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An Optimization Model for Teaching Assignment based on Lecturer's Capability using Linear Programming

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ABSTRACT
In the campus, the arrangement of teaching assignment for the lecturers have been the problem encountered by the faculty on the beginning of each semester. This process including assigning a class with suitable lecturer while adjusting the appropriate load for the lecturer. Such problem is non-trivial and can be considered as a linear system model. In this article, we try to solve the problem of teaching assignment using optimization model. We tried to maximize the capability of lecturers to teach particular subject while also considering their loads. Using branch and bound algorithm, the optimal solution were found and the problem are well solved.

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1. INTRODUCTION

We often encountered the assignment problem in the real world. The classic assignment problem is related to the problem of pairing the "workers" who have diverse expertise with "jobs" according to their expertise. The diverse capabilities will ultimately affect the costs required to complete the whole work. Therefore, the main objective of solving this assignment problem is to minimize the cost of assigning the workers while still maximizing the capabilities of the workers doing their job. The assignment problems can be seen as a linear programming model [1]. On the campus determining the teaching load of the lecturers in each semester is one of the assignment problems that is often encountered and cannot be avoided by the faculty.

Every semester, the faculty always conducts teaching activities with varied class composition and courses but with a relatively fixed number of lecturers. Therefore, the lecturer teaching load is determined on a regular basis every semester. Determination of the teaching load of lecturers is usually done manually by the faculty by considering the area of expertise of the lecturers. The activity of determining teaching load is also carried out so that the teaching load for each lecturer does not exceed the specified maximum limit. Therefore, we need an optimization model that can determine the optimum teaching load of lecturers by considering the area of expertise of lecturers. The problem of determining the teaching load of lecturers can be seen as an assignment problem [2], where the main objective is to find the right composition between the desired class and the lecturer that meet certain criteria.

Some previous studies used a heuristic approach to solve the problem of determining the teaching load. Mahmudy [1] and Nopianty [3] implemented the genetic algorithm model to determine the optimum combination between teaching assignments of lecturers and subjects based on the interest of lecturers in certain subjects. Genetic algorithm works by imitating the biological evolutionary process of living things in finding solutions to problems [4]. Abduh et.al. [5] implements the particle swarm optimization (PSO) algorithm to optimize the teaching load of lecturers. This study aims to create a mathematical model of the problem of determining the teaching load of lecturers with two objectives, namely maximizing the capability of lecturers based on their preference for certain subjects.

2. METHODOLOGY

2.1. Teaching Load Assignment

According to the Directorate General of Higher Education [10] , the main task of lecturers is to carry out the tridharma (three main tasks of the lecturer) of the university with a load of at least 12 credits and at most 16 credits in each semester in accordance with their academic qualifications. Provisions imposed on lecturers in carrying out the three tridharma of the university are teaching, research, and community service which are with the maximum amount equivalent to 16 credits semester (or called SKS). The main task of lecturers in the form of teaching and research is at least equivalent to 9 SKS in the faculty and also at least equivalent to 3 SKS for community service.

2.2. Linear Programming

A linear programming problem is an optimization problem that should meet these following criteria [7]:

1. The goals is to maximize (or minimize) a linear function of the decision variable. This function is called an objective function.
2. The value of the decision variable must meet certain constraints. Each constraint must be a linear equation or inequality.
3. Sign delimiter is initialized to each decision variable. For each decision variable, a sign delimiter requires that it must be non-negative ($x_{ij} \geq 0$) or there is no sign boundary.

2.3. Assignment Model

The assignment problem is one of the special cases of linear programming problems [8] where the assignee (or the worker) is assigned to do the work that is available. Recipients are not only limited to human resources. The assignee can be a machine, vehicle, factory and even a time slot to be given for the task. The assignment problem needs to be formulated so that it meets the following assumptions [9]:

1. There are same number of workers and the number of assignments (notated with n).
2. Each assignee is assigned to exactly one job.
3. Each job is done by exactly one assignee.
4. The cost c_{ij} is associated to the worker i ($i = 1, 2, \ldots, n$) doing the job j ($j = 1, 2, \ldots, n$).
5. The purpose of the assignment model is to determine how to optimize the total coast of assigning each of the n job to each of n worker.

Generally, the mathematical model for the assignment problem defined as follows:

$$\text{Min } Z = \sum_{i,j=1}^{n} c_{ij}\, x_{ij} \tag{1}$$

With constraints:

$$\sum_{j=1}^{n} x_{ij} = 1, \qquad \forall i = 1,2, \ldots, n \tag{2}$$

$$\sum_{i=1}^{n} x_{ij} = 1, \qquad \forall j = 1,2, \ldots, n \tag{3}$$

$$x_{ij} \in \{0,1\}, \qquad \forall i, j = 1,2, \ldots, n \tag{4}$$

Where the decision variable x_{ij} = 1 if the i^{th} assignee do the j^{th} work, and x_{ij} = 0 otherwise. c_{ij} is the cost component.

3. THE MATHEMATICAL MODEL

Mathematically, the assignment of teaching load can be seen as a linear equation system model. Such a model has an objective function that is maximizing the lecturer's capabilities to teach a certain subject based on their expertise.

3.1. Model Parameters and Variables

The optimization model developed for solving teaching assignment load consists of three main sets to be satisfied, there are the lecturer set **L** with cardinality of l, course subject set **S** with cardinality s, and the class set **C** with cardinality c.

The parameter used are p which represent the minimum teaching load of the lecturer, q which represent the maximum load of the lecturer, r which represent the number of lecturer teaching for a course subject, u which represent the maximum number of course subject assigned to a lecturer, and v represent the maximum number of class assigned to a lecturer for the same course subject.

Moreover, the model has also several additional decision variables as follows:

$$
\begin{aligned}
x_{ijk} &= \begin{cases} 1, & \text{if the } lecturer\ i \text{ assigned to course } j \text{ for class } k \\ 0, & \text{otherwise} \end{cases}; \quad \forall i \in \mathrm{L}, j \in \mathrm{S}, k \in \mathrm{C}, \\
y_{ij} &= \begin{cases} 1, & \text{if the lecturer } i \text{ assigned to course } j \\ 0, & \text{otherwise} \end{cases}; \quad \forall i \in \mathrm{L}, j \in \mathrm{S}, \\
\mathrm{st}_i &= \begin{cases} 1, & \text{if the lecturer } i \text{ is active} \\ 0, & \text{otherwise} \end{cases}; \quad \forall i \in \mathrm{L}.
\end{aligned} \tag{5}
$$

3.2. Objective Function

The model has an objective function to maximize the lecturer's capability in certain course subjects.

$$Maximize\ z = \sum_{i,j,k=1}^{l,s,c} \mathrm{st}_i \times c_{ij} \times x_{ijk} \tag{6}$$

The constraints are:

1. For each class k for course subject j is assigned to one lecturer.

$$\sum_{i=1}^{l} x_{ijk} \leq 1, \qquad \forall j \in \mathrm{S}, k \in \mathrm{C} \tag{7}$$

2. Each subject is assigned to a maximum of r lecturer.

$$
\begin{gathered}
\sum_{k=1}^{c} x_{ijk} \geq 1 - M\left(1 - y_{ij}\right), \qquad \forall i \in \mathrm{L}, j \in \mathrm{S} \\
\sum_{k=1}^{c} x_{ijk} \leq 0 + M\left(y_{ij}\right), \qquad \forall i \in \mathrm{L}, j \in \mathrm{S} \\
\sum_{j=1}^{s} y_{ij} \leq r, \qquad \forall i \in \mathrm{L}
\end{gathered} \tag{8}
$$

3. At least one of the lecturers assigned to each class k for subject j.

$$\sum_{k=1}^{c} x_{ijk} \times \mathrm{st}_i = 1, \qquad \forall i \in L, j \in \mathrm{S} \tag{9}$$

4. For each active lecturer, they are assigned to minimum one class.

$$\sum_{j,k=1}^{s,c} x_{ijk} \geq 1 - M(1 - \mathrm{st}_i), \qquad \forall i \in \mathrm{L} \tag{10}$$

$$\sum_{j,k=1}^{s,c} x_{ijk} \leq 0 + M(\mathrm{st}_i), \qquad \forall i \in \mathrm{L}$$

5. Each of the lecturers is assigned to a minimum number of p SKS and maximum of q SKS.

$$p \times \mathrm{st}_i \leq \sum_{j,k=1}^{s,c} x_{ijk} \times \mathrm{st}_i \leq q \times \mathrm{st}_i, \qquad \forall i \in \mathrm{L} \tag{11}$$

6. Each of the lecturers assigned to a maximum of u course subjects.

$$\sum_{j=1}^{s} y_{ij} \leq u, \qquad \forall i \in \mathrm{L} \tag{12}$$

7. The number of classes assigned to each lecturer for each course subject cannot exceed to v.

$$\sum_{j,k=1}^{s,c} x_{ijk} \leq v, \qquad \forall i \in \mathrm{L} \tag{13}$$

8. The decision variable x_{ijk} and y_{ij} are binary valued.

$$x_{ijk}, y_{ij} \in \{0,1\}, \qquad \forall i \in \mathrm{L}, j \in \mathrm{S}, k \in \mathrm{C} \tag{14}$$

4. CASE STUDY

In Indonesia, all lecturer in the university have the responsibilities to fulfill the tridharma of the university, i.e. teaching, research, and community service. The tridharma activities are assigned to the lecturer for each semester with a maximum value equivalent to 16 SKS and with a minimum value of community service and other supporting activities equivalent to 3 SKS [6]. Therefore, based on this regulation, the value of p and q are 9 and 13 SKS respectively. Moreover, in this case study, the value of r, u, and v are 2, 2 and 3 respectively. In this section, we applied the model formulated above using the case that have been reported in [1]. The case is divided into two scenarios.

4.1 Scenario: Equal Number of Lecturer and Course Subject

For the case of evenly distributed number of classes, the lecturer's capability to teach a certain subject is assumed to be a degree of lecturer's interest in a certain course subject. A value of 100 describes the lecturer as having no interest in a particular course subject. Table 1 shows the capability matrix for the scenario.

Table 1. Capability matrix of lecturer *D* and course subject *S*

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
D1	2	1	100	3	100	100	100	100	100	100
D2	2	100	100	100	100	4	100	100	1	3
D3	100	1	100	100	100	100	2	4	3	100
D4	100	3	100	1	2	100	100	100	100	100
D5	2	4	1	100	100	6	5	7	3	100
D6	3	100	2	1	100	100	100	100	100	100
D7	100	2	100	1	100	100	3	100	100	100
D8	100	100	1	2	100	3	100	100	100	100
D9	100	1	100	100	100	100	100	100	3	2
D10	100	100	100	100	3	4	2	100	1	100

With an assumption that all the lecturer is active, the result of the experiment using the branch and bound algorithm yields a value of 20 as the solution. The branch and bound method can be guaranteed to produce the optimal solution [10] for the assignment problem. The value of 20 describes the maximum value of all possible combinations of teaching load assignment. The results of the teaching assignment is shown on

Table 2. From the result, we can see that each lecturer is assigned to a different course subject and also each course subject is assigned to a different lecturer.

Table 2. Teaching Assignment Matrix

Lecturer	Course Subject	Lecturer	Course Subject
D1	S2	D6	S4
D2	S1	D7	S7
D3	S8	D8	S6
D4	S5	D9	S10
D5	S3	D10	S9

In this scenario, we also investigate the case if at least one lecturer is not active, so he/she cannot be assigned to the class or particular subject. The lecturers who are not active, are assigned to 0 value for their respected parameter st_i. Based on the simulation performed, if the number of classes for each course subject are more than double the number of lecturers, the branch and bound algorithm yields an infeasible solution. This happens because each of the lecturers are assigned to a maximum of two different classes or subjects. If the value of parameter u and v are changed by adjusting the ratio between the number of classes or subject with the number of lecturers, so the solution would be feasible.

4.2 Scenario: Different Number of Lecturer and Course Subject

In this scenario, we investigate if the number of lecturers is less than the total number of courses or classes. This scenario is very possible because of several factors such as, the total of number of course subjects offered are more than total number of the lecturer in the faculty, parallel classes in several subjects which causes the number of courses to multiply with different classes, or some of the lecturer cannot be assigned to some number of class because they are assigned to a management position, overseas study, etc.

For this case, the number of lecturers is assumed to be 10 and the total number of course subjects is 12 in which some of them are parallel classes as described in Table 3. Also, for this scenario, we use a different capability matrix which is shown in Table 4.

Table 3. The Distribution of Parallel Class

Course Subject	# of Parallel Class	Course Subject	# of Parallel Class
S1	1	S7	1
S2	2	S8	1
S3	3	S9	1
S4	2	S10	1
S5	1	S11	1
S6	1	S12	1

Table 4. New capability matrix of lecturer *D* and course subject *S*

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
D1	3	2	5	4	7	100	6	100	100	100	100	1
D2	2	5	100	100	100	4	100	100	1	3	100	6
D3	100	7	6	100	8	100	2	5	4	1	100	3
D4	100	3	100	1	2	5	6	100	100	100	4	100
D5	2	4	1	100	100	6	5	7	3	100	100	100
D6	3	100	2	1	100	100	100	5	6	100	100	4
D7	100	2	5	1	7	6	3	8	100	100	4	100
D8	100	100	1	2	100	3	100	100	100	6	5	4
D9	100	1	100	6	5	100	100	100	3	2	100	4
D10	100	100	6	100	3	5	2	100	1	100	4	100

Based on simulation, the branch and bound algorithm yields an objective function with a value of 28. This value is the optimal solution for the case of different number of lecturer and course subject. In this case, the value of r = 2, u = 2, and v = 2 with the assumption of all the lecturer is active. The detailed result of the assignment can be seen on Table 5.

Table 5. Assignment results

Course Subject	Parallel Class	Lecturer
S1	A	D2
S2	A	D9
S2	B	D9
S3	A	D8
S3	B	D5
S3	C	D5
S4	A	D6
S4	B	D7
S5	A	D4
S6	A	D8
S7	A	D10
S8	A	D6
S9	A	D2
S10	A	D3
S11	A	D7
S12	A	D1

As we can see from the results, some of the lecturers are assigned to more than one class, i.e. D2, D5, D6, D7, D8 and D9. However, there is no lecturer who teaches more than 2 classes. This is because we defined the constraint for the maximum number of courses assigned to each lecturer (7) and also the maximum number of parallel classes within the same subject assigned to each lecturer (8). In this case, the maximum number of subjects assigned to each lecturer is 2 subjects. Whereas, the maximum number of parallel classes within the same subject assigned to each lecturer is also 2 classes.

5. CONCLUSIONS

Based on results of the study, the optimization model of teaching load for lecturers can solve the problem of teaching load assignments. This optimization model produces an optimum solution using the branch and bound algorithm. The optimum solution is produced by assigning the lecturers with classes per subject that produces the optimum combination.

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