

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

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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)

What you should know about COVID-19 to protect yourself and others



Know about 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.



Know how COVID-19 is spread

- You can become infected by coming into close contact (about 6 feet or two arm lengths) with a person who has COVID-19. COVID-19 is primarily spread from person to person.
- You can become infected from respiratory droplets when an infected person coughs, sneezes, or talks.
- You may also be able to get it by touching a surface or object that has the virus on it, and then by touching your mouth, nose, or eyes.



Protect yourself and others from COVID-19

- There is currently no vaccine to protect against COVID-19. The best way to protect yourself is to avoid being exposed to the virus that causes COVID-19.
- Stay home as much as possible and avoid close contact with others.
- Wear a cloth face covering that covers your nose and mouth in public settings.
- Clean and disinfect frequently touched surfaces.
- Wash your hands often with soap and water for at least 20 seconds, or use an alcohol-based hand sanitizer that contains at least 60% alcohol.



Practice social distancing

- Buy groceries and medicine, go to the doctor, and complete banking activities online when possible.
- If you must go in person, stay at least 6 feet away from others and disinfect items you must touch.
- Get deliveries and takeout, and limit in-person contact as much as possible.



Prevent the spread of COVID-19 if you are sick

- Stay home if you are sick, except to get medical care.
- Avoid public transportation, ride-sharing, or taxis.
- Separate yourself from other people and pets in your home.
- There is no specific treatment for COVID-19, but you can seek medical care to help relieve your symptoms.
- If you need medical attention, call ahead.



Know your risk for severe illness

- Everyone is at risk of getting COVID-19.
- Older adults and people of any age who have serious underlying medical conditions may be at higher risk for more severe illness.



cdc.gov/coronavirus

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

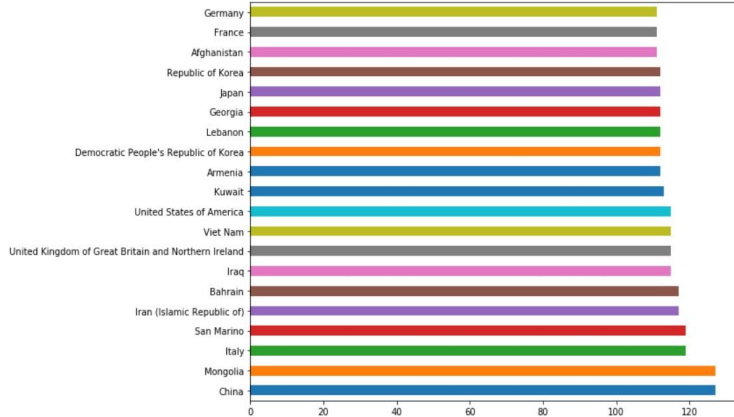
Problem

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.

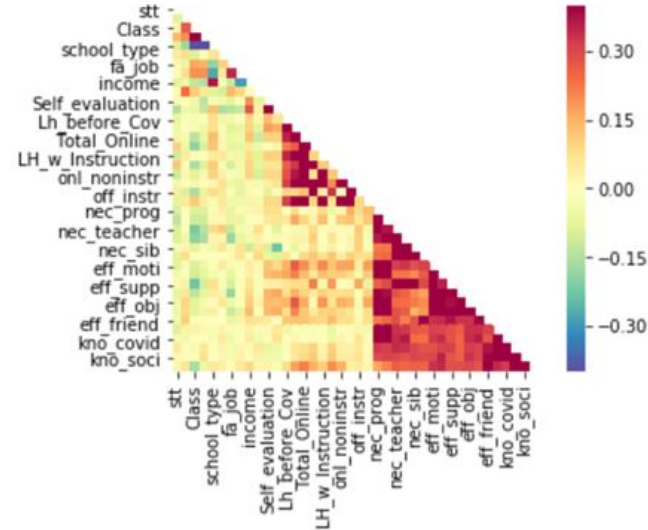


Analysis



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

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



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



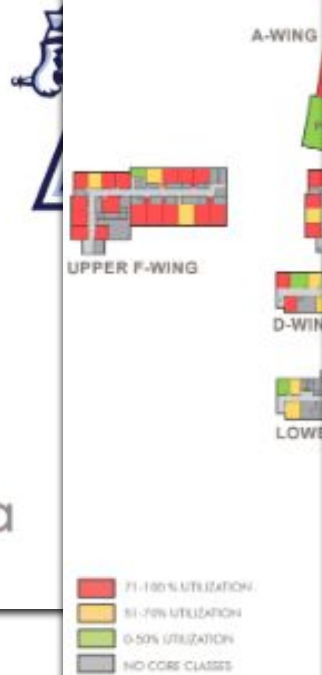
- School population: 1091 all day
- 8 periods per day
- 47 minute periods
- 2 Lunch Periods
- Maximum Class Size: 28
- Minimum Class Size: NA
- Optimum Class Size: 22
- Students have between 25-50 square feet depending on room function/size

Facilities Assessment

May 2020



CURRENT BUILDING UTILIZATION FLOOR PLAN



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= x_1 , MidRoom= x_2 , LargeRoom = x_3 ,

$$6x_1 + 10x_2 + 15x_3 = \text{SUM(students)} \min$$

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

$$6x_1 > 10x_2$$

$$10x_2 > 15x_3$$

Optimized results were $6x_1 = 21$, $10x_2 = 18$, $15x_3 = 16$, 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	$6x_1 \geq 10x_2$
History room per class	10	18	180	$10x_2 \geq 15x_3$
science lab stdts per class	15	16	240	
		55	546	$6x_1 + 10x_2 + 15x_3 = 546$

Optimizing First Period

Freshman = x_1 , Sophomore = x_2 , Junior = x_3 , Senior = x_4

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

There were 44 constraints needed

The Objective function was minimizing the sum of the rooms:

$SUM(6x_1 + 6x_2 + 18x_3 + 16x_4)$

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.

Product Selection Wizard

Your optimization model has 548 variables, 548 integers and 3 constraints. This exceeds the size limits of the Standard LP/Quadratic Engine in Analytic Solver Comprehensive, which handles 200 variables, 200 integers and 8000 constraints. But your model **will** fit within the size limits of an upgraded Analytic Solver version, as shown below.

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You can try a **"Test Run"** of your current model right now, using the product(s) recommended above, before you order an upgrade to the "real thing". You'll get only some summary information about the run, not all the results, but you'll be able to see how it actually runs, the time taken, and the kind of solution found. After trying a Test Run, if you'd like to see the full results "for free" without com-

[Live Chat](#)

		Math	English	Social Studies	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
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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
31	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

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

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