Research Article

CLAPS: Course and Lecture Assignment Problem Solver for Educational Institution Using Hungarian Method

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Abstract
A linear programming relates to solve the complicated problem concerning distribution of various resources such as men, machine, money, material, and time quantity satisfying certain constraints in the form of algebraically represented linear equations/inequalities.so as to maximize the profit or minimize the cost. The Assignment Technique is applied in the class of very practical linear programming model to assign a number of source variable jobs or persons to equal number of machines or tasks with minimum cost or maximum profit. The job to machine or person to task selection complicacy is generally known as Assignment problems. In this paper the Assignment problem objective is to assign a number of sources (jobs) to equal number of faculties (persons) at a minimum cost to manage the listed courses in an educational institution's various lecturer arrangements. Assignment problem arises while n number of jobs are assigned to m number of machines, where n may or may not equal to m and the number of persons is intended to operate m number of machines or engage n number of cranes at m number of quarries. The assignment, employment or allotment is targeted with the goal to expend minimum cost or maximum effectiveness in the operation. The assignment problems are usually solved by using Hungarian method. In case, more restrictions or constraints are imposed in the jobs dimension or machines tool instruments' performance, or energy consumptions restrictions the assignment goal simplicity hampers and out of track. So, in spite of computational logistic flow diagrams availability, there is inadequate computer programming methods available to implement Hungarian method to solve the assignment problem. In this paper, the authors presenting the Hungarian method applied case study that discusses the Course and Lecturer assignment problem solvation process adopted by a course coordinator in tertiary institution (CLAPS). Despite the usefulness of operations research techniques in both manufacturing and service sectors, course coordinators in the regional institutions still make use of heuristic approach while assign courses to lecturers in department which rarely bring out maximum effectiveness in these lecturers. The study demonstrates the usefulness of Hungarian method in solving course assignment problem in a specific institution. The assignment problem was formulated and solved with Hungarian method based on the data obtained from five lecturers in a department in the specific department in the specific institution. So, it is necessary for the administrators to use Operation Research techniques are as powerful tools in decision making.

Keywords: Allocation; Hungarian; Assignment; Education; Lecturers

1. Introduction

In Odisha state of India, the education system is 5-2-3-2-4 years of scheme mainly. Starting from primary school in which the students are expected to spend 5 years getting elementary knowledge after which they move to middle education school to spend 2 years and another 3 years in Secondary school. Then the successful students continue 2 years in higher secondary schools. The graduate stage is the institution where an individual student is expected to spend a minimum of 4 years of studies. Those continue post graduate studies are engaged four semesters or two years depending on the demand of the courses of studies. At graduate study stage, the individual student in higher institutions is expected to be trained by experts called lecturers or professional teachers in their duration of the studies. These experts impact their students with their knowledge in order to enhance their intellectual capacity. Implications of teacher tenure on teacher quality and student performance opined that the level of these professionals' effectiveness affects the quality of education; the enrolled students get in the institution. Quality of teachers and performance: evidenced from the schools affiliated to the regional universities. On the other hand, the impact of these professionals called lecturers on students is undisputable in the society. It is the responsibility of 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 lecturers teaching 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 decision on the allocation of courses teaching based on their intuition, lecturers' experiences and their own understanding of lecturers' capacity with no regards to scientific techniques of job assignment. The present study set to demonstrate the usefulness of assignment model techniques in allocating lecturers to course in university system, maximize effectiveness in course allocation and determine optimal course allocation.

The rest of the paper is organized as follows. Section 2 presents the related works, section 3 describes assignment

model building, section 4 describes data process materials and methods, section 5 describes data presentation and analysis and section 6 describes conclusion of the work.

2. Related Works

Several works have introduced by applying the concept of assignment model as well as the empirical framework. These are described as follows.

2.1 Concept of Assignment Model

Assignment problem is a one case of transportation problem where number of jobs (or origins or sources) and number of facilities (or destination or machines or person and so on) are equal. It arises as a result of different decision-making situation relating to job or task assignment in the day-to-day activities [9],[10]. Assignment Problem is a one-to-one matching problem. Assignment model comes under 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 [11]. In assignment model, all tasks are to be performed must be assigned on one-on-one basis; two tasks or jobs cannot be assigned to a machine or personnel [1]. The assignment problem play a significant role in solving real life problem and it is acceptable and well utilized tool around the world. The authors of the paper [2] 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 operation research that can be used to derive optimization, it has capacity to minimize and maximize depending on the objective of the model. 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. The learning has been affected during the Covid-19 [12-14] and at the same time it appears with several other opportunities of online methods, curriculum etc. to overcome this.

2.2 Empirical Framework

The authors of the paper [3] applied assignment model to study the allocation of workers to different section in the store located at Alhram Plaza Centre in Saudi Arabia who specializes in the sales of clothes. The authors of the paper [4] used a 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. The authors of the paper [5] have developed a mathematical model to solve course – classroom assignment problem in FEIT 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. The authors of the paper [6] used assignment problem to solve staff-subject allocation with the aim of maximizing quality on teacher's knowledge impact to students' lives. Optimal solution was obtained at end of the analysis. The paper [7] describes assignment model in solving teachers' allocation problem in order to minimize the time to be spent in preparing lecturers for four teachers who are capable of teaching four different courses were selected for the study. Optimum solution was discovered with the help of Hungarian method employed to solve the assignment problem.

3. Assignment Model Building

Assignment model or mathematical model for assignment problem [8] is a branch of linear programming that requires n persons or lecturers to perform m tasks/ teach courses. Also let C_{ij} be the cost of assigning i^{th} job (i=1,2,3--------n) to j^{th} machine (j=1,2,3-------m). The main focus is to assign the tasks/jobs to the machines (one task/job per machine) at the least total cost or the maximum total profit or efficiency. The problem can be formulated in this canonical form as follows.

$$Z=\sum_{j=1}^{m} \sum_{i=1}^{n} Cij\ Xij \qquad (1)$$

Subject to the following constraints

$\sum_{i=1}^{n}$ Xij = 1, i = 1,2,3…. n (A lecturer take a course)

$\sum_{j=1}^{m}$ Cij=1, j = 1,2,3…. m (A lecturer take a course)

Xij = 1 or 0 (1 = Course assigned; 0 = Course not assigned)

where,

n = Number of persons or lecturers to perform the task/ teach the courses

m = Number of tasks/courses to perform (teach)

C = Lecturer's effectiveness

i = row number representing tasks/courses

j = Column number representing lecturers

X = 1 if the task/course is assigned to a lecturer, 0 if not assigned
C_{ij} = Lecturer i effectiveness taking course j
X_{ij} = 1 if Lecturer i will be taking course j
(0 if Lecturer i will not be taking course j)
Z = Objective Function (Maximize)
$Z = C_{11}X_{11} + C_{12}X_{12}$

3.1 Techniques for solving Assignment Model (CLAPS)

The mathematician from Hungary, D. Konig in 1955 developed a method for finding an optimal solution without any direct comparison of every solution due to the special structure of assignment model, known as Hungarian method, which works on the principle of matrix reduction. It means that by adding and subtracting required numbers in the cost table or matrix and manipulating the cells of the matrix. The problem can be reduced to a matrix of real numbers relating opportunity cost. To make the best or least cost assignment the opportunity cost should show the relative penalties of assignment of any worker to a task/job as opposed. If we can decrease the matrix cell into one zero element in each row and column, it will then be feasible to make optimal assignments i.e. assignments in which all the opportunity costs are zero. Hungarian method can be deployed to solve assignment problem by taking the following steps. The value of the objective function is obtained by adding the original values of the assignment matrix in the assigned cell.

The steps involved for computational procedure to obtain optimal solution are described as follows.

Step 1: Create a cost matrix. If the cost matrix is not a square matrix, formulate the problem in a square matrix form by introducing dummy row or column (if the job m is not equal to machine n) to make it balance and form square matrix, the cost of dummy row/column is zero (0).

Step 2: Convert the problem to minimization problem in case the problem objective is maximization, 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. So, there will be at least one zero in each row of this new matrix which is referred to as the first reduced cost matrix.

Step 4: Perform column reduction by subtracting the smallest entry in each column from all the entries of the respective columns. So, there would be at least one zero in each row and column of the second reduced cost matrix, as a result.

Step 5: Procedure for determining an optimal assignment.

(i) Starting with first row of the reduced matrix, examine all the rows of this matrix which contains only one zero in it. Mark this zero within the circle and cross out the columns containing these assigned zeros. This process will be going on until all the rows have been examined. If any row deals with more than one zero, then that row will not be considered and it will pass on to the next row.

(ii) Start from the first column and examine all the uncovered columns to find the columns containing exactly one remaining zero. Mark this zero within the circle as an assignment will be made there. Cross out the rows containing this assigned zero.

Steps (i) and (ii) will be repeated until all zeros are either crossed out or assigned.

Step 6: If the minimum number of lines required to cover all zeros is equal to the order of the cost matrix, then assignment made in Step -5 is the optimal solution. Otherwise go to next step.

Step 7: Revised the cost matrix as follows.

(i) Select the smallest element among the uncrossed elements. Then subtract this element from all the uncrossed elements and add the same at the point of intersection of two crossed out lines whereas the other elements crossed by the lines remain unchanged.

Step 8: Go to step 5 and the procedure will be repeated till an optimum solution is obtained.

4. Data Process Materials and Methods

Data used for the study was obtained from five lecturers in a college with the help of a well-structured questionnaire administered to the lecturers. Courses available for final year students are derived from the 2019/2020 university first semester timetable. Out of six courses that students have registered in the semester, five are core courses that are mandatory for students in the department while other one course is elective. The study focused on the five core courses that are available for students in the semester. A well-structured questionnaire was administered to five lecturers who are Ph. D holders in the department. All of them possessing efficiencies in the operating computing system devices and have capacity required to teach any of the five topics that are embedded in the Basic Sciences. Each lecturer is to rate himself on 100% scale on their level of effectiveness in taking any of the five topic in Basic Sciences.

5. Data Presentation and Analysis

The data presentation and analysis mechanism is represented in Table 1 to Table 9. Table 1 describes the effectiveness rating of faculty.

Table 1: Faculty Effectiveness Rating

Course Title	**Course Code**	**Rating (100%)**
Faculty X		
Engineering Mathematics	Topic 1	87
Engineering Physics	Topic 2	75
Engineering Mechanics	Topic 3	92
Engineering Chemistry	Topic 4	100
Computer Application	Topic 5	94
Faculty Y		
Engineering Mathematics	Topic 1	85
Engineering Physics	Topic 2	82
Engineering Mechanics	Topic 3	95
Engineering Chemistry	Topic 4	85
Computer Application	Topic 5	96
Faculty Z		
Engineering Mathematics	Topic 1	88
Engineering Physics	Topic 2	85
Engineering Mechanics	Topic 3	75
Engineering Chemistry	Topic 4	85
Computer Application	Topic 5	87
Faculty P		
Engineering Mathematics	Topic 1	90
Engineering Physics	Topic 2	88
Engineering Mechanics	Topic 3	78
Engineering Chemistry	Topic 4	70
Computer Application	Topic 5	85
Faculty Q		
Engineering Mathematics	Topic 1	92
Engineering Physics	Topic 2	92
Engineering Mechanics	Topic 3	85
Engineering Chemistry	Topic 4	87
Computer Application	Topic 5	94

Entries in Table 1 show lecturers' self-rating in 100% scale and the entries in the first column are the topic-titles to be allocated. The second column is displaying the segmentation of the topics.

5.1 Data Analysis

The formulation of assignment model table is described in Table 2 and Figure 1.

Table 2: Assignment Model Table formulation

Courses / **Lecturers**	**Topic 1**	**Topic 2**	**Topic 3**	**Topic 4**	**Topic 5**
Faculty X	87	75	92	100	94
Faculty Y	85	82	95	85	96
Faculty Z	88	85	75	85	87
Faculty P	90	88	78	70	85
Faculty Q	92	92	85	87	94

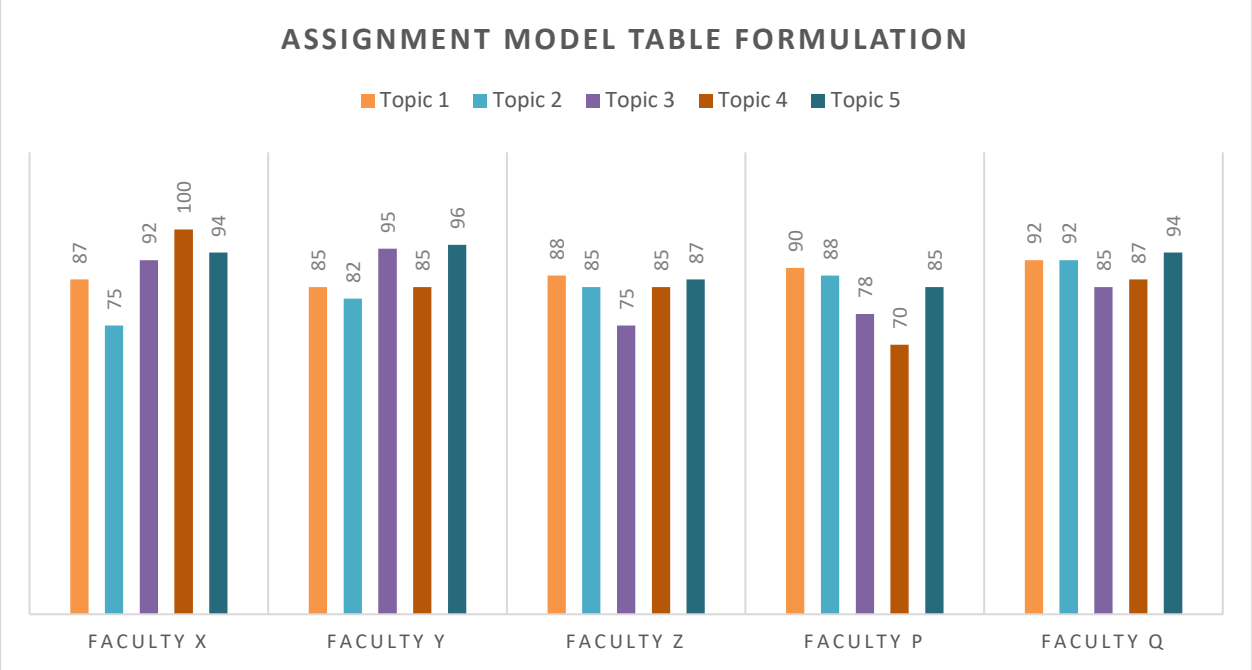

Fig. 1: Assignment Model Table formulation

100 is the highest entry in the table, so all the cell entries will be subtracted from 100, in the table as it is a maximize efficiency assignment problem, as mentioned in the step 2 above section 3.1. Table 3- Table 9 describes the conversion mechanism for minimization problem.

Table 3: Regret Table

Courses / Lecturers	**Topic 1**	**Topic 2**	**Topic 3**	**Topic 4**	**Topic 5**
Faculty X	13	25	8	0	6
Faculty Y	15	18	5	15	4
Faculty Z	12	15	25	15	13
Faculty P	10	12	22	30	15
Faculty Q	8	8	15	13	6

Table 4: Row Reduction Table: Minimum in a row

Courses / Lecturers	**Topic 1**	**Topic 2**	**Topic 3**	**Topic 4**	**Topic 5**	**Minimum Row Entry**
Faculty X	13	25	8	0	**6**	**0**
Faculty Y	15	18	5	15	**4**	**4**
Faculty Z	12	15	25	15	**13**	**12**
Faculty P	10	12	22	30	**15**	**10**
Faculty Q	8	8	15	13	**6**	**6**

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

Table 5: Row Minimization: Subtract the minimum value from row elements.

Courses / Lecturers	**Topic 1**	**Topic 2**	**Topic 3**	**Topic 4**	**Topic 5**
Faculty X	13	25	8	0	6
Faculty Y	11	14	1	11	0

Faculty Z	0	3	13	3	1
Faculty P	0	2	12	20	5
Faculty Q	2	2	9	7	0

Table 6: Column Minimization: Minimum value in a column

Courses / Lecturers	**Topic 1**	**Topic 2**	**Topic 3**	**Topic 4**	**Topic 5**
Faculty X	13	25	8	0	6
Faculty Y	11	14	1	11	0
Faculty Z	0	3	13	3	1
Faculty P	0	2	12	20	5
Faculty Q	2	2	9	7	0
Minimum Entry in columns	**0**	**2**	**1**	**0**	**0**

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

Table 7: Column Minimization: Subtract the minimum value from column elements.

Courses / Lecturers	**Topic 1**	**Topic 2**	**Topic 3**	**Topic 4**	**Topic 5**
Faculty X	13	23	7	0	6
Faculty Y	11	12	0	11	0
Faculty Z	0	1	12	3	1
Faculty P	0	0	11	20	5
Faculty Q	2	0	8	7	0

Table 8: Row Inspection

Courses / Lecturers	**Topic 1**	**Topic 2**	**Topic 3**	**Topic 4**	**Topic 5**
Faculty X	13	23	7	0	6
Faculty Y	11	12	0	11	0
Faculty Z	0	1	12	3	1
Faculty P	0	0	11	20	5
Faculty Q	2	0	8	7	0

If the total number of allocation is equal to Total number of row orders of the matrix, then the assignment is optimal. Since result is optimal, we can allocate lecturers to the topics from the assignment model. Allocation will be made to each cell with a squared zero.

Table 9: Optimum Allocation Table

Topic	Topic Segmentation	Lecturer	Effectiveness
Engineering Mathematics	Topic 1	Faculty Z	88
Engineering Physics	Topic 2	Faculty P	88
Engineering Mechanics	Topic 3	Faculty Y	95
Engineering Chemistry	Topic 4	Faculty X	100
Computer Application	Topic 5	Faculty Q	94
Total effectiveness			**465**

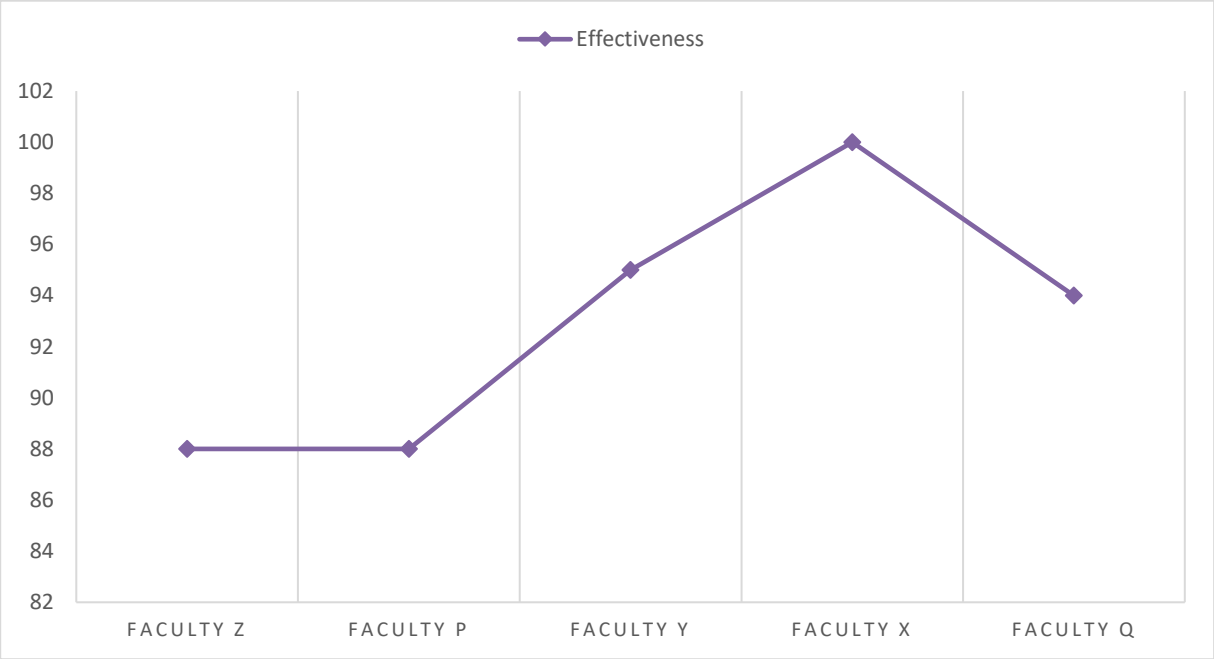

Table 9 and Figure 2 shows the person and courses assignment result obtained from the computation using the Hungarian Method. The result shown that the University should assign Engineering Mathematics (Topic 1) to Faculty Z in order to obtain 88% effectiveness in the knowledge of Engineering Mathematics, Engineering Physics (Topic 2) should be assign to Faculty P to get 88% effectiveness; Faculty Y should take Engineering Mechanics (Topic 3) in order to achieve 95% effectiveness. Engineering Chemistry (Topic 4) should be assigned to Faculty X to derive 100% of effectiveness; finally Computer Application (Topic 5) should be assigned to Faculty Q to get 94% effectiveness. Presently, Engineering Mathematics (Topic 1) is allocated to Faculty X who is 87% effective in teaching of that topic, Engineering Physics (Topic 2) is allocated to Faculty Y with 82% level of effectiveness, Engineering Mechanics (Topic 3) is given to Faculty Z with 75% effectiveness while Engineering Chemistry(Topic 4) is allocated to Faculty P who is 70% effective in teaching that topic and lastly Computer Application(Topic 5) is allocated to Faculty Q with 94% effective in taking the topic, leaving the department to achieve 411 (82.20%) effectiveness based on heuristic approach employed by the Head of Department If the computed solution is analyzed and accepted by the Head of Department, the department will experience 465 maximum effectiveness on the five topics which is effective in analyzing the business decision is to be undertaken by the department of the College.

6. Conclusion

This paper focuses on the approach to solve the education institution course assignment problem. This CLAPS approach mainly focuses on Hungarian method to solve this problem. Indeed, the assignment model building algorithm is a powerful tool that is executable through a computer program for assigning n number of lecturers to n number of courses, for n larger than 5 and by the way, it can ease the decision-making procedure for solving a real life problem that has to do with the maximum effective and minimum cost allocation or assignment. The computer software QM and TORA are used for solving the assignment problem having large number of persons and large number of jobs. Our manually solved assignment model by using the Hungarian method provide equal assignment result that is obtained from using QM and TORA software based computing the same problem.

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