MIT MANAGEMENT SLOAN SCHOOL

Master of Business Analytics

6.7201: Optimization Methods

Is it possible to be an MBAn?
Optimal scheduling for the Master of Business Analytics class of 2023

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Contents

1 Introduction

The Master of Business Analytics (MBAn) program at MIT Sloan and The Operations Research Centre is a 12-month intensive program that equips its graduates with the machine learning and optimization tool-kit required to be effective data scientists in industry. A primary component of the program is the Fall core, during which the students take five classes, four of which have semester-long group projects, three of which have bi-weekly problem sets and two of which have final exams. On top of this, many within the cohort take on research assistantships (RAs), a 10-hour-per-week commitment. Some join the leadership team, MIT clubs and other extracurriculars. Arguably most importantly, all students need time to take care of themselves physically and mentally, eat properly and maintain a healthy sleep schedule. This means students need to plan weekly meetings with potentially 10s of others, complete their work, attend classes and recitations, engage in student life and find time to rest and take care of themselves. Not only does planning all of this take time, but can be highly stress inducing for many. To this end, we sought out to build an optimal scheduling model to help our friends plan their time, ensuring they engage in all their commitments, while making the most out of their time here.

2 Data

In order to gather relevant data, we sent a form to the whole MBAn class (78 students), requesting each student to list:

- all their team members for each class' group project
- whether or not they are doing an RA
- any other personal commitments e.g participation in student clubs or praying schedules

We received 47 responses, which is more than 60% of the entire MBAn class. Based on collected data, each student was assigned a unique index (denoted as S in 2) and all the activities were grouped into 11 categories (denoted as A in 2). Subsequently, survey data was further pre-processed into a matrix structure for each subject of the form:

$$[[Student\,1, Student\,5], [Student\,3, Student\,99], [Student\,10, Student\,4], ...] \tag{1}$$

where each array contains indices of students doing projects together.[1]

$$\begin{aligned} S =& [47] \\ A =& \{sleep, free\,time, class, Analytics\,Lab\,project\,meeting, \\ & Analytics\,Edge\,project\,meeting, Machine\,Learning\,project\,meeting, \\ & Optimization\,project\,meeting, research\,work, \\ & eat, study, personal\,commitments\} \end{aligned} \tag{2}$$

[1]In the case of project groups that contained student names who didn't submit their survey or to maintain proper array lengths, the index 99 was imputed.

3 Problem Formulation

What makes a schedule optimal is extremely subjective. While some aspects of proper scheduling are ubiquitous, others depend greatly on personal preferences. For example, some prefer waking up earlier to be productive, while others prefer staying up later in the evening. Furthermore, the nuances and levels of complexity that can be included in this problem create a rabbit hole; there is always something else that could be added to the model. In order to make our model generalizable, we make as few assumptions as possible. All the necessary assumptions are described in subsection 4.3.

4 Optimization Formulation

4.1 Decision Variables

For each student ($s \in [S]$), we want to define a weekly schedule, i.e. tell them what activity ($a \in [A]$) to do, every day ($d \in [7]$), at every 30-minute time slot ($t \in [48]$). We therefore have a decision variable of the form: $x \in \mathbb{R}^{|S|,|A|,7,48}$, where:

$$x_{s,a,d,t} = \begin{cases} 1 & \text{if student } s \text{ is doing activity } a \text{ on day } d \text{ at time } t \\ 0 & \text{otherwise} \end{cases} \tag{3}$$

We also have secondary decision variables, one for each class $c \in [C]$:

$$z^c_{g,d,t} = \begin{cases} 1 & \text{if group } g \text{ for class } c \text{ meets on day } d \text{ starting at time } t \\ 0 & \text{otherwise} \end{cases} \tag{4}$$

This decision variable is explained in equation 4.3.

4.2 Objective function

In the spirit of making as few assumptions as possible, we simply try to maximize free time, weighted such that the value of 30 minutes of free time is:

$$v_{d,t} = \begin{cases} 5 & \text{during Friday / Saturday 5pm on-wards} \\ 3 & \text{during weekday (except for Friday) / Sunday 5pm on-wards} \\ & \text{or Saturday / Sunday 11 am - 5 pm or weekday 8 am - 9 am} \\ 1 & \text{otherwise} \end{cases} \tag{5}$$

We can then formulate our objective function as follows:

$$\max_{x,z} \quad \sum_{s=1}^{S} \sum_{d=1}^{7} \sum_{t=1}^{48} v_{d,t} x_{s,free\,time,d,t} \tag{6}$$

4.3 Constraints

Given we have constructed the decision variable to include *free time* as an activity, we have that every student must be doing an activity at all times, namely:

$$\sum_{a=1}^{A} x_{s,a,d,t} = 1 \quad \forall s \in [S] \quad \forall d \in [7] \quad \forall t \in [48] \tag{7}$$

We also want to guarantee certain amounts of sleep every night. Note, in a setting where each student inputs their own sleep requirements, this can be made more flexible. Our base assumption is 8 hours of sleep per weekday night and 9 per weekend night, while assuming that on Friday and Saturday nights, students might choose to stay up later.[2]

$$\begin{aligned} &x_{s,sleep,d,1:14\cup 47:48} = 1 \quad \forall s \in [S] \quad \forall d \in [4] \\ &x_{s,sleep,5,1:14} = 1 \quad \forall s \in [S] \\ &x_{s,sleep,6,3:20} = 1 \quad \forall s \in [S] \\ &x_{s,sleep,7,3:20\cup 47:48} = 1 \quad \forall s \in [S] \end{aligned} \tag{8}$$

Additionally, once we had a constraint on the minimum amount of sleep, we added a constraint for eating and getting ready, in order to assure that students have enough time to wake up, eat properly and get to where they need to be. We assumed 1h for breakfast and 30 minutes for lunch, given that student will likely already be awake and on campus by lunchtime. We didn't include a specific time for dinner, since it varies greatly person to person. We assume everyone will eat dinner during their free time (free time is very likely to happen during the evening, since it is considered more valuable by the objective function, see 5).

$$\begin{aligned} &x_{s,eat,d,15:16\cup 26} = 1 \quad \forall s \in [S] \quad \forall d \in [5] \\ &x_{s,eat,6,21:22\cup 31:32} = 1 \quad \forall s \in [S] \\ &x_{s,eat,7,21:22\cup 31:32} = 1 \quad \forall s \in [S] \end{aligned} \tag{9}$$

We enforce everyone to attend class and recitations, in order to keep up with coursework properly.

$$x_{s,class,d,classes(d)} = 1 \quad \forall s \in [S] \quad \forall d \in [7] \tag{10}$$

where $classes(d)$ = time slots on day d in which MBAns have class.

Every student has to meet with each of their project groups for 2 hours per week. For now we assume this to be consecutive, however, it could easily be adjusted to be two 1-hour sessions. We introduce our secondary decision variable, $z^c_{g,d,t}$, which acts as an indicator for groups being able to meet, as described in equation 4.1

$$\begin{aligned} &z^c_{g,d,t} \leq x_{s,c,d,t'} \quad \forall g \in [G_c] \quad \forall c \in [C] \quad \forall d \in [7] \quad \forall t \in [45] \quad \forall t' \in [t, t+1, t+2, t+3] \quad \forall s \in g \\ &\sum_{d=1}^{7} \sum_{t=1}^{45} z^c_{g,d,t} \geq 1 \quad \forall g \in [G_c] \quad \forall c \in [C] \end{aligned} \tag{11}$$

[2]Given the problem construction, this will almost certainly be free time, meaning students can opt to spend it sleeping if they wish.

Additionally, since classes require regular revising of advanced materials presented during lectures, completing homework and working on individual tasks assigned in different projects, we estimate a total of 44 hours of studying per week per student. This is based on estimates provided by MIT's Registrar Office.

$$\sum_{d=1}^{7}\sum_{t=1}^{48} x_{s,study,d,t} \geq 88 \quad \forall s \in [S] \tag{12}$$

We assigned an additional 10 hours of research per week to each student who is participating in an RA, according to the survey (S_{RA}).

$$\sum_{d=1}^{7}\sum_{t=1}^{48} x_{s,research\,work,d,t} \geq 20 \quad \forall s \in [S_{RA}] \tag{13}$$

We added personal commitments specified by students in the survey. They included activities such as study clubs, praying times, calls with family, sports etc... Due to their private nature, we decided not to present them explicitly. Some of these could be flexible, like the research constraint 4.3, or hard-coded for a specific time like class constraints 4.3.

Last but not least, we have our binary enforcement constraints:

$$\begin{aligned} z^c_{g_i,d,t} &\in \{0,1\} \quad \forall g \in [G_c] \quad \forall c \in [C] \quad \forall d \in [7] \quad \forall t \in [45] \\ x_{s,a,d,t} &\in \{0,1\} \quad \forall s \in [S] \quad \forall a \in [A] \quad \forall d \in [7] \quad \forall t \in [48] \end{aligned} \tag{14}$$

5 Results

After successfully developing and executing the models, we can confidently state that it is indeed possible to be an MBAn during the fall semester, while maintaining some form of work-life balance, at least during the weekends. This however, varies dramatically student to student, in large part due to some being more involved than others, but partially due to luck of the draw, as to how the "optimal" scheduling plays out. Note that minimizing a cumulative objective means that there could be large disparities across students, even when we ignore varying levels of commitments. This can be observed in Figure 1.

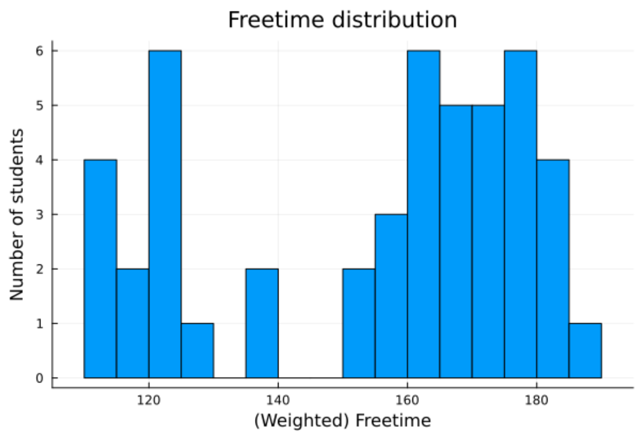

Figure 1: The distribution of weighted free time amongst students in the class.

Furthermore, as we can observe in Figure 2, not all students can study during ideal times. Because of additional private commitments, research, or poor luck relative to the global optimum, some students are required to spend some evenings and weekends working.

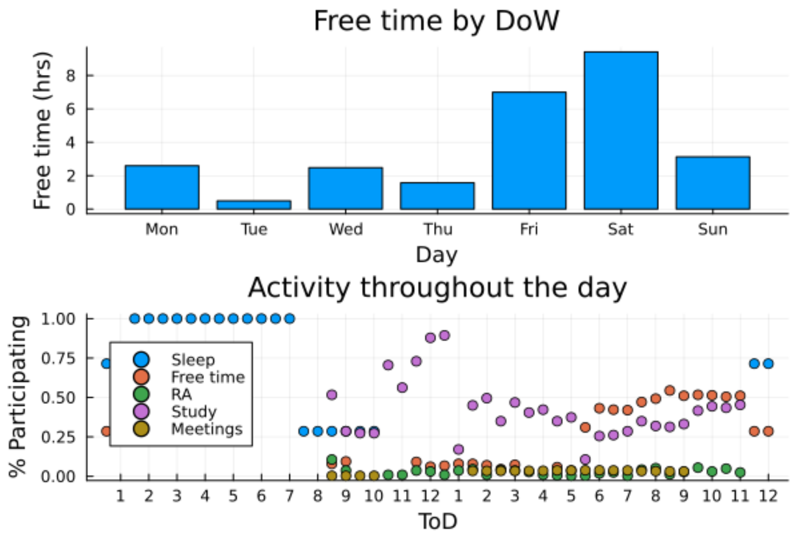

Figure 2: Amount of free time by day (top) and average activity over the hours of the day (bottom). Note, studying dominates regular working hours, however starting at 5pm, students slowly enjoy more and more free time.

Nevertheless, the majority of students, if fully committed to work during weekdays, including most evenings, can enjoy most of their Fridays evenings and Saturdays as free time (Figure 2). Additionally, what is interesting to notice is the relatively high workload on Tuesdays. Even though on this day of the week MBAns only have 1 class (an Optimization lecture from 8:30 am to 10 am), the majority of meetings take place then, since working on weekdays from 9 am to 5 pm is penalized the least, and on this day, students have lots of availability. For example, Victor, Marco and Michal all have ALab meetings at the same time, however are all on different ALab teams2. This indicates that lining up meetings across teams within a class benefits everyone, as it leaves more options for meeting slots for other classes during ideal (less penalized) times. Furthermore, as evident in Figure 2, as intended, most of the free time is during evenings and weekends, whereas study time is scheduled mainly for the middle of the day and is overtaken by free time in the evenings. Meeting times and RA work are nearly uniformly distributed, with slight peaks during the workday.

In Figure 3, we can see a sample of the end product - personalized calendars for MBAn students who work together. On Tuesday, Victor and Michal meet to work on their machine learning project at the same time as Marco and Tom. Right after this, Victor and Marco have their optimization project meeting, while Michal and Tom are "Studying" (an activity combining all class' homework and projects). Tom additionally has Sloan Senate and his RA meeting, which both fall under "Other".

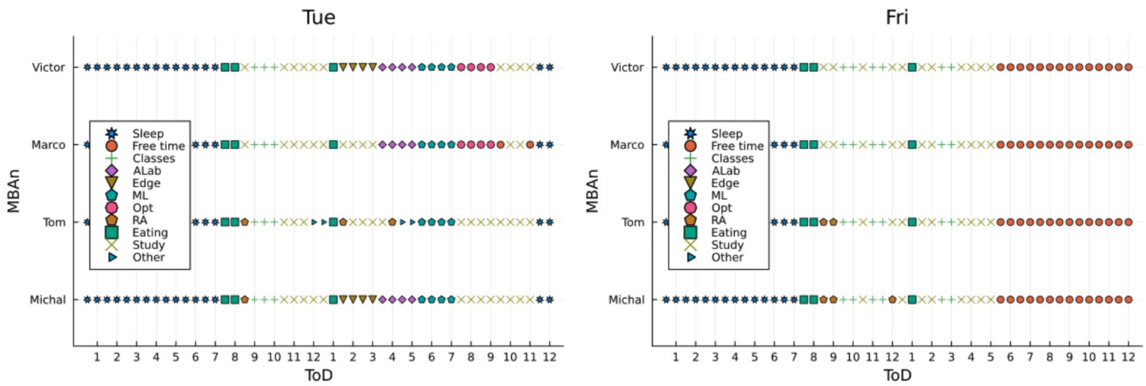

Figure 3: Monday (left) and Friday (right) schedules for four MBAns, who all work together on various projects.

6 Conclusion

6.1 Summary

The project aimed to create optimal schedules for the MBAn class which maximizes weekend/evening free time, while ensuring students meet their academic and private commitments. Based on survey data collected from the MBAn class, the mixed integer model included the students' obligations such as attending class, recitations, completing homework, projects and having all the required meetings in different working groups, in addition to their various private commitments. Assuming the average MBAn spends 30 minutes per week planning their time, we save 1280 hours over one year for the entire MBAn class, in addition to reducing stress and increasing optimal free time. With the created optimization model, the feasibility of the problem was proved, time and energy was saved, and as an end result, optimal personalized calendars were created for the MBAn class.

6.2 Future work

This project is a double-edged sword; there are always more nuances that can be added to the model. Our next steps would be:

- Enforce 30 minutes for dinner sometime during the evening
- Add more granular weighting to free time (hourly)
- Reward consistency throughout the week
- Penalize performing an activity for only one 30-minute period at a time
- Create a web app / interface:
  Students add their granular calendar details online, and once a week, the algorithm runs (converges to 5% optimality gap in 5 minutes) generating schedules for that upcoming week

A Appendix

A.1 Final formulation

$$
\begin{aligned}
\max_{x,z} \quad & \sum_{s=1}^{S}\sum_{d=1}^{7}\sum_{t=1}^{48} v_{d,t} x_{s,free\,time,d,t} \\
\text{s.t.} \quad & \sum_{a=1}^{A} x_{s,a,d,t} = 1 \quad \forall s \in [S] \quad \forall d \in [7] \quad \forall t \in [48] \\
& x_{s,sleep,d,1:14 \cup 47:48} = 1 \quad \forall s \in [S] \quad \forall d \in [4] \\
& x_{s,sleep,5,1:14} = 1 \quad \forall s \in [S] \\
& x_{s,sleep,6,3:20} = 1 \quad \forall s \in [S] \\
& x_{s,eat,d,15:16 \cup 26} = 1 \quad \forall s \in [S] \quad \forall d \in [5] \\
& x_{s,eat,6,21:22 \cup 31:32} = 1 \quad \forall s \in [S] \\
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& x_{s,sleep,7,3:20 \cup 47:48} = 1 \quad \forall s \in [S] \\
& x_{s,class,d,classes(d)} = 1 \quad \forall s \in [S] \quad \forall d \in [7] \\
& z^{c}_{g_i,d,t} \leq x_{s,c,d,t'} \quad \forall g \in [G_c] \quad \forall c \in [C] \quad \forall d \in [7] \quad \forall t \in [45] \quad \forall t' \in [t, t+1, t+2, t+3] \quad \forall s \in g \\
& \sum_{d=1}^{7}\sum_{t=1}^{45} z^{c}_{g,d,t} \geq 1 \quad \forall g \in [G_c] \quad \forall c \in [C] \\
& z^{c}_{g,d,t} \in \{0,1\} \quad \forall g \in [G_c] \quad \forall c \in [C] \quad \forall d \in [7] \quad \forall t \in [45] \\
& x_{s,a,d,t} \in \{0,1\} \quad \forall s \in [S] \quad \forall a \in [A] \quad \forall d \in [7] \quad \forall t \in [48] \\
& \sum_{d=1}^{7}\sum_{t=1}^{48} x_{s,study,d,t} \geq 88 \quad \forall s \in [S] \\
& \sum_{d=1}^{7}\sum_{t=1}^{48} x_{s,research\,work,d,t} \geq 20 \quad \forall s \in [S_{RA}]
\end{aligned} \tag{15}
$$