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Developing an efficient optimization of course-lecturer distribution timetabling using transportation algorithm: A case study of Federal Polytechnic Offa

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Abstract

The institution course timetabling problem (ICTP) is a multidimensional assignment-problem that varies from course timetabling, class-teacher timetabling, student scheduling, teacher assignment, and classroom assignment. Many researchers have attempted to solve problems as related to timeslot but neglecting areas of course allocation to lecturers. The paper presented a course allocation and distribution model for lecturers based on their fields of interest and qualification to a transportation algorithm which was aimed at optimising the performance of lecturers in each course. It also evaluated overall efficiency of lecturers without exceeding the maximum workload. The performance of the course-to-lecturer allocation of the electrical/electronic engineering department, federal Polytechnic Offa, Kwara State was collected using simple questionnaire. The information obtained from the questionnaire was used to test the Algorithm developed. The result showed that using the developed algorithm for course distribution, the performance is 76.98% and 82.1% for the first and second semesters respectively. This showed that using the algorithm for allocation of courses to the lecturers of any department can be done based on input data without exceeding the recommended workloads of each cadre. This improved the quality of teaching, save time, and resources compare with manual methods. The study therefore recommended that future work should include practical distribution among technologists, sharing the excess workload to a particular lecturing grade as the case may be.

Keywords: Time tabling; Transportation Algorithm; Course-Distribution; Performance Efficiency

1. Introduction

The research on timetabling problems has a long history and can be dated back to the last sixty years. Before 1980, various attempts had been made to address the issue timetabling problems. Numerous researchers have studied Timetabling as a complete Network Problem (NP), Even, Itai, and Shamir (1976) & Garey and Johnson (1979). Timetabling problem has received special attention of the scientific community over the years. For instance, a biennial conference on the Practice and Theory of Automated Timetabling (PATAT) has been going on since 1995. Similarly, both Association of European Operational Research Societies (AEORS), and Working Group on Automated Timetabling (WATT) were established in 2002.

Timetabling process can be divided into two phases. The first phase is the curriculum definition of each class of students and assigning of teachers to courses. The second phase is scheduling of the curriculum courses into time slot, based on the available resources such as manpower, and equipment to the classes which is compatible with the entire previously defined requirement. Abramson and Abela, (1991), Erben and Keppler (1995), Herz (1992), Monfroglio (1988) Paechter, Rankin, Cumming, and Fogarty (1998), Ross, Hart and Corne, (1994), Schaerf (1996), Carter and Laporte

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(1998), De Werra (1985), Schaerf (1999) & Burke and Petrovic (2002) propose methods used in solving the timetabling problems. Carter and Laporte, (1998) present the major differences between different methods of solving the course timetabling problems at the school level, such as that of high school and also at the university level. According to them, the institution course timetabling problem (ICTP) is a multi-dimensional assignment problem, in which students and lecturers are assigned to courses, venues and time slots.

On the first phase, Andrew and Collins (1971) proposed a procedure for assigning the teachers to courses, based on a simple linear programming technique with some limitations pointed out by Tillett, (1975), while Breslaw, (1976) propose a model to overcome the limitation of the model proposed by Tillett (1975). Schaerf, (1996) applied a tabu search to solve the school timetabling problem for an Italian school. Randall, Abramson, and Wild (1999) has also used a tabu search to solve the Abramson set of school timetabling problems. Harwood and Lawless (1975) used a goal programming model to solve the teacher assignment problem. Liu, Zhang and Leung (2009) & Randall, Abramson and Wild (1999) have also successfully applied simulated annealing to the school timetabling problem. Schniederjans and Kim (1987) highlighted the drawbacks in implementing this model and proposed a model to overcome it and also mentioned some factors that could affect the size and complexity of the teacher assignment problem.

In solving timetabling problem, most researches such as Burke, Bykov and Soubeia (2003b) focused on employee shift timetabling, Asmuni, Burke and Garibaldi, (2005), Burke, Mc Collum, Meisels, Petrovic and Qu (2007) & Qu, Burke, McCollum, Merlot and Lee (2009) worked on course timetabling while De Werra (1985), Fang (1994), Schaerf (1999), Alkan and Ozcan (2003), Burke and Newall (2004) & Ozcan (2005) worked on examination timetabling. Other combinatorial optimisation problems are Ross, Hart, Corne, (1998) worked on bin-packing, Burke et al. (2003b) worked on production scheduling, personnel scheduling. (Merlot, Borland, Huges and Stuckey (2002) proposed a hybrid approach for solving the final examination timetabling problem that generates an initial feasible timetable using constraint programming, and then applied simulated annealing with hill climbing to obtain a better solution.

Beligiannis and Tassopoulos (2012) solved the Greek school timetabling problem using particle swarm optimization. The particle swarm optimization produced better timetables than other techniques such as evolutionary algorithms and constraint programming. Burke and Bykov, (2008) proposed a general and fast adaptive method that arranges the heuristic to be used for ordering examinations. Turabieh and Abdullah (2009) proposed an electromagnetism-like mechanism with force decay rate great deluge algorithm for university course timetabling which is based on an attraction-repulsion movement for solutions in the search space. All these focused on the second phase of timetabling problem. From the literature, very few works pay attention to the performance of course-to-lecturer problems where the bulk of the performance efficiency of the students lies; the aspect of the professional degree required for teaching a particular course of all lecturers and the workload of the lecturers. The present paper addresses the aspect of assigning courses to measure the performance of curriculum management and course-to-lecturer efficiency. The paper specifically focuses on the transportation algorithms modelling and optimization of the algorithm.

2. Transportation Algorithms Modelling

This involves determining an optimal strategy to maximize quality of teaching and performance of lectures through allocating to them courses that are relevant to their professional qualification and their field of interest or study without exceeding the maximum workload. In this case, the courses have their credit units, the lecturer have their maximum workload depending on their cadre, level and other responsibilities. The courses are regarded as sources to various lecturers called destination. The problem to be solved is how to maximize the efficiency of courses allocated with performance of lecturers. Each lecturer has a fixed workload of the credit units usually called capacity or availability.

2.1. Definition of Notation

P_{ij} represents the percentage of professional degree that lecturer i can teach a course j

x_{ij} represents the number of credit unit to be distributed from course j to lecturer i (i= 1,2,3,…,n; j=1,2,3,…,m)

S_i represents total workload of lecturer i

d_{ij} represents credit unit of course j

a, b, c, g and h represent the number of Assistant Lecturer, Lecturer III-Lecture II, Lecturer I, Senior lecturers, Principal Lecturers and Chief lecturers with responsibility and Principal Lecturer –Chief lecturer without responsibility respectively, , , and represent the maximum workload of Assistant Lecturer, Lecturer III-Lecture II, Lecturer I- Senior lecturer, Principal Lecturer –Chief lecturer with responsibility and Principal Lecturer –Chief lecturer without responsibility respectively

The decision variable, x_{ij} are the credit unit of course j to lecturer i

Let Z = the percentage efficiency of the course allocation and distribution in a semester containing total course m and in a department with total lecturer n

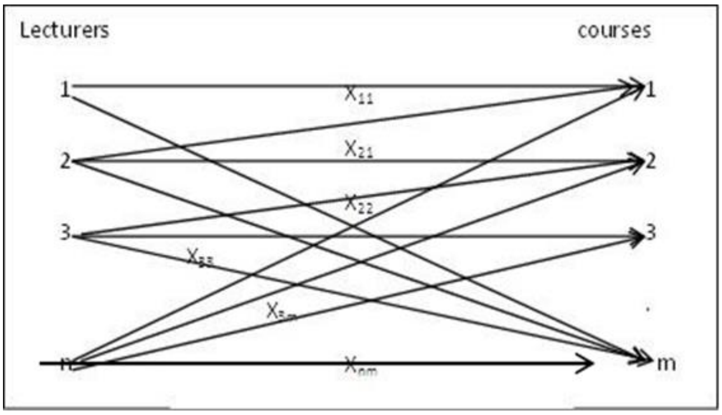

Figure 1 Constructing a Transportation Problem

Table 1 Lecturers-Courses Allocation and Distribution with their % performance

		Courses								**Workload**
		1	**2**	**3**	**4**	**.**	**.**	**.**	**M**	
	1	P11	P12	P13	P14				P1m	s1
	2	P21	P22	P23	P24				P2m	s2
Lecturers	3	P31	P32	P33	P34				P3m	s3
	.	.	.	.	.				.	.
	.	.	.	.	.				.	.
	.n	Pn1	Pn2	Pn3	Pn4	.	.	.	Pnm	sn
Credit unit		d1	d2	d3	d4				dm	Total credit units

Total percentage overall performance,

$$Z=\frac{\sum \%performance \times credit\ unit}{\sum course\ credit\ units} \qquad \text{(i)}$$

Total percentage of Lecturer performance

$$L_{ij}=\frac{\sum \%P_{ij} \times credit\ unit}{course\ credit\ load} \qquad \text{(ii)}$$

The optimum performance is given as:

$$\text{Maximize, } Z=\frac{\sum P_{ij} \times x_{ij}}{\sum d_j} \qquad \text{(iii)}$$

To maximize the performance, the problem can be rewrite as follow:

Minimize, W= 1-Z (iv)

The objective function is given as

Minimize, $W = \sum_{i=1}^{n}\sum_{j=1}^{m}\frac{(1-P_{ij})\times x_{ij}}{\sum d_j}$ (v)

Subject to

$\sum_{j=1}^{m} x_{ij} = s_j$; For j= 1,2,3 … m (vi)

$\sum_{i=1}^{n} x_{ij} = d_j$; For i= 1,2,3 … n (vii)

$x_{ij} \geq 0$ (viii)

Total credit unit, $TU = \sum_{j=1}^{m} d_j$ (ix)

Total credit load $TL = \sum_{i=1}^{m} s_i$ (x)

For all i and j

Total index ratio, I.R=$\frac{\text{total credit unit}}{\text{total credit load}}$ (xi)

Adjusted credit load for each grade level =$s_i \times I.R$ (xii)

Adjusted total credits load,

TL = (s_{ia} x a+ $s_{ib} \times b + s_{ic} \times c + s_{ig} \times g + s_{ih} \times h$) $\times$ I.R (xiii)

The constraints are:

Assistant Lecturers should have maximum of 6 credits load

Lecturer III – Lecturer II have maximum of 12 credits load

Lecturer I – Senior Lecturer have maximum of 16 credits load

Principal Lecturer –Chief Lecturer with Responsibility have maximum of 6 credits load

Principal Lecturer –Chief Lecturer without Responsibility have maximum of 9 credits load

Maximum of two lecturers for 2 credit unit course

Maximum of three lecturers for 3 credit unit course

Total credit unit TU = sum of all the credit unit of all courses

Table 2 Lecturers Grade Level with their Population and adjusted Credit Load

Lecturer Grade level	**Number of Lecturers**	**New Load**	**Credit**
Assistant Lecture	a	6 x I.R	
Lecturer III – Lecturer II	b	12 x I.R	
Lecturer I – Senior Lecturer	c	16 x I.R	
Principal Lecturer –Chief Lecturer with Responsibility	g	6 x I.R	
Principal Lecturer –Chief Lecturer without Responsibility	h	9X I.R	

Table 3 Percentage (%) grading of Lecture ID against all the departmental courses

Course Code	Course title	Less than 40%	40%	50%	60%	70%	Above 70%
EEC 123	Electrical Machine I				√		
EEC 122	Electrical Power System						

3. Algorithm optimization

The total number of courses taken by the student can be divided into two. These are the departmental courses taught by the lecturers of the departments and external courses taught by the lecturers of other departments. Our focus is on the departmental courses which can be categorised into three options; i.e. computer, control and instrumentation; electronics and telecommunication; and power and machine. The problem of assigning of lecturers to the courses and course sections are in 2 phases.

3.1. Phase 1

The first phase is allocating lecturers to the courses base on their professional options and skills, and determining the number of courses to be assigned to each lecturer. The Second phase is, scheduling the teacher to the course sections in order to balance the teachers' workload.

3.2. Phase 2: Algorithm Optimization

Feasible Solution using North-west corner method and Stepping-stone method

Step 1: arrange the data into row (lecturers) in descending order of grade levels and column (courses)

Step 2: start by selecting the cell in the North-west corner of the table

Step 3: assign the maximum credit unit of course in this cell, based on the requirements and lecturer and course constraints

Step 4: Exhaust the credit load from each lecturer before moving to the next lecturer

Step 5: exhaust the credit load of each column before moving to the next column

Step 6: check if total credit units is equal to total credit load

Step 7: if yes, select an unused square box to be evaluated

Step 8: begin from at the unused square box to trace a close-path back to the original by moving horizontally or vertically only.

Step 9: Beginning with positive sign (+) at the unused square box by placing alternatively minus sign (-) in the next square box follow by plus sign (+) to each corners square box of the traced close path

Step 10: evaluate an improvement index, I_{ij} by adding the performance found in each square box containing a plus sign and the subtracting the units performance in each square box containing minus sign (-) and divide all by total credit unit

Step 11: go back to step 7 until an improvement index, I_{ij} has been calculated for all the unused square box

Step 12: check if all $I_{ij} \geq 0$, an optimal solution has been reached

Step 13: if $I_{ij} \leq 0$, it is possible to improve the current solution and increase total performance

Step 14: choose the closed-path with $I_{ij} \leq 0$

Step 15: select the minimum credit unit in the closed path and add or subtract from each cell using the assign signs

Step 16: go back to step 7

Step 17: print the lecturers name, assigned courses and credits, percentage of performance and optimum performance.

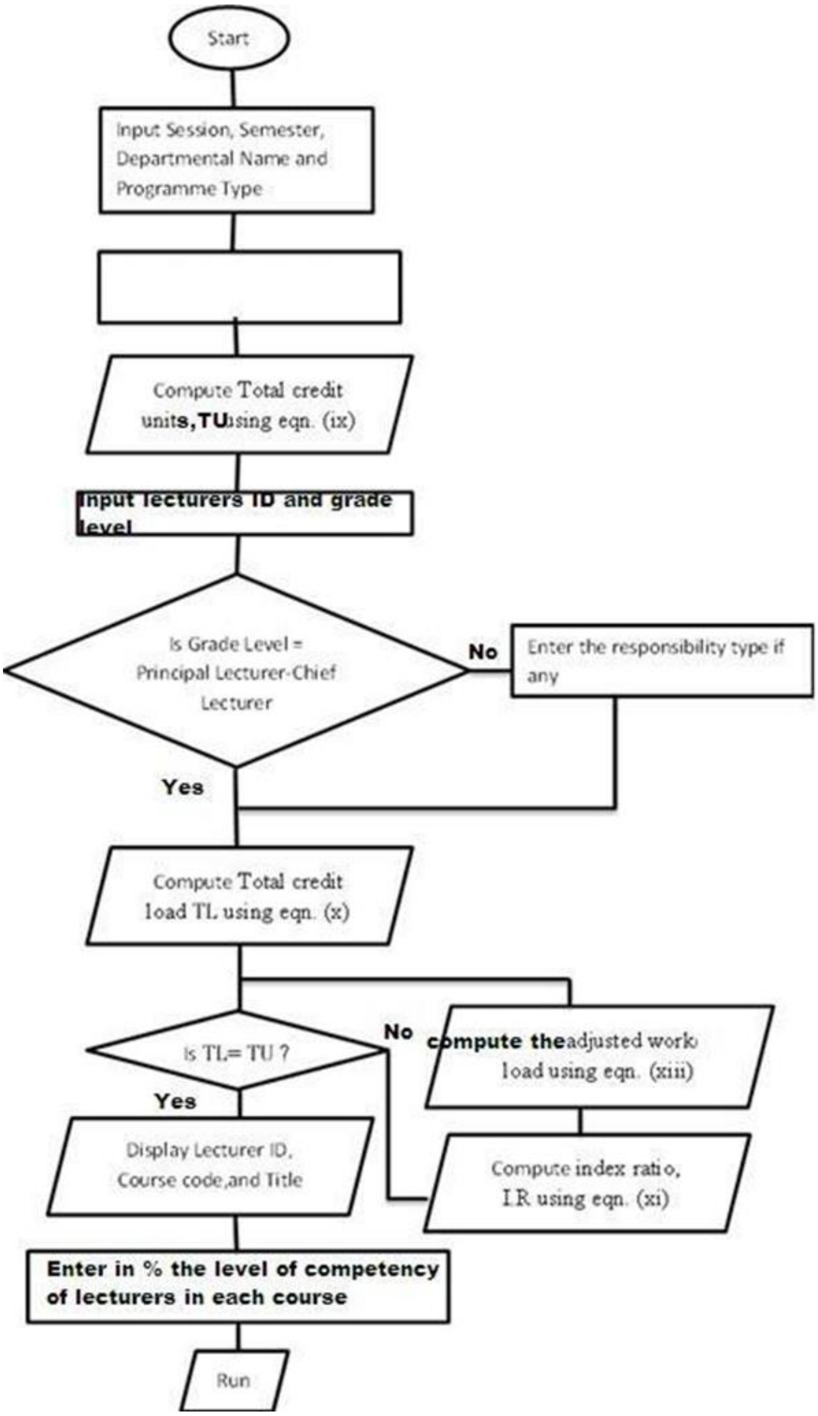

Figure 2 Flow Chart for the Input stage

4. Results and discussion

Data of all lecturers of both computer engineering and Electrical/Electronics Engineering departments were collected using questionnaire format. The questionnaire is divided into two sections: A and B. section A consists of the personal data of the lecturer/ respondent: id number L_n, grade level, professional cadre and other responsibility. Section B consists of the professional course individual lecturer can teach and those interested in each course. The number of lecturer samples and their grade level is shown in fig. 3.0.

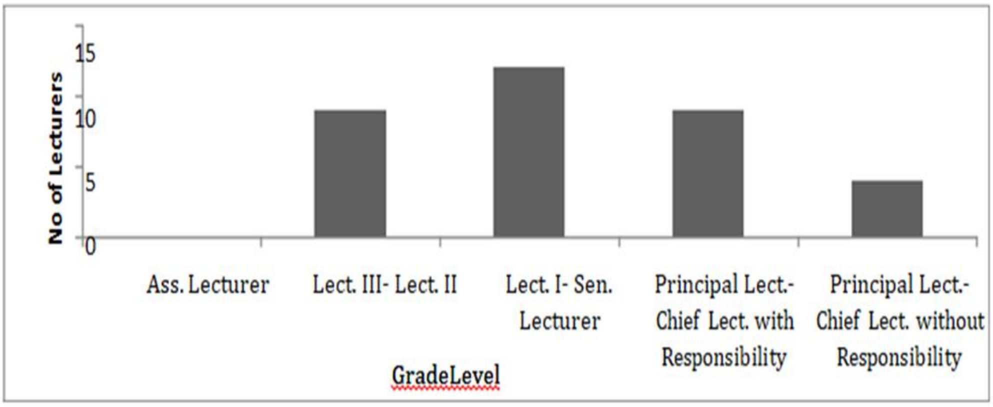

Figure 3 The Lecturers Grade Level Distribution in the 2 Departments

The total number of courses taught at departmental level in electrical engineering for both HND and ND programme are 89. Courses taught by the external lecturers are 18. Those taught by internal lecturers are 71. For the first semester, 36 courses are internal courses while 10 are external courses. The total is 46 courses. Second semester, 35 courses are internal courses and 8 courses are external courses, and the total of 43 courses. The total credit load in the first semesters is 98. 6 courses with 3 credit units and 40 courses with 2 credit units. Second semester total credit load is 92. 6 courses with 3 credit units and 37 courses with 2 credit units. However, in the first semester, HND seminar which is 1 credit unit will be supervised by all lecturers from Lecturer I and above while in the second semester, HND project which is 4 credit units will be supervised by all lecturers from lecturer I. The ND project which is 4 credit units will be supervised by all lecturers from Lecturer III and above. This will not be input since it involves almost all the lecturer taking a particular course.

For the first semester, the total credit load = 390, Index ratio = 0.251, and for the second semester, index ratio = 0.236. The new credit load is displayed in fig. 4

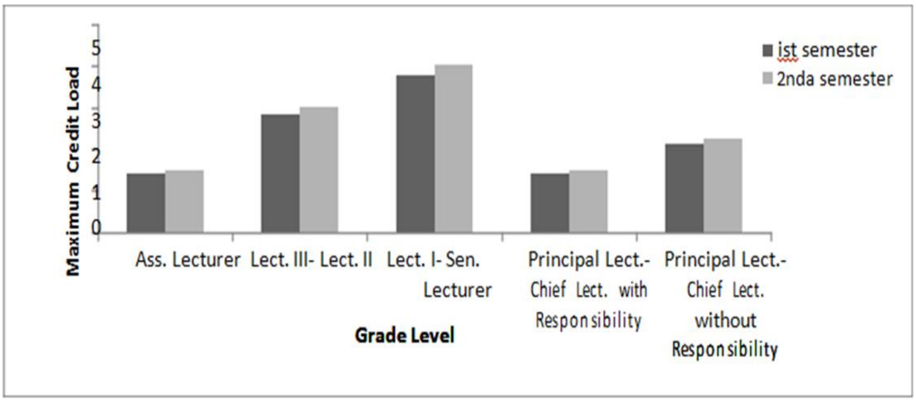

Figure 4 The adjusted maximum Credit load per Grade level for the 2 semesters

The output of transportation algorithm is summarised in the Fig. 5-9 in descending order of grade level and responsibility. L1 to L4 are principal to chief lecturer with responsibility; L5 to L13 are principal to chief lecturer without responsibility; L14 to L25 are Lecturer I to senior lecturer; L25 to L34 are Lecturer III to Lecturer II; and there is no Assistant Lecturer.

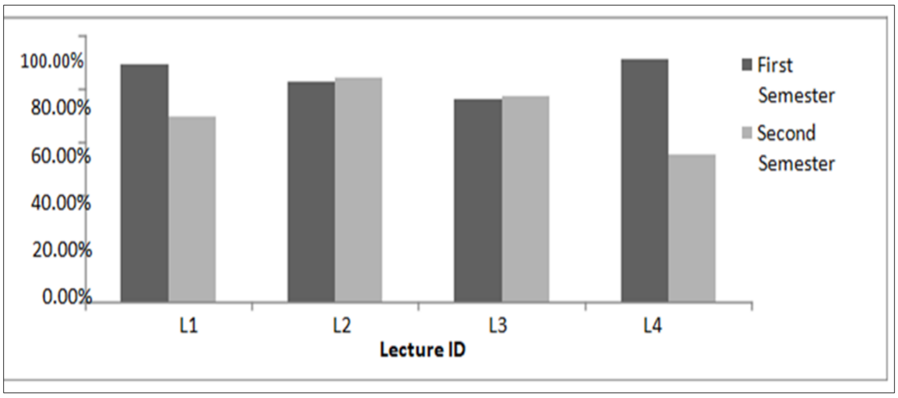

Figure 5 Comparison of % efficiency performance of Principal Lecturer - Chief Lecturer with Responsibility for the 2 semesters

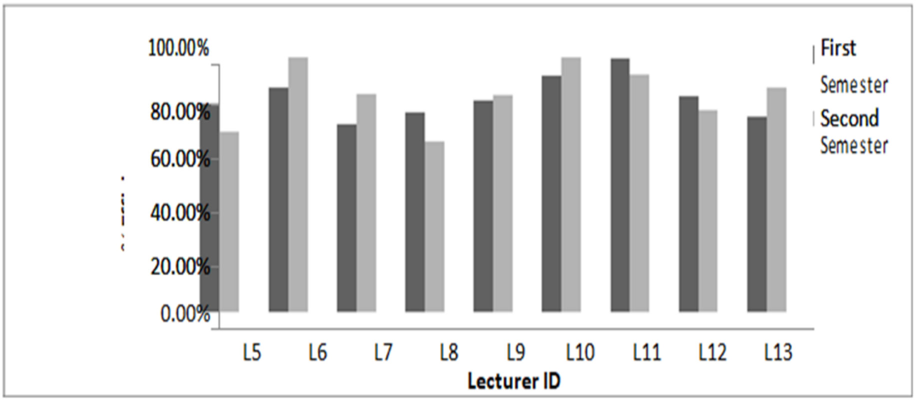

Figure 6 Comparison of % efficiency performance of Principal Lecturer - Chief Lecturer without Responsibility for the 2 semesters

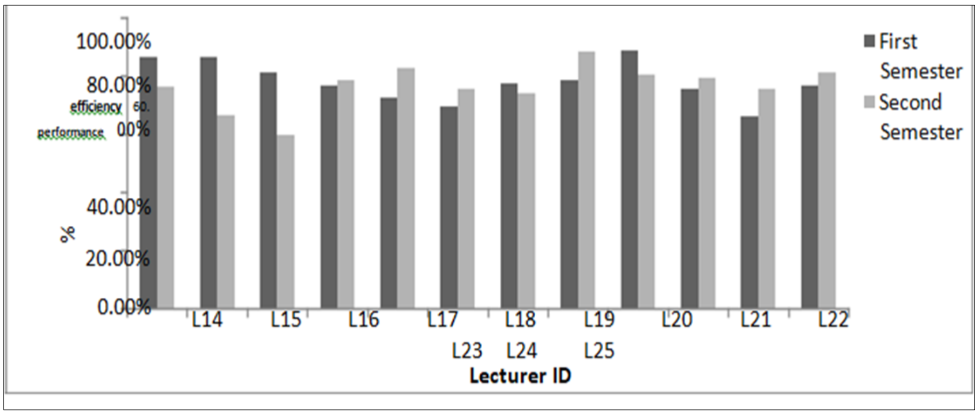

Figure 7 Comparison of % efficiency performance of Lecture I- Senior Lecturer for the 2 semesters

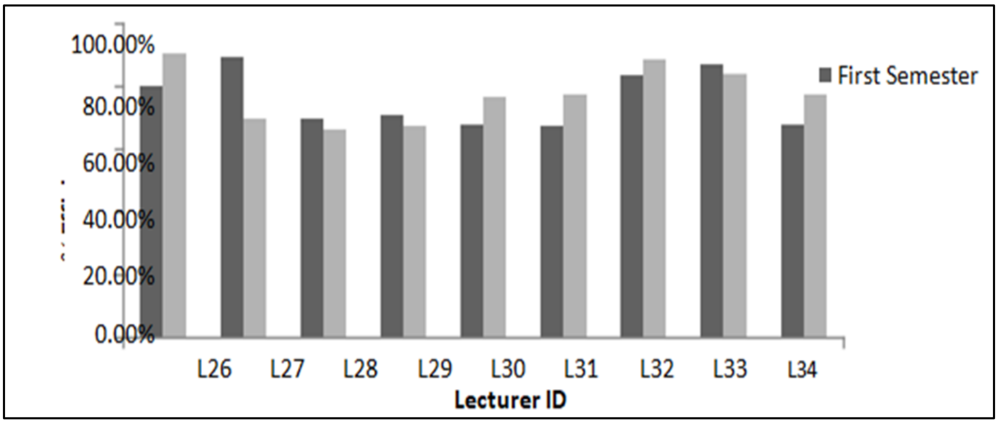

Figure 8 Comparison of % efficiency performance of Lecturer III – Lecturer II for the 2 semesters

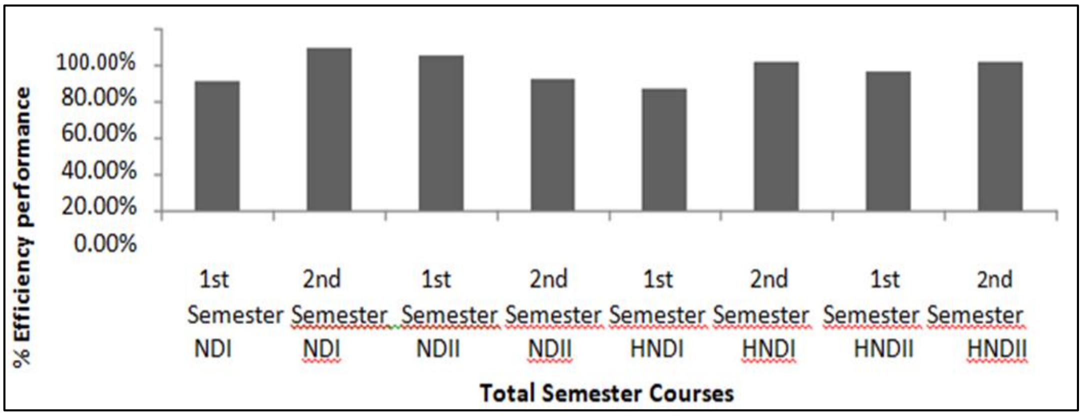

Figure 9 Comparison of % efficiency performance of all the classes per semester

5. Findings and Conclusion

Based on the instruments employed in this study, it was discovered that the performance of the lecturers in any course after the course allocation is not less than 60% and the overall % performance for electrical engineering courses if all the courses are assigned according to the output of the programme is 76.98%for the first semester and 82.1% for the second semester base on the input performance of all lecturers in each course. It was also found out that any variation in the input performance of lecturer in a course will result into new assignment of courses and new % level of performance. With this algorithm, this study concluded that the course allocation of any department can be done based on the input data of lecturers and courses without overloading any lecturer and with the best performance combination. The course allocation and distribution can be modelled into transportation and assignment problems and solved using other linear algorithms. We believe that the performance of Transportation algorithm for the course allocation and distribution can be improved by applying advanced assignment operators and heuristics.

Compliance with ethical standards

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Disclosure of conflict of interest

All authors declare that they do not have conflict of interest.

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