STUDENT CLASS SCHEDULING WITH LINEAR PROGRAMMING

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ABSTRACT

This paper describes a case that illustrates a real-life application that is understandable to undergraduate business students in an introductory management science course. The case shows how to use a simple integer linear programming model to find an optimal class schedule for a student. The case analysis is followed by an optional assignment in which students formulate their own class schedule using the similar approach. This case-and-assignment combination offers students several benefits: an interesting example they can identify with, applying an optimization method immediately in their own life, and experiencing the modeling process from start to finish.

Teaching optimization, scheduling, integer programming

1. INTRODUCTION

Class scheduling, from the perspective of a school or a department, is a difficult problem. Typically, each course must be assigned an instructor, time slot(s) during the week, and a classroom. At any given time slot, at most one course can be assigned to an instructor and a room. The requirements and preferences of the instructors, estimated enrollment of students, and characteristics of the course must also be taken into account. There is extensive literature on the class scheduling (see for examples [1] [3] [4] [5] [6] [8]). From the perspective of the student, class scheduling is not as complicated as creating an entire schedule of classes for the department, but it involves balancing numerous desires and constraints. At many universities, students typically spend a significant amount of time choosing classes to take each term, poring over many alternative schedules that may fit around their internship and work schedule and discussing with others the advantages and disadvantages of various courses and instructors.

The case presented here shows how a student's class schedule can be designed using a linear programming model. It is simple enough for an introductory undergraduate management science course. It is highly motivating and relevant to the students. After the case discussion, students are asked to formulate their own class schedule for the upcoming term. This follow-up assignment lets students see the benefit of using an optimization method in their own life. In addition, they gain the experience of undergoing all the typical steps of the quantitative decision making process: problem definition, model development, data collection, model solution, and implementation.

Teaching cases and pedagogical articles that cover the use of optimization models for scheduling exist in the management science literature. For example, Birge (2004) and Trick (2004) both address using integer programming in scheduling sports teams. However, to the best of our knowledge, class scheduling by students - as an application of optimization - has not been addressed in a teaching case or article. The next section contains the case and the assignment given to the students. It is followed by discussion of background and teaching objectives in section 3 and case analysis process in section 4. Our experience with the case-and-assignment combination is discussed in section 5 and alternative approaches are given in section 6.

2. CASE AND ASSIGNMENT DESCRIPTION

2.1 Case: Kelly's Class Scheduling

Kelly is a senior majoring in finance at Smith University with one more semester left to go. After a graduation audit, she was told she has five more courses she needs to take: Business Strategy (MGT 490), International Finance (FIN 358), one service-learning course and any two finance elective courses. A service-learning course is a requirement at the university that has a community service component. Many of the service-learning courses are offered by the Computer Information Systems Department, and Kelly would like to take one of those. In particular, two courses she finds interesting are Intergenerational Computing (CIS 102T), which involves teaching senior citizens how to use the computer, and Web Design for Non-Profit Organizations (CIS 102W). After looking at the finance course offerings, she noticed four potential finance elective courses she would consider taking: Data Analysis in Finance (FIN 325), Risk Management (FIN 352), Options, Futures and Swaps (FIN 356) and Fixed Instruments and Markets (FIN 359). Kelly would like to avoid morning classes because her internship requires her to work a few hours in the morning most of the weekdays.

As she makes up her schedule, Kelly would like to keep in mind her priorities. Her priorities are first, the content of the course, second, the reputation of the instructor, and the third, the timing of the course. She decided she will assign a rating between 1 and 5 to each course section under consideration. From the online class schedule, she has made a list of course sections offered. These data are given in Table 1. All of the courses have at least two alternative sections. Some sections meet once a week for three hours, and some meet twice a week alternating between one-hour and two-hour periods. Note an "hour" at Smith University is 55 minutes long. To get the rating of the course sections, Kelly took into account three factors, content, instructor, and timing. The rating is the weighted average of the three factor ratings. She rated the content of the course based on her interest in it, and this is a value from 1 (poor) to 5 (extremely interested). The reputation of the instructor is also a value from 1 to 5, coming from published student comments (www.ratemyprofessors.com) and word of mouth from classmates. The timing of the course is also a number from 1 to 5, and takes into account things such as the times that most of the senior class gets together in the Common Rooms to watch shows such as *Glee, The Walking Dead,* and *Jersey Shore*.

Questions

Determine a schedule of classes for Kelly that will yield the maximum total rating.

(1) Kelly heard a rumor that the management department is considering offering an online section of MGT 490 taught by Professor Dan Braun. Kelly had a good experience with Prof.

Braun when she took Introduction to Management course from him. In addition, as an online course does not have meeting times, it would not conflict with other courses. She would give such a course rating of 5. How would Kelly's schedule change if this online course became available?

Table 1: Available courses data

Course	Title	Meeting Time(s)	Rating
MGT 490	Business Strategy	M 6-8:45 pm	4.3
MGT 490	Business Strategy	T 6-8:45 pm	3.8
MGT 490	Business Strategy	W 6-8:45 pm	3.5
MGT 490	Business Strategy	F 6-8:45 pm	3.5
MGT 490	Business Strategy	M 1:25-2:20 pm & W 1:25-3:15 pm	4.6
MGT 490	Business Strategy	T 1:25-3:15 pm & Th 1:25-2:20 pm	2.7
FIN 358	International Finance	W 6-8:45 pm	3.5
FIN 358	International Finance	T 1:25-3:15 pm & Th 1:25-2:20 pm	3.3
CIS 102T	Intergenerational Computing	W 2:30-5:15 pm	4.4
CIS 102T	Intergenerational Computing	Th 2:30-5:15 pm	3.1
CIS 102W	Web Design for Non-Profit Org'ns	T 6-8:45 pm	3.7
CIS 102W	Web Design for Non-Profit Org'ns	W 2:30-5:15 pm	3.5
FIN 325	Data Analysis in Finance	Th 6-8:45 pm	3.0
FIN 325	Data Analysis in Finance	M 1:25-2:20 pm & W 1:25-3:15 pm	3.7
FIN 352	Risk Management	M 6-8:45 pm	3.6
FIN 352	Risk Management	M 1:25-3:15 pm & W 1:25-2:20 pm	3.9
FIN 356	Options, Futures and Swaps	T 6-8:45 pm	3.2
FIN 356	Options, Futures and Swaps	T 1:25-3:15 pm & Th 1:25-2:20 pm	3.4
FIN 359	Fixed Instruments and Markets	M 6-8:45 pm	3.0
FIN 359	Fixed Instruments and Markets	W 6-8:45 pm	3.5

(2) Kelly would like to see if she can have a schedule that requires her to attend class only three days a week. She feels such a schedule may help her allocate her time better between study

and relaxation. She may consider it if this does not lower her maximum rating too much. Determine the maximum rating three-day schedule.

2.2 Follow-up Assignment: Make Your Own Schedule

The purpose of this assignment is to create a good schedule for your next semester. If you will not be taking classes next semester, you can create a hypothetical schedule as if you were going to repeat your current semester during the upcoming semester.

Part 1: Formulate the problem and collect data. **(This part is due before the case discussion.)**

- What is important to you as you make up your schedule? If there is more than one important consideration, see if you can rank them. (For example, quality of instructor, time of the day, course content, etc.) What are the constraints? For example, no class on certain day of the week, at least one day off from classes, work schedule, time of day, etc.
- What are the courses you need to take next semester?
- What are the courses you might take next semester if they fit in your schedule, but could take later?
- List all the possible course sections that you could take from the online class schedule.
- Assign a rating to each of these sections. The rating would depend on the factor(s) that are important to you. If you are indifferent, you can assign the same rating (say, 1) to each section.

Part 2: Formulate the model and solve.

- Determine your optimal class schedule by following the method used in the case analysis. Specifically, using your own data from Part 1, build a model in Excel and solve with Excel Solver.

Part 3: Summarize the solution.

- What is the optimal schedule? Make a list of the courses with the meeting times.
- Make an alternate schedule that you might use if one of the course sections in your optimal schedule is closed.

Part 4: Evaluation:

- Do you plan to use the schedule you came up with from this method? Why or why not?

3. BACKGROUND AND TEACHING OBJECTIVES

The case, “Kelly’s Class Scheduling,” has been used in MGT 355 at Pace University, a junior-level introductory management science course required of all undergraduate students in the business school. This course typically covers decision analysis, forecasting, linear programming (may include some network models), Monte Carlo simulation, inventory models, queueing models, and project scheduling. Students are juniors and seniors who have taken a finite mathematics (a freshman level course covering introduction to probability concepts, linear programming and basic financial mathematics) and a statistics course as pre-requisites. A substantial portion of students have very weak quantitative skills, and many have only rudimentary knowledge of Excel.

The main objective of this case is to expose students to a realistic, but fairly basic, optimization model that even the weaker students can formulate and solve on their own. For all students, formulating upcoming semester's schedule is an important part of their student life. Since class scheduling is a familiar situation, the instructor does not need to spend time on any background information, and students do not need to read any background material to understand the case. The case discussion takes approximately 1 ¼ hours.

This case alone was used for class discussion for two semesters with varied data. During that time, several students indicated they would like to try to build their own class schedule following the same method. In the most recent semester, we added "Make Your Own Schedule" assignment as a follow up to the case. The addition of such an assignment helps students retain the modeling concepts, see how the optimization model can be applied to their own life and experience the whole process of problem definition, data collection, modeling, analysis and the evaluation.

4. CASE ANALYSIS PROCESS

4.1 Preparation

The way we have integrated the case and the follow-up assignment is to show how to solve the case in class then have students work on their own schedule. The case is discussed after the students have been exposed to linear programming and simple transportation and assignment models. The case discussion is timed just before the registration period, after the subsequent semester's course offerings become available online. Both the case and the assignment are handed out before the case discussion. They are also asked to read the case and complete Part 1 of the assignment where they:

- Identify the important priorities and requirements for the next semester's schedule
- Using the online class schedule, make a list of the course sections they would consider taking
- Rate each course section based on their priorities

Hence, when they come to the case discussion, students have defined their problem, have collected the relevant data, and are motivated to learn how to model the problem. The case discussion proceeds in the following steps:

1. Organize the data in a table with distinct time slots as rows and courses as columns.
2. Find a near-optimal solution by a simple greedy heuristic of choosing the highest ranking choice at each step.
3. (Optional) Express the problem as a linear programming model.
4. Formulate the model in Excel and solve with Excel Solver.
5. (Optional) Discuss variations to the model such as limiting the number of school days and adding the option of online courses.

Due to the space limitation, we do not describe every step in detail here. The teaching note with detailed steps, the full algebraic model and the Excel solution file are available from the corresponding author.

The key step in the modeling process is to organize the data in a table in a way that is understandable and manageable. Such a data table is shown in Figure 1. The rows in the data table represent distinct meeting patterns, the columns represent distinct courses, and the entries correspond to the course section ratings. The rows are allowed to overlap in time. For example, one row might represent the meeting pattern of Mondays 1:25-2:20 pm and Wednesdays 1:25-3:15 pm and another row might represent the meeting pattern of Wednesdays 2:30-5:10 pm. (These rows correspond to time slots 7 and 8 in Figure 1.) The possibility of a student choosing courses in the overlapping time patterns is eliminated by adding an appropriate constraint. This approach is simpler than having rows represent all of the non-overlapping time periods throughout the week (for example, 8 rows for Monday, 8 rows for Tuesday, etc.), which can quickly become unwieldy when courses have a variety of meeting patterns.

Figure 1: Data table

	A	B	C	D	E	F	G	H	I	J
3	**Data**									
4										
5					**Available Courses, Time slots, and Ratings**					
6			Courses							
7			1	2	3	4	5	6	7	8
8		Time Slots	MGT 490	FIN 358	CIS 102T	CIS 102W	FIN 325	FIN 352	FIN 356	FIN 359
9	1	M Eve	4.3					3.6		3
10	2	T Eve	3.8			3.7			3.2	
11	3	W Eve	3.5	3.5						3.5
12	4	Th Eve					3			
13	5	F Eve	3.5							
14	6	M 1:25-3:15 W 1:25-2:20						3.9		
15	7	M 1:25-2:20 W 1:25-3:15	4.6				3.7			
16	8	W 2:30-5:15			4.4	3.5				
17	9	T 1:25-3:15 Th 1:25-2:20	2.7	3.3					3.4	
18	10	Th 2:30-5:15			3.1					

In general, we have found it helpful in our introductory course to experiment and explore hypothetical solutions before formally modeling the problem. This helps students develop intuition and understand the model when it is presented. For this purpose, the second step is important. We have borrowed a version of the minimum-cost method from the transportation model algorithm for this, choosing the highest-rated cell each time instead of the minimum-cost cell. For example, in the first step, we choose the cell in row 7 and column 1 with 4.6, the highest rating. The corresponding course, MGT 490 meeting at MW 1:25 pm is added to the schedule. Then row 7 and column 1 are crossed out, and next, we choose the cell with the highest rating among the remaining cells. These steps are repeated until all of the rows and columns are crossed out. This approach leads to a schedule with the total rating of 18.8. This greedy heuristic makes intuitive sense, and the act of crossing out rows and columns that are “done” (highlighting the corresponding cells in Excel) visually drives home the point that each decision eliminates many other potential choices. The first two steps, organizing the data in a table and using some intuitive logic to make choices, are valuable lessons in themselves even if students do not retain the optimization modeling concepts in the long run.

4.2 Basic Model

The model we use is a variant of assignment model with binary decision variables. We explain that for each available course section, we either take it or not take it, so we can assign a “yes-or-no” variable for each, the same way as in assignment models. Let

$$x_{ij} = \begin{cases} 1, & \text{if course } j \text{ is taken at time slot } i \\ 0, & \text{else} \end{cases} \qquad (i = 1, 2, \ldots, 10;\ j = 1, 2, \ldots, 8)$$

The objective is to maximize the total rating from the courses in the schedule:

$$\sum_{i=1}^{10} \sum_{j=1}^{8} c_{ij} x_{ij}$$

where c_{ij} = rating of the course j at time slot i shown in the data table in Figure 1.

The constraints need to be formulated to account for following requirements:

1. Do not take more than one section of each course.
2. Do not take more than one class during any time slot or during any set of overlapping time slots.
3. Take MGT 490 and FIN 358.
4. Take exactly two courses out of FIN 325, 352, 356, and 359.
5. Take one of CIS 102T and CIS 102W.
6. Take exactly five courses.

Figure 2 displays the Excel model with the optimal solution and formulas shown in cells. Each row sum in column K represents the number of courses taken during the corresponding time slot (or during a number of overlapping time slots), and each column sum in row 38 represents the number of sections taken of the corresponding course. The fourth and the fifth requirements are shown in rows 44 and 45. Of course, the nonnegativity constraint should be specified in Excel Solver.

As the problem size is small, it is not necessary to limit the decision variables to only the existing course sections. Here, it should be clarified to the students that because the ratings for non-existing course sections are 0, including non-existing course sections in the Excel model does not affect the solution.
Notice the model can be represented by a minimum-cost network flow problem (MCNFP) with integer right-hand-side values. Because of total unimodularity, there is no need to add integer constraints to ensure the integer optimal solution [7, Ch7 and 13]. In addition, because of the

first two requirements, no variable will be assigned a value higher than one, so there is no need for upper bound constraints on the variables.

Figure 2: Excel model with the formulas

	A	B	C	D	E	F	G	H	I	J	K	L	M
5					Available (								
6			Courses										
7			1	2	3	4	5	6	7	8			
8		Time Slots	MGT 490	FIN 358	CIS 102T	CIS 102W	FIN 325	FIN 352	FIN 356	FIN 359			
9	1	M Eve	4.3					3.6		3			
10	2	T Eve	3.8			3.7			3.2				
11	3	W Eve	3.5	3.5						3.5			
12	4	Th Eve					3						
13	5	F Eve	3.5										
14	6	M 1:25-3:15 W 1:25-2:20						3.9					
15	7	M 1:25-2:20 W 1:25-3:15	4.6				3.7						
16	8	W 2:30-5:15			4.4	3.5							
17	9	T 1:25-3:15 Th 1:25-2:20	2.7	3.3					3.4				
18	10	Th 2:30-5:15			3.1								
19													
20	Model												
21													
22		Decision Variables											
23			Courses										
24			1	2	3	4	5	6	7	8	Time Slot Const		
25		Time Slots	MGT 490	FIN 358	CIS 102T	CIS 102W	FIN 325	FIN 352	FIN 356	FIN 359	Time Slot Taken		Limit
26	1	M Eve	1	0	0	0	0	0	0	0	=SUM(C26:J26)	≤	1
27	2	T Eve	0	0	0	0	0	0	0	0	=SUM(C27:J27)	≤	1
28	3	W Eve	0	1	0	0	0	0	0	0	=SUM(C28:J28)	≤	1
29	4	Th Eve	0	0	0	0	0	0	0	0	=SUM(C29:J29)	≤	1
30	5	F Eve	0	0	0	0	0	0	0	0	=SUM(C30:J30)	≤	1
31	6	M 1:25-3:15 W 1:25-2:20	0	0	0	0	0	1	0	0			
32	7	M 1:25-2:20 W 1:25-3:15	0	0	0	0	0	0	0	0	=SUM(C31:J32)	≤	1
33	8	W 2:30-5:15	0	0	1	0	0	0	0	0	=SUM(C32:J33)	≤	1
34	9	T 1:25-3:15 Th 1:25-2:20	0	0	0	0	0	0	1	0	=SUM(C34:J34)	≤	1
35	10	Th 2:30-5:15	0	0	0	0	0	0	0	0	=SUM(C35:J35)	≤	1
36													
37		Course Constraints											
38		Course Taken	=SUM(C26:C35)	=SUM(D26:D35)	=SUM(E26	=SUM(F26	=SUM(G26	=SUM(H26	=SUM(I26:	=SUM(J26:	=SUM(C38:J38)		
39			=	=	≤	≤	≤	≤	≤	≤	=		
40		Required	1	1	1	1	1	1	1	1	5		
41													
42		Other Constraints											
43				Taken		Required							
44		One CIS course		=SUM(E26:F35)	=	1							
45		Two FIN Electives		=SUM(G26:J35)	=	2							
46													
47		Objective Function											
48		Total Rating	=SUMPRODUCT(C9:J18,C26:J35)										

4.3 Extensions

In Kelly's Class Scheduling case, the first question asks to find the optimal schedule. The second and the third questions give variations to the model. If the students are asked to build their own schedule as a follow-up assignment, some will think of other variations pertinent to their situation that are not included in the case. This can lead to a lively class discussion. First, we discuss the variations that are mentioned in the case.

Question 2 in Case - Online Courses. Online courses can be added to the model simply by adding a time slot named "online." Since there is no concern of time conflict for online courses, we do not need a time slot constraint for the online time slot.

Question 3 in Case - Limiting the Number of School Days. Many students tend to be concerned with limiting the number of days they have to be at school. This can be handled with additional variables as follows:

$$y_k = \begin{cases} 1, & \text{if any course is taken on day } k \\ 0, & \text{else} \end{cases} \qquad (k = M, T, W, Th, F)$$

As Kelly does not want to come to school more than 3 days of the week, we need a constraint:

$$y_M + y_T + y_W + y_{Th} + y_F \le 3$$

The relationship between *x* and *y* variables is on the days for which $y = 1$, Kelly can take classes, and on the days for which $y = 0$, she cannot take classes. Hence, we need a constraint for each day of the week that says: the number of courses taken on that day should be no more than a multiple of the corresponding *y* value. This multiple can be any value greater than or equal to the total number of courses that should be taken. Hence, the additional constraints (using only the relevant variables) can be written as:

$$\begin{aligned}
&x_{11} + x_{16} + x_{18} + x_{66} + x_{71} + x_{75} && \le 5y_M \\
&x_{21} + x_{24} + x_{27} + x_{91} + x_{92} + x_{97} && \le 5y_T \\
&x_{31} + x_{32} + x_{38} + x_{66} + x_{71} + x_{75} + x_{83} + x_{84} && \le 5y_W \\
&x_{45} + x_{91} + x_{92} + x_{97} + x_{10,3} && \le 5y_{Th} \\
&x_{51} && \le 5y_F \\
&y_M + y_T + y_W + y_{Th} + y_F && \le 3 \\
&y_M, y_T, y_W, y_{Th}, y_F && = 0 \text{ or } 1
\end{aligned}$$

The addition to the Excel model is shown in Figure 3. In Solver, in addition to the new variables and constraints in Figure 3, binary constraints for *y* variables need to be included. Below, we discuss other various issues that may arise when students build their own schedules.

- *Need for multiple schedules*. In building their own schedules, students usually like to have alternative schedules. Some other constraints might arise after the optimal schedule is found. These could include courses that close before they can register, changes in work schedules, and so on. A simple way to handle this is to run solver after deleting the rating of a course that is likely to fill up or the ratings of the time slots that may become unavailable. It can be also be handled by adding constraints forcing some variables to be 0 (for course sections that might not be allowed) or 1 (course sections that might have to be chosen).

Figure 3: Additional variables and constraints in the three-day schedule Excel model

	H	I	J	K	L	M
42	**Number of School Days Constraints**					
43		School Day?		No. of classes on this day		
44	M	1		=SUM(C26:J26,C31:J32)	≤	=$K$40*I44
45	T	1		=SUM(C27:J27,C34:J34)	≤	=$K$40*I45
46	W	1		=SUM(C28:J28,C31:J33)	≤	=$K$40*I46
47	Th	0		=SUM(C29:J29,C34:J35)	≤	=$K$40*I47
48	F	0		=SUM(C30:J30)	≤	=$K$40*I48
49						
50	Sum	=SUM(I44:I48)			≤	3

- *No class certain day of the week (say Friday).* Do not include courses that are held on that day in the data table or assign 0 rating to the corresponding variables.

- *No more than two evening courses.* This can be formulated as: sum of variables that correspond to evening sections ≤ 2.

- *Paired courses.* For example, Introduction to Business (BUS 150) that meets MW 1:25 must be taken with Introduction to Computing (CIS 101) that meets W at 2:30. The pair of these course sections should be treated as one course.

- *Co-requisites.* Managerial Accounting (ACC 204) is a co-requisite to Introduction to Finance (FIN 206), so if a student takes FIN 206, he needs to take ACC 204 as well, but not vice versa. The constraint should be: number of FIN 206 sections taken $\leq$ number of ACC 204 sections taken.

5. EXPERIENCE

As the solution of the case was discussed in class, we focus the discussion of our experience on the follow-up assignment. In the semester we included the "Make Your Own Schedule" assignment, the assignment was collected from 46 students. Approximately 40 students had no trouble with the basics: building a table from the list of their course sections, taking no more than one class per time slot, taking no more than one section of the same course, using Excel =SUM and =SUMPRODUCT functions and solving with Excel Solver. Three others did the problem using only the heuristic and skipped the optimization model, and three students turned in a nonsensical solution. Among those who understood the basics, a common error was forgetting a constraint for overlapping time slots. Grading of the assignment took more time than usual since it was individualized. However, it was not overly burdensome as everyone had formulated the same type of model.

As a part of the assignment submission, students were asked the question, "Do you plan to use the schedule you came up with from this method? Why or why not?" Out of 46 students who submitted the assignment, 33 students said yes, 3 said no, 4 were unsure, and 6 did not answer. Among the three students who said no, two were graduating students (so they will not be registering for classes) and one apparently did not understand the case and submitted a completely wrong solution. Some of the stated reasons for using the optimal schedule was as follows:

"Solver did the thinking for me when it comes to figuring out what time to take each class and that was very cool."

"Usually when making my schedule, I would make chart after chart with all the alternatives. This saved me a lot of time!"

"I do plan to use this schedule because it incorporates all my constraints and solver's optimal solution is my own optimal solution. Additionally, it allows me to put in more hours at work."

Some reasons for being unsure were:

"I might use this schedule for my classes next semester if my current work and internship situation stay the same."

"I would like to use this method I came up with, but I would prefer to make my own schedule myself. This takes too much time to choose classes."

"I plan to use the schedule as a guideline because my work schedule can change and I need to get more information on the professors before deciding on the final schedule."

Of course, the situation can change between the completion of this assignment and the actual registration. To follow up, students were asked on an anonymous end-of-semester survey whether they ended up using the optimal schedule they obtained from this assignment. Approximately 40 percent chose the response "yes," 30% chose the response "yes with some changes," and the remaining 30% responded "no." The reasons for not using the optimal schedule were: a desired class filled up (the most common reason), changed mind about what courses to take or what days to take courses, found out new requirements or new prerequisites after talking to the adviser, work schedule changed, and forgot to account for some constraints in the model, and made mistakes in the assignment.

It is not clear whether this assignment helped students save time in building their class schedule. There were mixed opinions as seen in the comments above. The assignment forced students to collect and systematically organize all their options and use a new method to make the decision. This may have taken more time than their usual trial-and-error method. However, most students felt this method improved the quality of their decision. On the student course evaluation, the optional comment section contains the question "what aspects of this course did you like the most?" Several students responded along the lines of "practical applications to everyday life/real world."

6. ALTERNATIVE APPROACHES

In our experience, the class scheduling case was used in an introductory course with limited time and a substantial portion of students with weak quantitative skills. Thus, our approach was to go through the entire process in detail inviting students to give input at each step. The emphasis was on the assignment, and the case discussion was viewed as a means to completing the assignment. However, there are a number of alternative approaches other instructors might consider. Whichever approach is used, instructors may find it worthwhile to modify the case data based on the courses and meeting times offered at their institution. It helps increase students' interest when they recognize the familiar settings.

Having students create their own schedules allowed them to apply what they learned immediately in their own life, and increased their enthusiasm about the subject. However, assigning such an individualized assignment may not be practical or feasible for many instructors. Some of the possible problems are grading burden, difficulty of coordinating with the registration schedule, and insufficient number of class choices to make an interesting model. Hence, many instructors may choose to assign the case itself rather than include a follow-up assignment. The case can be analyzed in class, and students can be assigned to submit the finished solution. In that case, we suggest the following steps.

1. Before the case discussion, ask the students to read the case and build a data table with distinct time slots as rows and courses as columns. To guide the students, instructors may want to distribute an Excel template that contains only the basic layout of the data and the model.
2. Review the data table in class.
3. Explain the greedy heuristic and show the first step or two. Have students finish the rest. Review the results of heuristic.
4. (Optional) If using algebraic model, introduce the decision variables. Using the heuristic solution, illustrate the objective function. Write in words some of the constraints and translate into algebraic expressions. Ask students formulate some of the other constraints.
5. Explain that each cell in the blank table of the shell represents course in a time slot. The value in that cell could be either one (indicating take that course in that time slot) or zero (don't take that course in that time slot). Illustrate the heuristic solution by placing 1's in the corresponding cells.
6. Ask students to submit the case solution by completing and solving the model. Students should be able to do this assuming they have been exposed to an Excel model of transportation or assignment problem.

Question 3 in the case is difficult for inexperienced undergraduate students. If students are assigned to solve the case, we recommend either omitting this question or replacing it with a question about specific three-day combinations. For instance, can Kelly have Monday/Wednesday/Friday schedule? How about Monday/Tuesday/Thursday?
In a more advanced course, the case could be assigned as a homework problem without much class discussion. In that case, instructors may want to distribute a template with more information, giving guidance on the constraints and the objective function. Another approach is to completely discuss the case solution in class then give students an assignment of modifying

the case model to account for various situations. These can include the variations included in the teaching notes. Other variations such as scheduling for two terms could be considered.

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