to Dr. Amos in order to obtain 100% effectiveness in the knowledge of linear programming techniques, Marcov chain analysis (Topic 2) should be allocated to Dr. Joachim to get 90% effectiveness, Dr. Matthew should take transportation model (Topic 3) in order to achieve 96% effectiveness. Finally, simulation (Topic 4) should be allocated to Dr. Jonathan to derive 88% effectiveness.

Presently, linear programming techniques (Topic 1) is allocated to Dr. Joachim, who is 80% effective in the teaching of that topic, Marcov chain analysis (Topic 2) is allocated to Dr. Jonathan with 85% level of effectiveness, transportation model (Topic 3) is given to Dr. Matthew with 96% effectiveness while simulation is allocated to Dr. Amos, who is 60% effective in taking the topic, leaving the department to achieve 321 (80.25%) effectiveness based on a heuristic approach employed by the head of department.

If the solution suggested by the analysis is followed by the head of department, the department will experience 374 (93.5%) maximum effectiveness on the four (4) topics in analysis for business decision to be undertaken by final year students in the department of business administration in the case school.

5.3 Conclusion

Indeed, the assignment model is a powerful tool that is employable in solving any real life problem that has to do with allocation or assignment. Head of department and course

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coordinators should not rely on heuristic approach, but learn to adopt operations research techniques in decision making. Adoption of the assignment model in course allocation will help the institution to experience 13.20% increment in lecturers effectiveness in taking each topic in analysis for business decision. This will lead to increase in the quality of education students get.

5.4 Implications of the study

The results of this study have shown that operations research tools like the assignment model is a powerful tool that can be used to solve the assignment problem in order to achieve optimality. In terms of theoretical implication, the result of this study strengthens our knowledge that assignment model is a suitable technique that can be used to solve allocation or assignment problem even in the education sector. In terms of practical implications, the head of department or course coordinators should endeavor to integrate assignment model in course allocation in order to get the best from lecturers and improve the quality of education students get in the department.

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