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STATEWIDE RE-OPENING

MAE634 QUALITY ENGINEERING | PROF. ROMEU

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Abstract

Utilizing quality engineering tools, this report takes a qualitative look at the issue of Statewide economic and social economic reopening in order to combat the hardships brought upon due to the Covid-19, coronavirus, pandemic. Through various tools, we are able to look at the impact of different factors when implementing a new process, providing the best solution to the given problem. In the process of finding solutions to the given problem, techniques such as brainstorming, visual aids, help define solutions while cost of poor-quality help eliminate defects found. Tools used in quality engineering like six sigma, quality function deployment, and design of experiments were all used to help develop, define, and qualify our process in statewide reponing of the state economy. Ultimately, allowing qualitative solutions to be defined and proposed with controls and measures ensuring a successful process is implemented while lowering and controlling infection rates among the populace.

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Topic

Background

Covid-19, also known as Coronavirus and SARS-CoV-2, is believed to have originated in Wuhan, China, with the first known case in December of 2019. The virus was first detected in January 2020 in the United States and would soon become widespread causing states to issue stay-at-home orders, mandated mask policies, closures of businesses, and social distancing. This impact would soon have devastating results on the public, especially those of lower income. As of today, there is approximately 33 million positive cases in the US and approximately 581,000 deaths. In the state of New York, where we will look at the process of reopening the state, there has been two million cases and 52,000 deaths. The state still has restrictions on gatherings, non-essential travel, mandated mask policies, and closures on businesses.

Problem Statement

It has been over a year since the coronavirus pandemic started to wreak havoc on the United States. Other than the social and public health crisis that this has created, the economic crises is just as catastrophic. In order to return to some level of normal, local, and federal governments must focus on re-opening the economy in an efficient, calculated, and responsible manner. By re-opening the economy, business can start to open, and people can go back to work and make money. However, if certain measures and controls are not put in place to control the spread of the virus in relation to the economy, then we run the risk of fueling another wave of severe infections.

Brainstorming and Ishikawa Chart

Brainstorming

Brainstorming is used to determine the possible causes of a problem or the solution, even multiple solutions in which a team is asked to think creatively by interacting with each other within the team. This systematic process as used to help establish potential solutions in a process for the re-opening of the economy statewide. Utilizing this process, using a simple and effective visual, the following table below was created for potential solutions on varying levels for reopening the sate economy.

Schools	Food Service Industry	Retail	Public Services	Healthcare services	Sports and Recreation
Mask policies	Mask policies	Mask policies	Mask policies	Disinfecting procedures	Allow outdoor events
Social Distancing	Social Distancing	Social Distancing	Social Distancing	HVAC upgrades	Limited indoor events
Classroom capacity	Disinfecting procedures	Disinfecting procedures	Disinfecting procedures	PPE availability	Limit capacity for events
Vaccine availability	HVAC upgrades	HVAC upgrades	Contactless payment options	Adequate number of hospital beds	Vaccine availability
Disinfecting procedures	Limit indoor seating and increase outdoor	Store capacity limits	Frequent COVID-19 testing available	Updated and operational equipment	Limited travel for games
HVAC upgrades	Financial assistance waivers/programs	Limited hours	Accurate and clear guidelines of current policies	~100% vaccination of healthcare workers	State/local competitions and events

Table 1: Brainstorming chart

The idea was to break down different industries into categories, those being schools, food service, retail, public services, healthcare services, and finally sports and recreation. Within these categories, certain aspects were developed that needed to be addressed in order to have control measures developed to have a successful state opening of businesses and removing a stay-at-home order.

Ishikawa Chart

Following the brainstorming process an Ishikawa Chart, also known as a fishbone diagram, can be used for quality defect prevention. The following Ishikawa chart groups together causes under major categories in order to identify sources of variation in the process. The advantage of this process is it builds upon brainstorming and turns it into a highly visual brainstorming tool. This also allows for quick identification of the root cause if it is found multiple times in different branches with all causes being displayed simultaneously.

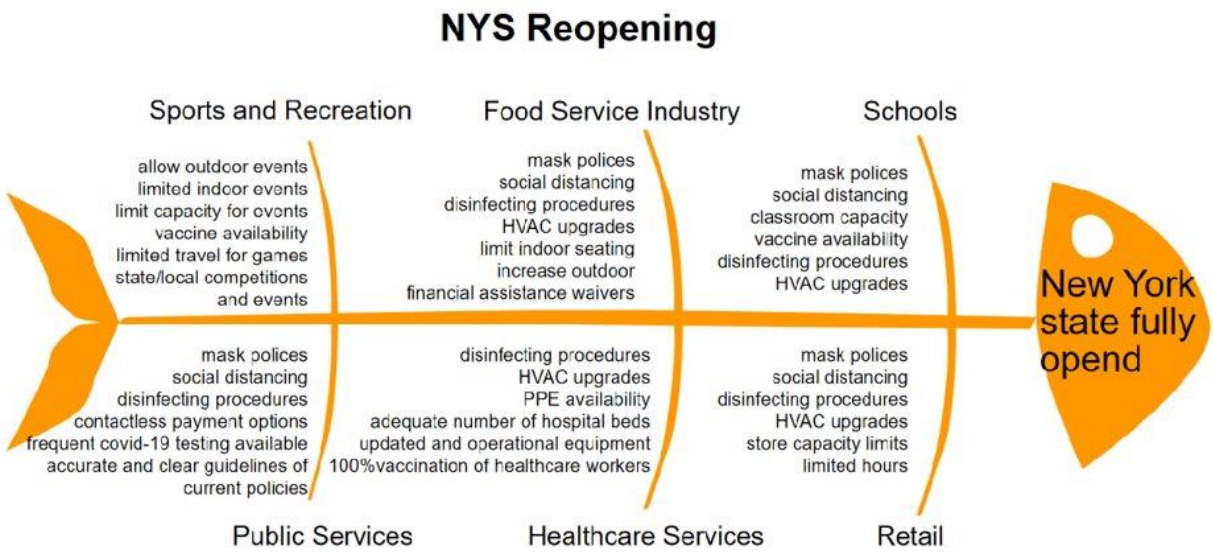


Figure 1: Ishikawa Chart

As you can see the following categories have remained the same from the brainstorming chart, however, representing in a much more visually effective manner. All major categories are pointing to the problem of New York State being fully opened with businesses running as needed in order to allow the economy to function and provide jobs, reducing the unemployment rate caused by the pandemic.

Analysis of COPC and Quality Assessment

Cost of Poor Quality

One of the first tools in quality when looking at a process is Cost of Poor Quality, this allows an organization to determine how effectively and efficiently they are using their resources. This information will provide information to prevent monetary loss as a result of poor quality. The cost of poor-quality chart formulated below is a result from brainstorming solutions to a given problem.

COPQ	Internal	External	Appraisal	Prevention
infection	·Extremely contagious ·Long incubation period multiple modes of transmission	·Advance transportation makes virus easy to pass ·Lack of awareness ·Large flow of people at downtown	·Trace contacted people and do nucleic acid detection ·Mandatory two-week quarantine for foreign visitors	·Prepare quarantine rooms ·Appeal to residents to stay at home as long as possible ·Keep disinfecting everyday
monitoring	·Lack of detection staff and equipment ·Hard to inform everyone to have nucleic acid detection	·Infected people do not immediately show symptoms ·There are people who fake their travel trajectory	·Check the registration forms of each unit for the temperature and health of visitors on time ·Establish a statewide database of personal health information	·Prepare spare inspection equipment and personnel ·Prepare plan for apply multiple and large scale nucleic acid tests for one region in emergency
medical treatment	·lack of equipment and medical staff ·It takes months to completely cure a patient ·Overwork can make medical workers sick	·Too many patients can cause cross-infection ·Other kind of patients are unable to see doctors, the contradiction between doctors and patients increase	·Count the length and life of the device ·Carry out survey of the working status of doctors ·Nucleic acid testing in hospital environments	·Gather patients who cannot be treated yet in case enlarge infection ·Popularize medical knowledge of the epidemic to the population ·Minor patients who treated can isolated at home on their own ·Build additional hospitals to deal with the covid-19
vaccination	·Some people are allergic to the vaccine or certain ingredients in it ·It can't guarantee 100 percent effective	·Availability of vaccines ·Access to reliable transportation networks ·Improper handling of vaccine ·Misinformation of vaccine statistics	·Investigate the severity of epidemic in different regions ·Ensure that the vaccine storage equipment has a backup power supply and check all equipment in a timely manner ·Check the skills of workers of injecting others.	·Train nurses and make sure people that are injected with vaccine continue to follow all health and safety mandates ·Make vaccine sites convenient and readily available to large portion of population ·Optimize transportation routes

Table 2: Cost of Poor Quality Chart

Quality Assessment

From the Cost of Poor Quality, a list of items of concern can be developed, these concerns will be used to consider what list of individuals to interview, development of a list of questions for those individuals to be interviewed, developing a diagnostic of issues revealed, to be able to propose a root-cause analysis of possible reasons for existing problems, the proposition of solutions and measures to assess improvements desired and to make such improvements sustainable. Below you find a list that covers these criteria in a quality assessment.

1. **List of Items of Concern, from the COPQ**
    - Lack of awareness of symptoms of covid-19
    - Lack of self-control to obey the rules like wearing mask, disinfecting hands.
    - Poor quality of education progress and reopening will cause a large movement of people.
    - The economy is struggling to recover; the numbers of unemployed people can lead to a vicious circle of economy.
    - Lack of safety knowledge and measures to prevent infection.
    - Lack of protection for people at high risk of infection.
    - Lack of publicity about the importance of epidemic prevention
2. **List of Individuals within your organization, to interview.**
    - Students
    - Teachers
    - Retail
    - Bus drivers
    - Restaurateurs
    - Residents
    - Security
    - Government officials
3. **List of Questions (questionnaire) for these**
    - **Students**
        - Has the pandemic affected your study and life? What are the specific aspects? Do you have plans to catch up with your study progress after the reopening?
    - **Teachers**
        - Do you have any changes in your teaching style? Is there any reduction in your teaching quality? Do you have any suggestion to better adapt to this epidemic situation?
    - **Retail**
        - What are the changes of customer's flow after reopening and before the covid-19 comparing with closing period? Do you add extra ways to check if there are viruses on your goods now compared with before the epidemic?
    - **Bus drivers**

- Are you responsible for checking whether passengers wear masks and keeping distance from each other? According to your observation, are passengers following all these rules? How is the current passenger flow?

- **Restaurateurs**
  - What are the specific requirements for incoming customers before they enter the restaurant? Do you limit the number of customers in there? How do you sanitize the restaurant? And how do you ensure food safety?

- **Residents**
  - Is there a special testing and quarantine site in your community? Will community leaders test and quarantine residents with a history of travel to high-risk areas? Can the number of daily infections in the community be known from some websites or news reports? Will the recent routes of the infected person be made public? Can you get help from relevant personnel when you have symptoms of infection？
- **Security staff**
  - Do visitors follow the rules that they must wear mask and disinfect hands before getting in? What are your checking processes? And what is your measures when you finding someone has symptoms?
- **Government officials**
  - What measures should authority take to ensure the health and safety of more people during the outbreak？

4. **Succinctly answer (yourselves) questions posed above.**
   - **Students**
     - Schools have closed around two more months than before the pandemic, and class time online is always changing. It was inefficient for senior school and high school students to study during that period. However, this situation promoted improvement of online education, so after reopening, students will combine online and offline ways to study which will make effort for their study progresses.
   - **Teachers**
     - Teachers used an online education model for nearly a whole semester, which is easier for students to learn knowledge by teacher talking and showing PowerPoints at the same time, meanwhile, students can search on the internet about their questions or confusion immediately. Also, they can watch recordings of class to get better reviews. But for teachers, this method is hard to communicate with students because without seeing students physically, teachers cannot get information that do students get their points or even are students still listening. All in all, online model is a great tool and teachers will keep using it in some fields after reopening.
   - **Retail**
     - During the pandemic, nearly half of the stores closed, and the opening stores are mostly selling daily necessities and food. The number of

customers of these stores did not decrease much, but people always got there and purchased a lot of stuff, which resulted in others coming there for nothing. Reopening has relieved such phenomenon and the customer's flow keeps increasing and supplies of many commodities have resumed. Things are getting normalized every day. However, the situation of restaurants is much worse that many of them closed not because of policy but because there were no customers for several weeks. And the food in their warehouse had expired so they had to drop many goods. Such damage made many restaurateurs go broke.

- **Bus drivers**
  - It is hard to monitor passengers whether they follow rules because the government did not publish a clear policy about it. And there are many kinds of passengers that some people have good awareness about, some people do not, some people even do not believe the existence of covid-19. What drivers can do is protect themselves and provide masks for people who need it.
- **Restaurateurs**
  - Before the customers come in, they need to wear mask and body temperature must be normal and it cannot exceed 98.6℉. We have no limit on the number of people. Special staff will use disinfectant to disinfect the dining table and doors and open the window to ventilate occasionally. We know that viruses are afraid of high temperatures, so when the cook is cleaning dishes, soak them in hot water for 10 minutes first.
- **Residents**
  - Some communities have testing and isolation sites, but there are cases where the number of medical personnel is insufficient. For people with high-risk tourism history, if they are no symptoms of infection, will not be forced quarantine. People will get data on the news about the number of new infections and deaths, but recent routes of the infected person will not be reported. When people feel symptoms, most people will take medicine and home quarantine, because there is not enough space to accommodate the hospital patients.
- **Security**
  - Wearing a mask and disinfection are mandatory requirements, most people will follow the rules, if someone does not abide by, they will be no admittance. Security staff will test every tourist's body temperature, if it is found that the body temperature is not normal, then they will take tourist to the quarantine for testing immediately, and will go to the hospital when necessary, meanwhile, security staff requires close contacts for detection and quarantine to prevent infect more people.
- **Government officials**
  - Public health is as important as national security. As the number of infected people increases, the government should pay more attention than before.

- The medical and health system should be further strengthened, such as medical services, medical security, and medicine supply.
- Recruitment of medical experts is also important because scientists, doctors, epidemiologists, and other professionals play an indispensable role in dealing with diseases and natural disasters.
- In addition to improving the health management system, advanced technological means are also necessary, for instance, internet medical, health care big data, medical artificial intelligence, and other technological means. These methods can play a role in predicting the development trend of the epidemic, tracing the journey of suspected patients, assisting doctors with CT scan reading and providing rapid diagnostic reference and so on.

5. **Diagnostic of issues uncovered through such answers.**
    - People's Awareness of the severity of the pandemic should be strengthened, especially if they realize this virus is highly contagious. The state-wide reopening is going well, so we should do everything to keep it going. For education, all schools should cancel large outdoor activities as much as possible and try to reduce visitors outside schools. Teenagers are smart and they can easily understand knowledge, policy, and precautions about covid-19, so we can let them to spread awareness to all of their families. It may work better in this way. Install monitoring equipment to ensure workers and students have a safe environment. The government should publish location tracing app for everyone individual, for those people who are detected with symptoms, there should be serious laws to restrict their movement, and force them to quarantine. Vaccines need to be used as soon as possible as a guarantee for sustained reopening.
    - Like restaurant where people easy to gather workers should reduce put desk and chair, so that customers can keep a safe distance, also people should use public tableware so that avoiding cross-infection. Some in-store food services should be suspended, more in-store pickup and take-out services should be provided, so that human contact should be reduced or avoided. For tourist destinations and other public places, they can use infrared thermometer or other temperature measuring tool measuring body temperature to visitors. Visitors are required to register (name and contact information), since if suspected patients or infected people are found, they can be tracked down and tested to ensure the safety of themselves and their families. Tourist destination site and quarantine should set up enough medical first aid, and equipped with medical thermometer, including medical disposable masks, disinfectant supplies. The management of residential communities should also be stricter, and people from other places, especially high-risk places, need to register basic information to ensure the health of local residents.
6. **Then, propose a Root-Cause analysis of possible reasons for problems.**
    - Lack of Social Distancing
    - Lack of Medical Equipment
    - Misinformation / Lack of Awareness

- Lack of Quarantine of Infected Individuals

7. **Then invent Results of the Diagnostics and Root Cause Analyses.**
    - Improved medical care with adequate medical equipment for those infected individuals.
    - An awareness campaign would help reduce the spread of disease (COVID-19)
    - Social distancing, mask wearing, and proper hygiene (wash hands, sanitize) helps reduce the spread of disease.
8. **Propose in your analysis, some solutions for fixing the Quality issues.**
    - Identify high infection zones.
    - Increase funding for medical equipment, vaccinations, and proper ventilation systems in facilities.
    - Invest in more medical research on COVID-19.
    - Mandate social distancing and wearing of masks.
9. **Propose some measures to assess the Improvements to be obtained.**
    - Contract tracing for potential infected individuals (helps quarantine)
    - Daily infection rate data tracking.
    - Number of vaccinated people.
    - Availability of medical equipment.
    - General Public is more aware of infection risks.
10. **Propose some measures to make such Improvements Sustainable.**
    - Long term contact tracing program (monitoring of infections)
    - Regular testing for COVID-19
    - Eliminating the source of spread
    - Availability of vaccine

Quality Function Deployment (QFD Matrix)

Another quality method that was used in this analysis was quality function deployment (QFD) also known as matrix product planning or decision matrices. The quality function deployment is a process and set of tools used to define customer requirements and convert them into detailed engineering specifications and plans to produce the products that fulfill those requirements. Quality function deployment is used to translate customer requirements found during the voice of the customer analysis into measurable design targets and drive them from the assembly level down through the sub-assembly, component, and production process levels. Quality function deployment provides a defined set of matrices utilized to facilitate this progression.

To create these matrices, we first must determine what are the customer requirements needed to re-open the state and in turn re-open the economy. The customer in this case are the people and business that were affected by the state-wide shut down. Those customers are retail stores, restaurants, government officials such as governors and state representatives/senators, everyday citizens, workers and employees of businesses and business owners. From here, we can listen to these customers and create a voice of the customer analysis from which we can determine what are the needs of each customer. With this, a pareto chart was created to represent the significance of each customer requirement, this is shown below in table three.

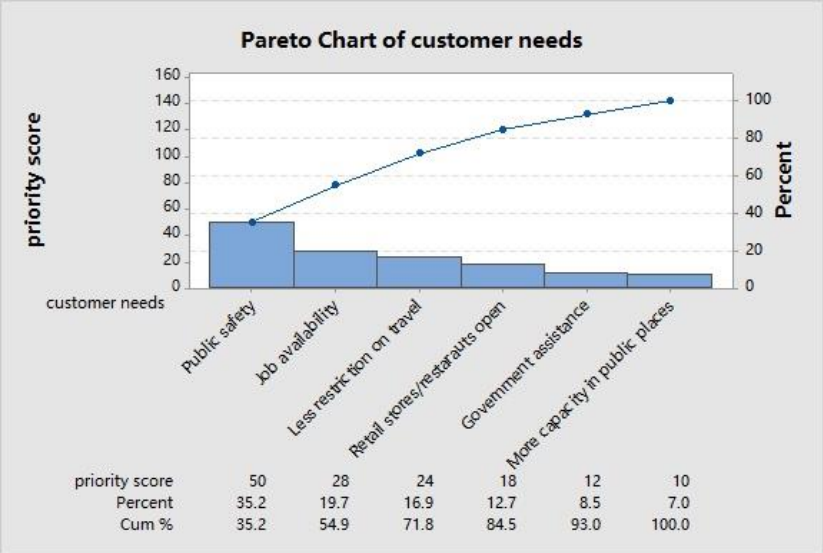


Figure 2: Pareto Chart

From the voice of the customer, we determined that the aspects that are important to our customers are the safety of the public, job availability across new and old industries, less restrictions on travel both locally and internationally, retail and restaurants to reopen, some kind of financial assistance from government entities and finally more capacity in public places both indoor and outdoor. With these, the pareto chart above is created. Here we can see that the

most important customer need is public safety. Public safety meaning that everyone is health and fully vaccinated and does not pose a threat to the public and community as a whole.

Now that the customers and the customer needs are identified, we may proceed to create the quality function deployment matrices. These matrices can provide a visual representation of the customer's needs, desired product and process features, as well as any process controls wanting to be implemented. Below are the matrices created for the state-wide reopening.

Customer Needs

Customers	Retail stores/restaurnts open	Job availability	More capacity in public places	Less restrictions on travel	Government assistance	Public safety
Retail stores	9	9	5	0	6	9
Restaurants	9	9	5	0	6	9
Government officials	0	5	0	1	1	9
Everyday citizens	5	9	0	9	9	9
Workers	6	9	0	9	5	9
Business owners	9	5	0	5	5	5

Product features

Customer needs	New technical and non-technical jobs	Government stimulus check/pandemic relief fund	Vaccinated public	Investment in new and old industries	Safety plan	Thriving economy
Retail stores/restaurnts open	5	9	7	7	5	9
Job availability	9	4	7	9	0	9
More capacity in public places	0	0	1	1	5	0
Less restrictions on travel	0	0	0	0	9	0
Government assistance	5	9	0	7	0	7
Public safety	0	0	9	0	9	5

Process features

Product Features	Data collection	Problem defining	Data analyzing	Improvement plan	Processes supervision	Controlling implements
New technical and non-technical jobs	1	1	5	1	5	5
Government stimulus check/pandemic relief fund	5	0	5	0	5	0
Vaccinated public	5	5	5	9	5	1
Investment in new and old industries	9	1	9	1	5	5
Safety plan	5	9	5	9	7	5
Thriving economy	9	9	9	9	8	5

Process features	Process Control: Clear guidelines	Funding planning	Penalties and rewards	Improvement feedback	Processes modify	Alternative solution management
Data collection	6	5	1	9	0	1
Problem defining	0	4	5	1	5	5
Data analyzing	1	5	5	9	1	5
Improvement plan	7	5	5	0	9	7
Processes supervision	7	0	9	5	9	5
Controling implements	7	9	5	1	5	7

Figure 3: Quality Function Deployment Matrices

From these matrices, we can see there is a cascade effect between the customer needs, product features, process features, and process control showing that there is a relation between all of these issues. Each matrix is using a 10-point scale (0-9) to determine how high of a priority it is in relation to our problem of reopening the state. From these point scale evaluations, we can create a house of quality chart which is shown below.

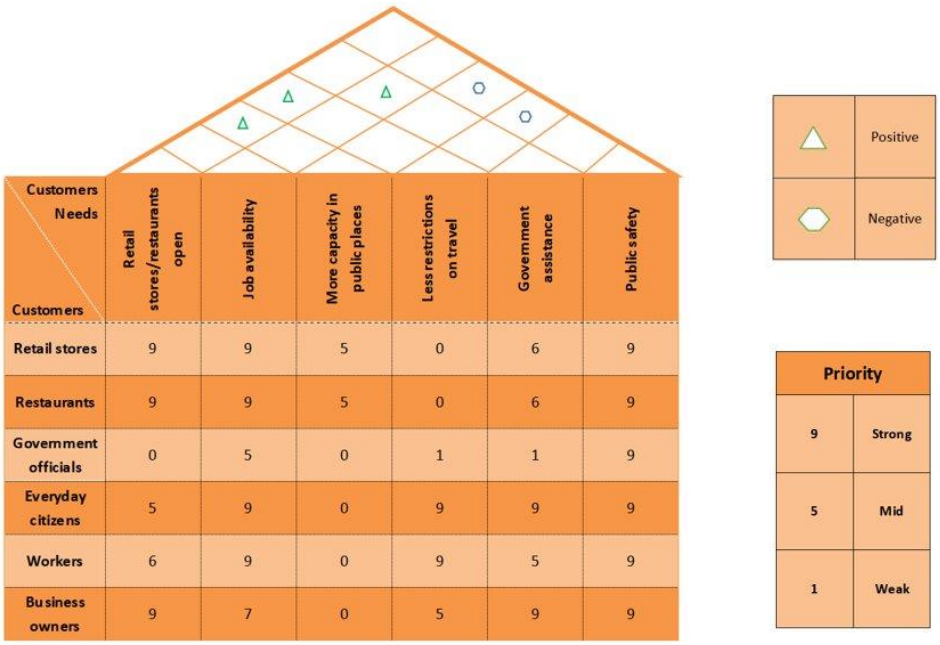


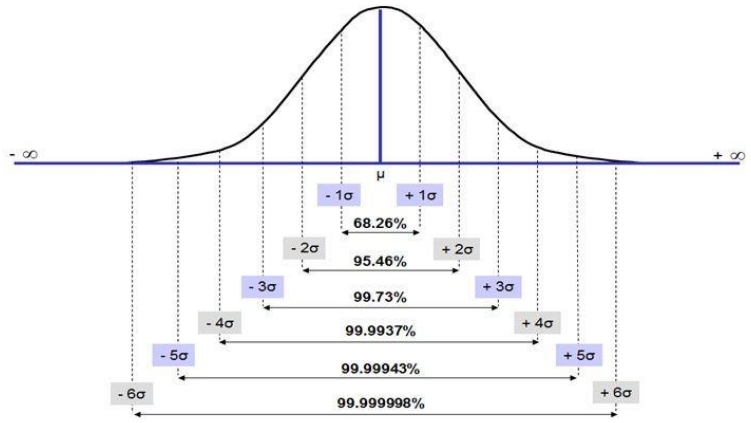
Figure 4: House of Quality

The House of Quality (HOQ) is defined as a product planning matrix that is built to show how customer needs relate directly to the ways and methods companies can use to achieve those requirements. This is considered the primary tool used during quality function deployment to help with group decision making. In our case, the house of quality relates our customers and their specific needs which were outlined previously. From figure four above we see that for all

customers public safety is top priority, which confirms our findings in the voice of the customer and pareto chart analysis. Some other top priorities are job availability and the reopening of retail stores and restaurants. According to our customers, these are the top priorities for them to achieve the goal or reopening the state which would then reopen and stimulate the economy.

Six Sigma DMAIC

Six Sigma is a disciplined, data-driven approach and methodology for eliminating defects in any process or system. Six Sigma addresses process control and quality through the reduction of "variation" in a system or process. Variation is often a cause of defects, so as a result we would like to reduce or ideally eliminate any potential defects from our system or process. The term "six sigma" refers to the fact that a process can be measured by its sigma level which is a measurement of variation in a system or specific process. The so called "sigma (σ)" is a measurement of the variability around a mean value, so the lower the sigma level the more variation which means that there will be a higher chance for defects to emerge. To have a sigma level of 3σ means that 99.73% of the process is defect free while 6σ means that 99.999998% of the process is defect free. While these percentages may seem similar most companies strive for a sigma level of 6σ because at that level there are only 3.4 defect parts per million opportunities (DPMO) while a sigma level of 3σ will give 66,800 DPMO which is a significant difference. If we can achieve a 6σ level, then that will allow for less time loss due to defects and more money made. Below is a representation of the sigma levels.



There are many six sigma methodologies, but the most commonly used methodology is DMAIC. DMAIC stands for Define, Measure, Analyze, Improve, and Control. This is a very structured and analytical approach to identify potential problems and determine appropriate and effective solutions as well as ways to maintain the process in control.

The first phase in the DMAIC process is the define phase. Here we define or identify our problem which in our case is the closure of the state and the desire to reopen. Our problem statement in other words would be that:

> *Due to the Covid-19 pandemic, on March 20th, 2020 New York State shut down to slow the spread of the virus. This closure led to the loss of over 1 million jobs in 2020 alone which accounted to over 8% of the state's total workforce.*

With a clear problem statement created we can move on evaluate certain projects that we have determined would be beneficial to start with first. The three projects analyzed were to reopen import/export channels into the state, reopen retail businesses, and to reopen manufacturing plants in the state.

Projects	Savings, $thousands	Probability	Cost, $ Thousands	Time (Years)	PPI
(1)	10	85%	2	0.25	17
(2)	15	90%	4	0.25	13.5
(3)	***30***	***95%***	***3***	***0.5***	***19***

Table 3

In table three above, we have evaluated the three projects based on its savings, probability of success, cost, and overall time it would take to complete. With these specifications we were then able to calculate the Pareto Priority Index (PPI). The Pareto priority index is essential a data point that evaluates the cost and benefits of a specific entity. In our case, we can see that project 3, which was to reopen manufacturing plants, has the highest PPI of 19. This means that this will be the first project that we will undertake to help the state reopen in a safe and effective manner. To calculate the PPI value the following equation is used:

$$PPI = \frac{savings \times probability\ of\ success}{cost \times time\ to\ completion}$$

Equation 1: Pareto Priority Index

The next phase in the DMAIC process is the measure phase. In this phase we will create a data collection plan to be able to recognize what kind of data we would want to obtain. For our case, the types of data that we collected was the number of jobs created, the number of new infections, and overall number of new and previous businesses opening. With this data we verify that it is accurate. To verify we can compare our data to data collected by government agencies such as the department of health and the department of labor. Here we can compare pre covid and current covid conditions to see what needs to be done to improve. We then can determine a baseline performance and process capability to use throughout our further analysis.

The next phase of the DMAIC process is the analyze phase. In this phase we analyze the data that was collected during the measure phase. Here we determine if the process is capable and stable and if it is found not to be then we must go back and reevaluate the data collected in the previous phase. Below is analysis of the number of new business opening before and after our improvement is put into place.

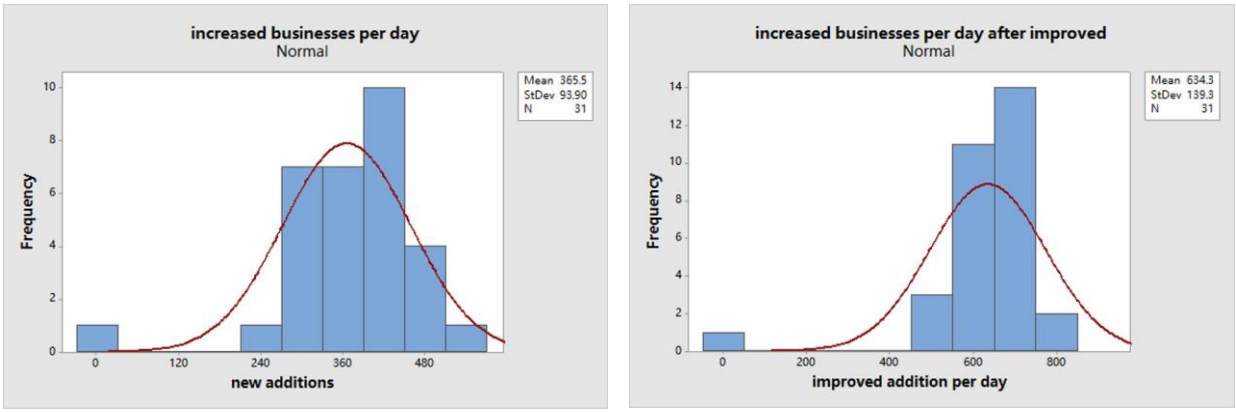


Figure 5

In figure five Above we see that before the improvement is put into place only about 365 businesses were opening and then after the improvement is put into place the new number of businesses opening was 635, which is almost double the amount before.

The next phase in the DMAIC process is the improve phase. In this phase we get to "solve" the problem. We get to implement our solutions, potential changes, and process improvements and see if they are outputting the desired results to make us confident in being able to reopen the state in a safe and responsible manner. Some suggestions of improvement that we have determined were to define clear criteria on opening business, keeping them open, and if needed, criteria on how to shut down with reduced negative effects on the business and community as a whole. If there is an increase in the infection rate in a certain region, these businesses need to shut down until the daily infection rate is below 5%. Another improvement would be to set up deadlines or "check points" to encourage businesses to reopen in a timely and safe manner in order to stabilize and improve the economy of the state. In connection to this, implementing phases would be a safe and smart way to limit the high spikes of infection rates that could happen if everything in the state opened at the same time. Starting off with reopening essential services and monitoring the infections rates and if it is satisfactory then we can move onto the next phase until the state is fully open again.

Once the problem is defined, measured, analyzed, and improved, we must include controls to maintain the process and ensure that it is followed correctly. This leads us to the last phase in the DMAIC process which is the control phase. In this phase, rules or controls are put into place in order to prevent the process from returning to its original state which would result in a failure

in the process. Some controls that can be put in place are as follows. Make sure all protocols are clearly documented and available to the public. We need to have clear guidance on what we can and cannot do in order to keep the system from straying from the process. We need to ensure that the public is fully aware of current and any new guidelines on the local, state, and federal level. The use of social media, outdoor signage, and public service announcements can help ensure that the public is fully aware of what to do. Maintaining daily updates on the rolling number of infection rates will be critical in ensuring that the state can reopen in a safe manner. Public and private business should implement temperature checks, mandate social distancing and masks for its employees and customers to help limit the spread and exposure to the virus.

Design of Experiments

So far, we did all the improvements, that we vaccinated people and invest industries, and we Encourage people to work and start a business. Every substance seems to be good now, however the fact is that infection never be vanished, which means we have to control capacity allowed in building, at the same time, we also need to supervise job availability to see if the reopen economy is going on well.

So, we used Design of Experiment. It is a tool used to for predicting and analyzing the effect of single or multiple changes to a process. The design of experiments process will look at three factors that impact the ability to open the State's economy, these factors are infection rates (A), job availability (B), and capacity allowed in buildings (C). By looking at these three factors we will be able to see not only the correlation between all three factors, but also which factor has the greatest impact on the process. In this reopen situation, we need to figure out that are these three factors have fluence to the number of new stores or merchants every day, and if they do have influence, how can we increase number of new stores by modifying these factors. For the DoE, each factor has an upper and lower limit, the factors with their limits can be seen the table four.

A	Infection Rates	UprLimit	15%	LwrLimit	5%
B	Job Availability	UprLimit	50%	LwrLimit	10%
C	Capacity Allowed in Building	UprLimit	80%	LwrLimit	40%

Table 4:DOE Factors

For factor (A), we recorded every day, every hospital in every region, officially counted data.

For factor (B), we collect big companies' information on employees and execute sample survey of small business demand for employees.

For factor (C), we selected representative places, including shopping malls, hospital, office building, school binary statistics real-t headcount.

Here is the data distribution, we used 8 runs to do it, each run includes 3 days' statistical results and 3 replications, which means we did experiment once a day and spent 24 days to achieve it. We use this experiment to figure out the relationship between factor A B and C and the interactional factors AB AC and ABC. And we also probe the relationship between A, B, C. From the equation, we can get the effect values which are the coefficients for the fluence regression equation, then we calculate the variance of model and variance of effect, and the standard deviation of them. Then by equation we can get the value of confidence interval half width. Compare the size of C.I half width with effect, we can select the significant factors. Here they are

factor A B and C, and we can also learn the magnitude of their influence arrangement from the right side pareto chart.

Run	A	B	C	AB	AC	BC	ABC	Y1	Y2	Y3	Avg.	Var.
1	-1	-1	-1	1	1	1	-1	-2.49522	-2.4232	1.721714	-1.07	5.8280
2	1	-1	-1	-1	-1	1	1	3.561609	0.72755	6.868266	3.72	9.4457
3	-1	1	-1	-1	1	-1	1	-1.70987	-0.75186	0.721008	-0.58	1.4994
4	1	1	-1	1	-1	-1	-1	10.97971	11.63553	13.4965	12.04	1.7046
5	-1	-1	1	1	-1	-1	1	10.51655	4.122255	8.611666	7.75	10.7784
6	1	-1	1	-1	1	-1	-1	14.7701	17.99574	13.5711	15.45	5.2366
7	-1	1	1	-1	-1	1	-1	11.18758	12.09465	9.996949	11.09	1.1068
8	1	1	1	1	1	1	1	19.7119	15.0226	20.19426	18.31	8.1614
								Sum 66.52235	58.42327	75.18146	66.70903	43.76087
											8.338628	5.470108

Table 5: Data Distribution for DoE

Table five provides the data distributions used in the design of experiments when testing our factors. Utilizing either excel or Minitab, in our case Minitab, we can generate our regression estimation, among other values, shown in the next table.

ToSum							
SumY+	49.5116	40.8596	52.5984	37.0314	32.1094	32.0562	29.1986
SumY-	17.1974	25.8494	14.1106	29.6776	34.5996	34.6528	37.5104
AvgY+	12.3779	10.2149	13.1496	9.2579	8.0274	8.0141	7.2997
AvgY-	4.2994	6.4623	3.5276	7.4194	8.6499	8.6632	9.3776
Effect	8.0786	3.7526	9.6220	1.8385	-0.6225	-0.6491	-2.0779
Var+	6.1371	3.1180	6.3208	6.6181	5.1813	6.1355	7.4712
Var-	4.8031	7.8222	4.6194	4.3221	5.7589	4.8047	3.4690
F	0.7826	2.5087	0.7308	0.6531	1.1115	0.7831	0.4643

Regression Estimation

Regression: b0+b1*A+b2*B+b3*C+b4*AB+b5*AC+b6*BC+b7*ABC

RegCoef	b1	b2	b3	b4	b5	b6	b7
estimat.	4.039277	1.8762837	4.8109835	0.919226	-0.311272	-0.324575	-1.038967

Var.of Model	5.4701084	StdDv	2.3388263
Var.of Effect	0.9116847	StdDv	0.9548218
Student T (0.0025;DF)=	2.1199053		
C.I. Half Width=	2.0241319		

Significant Factors & 95% CI Limits:

Factor	A	B	C	AB	AC	BC	ABC

Signific	Yes	Yes	Yes	No	No	No	No
LwrLimit	8.0786	1.7284	7.5978	-0.1857	-2.6467	-2.6733	-4.1021
UprLimit	10.1027	5.7767	11.6461	3.8626	1.4016	1.3750	-0.0538
Regression we will use:							
Regression: 8.33+4.03A+1.87B+4.81C							

Table 6: DoE Data

From this given data, we can see when finding which factors and their interactions are significant, we find each factor on their own is in fact significant, however, their interactions, given AB, AC, BC, and ABC, are not significant to the process. The following Pareto Chart shows which factors are significant, with the defining number being 2.12.

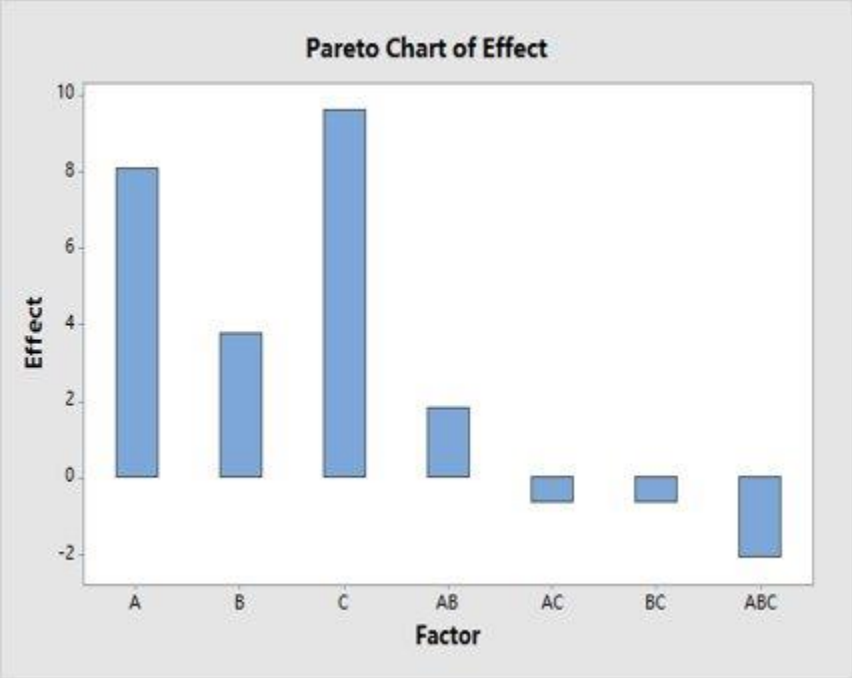


Figure 6: Pareto Chart

Next, the original process capability is analyzed, with an original distribution of new businesses opening. The original process is found to be unacceptable for the following reasons, the process capability ratio value is 0.203 which is too low and must be improved, the precent scrap tiles is 27.1% which is too high and needs to be reduced and finally, the Cp value is lower than 0.67. The lower set limit (LSL) and upper set limit (USL) is 5 and 25 respectively, below is the following calculations:

Cpk= $\min\{\frac{\bar{x}-LSL}{3\delta}, \frac{USL-\bar{x}}{3\delta}\}$ = **(8.33-5)/F94(3*5.47) =** **0.202925**

Cp= $\{\frac{USL-LSL}{6\delta}\}$ = **0.609385**

Factor	High	Low	Unit	Range	Mid.	Val+	Val-
A: Infection Rates	15	5	%	10	10	1	-1
B: Job Availability	50	10	%	40	30	1	-1
C: Capacity Allowed in Building	80	40	%	40	60	1	-1

(value of A and B is the ratio of added number to existed number one day before.)

Regression: 8.33+4.03A+1.87B+4.81C

The distribution can be seen in the following the plot below: we can find out that there are only about 8 new stores per day, and the unaccepted value 5, is nearly to Mean, which is obviously not good.

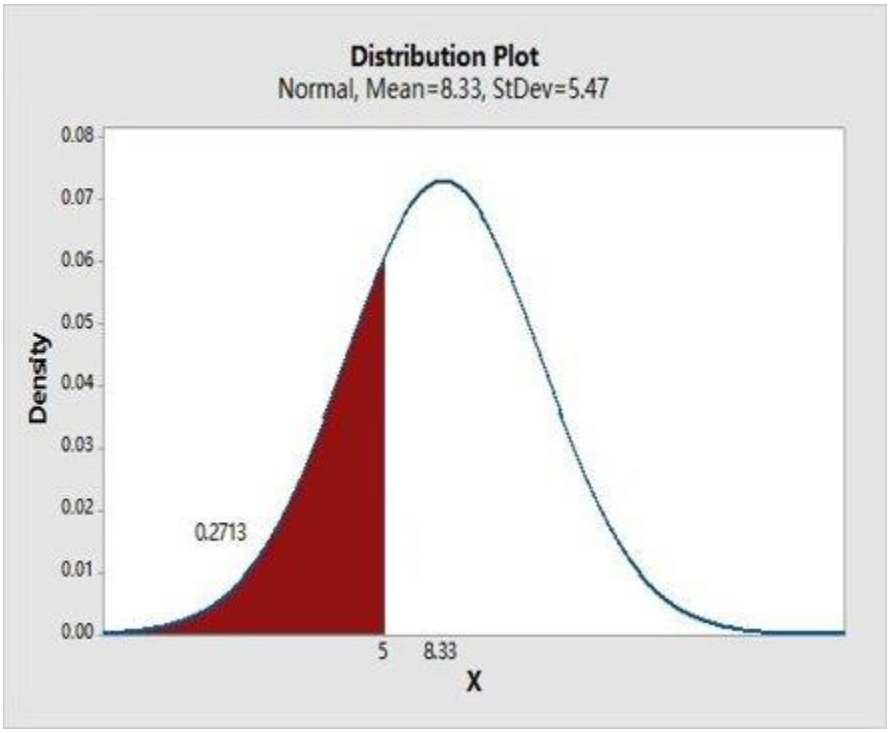


Figure 7: Distribution Plot

In order to improve upon the process, the following steps were taken. Here comes the improved process, we know that infection rate is not easy to reduce. So, we decide reduce factor A by 10%, and try our best to move factor B and C to their Max range, so we get this coded value, for A is 0.1, for B and C is 1, and we take them into regression equation, we can work out that now the Mean of process is up to almost 15.

The improved Factors			**=(coded*range)/2+mid.**	
A	**before:**	10%	**after:**	10.5%
B	**before:**	30%	**after:**	50%
C	**before:**	60%	**after:**	80%

The overall distribution improves and the scrap tile % is 3.92. The driving factor here is A, infection rates, and by reduction infection rates we see an overall improvement upon the process shown in the following distribution plot:

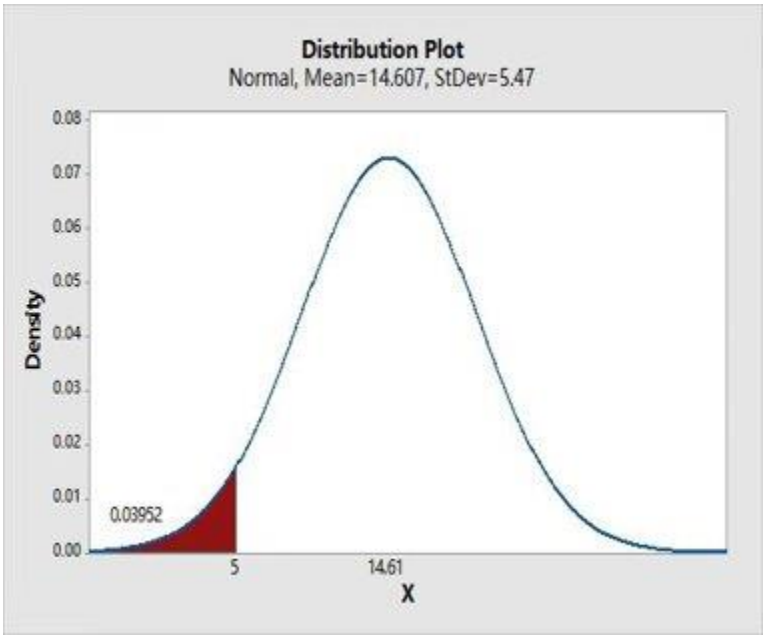


Figure 8: Distribution Plot Updated

Finally, we get our improvement plan and modified the limit for these three factors. From now, if we can maintain the range of these three factors, we can keep the number of new stores on average, 15 per day. From the design of experiments, when proposing solutions, the infection rate must be taken into consideration in order to have a successful implementation of reopening the state's economy.

We also did this experiment in Minitab to have a more intuitive comparison of the magnitude of factors A, B, C. and here is the contour plot and surface plot of A, B:

Figure 9: contour plot of response of A, B

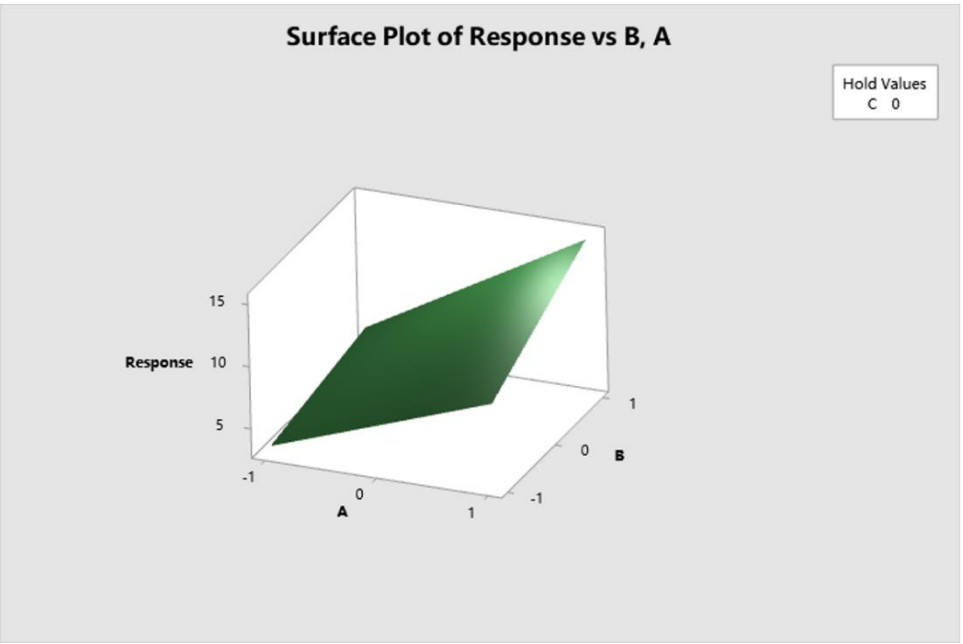


Figure 10: surface plot of response of A, B

These two figures are straightforward to show us the magnitude level between factor A and B. from contour plot, the direction of inclination of contour of every value is upward, which means that when B stays the same, the change of A has a greater effect on the changes in outcome. We

can see the same results from surface plot. When both A and B are fixed at about –1, it is obviously that the gradient on A side is changing faster than the gradient on B side.

Moreover, we studied the relationships of A, B, C. and here is the interaction plot for these three:

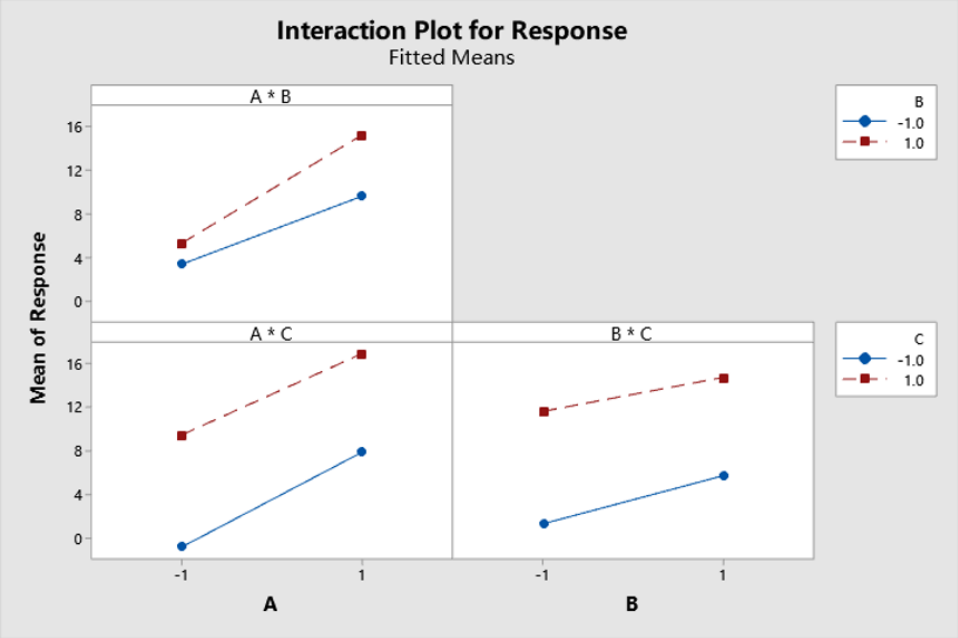


Figure 11: interaction plot of factor A, B, C

From this interaction plot, we can see that A has a close relationship with B and has a tenuous relationship with C. and here seems that no interaction between B and C.

Proposed Solutions

From our analysis done in implementing the process of statewide reopening, the following proposed solutions have been developed to control and reduce infections rates among the populace for a successful economic opening of the state.

Our priority solution is for monitoring infection rates, we used Design of Experiments to specifically look at percentages of the three influencing factors (infection rates, job availability, capacity allowed in building) and these percentages were calculated and adjusted to maintain the stability of the reopening. The greatest factor was infection rates, which makes sense given the imposed restrictions to help reduce infection rates. The proposed solution is to incorporate a plan for continued monitoring of individuals in the work environment. The plan includes self-reporting of illness, temperature checks upon entry of buildings or place of work, as well as close contact tracing of an infected individual to include a COVID test.

To help with continued monitoring, an increase in the number of days a person has to quarantine, twenty-one days versus fourteen days, will help with infection rate reduction. This can also work in conjunction with a longer phase in-between the implementation of phase openings of business. This slower process also allows for better contact tracing and continued monitoring procedures to take effect with the overall goal of reducing infection rates. The addition time can help with continued data analysis and time adjustments can then be implemented based on daily infection rate data.

Making COVID test sites readily available to the public further pushes the effectiveness of continued monitoring of individuals as businesses and public areas continue to open in the phased timeline. Readily available COVID tests, with rapid testing, can provide effective data to the health department of localized daily infection rates, creating accurate data, ensuring trained personnel are administering these tests, allowing a control measure to be in place. This ensures decisions are being made with quality data provided on the successful opening of the state's economy.

General Conclusions

In order for New York State to fully reopen, the economy must be a top priority. Businesses need to be comfortable and confident enough in the science and our proposed solutions that they will be willing to reopen. Public health was a top concern for our customers in our analysis, so a fully or close to fully vaccinated public will need to be achieved to aide in preventing infection rates from increasing. For business to reopen people will need to be able to go to work and for that to happen other services such as schools and childcare need to be available so that those workers that do have families would not have to choose between working or staying home. With the quality engineering tools and process used and outlined above, we can see that while they are most commonly used towards situations involving product development, it can also be widely used to analyze and solve social problems, such as reopening the state during a global pandemic. Lean tools such as value steam map, six sigma, design of experiments, and so on, have helped us identify waste, reduce processing times, and eliminate causes of failures. With the state reopen the economy can reopen which will allow both businesses and individuals to thrive and help come back to some form of normal.