A MIP-based Approach to Optimizing Course Scheduling at USC Marshall

Final Project Report

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Executive Summary

For several universities across the world, the implementation of a systematic approach to course scheduling remains a problem. Discrete optimization approaches have been used to solve the problem independently at such institutions, however owing to the complex nature of the problem compounded by the viewpoints of various stakeholders, a universal “cookie-cutter” solution does not exist. There are 7 departments in the Marshall School of Business at USC, and course scheduling is currently performed by reusing the course schedule from the previous year as closely as possible and manually implementing a series of reforms to improve efficiency and transparency. The current process assigns over 400 courses into 45 schedulable rooms at 42 different times. However, the schedules produced by the current process are not always transparent and efficient. Additionally, sections are scheduled and de-scheduled multiple times during the course allotment process which makes greedy approaches to the allocation problem inefficient.

Our solution to the problem involves the creation of a tractable MIP-based allocation tool that equitably assigns departments to classroom-timeslots. An algorithm[1] developed in-house generates classroom-timeslot preference scores for each department based on survey results[2], and every run of the allocation tool outputs candidate sets of classroom-timeslots for each department. The size of the candidate sets is dependent upon a model-tuning parameter that controls the greediness of the allocation approach. This grants a greater degree of flexibility in course-scheduling and ensures that a certain quantity of classroom-timeslots of each category[3] are available for the next (potential) run of the allocation tool to assign the remaining sections. The focus of this report is to describe the functioning of the tool, and the business value it offers to the administrative wing of the Marshall School of Business.

In the first step of the report, we propose a precise and high-level explanation on how the application of Mixed Integer Programming can be used to solve the course scheduling problem. In the second step of the report, we formulate a Mixed Integer Program by creating the input and output data, the decision variables, the objective function and the constraints. We conclude with a description of the output from one run of the model, and why the model makes sense and is easily implementable.

Introduction

Course scheduling refers to the administrative process of assigning course to rooms and times. There are many resources involved in the course scheduling process, such as students, type of students, rooms, instructors, departments, and programs. USC Marshall has 7 departments, 22 academic programs, and enrollment of around 5000 undergraduates and 1000 graduate students. Due to the many restrictions and preferences on rooms assignments, it is difficult to find an optimal schedule.

There are mainly two phases in the current scheduling of courses and classrooms at USC Marshall, which begins almost one year before the semester begins. This process is guided by Shannon Faris, the Assistant Dean of Institutional Research and Academic Administration at the USC Marshall, and her colleague Hal Warning.

- Phase 1: Each department head administrator at USC Marshall determines which courses and time slots to populate while satisfying the particular needs of each course. Instructors may also reach out to the department head to indicate preferences for teaching times.

- Phase 2: Using historical schedules, changes are made according to the initial allocation results of Phase 1. Shannon and Hal then schedule the remaining courses. Any unused time slots become open for any department at USC Marshall to use.

With this current scheduling process, only 40% of course-sections are completely scheduled by the end of Phase 1. Faculty preferences for classrooms and times become increasingly difficult to accommodate. Some courses may be placed into classrooms too large for the number of students enrolled in the course, and in rare cases, some classroom may still be unassigned at the time students register for their class or even well before registration starts.

An automated scheduling system would help Shannon and Hal solve these challenges more efficiently. The goal of this report is to improve the administrative aspects of course scheduling at USC Marshall School of Business by creating a department timeslot allocation tool for Shannon and Hal that outputs a candidate set of possible allocations based on mutually agreeable switches between departments, while addressing the challenges described above.

Mathematical Background

While there are several mathematical methods to solve the course scheduling problem, we believe Linear Programming to be the best advanced business analytics technique. Therefore, it is important to understand the quantitative concepts of Linear Programming (LP) used to solve the course scheduling problem at USC Marshall School of Business.

Linear Programming

In solving a course scheduling problem, it is helpful to first understand the definition of Linear Programming. Linear programming is an optimization model that maximizes (or minimized) a linear function, called the objective function subject to a set of linear constraints. The objective function and the constraints are expressed in terms of decision variables, which are the variables that define the solution of the problem.

A linear function of variables $x_1, x_2, ..., x_n$ is one that can be expressed in the form:

$$f(x) = a_0 + \sum_{i=1}^{n} a_i x_i$$

where $a_0,\ a_1, ...,\ a_n$ are all numerical constants(not variables)

Solutions of a linear program that satisfy all constraints in the problem are called feasible solutions.

Mixed Integer Programming

Like LP, Mixed Integer Programming (MIP) an optimization model with a linear objective function, linear constraints, and decision variables that can either be continuous or integers. Because of the allowance of integer constraints, MIPs is a generalization of LP and is thus more flexible. In focusing on the course scheduling problem, a MIP formulation can help Shannon and Hal improve the current system at USC Marshall School of Business. All decision variables will be binary variables since we essentially build a model model based on yes/no decisions for the course scheduling.

Application of MIP in Course Scheduling

Explanation

- **Who:** Shannon and Hal, the management team. It outputs a first draft of possible allocations for departments.
- **What:** The management team needs to conduct a survey for department preference scores. The preference data stems from historical preferences of departments for classroom-timeslots. Ex: If Dept 1 were assigned the same classroom-timeslot over the past years, it is reasonable to believe that the department has a preference for the timeslot, and the department was not being consistently assigned the timeslot by luck.
- **When:** This fills in the requirement pre-survey. Historical preference data is curated and fed to the optimizer, which outputs a set of candidate time slots for each department. For the final deliverable, we aim to implement a "switching" algorithm that uses the output of the present MIP optimizer and rank-ordered department change-requests, new course scheduling, etc. and delivers a final set of allocations.
- **Caveat:** Individual faculty preferences would be much more difficult to tackle, and it is best that individual departments deal with the same – as is the current norm. With our optimizing tool, we aim for an equitable distribution of classroom sessions to departments without delving into the granularity of what happens at the individual course level. It is naturally assumed that departments will investigate faculty preferences for various time slots and output the final preference list across all classroom sessions to Shannon and Hal.

Limitation

- The number of courses offered would be different for each department. Some departments offer a few courses while some others offer many. We need to set up constraints such that this discrepancy in the "department-wise bulk of classrooms" is mitigated.
- Professors may have additional possible preferences.
- Classroom Sessions (CS) preferences would be the same for many departments. Some CS will tend to have a higher preference overall across departments. We can think of using a game-theory approach to minimizing.
- There is a possibility that all department would black out the same time-slots.
- The scaling factor for the department preference inequality would be different, depending on what dataset we have.
- Classroom utilization is not taken into account.

Mathematical Formulation of MIP in Course Scheduling

As a proof of concept, we construct a test dataset (Final_TOYDATA.xlsx) to implement the mathematical formulation of MIP described below.

Model Assumptions

For the purpose of this project, we consider 3 departments offering 10, 9 and 7 sections respectively; 5 classrooms of 3 different size types, with 3 available time slots for each classroom on each day of the week except Friday.

Input Data

- $I = \{D_1, ..., D_i\}$ *is the set of 'i' Departments*
- $J = \{M, T, W, H, MW, TH, F\}$
- $K = \{CS_1, ..., CS_k\}$ *is the set of i Classroom Sessions Timeslots .*
  The index i corresponds to a classroom − timeslot combination.
  For example : $JKP212 - 1700 - 1830$ *is a unique CS index.*
  Note that each CS has a time slot duration of 1.5 *hours.*
- $CS = \{Small\ (S),\ Medium\ (M),\ Large\ (L)\}$ *is the set of Classroom Size types*
- $J_{1.5} = \{M, T, W, H, F\}$ *is the subset of days where a department 'i' is assigned a* 1.5 *unit course*
- $J_3 = \{M - W, T - H\}$ *is the subsets of days where a department 'i' is assigned a* 3 *unit course*
- $x_{ijk} =$ *is the set of binary decision variables for allocation of a Department 'i' to a CS 'k' on day 'j'*
- $P_{ijk} =$ *is the set of historical preference scores of a Department 'i' for a CS 'k' for day 'j'.*
- $Q_j = \{q_1, ..., q_j\}$ *is the set of minimum number of timeslots required by department 'i'*
- $Q_{Sj} = \{q_{S1}, ..., q_{Sj}\}$ *is the set of minimum number of Small timeslots required by department 'i'*
- $Q_{Mj} = \{Q_{M1}, ..., Q_{Mj}\}$ *is the set of minimum number of Medium timeslots required by department 'i'*
- $Q_{Lj} = \{Q_{L1}, ..., Q_{Lj}\}$ *is the set of minimum number of Large timeslots required by department 'i'*
- $Q_{Sj_{1.5}} =$ *Number of timeslots required by Department 'i' for "Small" sections worth* 1.5 *credits*
- $Q_{Sj_{3.0}} =$ *Number of timeslots required by Department 'i' for "Small" sections worth* 3.0 *credits*
- $Q_{Mj_{1.5}} =$ *Number of timeslots required by Department 'i' for "Medium" sections worth* 3.0 *credits*
- $Q_{Mj_{3.0}} =$ *Number of timeslots required by Department 'i' for "Medium" sections worth* 3.0 *credits*
- $Q_{Lj_{1.5}} =$ *Number of timeslots required by Department 'i' for "Large" sections worth* 3.0 *credits*
- $Q_{Lj_{3.0}} =$ *Number of timeslots required by Department 'i' for "Large" sections worth* 3.0 *credits*
- $ƛ =$ *Tuning Parameter for model*
- $U_{DP} =$ *Maximum : Weighted Cumulative Department Preference*
- $L_{DP} =$ *Minimum : Weighted Cumulative Department Preference*
- $S =$ *Set of all Small classroom sessions*

Survey Data

In this section we describe the procedure adopted to populate department preferences for classroom-timeslots. It would be impractical to ask a department coordinator to populate preference scores for each classroom-timeslot, and we need a smarter method of getting the overall notion of "preference" for classrooms and timeslots. Indeed, in many instances the department coordinators might be "classroom agnostic", i.e. would not care much about the classroom being allotted for a section as long as the enrolled students can be accomodated in a class. Thus there is a need for an algorithm that takes preferences (if any) from department coordinators for classrooms and timeslots for individual sections and aggregates the same to the department level.

The management obtains a list of sections to be scheduled from each department coordinator before every run of the MIP. Each section is classified as a small (S), medium (M), or a large (L) section based on the estimated enrolment. The existing classrooms are also classified similarly into S, M and L classrooms using the same thresholds. The department coordinator then submits -

- Up to 3 classrooms of preference (sorted in increasing order of preference, stored as a vector [C_{S1}]) from all classrooms of the same category (S, M , L) as the section and/or
- 3 timeslots (sorted in increasing order of preference) [TS_{S1}]. For example, a sample set of preferences for DSO570_16298 would look as follows. C_{DS0570_16298} denotes the vector of classroom preferences in increasing order, TS_{DSO570_16298} denotes the vector of timeslot preferences in increasing order :

	Classroom Preferences			Timeslot Preferences		
DSO570_16298	JKP212	JFF211	JKP312	TS1	TS5	TS8

Algorithm to populate Department D1's Preference Scores for Classroom-Timeslots:

Let D1 have 'n' sections (S1, S2, S3,...Sn) to be scheduled. Then;

1) Set P_{ijk} to a small non-zero value ϵ for all j in J, k in K
2) For **sec** in S1, S2, S3,….Sn:
   a) If **sec** is S:
      (i) for m in $C_{\mathbf{sec}}$:
         for n in TS_{sec}:
            k = CONCATENATE(m,n)
            $P_{ijk} = P_{ijk} + \text{index}(m, C_{sec})*\text{index}(n, TS_{sec}) + \beta_0$
      (ii) for m in {$C_{SMALL} - C_{\mathbf{sec}}$}:
         for n in TS_{sec}:
            k = CONCATENATE(m,n)
            $P_{ijk} = P_{ijk} + \text{index}(n, TS_{sec})$

b) If **sec** is M:

(i) for m in $C_{\mathbf{sec}}$:

for n in TS_{sec}:

k = CONCATENATE(m,n)

$P_{ijk} = P_{ijk}$ + index(m, C_{sec})*index(n, TS_{sec}) + β_0

(ii) for m in {C_{MEDIUM} - $C_{\mathbf{sec}}$}:

for n in TS_{sec}:

k = CONCATENATE(m,n)

$P_{ijk} = P_{ijk}$ + index(n, TS_{sec})

c) If **sec** is L:

(i) for m in $C_{\mathbf{sec}}$:

for n in TS_{sec}:

k = CONCATENATE(m,n)

$P_{ijk} = P_{ijk}$ + index(m, C_{sec})*index(n, TS_{sec}) + β_0

(ii) for m in {C_{LARGE} - $C_{\mathbf{sec}}$}:

for n in TS_{sec}:

k = CONCATENATE(m,n)

$P_{ijk} = P_{ijk}$ + index(n, TS_{sec})

3) $P_{ijk} = P_{ijk}$ / n

Notes

A. C_{SMALL}, C_{MEDIUM}, C_{LARGE} are the sets of all S, M and L classrooms respectively.

B. If C_{sec} is not provided for a section (classroom agnostic), a random subset of size 3 is chosen from classrooms of corresponding category.

C. B_0 is a non-zero "bias" value that serves to naturally increase preference scores specified by department coordinators. Note that the bias term does not exist in the updates made to P_{ijk} for classrooms not explicitly mentioned by coordinators.

D. Cumulative scores are scaled by total number of sections to be scheduled. This is to ensure that "large" departments, i.e. departments offering many sections do not have an unfair advantage.

Output Data

A table matrix of decision variables x_{ijk} indicating whether classroom sessions 'k' is assigned to department 'i' on day-index 'j'

Decision Variables

x_{ijk} : *Whether the classroom session* (CS) *k is allocated to a department 'i' on a day 'j'* .

Total of 270 *decision variables* .

Tuning Parameters

λ : *tuning parameter to scale the preference score inequality. In this problem,* $\lambda = 100$

Ω : *tuning parameter to control the maximum number of classroom session assignments.*

In this problem, $\Omega = 1.5$

Objective Function

The objective function of our optimization involves 2 terms. The first term is a summation of the preference score of each department for a given classroom session multiplied by the binary decision variable of whether they were assigned to a classroom session. The second term of the objective function is a fairness factor, which we multiply by lambda to scale. The fairness factor is defined as (U-L), with U being the maximum summed department preference scores divided by the number of classes in that department, and L being the minimum summed department preference score divided by the number of classes in that department. This term aims to ensure that all departments are assigned a similar overall preference score for their requested classes.

Maximize: $\sum_{i \in I} \sum_{j \in J} \sum_{k \in K} x_{ijk} * p_{ijk} - \lambda * (U_{DP} - L_{DP})$

Subject to:

Binary DV: $x_{ijk} \in \{0, 1\}$

Upper bound: $U_{DP} \geq \frac{\sum_{i \in I} x_{ijk} * p_{ijk}}{q_i}, \text{ for all } i \in I$

Lower bound: $L_{DP} \leq \frac{\sum_{i \in I} x_{ijk} * p_{ijk}}{q_i}, \text{ for all } i \in I$

One dept ~ one slot: $\sum_{i \in I} x_{ijk} \leq 1, \text{ for all } j \in J, k \in K$

Small section, 1.5 Credit Timeslots: $\sum_{k \in S} \sum_{j \in J_{1.5}} x_{ijk} \geq Q_{Sj_{1.5}} \text{ for all } i \in I$

Small Section, 3.0 Credit Timeslots: $\sum_{k \in S} \sum_{j \in J_{3.0}} x_{ijk} \geq Q_{Sj_{3.0}}, \text{ for all } i \in I$

Medium section, 1.5 Credit Timeslots: $\sum_{k \in S} \sum_{j \in J_{1.5}} x_{ijk} \geq Q_{Mj_{1.5}} \text{ for all } i \in I$

Medium section, 3.0 Credit Timeslots: $\sum_{k \in S} \sum_{j \in J_{3.0}} x_{ijk} \geq Q_{Mj_{3.0}}, \text{ for all } i \in I$

Large section, 1.5 Credit Timeslots: $\sum_{k \in S} \sum_{j \in J_{1.5}} x_{ijk} \geq Q_{Lj_{1.5}} \text{ for all } i \in I$

Large section, 3.0 Credit Timeslots: $\sum_{k \in S} \sum_{j \in J_{3.0}} x_{ijk} \geq Q_{Lj_{3.0}}, \text{ for all } i \in I$

Max Allocations, Small 1.5 Credits:

$$\sum_{i \in I} \sum_{j \in J_{1.5}} \sum_{k \in S} x_{ijk} < \Omega * \sum_{i \in I} Q_{S_{j_{1.5}} i}, \; for\ all\ i \in I,\ for\ all\ j \in J_{1.5},\ for\ all\ k \in S$$

Max Allocations, Small 3.0 Credits:

$$\sum_{i \in I} \sum_{j \in J_{3.0}} \sum_{k \in S} x_{ijk} < \Omega * \sum_{i \in I} Q_{S_{j_{3.0}} i}, \; for\ all\ i \in I,\ for\ all\ j \in J_{3.0},\ for\ all\ k \in S$$

Max Allocations, Medium 1.5 Credits:

$$\sum_{i \in I} \sum_{j \in J_{1.5}} \sum_{k \in M} x_{ijk} < \Omega * \sum_{i \in I} Q_{M_{j_{1.5}} i}, \; for\ all\ i \in I,\ for\ all\ j \in J_{1.5},\ for\ all\ k \in S$$

Max Allocations, Medium 3.0 Credits:

$$\sum_{i \in I} \sum_{j \in J_{3.0}} \sum_{k \in M} x_{ijk} < \Omega * \sum_{i \in I} Q_{M_{j_{3.0}} i}, \; for\ all\ i \in I,\ for\ all\ j \in J_{3.0},\ for\ all\ k \in S$$

Max Allocations, Large 1.5 Credits:

$$\sum_{i \in I} \sum_{j \in J_{1.5}} \sum_{k \in L} x_{ijk} < \Omega * \sum_{i \in I} Q_{L_{j_{1.5}} i} for\ all\ i \in I,\ for\ all\ j \in J_{1.5},\ for\ all\ k \in S$$

Max Allocations, Large 3.0 Credits:

$$\sum_{i \in I} \sum_{j \in J_{3.0}} \sum_{k \in L} x_{ijk} < \Omega * \sum_{i \in I} Q_{L_{j_{3.0}} i} for\ all\ i \in I,\ for\ all\ j \in J_{3.0},\ for\ all\ k \in S$$

Preferences > Allotment: $p_{ijk} \geq x_{ijk}\ for\ all\ i \in I,\ for\ all\ j \in J,\ for\ all\ k \in K$

IntraDept conflict:

$$x_{iMk} + x_{iMWk} \leq 1\ for\ all\ i \in I,\ k \in K$$
$$x_{iWk} + x_{iMWk} \leq 1\ for\ all\ i \in I,\ k \in K$$
$$x_{iTk} + x_{iTHk} \leq 1\ \ for\ all\ i \in I, k \in K$$
$$x_{iHk} + x_{iTHk} \leq 1\ for\ all\ i \in I,\ k \in K$$

InterDept conflict: $x_{i*Mk} + x_{iMWk} \leq 1\ for\ all\ \ i \in I,\ i^* \in I - \{i\},\ k \in K$

$$x_{i*Wk} + x_{iMWk} \leq 1\, for\ all\ \ i \in I,\ i^* \in I - \{i\},\ k \in K$$
$$x_{i*Tk} + x_{iTHk} \leq 1\, for\ all\ \ i \in I,\ i^* \in I - \{i\},\ k \in K$$
$$x_{i*Hk} + x_{iTHk} \leq 1\, for\ all\ \ i \in I,\ i^* \in I - \{i\},\ k \in K$$

Results and Implementation

In this section the results of the optimization are presented. Using the Gurobi Optimizer as the optimization solver for the MIP model constructed above, the optimal solution which maximizes the cumulative department preference score while minimizing the department preference score inequality is 81.83. Following is a summary of the classroom session allocation by each department based on the first 16 rows of the entire dataset:

- Department 1 ACCT: From table 10, most of the classroom sessions (highlighted in green) are allocated on Friday to ACC201. ACC201-TS6 can be allocated on two different days of the week, Tuesday and Thursday. Only one classroom session is allocated on Monday-Wednesday

- Department 2 BAEP: From table 11, none of the classroom sessions are allocated on Tuesday, Wednesday or Thursday. Only one classroom session is allocated on Monday and 2 different classroom sessions are allocated on Monday-Wednesday

- Department 3 BUCO: From table 12, most of the classroom sessions are allocated on Friday. None of the classroom sessions are allocated on Monday, Monday-Wednesday or Tuesday-Thursday. Only 2 classroom sessions are allocated on Wednesday.

- Department 4 DSO: From table 13, most of the classroom sessions are allocated on Tuesday, Friday, and Tuesday-Thursday. Only one classroom session ACC201-TS4 is allocated on Monday-Wednesday.

- Department 5 FBE: From table 14, most of the classroom sessions are allocated on Tuesday, Monday-Wednesday, and Tuesday-Thursday. Only one classroom session is allocated on Wednesday, Thursday, and Friday.

- Department 6 MKT: From table 15, none of the classroom sessions are allocated to Tuesday, Wednesday, Thursday, Monday-Wednesday or Tuesday-Thursday.

ACC201-TS1 is allocated on Friday and ACC201-TS2 is allocated on Monday.

- Department 7 MOR: From table 16, most of the classroom sessions are allocated on Monday and Monday-Wednesday. Only one classroom session is allocated on Wednesday, Thursday, and Tuesday-Thursday. None of the classroom sessions are allocated on Friday.

The output makes sense because each department at USC Marshall has different number of 1.5 unit courses and different number of 3.0 unit courses. Additionally, each department requires different room size depending on the program and the number of students enrolled in the program.

With this automated Optimizer scheduling system, Shannon and Hal can send the preferences score survey as shown in table 5 to each coordinator head a year before. The preference score survey is flexible because each department coordinator head can remove or add as many courses as they wish for the new USC Marshall academic schedule. A proprietary algorithm converts the input survey data into preference data for classroom-timeslot combinations. Shannon and Hal will then gather all the input data and implement them into our optimizer. The MIP uses preference data to allocate candidate sets for each category of sections, for each department. The automated optimizer scheduling system provides a faster, easier, and more efficient implementation of each courses to each classroom session by each department.

Conclusion

The proposed MIP optimization model seeks to aid Shannon and Hal in Phase-1 for allocating departments to classroom sessions. The optimization maximizes the cumulative department preference while minimizing inter-department cumulative preference score inequality. The final results of the optimization model satisfy all constraints, listed in part 2, which guarantees that it is in fact a valid course schedule, and it could be applied as long as there are no restrictions from other departments. A potential step for future improvement would be to add classroom utilization along with the cumulative department preference and the inter-department cumulative preference inequality within the objective function.

For the Final Project, we attempted to implement a “switching” algorithm using the output of the current MIP program to satisfy new department requests in light of altered course preferences, new course/section accommodation, etc. The algorithm shall output matches for plausible, mutually agreeable classroom-session switches between departments.

Future improvements that could be made on this MIP would be to enable consecutive 3 unit courses and factor in room utilization. The current model only allows 3 unit courses to be scheduled for the same time slot Monday and Wednesday or Tuesday and Thursday, however some professors prefer 2 consecutive time slots in this situation as opposed to different days. The current model does not allow for 3 unit courses to be scheduled in 2 consecutive time slots on the same day, so a future improvement on the model would allow for this. Another future improvement could be to better account for room utilization. The current model categorizes room size into 3 categories, which could lead to classes being assigned to rooms slightly larger or smaller than necessary. An improvement to this would be either to create more classifications to better match room size, or create a second MIP to run after department assignments to better allocate room size.

In conclusion, we recommend to implement our model as it is more efficient than the current system, feasible to implement, very flexible and takes department and professor preferences into account. The current system is primarily manual which leads to a lot of time wasted by Shannon and Hal, and this model would decrease a significant amount of manual work. It would also be very easy to implement this system because the timeline and data required is very similar to what is already used. This model is very flexible because there are many parameters that can be easily adjusted, such as the number of classes assigned to each department and the number of class size classifications we choose to use. Lastly, this program will take into account department and professor preferences, which leads to less discontent and changes needed throughout the scheduling process. We highly recommend this model as an implementable alternative to the current system in order to save wasted time and labor.

Appendix - Results of MIP Optimization

Table 1. Classroom type

Classroom	Type
ACC201	M
ACC205	S
ACC236	S
ACC303	M
ACC306B	S
ACC310	M
ACC312	S
BRI202	S
BRI202A	S
BRI-5	S
BRI8	S
EDI	L
HOH1	M
HOH2	M
HOH506	S
HOH706	S
JFF101	M
JFF102	M
JFF103	M
JFF105	L
JFF125	L
JFF 233	M
JFF236	M
JFF239	M
JFF 240	M
JFF241	M
JFF312	S
JFF313	S
JFF316	M
JFF322	M
JFF 327	S
JFF328	S
JFF 331	S
JFF414	M
JFF416	M
JFF417	S
JKP 102	M
JKP 104	M
JKP 110	L
JKP 112	L
JKP 202	M
JKP 204	M
JKP 210	L
JKP 212	L

Table 2. Timeslots type

Timeslots	Time
TS1	8:00-9:30
TS2	9:30-11:00
TS3	11:00-12:30
TS4	12:30-14:00
TS5	14:00-15:30
TS6	15:30-17:00
TS7	17:00-18:30
TS8	18:30-20:00

Table 3.Input: Preference Score Survey by D1: ACCT

ACCT	M	T	W	H	F	MW	TH
ACC201-TS1	10	10	6	2	6	9	3
ACC201-TS2	4	7	3	2	6	5	5
ACC201-TS3	2	5	4	3	8	10	7
ACC201-TS4	6	8	1	6	4	4	8
ACC201-TS5	8	5	7	7	8	1	5
ACC201-TS6	1	10	5	7	4	6	4
ACC201-TS7	3	8	10	2	8	1	1
ACC201-TS8	3	4	1	2	1	1	9
ACC205-TS1	1	9	9	7	5	8	3
ACC205-TS2	1	7	4	7	3	3	3
ACC205-TS3	8	7	1	2	2	10	5
ACC205-TS4	10	8	5	3	4	5	6
ACC205-TS5	2	4	6	2	10	3	4
ACC205-TS6	5	4	1	5	7	9	3
ACC205-TS7	4	7	9	2	6	2	6
ACC205-TS8	10	9	5	6	1	3	5

Table 4. Input: Preference Score Survey by D2: BAEP

BAEP	M	T	W	H	F	MW	TH
ACC201-TS1	8	6	10	7	9	10	10
ACC201-TS2	1	8	10	3	4	6	6
ACC201-TS3	9	6	1	9	1	10	10
ACC201-TS4	10	5	8	6	1	9	2
ACC201-TS5	10	3	3	2	10	7	9
ACC201-TS6	3	1	6	6	10	3	5
ACC201-TS7	9	5	4	1	6	5	4
ACC201-TS8	4	9	3	5	5	3	5
ACC205-TS1	5	8	7	3	10	10	5
ACC205-TS2	9	3	4	4	8	2	5
ACC205-TS3	2	2	3	1	5	1	4
ACC205-TS4	10	10	6	6	6	1	2
ACC205-TS5	2	5	5	1	9	1	5
ACC205-TS6	8	10	2	10	1	10	9
ACC205-TS7	10	8	7	6	3	7	4
ACC205-TS8	10	6	4	3	5	10	9

Table 5. Input: Preference Score Survey by D3: BUCO

BUCO	M	T	W	H	F	MW	TH
ACC201-TS1	1	8	6	9	5	2	2
ACC201-TS2	4	7	8	8	5	9	8
ACC201-TS3	2	10	2	5	1	9	7
ACC201-TS4	6	2	10	7	1	9	3
ACC201-TS5	2	1	3	6	4	4	3
ACC201-TS6	7	6	5	4	2	6	3
ACC201-TS7	3	7	4	7	8	8	6
ACC201-TS8	2	9	10	7	8	3	5
ACC205-TS1	8	9	10	9	3	8	2
ACC205-TS2	4	1	7	4	8	4	8
ACC205-TS3	3	9	7	2	9	8	6
ACC205-TS4	5	9	1	1	6	5	10
ACC205-TS5	4	10	5	6	4	9	6
ACC205-TS6	9	7	1	9	5	10	8
ACC205-TS7	10	10	8	6	9	5	10
ACC205-TS8	5	1	10	1	8	2	4

Table 6. Input: Preference Score Survey by D4: DSO

DSO	M	T	W	H	F	MW	TH
ACC201-TS1	6	1	7	2	1	10	5
ACC201-TS2	6	7	2	5	5	4	5
ACC201-TS3	2	1	8	1	2	4	4
ACC201-TS4	9	6	8	8	5	7	7
ACC201-TS5	9	8	6	1	3	1	3
ACC201-TS6	1	6	1	6	6	10	2
ACC201-TS7	1	3	5	6	2	10	6
ACC201-TS8	3	7	9	3	5	10	7
ACC205-TS1	10	7	5	4	5	2	5
ACC205-TS2	9	7	2	5	4	8	4
ACC205-TS3	2	5	8	1	9	4	2
ACC205-TS4	6	9	2	5	10	10	5
ACC205-TS5	7	9	7	10	3	7	4
ACC205-TS6	6	10	2	8	9	5	3
ACC205-TS7	10	8	5	6	3	10	8
ACC205-TS8	2	9	1	7	3	3	5

Table 7. Input: Preference Score Survey by D5: FBE

FBE	M	T	W	H	F	MW	TH
ACC201-TS1	5	5	7	6	10	10	10
ACC201-TS2	8	2	8	5	8	2	8
ACC201-TS3	8	2	2	9	3	2	2
ACC201-TS4	7	9	7	4	9	3	9
ACC201-TS5	9	1	9	1	5	2	4
ACC201-TS6	6	1	5	9	4	8	10
ACC201-TS7	7	2	5	6	2	5	8
ACC201-TS8	9	8	4	10	2	9	8
ACC205-TS1	1	10	10	3	1	8	5
ACC205-TS2	1	8	5	10	2	8	2
ACC205-TS3	4	5	2	2	1	4	6
ACC205-TS4	8	2	1	8	5	7	9
ACC205-TS5	9	1	4	2	2	2	7
ACC205-TS6	7	1	7	3	3	9	7
ACC205-TS7	4	6	4	8	6	3	10
ACC205-TS8	2	10	6	8	7	4	7

Table 8. Input: Preference Score Survey by D6: MKT

MKT	M	T	W	H	F	MW	TH
ACC201-TS1	9	9	3	3	2	5	6
ACC201-TS2	3	4	10	7	4	2	5
ACC201-TS3	1	8	7	6	3	10	1
ACC201-TS4	7	6	5	9	7	9	5
ACC201-TS5	2	8	1	10	2	8	1
ACC201-TS6	2	4	3	3	9	3	1
ACC201-TS7	10	9	2	7	10	1	10
ACC201-TS8	1	7	6	7	9	7	7
ACC205-TS1	9	1	2	8	3	6	9
ACC205-TS2	3	1	1	1	6	9	5
ACC205-TS3	6	3	5	9	4	2	7
ACC205-TS4	3	6	5	7	2	9	5
ACC205-TS5	6	9	2	10	3	7	4
ACC205-TS6	6	7	1	10	9	8	4
ACC205-TS7	7	1	2	7	4	2	2
ACC205-TS8	7	3	10	7	10	5	9

Table 9. Input: Preference Score Survey by D7: MOR

MOR	M	T	W	H	F	MW	TH
ACC201-TS1	3	6	4	8	1	6	8
ACC201-TS2	4	7	8	5	8	9	6
ACC201-TS3	10	6	10	6	5	4	2
ACC201-TS4	9	2	5	8	2	8	3
ACC201-TS5	5	5	2	4	6	4	5
ACC201-TS6	7	2	5	5	6	6	6
ACC201-TS7	3	3	9	1	4	10	10
ACC201-TS8	9	6	10	7	10	5	6
ACC205-TS1	2	9	10	7	10	10	4
ACC205-TS2	4	9	7	1	4	3	5
ACC205-TS3	5	3	10	5	1	9	7
ACC205-TS4	4	1	8	10	7	10	3
ACC205-TS5	5	10	6	4	10	10	2
ACC205-TS6	9	6	9	6	3	10	3
ACC205-TS7	3	10	6	3	8	7	1
ACC205-TS8	10	1	10	1	10	8	5

Table 10. Output: Classroom Sessions allotted to Department 1: ACCT

ACCT	M	T	W	H	F	MW	TH
ACC201-TS1	0	0	0	0	0	0	0
ACC201-TS2	0	0	0	0	0	0	0
ACC201-TS3	0	0	0	0	0	0	0
ACC201-TS4	0	0	0	0	1	0	0
ACC201-TS5	0	0	0	0	0	0	0
ACC201-TS6	0	1	0	1	0	0	0
ACC201-TS7	0	0	0	0	0	0	0
ACC201-TS8	0	0	0	1	1	0	0
ACC205-TS1	0	0	0	1	1	0	0
ACC205-TS2	0	0	0	1	1	0	0
ACC205-TS3	0	0	0	0	1	0	0
ACC205-TS4	0	0	0	0	0	0	0
ACC205-TS5	1	0	0	0	0	0	0
ACC205-TS6	0	0	0	1	0	1	0
ACC205-TS7	0	0	0	0	0	0	0
ACC205-TS8	0	0	0	0	1	0	0

Table 11. Output:Classroom Sessions allotted to Department 2: BAEP

BAEP	M	T	W	H	F	MW	TH
ACC201-TS1	0	0	0	0	0	0	0
ACC201-TS2	0	0	0	0	0	0	0
ACC201-TS3	1	0	0	0	0	0	0
ACC201-TS4	0	0	0	0	0	0	0
ACC201-TS5	0	0	0	0	0	0	0
ACC201-TS6	0	0	0	0	0	0	0
ACC201-TS7	0	0	0	0	0	0	0
ACC201-TS8	0	0	0	0	0	0	0
ACC205-TS1	0	0	0	0	0	1	0
ACC205-TS2	0	0	0	0	0	0	0
ACC205-TS3	0	0	0	0	0	0	0
ACC205-TS4	0	0	0	0	0	0	0
ACC205-TS5	0	0	0	0	0	0	0
ACC205-TS6	0	0	0	0	0	0	0
ACC205-TS7	0	0	0	0	1	0	0
ACC205-TS8	0	0	0	0	0	1	1

Table 12. Output: Classroom Sessions allocated by Department 3: BUCO

BUCO	M	T	W	H	F	MW	TH
ACC201-TS1	0	0	1	0	0	0	0
ACC201-TS2	0	0	0	1	0	0	0
ACC201-TS3	0	0	0	0	0	0	0
ACC201-TS4	0	0	0	0	0	0	0
ACC201-TS5	0	0	0	0	1	0	0
ACC201-TS6	0	0	0	0	1	0	0
ACC201-TS7	0	0	0	0	1	0	0
ACC201-TS8	0	0	0	0	0	0	0
ACC205-TS1	0	0	0	0	0	0	0
ACC205-TS2	0	0	0	0	0	0	0
ACC205-TS3	0	0	1	0	0	0	0
ACC205-TS4	0	0	0	0	0	0	0
ACC205-TS5	0	0	0	0	1	0	0
ACC205-TS6	0	1	0	0	0	0	0
ACC205-TS7	0	0	0	0	0	0	0
ACC205-TS8	0	0	0	0	0	0	0

Table 13. Output: Classroom Sessions allocated by Department 4: DSO

DSO	M	T	W	H	F	MW	TH
ACC201-TS1	0	0	0	0	0	0	1
ACC201-TS2	0	1	1	0	1	0	0
ACC201-TS3	0	0	0	1	1	0	0
ACC201-TS4	0	0	0	0	0	1	1
ACC201-TS5	0	0	0	0	0	0	1
ACC201-TS6	0	0	0	0	0	0	0
ACC201-TS7	0	0	0	0	0	0	0
ACC201-TS8	0	1	0	0	0	0	0
ACC205-TS1	0	1	0	0	0	0	0
ACC205-TS2	0	0	0	0	0	0	0
ACC205-TS3	0	0	0	0	0	0	0
ACC205-TS4	0	0	0	0	1	0	0
ACC205-TS5	0	0	1	0	0	0	0
ACC205-TS6	0	0	0	0	0	0	0
ACC205-TS7	0	0	0	0	0	0	0
ACC205-TS8	0	0	0	0	0	0	0

Table 14. Output: Classroom Sessions allocated by Department 5: FBE

FBE	M	T	W	H	F	MW	TH
ACC201-TS1	0	0	0	0	0	0	0
ACC201-TS2	0	0	0	0	0	0	0
ACC201-TS3	0	0	0	0	0	0	0
ACC201-TS4	0	0	0	0	0	0	0
ACC201-TS5	0	0	0	0	0	0	0
ACC201-TS6	0	0	0	0	0	0	0
ACC201-TS7	0	0	0	0	0	0	0
ACC201-TS8	0	0	1	0	0	0	0
ACC205-TS1	0	0	0	0	0	0	0
ACC205-TS2	0	1	0	0	0	0	0
ACC205-TS3	0	0	0	1	0	0	0
ACC205-TS4	0	0	0	0	0	1	1
ACC205-TS5	0	0	0	0	0	0	1
ACC205-TS6	0	0	0	0	1	0	0
ACC205-TS7	0	1	0	0	0	1	0
ACC205-TS8	0	0	0	0	0	0	0

Table 15. Output: Classroom Sessions allocated by Department 6: MKT

MKT	M	T	W	H	F	MW	TH
ACC201-TS1	0	0	0	0	1	0	0
ACC201-TS2	1	0	0	0	0	0	0
ACC201-TS3	0	0	0	0	0	0	0
ACC201-TS4	0	0	0	0	0	0	0
ACC201-TS5	0	0	0	0	0	0	0
ACC201-TS6	0	0	0	0	0	0	0
ACC201-TS7	0	0	0	0	0	0	0
ACC201-TS8	0	0	0	0	0	0	0
ACC205-TS1	0	0	0	0	0	0	0
ACC205-TS2	0	0	0	0	0	0	0
ACC205-TS3	0	0	0	0	0	0	0
ACC205-TS4	0	0	0	0	0	0	0
ACC205-TS5	0	0	0	0	0	0	0
ACC205-TS6	0	0	0	0	0	0	0
ACC205-TS7	0	0	0	0	0	0	0
ACC205-TS8	0	0	0	0	0	0	0

Table 16. Output: Classroom Sessions allocated by Department 7: MOR

MOR	M	T	W	H	F	MW	TH
ACC201-TS1	1	0	0	0	0	0	0
ACC201-TS2	0	0	0	0	0	0	0
ACC201-TS3	0	1	1	0	0	0	0
ACC201-TS4	0	0	0	0	0	0	0
ACC201-TS5	0	0	0	0	0	1	0
ACC201-TS6	0	0	0	0	0	1	0
ACC201-TS7	0	0	0	0	0	1	1
ACC201-TS8	1	0	0	0	0	0	0
ACC205-TS1	0	0	0	0	0	0	0
ACC205-TS2	0	0	0	0	0	1	0
ACC205-TS3	1	1	0	0	0	0	0
ACC205-TS4	0	0	0	0	0	0	0
ACC205-TS5	0	0	0	0	0	0	0
ACC205-TS6	0	0	0	0	0	0	0
ACC205-TS7	0	0	0	1	0	0	0
ACC205-TS8	0	0	0	0	0	0	0