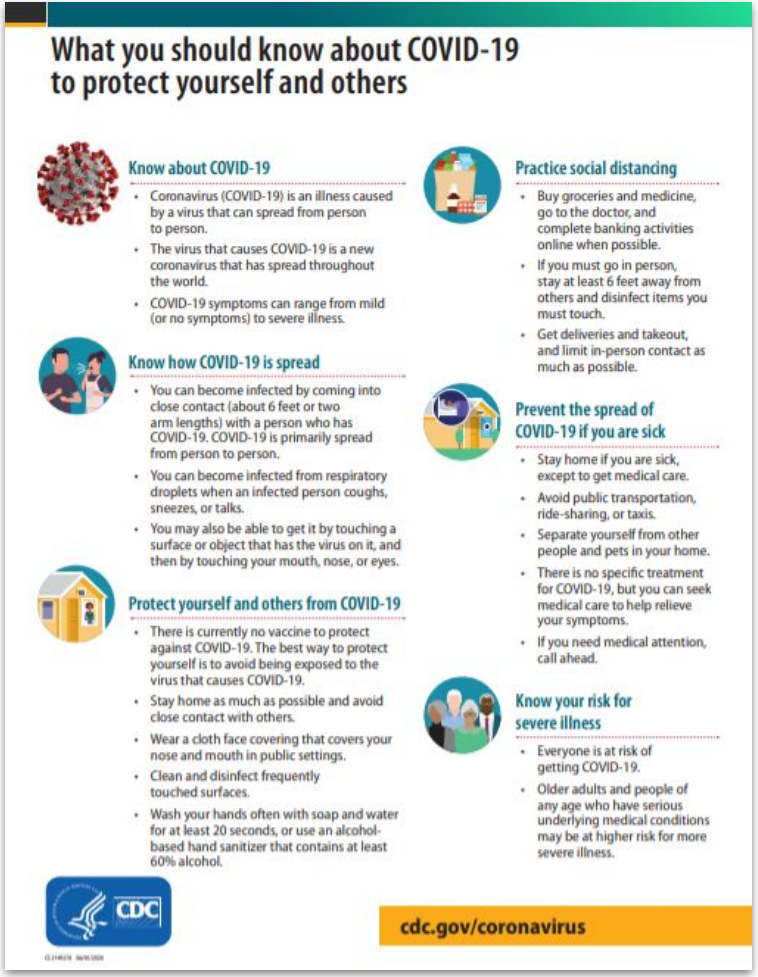
# Safely Reopening Schools During COVID-19

Creating Optimization Systems for Scheduling School hours
that follow COVID-19 health safety guidelines

Northwestern University
Decision Analytics 460
Jessica Hsu, Joel Riesen, Edward Huang, Juan Espinosa

# What is COVID-19?

Coronavirus (COVID-19) is an illness caused by a virus that can spread from person to person. The virus that causes COVID-19 is a new coronavirus that has spread throughout the world. COVID-19 symptoms can range from mild (or no symptoms) to severe illness. 421,795 people have currently died as a result of this virus. (WHO)



# Schooling During COVID-19

“COVID-19 is mostly spread by respiratory droplets released when people talk, cough, or sneeze. It is thought that the virus may spread to hands from a contaminated surface and then to the nose or mouth, causing infection. Therefore, personal prevention practices (such as handwashing, staying home when sick) and environmental cleaning and disinfection are important principles that are covered in this document. Fortunately, there are a number of actions school administrators can take to help lower the risk of COVID-19 exposure and spread during school sessions and activities.”

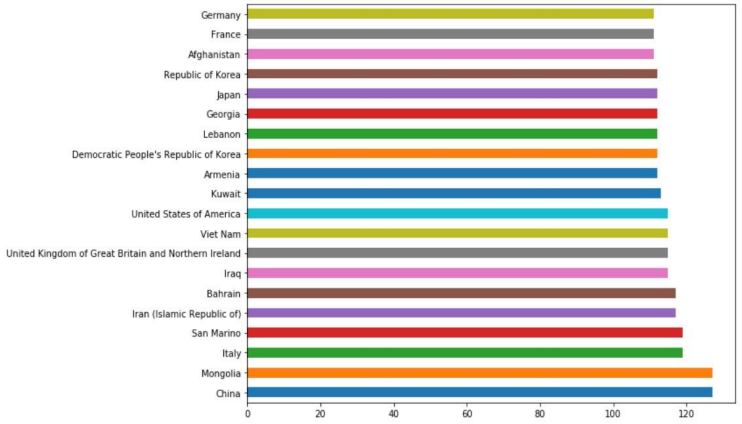
-Center for Disease Control

# Problem

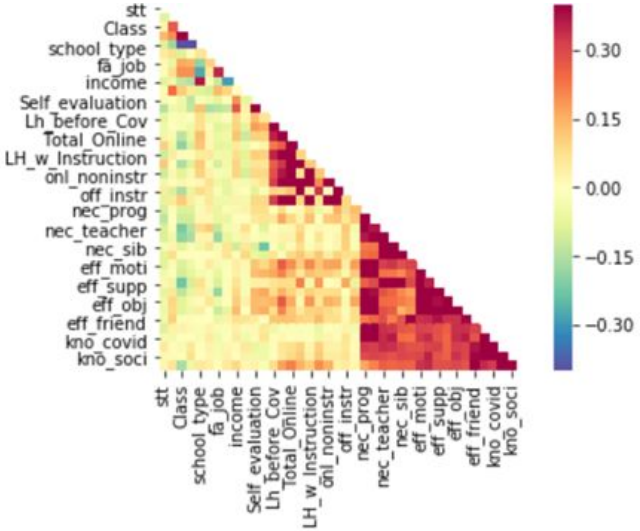
COVID-19 has shut down schools around the world and many countries are currently trying to establish a way to safely reopen schools while following social distancing guidelines to prevent further spread of COVID-19.

- 70% of students engaged in online learning
- 42% of parents concerned about negative impact
- It is recommended to have 6ft or 2 meters of distance between individuals to minimize the possibility of transmission of the virus
- Schools have limited the number of students per classroom
- Safe reopening of schools that will prevent increases in COVID-19 cases, aiding in containing the virus.

# Analysis




This graph to the left shows the number of days schools have been shut down for the top 20 countries




This correlation matrix shows strong correlation between student's ability to define daily learning objectives and proper concentration and motivation for learning

# Objectives

The objective of our research, is using a real school as a model, to optimize the the highest number of students which can be accomodated in the school at a time while honoring social distancing requirements. This would give academic institutions a better understanding on how they should adjust scheduling that allows for safe reopening of schools.

# Prior Research

Integer Linear Programming (ILP)

- Using integers only allows for whole numbers and not fractions
- Commonly used in scheduling creating schedules
- Provided optimal solutions within the defined constraints of the model

# Subject: Nicolet High School-Glendale Wisconsin

# Nicolet High School

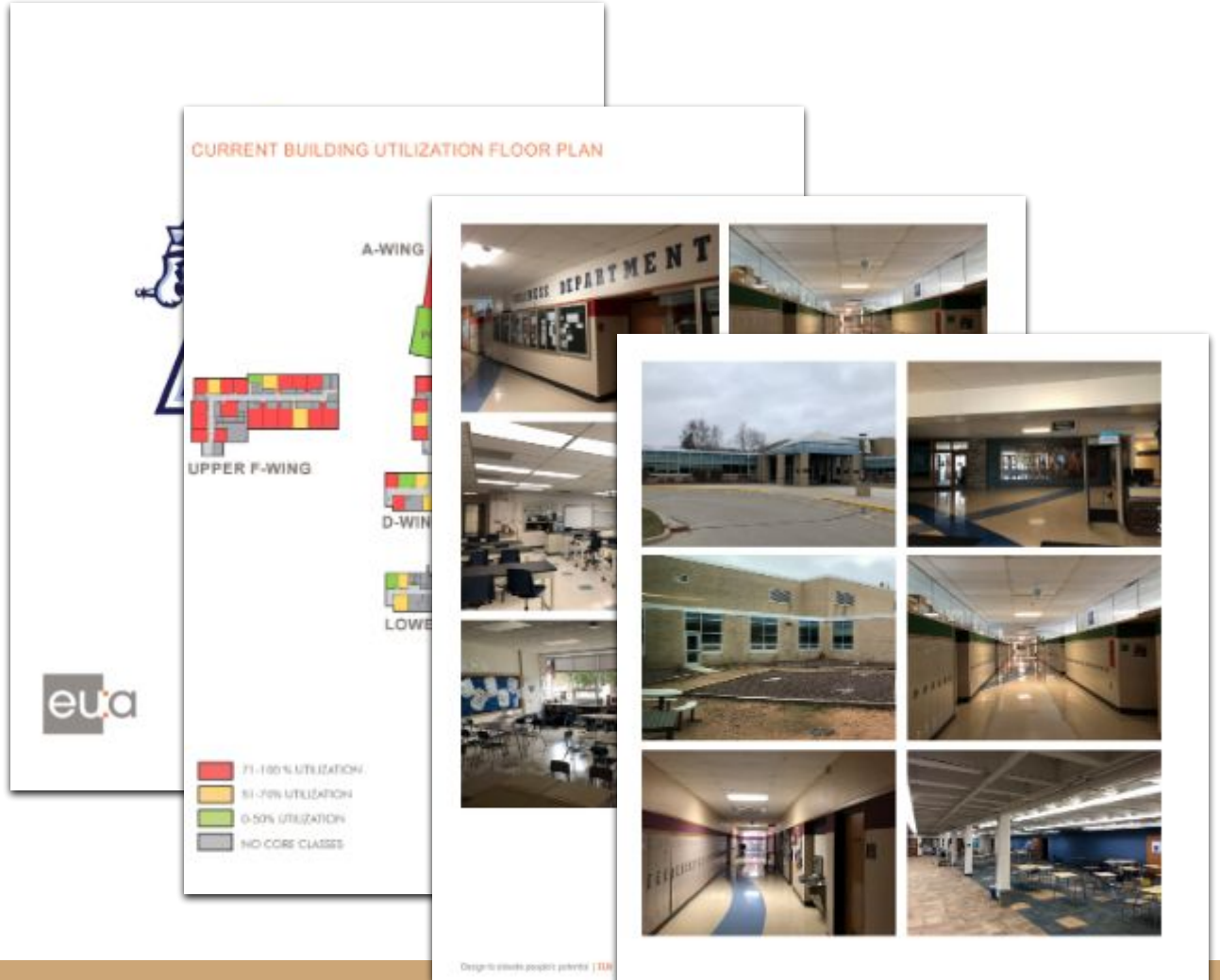
- Suburban Public High School
- Median income of $74,000
- Grades 9-12 with 1,091 students
- Student-teacher ratio of 14 to 1

# **Current** Scheduling Key Features

- School population: 1091 all day
- 8 periods per day
- 47 minute periods
- 2 Lunch Periods
- Maximum Class Size: 28
- Minimum Class Size: NA
- Optimum Class Size: 22
- Students have between 25-50 square feet depending on room function/size

# Facilities Assessment

May 2020



# **Proposed** Scheduling Key Features

- School population staggered:
  - 546 am + 545 pm= 1091 total
- 4 periods per day
- 45 minute periods
- Eliminate Lunch Periods
  - AM/PM transition time/Cleaning Time
- Maximum Class Size: 15
- Minimum Class Size: 6
- Optimum Class Size: 10
- Students are given a personal proximity of 100 square feet

# Justification

- Covid restrictions require at least 36 square feet (6 feet). 100 square feet allows for students to be added to space.
- Smaller population/class size reduces the chance of contagion (CDC)
- Reduced class period to 45 mins from 47
- Eliminating lunch periods decreases student to student exposure
- Based on recommendations from the CDC.
- Still uses online learning to lower chance of contagion.

- After School Activities were not considered as part of this project

# Scheduling ILP Model

For this example the school population was taken in half. Then that number was divided by four. For the four grades, Freshman, Sophomore, Junior and Seniors. This would be 136 - 137 per grade.

To get the current room sizes the current averages were used

General Room = 660 sq ft (Math, English) **6** students per class

Mid Size Room = 1000 sq ft (Soc. Studies) **10** students per class

Large Size Room = 1500 sq ft (Science/Tech lab) **15** students per class

# Objective Function for Class Optimization

GeneralRoom= x1, MidRoom= x2, LargeRoom = x3,

6x1+ 10x2 + 15x3 = SUM(students) min

The constraints used were for making sure that the smaller rooms were utilized more.

6x1 › 10x2

10x2 › 15x3

Optimized results were 6x1 =21, 10x2 = 18, 15x3 = 16 , 55 rooms total

Picture of variables, constraints and objective function

| | $6x_1 + 10x_2 + 15x_3$ | | | Constraints |
|---|---|---|---|---|
| General Room students per clas | 6 | 21 | 126 | $6x_1 \geqq 10x_2$ |
| History room per class | 10 | 18 | 180 | $10x_2 \geqq 15x_3$ |
| science lab stdts per class | 15 | 16 | 240 | |
| | | 55 | 546 | $6x_1 + 10x_2 + 15x_3 = 546$ |

# Optimizing First Period

Freshman = x1, Sophomore = x2,  Junior = x3, Senior = x4

General Room gets divided into Math = 10, English =11.

There were 44 constraints needed

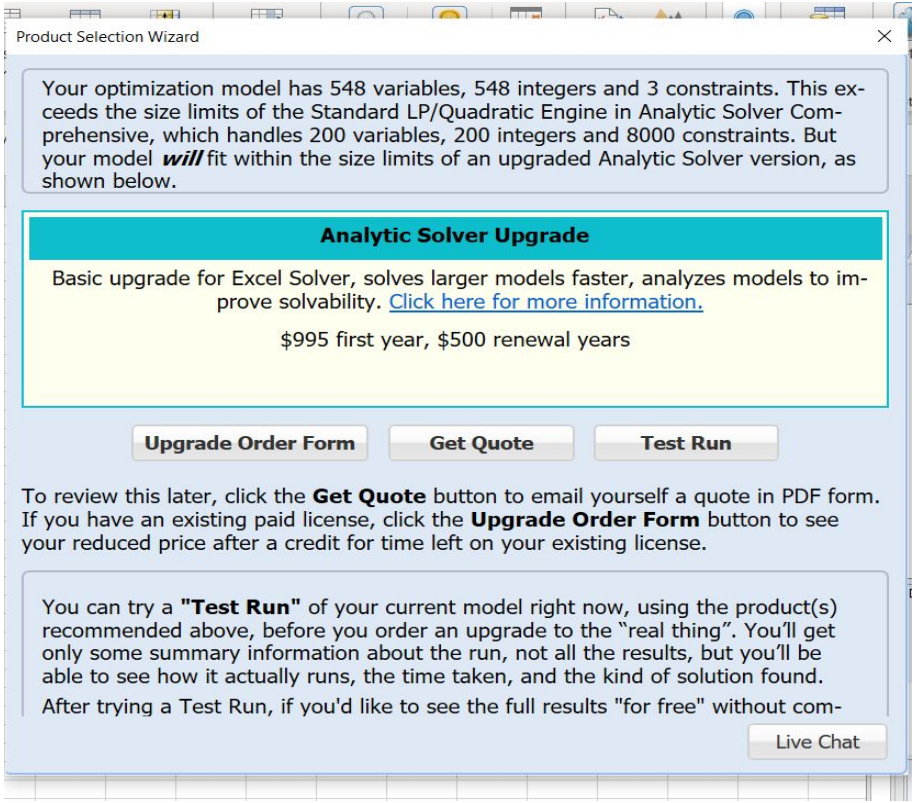
The Objective function was minimizing the sum of the rooms:

SUM(6x + 6x + 18x +16x )

# Screenshot of the first period with classes and grades optimized

| | Math | English | Soc. Studies | Science | | | |
|---|---|---|---|---|---|---|---|
| Freshman0 | 2 | 3 | 6 | 3 | 14 | | |
| sophmore0 | 2 | 2 | 4 | 5 | 13 | 14 | |
| junior0 | 2 | 4 | 4 | 4 | 14 | | |
| senior0 | 4 | 2 | 4 | 4 | 14 | 546/4 | |
| Freshman1 | 12 | 17 | 60 | 48 | 137 | 136 | |
| sophmore1 | 14 | 12 | 40 | 70 | 136 | 137 | |
| junior1 | 12 | 24 | 40 | 60 | 136 | | |
| senior1 | 22 | 13 | 40 | 62 | 137 | | |
| | 10 | 11 | 18 | 16 | 55 | | |
| | | 21 | | | | | |

Side note: The use of binary was over the limit of the educational version.




| | | Math | English | Social Stu | Science |
|---|---|---|---|---|---|
| 1 | X1 | 1 | 0 | 0 | 0 |
| 2 | X1 | 1 | 0 | 0 | 0 |
| 3 | X1 | 1 | 0 | 0 | 0 |
| 4 | X1 | 1 | 0 | 0 | 0 |
| 5 | X1 | 1 | 0 | 0 | 0 |
| 6 | X1 | 1 | 0 | 0 | 0 |
| 7 | X1 | 1 | 0 | 0 | 0 |
| 8 | X1 | 1 | 0 | 0 | 0 |
| 9 | X1 | 1 | 0 | 0 | 0 |
| 10 | X1 | 1 | 0 | 0 | 0 |
| 11 | X1 | 1 | 0 | 0 | 0 |
| 12 | X1 | 1 | 0 | 0 | 0 |
| 13 | X1 | 0 | 1 | 0 | 0 |
| 14 | X1 | 0 | 1 | 0 | 0 |
| 15 | X1 | 0 | 1 | 0 | 0 |
| 16 | X1 | 0 | 1 | 0 | 0 |
| 17 | X1 | 0 | 1 | 0 | 0 |
| 18 | X1 | 0 | 1 | 0 | 0 |
| 19 | X1 | 0 | 1 | 0 | 0 |
| 20 | X1 | 0 | 1 | 0 | 0 |
| 21 | X1 | 0 | 1 | 0 | 0 |
| 22 | X1 | 0 | 1 | 0 | 0 |
| 23 | X1 | 0 | 1 | 0 | 0 |
| 24 | X1 | 0 | 1 | 0 | 0 |
| 25 | X1 | 0 | 1 | 0 | 0 |
| 26 | X1 | 0 | 1 | 0 | 0 |
| 27 | X1 | 0 | 1 | 0 | 0 |
| 28 | X1 | 0 | 1 | 0 | 0 |
| 29 | X1 | 0 | 1 | 0 | 0 |
| 30 | X1 | 0 | 0 | 1 | 0 |

# Cost Minimization Model

Key Model Data:

- Room Types and Capacity
- Teacher Salaries
- Teaching Hours
- Minimum Required Learning Hours
- Student Population

| Key Data | | |
|---|---|---|
| **Rooms** | | |
| | **Capacity** | **Number of Rooms** |
| Room Type A | 6 | 32 |
| Room Type B | 9 | 20 |
| Room Type C | 15 | 12 |
| **Average Weekly Instruction Hours Per Teacher** | | |
| 19 | | |
| **Salaries** | | |
| English Teacher | $ | 75,402.00 |
| Math Teacher | $ | 74,360.00 |
| History Teacher | $ | 82,998.00 |
| Science Teacher | $ | 82,468.00 |
| **Student Population** | | |
| 1,091 | | |
| **Weekly Minimum Learning Hours/Student** | | |
| 20 | | |

# Objective Function

Minimize:

$$S_E ((X_1 + X_2 + X_3)/ T_H) + S_M ((X_4 + X_5 + X_6)/ T_H) + S_S ((X_7 + X_8 + X_9)/ T_H) + S_H ((X_{10} + X_{11} + X_{12})/ T_H) = \text{Total Personnel Cost}$$

Where:

$S_i$ = Salary by Subject *i*

$X_i$ = Rooms Type by Subject *i*

$T_H$ = Average Teaching Hours

# Decision Variables

| | |
|---|---|
| $X_1$ | Number of English Classes Held in Room Type A |
| $X_2$ | Number of English Classes Held in Room Type B |
| $X_3$ | Number of English Classes Held in Room Type C |
| $X_4$ | Number of Math Classes Held in Room Type A |
| $X_5$ | Number of Math Classes Held in Room Type B |
| $X_6$ | Number of Math Classes Held in Room Type C |
| $X_7$ | Number of Science Classes Held in Room Type A |
| $X_8$ | Number of Science Classes Held in Room Type B |
| $X_9$ | Number of Science Classes Held in Room Type C |
| $X_{10}$ | Number of History Classes Held in Room Type A |
| $X_{11}$ | Number of History Classes Held in Room Type B |
| $X_{12}$ | Number of History Classes Held in Room Type C |

# Constraints

| |
|---|
| $X_1 + X_4 + X_7 + X_{10} \leq 640$ |
| $X_2 + X_5 + X_8 + X_{11} \leq 400$ |
| $X_3 + X_6 + X_9 + X_{12} \leq 240$ |
| $6X_1 + 9X_2 + 15X_3 \geq 2728$ |
| $6X_4 + 9X_5 + 15X_6 \geq 2728$ |
| $6X_7 + 9X_8 + 15X_9 \geq 2728$ |
| $6X_{10} + 9X_{11} + 15X_{12} \geq 2728$ |
| $X_i \geq 0$ |
| $X_i$ = Integer |

# Results

Below are the results of the model.  Based on the results, the total minimum cost of personnel is $5.3 million per year.

| | Capacity | Number of Room | English A | Math A | Science A | History A | Total Classes Held in A |
|---|---|---|---|---|---|---|---|
| Room Type A | 6 | 640 | 185 | 455 | 0 | 0 | **640** |
| | | | English B | Math B | Science B | History B | Total Classes Held in B |
| Room Type B | 9 | 400 | 126 | 0 | 209 | 55 | **390** |
| | | | English C | Math C | Science C | History C | Total Classes Held in C |
| Room Type C | 15 | 240 | 33 | 0 | 57 | 150 | **240** |
| | | | | | | | Total Learning Hours |
| Learning Hours | | | 2,739 | 2,730 | 2,736 | 2,745 | **10,950** |
| Required Learning Hours | | | 2,728 | 2,728 | 2,728 | 2,728 | 10,910 |

| | Number of Classes Held | Number of Teachers Needed | Teacher Salary |
|---|---|---|---|
| English A | 185 | 10 | $ 75,402.00 |
| English B | 126 | 7 | $ 75,402.00 |
| English C | 33 | 2 | $ 75,402.00 |
| Math A | 455 | 24 | $ 74,360.00 |
| Math B | 0 | 0 | $ 74,360.00 |
| Math C | 0 | 0 | $ 74,360.00 |
| Science A | 0 | 0 | $ 82,468.00 |
| Science B | 209 | 11 | $ 82,468.00 |
| Science C | 57 | 3 | $ 82,468.00 |
| History A | 0 | 0 | $ 82,998.00 |
| History B | 55 | 3 | $ 82,998.00 |
| History C | 150 | 8 | $ 82,998.00 |
| Totals | **1,270** | **68** | |

# Conclusions

- These models are simplifications for real-world scenarios
- Expand specific data utilized in the model to include:
  - Specific Teacher Salaries
  - Additional Curriculum Requirements
  - Curriculum requirements by grade level