Optimize Instructor Assignment & Class Scheduling in a Department

Ashish Saxena, Lohit Borah

Optimization (BANA 7020)

MS Business Analytics Program

University of Cincinnati Carl H. Lindner College of Business, Spring 2021

Abstract

Instructor assignment and class scheduling is a complex problem and can be time-consuming. It is also difficult to account for instructor preference and create a balanced schedule. A regularized course schedule boosts both student and instructor performance. By optimizing the assignment process of courses, we can allocate the best instructor to their course of preference. Also, given the current COVID situation and consequent restriction, we need to meet the restriction of maximum utilization threshold of classrooms on campus at a given time.

The problem combines both teacher assignment and course scheduling problems simultaneously and is presented as a mathematical programming model. The model optimizes the instructor satisfaction based on course preference while meeting all other requirements and constraints.

I understand that this project report is optional for extra credit, that the amount of points awarded by this submission is solely determined by the instructor assessment, and that no requests for regrading or complaints about the number of extra points awarded will be admitted.

Lohit Borah | Ashish

(Lohit Borah) | (Ashish Saxena)

Table of Contents

Introduction and Motivation

For the effective working of an institution, available resources should be utilized efficiently. One of the key aspects in achieving this is to instate an efficient instructor assignment and class scheduling system.

Colleges and schools always face the problem of creating a schedule, leading to unequal distribution of classes and subsequent dissatisfaction amongst the instructors. Additionally, sometimes teachers are given courses that they are not equipped to teach. Given the current pandemic situation, educational institutions have also been required to meet COVID restrictions of capacity in and around the campus.

Assignment and scheduling problems have been widely studied for the past several decades to improve delivery and satisfaction in various academic portfolios. Traditionally in colleges and schools, schedules used to be created manually using permutations and combinations to arrive at the best solutions. In large institutions, it had been a very difficult task to do this manually, and mostly these schedules used to be created by looking into past schedules and adjusting schedule instructors/courses based on availability. With modern research in this domain and readily available tools, institutions can utilize resources more optimally.

In this project, we have developed an optimization model to maximize instructor satisfaction based on preference considering several constraints. For this project, we have taken a sample dataset and created an optimized schedule for Master’s in Business Analytics for the upcoming semester.

Literature Review

Instructor assignment and class scheduling is a subset of the larger field of personnel scheduling. It has attracted the interests of many researchers from a variety of disciplines. Since 1960, there have been various approaches to solve this problem. S Daskalaki and T Birbas solved this problem in 2005 by using a decomposition approach involving solution by dividing into two stages. However, by using this approach two models need to be formulated and solved sequentially.

With the advancement in the field of computer science and the availability of various solvers, this problem can be solved easily by IP and MIP formulations. Eddie Cheng, Serge Kruk presented an integer linear model for Oakland University for assigning instructor to courses. The objective of the resulting model was to maximize satisfaction of faculty preferences and department preferences.

Stephen J. Ward, Joseph Foraker, and Nelson A. Uhan proposed a model for creating schedules for courses and instructors at the United States Naval Academy (USNA) in 2017. In this model their objective was to minimize the number of changes required to an existing schedule because of uncertainty of available manpower.

Inga Lilja Eiríksdóttir also presented an optimization model to assign teachers to classes. The objective function was to ensure equality between teachers while trying to grant teacher's preference.

Chirag Ojha developed an optimization model for class scheduling at a dance studio. The resulting model aims to maximize the individual and collective satisfaction of faculty members.

Problem Definition

The OBAIS department at the University of Cincinnati seeks to create a new class schedule which is coherent with university's COVID-19 guidelines restricting attendance and capacity of the available classrooms. The upcoming semester of Spring batch of MS Business Analytics needs a set up that aids instruction simultaneously adhering to the University's directive.

The primary objective is to assign instructors to the subjects being allotted in the semester and schedule their respective classes. While all instructors are competent in teaching all subjects, each has his/her preference order for the same and does not wish to teach some of the offered subjects.

To ensure social distancing, the University has directed that every program should comply with the following guidelines:

1. Each instructor is allowed to teach only a maximum number of subjects to prevent interaction and subsequent hyper-spreading
2. Only a specific percentage of the available classrooms can be occupied at a given time thereby restricting student headcount in the campus

While the university has its guidelines, the department must abide by the following set of specific rules to optimize delivery:

1. Each instructor has to teach for a maximum and minimum number of credits in the semester
2. Not more than a maximum number of teachers can be allotted the same subject
3. In a timeslot, not more than a specific number of courses can be taught

Proposed Model

The department consists of instructors ($t \in T$), who are competent to teach all subjects. However, they have a preference (set P) and will be the most satisfied if subjects of individual preferences are allotted to each of them. The program consists of several courses ($c \in C$) which can be taught in different timeslots ($s \in S$) in available classrooms ($h \in H$) in the department building.

Here T, C, S and H represents the sets of all available instructors, courses, timeslots and classrooms in any semester.

Decision Variables

The decision variable for selection is defined as follows:

X_{tcsh} = 1 if instructor t is selected to teach course c at timeslot s in classroom h
0 otherwise

Objective Function

The solution seeks to maximize the collective satisfaction score of all instructors teaching respective subjects in different available timeslots and classrooms.

Objective function thus becomes:

$$\text{Max} \sum_{t \in T} \sum_{c \in C} M_c \sum_{h \in H} \sum_{s \in S} X_{tcsh} \qquad (1)$$

where M_c represents the number of credits of each course.

Constraints

The objective function is subject to following constraints:

$$\sum_{c \in C} \sum_{h \in H} \sum_{s \in S} X_{tcsh} <= Z_t \quad \text{for every } t \in T \qquad (2)$$

$$\sum_{c \in C} M_c \sum_{h \in H} \sum_{s \in S} X_{tcsh} >= L_t \quad \text{for every } t \in T \qquad (3)$$

$$\sum_{c \in C} M_c \sum_{h \in H} \sum_{s \in S} X_{tcsh} <= U_t \quad \text{for every } t \in T \qquad (4)$$

$$\sum_{t \in T} \sum_{s \in S} \sum_{h \in H} X_{tcsh} <= O_c \quad \text{for every } c \in C \qquad (5)$$

$$\sum_{c \in C} \sum_{h \in H} X_{tcsh} <= O_{ts} \quad \text{for every } t \in T,\ s \in S \qquad (6)$$

$$\sum_{t \in T} \sum_{c \in C} X_{tcsh} <= UL_{hs} \quad \text{for every } h \in H,\ s \in S \qquad (7)$$

$$\sum_{t \in T} \sum_{c \in C} \sum_{h \in H} X_{tcsh} <= OT_s \quad \text{for every } s \in S \qquad (8)$$

$$\sum_{s \in S} \sum_{c \in C} \sum_{h \in H} X_{tcsh} <= K_t \quad \text{for every } t \in T \qquad (9)$$

$$\sum_{t \in T} \sum_{c \in C} \sum_{h \in H} X_{tcsh} <= KT_s \quad \text{for every } s \in S \qquad (10)$$

The objective function (1) will be maximized based on the constraints restricting that each instructor can teach a maximum of Z_t subjects (2), minimum credits mandatory for each instructor are L_t (3), maximum credits mandatory for each instructor are U_t (4), each course can have a maximum of O_c instructors (5), for each instructor in a given timeslot a maximum of O_{ts} courses can be taught (6), each classroom can have at most UL_{hs} courses in a given timeslot (7), in a timeslot at most OT_s courses can be taught (8), each course can have only K_t instructors (9), a maximum of KT_s halls can be utilized in a given timeslot (10).

Model Validation

A sample scenario was considered to validate the model formulation. The scenario is described as in the table below. On formulation and computation using OpenSolver for Excel, the results obtained satisfied all constraints with the optimized assignment and class schedule.

Table 1: Detailed Input Variables for Scenario

Parameter Name	Value
Number of courses	6 (C1: Optimization, C2: Computing, C3: Statistics, C4: Probability, C5: Regression, C6: Forecasting)
Number of instructors	4 (T1: Dr. Alicia, T2: Dr. Muller, T3: Dr. Williams, T4: Prof. Paul)
Number of timeslots	4 (S1: Tue 3-7 PM, S2: Wed 1-5 PM, S3: Thu 6-10 PM, S4: Mon 1-5 PM)
Number of available classrooms	4 (H1: 1020, H2: 1140, H3: 2145, H4: 2210)

For the six selected courses, the respective credits were as in the table below

Table 2: Course Credits

Course Code	Course Name	Credits
C1	Optimization	3
C2	Forecasting	2
C3	Computing	1
C4	Statistics	1
C5	Regression	2
C6	Probability	2

For the parameters, a total of 384 decision variables were created corresponding to each combination. The matrix was then summarized and consumed for constraint calculation and implementation.

For instructors, preference set was selected as in the table below. The highest preference is represented by largest number for each instructor.

Table 3: Instructor Preference Set

	Instructor			
Course Code	T1	T2	T3	T4
C1	4	2	2	4
C2	2	3	1	5
C3	3	1	0	1
C4	1	5	3	0
C5	0	4	0	2
C6	0	0	4	3

The subsequent constraints for formulation of the scenario were as in the table below

Table 4: Detailed Constraint Values for Scenario

Constraint #	**Constraint**	**Value**
1	Maximum subject (Z_t)	2
2	Minimum Credits (L_t)	2
3	Maximum Credits (U_t)	5
4	Maximum Instructors (O_c)	1
5	Maximum courses per Instructor (O_{ts})	1
6	Maximum courses per timeslot-classroom (UL_{hs})	1
7	Maximum courses per timeslot (OT_s)	3
8	Maximum instructors per course (K_t)	1
9	Maximum classrooms per timeslot (KT_s)	3

The resultant course schedule obtained was as in the table below

Table 5: Optimal Course Schedule for Scenario

			Course Code					
Instructor	**Timeslot**	**Classroom**	C1	C2	C3	C4	C5	C6
T1	S2	H4	1	0	0	0	0	0
T1	S4	H4	0	0	1	0	0	0
T2	S2	H1	0	0	0	1	0	0
T2	S3	H1	0	0	0	0	1	0
T3	S1	H3	0	0	0	0	0	1
T4	S3	H2	0	1	0	0	0	0

Conclusion

In this paper, we addressed the teacher assignment and class scheduling problem and proposed a linear algorithm for solving this problem. The experiment conducted in this paper suggest that such an approach can be used to model and solve similar problems. However, as the complexity of the problem or size of data increases, formulation becomes difficult and thus requires an advanced approach. For a small parameter set, the total number of decision variables created was 384. In case of a large size of parameter set, the decision variables would increase significantly.

References

S Daskalaki and T Birbas. An integer programming formulation for a case study in university timetabling.
Link:https://doi.org/10.1016/S0377-2217(03)00103-6

Eddie Cheng, Serge Kruk. An integer linear model for Oakland University for assigning instructor to courses.
Link:http://www.mistaconference.org/2007/papers/A%20Case%20Study%20of%20an%20Integer%20Programming%20Model%20for%20Instructor%20Assignments%20and%20Scheduling%20Problem.pdf?origin=publication_detail

Stephen J. Ward, Joseph Foraker, and Nelson A. Uhan. Create schedules for courses and instructors at the United States Naval Academy (USNA).
Link: http://www.optimization-online.org/DB_FILE/2017/09/6218.pdf

Inga Lilja Eiríksdóttir. An optimization model to assign teachers to classes.
Link:https://skemman.is/bitstream/1946/25612/1/IngaLilja_OptimizationModelforAssigningTeacherstoClasses.pdf

Chirag Ojha. An optimization model for class scheduling at a dance studio.
Link:https://tigerprints.clemson.edu/cgi/viewcontent.cgi?article=2729&context=all_theses