Teaching load allocation in a teaching unit: optimizing equity and quality

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Structured Abstract

BACKGROUND

Teaching load allocation, that is, which teaching staff teaches which subject, is an essential task that is carried out in all teaching and teaching/research institutions every year or every semester. Teaching load allocation has been well recognized as a major contributing factor to the teaching quality. The teaching load must be reallocated for changes of staff and/or program. As a consequence, teaching load has to be reallocated in each teaching unit at least once a year. We have interviewed 15 teaching units in 8 universities in Asia, Europe and Australia, and found that all the teaching units allocate teaching load manually in a trial-and-error manner. As a result, teaching load allocation is a time-consuming process. Moreover, the manual allocation may lead to unfavourable results. For example, (i) some staff may have much more teaching load than they should, while other staff may have much less teaching load; and (ii) some staff members may have to teach subjects that they are not proficient with, and two staff may be favourable of exchanging two subjects between them.

PURPOSE

In this study, we aim to develop a teaching load allocation model to optimize the teaching quality taking into account the staff equity.

DESIGN/METHOD

The objective of our study is to develop an optimization model that could obtain the optimal teaching load allocation plan. This model provides a new approach that could improve the overall teaching quality of a teaching unit virtually at no cost.

RESULTS

We will develop an optimization model for teaching load allocation. Based on a case study, the teaching quality could be increased by 7% without any additional cost. Further, the teaching load does not need to be manually allocated, which saves the time of program convenors or heads of school.

CONCLUSIONS

The main benefit of using this optimization model is to improve teaching quality by allocating suitable teaching staff to teach the subjects. Another benefit is that the teaching load does not need to be manually allocated, which is a time-consuming process, and the maximum teaching load of each staff will not be violated as it is modelled as hard constraints.

KEYWORDS
Teaching load allocation; integer programming; efficiency and equity.

Introduction

Teaching load allocation, that is, which teaching staff teaches which subject, is an essential task that is carried out in all teaching and teaching/research institutions every year or every semester (McClure and Wells, 1985). Teaching load allocation has been well recognized as a major contributing factor to the teaching quality (McClure and Wells, 1987; Partovi and Arinze, 1995; Shin and Jung, 2013). The teaching load must be reallocated for changes of staff (some teaching staff are no longer available (resignation, sabbatical, retirement, other commitment) and new teaching staff are available) and/or program (some subjects are cancelled and some subjects are developed). As a consequence, teaching load has to be reallocated in each teaching unit at least once a year.

In teaching load allocation, three objectives should be achieved. First, all subjects must be taught. Second, a teaching staff should not be allocated a higher teaching load than that required by her/his role. Third, teaching staff should teach subjects that they are proficient with; otherwise they have to struggle with effectively managing teaching tasks and schedules to find time for the many other activities, events, and responsibilities.

We have interviewed 15 teaching units in 8 universities in Asia, Europe and Australia, and found that all the teaching units allocate teaching load manually in a trial-and-error manner. As a result, teaching load allocation is a time-consuming process. Moreover, the manual allocation may lead to unfavourable results. For example, (i) some staff may have much more teaching load than they should, while other staff may have much less teaching load; and (ii) some staff members may have to teach subjects that they are not proficient with, and two staff may be favourable of exchanging two subjects between them.

Literature review

Improving the teaching quality is the key focus in all teaching activities. Researchers have been developing new educational theories and teaching techniques to cope with the ever-changing teaching environment (e.g. Horta, 2009; Hu and Lei, 2013; Oleson and Hora, 2013; Horta, 2013). In the literature, some optimization models have been proposed to better allocate teaching load. Breslaw (1976) developed a linear programming solution to the faculty assignment problem by optimizing the faculty preference. Schniederjans and Kim (1987) proposed a goal programming model to optimize departmental preference in course assignments. Badri (1996) proposed a two-stage multi-objective scheduling model for faculty-course-time assignments by using faculty course preference and faculty time preference as objectives. As discussed in Badri (1996), these models could resultantly improve the teaching quality by fulfilling the faculty preference. However, it would be more appropriate to optimize the teaching quality rather than faculty preference as the former is the key focus in all teaching activities.

In addition to the teaching quality, another important issue is the workload equity, namely, the workload of an academic staff should be in line with his or her academic role. Burgess (1996) compared different approaches to allocating work to university academics. Vardi (2009) conducted a study analyzing the impacts of different types of workload allocation models on academic satisfaction and working life. Bentley and Kyvik (2012) carried out a comparative study of academic workload across 12 countries. Horta et al. (2012) indicated that it is critical to consider the nature of the learning environment associated with the teaching efforts. A bunch of researchers have discussed the research – teaching nexus for academic staff (e.g. Simons and Elen, 2007; Halse et al., 2007; Taylor, 2007; Shin et al., 2011; Malcolm, 2013). All these works acknowledged the importance of equity on academics' satisfaction. Unfortunately, the equity issue is not properly addressed in the above-mentioned teaching load allocation optimization models.

In this study, we aim to develop a teaching load allocation model to optimize the teaching quality taking into account the staff equity. The model can be used to alleviate the

tedious task for teaching units. More importantly, it will enhance the “match” between teaching staff and subjects without neglecting the equity.

Objectives and contributions

The objective of our study is to develop an optimization model that could obtain the optimal teaching load allocation plan. The contribution of the paper is two-fold: First, this model provides a new approach that could improve the overall teaching quality of a teaching unit virtually at no cost. This is because the optimization results would enable more teaching staff to teach subjects that they are proficient with, thereby improving their satisfaction and teaching quality. We believe that there is no denying that when allocating the teaching load, one should try to let as many teaching staff teach subjects that they are proficient with as possible. The challenge is that when this is done manually, one cannot guarantee that the optimal decision is made. However, our model could guarantee that the optimal decision is made, in terms of the number of teaching staff who teach subjects that they are proficient with. Second, the teaching load is usually allocated by some senior academic staff, for example, the head of school. Our model would save her/his valuable time so that she/he can devote more time on teaching and research. Moreover, the maximum teaching load of each staff will be modelled so that it will not be violated in the allocation. As a result, teaching staff would be satisfactory with the teaching load allocation.

The remainder of this paper is organized as follows. Section 2 elaborates the problem of teaching load allocation. Section 3 builds an optimization model. Section 4 reports the applications of the proposed model to a higher education teaching institution in Australia. Conclusions and discussions are presented in Section 5.

Problem Description

We consider the teaching load allocation at a teaching unit, for example, a department or school. A number of subjects must be taught, including undergraduate subjects and postgraduate subjects, by the available teaching staff. Different subjects may have different teaching hours. For example, at the teaching unit A, XXX141 (a year 1 subject) has 3 hours of lectures and 2 hours of tutorial every week; XXX202 (a year 2 subject) has 3 hours of lectures and 1 hour of tutorial every week; and XXX313 (a year 3 subject) has 2 hours of lectures and 1 hour of tutorial every week. Therefore, the teaching loads of different subjects are different. The teaching unit may also require that some subjects be taught by two teaching staff, especially subjects with a large number of enrolees, so that one teaching staff can cover the other teaching staff’s teaching contents in case of absence due to conferences/sickness. In this case, each teaching staff teaches half of the subject.

A teaching staff has a maximum number of teaching hours each week. Different teaching staff has different maximum numbers of teaching hours because (i) some staff may not work full time; (ii) some staff is new to university/academia; and (iii) some staff has other time commitment such as administrative tasks. A teaching staff can also teach only a limited number of subjects, for example, at most two subjects per semester. It should be noted that teaching half a subject is considered as one subject in this requirement. For example, the convention that a teaching staff teaches at most two subjects means that she/he cannot teach three half subjects simultaneously, either.

As different teaching staff has different expertise, we classify the relation between a subject and a teaching staff into four categories:

Category 1: The teaching staff cannot teach that subject. For example, in a department of foreign languages, a teaching staff with expertise in French cannot teach the subject “Advanced Russian Literature”. Another example is that some teaching units may have policies such as new staff do not need to teach a particular type of subjects.

Category 2: The teaching staff can teach that subject, but is not the most suitable person. For example, a teaching staff with expertise in the history of Europe can teach the elective subject “Introduction to the History of Asia” for science and engineering students, but she/he is not the most suitable person for teaching it.

Category 3: The teaching staff is one of the most suitable persons to teach that subject. For example, a teaching staff with expertise in quantum physics should teach the subject “Modern Quantum Physics” if possible. Another example is that if the teaching staff taught this subject last year, she/he should also teach it this year if possible.

Category 4: The teaching staff must teach that subject. This is usually the case where a part-time teaching staff is hired to teach all or part of a particular subject.

Based on the above description, the teaching load allocation problem aims to allocate the teaching staff to the subjects, such that all subjects are taught and the maximum teaching load of each teaching staff is not violated, while maximizing the total number of subjects that are taught by the most suitable teaching staff.

Optimization Model

To address the teaching load allocation problem, we develop a mathematical optimization model. The notation is listed below.

Sets

I: Set of subjects, lowercase letter $i \in I$ refers to a particular subject;

I_1: Set of subjects which are taught by one teaching staff;

I_2: Set of subjects that are taught by two teaching staff, $I_1 \cup I_2 = I$;

J: Set of teaching staff, lowercase letter $j \in J$ refers to a particular teaching staff;

J_i^0: Set of teaching staff who cannot teach subject $i \in I$;

J_i^1: Set of teaching staff who can teach, but are not the most suitable for teaching subject $i \in I$;

J_i^2: Set of teaching staff who are the most suitable for teaching subject $i \in I$;

J_i^3: Set of teaching staff who must teach subject $i \in I$;

Parameters

$n_j^{\min}$: Minimum number of subjects that must be taught by teaching staff $j \in J$; it can be set at 0 if there is no such requirement.

$n_j^{\max}$: Maximum number of subjects that must be taught by teaching staff $j \in J$;

t_i: The number of teaching hours required for subject $i \in I$;

$t_j^{\min}$: Minimum number of teaching hours per week for teaching staff $j \in J$;.

$t_j^{\max}$: Maximum number of teaching hours per week for teaching staff $j \in J$;

Decision variables

x_{ij}: A binary decision variable which equals 1 if teaching staff $j \in J$ teaches subject $i \in I$ and 0 otherwise;

The teaching load allocation problem can be formulated as:

$$\max \sum_{i \in I_1} \sum_{j \in J_i^2} x_{ij} + \sum_{i \in I_2} \sum_{j \in J_i^2} 0.5 x_{ij} \quad (1)$$

subject to:

$$\sum_{j\in J} x_{ij} = 1, i \in I_1 \tag{2}$$

$$\sum_{j\in J} x_{ij} = 2, i \in I_2 \tag{3}$$

$$t_j^{\min} \le \sum_{i\in I_1} t_i x_{ij} + \sum_{i\in I_2} 0.5 t_i x_{ij} \le t_j^{\max}, j \in J \tag{4}$$

$$n_j^{\min} \le \sum_{i\in I_1} x_{ij} + \sum_{i\in I_2} x_{ij} \le n_j^{\max}, j \in J \tag{5}$$

$$x_{ij} = 0, i \in I, j \in J_i^0 \tag{6}$$

$$x_{ij} = 1, i \in I, j \in J_i^3 \tag{7}$$

$$x_{ij} \in \{0,1\}, i \in I, j \in J \tag{8}$$

The objective function (1) maximizes the total number of subjects that are taught by the most suitable teaching staff. Eqs. (2)-(3) impose that all subjects are taught. Eqs. (4)-(5) enforce that the teaching load requirement of each teaching staff is not violated. Eq. (6) defines the relation that some subjects cannot be taught by some teaching staff. Eq. (7) defines the relation that some subjects must be taught by some teaching staff. Eq. (8) defines x_{ij} as binary decision variables.

Applications

We apply the proposed optimization model to teaching load allocation at a higher education teaching institution in Australia. There are a total of 17 subjects, as show in

Table 1. The profile of 20 teaching staff is shown in Table 2, where the names of the staff are replaced by initials for privacy. The column “Expected hours” is the number of hours that a staff is expected to teach. We assume that the minimum number of teaching hours is 50% the expected value, and the maximum number of teaching hours is 150% the expected value.

Table 3 shows the relation between teaching staff and subjects, where “0” means that the teaching staff cannot teach the subject; “1” means that the teaching staff can teach but is not the most suitable for the subject; “2” means that the teaching staff is the most suitable for the subject; and “3” means that the teaching staff must teach that subject (in this example there is no one who must teach a subject).

Table 1 Subjects

Subject ID	Hours of teaching per week	Number of teaching staff
XXX110	5	1
XXX131	5	1
XXX141	5	2
XXX151	4	2
XXX187	5	2
XXX201	5	2
XXX203	4	2
XXX222	4	2

XXX283	2.5	1
XXX302	3	2
XXX312	3	2
XXX317/941	3	2
XXX322	3	1
XXX329	3	1
XXX9/407	3	2
YYY412	3	1
XXX900	3	2

Table 2 Teaching staff

Staff	Expected hours	Minimum subjects	Maximum subjects
BN	5	1	2
CW	5	1	2
EM	5	1	2
GJ	5	1	2
LJ	5	1	2
LX	5	1	2
MJ	5	1	2
NM	5	1	2
NP	5	1	2
NR	5	1	2
PD	5	1	2
RM	5	1	2
SC	5	1	2
TN	5	1	2
WS	5	1	2
WA	5	1	2
ZS	5	1	2
SA	5	1	2
WG	2	1	2
WM	4	1	2

Table 3 Relation between teaching staff and subjects

Subject ID	BN	CW	EM	GJ	LJ	LX	MJ	NM	NP	NR	PD	RM	SC	TN	WS	WA	ZS	SA	WG	WM
XXX110	2	1	2	1	1	2	2	2	2	2	1	1	2	1	1	1	1	1	2	2

XXX131	1	0	2	1	0	0	0	1	1	2	0	0	2	1	0	2	0	0	0	0
XXX141	2	1	2	1	2	2	1	2	1	2	1	1	2	2	1	1	1	1	2	1
XXX151	2	1	2	1	1	2	2	2	2	2	1	1	2	1	1	1	1	1	2	2
XXX187	2	1	2	1	1	2	2	2	2	2	1	1	2	1	1	1	1	1	2	2
XXX201	2	1	2	1	1	2	2	2	2	2	1	1	2	1	1	1	1	1	2	2
XXX203	2	1	2	1	1	2	2	2	2	2	1	1	2	1	1	1	1	1	2	2
XXX222	2	0	0	0	1	0	1	0	1	1	2	0	0	0	0	0	0	2	1	2
XXX283	2	1	2	1	1	2	2	2	2	2	1	1	2	1	1	1	1	1	2	2
XXX302	0	1	2	2	2	1	2	1	0	0	0	2	0	1	1	2	2	0	0	0
XXX312	0	2	2	2	0	1	1	2	0	0	0	0	0	2	2	2	2	0	0	0
XXX317/941	0	2	0	2	0	2	0	0	0	0	0	2	0	0	0	0	2	0	0	0
XXX322	2	0	0	0	1	0	1	0	2	2	2	0	0	0	0	0	0	2	2	2
XXX329	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	2	0	0	0	0
XXX9/407	1	2	1	2	1	1	1	2	1	1	1	2	1	1	1	1	2	0	0	0
YYY412	2	0	0	0	1	0	1	1	1	2	1	0	0	0	0	0	0	1	1	1
XXX900	2	1	0	0	2	0	2	0	1	0	1	0	0	0	0	0	0	0	1	1

The initial teaching load allocation that is carried out manually is shown in Table 4, where “1” means that the staff teaches that subject by herself/himself, and “-” means that the staff teaches that subject with another staff. Table 4 shows that when the teaching unit allocates the teaching load, three principles are obeyed: First, the teaching staff who teaches a subject must be able to teach it. That is, a staff will not teach the subjects corresponding to “0” in Table 3. However, there are 6 subjects that are not taught by the most suitable staff, as indicated by grey background in Table 4. Second, each staff teaches at least one subject, and at most two subjects. Third, the minimum and maximum teaching loads should be satisfied as much as possible. In Table 4, only two staff’s teaching loads are smaller than their minimum ones: NM and TN. Their expected hours are both 5, which means that their minimum numbers of teaching hours are both 2.5. However, NM teaches only 2 hours, and TN teaches only 1.5 hours.

Table 4 The initial teaching load allocation

Subject ID	BN	CW	EM	GJ	LJ	LX	MJ	**NM**	NP	NR	PD	RM	SC	**TN**	WS	WA	ZS	SA	WG	WM
XXX110																			1	
XXX131													1							
XXX141							-			-										
XXX151								-								-				
XXX187			-								-									
XXX201					-							-								
XXX203		-		-																
XXX222	-																	-		
XXX283						1														
XXX302				-											-					
XXX312		-												-						
XXX317/941												-					-			
XXX322									1											
XXX329																1				

XXX9/407														-		-				
YYY412									1											
XXX900	-																			-

The optimization model can be efficiently solved using CPLEX-12.2 (http://www-03.ibm.com/software/products/us/en/ibmilogcpleoptistud/) with default settings, running on a 3 GHz Dual Core PC with 4 GB of RAM, in less than 1 second. The optimized teaching load allocation is shown in Table 5. In the optimized allocation, only 0.5 subject is not taught by the most suitable staff, as indicated by grey background. Nevertheless, in the initial manually designed allocation, 6 subjects are not taught by the most suitable staff. If we assume that the teaching quality is 1 if a subject is taught by the most suitable staff, and 0.8 if it is not taught by the most suitable staff, then compared with the initial manual allocation, the optimized teaching load allocation improves the teaching quality of the school by

$$\frac{(16.5 \text{ subjects} \times 1 + 0.5 \text{ subject} \times 0.8) - (11 \text{ subjects} \times 1 + 6 \text{ subjects} \times 0.8)}{11 \text{ subjects} \times 1 + 6 \text{ subjects} \times 0.8} \approx 7\% \qquad (9)$$

That is, the overall teaching quality is improved by 7% without any additional cost. Moreover, in the optimized allocation, all staff teach 1 or 2 subjects, and their teaching hours are within the minimum and maximum values, because these requirements are captured in the optimization model. In other words, the optimized allocation is more equitable.

Table 5 Optimized teaching load allocation

Subject ID	BN	CW	EM	GJ	LJ	LX	MJ	NM	NP	NR	PD	RM	SC	TN	WS	WA	ZS	SA	WG	WM
XXX110									1											
XXX131			1																	
XXX141					-									-						
XXX151																			-	-
XXX187						-		-												
XXX201													-		-					
XXX203							-			-										
XXX222											-							-		
XXX283										1										
XXX302												-					-			
XXX312		-		-																
XXX317/941												-					-			
XXX322											1									
XXX329																1				
XXX9/407		-		-																
YYY412	1																			
XXX900					-		-													

Conclusions and Discussions

We have developed an optimization model for teaching load allocation. The main benefit of using such an optimization model is to improve teaching quality by allocating suitable teaching staff to teach the subjects. Another benefit is that the teaching load does not need to be manually allocated, which is a time-consuming process, and the maximum teaching load of each staff will not be violated as it is modeled as hard constraints. We have demonstrated the applicability of the model by applying it to the teaching load allocation at a teaching institution in Australia.

Different institutions may have different requirements for teaching load allocation. For example, each subject has a subject coordinator, and it may be considered as one hour's additional teaching load for being a subject coordinator, or two hours' additional teaching load for being a subject coordinator of a subject with more than 200 enrollees. These additional requirements could easily be incorporated in the model by adding constraints and changing the objective function.

A potential improvement of the model is to use teacher evaluation and/or subject evaluation as the indicator of whether a staff is suitable for teaching a subject. In this case, the suitability of a staff for a subject might be a number between 0 and 1, where 0 indicates the lowest suitability and 1 indicates the highest suitability. Then the objective function should be changed to maximize the overall suitability. Again, the model could easily handle this consideration.

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