# Scheduling the Summer Non-major Math Courses

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## 1 Problem description

Recently, the Math Department of the University of Washington found that during the summer quarters, the number of sections offered for math courses is not appropriate sometimes. Specifically, some sections were offered with fewer students than expected, while some others were offered with more students than expected.

Based on our interview with the director of the Math Department, students' tuition during the summer quarter goes completely into the salary of instructors. Therefore there will be a threshold for opening a section, the student enrollment of the section, which is 10 students out of a 35 limit. In other words, if there are only 9 students in a section with 35 capacity, this section will be canceled by the Math Department because the cost of an instructor will not be capable to cover by tuition. Consequently, he or she might teach another class section due to signed contract in the spring quarter or might lose teaching chance during that quarter without expected salaries.

The director of the Math Department, Sarah Garner met the problem. The approach Mrs. Garner applied previously, was to make some guesses based on previous years' data. She would close a section once its enrollment goes under 10 students; she would open a section once its enrollment goes over max limit and would schedule it an hour after that. With the limited resources, she would like to seek a new optimization method to reduce such cases while still providing as many appropriate numbers of sections for 9 non-major service courses.

## 2 Goal

To find appropriate schedules of sections for the following 9 non-major math courses,

MATH 111/120/124/125/126/307/308/309/324,

such that each section has at $57\%^1 - 80\%^2$ enrollment for at least $95\%^3$ of the time.

## 3 Impacts and community contacts

### 3.1 Our community contact:

Sarah Garner, Department of Mathematics, 206-543-0388, sterrs@uw.edu

### 3.2 Impacts:

As requested, we would like to find out appropriate schedules for the 2019 math summer courses, including the number of sections and time slots of sections.

Mrs. Garner is currently planning on making a summer schedule for non-major courses. We will help Mrs. Garner with the scheduling with our knowledge of linear programming and mathematical modeling to find one or more convincing schedules.

For the end of the project, we will be able to answer the following questions for Mrs. Garner:

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[1]The number 57% comes from 10/35 as 10 out of 35 enrollment is a requirement.
[2]The number 80% comes from a preferred range between $75\% - 80\%$ given by Mrs. Garner.
[3]The number 95% gives the confidence that most schedules will be within the preferred range.

- What's the recommended # sections and time slots for 9 non-major math courses?
- If we want to open/close a section, which section would we recommend to open/close?
- If we want to open/close a course, which course would we recommend to open/close?

# 4 Methodologies and modeling

With the 2008 - 2018 summer course end-of-quarter schedules provided by Mrs. Garner, we will analyze from multiple perspectives of the raw data.

## 4.1 Modeling

### 4.1.1 Assumptions:

1. Focus on 9 non-major math courses.
2. No limitations caused by the supply of professors.
3. The enrollment of each math course will not affect each other.
4. There will be no influence from class locations.

### 4.1.2 Hard Constraints (Requirements):

1. All 9 math courses will have at least 1 section open during the summer.
2. All sections need at least 10 out of 35 enrollments. The threshold lower bound: $10/35 \approx 28.6\%$
3. All section time slots need to start from 8:30 am, 9:40 am, 10:50 am, 12:00 am, 1:10 pm, 2:20 pm, 3:30 pm, 4:40 pm, 5:50 pm, 7:00 pm, 8:00 pm, 9:00 pm as required by Office of the University Registrar.
4. All section duration will be an hour for these courses.
5. All sections will be scheduled at MWF.

### 4.1.3 Soft Constraints:

1. The average enrollment of students will be around: $20/35 \approx 57\%$ (**lower bound**)
2. The preferred enrollment of students will be around: $75 - 80\%$ (**upper bound**)
3. Mrs. Garner prefers more time variety over the repeated section at the same time slot.
4. She would like to appropriately maximize the number of sections with the limited resources.

## 4.2 Methods:

First, we will evaluate the percentages of the student enrollment of each section and record in Table 1. Then, We will also look into the average percentage of the number of sections for each course and record in Table 2. Additionally, we will also take the time slots into account. By calculating an average percentage for each time slot overall 9 courses versus an average percentage for each time slot over 1 course, results will be recorded in Table 3 and 4.

# 5 Example of the main problem

In Figure 2 in Appendix, the distribution shows several outliers going far beyond the expectations, which raises some concerns for adding or canceling sections. After our optimization, these outliers will be reduced and most dots will concentrate in the preferred region. For example, for MATH 120 in 2014 summer, it offered 2 sections, and 1 section could be canceled due to low enrollment percentage, and then 1 section could be offered with higher enrollment percentage; for MATH 120 in 2008 summer, we would like to maintain these 3 sections as where they were, because those are within the preferred region and offering various time slots leads to convenience for students.

# References


[1] Cocchi, Guido, et al. "Scheduling the Italian National Volleyball Tournament." *Interfaces*, vol. 48, no. 3, 2018, pp. 271–284., doi:10.1287/inte.2017.0932.

[2] Kong, Yanmeng (Anny), et al. "Math Summer Course Scheduling Interview." `https://drive.google.com/file/d/1V98-hL3KeOjKKFHi52uePkMsEZOvSAfI/view?usp=sharing`, 31 Oct. 2018.

[3] Garner, Sarah. "2008-2018 Math Summer Enrollments." `Https://Drive.google.com/File/d/1riRba01zYr4EtKn3hpP62hHETIFBDvdV/View?Usp=Sharing`, 4 Nov. 2018.

[4] "Summer Start Times." *Summer Start Times*, Office of the University Registrar, 29 July 2015, `registrar.washington.edu/classrooms/summer-start-times/`.

[5] "COLLEGE OF ARTS SCIENCES MATHEMATICS." *University of Washington*, `www.washington.edu/students/crscat/math.html`.

[6] "Summer Quarter." *Summer Quarter - University of Washington*, `www.summer.uw.edu/registration-costs/tuition-fees/`.

[7] "Department of Mathematics." *Sarah Garner | Department of Mathematics | University of Washington*, `math.washington.edu/people/sarah-garner`.

# 6 Appendix

## 6.1 Community Contact:

Sarah Garner
Director of Student Services
Department of Mathematics
Applied and Computational Mathematical Sciences
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University of Washington Seattle, WA 98195-4350
206.543.0388 / sterrs@uw.edu

## 6.2 Tables:

| Year | section A | section B | section C | ... |
|---|---|---|---|---|
| 2008 | | | | |
| 2009 | | | | |
| 2010 | | | | |
| 2011 | | | | |
| 2012 | | | | |
| 2013 | | | | |
| 2014 | | | | |
| 2015 | | | | |
| 2016 | | | | |
| 2017 | | | | |
| 2018 | | | | |

Table 1: the percentages of the student enrollment of each section for Math 111

| # sections | Avg. Percentage of Enrollment |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| ... | |

Table 2: Average percentage of number of sections for Math 111

| Time Slot | Avg. Percentage of Enrollment |
|---|---|
| 830 am | |
| 940 am | |
| 1050 am | |
| ... | |

Table 3: Average percentage of each time slot over 9 courses

| Time Slot | Avg. Percentage of Enrollment |
|---|---|
| 830 am | |
| 940 am | |
| 1050 am | |
| ... | |

Table 4: Average percentage of each time slot for Math 111

### 6.3 Figures and more examples:

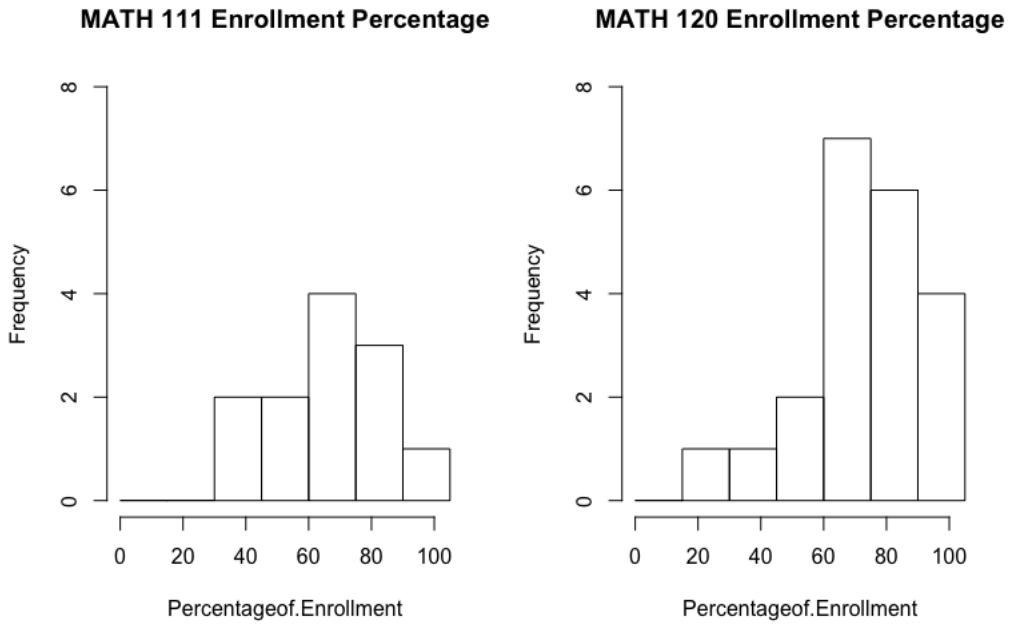


Figure 1: Comparison of MATH 111 and MATH 120 Enrollment Percentage

Take MATH 111 and MATH 120 as compared examples, in Figure 1, for both courses, the most frequent of the percentage of enrollment fits in the satisfied region: 57%-80%. MATH 111 is relatively normal distributed, but MATH 120 is skewed, which maintains a good property that it skews in the better direction, which focuses more on the higher percentage of enrollment.

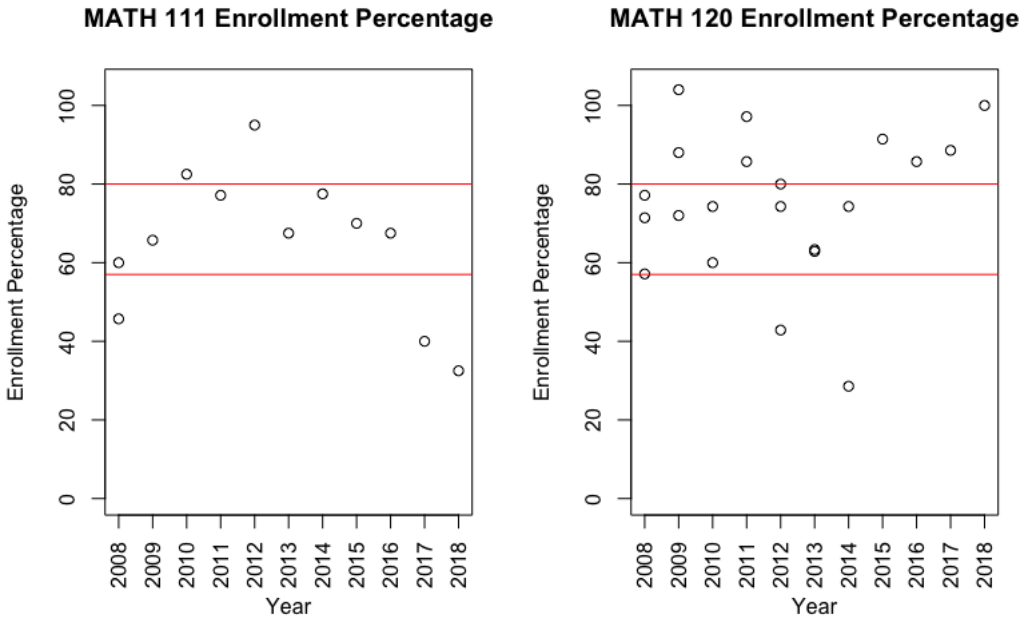


Figure 2: Scatter Plot of MATH 111/120 Enrollment Percentage over 2008 - 2018

| Start_Time | Sum_Enroll | Sum_Limit | Perct_Enroll |
|---|---|---|---|
| | | | |
| 110 | 1378 | 1957 | 70.4138988 |
| 220 | 274 | 332 | 82.5301205 |
| 940 | 2541 | 3607 | 70.4463543 |
| 1050 | 2582 | 3652 | 70.7009858 |
| 1200 | 2453 | 3037 | 80.7704972 |

Figure 3: Enrollment Percentages of different Start Times

| Count = 599 | Yr | Crs No | Section | Current Enrl | Percentage | Limit/Est Enr | Room Cap | Space Avail | Days of Wee | Start Time | End Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 55 | 2009 | 120 | B | 22 | 88 | 25 | 35 | 3 | M W F | 940 | 1040 |
| 53 | 2009 | 120 | A | 26 | 104 | 25 | 35 | -1 | M W F | 1200 | 100 |
| 105 | 2010 | 120 | A | 21 | 60 | 35 | 35 | 14 | M W F | 1200 | 100 |
| 109 | 2010 | 120 | C | 26 | 74.2857143 | 35 | 35 | 9 | M W F | 1050 | 1150 |
| 162 | 2011 | 120 | C | 30 | 85.7142857 | 35 | 50 | 5 | M W F | 1050 | 1150 |
| 158 | 2011 | 120 | A | 34 | 97.1428571 | 35 | 35 | 1 | M W F | 1200 | 100 |

Figure 4: Example of MATH 120's Enrollment Percentage exceeds upper bound

In Figure 3 and Figure 4, we can illustrate Mrs. Garner's expectation of various sections. In 2009 and 2011, each section enrollment percentage exceeded the upper bound of the satisfied region, we could add an additional section to distribute concentrated students in those time slots, and referring to Figure 3, we could add 2:20 section to increase variance.