DSO 570 Final Project Report –
Department Scheduling Optimization Strategy

Team 6: 12:30 section

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Table of Contents

Department Scheduling - Optimization Report

0. Executive Summary:

After deeply analyzing the problem, our team determined that the biggest opportunity for improvement was found within the initial time slot allocation stage (Phase I). If the time slots are assigned without considering the departments' individual preferences and needs, then it is not surprising that many adjustments would need to be made in the later stages. In order to reduce the need for additional allocation adjustments, we aim to create a tool that takes into consideration current departmental demands when allocating JKP timeslots.

Based on the analysis and optimization strategy, our team gained insights into how best to coordinate classroom scheduling for the seven graduate departments within Popovich Hall (JKP), while considering each Marshall graduate department's individual preferences and ensuring that the available classroom space was well-utilized. Leveraging our optimization tool, the Office of Academic Records and Registrar can potentially gain an estimated 11 points on average in the total departmental preference score (a recorded improvement seen from over 100 simulations).

Thus, our final recommendation for both Ms. Faris and Mr. Warning is to not only consider historical data while initially scheduling classes in Phase I, but also departmental time-slot preferences. By employing our proposed allocation approach, they will maximize the overall graduate departments' satisfaction score, while also ensuring that departments' teaching demands will be well-accommodated in JKP's classrooms.

1. Problem Statement:

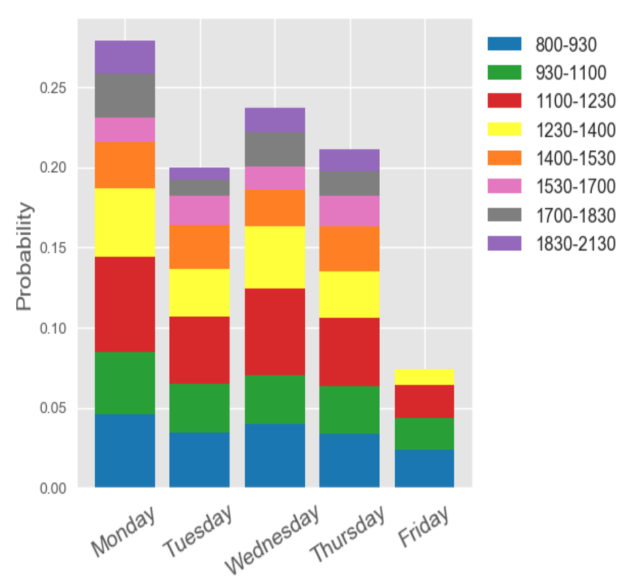
While scheduling classes for Marshall Business School, Ms. Faris and Mr. Warning face a myriad of obstacles, including conflicting demands from both professors and departments, the need to maximize and take advantage of current classroom space, and limited resources and time to solve the problem of scheduling. Transparency and fairness in the time-slot allocation is also integral, but must be completed in a way that does not weigh down current administrative processes. To alleviate these constraints, we aimed to craft a flexible optimization tool.

2. Opportunity for Improvement:

Through our simulation and data analysis, our team identified that the main weakness within the current scheduling process is that the decision of assigning time slots to departments is made based on no clear logic, which leads to time-consuming manual schedule changes in later Phases. If the time slots assigned to each department does not align with that department's current needs, Ms. Faris and Mr. Warning will have to make multiple adjustments manually later on in the scheduling process based on the different departments' conflicting needs. Hence, our team believes that initially assigning the timeslots in a way that suits the departments' current requirements, while also ensuring that the overall satisfaction can be quantified and maximized, will help alleviate a sizable part of the team's workload.

For the purpose of deeply understanding each department's preferences, the data of class schedules from 2015 to 2019 was collected and analyzed. Shown in Figure 2.1, most of the Graduate classes occur on Monday. While, the time slot "11:00-12:30" was the busiest time slot throughout the week. Figure 2.1 confirms that most of the professors within the departments prefer teaching at prime time slots. Also, regardless of which day of the week, teaching activities gradually increased and peaked at 11:00 a.m. - 12:30 p.m. After that, the trend of teaching activities gradually decreased. We leveraged this probability distribution to imitate actual professors' preference scores to better create simulations that mirror the real-world situation.

Figure 2.1: Timeslot Distribution by Weekday from 2015 to 2019 (Classes in JKP Only)



Before simulation, a few assumptions needed to be made. We assumed that:

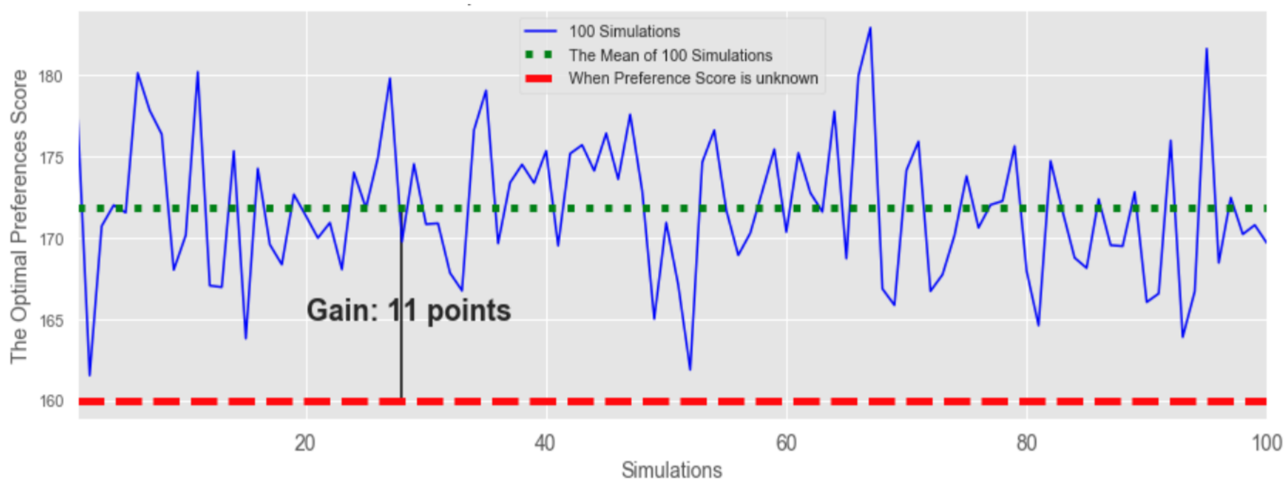
1. Professors do not have special preferences for which classrooms they are going to teach, as long as the classrooms are able to accommodate the registered number of students.
2. The percentage of professors who will teach in a given time slot for a given department follows a normal distribution, which means most departments will give a relatively higher preference score ranging from 0 to 1 to a prime time slot (starting from 9:30 to 15:30 as shown in Figure 2.1). However, there will be some fluctuation within one standard deviation across departments to reflect varying preferences.
3. For the situation, in which Ms. Faris and Mr. Warning do not receive a department's timeslot preference score, we assume the preference score to be 0.5 (shown in Table 2.1), which means that half of professors in a given department are willing to teach at that particular timeslot. Also, from the team's perspective, different timeslots are equally weighted when they do not know the department's preferences, which means they will either select a given timeslot or not.

Table 2.1: Preference Scores for All Departments When Department Preference is Unknown

	1	2	3	4	5
weekday					
800-930	0.5	0.5	0.5	0.5	0.5
930-1100	0.5	0.5	0.5	0.5	0.5
1100-1230	0.5	0.5	0.5	0.5	0.5
1230-1400	0.5	0.5	0.5	0.5	0.5
1400-1530	0.5	0.5	0.5	0.5	0.5
1530-1700	0.5	0.5	0.5	0.5	0.5
1700-1830	0.5	0.5	0.5	0.5	0.5
1830-2130	0.5	0.5	0.5	0.5	0.5

Shown below in Figure 2.3, we ran over 100 simulations of department timeslot preferences. It was found that for each simulation, the overall department satisfaction is consistently higher when the class scheduling was performed on the simulated preference scores (based on the historical data's distribution) in comparison to the situation in which the department's preference is unknown (meaning we assumed the preference score to be .5 for all departments). This reveals the benefit of using individual department preferences rather than assuming department preference is equal across timeslots. Given that the scheduling team acquires the preference scores of all graduate departments, they can utilize our model to accommodate each department's teaching needs accordingly and gain an extra 11 points on average in overall departmental satisfaction.

Figure 2.3: The Optimal Preferences Score for over 100 Simulations



From these 100 simulation results, our team has identified the need and benefit of taking the preference of each department into consideration when scheduling, and our team aims to apply these preference scores in our optimization methodology.

3. Optimization Methodology:

3.1 Optimization Methodology - Summary

Our team's optimization strategy focuses on maximizing overall department satisfaction based on the department time-slot allocation of classrooms in JPK, while balancing each department's satisfaction level so as to weigh each department's needs equally. Regarding the constraints of the optimization model, it will also guarantee that all projected teaching demands are well-accommodated, and that the same timeslots from 8:00 a.m. to 6:30 p.m. of a given classroom on Monday & Wednesday, and on

Tuesday & Thursday should be assigned to the same department in order to align with the current class scheduling practices.

3.2 Optimization Methodology - Inputs

As can be seen by our "Sample_Input.xlsx," the input Excel file contains ten sheets. These sheets include information about the classrooms within JKP, the available time slots, the department's hourly needs, and each department's time-slot preference. Each of these input Excel sheets will be discussed below:

- **3.2.1 "classroom – Pr"**: Describes the available graduate classrooms within JKP. Within this table of information, there is a column with the identifying classroom number, a column with the capacity of the classroom, and a binary identifier that signals whether the classroom is considered "Big" (1), meaning the capacity is greater than or equal to 77, or "Small" (0), meaning the classroom capacity is less than 77.

- **3.2.2 "hours - ht"**: Describes the time-slots across the different weekdays. Weekdays are displayed numerically – Monday through Friday corresponds to the numbers 1 to 5. There are a total of eight timeslots from 8:00 a.m. to 21:30 p.m. This table gives information about the amount of teaching hours within each of the eight time-slots for each weekday. For example, Tuesday (2) timeslot 930-1100 corresponds to 1.5 hours of class time.

- **3.2.3 "md"**: Describes the 7 graduate departments and the total hours of teaching that each will provide in that semester. For example, DSO is shown to be planning on teaching 42 hours' worth of courses.

- **3.2.4 "MKT", "BUCO", …, "BAEP"**: These final sheets represent the seven graduate department's individual preference scores for specific timeslots across the five weekdays. These sheets are all formatted the same, with table information corresponding to the proportion of teachers within each department that want that time-slot for that particular day. For example, if there are 10 professors in the DSO department and 3 of them would like to teach in a certain time slot, then the preference score of that department in that timeslot would be 0.3.

From these Excel sheets of information, our team built the variable inputs for our optimization tool. These include:

- The set of 7 graduate departments (BUCO, DSO, FBE, ACCT, MOR, MKT, BAEP).
- The set of 5 weekdays (1,2,3,4,5) that correspond to Monday, Tuesday, Wednesday, Thursday, and Friday.
- The set of available time slots in a day (8:00−9:30,9:30−11:00,11:00−12:30,⋯, and 18:30−21:30).
- The set of available rooms within JKP, each identified by their room number (102, 104, 110, 112, 202, 204, 210, and 212).
- The total number of hours a department teaches in a semester.
- The proportion of professors from each department who prefer to teach in a timeslot on a specific weekday.
- Whether a classroom in JKP has a capacity greater than or equal to 77, meaning it is designated as being "Big" in comparison to other classrooms.
- The number of teaching hours in a particular time slot. This value will either be 1.5 or 3 hours.

3.3 Optimization Methodology – Objective

To restate our goal, our optimization tool aims to provide Mr. Warning and Ms. Faris with a flexible and fair way to allocate timeslots across the week of different classrooms in JKP to different departments. Our optimization tool will determine fairness, by ensuring that each department's timeslot preference scores are taken at equal value.

3.4 Optimization Methodology – Decision Variables

The decision variable for our optimization tool is binary, meaning it can either take on the value 0 or 1. This variable represents whether a particular department takes up a timeslot of a specific classroom on a specific day – if a given department does, this variable for that department will be 1, otherwise this variable will be 0.

3.5 Optimization Methodology – Auxiliary Variables

Our methodology also includes two continuous, auxiliary variables that represent the upper and lower bound of the total timeslot preference scores of each of the departments.

In order to accomplish these goals, our team formulated our objective function to maximize the preference scores summed across departments, timeslots, all JKP rooms, and days of the week, while maintaining a level of equality across departments in order to promote fairness.

3.6 Optimization Methodology – Constraints

In order to make our optimization tool more closely aligned with reality's limitations, we considered several constraints when creating our objective function:

- **3.6.1 Matching Principle Constraint**: This constraint considers that for timeslots that are 1.5 hours in length, there needs to be a match scheduled at the same time, but for a complementary day. So, for 1.5 hour courses scheduled on Monday, there needs to be a complement on Wednesday at the same time. The same is true with Tuesday and Thursday pairings. An example of this constraint is that if the optimization tool schedules BUCO for timeslot 8:00-9:30 a.m. on Monday, BUCO must also fill the 8:00-9:30 a.m. slot on Wednesday. An important thing to note about this constraint, is that night timeslots (marked as being 3 hours long) during 18:30–21:30 p.m., do not need a complement and are thus not limited by this constraint. Also, Fridays (day 5) are not involved in this constraint either.

- **3.6.2 Full Arrangement Constraint**: This constraint ensures that one timeslot is only assigned to one department. This limitation guarantees that the optimization tool does not schedule multiple departments for the same timeslot of a given classroom on a given day of the week.

- **3.6.3 Big Room Constraint**: As a reminder, one of our inputs is a binary variable signifying if a JKP classroom is considered "Big" (1) or "Small" (0). The Big Room constraint provides departments with an advanced level of fairness in classroom assignments, meaning that each department should at least be assigned to a "Big" room once throughout the week. This helps protect against one department getting zero large capacity room, which would put them at an unfair disadvantage over the other departments.

- **3.6.4 Preference Balance Constraint**: This constraint defines our auxiliary variables - the upper and lower bounds of the average timeslot preference score of each of the seven departments. The average timeslot preference score denotes how many percent of a department's preference is satisfied.

- **3.6.5 Hours Demand Constraint**: One of the most important constraints in our tool, is to ensure that the department's individual hourly needs are met. A reminder, one of our data inputs includes the total number of teaching hours each department expects for the entire semester. Our optimization tool ensures that for each department, the summation of their designated timeslots results in a total number of teaching hours greater than or equal to the required number of teaching hours.

3.7 Optimization Methodology – Outputs

Our scheduling optimization tool will provide the optimal time-slot allocation plan of all classrooms within JKP for seven departments across the week, while considering the known constraints.

This output will be in an organized table format, with columns representing the classrooms available in JKP and rows representing all time slots for each day of the week. Within these tables our optimization strategy will designate which of the seven graduate departments (BUCO, DSO, FBE, ACCT, MOR, MKT, BAEP) have been allocated to that individual timeslot.

3.8 Optimization Methodology – "How it Will Be Used"

We envision that our optimization method will be used by Ms. Faris and Mr. Warning before Phase I of the department allocation process, which is currently being done based on historical data, rather than on current departmental needs.

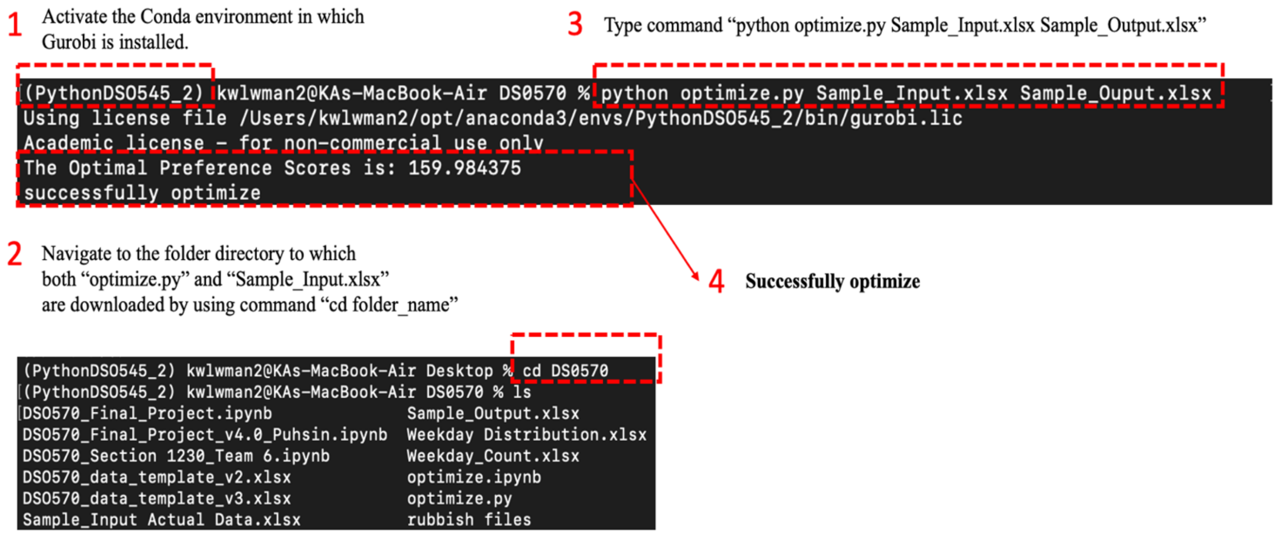
In order to execute this tool, Ms. Faris and Mr. Warning's team would need to collect and process each department's preference score and fill in the input excel file as we described in the previous section. To provide this information, each department must survey their professor's preferred teaching hours so that Ms. Faris and Mr. Warning's team could transform the collective data into a unified preference score for that department. The preference score of each department for a particular timeslot can be calculated as follows:

Formula 3.7.1 The Calculation of Preference Score

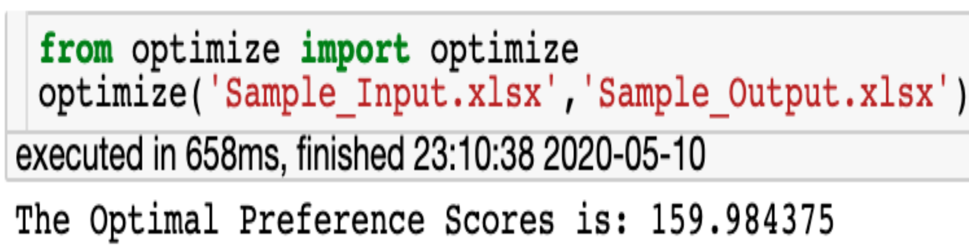
$$\frac{\#\ of\ professors\ willing\ to\ teach\ at\ a\ given\ time\ slot\ in\ a\ given\ department}{total\ \#\ of\ professors\ who\ are\ a\ part\ of\ a\ given\ department}$$

<u>After completing the input file, the team can simply follow the instructions shown in both the Flowchart 3.8.1 and Flowchart 3.8.2 to produce the optimal scheduling solution</u>:

Flowchart 3.8.1 The Instructions to Run the Optimization Tool via Command Prompt



Flowchart 3.8.2 The Instructions to Run the Optimization Tool via Jupyter Notebook



4. Optimization Results:

Now our team will discuss the results of our optimization methodology using our constructed inputs and constraints.

Below, you will find a visual example of the departmental timeslot allocation output. The column denotes the available JKP classrooms and double-index denotes the weekdays and the timeslots. Note that on Wednesday and Thursday, our team only shows the 18:30-21:30 timeslots, since all the other time slots are the same as those on Monday and Tuesday in a week and thus redundant.

As you can see (Table 4.1) for each available timeslot across the week, a particular department is assigned to it:

Table 4.1: The Sample Output

Weekday	Timeslot	102	104	110	112	202	204	210	212
Mon & Wed	800-930	DSO	ACCT	MKT	ACCT	ACCT	BAEP	FBE	MKT
	930-1100	DSO	DSO	ACCT	BUCO	ACCT	DSO	MOR	MKT
	1100-1230	DSO	MKT	MKT	MOR	DSO	DSO	FBE	MKT
	1230-1400	DSO	DSO	DSO	BAEP	BAEP	BAEP	DSO	MKT
	1400-1530	FBE	DSO	FBE	BUCO	BAEP	ACCT	MOR	FBE
	1530-1700	BAEP	MKT	MKT	ACCT	BAEP	FBE	MKT	MKT
	1700-1830	BAEP	ACCT	MOR	MKT	BAEP	MOR	MKT	BAEP
Mon	1830-2130	MKT	ACCT	BUCO	BUCO	MOR	MOR	BUCO	BUCO
Wed	1830-2130	DSO	MOR	MOR	BUCO	MOR	BUCO	MOR	MKT
Tue & Thur	800-930	BAEP	BAEP	DSO	MKT	BAEP	FBE	MKT	MKT
	930-1100	BUCO	DSO	FBE	FBE	ACCT	FBE	FBE	MOR
	1100-1230	BAEP	ACCT	BUCO	FBE	ACCT	DSO	DSO	MOR
	1230-1400	DSO	ACCT	MKT	BUCO	MOR	FBE	MKT	FBE
	1400-1530	BUCO	BAEP	FBE	BUCO	BAEP	DSO	MOR	MOR
	1530-1700	MOR	ACCT	BUCO	FBE	DSO	FBE	FBE	ACCT
	1700-1830	BAEP	BAEP	MOR	MOR	BAEP	FBE	MOR	BAEP
Tue	1830-2130	ACCT	BUCO	BUCO	MOR	MOR	ACCT	ACCT	ACCT
Thur	1830-2130	MOR	ACCT	BUCO	DSO	DSO	BUCO	BUCO	MOR
Fri	800-930	FBE	DSO	MKT	BUCO	BUCO	BUCO	MKT	MOR
	930-1100	ACCT	ACCT	MOR	MKT	BUCO	BAEP	MKT	FBE
	1100-1230	BUCO	DSO	MOR	BUCO	ACCT	ACCT	BUCO	MOR
	1230-1400	MOR	FBE	ACCT	ACCT	BUCO	BUCO	FBE	DSO
	1400-1530	BUCO	BAEP	ACCT	DSO	BUCO	BAEP	MOR	MKT
	1530-1700	ACCT	BUCO	FBE	DSO	MKT	BUCO	BAEP	MKT
	1700-1830	ACCT	MOR	MKT	BUCO	ACCT	BUCO	FBE	MOR
	1830-2130	ACCT	BUCO	FBE	BUCO	ACCT	BUCO	BUCO	BAEP

We also quantified the potential gains of using our optimization methodology. In comparison to our control group (where we assumed that all preferences between departments were equal at 50%), our new allocation strategy based on 100 simulations of data displays an improvement of around 11 satisfaction points on average.

Qualitatively, we can attribute these calculated gains to utilizing specific and current departmental demand data when scheduling instead of a uniform approach. We can also attribute this improvement in satisfaction to also providing the departments with a level of equality, fairness, and transparency, as with our constraints, we protect against unfair treatment and favoritism within our allocation process.

5. Discussion:

5.1 Discussion – Appropriateness of Methodology:

Our proposed optimization tool is the best fit for the department scheduling situation, because it addresses one of the most pressing issues of Phase I – the scheduling of departments within timeslots. Our goal is to allocate in a way that maximizes the preference scores of each department. The input required to update each semester is the required teaching hours and timeslot preference score of each department. Whoever uses this scheduling model will only need to update the preference numbers of the existing excel sheet, so we believe that the tool is manageable even for someone without a technical background.

We also constructed the output to be familiar to the current scheduling staff, in order to increase our tool's usability. As you can see from our previous output image, it follows the same layout as the Phase I schedules used in previous years.

We also decided to craft our objective in a way that encapsulates the ultimate goal of our tool – to allocate daily timeslots in a way that maximizes the department's satisfaction.

Below, we discuss the rationale behind each of our seven defined constraints:

- Matching Principle Constraint: As a reminder, this constraint enforces that 1.5 hour courses on Monday and Tuesday must have a complement on Wednesday and Thursday, respectively. Our rationale for including this constraint was that typically USC will break a course up into two 1.5 hour matching segments, either in Monday/Wednesday or Tuesday/Thursday pairs. In order to better reflect this reality, we ensured that our tool includes this constraint. We also ensured that in the case of a 3 hour long class (as seen in the case of the night timeslots) we do not require this matching principle.

- Full Arrangement Constraint: Ensuring only one department can fill a particular timeslot assignment makes sure that we are not incorrectly allowing two departments to fill one slot.

- Big Room Constraint: The constraint provides a quantifiable level of fairness and equality in timeslot allocation across the different departments. For example, it would be unfair if one department was slated to have all the "Big" classrooms, as this added space could provide them with more teaching opportunities. Thus, we enforce that each department at least gets one big classroom assigned to them.

- Preference Balance Constraint: We hope that each department's satisfaction is fulfilled at a similar level. Hence, we divide the preference score being fulfilled by the sum of the total preference score. We utilized this constraint in order to minimize the difference between department preference scores in order to better promote fairness and equality.

- Hours Demand Constraint: In the reality of the scheduling scenario, each of the individual departments will have a different need for classroom hours. With this constraint we aimed to ensure that each department is scheduled for all their estimated teaching hours.

Discussion – Assumptions:
Our main assumptions when creating this optimization tool include:
- We assumed that JKP could accommodate all educational purposes the departments require in a week.
- We also assumed that Friday schedules will act similarly to the rest of the week, meaning that each department has an equal chance of also being scheduled on a Friday.
- We assumed that 1.5 hour classes on Mondays and Tuesdays must have complements on Wednesday and Thursdays respectively.
- We assumed that all courses could be separated into 1.5 hour sessions. Hence, the time slots are partitioned using this time range.
- We assumed that professors' preferences are only time slot-based rather than classroom-based. Thus our score is only reflective of their preference for the timeslot.

Discussion – Weaknesses:
Though our optimization methodology addresses many of the problems the Academic Scheduling team is facing, it does have room for improvement. Some of our addressable weaknesses include:
- Some departments might want to have consecutive time slots assigned to them, however, if the preference score does not reflect this need, then our model would not be able to take this into account.
- It might be hard for the department to hand in the professor's available time slots on time. In addition, there might be cases that no one wants to teach in certain time slots across departments. If there are too many of these kinds of unpopular time slots, we might not be able to fulfill the "hours demand" constraint and thus cannot get a unified result.
- By including the one big room constraint, we potentially ignore a scenario in which one department has a greater need for larger rooms in comparison to the other departments.

5.2 Discussion – Final Recommendations:

After our analysis of the current situation and our proposed improvements, we suggest that Ms. Faris and Mr. Warning implement our optimization tool before Phase I of the departmental allocations in order to improve their current methodologies. Though our method requires an extra step in surveying, it reduces scheduling conflicts and thus reduces overall administrative efforts.

In addition, because we have made many assumptions to simplify our model, we would also suggest for later updates of our solution to consider more complex situations and constraints. We also suggest that they acquire new information from the departments every semester, so that their data reflects current needs.

6. Technical Appendix

Now we will dive into the mathematical construction of our optimization tool and the quantitative aspects of our results.

6.1 Mathematical Formulation - Data:
Below is a comprehensive list of our data variables that we utilized to build our optimization tool:

- $D =$ {BUCO, DSO, FBE, ACCT, MOR, MKT, BAEP}, represents the set of 7 Marshall graduate departments.
- $C =$ {1, 2, 3, 4, 5}, represents the set of 5 weekdays (1,2,3,4,5) that corresponds to Monday, Tuesday, Wednesday, Thursday, and Friday.
- $T =$ {8:00−9:30, 9:30−11:00, 11:00−12:30,⋯, 6:30−21:30}, represents the set of available timeslots in a day (8:00−9:30,9:30−11:00,11:00−12:30,⋯, and 18:30−21:30).
- $R =$ {102, 104, 110, 112, 202, 204, 210, 212}, represents the available rooms within JKP, each identified by their room number.
- m_d, represents the total number of hours a department (d) teaches in a semester.
- $p_{dtc} \in$ {0, ..., 100}, represents the percentage of professors from each department d who prefer to teach on timeslot t on weekday c.
- b_r, represents whether a classroom r's capacity is greater than or equal to 77 seats (distinguishing it as a "Big" classroom).
- h_t, represents the number of hours in a particular timeslot t (either 1.5 or 3 hours). Three hour timeslots are only found in the night, and thus are also called "night timeslots".

<u>Mathematical Formulation – Decision Variables:</u>
Below is a mathematical representation of our decision variable for our optimization methodology:

- a_{dtrc}, our binary decision variable represents whether or not department d takes up timeslot t in classroom r on weekday c.

Mathematical Formulation – Auxiliary Variables:
Below is a mathematical representation of our auxiliary variables:

- L, represents the continuous lower boundary of the total preference score for each department (d).
- U, represents the continuous upper boundary of the total preference score for each department (d).

Mathematical Formulation – Objective Function:
Below is an in-depth look at our objective function, which aims to maximize the overall preference score of the departments based on optimal timeslot scheduling:

- $\sum_{d \in D} \sum_{t \in T} \sum_{r \in R} \sum_{c \in C} a_{dtrc} p_{dtc} - (U - L)$

Mathematical Formulation - Constraints:
Each of our seven mathematical constraints can be seen written in the list below:

- Matching Principle Constraint: $a_{dtrc} = a_{dtr(c+2)}$ for each $d \in D$, $c \in \{1,2\}$, $r \in R$, $t \in T / \{6{:}30–21{:}30\}$.

- Full Arrangement Constraint: $\sum_{d \in D} a_{dtrc} \leq 1$ for each $c \in C$, $r \in R$, $t \in T$.

- Big Room Constraint: $\sum_{t \in T} \sum_{r \in R} \sum_{c \in C} b_r a_{dtrc} \geq 1$ for each $d \in D$.

- Preference Balance Constraint: $L \leq \frac{\sum_{t \in T} \sum_{r \in R} \sum_{c \in C} a_{dtrc} p_{dtc}}{\sum_{c \in C} \sum_{t \in T} p_{dtc}} \leq U$ for each $d \in D$.

- Hours Demand Constraint: $\sum_{t \in T} \sum_{r \in R} \sum_{c \in C} h_t a_{dtrc} \geq m_d$ for each $d \in D$.

6.2 Discussion of Technical Details

Mathematical Assumptions:
Our optimization tool runs on some assumptions, which include the following:
- We assumed that JKP could accommodate all educational purposes the departments require in a week, this affects our Hours Demand Constraint (which

can be seen formulated above). We assumed that JKP and its available classrooms can handle all departmental demands, when in reality some courses may have to be taught in JFF or HOH for both capacity and technical reasons.

- We also assumed that Friday schedules will act similarly to the rest of the week, meaning that each department has an equal chance of also being scheduled on a Friday. This constraint may make our scheduling tool a little less realistic, as from historical data, it appears that Friday's are primarily filled with EMBA, IBEAR, and MBV graduate courses.
- We assumed that all courses could be separated into 1.5 hours sessions. Hence, the time slots are partitioned using this time range, which affects how we define our timeslot (t). We based our time slots on 1.5 hour sessions, because on average classes are taught in 1.5 hour segments across the week.
- We assumed that 1.5 hour classes on Mondays and Tuesdays must have complements on Wednesday and Thursdays respectively. This constraint is found within our mathematical formulation of the Matching Principle Constraint, $a_{dtrc} = a_{dtr(c+2)}$.
- We presume that professors' preferences are only time slot-based rather than classroom-based. Thus our score is only reflective of their preference for the timeslots. This affects our definition of the preference variable, p_{dtc}, and this variable may be affected if we also included classroom preference into the calculation.

<u>Quantitative Weaknesses</u>:

Some of our addressable quantitative weaknesses include the following:

- Some departments might want to have consecutive time slots assigned to them, however, if the preference score did not reflect this need, then our model would not be able to take this into account. This weakness could be later resolved if we added additional constraints and included more input variables, but in order to simplify our model and make it more flexible we did not include this scenario.
- Another possible weakness is that it might be difficult for the departments to hand in the professor's available time slots on time. In addition, there might be cases that no one wants to teach in certain time slots across departments. If there are too many of these kinds of unpopular time slots, we might not be able to fulfill the "hours demand" constraint and thus cannot get a converged result. This may be solved by requiring teachers to select one timeslot within the less popular teaching times.
- By including the one big room constraint, we potentially ignore a scenario in which one department has a greater need for larger rooms in comparison to the

other departments. This can later be solved by adding additional constraints or variables to indicate how many big rooms the departments' needs.