

# **Stevens Institute of Technology**



**SYS 660 : Decision & Risk Analytics**

## **Pandemic Decision & Risk Analysis (COVID-19)**

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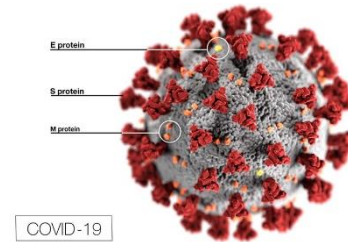
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## 1. Introduction:

### 1.1 What is COVID-19?

COVID -19 is a SARS-CoV-2 type of coronavirus, which first surfaced in December 2019. Millions of people around the globe have died from COVID-19, which can be a serious illness that can also leave some survivors with long-term health issues. People can contract the coronavirus from one another. It is diagnosed with a test. The best method to protect yourself is to follow testing instructions, get vaccinated and booster shots when you are eligible, don a mask, wash your hands, and engage in physical separation. It is spread through droplets and virus particles released into the air when an infected person breathes, talks, laughs, sings, coughs or sneezes. Larger droplets may fall to the ground in a few seconds, but tiny infectious particles can linger in the air and accumulate indoors, especially where there is poor ventilation and people are gathered.



### 1.2 Signs & Symptoms

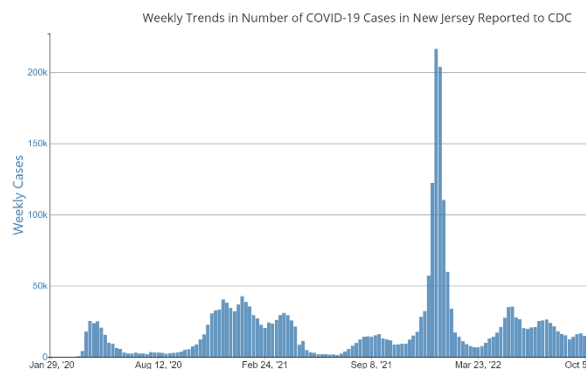
COVID-19 signs and symptoms include: cough, fever or chills, sore throat, muscle or body aches, headache, fatigue, nausea or vomiting, shortness of breath, difficulty breathing, runny nose, congestion, loss of taste or smell. Symptoms start showing up within 2 to 14 days of exposure to the virus. When a person is infected with the coronavirus which is contagious for up to 2 days before the symptoms start to appear and it remains contagious to others for 10 to 20 days depending upon the immune system of the infected and the severity of their illness.

### 1.3 Treatment of the infected & Prevention

Treatment for COVID-19 depends on the variant and severity of the infection. For Severe cases hospitalization may be required, with treatment that include medications, supplemental oxygen, assisted ventilation and other supportive measures are to be taken. If the illness is milder then resting at home and taking medicines to reduce fever is sufficient. Two COVID-19 vaccines – Pfizer and Moderna have been fully approved by FDA and recommended by the CDA as highly effective in preventing serious disease, hospitalization and death from COVID-19.

### 1.4 History

The SARS-CoV-2 was the cause of the first case of COVID-19, which was reported on December 1, 2019. The COVID-19 pandemic reached the US state of New Jersey with the first confirmed case occurring Bergen County on March 2, 2020, and testing positive on March 4. SARS-CoV-2 may have evolved (mutated) from an animal source to be able to infect people. Viruses that originated in birds, pigs, bats, and other animals and mutated to become dangerous to people have been linked to several infectious disease



outbreaks in the past. More investigation could possibly shed light on the processes by which the coronavirus changed over time to become a pandemic illness. The word "corona," which means "crown," is used to describe how these viruses look. Spike proteins that encircle the virus' outer layers like a crown encase them. The first wave approximately lasted for 4 months.

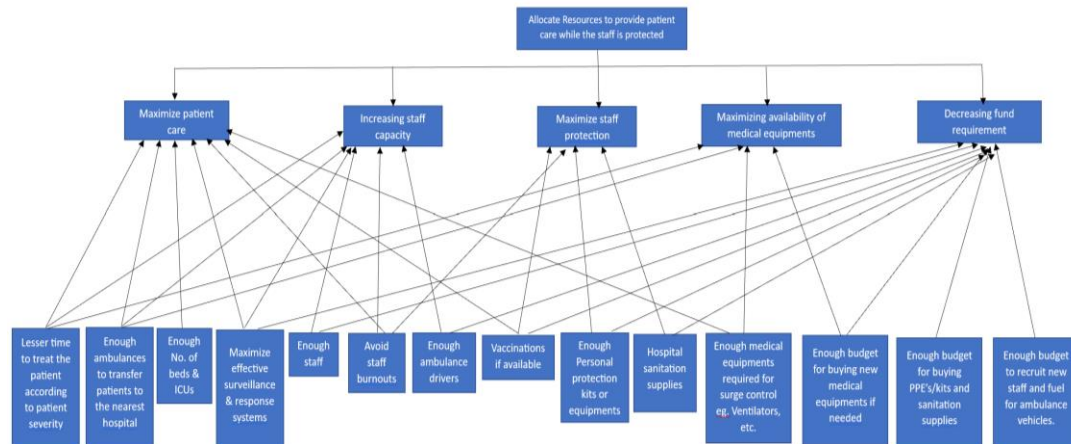
## 2. Methodology

### 2.1 Overview of the situation

COVID-19 had an effect on every single one of us on a global, national, and local level. The difficulties we faced spanned several different industries. The COVID-19 outbreak was a tragedy for thousands of individuals as well as the world economy. The circumstances were continuously changing, with various implications. In order to mitigate risk as much as possible, if possible, we require quick and reliable analyses now more than ever before. The sudden influx of patients to hospitals that were at capacity in terms of staffing, medical apparatus, and personal protection equipment was one of the many difficulties that states and hospitals were dealing with. (PPEs). The situation at hand is that DeciMake.Inc is interested in expanding our understanding of the demand/supply challenges hospitals face at times of crisis. We would like to use your expertise. Specifically, we would like you to help us with the following case: A CEO of a 100-bed hospital with 10 ICU beds in New Jersey. The next nearby 1000- bed hospital is 100 miles away. Budget is \$4 million to deal with the surge. Allocation of resources to make sure patients receive the care they need while staff are protected, worst-case and best-case scenarios (uncertainly analysis) in terms of fatality and sensitivity of the results to the inputs you are using or assuming. The situation was aggravated by a blatant lack of staff and essential supplies. Preparation and hospital emergency planning are crucial factors in order to successfully cope with such a challenging situation.

### 2.2 Fundamental and mean objectives

The definition of the goal that must be sought and attained first. Maintaining the response category "conventional care" or at least "contingency care" for as long as feasible in the event of a mass influx of critically ill patients is the primary objective in the case of pandemic taking into consideration current and accepted medical standards. Disaster medicine-based "crisis care" must be prevented at all costs or put off as long as possible by taking the necessary precautions. The three elements—staff, location, and supplies—are the crucial connecting factors for care planning. The degree of care that a hospital can offer depends on their organization and availability.



Firstly, the primary fundamental objective is to maximize patient care. The second fundamental objective is increasing the staff capacity which includes doctors, nurses, allied health professionals like dietitians, physiotherapists, occupational therapists, pharmacists, speech pathologists, podiatrists and other hospital staff like clinical assistants, patient service assistants, porters, volunteers, ward clerks. Thirdly, it is to maximize staff protection by providing vaccinations to the frontliners if there are any well-tested and trusted vaccine available, having enough personal protection kits/ equipments like the masks, disinfectants, respirators and their disposable material, and drugs and having enough hospital sanitation supplies. Maximizing availability of medical equipments like ventilators, etc. Managing all the expenses made towards handling the surge is extremely important.

### 3. Decision Modelling

#### 3.1 Key Assumptions

The surge period assumed here is 4 months. The first assumption is that each month has 28 days only for calculation purposes. Next assumption is that when patients come to the hospital to get treated, if our hospital does not have any ICUs available according to the cater the patient with high severity of illness/emergency, we provide an alternative solution by providing the contact to external an ambulance service to get the nearest hospital which is 100 miles away. The second assumption being that there is 50-50 chance of patients being COVID-19 patient or a non-COVID-19 patient when comes for treatment to the hospital. As the COVID-19 first wave lasted for 3-4 months in NJ, assuming 4 months as the surge period. The approximate average salary for hiring a doctor in NJ is \$180,000/year, so it's \$15,000/month. Average Salary for Registered nurses in NJ is \$89,690/year so assuming it's approx.\$7000/month. Average salary for allied health professionals in NJ is \$81,782/year, so assuming it's approx.\$6800/month. Average salary for other clinical staff in NJ is \$38,467/year, so assuming it's approx.\$3200/month. According to the patient severity, we have 3 categories : high, medium and low. Whether it is a COVID-19 patient or non-COVID-19 patient, if the severity of the illness is high then the patient gets assigned to an ICU if available or gets navigated to an external ambulance service. Whether it is a COVID-19 patient or non-COVID-19 patient, if the severity of the illness is medium then the patient gets assigned to a bed if available or gets transferred to the nearest hospital through our ambulance service. Whether it is a COVID-19 patient, if the severity of the illness is low then the patient gets the required medicines to help cure and build immunity to the pandemic virus and gets to go home so no beds/ICUs would be used. Assuming that non-COVID-19 patients with low severity wouldn't come to the hospital due to government protocols/lockdown and from the fear of getting infected by the pandemic virus. Assuming that in the first month of the surge, the no. of patients is exponentially increasing, until 2<sup>nd</sup> month where the cases are at

peak and expansion of the patient care becomes necessary which can be used for the 3<sup>rd</sup> month of the surge too. In the 4<sup>th</sup> month of the surge the no. of patients tends to exponentially decrease until it's in control. Assuming that the occupancy rate is 100%. Assume that the medicines for one COVID patient with high severity in the 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup> and 4<sup>th</sup> month is \$1000, \$2000, \$2500 and \$3000 respectively for one person/week cause after it approximately takes 1 month for the inflation to rise as the scarcity increases. Demand for the medicines and supplies also keeps increasing. Assume that the medicines for one COVID patient with medium severity in the 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup> and 4<sup>th</sup> month is \$300, \$600, \$650 and \$700 respectively per week cause after it approximately takes 1 month for the inflation to rise as the scarcity increases. Assume that the medicines for one non-COVID patient with high severity in the 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup> and 4<sup>th</sup> month is \$500, \$1000, \$1500 and \$2000 respectively for one person/week cause after it approximately takes 1 month for the inflation to rise as the scarcity increases. Assume that the medicines for one non-COVID patient with medium severity in the 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup> and 4<sup>th</sup> month is \$200, \$400, \$450 and \$500 respectively per week cause after it approximately takes 1 month for the inflation to rise as the scarcity increases. Assuming, each month consists of 4 weeks and 28 days only. we could invest in expanding the capacity of the ICUs in the hospital by converting and opening popup ICUs. On average it costs \$7,50,000 (eg. Bergen county hospital) to increase the capacity more 36 Intensive care units for COVID-19 patients and 12 Intensive care units for non-COVID-19 patients. So. lets assume that we have space enough to expand 16 ICUs for COVID-19 patients and 6 ICUs for non- COVID-19 patients with high severity. Assuming that we divide 70 hospital beds for COVID patients and 30 beds for non-COVID-19 patients with medium severity. Assuming that one staff uses only one PPE kit during his or her shift.

### 3.2 Decision tree

For branch 1: Provide patient care

As the virus is still in the initial phase of growing into a pandemic, in the first month, there is no necessity for expansion of ICU until 2<sup>nd</sup> month which can be used for the 3<sup>rd</sup> month of the surge too. In the 4<sup>th</sup> month of the surge the no. of patients tends to exponentially decrease until it's in control. So, we could invest in expanding the capacity of the ICUs in the hospital by converting and opening popup ICUs. On average it costs \$7,50,000 (eg. Bergen county hospital) to increase the capacity more 36 Intensive care units for COVID-19 patients and 12 Intensive care units for non-COVID-19 patients. So, we shall assume we have 6 ICU beds for COVID-19 patients. Giving us a total of 22 ICUs, where 6 ICUs are already available at the hospital and 16 ICUs were expanded in order to cater to the patients' needs and care with COVID-19 patients and 4 ICUS to cater to the patients' needs and care with non-COVID-19 patients. According to my data available to us by the government, on an average bed occupancy rate for COVID-19 patients during the pandemic was for 7days (1 week) and for non- COVID-19 patients is 5 days. For the first month, the medicine for treatment for ICU COVID patients with high severity costs \$4000 for 4 patients occupying one bed over a month, so for 6 ICU beds, the expense will be \$24,000. For the second month, the medicine for treatment for ICU COVID patients with high severity costs \$8000 for 4 patients occupying one bed over a month as assumed due to inflation so for 22 ICU beds, the expense will be \$176,000. Similarly, the medicine expense for ICU COVID patient with high severity in the third will be \$10,000 and fourth month will be \$12,000 approximately similar for 4 patients occupying one bed over a month. For 2<sup>nd</sup>, 3<sup>rd</sup> and 4<sup>th</sup> month, the expense for medicines for 22 ICU beds, the expense will be \$176000, \$220000 and \$ 264000.

| Surge period<br>(in months) | No. of<br>ICUs beds<br>available | No. of patients<br>taken in ICU=<br>(No. of ICUs beds<br>available) *<br>(occupancy<br>factor (4)) | Expenses for setting<br>up pop-up ICUs for<br>increasing the<br>capacity to treat<br>patients(x) | Medicine costs<br>for hospitals(y) | Total<br>Expenses<br>for each<br>month =<br>x+y |
|-----------------------------|----------------------------------|--|--|------------------------------------|---|
|-----------------------------|----------------------------------|--|--|------------------------------------|---|

|                       |           |    |           |           |           |
|-----------------------|-----------|----|-----------|-----------|-----------|
| 1 <sup>st</sup> month | 6         |    |           | \$24,000  | \$24,000  |
| 2 <sup>nd</sup> month | 6+16 = 22 | 88 | \$256,000 | \$176,000 | \$432,000 |
| 3 <sup>rd</sup> month | 6+16 = 22 | 88 |           | \$220,000 | \$220,000 |
| 4 <sup>th</sup> month | 6+16 = 22 | 88 |           | \$264,000 | \$264,000 |

Total expense for COVID patients treatment during the surge period = \$940,000 and the total patient care and treatment would be 288 approximately. If we don't have ICU beds available for COVID-19 patients with high severity then we guide them to an external ambulance service that will help them get to the nearest hospital available to get treatment so, our expense in that case is \$0. For the first month, the medicine for treatment for COVID patients with medium severity costs \$1200 for 4 patients occupying one bed over a month, so for 70 beds, the expense will be \$120,000. For the second month, the medicine for treatment for COVID patients with medium severity costs \$2400 for 4 patients occupying one bed over a month as assumed due to inflation so for 70 beds, the expense will be \$240,000. Similarly, the medicine expense for COVID patient with medium severity in the third will be \$2600 and fourth month will be \$2800 approximately similar for 4 patients occupying one bed over a month. For 2<sup>nd</sup>, 3<sup>rd</sup> and 4<sup>th</sup> month, the expense for medicines for 70 beds, the expense will be \$240000, \$260000 and \$ 280000.

| Surge period (in months) | No. of ICUs beds available | No. of patients taken in = (No. of beds available) * (No. of weeks in a month) | Medicine costs for hospitals | Total Expenses for each month |
|--------------------------|----------------------------|--|------------------------------|-------------------------------|
| 1 <sup>st</sup> month    | 70                         | 280  | \$84,000                     | \$84,000                      |
| 2 <sup>nd</sup> month    | 70                         | 280  | \$168,000                    | \$168,000                     |
| 3 <sup>rd</sup> month    | 70                         | 280  | \$182,000                    | \$182,000                     |
| 4 <sup>th</sup> month    | 70                         | 280  | \$196,000                    | \$196,000                     |

Total expense for COVID patients treatment with medium severity during the surge period = \$630,000 and the total patient care and treatment would be 1000 patients approximately. For COVID patients with low severity, oral medication was given so there was no ICUs or beds occupied. Hence, hospital expenses for this scenario is \$0. For Non-COVID-19 patients with high severity of illness, in the first month, the medicine for treatment for ICU non-COVID-19 patients with high severity costs for 4 ICU beds and 22 patients would be \$11,000 with expense \$500 per patient. For the second month, the medicine for treatment for ICU COVID patients with high severity costs for 10 ICU beds for 56 patients would be \$ 56,000 with expense of \$1000 per patient. Similarly, the medicine expense for ICU COVID patient with high severity in the third will be \$1500 and fourth month will be \$2000 approximately similar for one patient. For 2<sup>nd</sup>, 3<sup>rd</sup> and 4<sup>th</sup> month, the expense for medicines for 22 ICU beds, the expense will be \$56000, \$84000 and \$ 112000.

| Surge period (in months) | No. of ICUs beds available | No. of patients taken in ICU= (No. of ICUs beds available) * (occupancy factor(ie. 5.6)) approximately | Expenses for setting up pop-up ICUs for increasing the capacity to treat patients(x) [Cost of one ICU setup = \$16,000] | Medicine costs for hospitals(y) | Total Expenses for each month = x+y |
|--------------------------|----------------------------|--|---|---------------------------------|-------------------------------------|
| 1 <sup>st</sup> month    | 4                          | 22   |   | \$11,000                        | \$11,000                            |
| 2 <sup>nd</sup> month    | 4+6 = 10                   | 56   | \$ 96,000   | \$56,000                        | \$152,000                           |
| 3 <sup>rd</sup> month    | 4+6 = 10                   | 56   |   | \$84,000                        | \$84,000                            |
| 4 <sup>th</sup> month    | 4+6 = 10                   | 56   |   | \$112,000                       | \$112,000                           |

Total expense for non-COVID patients treatment during the surge period = \$359,000 and the total patient care and treatment would be 190 approximately. If we don't have ICU beds available for non-COVID-19

patients with high severity then we guide them to an external ambulance service that will help them get to the nearest hospital available to get treatment so, our expense in that case is \$0. For the first month, the medicine for treatment for non-COVID-19 patients with medium severity costs \$200 per patient so monthly expense would be \$33,600. For the second month, the medicine for treatment for non-COVID patients with medium severity costs \$400 per patient as assumed due to inflation so for 30 beds, the expense will be \$240,000. Similarly, the medicine expense for non-COVID patient with medium severity in the third will be \$450 and fourth month will be \$500 per patient approximately similar. For 2<sup>nd</sup>, 3<sup>rd</sup> and 4<sup>th</sup> month, the expense for medicines for 70 beds, the monthly expense will be \$67200, \$75600 and \$84000.

| Surge period (in months) | No. of ICUs beds available | No. of patients taken in= (No. of beds available) * (No. of weeks in a month) | Medicine costs for hospitals | Total Expenses for each month |
|--------------------------|----------------------------|---|------------------------------|-------------------------------|
| 1 <sup>st</sup> month    | 30                         | 168   | \$33,600                     | \$33,600                      |
| 2 <sup>nd</sup> month    | 30                         | 168   | \$67,200                     | \$67,200                      |
| 3 <sup>rd</sup> month    | 30                         | 168   | \$75,600                     | \$75,600                      |
| 4 <sup>th</sup> month    | 30                         | 168   | \$84,000                     | \$84,000                      |

Total expense for non-COVID patients treatment with medium severity during the surge period = \$300,000 and the total patient care and treatment would be 670 patients approximately. For non-COVID patients with low severity, oral medication was given so there was no ICUs or beds occupied. Hence, hospital expenses for this scenario is \$0. Total expense of the first branch is approximately \$2.3 million.

For branch 2:

Out of 4million, \$2.3million got used, we are left with 1.7 million. Cost of one PPE kit is usually \$7 per kit but during the COVID-19 pandemic, it got sold for \$20 per kit.

No. of PPE/kits required =  $[2(2 \text{ shifts}) * \text{no. of hospital staff needed to provide their service} * \text{cost of one PP kit} * \text{no. of days in a month (ie. 28 days as assumed)}]$

In a day, there will be 2 shifts, 12 hours. So, considering the rates that were used during the pandemic. Average hospital staff needed for 110 beds hospital = 350 approximately. So, for 132 bed hospital = 650 but due to pandemic restrictions we cannot hire so many as it will too crowded. So instead, let's hire 150 approximately.

| Surge period (in months) | No. of beds | No. of hospital staff needed to provide their service | Total Expenses for each month |
|--------------------------|-------------|---|-------------------------------|
| 1 <sup>st</sup> month    | 110         | 350   | \$392,000                     |
| 2 <sup>nd</sup> month    | 132         | 400   | \$448,000                     |
| 3 <sup>rd</sup> month    | 132         | 400   | \$448,000                     |
| 4 <sup>th</sup> month    | 132         | 400   | \$448,000                     |

Total expenses on PPE/kits = 1.7 million

For branch 3:

Average hospital staff needed for 110 beds hospital = 350 approximately. So, for 132 bed hospital, we need an average hospital staff of 650 but due to pandemic restrictions we cannot hire so many as it will too crowded. So instead, let's hiring 50 approximately. Average salary for hiring medical staff is \$8000/month. So, if we hire in the 2<sup>nd</sup> month of surge then the expenses =  $50 * \$8000 * 3 \text{ months} = \$1.2 \text{ million}$ . We have no budget left to hire left to hire, so hence, we'll require 1.2 million from the



revenues generated by the hospital. So, for surge period we are falling short to hire new people hence we won't hire people.

## 4. Decision Analysis

### 4.1 Scenario based analysis:

The best-case scenario is that when we have less no. of COVID patients checking into the hospital and the Non- covid patients too, so there will be no requirement to expand the ICU beds which will save a lot of money, we'll be able to have some more amount left which can help us to hire some stuff in order to avoid burnout of the current hospital staff. The worst-case scenario would be when the hospital staff gets burnt out and protests against the management of the hospital which may lead to more expenses like fulfilling their demands like giving them a raise, hiring more staff, expenses for buying more PPE/ kits, etc. This will lead to loss and the hospital will face major issues. Hire approximately fifty individuals. The monthly average wage for hiring medical personnel is \$8000. Therefore, if we make the appointment during the second month of the surge, the costs would be  $50 * \$8000 * 3$  months, or \$1.2 million. Due to the fact that we are out of hiring money, we will need to take 1.2 million from the hospital's earnings. As a result, we won't be hiring any new employees during the peak time

## 5. Recommendation regarding the situation

The foremost important and primary objective is to provide patient care awhile protecting your staff. So, my recommendation is asses the patients whether they have COVID or not, depending on their severity of the illness admit them to ICU if they are critical and admit them to the normal bed ward if the severity is medium and if the severity is low, provide consultation and prescribe them with medicines. If the is no availability of beds in the hospital then guide them to the nearest hospital by providing them the contact of the external ambulance service available nearest. If in the second month of the surge as we know that there is a rise in the number of cases and the ICUs need more beds and services. So we can expand with \$16,000 per bed in the ICU. As we have expanded the capacity of patient intake, we need to be more protective of the staff providing their services, hence, we need to buy PPE/kits, sanitation supplies for them. We have also increased their shift timings in order to suffice the low staff issue. But there needs to be a balance, as the want is for more staff, we must hire as well depending on the funds left and the revenue generated by the hospital.

## 6. References:

- 1) [Hospital staff roles - Better Health Channel](#)
- 2) [COVID-19 pandemic in New Jersey - Wikipedia](#)
- 3) [Bergen County hospital converts unused space into ICU beds for coronavirus patients - nj.com](#)
- 4) [CDC COVID Data Tracker: Daily and Total Trends](#)
- 5) [50 things to know about hospital staffing \(beckershospitalreview.com\)](#)