Minimizing Schedule Changes

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Introduction

Our project had 2 parts:

1. Build a course schedule for the UMass Amherst Mathematics and Statistics Department that maximizes the faculty members' course preference and time availability
2. Take changes that need to be made to the schedule, and minimize how many other changes are made as a result

Goals

- We want to find what course schedule maximizes faculty preferences of course and time, while leaving only as many lower-level and large lecture courses as necessary unassigned to an instructor
- From the course schedule we want to minimize changes made to the original schedule, while satisfying issues coming up after the first schedule has been made
- Examples of this are a faculty member no longer being able to teach at the given time or the given course, or going suddenly on leave

Schedule Builder

The first portion of our project was constructing a linear program that creates a schedule maximizing the instructor preferences.

We will use this schedule as the starting point for changes that need to be made later.

Basic Information:

- 70 instructors (18 VAPs, 14 lecturers, 38 tenure-track professors)
- 133 total sections of 61 total courses to be taught
- 14 time slots (MWF 8-8:50 considered 1 time slot)

Schedule Builder

Decisions

We want to decide who is teaching what class and when, and which constraints to fully satisfy

Variables

- Assignment Variables: these are all binary variables that equal 0 if person i isn't teaching class j (at section level, not course) at time h, and 1 if they are.
  x_{ijh} = VAP $i \in \{1, \ldots, n_1\}$ teaching class $j \in \{1, \ldots, m\}$ at time $h \in \{1, \ldots, l\}$
  y_{ijh} = lecturer $i \in \{1, \ldots, n_2\}$ teaching class j at time h
  z_{ijh} = tenure-track professor $i \in \{1, \ldots, n_3\}$ teaching class j at time h
- Softness Variables: these are binary and non-negative integer variables added in to allow some constraints to not be fully satisfied

Schedule Builder

Goal

We want to find what schedule maximizes instructor time and course preferences

Objective Function

Let a_{ij} = preference weight for person i teaching course j, and b_{ih} = preference weight for person i teaching at time h. Then the objective is to:

$$\max \quad \sum_{i=1}^{n_1} \sum_{j=1}^{m} \sum_{h=1}^{l} f(a_{ij}, b_{ih}) x_{ijh} + \sum_{i=1}^{n_2} \sum_{j=1}^{m} \sum_{h=1}^{l} f(a_{ij,} b_{ih}) y_{ijh} + \sum_{i=1}^{n_3} \sum_{j=1}^{m} \sum_{h=1}^{l} f(a_{ij}, b_{ih}) z_{ijh} - \text{softness variables}$$

Where $f(a_{ij}, b_{ih})$ is some function of the preferences. We tested $f(a, b) = ab$ and $f(a, b) = a + b$

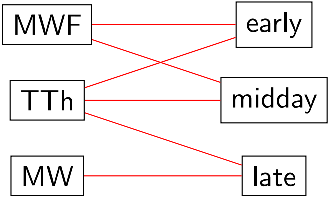
Schedule Builder

Determining *a*

- A weight of 0 is given to any course an instructor explicitly said they did not want to teach
- A weight of 0.25 is given to any course an instructor did not mention in the spreadsheet
- In general, a weight of 1 is given to a person and course if it was their top choice when ranking upper/lower/lecture courses.
- Similarly, a weight of 0.75 is given to second choices, and 0.5 to third choices
- However, if a person did not volunteer to teach large lectures, their preferences for those were reduced to 0.3, 0.2, and 0.1 respectively.

Schedule Builder

Determining *b*



1. Rank MWF/TTh/MW 1-3 (1 best)
2. Rank early/midday/late 1-3 (1 best)
3. Multiply the values as shown in the image
4. Assign the following preferences by the product:
    - $1 = 1$
    - $2 = 0.8$
    - $3 = 0.6$
    - $4 = 0.4$
    - $6 = 0.2$
    - $9 = 0$

Schedule Builder

Constraints

1. Each course should be assigned exactly one time slot and one instructor, with the exception of some lower-level courses or large lectures which may be filled in by new instructors later.

$$\sum_{i=1}^{n_1}\sum_{h=1}^{l} x_{ijh} + \sum_{i=1}^{n_2}\sum_{h=1}^{l} y_{ijh} + \sum_{i=1}^{n_3}\sum_{h=1}^{l} z_{ijh} = 1 - p_j \qquad \forall j \tag{1}$$

$$p_j = 0 \qquad \forall j \in \{\text{upper-level or grad class}\} \tag{2}$$

Schedule Builder Constraints

2. Each person teaches at most one class during any time-slot.

$$\sum_{j=1}^{m} x_{ijh} \leq 1 \qquad \forall i \in \{1, \ldots, n_1\}, h \tag{3}$$

$$\sum_{j=1}^{m} y_{ijh} \leq 1 \qquad \forall i \in \{1, \ldots, n_2\}, h \tag{4}$$

$$\sum_{j=1}^{m} z_{ijh} \leq 1 \qquad \forall i \in \{1, \ldots, n_3\}, h \tag{5}$$

Schedule Builder Constraints

3. Pre-assigned course-instructor c, i pairings are upheld.
   Let $C = \{j : j \text{ is a section of course } c\}$

$$\sum_{j \in C} \sum_{h=1}^{l} x_{ijh} = r_{ic} \tag{6}$$

if the instructor is a VAP,

$$\sum_{j \in C} \sum_{h=1}^{l} y_{ijh} = r_{ic} \tag{7}$$

if the instructor is a lecturer, and

$$\sum_{j \in C} \sum_{h=1}^{l} z_{ijh} = r_{ic} \tag{8}$$

if the instructor is a tenure-track professor, where $r_{ic} =$ the number of sections of course c instructor i is teaching.

Schedule Builder Constraints

4. Instructors that cannot teach certain classes should not be assigned to teach those classes.
   For fixed i^* and j^* being the instructor-course pair that cannot be assigned:
   $$\sum_{h=1}^{l} x_{i^*j^*h} = 0 \tag{9}$$
   if the instructor is a VAP,
   $$\sum_{h=1}^{l} y_{i^*j^*h} = 0 \tag{10}$$
   if the instructor is a lecturer, and
   $$\sum_{h=1}^{l} z_{i^*j^*h} = 0 \tag{11}$$
   if the instructor is a tenure-track professor.

Schedule Builder Constraints

5. Instructors that cannot teach at certain times should not be assigned to teach during those times.
   For fixed i^* and h^* being the instructor-time pair that cannot be assigned:

   $$\sum_{j=1}^{m} x_{i^*jh^*} = 0 \tag{12}$$

   if the instructor is a VAP,

   $$\sum_{j=1}^{m} y_{i^*jh^*} = 0 \tag{13}$$

   if the instructor is a lecturer, and

   $$\sum_{j=1}^{m} z_{i^*jh^*} = 0 \tag{14}$$

   if the instructor is a tenure-track professor.

Schedule Builder Constraints

6. Lecturers cannot teach upper-level classes.

$$\sum_{h=1}^{l} x_{ijh} = 0 \qquad \forall i \in \{1, \ldots, n_1\}, j \in \{\text{upper-level}\} \tag{15}$$

7. Each instructor teaches the correct number of courses. As this number cannot be generalized for everyone, we will assign each person a parameter L_{xi}, L_{yi}, or L_{zi} accordingly that represents the load or number of classes that person is able to teach. (SOFT, may teach 1 less course)

$$\sum_{j=1}^{m} \sum_{h=1}^{l} x_{ijh} = L_{xi} \qquad \forall i \in \{0, \ldots, n_1\} \tag{16}$$

$$\sum_{j=1}^{m} \sum_{h=1}^{l} y_{ijh} = L_{yi} \qquad \forall i \in \{0, \ldots, n_2\} \tag{17}$$

$$\sum_{j=1}^{m} \sum_{h=1}^{l} z_{ijh} = L_{zi} \qquad \forall i \in \{0, \ldots, n_3\} \tag{18}$$

Schedule Builder Constraints

8. Instructors should not be assigned to teach both MWF/MW and TTh.

$$\sum_{j=1}^{m} x_{ijh'} + \sum_{j=1}^{m} x_{ijh''} \leq 1 + q_{xi} \qquad \forall i, h', h'' \tag{19}$$

$$\sum_{j=1}^{m} y_{ijh'} + \sum_{j=1}^{m} y_{ijh''} \leq 1 + q_{yi} \qquad \forall i, h', h'' \tag{20}$$

$$\sum_{j=1}^{m} z_{ijh'} + \sum_{j=1}^{m} z_{ijh''} \leq 1 \qquad \forall i, h', h'' \tag{21}$$

Where $h' = \{1, \ldots, 8\}$, $h'' = \{9, \ldots, 14\}$, and $q_{xi}, q_{yi} = 1$ if a VAP or lecturer respectively would like to teach all 5 days, 0 otherwise.

Schedule Builder Constraints

9. Instructors should not be assigned to teach both early MWF and late MW. (SOFT for lecturers)

$$\sum_{j=1}^{m} x_{ij1} + \sum_{j=1}^{m} x_{ijw} \leq 1 \qquad \forall i \tag{22}$$

$$\sum_{j=1}^{m} y_{ij1} + \sum_{j=1}^{m} y_{ijw} \leq 1 \qquad \forall i \tag{23}$$

$$\sum_{j=1}^{m} z_{ij1} + \sum_{j=1}^{m} z_{ijw} \leq 1 \qquad \forall i \tag{24}$$

Where $w =$ the last MW time slot.

Schedule Builder Constraints

10. Instructors should not be assigned to teach both early and late TTh. (SOFT for lecturers)

$$\sum_{j=1}^{m} x_{ij(w+1)} + \sum_{j=1}^{m} x_{ijl} \leq 1 \qquad \forall i \tag{25}$$

$$\sum_{j=1}^{m} y_{ij(w+1)} + \sum_{j=1}^{m} y_{ijl} \leq 1 \qquad \forall i \tag{26}$$

$$\sum_{j=1}^{m} z_{ij(w+1)} + \sum_{j=1}^{m} z_{ijl} \leq 1 \qquad \forall i \tag{27}$$

Where $w =$ the last MW time slot, $l =$ the last TTh time slot.

Schedule Builder Constraints

11. For each time slot, there should be an appropriate number of lower- and upper-level courses being taught so we can assign classes to rooms. (SOFT with large penalty)

$$\left\lfloor \frac{\alpha}{\beta} \right\rfloor \leq \sum_{i=1}^{n_1} \sum_{j=1}^{\alpha} x_{ijh} + \sum_{i=1}^{n_2} \sum_{j=1}^{\alpha} y_{ijh} + \sum_{i=1}^{n_3} \sum_{j=1}^{\alpha} z_{ijh} \leq \left\lceil \frac{\alpha}{\beta} \right\rceil \qquad \forall h \in \{\text{not first or last of the day}\} \tag{28}$$

$$\left\lfloor \frac{m-\alpha}{\beta} \right\rfloor \leq \sum_{i=1}^{n_1} \sum_{j=\alpha+1}^{m} x_{ijh} + \sum_{i=1}^{n_2} \sum_{j=\alpha+1}^{m} y_{ijh} + \sum_{i=1}^{n_3} \sum_{j=\alpha+1}^{m} z_{ijh} \leq \left\lceil \frac{m-\alpha}{\beta} \right\rceil \qquad \forall h \in \{\text{not first or last of the day}\} \tag{29}$$

Where $\alpha =$ the number of lower-level and large lecture sections being taught, and $\beta =$ the number of time slots that are not the first or last of the day.

Schedule Builder Constraints

11. For less-popular time slots, we don't need to lower-bound the number of classes.

$$\sum_{i=1}^{n_1}\sum_{j=1}^{\alpha} x_{ijh} + \sum_{i=1}^{n_2}\sum_{j=1}^{\alpha} y_{ijh} + \sum_{i=1}^{n_3}\sum_{j=1}^{\alpha} z_{ijh} \leq \left\lceil \frac{\alpha}{\beta} \right\rceil \quad \forall h \in \{\text{first or last of the day}\} \tag{30}$$

$$\sum_{i=1}^{n_1}\sum_{j=\alpha+1}^{m} x_{ijh} + \sum_{i=1}^{n_2}\sum_{j=\alpha+1}^{m} y_{ijh} + \sum_{i=1}^{n_3}\sum_{j=\alpha+1}^{m} z_{ijh} \leq \left\lceil \frac{m-\alpha}{\beta} \right\rceil \quad \forall h \in \{\text{first or last of the day}\} \tag{31}$$

Schedule Builder Constraints

12. We do not want sections of core courses (lower-level, large lecture) to overlap too much. The number of sections of a given course that can overlap will depend on how many sections of that class there are, so we assign a parameter:
    s_c= max number of sections of core course c that can be taught during a time-slot.
    Let $C = \{j : j \text{ is a section of course } c\}$

$$\sum_{j\in C}\sum_{i=1}^{n_1} x_{ijh}+\sum_{j\in C}\sum_{i=1}^{n_2} y_{ijh}+\sum_{j\in C}\sum_{i=1}^{n_3} z_{ijh} \leq s_j \quad \forall h, c \in \{\text{core courses}\} \tag{32}$$

Schedule Builder Constraints

13. We want courses that are commonly taken together to have little overlap so that students are able to fit all of those courses in their schedule. For some courses that have many sections, there can be some overlap between that class and another, but for upper-level courses that have only one or two sections, we want these sections to be at different times. Take sets $D_1, D_2, \ldots$ to be sets of j that belong to lower-level courses often taken together.

$$\sum_{j \in D_k} \left(\sum_{i=1}^{n_1} x_{ijh} + \sum_{i=1}^{n_2} y_{ijh} + \sum_{i=1}^{n_3} z_{ijh} \right) \leq 2 \qquad \forall h, k \tag{33}$$

Take sets $F_1, F_2, \ldots$ to be sets of j that belong to upper level courses often taken together.

$$\sum_{j \in F_k} \left(\sum_{i=1}^{n_1} x_{ijh} + \sum_{i=1}^{n_2} y_{ijh} + \sum_{i=1}^{n_3} z_{ijh} \right) \leq 1 \qquad \forall h, k \tag{34}$$

Schedule Builder Constraints

14. If someone is up for promotion but has not taught a variety of courses yet, we want them to teach at least one new course during this semester.
    Let
    $\alpha_i = \{c : \text{person } i \text{ has taught course } c \text{ before}\}$
    $C_{\alpha_i} = \{j : j \text{ is a section of a course in } \alpha_i\}$

$$\sum_{j \in C_{\alpha_i}} \sum_{h=1}^{l} x_{ijh} + 1 \leq \sum_{j=1}^{m} \sum_{h=1}^{l} x_{ijh} \tag{35}$$

$$\forall i \in \{\text{VAPs to be promoted and needs new courses}\}$$

$$\sum_{j \in C_{\alpha_i}} \sum_{h=1}^{l} y_{ijh} + 1 \leq \sum_{j=1}^{m} \sum_{h=1}^{l} y_{ijh} \tag{36}$$

$$\forall i \in \{\text{lecturers to be promoted and needs new courses}\}$$

Schedule Builder Constraints

15. To ensure that courses for which some sections are left open still have a qualified chair, we want at least one of the sections to be taught by a tenure-track professor or permanent lecturer. (SOFT, and forced to not need to hold if a VAP is pre-assigned to a course)

$$\sum_{i=1}^{n_3} \sum_{j \in C} \sum_{h=1}^{l} z_{ijh} + \sum_{i=1}^{n_2} \sum_{j \in C} \sum_{h=1}^{l} y_{ijh} \geq 1 \tag{37}$$

$\forall c \in \{\text{lower-level or big lecture}\}$

Schedule Builder Results

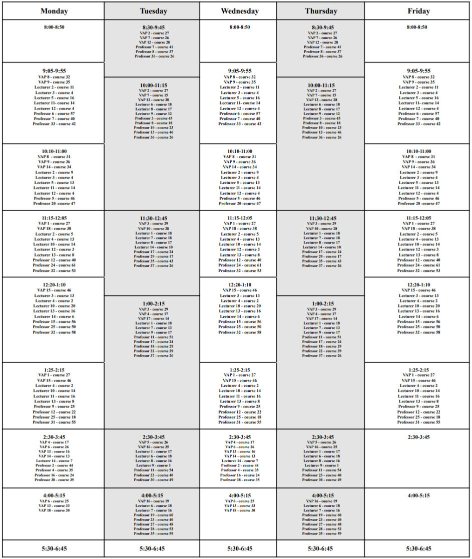


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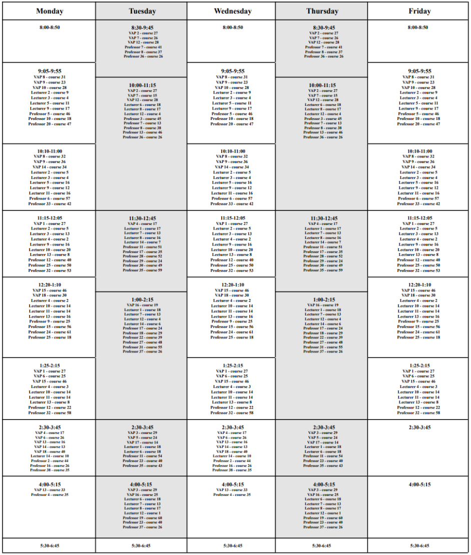
Figure 1: Optimal Schedule 1 ($a * b$)

Schedule Builder Results



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2:30-3:45 VAP 4 - course 17 VAP 6 - course 26 VAP 13 - course 16 VAP 14 - course 13 VAP 18 - course 40 Lecturer 14 - course 10 Professor 2 - course 44 Professor 16 - course 26 Professor 38 - course 35	2:30-3:45 VAP 3 - course 29 VAP 5 - course 24 VAP 17 - course 14 Lecturer 1 - course 18 Lecturer 6 - course 18 Professor 11 - course 54 Professor 23 - course 40 Professor 35 - course 43	2:30-3:45 VAP 4 - course 17 VAP 6 - course 26 VAP 13 - course 16 VAP 14 - course 13 VAP 18 - course 40 Lecturer 14 - course 10 Professor 2 - course 44 Professor 16 - course 26 Professor 38 - course 35	2:30-3:45 VAP 3 - course 29 VAP 5 - course 24 VAP 17 - course 14 Lecturer 1 - course 18 Lecturer 6 - course 18 Professor 11 - course 54 Professor 23 - course 40 Professor 35 - course 43	2:30-3:45
4:00-5:15 VAP 13 - course 33 Professor 4 - course 35	4:00-5:15 VAP 3 - course 29 VAP 16 - course 25 Lecturer 6 - course 18 Lecturer 7 - course 13 Lecturer 8 - course 17 Lecturer 12 - course 1 Professor 19 - course 60 Professor 23 - course 40 Professor 37 - course 26	4:00-5:15 VAP 13 - course 33 Professor 4 - course 35	4:00-5:15 VAP 3 - course 29 VAP 16 - course 25 Lecturer 6 - course 18 Lecturer 7 - course 13 Lecturer 8 - course 17 Lecturer 12 - course 1 Professor 19 - course 60 Professor 23 - course 40 Professor 37 - course 26	4:00-5:15
5:30-6:45	5:30-6:45	5:30-6:45	5:30-6:45	5:30-6:45

Figure 2: Optimal Schedule 2 $(a + b)$

Schedule Builder Results

A Closer Look at Some Instructors

Professor 8

- 2 classes
- Upper-level preferences: 37, (41,34), (28,39)
- Does not volunteer for large lectures
- Lower-level preferences: 18, 13
- No classes they prefer not to teach
- Time preferences: Early (not 8am MWF), midday, late
- Day preferences: TTh, MW, MWF
- Has reasons to only teach 2 days a week (didn't implement)
- No specific time they can't teach
- **Schedule 1:** teaching 37 (TTh 8:30-9:45) and 18 (TTh 10-11:15)
- **Schedule 2:** teaching 37 (TTh 8:30-9:45) and 38 (TTh 10-11:15)

Schedule Builder Results

A Closer Look at Some Instructors

Lecturer 11

- 3 classes
- Does not want to teach upper-level courses
- Large lecture preferences: (4,8), (9,1,2), (11,6,7) (volunteers)
- Lower-level preferences: 10, 40 (not lower-level), 14
- Time preferences: Early, midday, late
- Day preferences: TTh, MWF, MW
- No specific time they can't teach
- **Schedule 1:** teaching 14 (MWF 9:05-9:55), 14 (MWF 10:10-11), 16 (MWF 1:25-2:15)
- **Schedule 2:** teaching 16 (MWF 10:10-11), 14 (MWF 12:20-1:10), 14 (MWF 1:25-2:15)

Schedule Builder Results

A Closer Look at Some Instructors

VAP 2

- 2 classes
- Upper-level preferences: (28,39,41,36,23,37), (30,27), (34,26)
- Does not volunteer for large lectures
- Lower-level preferences: (18,13), (17,16), 14
- No classes they prefer not to teach
- Time preferences: Early, midday, late
- Day preferences: TTh, MW, MWF
- Can't teach Tuesdays 4-5pm
- **Schedule 1:** teaching 27 (MW 4-5:15), 27 (TTh 10-11:25)
- **Schedule 2:** teaching 27 (TTh 8:30-9:45), 27 (TTh 10-11:25)

Change Minimizer

Decisions

We want to decide who is teaching what class and when in the new schedule, and what has changes

Variables

- Assignment Variables: We will have the same x_{ijh}, y_{ijh}, z_{ijh}, and p_j variables in this program as in the schedule builder.
- Change Variables: We have binary variables (1 = yes, changed, 0 = no, stayed the same):
  $\hat{x}_{ijh}$ = whether the status of VAP i teaching class j at time h has changed
  $\hat{y}_{ijh}$ = whether the status of lecturer i teaching class j at time h has changed
  $\hat{z}_{ijh}$ = whether the status of tenure-track professor i teaching class j at time h has changed
- Softness Variables: more variables to allow some constraints to not be fully satisfied if necessary

Change Minimizer

Goal

We want to find the schedule the minimizes changes made to an original schedule.

Objective Function

$$
\begin{aligned}
\min \quad & \sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{h=1}^{l}\hat{x}_{ijh} + \sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{h=1}^{l}\hat{y}_{ijh} \\
& + \sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{h=1}^{l}\hat{z}_{ijh} + \text{ softness variables}
\end{aligned}
\tag{38}
$$

Change Minimizer

Constraints:

1. We will take an already-created schedule, and assign the following binary (1 = yes, 0 = no) parameters from that:
   $\overline{x}_{ijh}$ = lecturer *i* teaches class *j* at time h in original schedule
   $\overline{y}_{ijh}$ = VAP *i* teaches class *j* at time *h* in original schedule
   $\overline{z}_{ijh}$ = tenure-track professor *i* teaches class *j* at time *h* in original schedule
   Then we want the $\hat{x}, \hat{y}, \hat{z}$ variables to take on the right values, so we have:

$$\hat{x}_{ijh} = x_{ijh} + \overline{x}_{ijh} - 2\overline{x}_{ijh}x_{ijh} \qquad \forall i, j, h \tag{39}$$

$$\hat{y}_{ijh} = y_{ijh} + \overline{y}_{ijh} - 2\overline{y}_{ijh}y_{ijh} \qquad \forall i, j, h \tag{40}$$

$$\hat{z}_{ijh} = z_{ijh} + \overline{z}_{ijh} - 2\overline{z}_{ijh}x_{ijh} \qquad \forall i, j, h \tag{41}$$

Change Minimizer Constraints

2. All constraints from the schedule builder will apply for this program as well.
3. For instructor i^* who has an issue with teaching class j^*, we add a constraint as in (4) of the schedule builder.
4. For instructor i^* who has an issue with teaching at time h^*, we add a constraint as in (5) of the schedule builder.

Change Minimizer Constraints

5. For an instructor i^* who is suddenly on leave, we add a constraint

$$\sum_{j=1}^{m} \sum_{h=1}^{l} x_{i^*jh} = 0, \tag{42}$$

$$\sum_{j=1}^{m} \sum_{h=1}^{l} y_{i^*jh} = 0, \text{ or} \tag{43}$$

$$\sum_{j=1}^{m} \sum_{h=1}^{l} z_{i^*jh} = 0 \tag{44}$$

to match the level of instructor they are.

Change Minimizer Constraints

6. If pre-registration, all courses c should keep its original instructor i^* and have the time changed. (SOFT) Where $C = \{j : j \text{ is a section of course type } c\}$,

$$\sum_{j \in C} \sum_{h=1}^{l} x_{i^* jh} = 1 \qquad \forall c \tag{45}$$

$$\sum_{j \in C} \sum_{h=1}^{l} y_{i^* jh} = 1 \qquad \forall c \tag{46}$$

$$\sum_{j \in C} \sum_{h=1}^{l} z_{i^* jh} = 1 \qquad \forall c \tag{47}$$

7. If post-registration, a course c should keep its time-slot h^* and have the instructor changed. (SOFT)

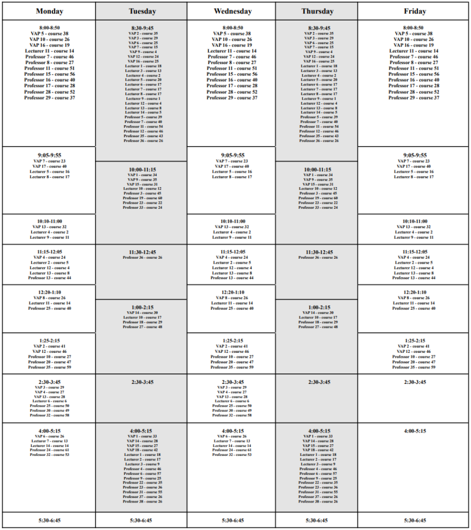
$$\sum_{j \in C} \sum_{i=1}^{n_1} x_{ijh^*} + \sum_{j \in C} \sum_{i=1}^{n_2} y_{ijh^*} + \sum_{j \in C} \sum_{i=1}^{n_3} z_{ijh^*} = 1 \qquad \forall c \tag{48}$$

Change Minimizer Results

Changes Made to Schedule 1 $(a * b)$ **:**

1. VAP 5 teaching course 26
2. VAP 14 teaching at time 7
3. Lecturer 11 teaching at time 3
4. Professor 14 teaching at time 11
5. Professor 2 on leave

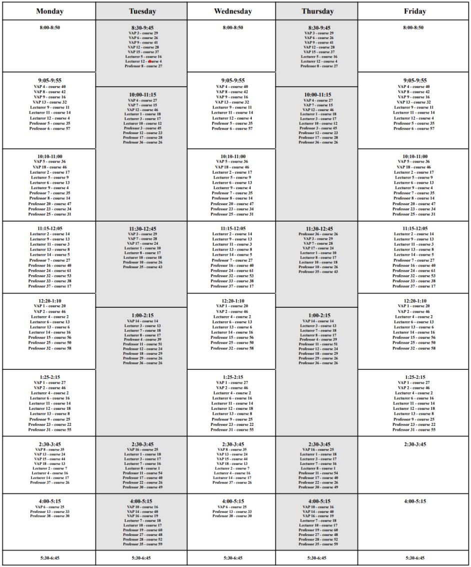
Change Minimizer Results



Monday	Tuesday	Wednesday	Thursday	Friday
8:00-8:50 VAP 5 - course 38 VAP 10 - course 26 VAP 16 - course 19 Lecturer 11 - course 14 Professor 7 - course 46 Professor 8 - course 27 Professor 11 - course 51 Professor 15 - course 56 Professor 16 - course 40 Professor 17 - course 28 Professor 28 - course 52 Professor 29 - course 37	8:30-9:45 VAP 2 - course 35 VAP 3 - course 29 VAP 6 - course 25 VAP 7 - course 15 VAP 9 - course 4 VAP 12 - course 24 VAP 16 - course 25 Lecturer 1 - course 18 Lecturer 3 - course 13 Lecturer 4 - course 2 Lecturer 5 - course 20 Lecturer 6 - course 17 Lecturer 7 - course 17 Lecturer 8 - course 17 Lecturer 9 - course 1 Lecturer 12 - course 4 Lecturer 13 - course 8 Lecturer 14 - course 5 Professor 5 - course 39 Professor 7 - course 40 Professor 11 - course 54 Professor 12 - course 46 Professor 35 - course 43 Professor 36 - course 26	8:00-8:50 VAP 5 - course 38 VAP 10 - course 26 VAP 16 - course 19 Lecturer 11 - course 14 Professor 7 - course 46 Professor 8 - course 27 Professor 11 - course 51 Professor 15 - course 56 Professor 16 - course 40 Professor 17 - course 28 Professor 28 - course 52 Professor 29 - course 37	8:30-9:45 VAP 2 - course 35 VAP 3 - course 29 VAP 6 - course 25 VAP 7 - course 15 VAP 9 - course 4 VAP 12 - course 24 VAP 16 - course 25 Lecturer 1 - course 18 Lecturer 3 - course 13 Lecturer 4 - course 2 Lecturer 5 - course 20 Lecturer 6 - course 17 Lecturer 7 - course 17 Lecturer 8 - course 17 Lecturer 9 - course 1 Lecturer 12 - course 4 Lecturer 13 - course 8 Lecturer 14 - course 5 Professor 5 - course 39 Professor 7 - course 40 Professor 11 - course 54 Professor 12 - course 46 Professor 35 - course 43 Professor 36 - course 26	8:00-8:50 VAP 5 - course 38 VAP 10 - course 26 VAP 16 - course 19 Lecturer 11 - course 14 Professor 7 - course 46 Professor 8 - course 27 Professor 11 - course 51 Professor 15 - course 56 Professor 16 - course 40 Professor 17 - course 28 Professor 28 - course 52 Professor 29 - course 37
9:05-9:55 VAP 7 - course 23 VAP 17 - course 40 Lecturer 5 - course 16 Lecturer 8 - course 17	10:00-11:15 VAP 1 - course 34 VAP 9 - course 35 VAP 15 - course 31 Lecturer 10 - course 12 Professor 3 - course 45 Professor 19 - course 60 Professor 23 - course 22 Professor 33 - course 24	9:05-9:55 VAP 7 - course 23 VAP 17 - course 40 Lecturer 5 - course 16 Lecturer 8 - course 17	10:00-11:15 VAP 1 - course 34 VAP 9 - course 35 VAP 15 - course 31 Lecturer 10 - course 12 Professor 3 - course 45 Professor 19 - course 60 Professor 23 - course 22 Professor 33 - course 24	9:05-9:55 VAP 7 - course 23 VAP 17 - course 40 Lecturer 5 - course 16 Lecturer 8 - course 17
10:10-11:00 VAP 13 - course 32 Lecturer 4 - course 2 Lecturer 9 - course 11		10:10-11:00 VAP 13 - course 32 Lecturer 4 - course 2 Lecturer 9 - course 11		10:10-11:00 VAP 13 - course 32 Lecturer 4 - course 2 Lecturer 9 - course 11
11:15-12:05 VAP 4 - course 24 Lecturer 2 - course 5 Lecturer 12 - course 4 Lecturer 13 - course 8 Professor 13 - course 44	11:30-12:45 Professor 36 - course 26	11:15-12:05 VAP 4 - course 24 Lecturer 2 - course 5 Lecturer 12 - course 4 Lecturer 13 - course 8 Professor 13 - course 44	11:30-12:45 Professor 36 - course 26	11:15-12:05 VAP 4 - course 24 Lecturer 2 - course 5 Lecturer 12 - course 4 Lecturer 13 - course 8 Professor 13 - course 44
12:20-1:10 VAP 8 - course 26 Lecturer 11 - course 14 Professor 25 - course 40	1:00-2:15 VAP 14 - course 30 Lecturer 10 - course 17 Professor 18 - course 29 Professor 27 - course 48	12:20-1:10 VAP 8 - course 26 Lecturer 11 - course 14 Professor 25 - course 40	1:00-2:15 VAP 14 - course 30 Lecturer 10 - course 17 Professor 18 - course 29 Professor 27 - course 48	12:20-1:10 VAP 8 - course 26 Lecturer 11 - course 14 Professor 25 - course 40
1:25-2:15 VAP 2 - course 41 VAP 12 - course 46 Professor 10 - course 27 Professor 20 - course 47 Professor 35 - course 59		1:25-2:15 VAP 2 - course 41 VAP 12 - course 46 Professor 10 - course 27 Professor 20 - course 47 Professor 35 - course 59		1:25-2:15 VAP 2 - course 41 VAP 12 - course 46 Professor 10 - course 27 Professor 20 - course 47 Professor 35 - course 59
2:30-3:45 VAP 3 - course 29 VAP 4 - course 27 VAP 13 - course 28 Lecturer 6 - course 6 Professor 25 - course 50 Professor 30 - course 49 Professor 32 - course 58	2:30-3:45	2:30-3:45 VAP 3 - course 29 VAP 4 - course 27 VAP 13 - course 28 Lecturer 6 - course 6 Professor 25 - course 50 Professor 30 - course 49 Professor 32 - course 58	2:30-3:45	2:30-3:45
4:00-5:15 VAP 6 - course 26 Lecturer 7 - course 13 Lecturer 14 - course 14 Professor 24 - course 61 Professor 32 - course 53	4:00-5:15 VAP 1 - course 33 VAP 14 - course 28 VAP 15 - course 27 VAP 18 - course 42 Lecturer 1 - course 18 Lecturer 2 - course 17 Lecturer 3 - course 9 Professor 4 - course 46 Professor 6 - course 57 Professor 9 - course 25 Professor 22 - course 35 Professor 23 - course 36 Professor 31 - course 55 Professor 37 - course 26 Professor 38 - course 26	4:00-5:15 VAP 6 - course 26 Lecturer 7 - course 13 Lecturer 14 - course 14 Professor 24 - course 61 Professor 32 - course 53	4:00-5:15 VAP 1 - course 33 VAP 14 - course 28 VAP 15 - course 27 VAP 18 - course 42 Lecturer 1 - course 18 Lecturer 2 - course 17 Lecturer 3 - course 9 Professor 4 - course 46 Professor 6 - course 57 Professor 9 - course 25 Professor 22 - course 35 Professor 23 - course 36 Professor 31 - course 55 Professor 37 - course 26 Professor 38 - course 26	4:00-5:15
5:30-6:45	5:30-6:45	5:30-6:45	5:30-6:45	5:30-6:45

Figure 3: New Schedule 1 - Pre Registration

Change Minimizer Results



Monday	Tuesday	Wednesday	Thursday	Friday
8:00-8:50	8:30-9:45 VAP 3 - course 29 VAP 6 - course 26 VAP 9 - course 41 VAP 12 - course 28 VAP 15 - course 37 Lecturer 5 - course 16 Lecturer 12 - course 4 Professor 8 - course 27	8:00-8:50	8:30-9:45 VAP 3 - course 29 VAP 6 - course 26 VAP 9 - course 41 VAP 12 - course 28 VAP 15 - course 37 Lecturer 5 - course 16 Lecturer 12 - course 4 Professor 8 - course 27	8:00-8:50
9:05-9:55 VAP 4 - course 40 VAP 8 - course 42 VAP 9 - course 16 VAP 13 - course 32 Lecturer 9 - course 11 Lecturer 11 - course 14 Lecturer 12 - course 4 Professor 5 - course 35 Professor 6 - course 57	10:00-11:15 VAP 4 - course 27 VAP 7 - course 15 VAP 12 - course 46 Lecturer 1 - course 18 Lecturer 3 - course 17 Lecturer 10 - course 12 Professor 3 - course 45 Professor 12 - course 23 Professor 17 - course 28 Professor 36 - course 26	9:05-9:55 VAP 4 - course 40 VAP 8 - course 42 VAP 9 - course 16 VAP 13 - course 32 Lecturer 9 - course 11 Lecturer 11 - course 14 Lecturer 12 - course 4 Professor 5 - course 35 Professor 6 - course 57	10:00-11:15 VAP 4 - course 27 VAP 7 - course 15 VAP 12 - course 46 Lecturer 1 - course 18 Lecturer 3 - course 17 Lecturer 10 - course 12 Professor 3 - course 45 Professor 12 - course 23 Professor 17 - course 28 Professor 36 - course 26	9:05-9:55 VAP 4 - course 40 VAP 8 - course 42 VAP 9 - course 16 VAP 13 - course 32 Lecturer 9 - course 11 Lecturer 11 - course 14 Lecturer 12 - course 4 Professor 5 - course 35 Professor 6 - course 57
10:10-11:00 VAP 5 - course 36 VAP 18 - course 46 Lecturer 2 - course 17 Lecturer 5 - course 9 Lecturer 6 - course 13 Lecturer 9 - course 4 Professor 7 - course 35 Professor 8 - course 14 Professor 20 - course 47 Professor 23 - course 34 Professor 25 - course 31		10:10-11:00 VAP 5 - course 36 VAP 18 - course 46 Lecturer 2 - course 17 Lecturer 5 - course 9 Lecturer 6 - course 13 Lecturer 9 - course 4 Professor 7 - course 35 Professor 8 - course 14 Professor 20 - course 47 Professor 23 - course 34 Professor 25 - course 31		10:10-11:00 VAP 5 - course 36 VAP 18 - course 46 Lecturer 2 - course 17 Lecturer 5 - course 9 Lecturer 6 - course 13 Lecturer 9 - course 4 Professor 7 - course 35 Professor 8 - course 14 Professor 20 - course 47 Professor 23 - course 34 Professor 25 - course 31
11:15-12:05 Lecturer 2 - course 14 Lecturer 9 - course 13 Lecturer 11 - course 3 Lecturer 13 - course 8 Lecturer 14 - course 5 Professor 7 - course 27 Professor 16 - course 40 Professor 24 - course 61 Professor 32 - course 53 Professor 33 - course 38 Professor 37 - course 17	11:30-12:45 VAP 3 - course 29 VAP 7 - course 28 VAP 17 - course 24 Lecturer 1 - course 10 Lecturer 8 - course 17 Lecturer 10 - course 18 Professor 10 - course 26 Professor 35 - course 43	11:15-12:05 Lecturer 2 - course 14 Lecturer 9 - course 13 Lecturer 11 - course 3 Lecturer 13 - course 8 Lecturer 14 - course 5 Professor 7 - course 27 Professor 16 - course 40 Professor 24 - course 61 Professor 32 - course 53 Professor 33 - course 38 Professor 37 - course 17	11:30-12:45 Professor 36 - course 26 VAP 3 - course 29 VAP 7 - course 28 VAP 17 - course 24 Lecturer 1 - course 10 Lecturer 8 - course 17 Lecturer 10 - course 18 Professor 10 - course 26 Professor 35 - course 43	11:15-12:05 Lecturer 2 - course 14 Lecturer 9 - course 13 Lecturer 11 - course 3 Lecturer 13 - course 8 Lecturer 14 - course 5 Professor 7 - course 27 Professor 16 - course 40 Professor 24 - course 61 Professor 32 - course 53 Professor 33 - course 38 Professor 37 - course 17
12:20-1:10 VAP 1 - course 20 VAP 2 - course 46 Lecturer 4 - course 2 Lecturer 6 - course 13 Lecturer 13 - course 6 Lecturer 14 - course 16 Professor 15 - course 56 Professor 25 - course 50 Professor 32 - course 58	1:00-2:15 VAP 14 - course 14 Lecturer 3 - course 13 Lecturer 7 - course 18 Lecturer 8 - course 17 Professor 4 - course 39 Professor 11 - course 51 Professor 12 - course 24 Professor 18 - course 29 Professor 29 - course 26 Professor 36 - course 26	12:20-1:10 VAP 1 - course 20 VAP 2 - course 46 Lecturer 4 - course 2 Lecturer 6 - course 13 Lecturer 13 - course 6 Lecturer 14 - course 16 Professor 15 - course 56 Professor 25 - course 50 Professor 32 - course 58	1:00-2:15 VAP 14 - course 14 Lecturer 3 - course 13 Lecturer 7 - course 18 Lecturer 8 - course 17 Professor 4 - course 39 Professor 11 - course 51 Professor 12 - course 24 Professor 18 - course 29 Professor 29 - course 26 Professor 36 - course 26	12:20-1:10 VAP 1 - course 20 VAP 2 - course 46 Lecturer 4 - course 2 Lecturer 6 - course 13 Lecturer 13 - course 6 Lecturer 14 - course 16 Professor 15 - course 56 Professor 25 - course 50 Professor 32 - course 58
1:25-2:15 VAP 1 - course 27 VAP 2 - course 46 Lecturer 4 - course 2 Lecturer 6 - course 16 Lecturer 11 - course 14 Lecturer 12 - course 18 Lecturer 13 - course 8 Professor 9 - course 25 Professor 23 - course 22 Professor 31 - course 55		1:25-2:15 VAP 1 - course 27 VAP 2 - course 46 Lecturer 4 - course 2 Lecturer 6 - course 16 Lecturer 11 - course 14 Lecturer 12 - course 18 Lecturer 13 - course 8 Professor 9 - course 25 Professor 23 - course 22 Professor 31 - course 55		1:25-2:15 VAP 1 - course 27 VAP 2 - course 46 Lecturer 4 - course 2 Lecturer 6 - course 16 Lecturer 11 - course 14 Lecturer 12 - course 18 Lecturer 13 - course 8 Professor 9 - course 25 Professor 23 - course 22 Professor 31 - course 55
2:30-3:45 VAP 8 - course 35 VAP 13 - course 24 VAP 15 - course 44 VAP 18 - course 13 Lecturer 2 - course 7 Lecturer 4 - course 16 Lecturer 14 - course 17 Professor 37 - course 26	2:30-3:45 VAP 16 - course 25 Lecturer 1 - course 18 Lecturer 3 - course 17 Lecturer 7 - course 16 Lecturer 8 - course 1 Professor 11 - course 54 Professor 17 - course 40 Professor 22 - course 26 Professor 30 - course 49	2:30-3:45 VAP 8 - course 35 VAP 13 - course 24 VAP 15 - course 44 VAP 18 - course 13 Lecturer 2 - course 7 Lecturer 4 - course 16 Lecturer 14 - course 17 Professor 37 - course 26	2:30-3:45 VAP 16 - course 25 Lecturer 1 - course 18 Lecturer 3 - course 17 Lecturer 7 - course 16 Lecturer 8 - course 1 Professor 11 - course 54 Professor 17 - course 40 Professor 22 - course 26 Professor 30 - course 49	2:30-3:45
4:00-5:15 VAP 6 - course 25 Professor 13 - course 33 Professor 38 - course 30	4:00-5:15 VAP 10 - course 16 VAP 14 - course 40 VAP 16 - course 19 Lecturer 7 - course 18 Lecturer 10 - course 17 Professor 19 - course 60 Professor 27 - course 48 Professor 28 - course 52 Professor 35 - course 59	4:00-5:15 VAP 6 - course 25 Professor 13 - course 33 Professor 38 - course 30	4:00-5:15 VAP 10 - course 16 VAP 14 - course 40 VAP 16 - course 19 Lecturer 7 - course 18 Lecturer 10 - course 17 Professor 19 - course 60 Professor 27 - course 48 Professor 28 - course 52 Professor 35 - course 59	4:00-5:15
5:30-6:45	5:30-6:45	5:30-6:45	5:30-6:45	5:30-6:45

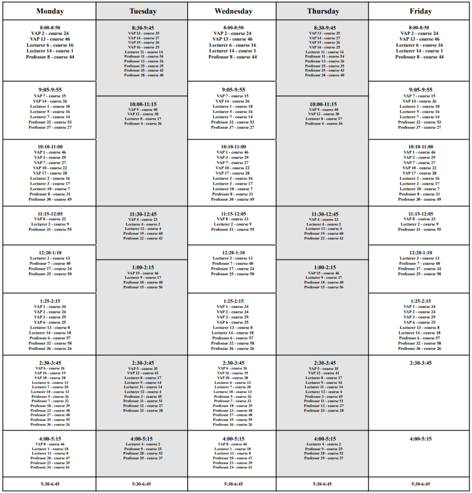
Figure 4: New Schedule 1 - Post Registration

Change Minimizer Results

Changes Made to Schedule 2 $(a + b)$ **:**

1. VAP 5 teaching course 24
2. VAP 14 teaching at time 7
3. Lecturer 11 teaching at time 3
4. Professor 13 teaching at time 10
5. Professor 2 on leave

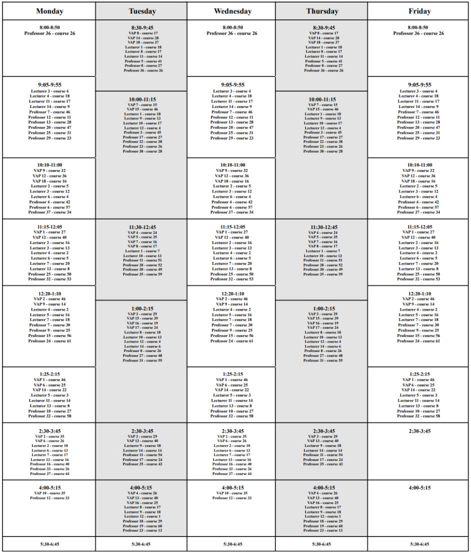
Change Minimizer Results



Monday	Tuesday	Wednesday	Thursday	Friday
8:00-8:50 VAP 2 - course 24 VAP 13 - course 46 Lecturer 6 - course 16 Lecturer 14 - course 1 Professor 8 - course 44	8:30-9:45 VAP 13 - course 35 VAP 14 - course 27 VAP 15 - course 26 VAP 16 - course 25 Lecturer 11 - course 14 Professor 11 - course 54 Professor 13 - course 26 Professor 25 - course 35 Professor 35 - course 43 Professor 38 - course 40	8:00-8:50 VAP 2 - course 24 VAP 13 - course 46 Lecturer 6 - course 16 Lecturer 14 - course 1 Professor 8 - course 44	8:30-9:45 VAP 13 - course 35 VAP 14 - course 27 VAP 15 - course 26 VAP 16 - course 25 Lecturer 11 - course 14 Professor 11 - course 54 Professor 13 - course 26 Professor 25 - course 35 Professor 35 - course 43 Professor 38 - course 40	8:00-8:50 VAP 2 - course 24 VAP 13 - course 46 Lecturer 6 - course 16 Lecturer 14 - course 1 Professor 8 - course 44
9:05-9:55 VAP 7 - course 15 VAP 14 - course 26 Lecturer 1 - course 18 Lecturer 5 - course 16 Lecturer 7 - course 14 Professor 32 - course 53 Professor 37 - course 27	10:00-11:15 VAP 9 - course 40 VAP 12 - course 30 Lecturer 8 - course 17 Professor 4 - course 36	9:05-9:55 VAP 7 - course 15 VAP 14 - course 26 Lecturer 1 - course 18 Lecturer 5 - course 16 Lecturer 7 - course 14 Professor 32 - course 53 Professor 37 - course 27	10:00-11:15 VAP 9 - course 40 VAP 12 - course 30 Lecturer 8 - course 17 Professor 4 - course 36	9:05-9:55 VAP 7 - course 15 VAP 14 - course 26 Lecturer 1 - course 18 Lecturer 5 - course 16 Lecturer 7 - course 14 Professor 32 - course 53 Professor 37 - course 27
10:10-11:00 VAP 1 - course 46 VAP 3 - course 29 VAP 7 - course 27 VAP 10 - course 22 VAP 17 - course 28 Lecturer 2 - course 16 Lecturer 3 - course 17 Lecturer 10 - course 7 Professor 8 - course 31 Professor 30 - course 49		10:10-11:00 VAP 1 - course 46 VAP 3 - course 29 VAP 7 - course 27 VAP 10 - course 22 VAP 17 - course 28 Lecturer 2 - course 16 Lecturer 3 - course 17 Lecturer 10 - course 7 Professor 8 - course 31 Professor 30 - course 49		10:10-11:00 VAP 1 - course 46 VAP 3 - course 29 VAP 7 - course 27 VAP 10 - course 22 VAP 17 - course 28 Lecturer 2 - course 16 Lecturer 3 - course 17 Lecturer 10 - course 7 Professor 8 - course 31 Professor 30 - course 49
11:15-12:05 VAP 8 - course 33 Lecturer 2 - course 9 Professor 31 - course 55	11:30-12:45 VAP 4 - course 23 Lecturer 4 - course 2 Lecturer 12 - course 4 Professor 19 - course 60 Professor 22 - course 42	11:15-12:05 VAP 8 - course 33 Lecturer 2 - course 9 Professor 31 - course 55	11:30-12:45 VAP 4 - course 23 Lecturer 4 - course 2 Lecturer 12 - course 4 Professor 19 - course 60 Professor 22 - course 42	11:15-12:05 VAP 8 - course 33 Lecturer 2 - course 9 Professor 31 - course 55
12:20-1:10 Lecturer 3 - course 13 Professor 7 - course 40 Professor 17 - course 24 Professor 25 - course 50	1:00-2:15 VAP 15 - course 46 Lecturer 9 - course 17 Professor 10 - course 40 Professor 15 - course 56	12:20-1:10 Lecturer 3 - course 13 Professor 7 - course 40 Professor 17 - course 24 Professor 25 - course 50	1:00-2:15 VAP 15 - course 46 Lecturer 9 - course 17 Professor 10 - course 40 Professor 15 - course 56	12:20-1:10 Lecturer 3 - course 13 Professor 7 - course 40 Professor 17 - course 24 Professor 25 - course 50
1:25-2:15 VAP 1 - course 34 VAP 2 - course 24 VAP 3 - course 29 VAP 6 - course 25 Lecturer 13 - course 8 Lecturer 14 - course 18 Professor 6 - course 57 Professor 32 - course 58 Professor 36 - course 26		1:25-2:15 VAP 1 - course 34 VAP 2 - course 24 VAP 3 - course 29 VAP 6 - course 25 Lecturer 13 - course 8 Lecturer 14 - course 18 Professor 6 - course 57 Professor 32 - course 58 Professor 36 - course 26		1:25-2:15 VAP 1 - course 34 VAP 2 - course 24 VAP 3 - course 29 VAP 6 - course 25 Lecturer 13 - course 8 Lecturer 14 - course 18 Professor 6 - course 57 Professor 32 - course 58 Professor 36 - course 26
2:30-3:45 VAP 6 - course 26 VAP 16 - course 19 VAP 18 - course 28 Lecturer 6 - course 13 Lecturer 7 - course 20 Lecturer 10 - course 13 Professor 5 - course 26 Professor 7 - course 32 Professor 18 - course 29 Professor 23 - course 38 Professor 27 - course 48 Professor 35 - course 59 Professor 36 - course 26	2:30-3:45 VAP 5 - course 35 VAP 12 - course 41 Lecturer 8 - course 17 Lecturer 9 - course 14 Lecturer 11 - course 14 Lecturer 12 - course 4 Professor 3 - course 45 Professor 11 - course 51 Professor 12 - course 27 Professor 33 - course 28	2:30-3:45 VAP 6 - course 26 VAP 16 - course 19 VAP 18 - course 28 Lecturer 6 - course 13 Lecturer 7 - course 20 Lecturer 10 - course 13 Professor 5 - course 26 Professor 7 - course 32 Professor 18 - course 29 Professor 23 - course 38 Professor 27 - course 48 Professor 35 - course 59 Professor 36 - course 26	2:30-3:45 VAP 5 - course 35 VAP 12 - course 41 Lecturer 8 - course 17 Lecturer 9 - course 14 Lecturer 11 - course 14 Lecturer 12 - course 4 Professor 3 - course 45 Professor 11 - course 51 Professor 12 - course 27 Professor 33 - course 28	2:30-3:45
4:00-5:15 VAP 8 - course 46 Lecturer 1 - course 18 Lecturer 13 - course 8 Professor 20 - course 47 Professor 23 - course 39 Professor 24 - course 61	4:00-5:15 Lecturer 4 - course 2 Professor 9 - course 25 Professor 28 - course 52 Professor 29 - course 37	4:00-5:15 VAP 8 - course 46 Lecturer 1 - course 18 Lecturer 13 - course 8 Professor 20 - course 47 Professor 23 - course 39 Professor 24 - course 61	4:00-5:15 Lecturer 4 - course 2 Professor 9 - course 25 Professor 28 - course 52 Professor 29 - course 37	4:00-5:15
5:30-6:45	5:30-6:45	5:30-6:45	5:30-6:45	5:30-6:45

Figure 5: New Schedule 2 - Pre Registration

Change Minimizer Results



Monday	Tuesday	Wednesday	Thursday	Friday
8:00-8:50 Professor 36 - course 26	**8:30-9:45** VAP 8 - course 17 VAP 14 - course 28 VAP 18 - course 37 Lecturer 1 - course 18 Lecturer 8 - course 17 Lecturer 11 - course 14 Professor 5 - course 41 Professor 8 - course 27 Professor 36 - course 26	**8:00-8:50** Professor 36 - course 26	**8:30-9:45** VAP 8 - course 17 VAP 14 - course 28 VAP 18 - course 37 Lecturer 1 - course 18 Lecturer 8 - course 17 Lecturer 11 - course 14 Professor 5 - course 41 Professor 8 - course 27 Professor 36 - course 26	**8:00-8:50** Professor 36 - course 26
9:05-9:55 Lecturer 3 - course 4 Lecturer 4 - course 18 Lecturer 11 - course 17 Lecturer 14 - course 9 Professor 7 - course 46 Professor 12 - course 11 Professor 13 - course 28 Professor 20 - course 47 Professor 25 - course 31 Professor 29 - course 23	**10:00-11:15** VAP 7 - course 15 VAP 15 - course 46 Lecturer 1 - course 18 Lecturer 9 - course 13 Lecturer 10 - course 17 Lecturer 12 - course 4 Professor 3 - course 45 Professor 17 - course 27 Professor 22 - course 38 Professor 23 - course 26 Professor 38 - course 28	**9:05-9:55** Lecturer 3 - course 4 Lecturer 4 - course 18 Lecturer 11 - course 17 Lecturer 14 - course 9 Professor 7 - course 46 Professor 12 - course 11 Professor 13 - course 28 Professor 20 - course 47 Professor 25 - course 31 Professor 29 - course 23	**10:00-11:15** VAP 7 - course 15 VAP 15 - course 46 Lecturer 1 - course 18 Lecturer 9 - course 13 Lecturer 10 - course 17 Lecturer 12 - course 4 Professor 3 - course 45 Professor 17 - course 27 Professor 22 - course 38 Professor 23 - course 26 Professor 38 - course 28	**9:05-9:55** Lecturer 3 - course 4 Lecturer 4 - course 18 Lecturer 11 - course 17 Lecturer 14 - course 9 Professor 7 - course 46 Professor 12 - course 11 Professor 13 - course 28 Professor 20 - course 47 Professor 25 - course 31 Professor 29 - course 23
10:10-11:00 VAP 9 - course 32 VAP 12 - course 36 VAP 18 - course 16 Lecturer 2 - course 5 Lecturer 3 - course 12 Lecturer 6 - course 4 Professor 4 - course 42 Professor 6 - course 57 Professor 37 - course 34		**10:10-11:00** VAP 9 - course 32 VAP 12 - course 36 VAP 18 - course 16 Lecturer 2 - course 5 Lecturer 3 - course 12 Lecturer 6 - course 4 Professor 4 - course 42 Professor 6 - course 57 Professor 37 - course 34		**10:10-11:00** VAP 9 - course 32 VAP 12 - course 36 VAP 18 - course 16 Lecturer 2 - course 5 Lecturer 3 - course 12 Lecturer 6 - course 4 Professor 4 - course 42 Professor 6 - course 57 Professor 37 - course 34
11:15-12:05 VAP 1 - course 27 VAP 12 - course 40 Lecturer 2 - course 16 Lecturer 3 - course 13 Lecturer 4 - course 2 Lecturer 6 - course 5 Lecturer 7 - course 20 Lecturer 13 - course 8 Professor 25 - course 50 Professor 32 - course 53	**11:30-12:45** VAP 4 - course 24 VAP 5 - course 35 VAP 7 - course 16 VAP 8 - course 17 Lecturer 1 - course 7 Lecturer 10 - course 13 Professor 11 - course 51 Professor 28 - course 52 Professor 30 - course 49 Professor 35 - course 59	**11:15-12:05** VAP 1 - course 27 VAP 12 - course 40 Lecturer 2 - course 16 Lecturer 3 - course 13 Lecturer 4 - course 2 Lecturer 6 - course 5 Lecturer 7 - course 20 Lecturer 13 - course 8 Professor 25 - course 50 Professor 32 - course 53	**11:30-12:45** VAP 4 - course 24 VAP 5 - course 35 VAP 7 - course 16 VAP 8 - course 17 Lecturer 1 - course 7 Lecturer 10 - course 13 Professor 11 - course 51 Professor 28 - course 52 Professor 30 - course 49 Professor 35 - course 59	**11:15-12:05** VAP 1 - course 27 VAP 12 - course 40 Lecturer 2 - course 16 Lecturer 3 - course 13 Lecturer 4 - course 2 Lecturer 6 - course 5 Lecturer 7 - course 20 Lecturer 13 - course 8 Professor 25 - course 50 Professor 32 - course 53
12:20-1:10 VAP 2 - course 46 VAP 9 - course 14 Lecturer 4 - course 2 Lecturer 5 - course 16 Lecturer 7 - course 18 Professor 7 - course 30 Professor 9 - course 25 Professor 15 - course 56 Professor 24 - course 61	**1:00-2:15** VAP 3 - course 29 VAP 15 - course 39 VAP 16 - course 19 VAP 17 - course 24 Lecturer 8 - course 18 Lecturer 10 - course 13 Lecturer 12 - course 4 Lecturer 14 - course 6 Professor 8 - course 26 Professor 27 - course 48 Professor 31 - course 55	**12:20-1:10** VAP 2 - course 46 VAP 9 - course 14 Lecturer 4 - course 2 Lecturer 5 - course 16 Lecturer 7 - course 18 Professor 7 - course 30 Professor 9 - course 25 Professor 15 - course 56 Professor 24 - course 61	**1:00-2:15** VAP 3 - course 29 VAP 15 - course 39 VAP 16 - course 19 VAP 17 - course 24 Lecturer 8 - course 18 Lecturer 10 - course 13 Lecturer 12 - course 4 Lecturer 14 - course 6 Professor 8 - course 26 Professor 27 - course 48 Professor 31 - course 55	**12:20-1:10** VAP 2 - course 46 VAP 9 - course 14 Lecturer 4 - course 2 Lecturer 5 - course 16 Lecturer 7 - course 18 Professor 7 - course 30 Professor 9 - course 25 Professor 15 - course 56 Professor 24 - course 61
1:25-2:15 VAP 1 - course 46 VAP 6 - course 25 VAP 14 - course 22 Lecturer 5 - course 3 Lecturer 11 - course 14 Lecturer 13 - course 8 Professor 10 - course 27 Professor 32 - course 58		**1:25-2:15** VAP 1 - course 46 VAP 6 - course 25 VAP 14 - course 22 Lecturer 5 - course 3 Lecturer 11 - course 14 Lecturer 13 - course 8 Professor 10 - course 27 Professor 32 - course 58		**1:25-2:15** VAP 1 - course 46 VAP 6 - course 25 VAP 14 - course 22 Lecturer 5 - course 3 Lecturer 11 - course 14 Lecturer 13 - course 8 Professor 10 - course 27 Professor 32 - course 58
2:30-3:45 VAP 2 - course 35 VAP 6 - course 26 Lecturer 2 - course 10 Lecturer 6 - course 13 Lecturer 7 - course 17 Lecturer 13 - course 16 Professor 16 - course 40 Professor 33 - course 26 Professor 37 - course 44	**2:30-3:45** VAP 3 - course 29 VAP 13 - course 40 Lecturer 9 - course 18 Lecturer 14 - course 14 Professor 11 - course 54 Professor 17 - course 24 Professor 35 - course 43	**2:30-3:45** VAP 2 - course 35 VAP 6 - course 26 Lecturer 2 - course 10 Lecturer 6 - course 13 Lecturer 7 - course 17 Lecturer 13 - course 16 Professor 16 - course 40 Professor 33 - course 26 Professor 37 - course 44	**2:30-3:45** VAP 3 - course 29 VAP 13 - course 40 Lecturer 9 - course 18 Lecturer 14 - course 14 Professor 11 - course 54 Professor 17 - course 24 Professor 35 - course 43	**2:30-3:45**
4:00-5:15 VAP 10 - course 35 Professor 12 - course 33	**4:00-5:15** VAP 4 - course 26 VAP 13 - course 40 VAP 16 - course 25 Lecturer 8 - course 17 Lecturer 9 - course 18 Lecturer 12 - course 1 Professor 18 - course 29 Professor 19 - course 60 Professor 23 - course 13	**4:00-5:15** VAP 10 - course 35 Professor 12 - course 33	**4:00-5:15** VAP 4 - course 26 VAP 13 - course 40 VAP 16 - course 25 Lecturer 8 - course 17 Lecturer 9 - course 18 Lecturer 12 - course 1 Professor 18 - course 29 Professor 19 - course 60 Professor 23 - course 13	**4:00-5:15**
5:30-6:45	5:30-6:45	5:30-6:45	5:30-6:45	5:30-6:45

Figure 6: New Schedule 2 - Post Registration

Comparing Change Minimizers

	$a * b$	$a + b$
Pre-Reg.	5 exact 16 same unassigned 49 same instructor	5 exact 17 same unassigned 46 same instructor
Post-Reg.	33 exact 15 same unassigned 108 at same time	39 exact 16 same unassigned 108 at same time

- Much better post-registration
- 133 sections total, so over 90% of assigned classes stay at same time post-registration
- $a + b$ leads to slightly better results, but more analysis needed to see if it is significant

Change Minimizer Results

A Closer Look at Some Instructors

Lecturer 11

- **Forced Change:** No teaching MWF 10:10-11
- **Schedule 1:** teaching 14 (MWF 9:05-9:55), 14 (MWF 10:10-11), 16 (MWF 1:25-2:15)
- **Schedule 1 PRE:** teaching 14 (MWF 8-8:50), 14 (12:20-1:10)
- **Schedule 1 POST:** teaching 14 (MWF 9:05-9:55), 3 (MWF 11:15-12:05), 14 (MWF 1:25-2:15)
- **Schedule 2:** teaching 16 (MWF 10:10-11), 14 (MWF 12:20-1:10), 14 (MWF 1:25-2:15)
- **Schedule 2 PRE:** teaching 14 (TTh 8:30-9:45), 14 (TTh 2:30-3:45)
- **Schedule 2 POST:** teaching 17 (MWF 8-8:50), 14 (MWF 1:25-2:15), 14 (TTh 8:30-9:45)

Change Minimizer Results

A Closer Look at Some Instructors

Professor 8

- No forced change, happy with original schedule
- **Schedule 1:** teaching 37 (TTh 8:30-9:45) and 18 (TTh 10-11:15)
- **Schedule 1 PRE:** teaching 27 (MWF 8-8:50)
- **Schedule 1 POST:** teaching 14 (MWF 10:10-11), 27 (TTh 8:30-9:45)
- **Schedule 2:** teaching 37 (TTh 8:30-9:45) and 38 (TTh 10-11:15)
- **Schedule 2 PRE:** teaching 44 (MWF 8-8:50), 31 (MWF 10:10-11)
- **Schedule 2 POST:** teaching 27 (TTh 8:30-9:45), 26 (TTh 1:00-2:15)
- None of new classes were highly ranked

Conclusions

- Schedule builder seems to create a reasonable schedule
- Even "minimizing" changes still creates a lot of changes
- Easier to keep courses at the same time than keep professors teaching the same courses
- Might want to make some schedule builder constraints soft(er) in change minimizer if the number of changes is more important
- Generating a schedule can be automated in a way that seems to be effective, but hard to know if the lack of "human touch" makes a difference without seeing the hand-made schedule
- At this stage, the change minimizer might be better used as a tool to see a possible way of accommodating changes
    - Our code might create a domino effect of changes to satisfy constraints when you could just switch two people and technically break a constraint, but save a lot of changes from being made

Future Ideas

- Implement constraints for same vs. different classes, back to back classes, forcing 2 days/week if needed
- Compare our output with actual schedule for next semester
- Make preference data less arbitrary by changing how the department gathers preferences: ask them to explicitly weight time slots and courses 0-1
- Experiment with other ways of formulating change minimizer objective function to get better results
  - More softness of schedule builder constraints
  - Potentially include preference data
- Look at individual-level results of more instructors to identify any potential biases or issues

Bibliography

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