Statewide COVID-19 Lockdown

Group 1
Siddarth Chavan
Francois Gerard Eco
Vaibhav Hakke
Miraj Kadam

Discussion Outline

- Overview, Assessment, and Cost of Poor Quality (COPQ)
- Six Sigma Process
- Design for Six Sigma (DFSS)
- Design of Experiments (DOE)
- Supply Chain Management
- Measurement System Analysis (MSA)
- Acceptance Sampling
- Statistical Process Control (SPC)
- Conclusions

Statewide COVID-19 Lockdown

Overview, Assessment, and Cost of Poor Quality (COPQ)

Introduction

- Coronavirus is an important human and animal pathogen. At the end of 2019, a novel corona virus was identified as the cause of a cluster of pneumonia cases spreading quickly across the global causing a global pandemic.
- This particular virus is highly contagious and spreads quickly through respiratory droplets from coughing, sneezing or talking.
- To negate the spread of this virus, a state of emergency is being declared causing the government to impose a lockdown.

Objectives

- To implement a statewide lockdown
- To ensure social distancing across the state
- To curb the spread of the virus
- To reduce the infection or positivity rate
- To impose and implement new traveling guidelines
- To spread awareness in the neighborhoods
- To ensure there is adequate historical data to gauge the demand and thereby maintain the required safety stock of materials

Major Pros and Cons

Pros

- Saving lives
- Drop in pollution
- Less dependence on natural non-renewable resources

Cons

- Economic downturn
- Disruption to education
- Mental health
- Delayed completion of projects

Assessment

Key people and organizations to interview

- World Health Organization (WHO) / National Institute of Health (NIH)
- Center of Disease Control (CDC)
- U.S. Department of Health and Human Services
- U.S. Department of Homeland Security
- U.S. Department of Transportation
- U.S. Department of the Treasury
- State governor
- City police departments

Assessment

Questions and answers

- **World Health Organization (WHO) / National Institute of Health (NIH)**
  1. What are the age groups and the pre-medical conditions that are more susceptible to the virus?
     - *Age groups above 60 with any chronic problems are more susceptible to the virus.*
  2. What is the severity of the virus in terms of age groups?
     - *The severity of the virus is higher in people in old-age groups and/or with weak immune systems will be affected quickly.*
  3. How quickly does the virus spread among people?
     - *The virus spreads among people through hand-to-hand contact and respirating airborne particles from infected people who are coughing or sneezing.*
  4. What are the diagnosis methods for this virus?
     - *Diagnosis methods for COVID include saliva testing and real-time PCR nasal testing.*
- **Center of Disease Control (CDC)**
  1. What measures are you taking/what is the general guideline to control this virus?
     - *Some ways to control the spread of the virus include social distancing guidelines, masks mandate, hand sanitizers, and free sanitation drives.*

Assessment

Questions and answers

- **U.S. Department of Health and Human Services**

1. How many rooms and places are in the hospitals to care for COVID-infected patients?
   - *There are not enough rooms and space in hospitals to care for COVID-infected patients, but they are working on creating makeshift hospitals to alleviate this problem.*
2. How many medical workers and volunteers have experience and/or are willing to resolve this pandemic?
   - *There are 600 medical workers and volunteers who have experience and/or are willing to resolve this pandemic. Inexperienced medical volunteers will be trained by professionals before working to bring an end to the pandemic.*
3. How will you keep track of usage of goods and services and increase demand in a particular region?
   - *The department will analyze historical data on usage of goods and services in a particular region in order to attempt maintaining excess inventory of needed supplies.*

Assessment

Questions and answers

- **U.S. Department of Homeland Security**

1. What is your plan in helping foreign travelers reach their home countries?
   - *The department will help foreign travelers be in constant communication with foreign embassies.*
2. How will you help citizens prepare and make things easier to sustain during the pandemic?
   - *The department will undertake awareness campaigns to make people aware of global situation.*
3. What percentage of trade would be affected by the lockdown?
   - *The department believes that high demand with low supply of needed goods will inflate the prices of these goods affecting trade by around 20-30%.*

Assessment

Questions and answers

- **U.S. Department of Transportation**
  1. What are the interstate traveling guidelines during the pandemic?
     - *Domestic travelers should immediately get tested and quarantine after reaching destination.*
  2. How would a potential lockdown impact public transportation?
     - *Frequency of operation would be reduced. Travelers would be required to wear a facemask before boarding. There would be a lower limit in number of onboard travelers.*
  3. What is an effective safety plan to get essential workers back into the workplace?
     - *A possible solution would be providing sanitized shuttle services to and from the workplace.*
- **U.S. Department of the Treasury**
  1. What is the anticipated financial loss associated with the pandemic?
     - *To overcome the financial aspects associated with the pandemic, the department will borrow loans from other countries to work on expenses and host charity fundraisers.*
  2. How are you going to convince the government to pass a financial stimulus package?
     - *The department will provide data on employment layoffs and financial analysis on daily expenditures by people.*

Assessment

Questions and answers

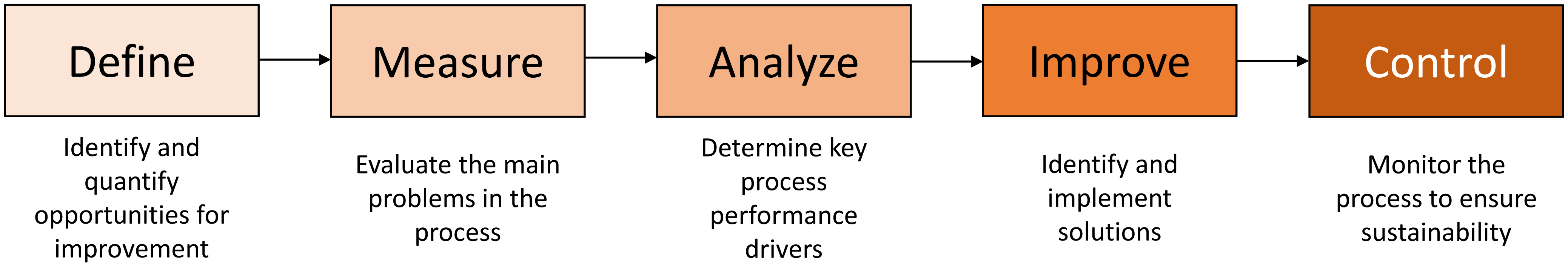
- **State governor**
  1. How are you going to handle interdepartmental operations effectively?
     - *He will appoint the best people with expertise in their fields and experience in handling such situations.*
- **City police departments**
  1. How many officials have you got to monitor different COVID-testing sites if there is an excess of appointees?
     - *They will have 400 police officials monitoring different sites. There should be COVID-proofing of testing centers with social distance guidelines and safety measures.*

Statewide COVID-19 Lockdown

Six Sigma Process

Six Sigma Process

- In Six Sigma, many approaches can be used to improve a process.
- The most-used approach for Six Sigma is the **DMAIC process**.
  - DMAIC is an abbreviation for the five components that are key to Six Sigma.
  - The five components: **Define**, **Measure**, **Analyze**, **Improve**, and **Control**



Six Sigma Process – Define Phase

DEFINE

Identify and quantify opportunities for improvement

Key objectives for the Define phase

- Define the problem
- Determined the desired state
- Complete pre-project administrative work

Key tools for the Define phase

- Project Charter
- Cost of Poor Quality (COPQ)
- Communication Plan
- SIPOC Diagram
- Identification of Critical To Quality Characteristics (CTQC)

Six Sigma Process – Define Phase

Project Charter	
Project Name	Implementing a Statewide COVID-19 Lockdown
Problem Statement	The World Health Organization (WHO) has been monitoring the global spread of COVID-19 since November 2019 and publicly declared a pandemic a few months later. As more COVID-19 cases began to accumulate globally, hospitalizations due to COVID-19 exceeded capacities of hospitals and created an overwhelming panic for medical staff. To ensure the protection, health, and safety of every person, the factors and impact of implementing a statewide COVID-19 lockdown are being determined.
Goal Statement	Implement a statewide lockdown by halting physical interactions and movement to limit the spread of the virus and thereby minimize the positivity rate of COVID-19 cases to under 5% for the health and safety of the community within a 2-month period.
Project Scope	The scope of this project will focus on COVID-19 diagnosis testing, continuous calculation of the COVID-19 positivity rate based on state population, and mandating social distancing guidelines and masks

Six Sigma Process – Define Phase

COPQ Chart				
COPQ	**Internal Problems**	**External Problems**	**Appraisal**	**Prevention**
Testing site	➢ Less space ➢ Shortage of testing equipment	➢ Inclement weather ➢ Location ➢ Protests ➢ Long wait lines	➢ Check weather ➢ Ensure adequate supply of testing equipment	➢ Use permanent building ➢ Police presence ➢ Update computers
Confirmed cases	➢ Backlog in reporting positive cases	➢ Delayed update which could mislead people	➢ High-performance IT generals for keeping database updated	➢ Compliance with lockdown guidelines
Hospitals	➢ Shortage of medical equipment and workers ➢ Shortage of beds ➢ Untrained medical workers	➢ More deaths ➢ Improper treatment for patients	➢ Construction of makeshift quarantine centers ➢ Lending support from non-medical companies	➢ Proper training for medical volunteers and hospital staff
Schools and workplaces	➢ Shift to entirely online platforms ➢ Maintaining attendance roster online ➢ Unstable internet connection	➢ Lack of understanding for students ➢ No interaction outside "bubble"	➢ Setting up online database (e.g. online library) ➢ Host weekly inter-department sessions for interactions	➢ Ensure proper internet connection ➢ Free access to recorded online sessions
Travel restrictions	➢ No transportation in case of emergency ➢ Shortage of daily household essentials	➢ Economic shutdown on businesses and transportation ➢ Delayed deliveries of needed supplies and services	➢ Lower operation frequency and occupancy in public transportation ➢ Host weekly food drives	➢ Allow shuttle services for medical emergencies ➢ Allow more food delivery services to homes ➢ Have non-medical volunteers help with delivery

Six Sigma Process – Define Phase

Communication Plan					
Audience	**Media**	**Purpose**	**Key Messages**	**Frequency**	**Notes**
People	Television news, public announcement, email updates, Q&A phone session	Buy-in, information, action	Stay updated and aware of pandemic, follow health and safety guidelines	Every day	Needed in all phases for DMAIC process
Health organizations	Television news, email updates, virtual meetings, phone calls	Information, action	Promote public awareness campaigns, find solutions to slow and end pandemic	Every day	Needed in all phases for DMAIC process
Hospitals	Television news, email updates, virtual meetings, phone calls	Information, action	Care for mildly- and severely-infected patients, update on number of positive cases and positivity rate	Every day	Needed in all phases for DMAIC process
Non-medical companies	Email updates, virtual meetings, phone calls	Buy-in, information, action	Create alliances with medical companies and orgs to assist in fight against pandemic	Every week	Needed in Analyze and Improve phases

Six Sigma Process – Define Phase

SIPOC Diagram				
Supplier	**Inputs**	**Process**	**Output**	**Customer**
Government	Leadership Communication	Social-distancing and mask mandates	Compulsory use of masks in public spaces	People Businesses
		Create website and toll-free helpline for COVID-19	COVID-19 updates on government website and toll-free helpline	
		Send stimulus checks to people and medical supply funding to hospitals	Adequate COVID-19 testing kits	Hospitals
Health organizations and hospitals	COVID-19 testing kits Doctors Nurses Health officials Information Communication	Check-in with patients and do COVID-19 nasal RT-PCR diagnosis test	Makeshift hospitals and quarantine centers	COVID-infected patients
		Count positive tests against local area population	Updated weekly regional infection rate	People

Six Sigma Process – Define Phase

<table>
<tr><th colspan="4">Critical to Quality Characteristics (CTQC) Chart</th></tr>
<tr><th>Customer</th><th>Need</th><th>Driver</th><th>CTQC</th></tr>
<tr><td>People</td><td>Protection from getting infected from COVID-19</td><td>Social distancing and mask mandates
COVID-19 diagnosis testing</td><td>Age, race, and gender
Medical conditions</td></tr>
<tr><td>Hospitals</td><td>More space for caring COVID-infected patients</td><td>Makeshift hospitals
Quarantine centers
COVID-19 testing sites</td><td>Average number of hourly drive-thru tests
Average number of daily tests
Amount of hospital beds in all hospitals
Infection positivity rate</td></tr>
<tr><td>Schools</td><td rowspan="2">Continued operation during lockdown</td><td rowspan="2">Reliable and useful online work platforms</td><td>Type of school
Student population size
Student grade levels
Graduation rates</td></tr>
<tr><td>Businesses</td><td>Type of business/industry
Employment</td></tr>
</table>

Six Sigma Process – Measure Phase

MEASURE

Evaluate the main problems in the process

Key objectives for the Measure phase

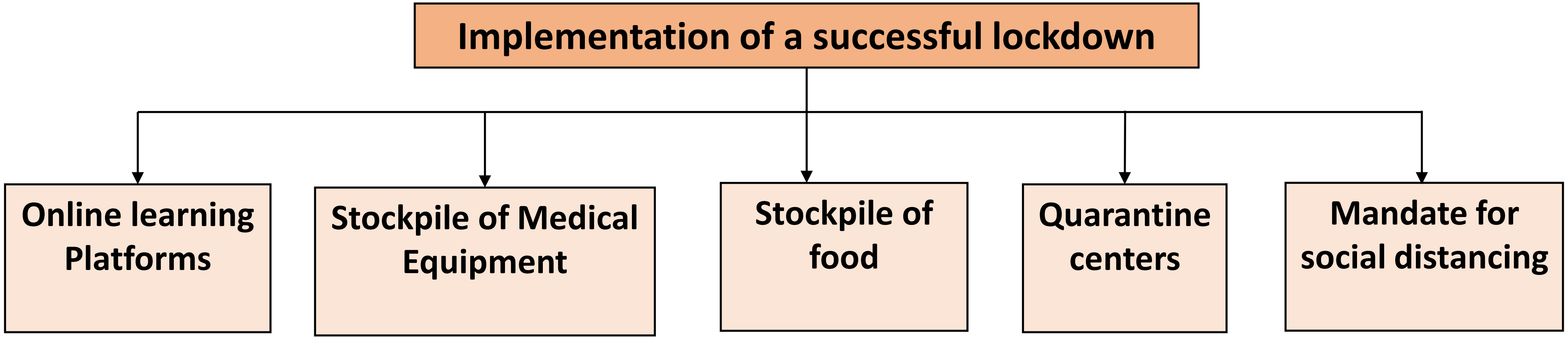
- ➢Define the current state
- ➢Collect data on the current state
- ➢Identify any unforeseen problems and opportunities

Key tools for the Measure phase

- ➢Key Performance Indicator (KPI) Tree Diagrams
- ➢Data Collection Methods

Six Sigma Process – Measure Phase

Key Performance Indicator (KPI) Tree Diagram for Implementing Lockdown



Six Sigma Process – Measure Phase

Data Collection Plan				
Performance Measure	**Data Source**	**Who Collects the Data?**	**When Is the Data Collected?**	**How Is the Data Collected?**
Number of positive cases	COVID-19 testing centers	Medical volunteers	Every 7 days	Test reports
Positivity rate	COVID-19 testing centers	Center of Disease Control (CDC)	Every 7 days	Positive test reports per number of tested patients
Compliance with social distancing	Colleges Public places	Non-medical volunteers	Everyday	Non-medical volunteers stationed at colleges and public places
Online work and education platforms	Employees Students	IT services	Every 7 days	Positive test reports per number of tested patients
Availability of essential daily goods and services	Food department Travel department	Regional heads of food and travel departments	Every 7 days	Weekly audits Demand forecasting

Six Sigma Process – Analyze Phase

Key objectives for the Analyze phase

- Analyze and report on collected data
- Identify any bottlenecks in the process
- Determine sources of defects and variation

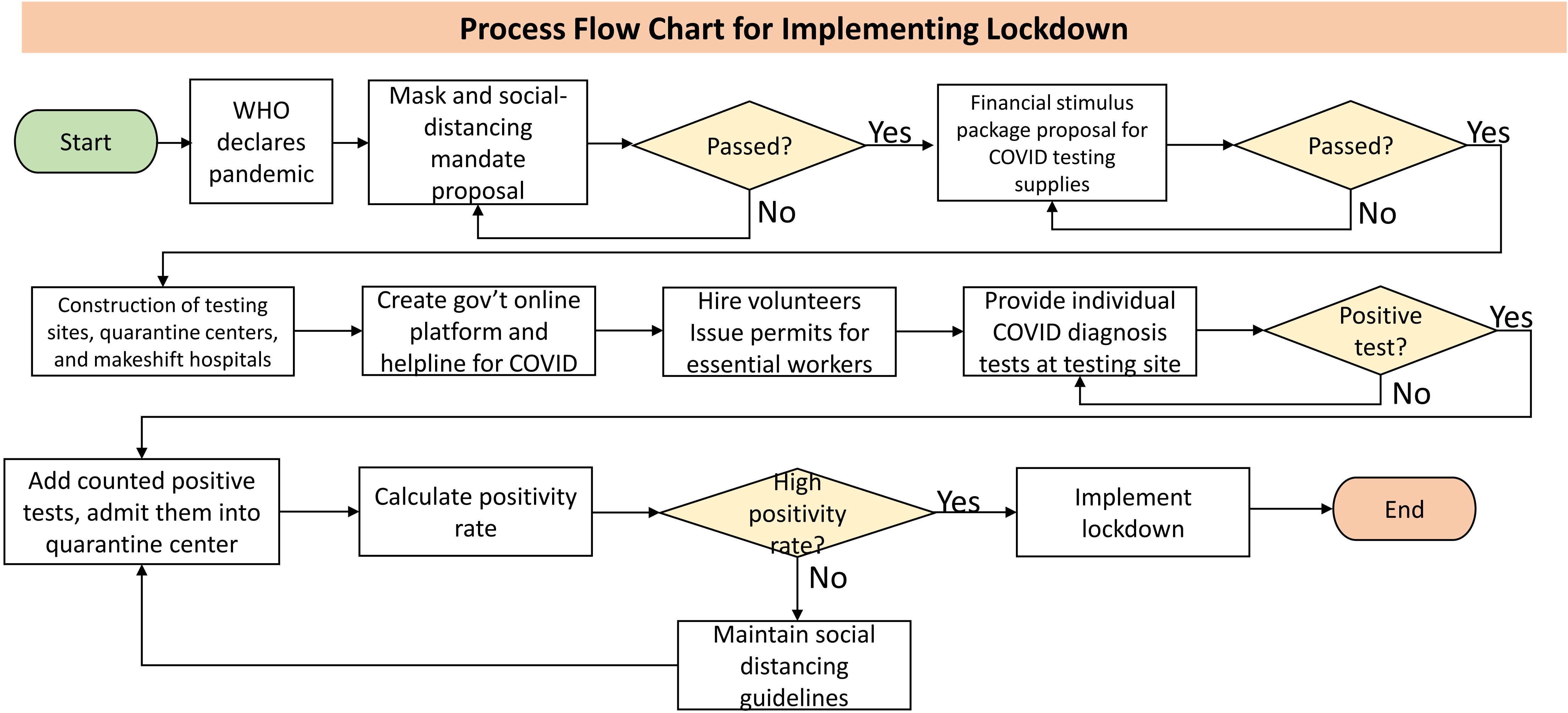
Key tools for the Analyze phase

- Process Mapping
- Organizational Flow Chart
- Affinity Diagram
- Ishikawa (Fishbone) Diagram

ANALYZE

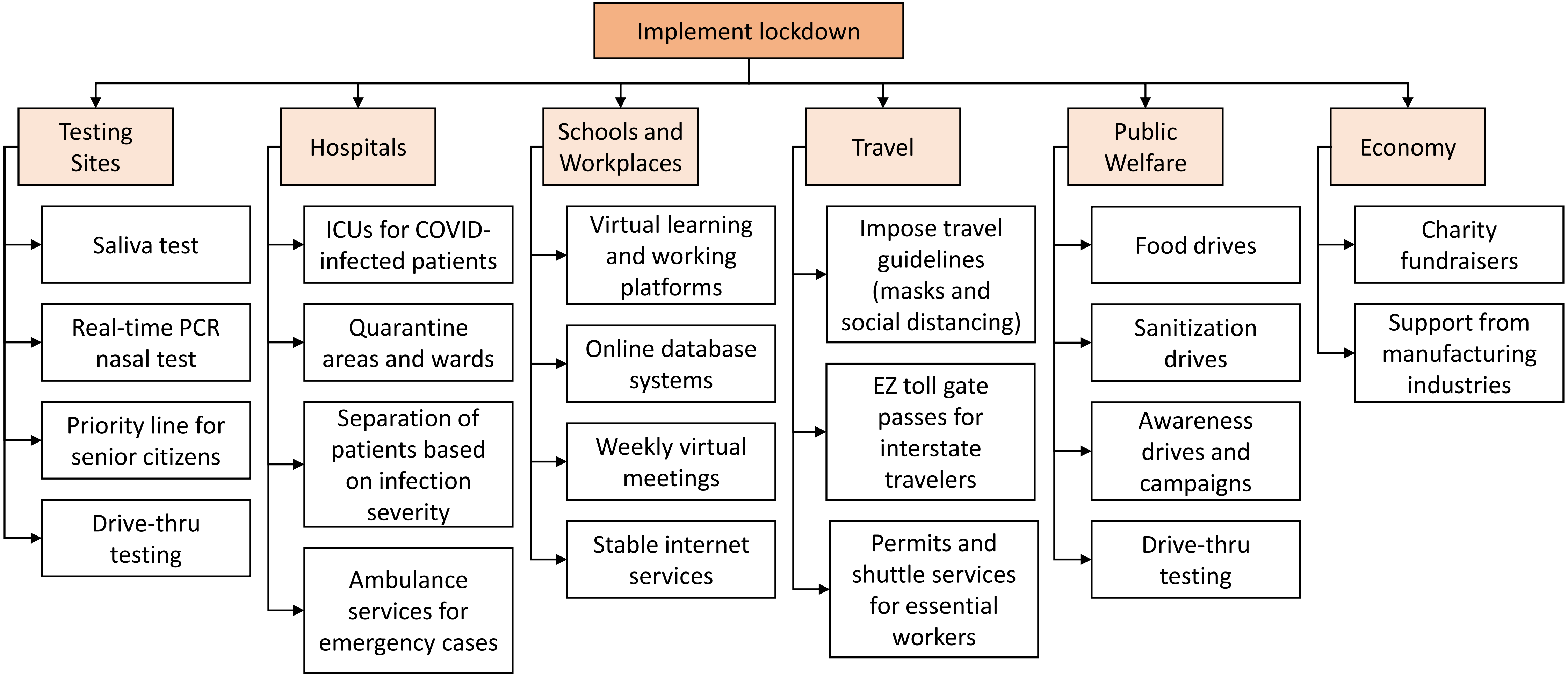
Determine key process performance drivers

Six Sigma Process – Analyze Phase



Six Sigma Process – Analyze Phase

Organizational Flow Chart for Implementing Lockdown

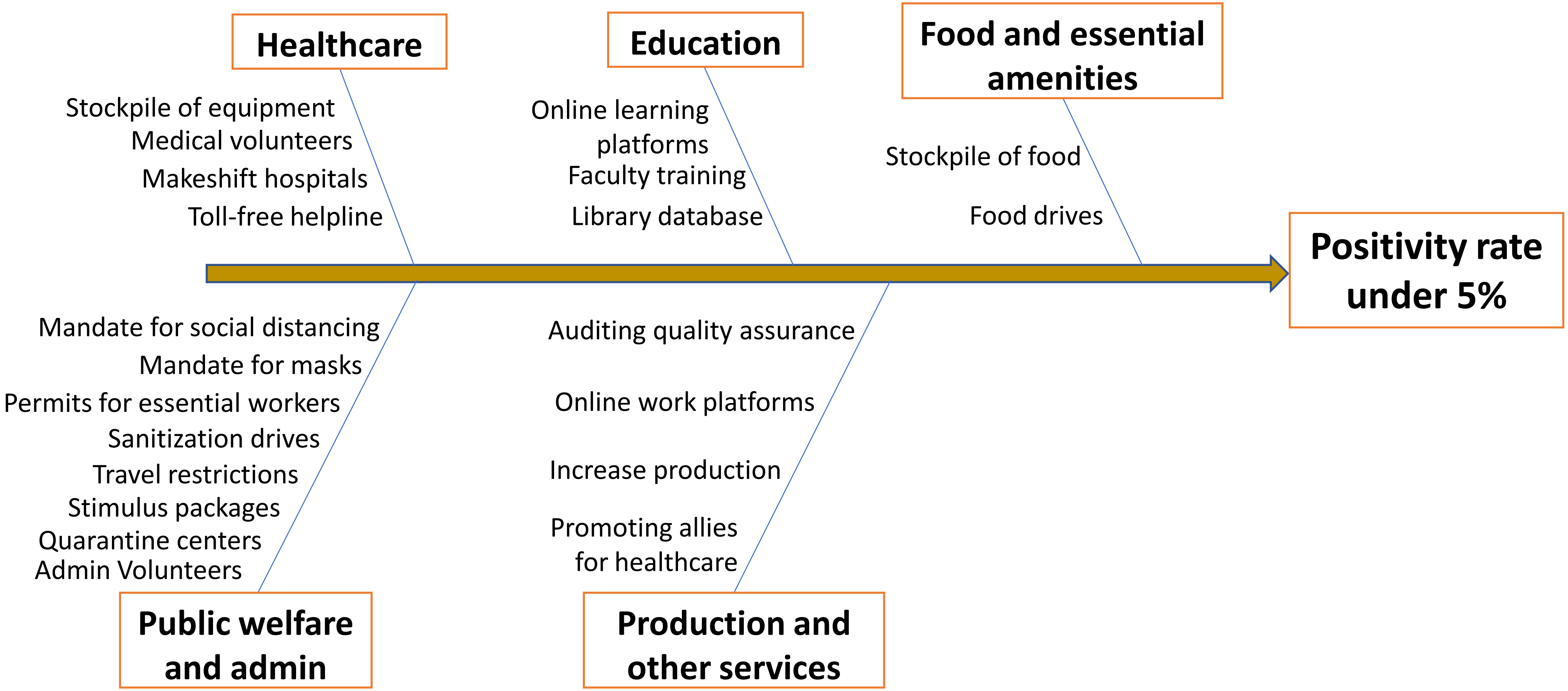


Six Sigma Process – Analyze Phase

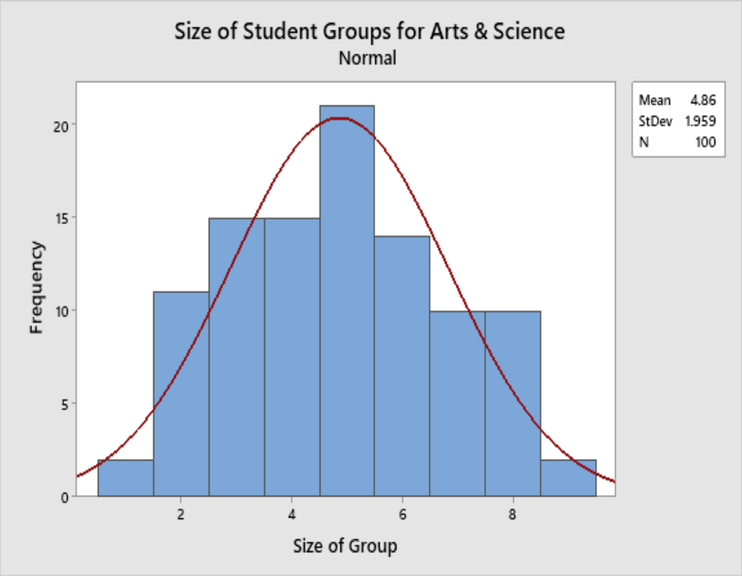
Affinity Diagram (Brainstorming)					
Sl. No.	**Healthcare**	**Public welfare and admin**	**Education**	**Food and essential amenities**	**Production and other services**
1	Stockpile of medical equipment	Mandate for social distancing	Online learning platforms	Stockpile of food	Auditing quality assurance
2	Medical volunteers	Mandate for masks	Faculty training	Food drives	Online work platforms
3	Makeshift hospitals	Permits for essential workers	Library database		Increase production
4	Toll-free helpline	Sanitization drives			Promoting allies for healthcare
5		Travel restrictions			
6		Stimulus packages			
7		Quarantine centers			
8		Admin volunteers			

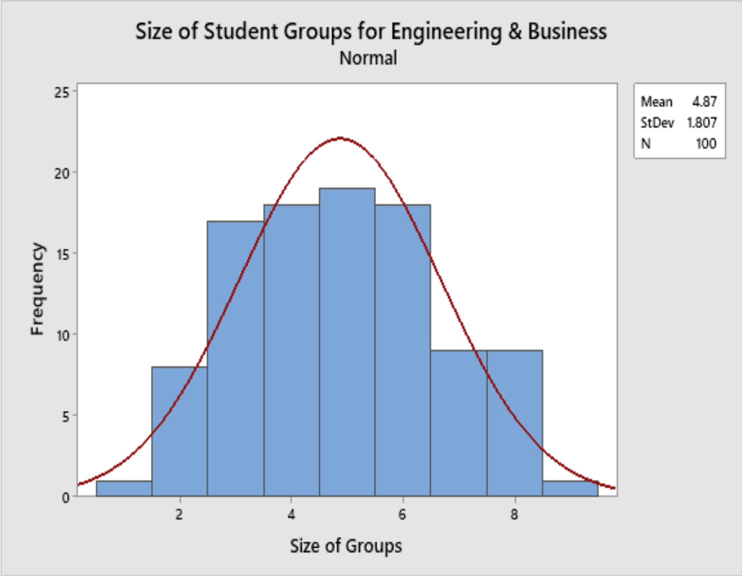
Six Sigma Process – Analyze Phase

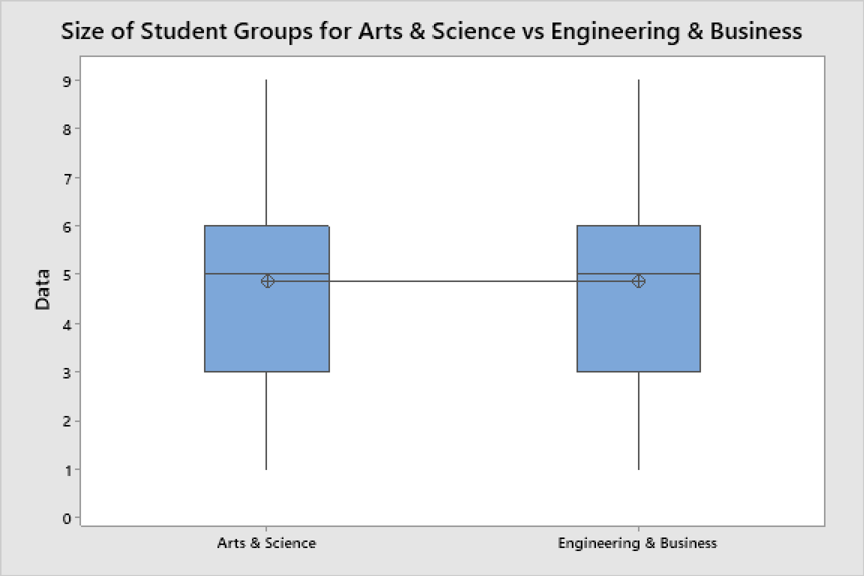
Ishikawa (Fishbone) Diagram for Implementing Lockdown



Six Sigma Process – Analyze Phase







Six Sigma Process – Analyze Phase

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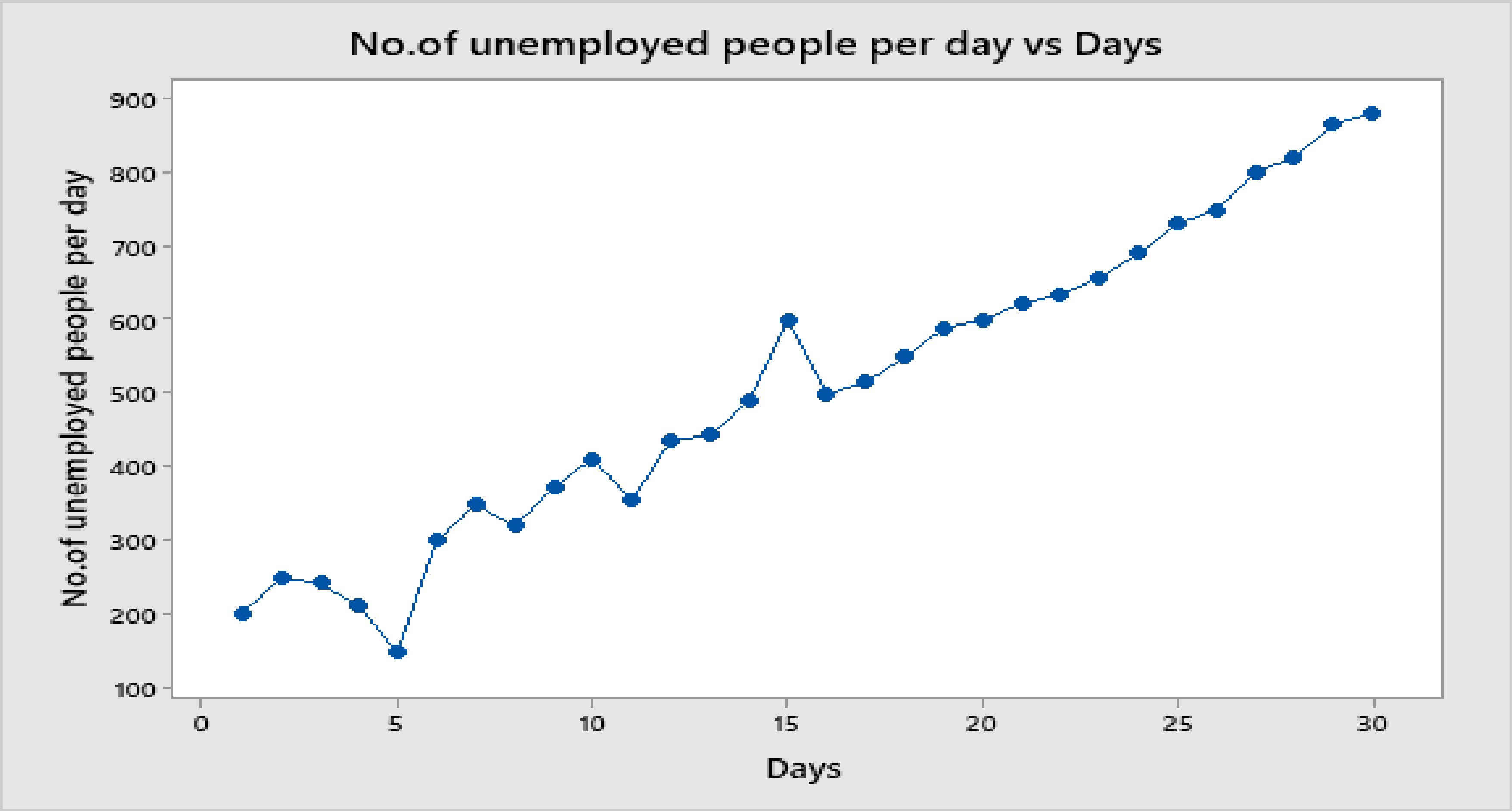
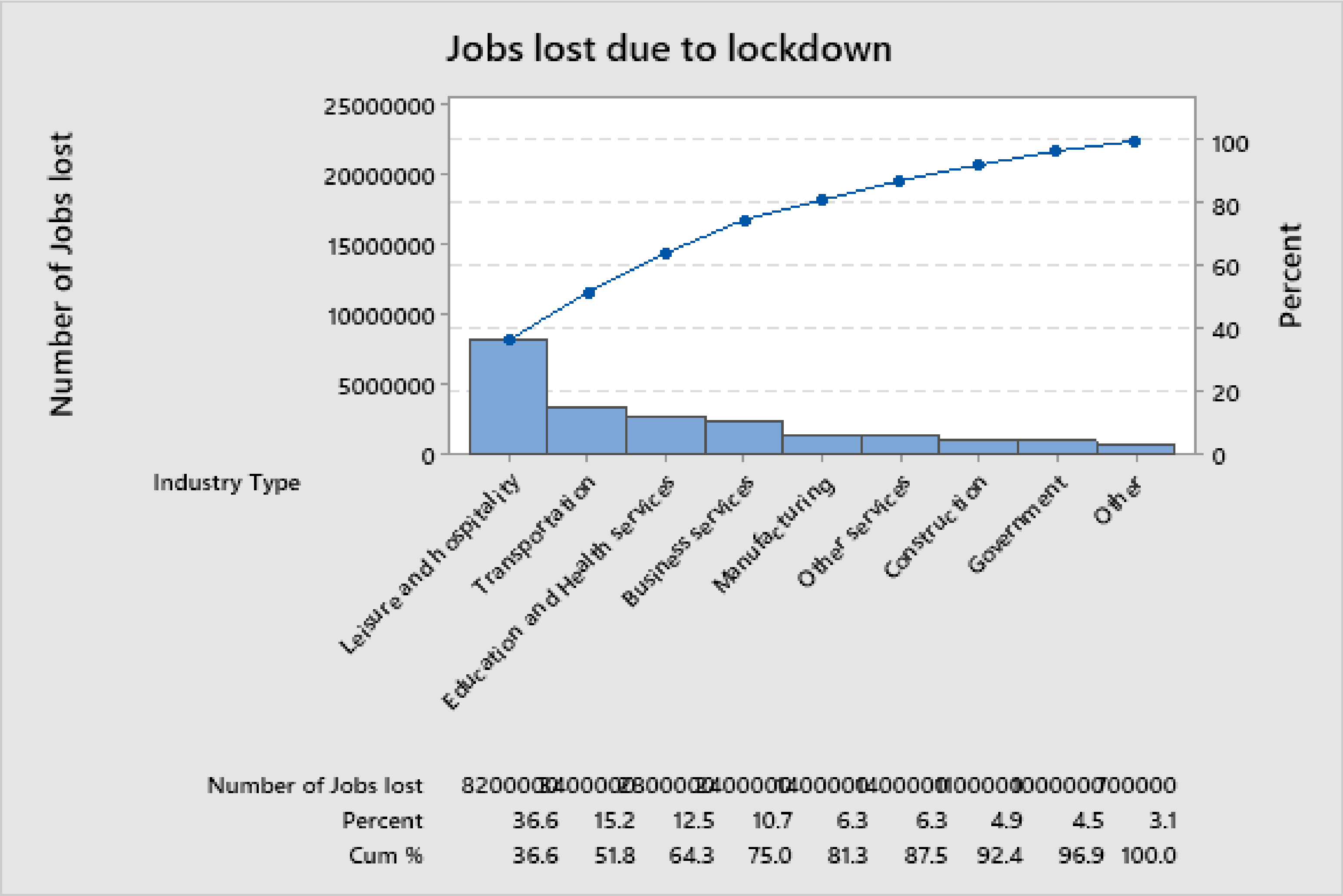


Six Sigma Process – Analyze Phase



Six Sigma Process – Analyze Phase

Results from Analysis of Models

- Student groups of Arts & Science and Engineering & Business are complying with the social-distancing guidelines.
- Demand for basic goods after lockdown is unclear and much higher than prior to lockdown.
- Unemployment follows a positive trend during a lockdown.
- Most number of jobs lost due to lockdown include leisure and hospitality, transportation, education and health services, business services, and manufacturing.

Six Sigma Process – Improve Phase

Key objectives for the Improve phase

- Brainstorm potential ideas and solutions
- Evaluate and select the best solutions
- Pilot-test selected solutions
- Implement solutions

IMPROVE

Identify and implement solutions

Key tools for the Improve phase

- Error-proofing and benchmarking
- Failure Modes and Effects Analysis (FMEA)

Six Sigma Process – Improve Phase

Error-Proofing			
Factor	**Problem Description**	**Solution**	**Impact Score (0-5)**
Social distancing	In-person classes and meetings Gatherings more than 4 people	Sharing social distance guidelines through emails and text messages Regular inspections at public places and colleges	5
COVID-19 testing	Symptomatic people not willing to get tested	Regular notice to get tested Quarantine themselves if required	4
Travel	Group of people traveling together and disobeying interstate travel guidelines	Follow quarantine rules and get tested if traveling interstate	2
Online platforms	Students and employees facing technical difficulties	Stable internet connection Recorded classes and meetings	3
Quarantine centers	Overpopulated centers	Proper food and medical services provided to patients	4
Testing kits	Shortage of testing kits limiting number of tests per day	Maintaining double stockpiles of testing kits Communicate with other testing centers	5

Six Sigma Process – Improve Phase

Failure Modes and Effects Analysis (FMEA)						
Failure	**Root Cause**	**Severity**	**Probability of Occurrence**	**Probability of Detection**	**RPN**	**Corrective Action**
Shortage of sanitary equipment	Lack of warehouse space, delayed deliveries	9	5	9	405	Order in advance, maintain standby warehouses
Shortage of hospital beds	Lack of hospital space	9	8	8	576	Makeshift hospitals
Social-distancing compliance	Disobedience of rules and guidelines	6	9	5	270	Fines, awareness campaigns
Online platform failure	Network connectivity issues	9	9	7	567	Stable and fast internet, specialized IT professionals
Shortage of testing kits	Delayed deliveries, demand uncertainties	10	8	8	**640**	Demand forecasting, order from nearby vendors

Six Sigma Process – Control Phase

Key objectives for the Control phase

- Develop a control plan
- Continually monitor performance
- Take corrective action
- Create a culture around the new process
- Consider the reluctance associated with implementing change

CONTROL

Monitor the process to ensure sustainability

Key tools for the Control phase

- Control checklist

Six Sigma Process – Control Phase

Control Checklist			
Chk	**Factor**	**Preventive Measures**	**Responsible Person or Organization**
	Stockpile of food	Incentives for farmers and distributors to maintain inventory	Agricultural head Food department
		More distribution centers to reach out to remote areas	
	Stockpile of equipment	Promote allies with non-medical manufacturers	Federation of state medical boards
		Temporary warehouses	
	Online platforms	Zoom and Blackboard	IT specialty services
		Remote servers	
	Social-distancing mandates	Make-shift quarantine centers	Non-medical volunteers
		Social-distancing guidelines	
	Quarantine centers	Provide food and proper medication	Doctors Nurses Medical volunteers
		Provide adequate beds	
		Adequate testing kits	

Statewide COVID-19 Lockdown

Design for Six Sigma (DFSS)

Design for Six Sigma – Define Phase

Key objectives for the Define phase

- Define the problem
- Determine the desired state
- Complete pre-project administrative work
- Determine the order and impact of shutting down certain economic activities
- Determine the order and impact of shutting down transportation activities

DEFINE

Identify and quantify opportunities for improvement

Design for Six Sigma – Measure Phase

Data Collection Plan				
Performance Measure	**Data Source**	**Who Collects the Data?**	**When Is the Data Collected?**	**How Is the Data Collected?**
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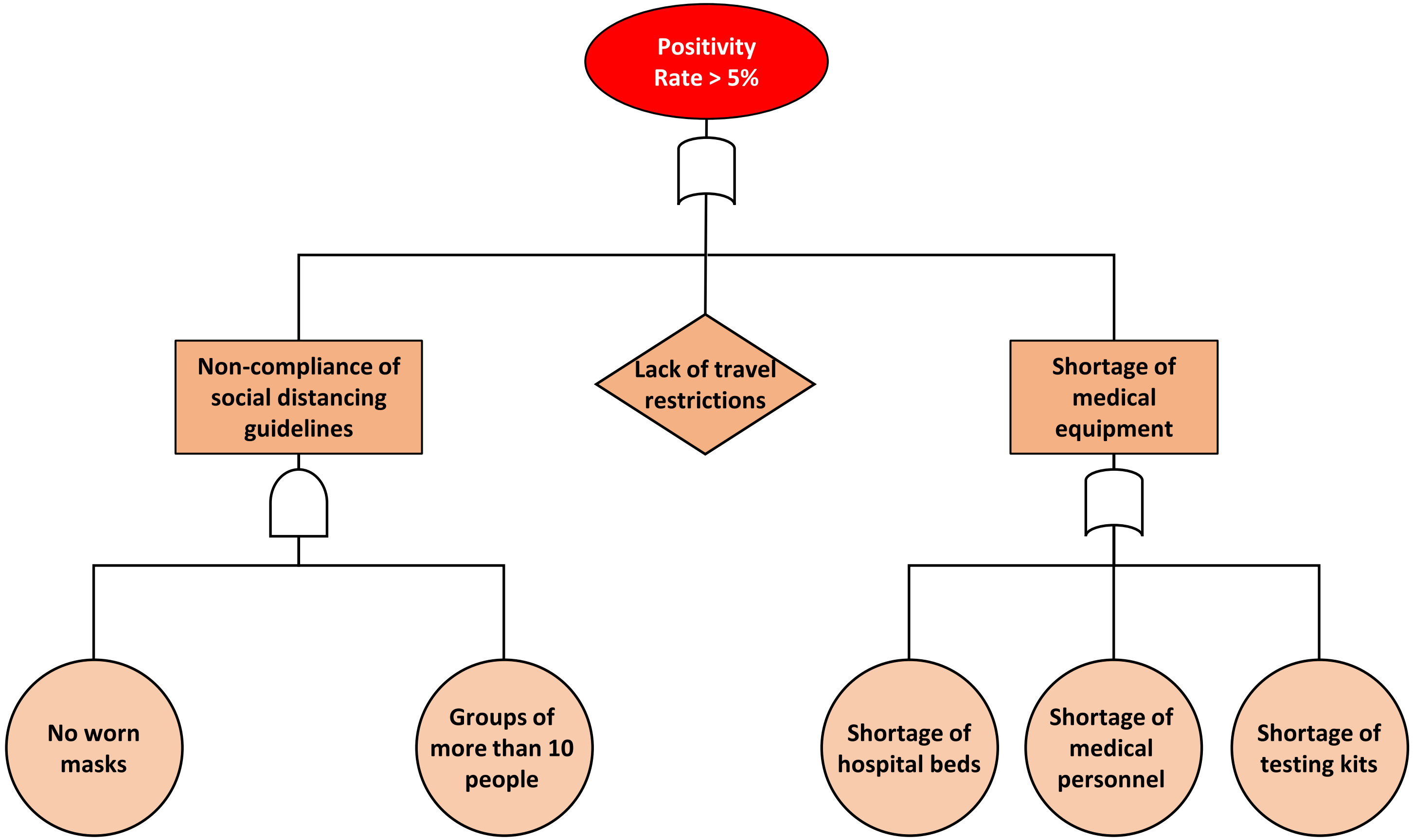
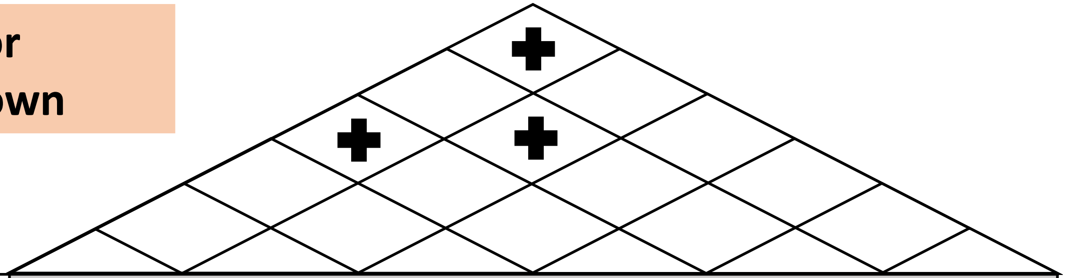
Design for Six Sigma – Analyze Phase

Fault Tree Analysis (FTA) for Implementing Lockdown



Design for Six Sigma – Design Phase

House of Quality for Implementing Lockdown

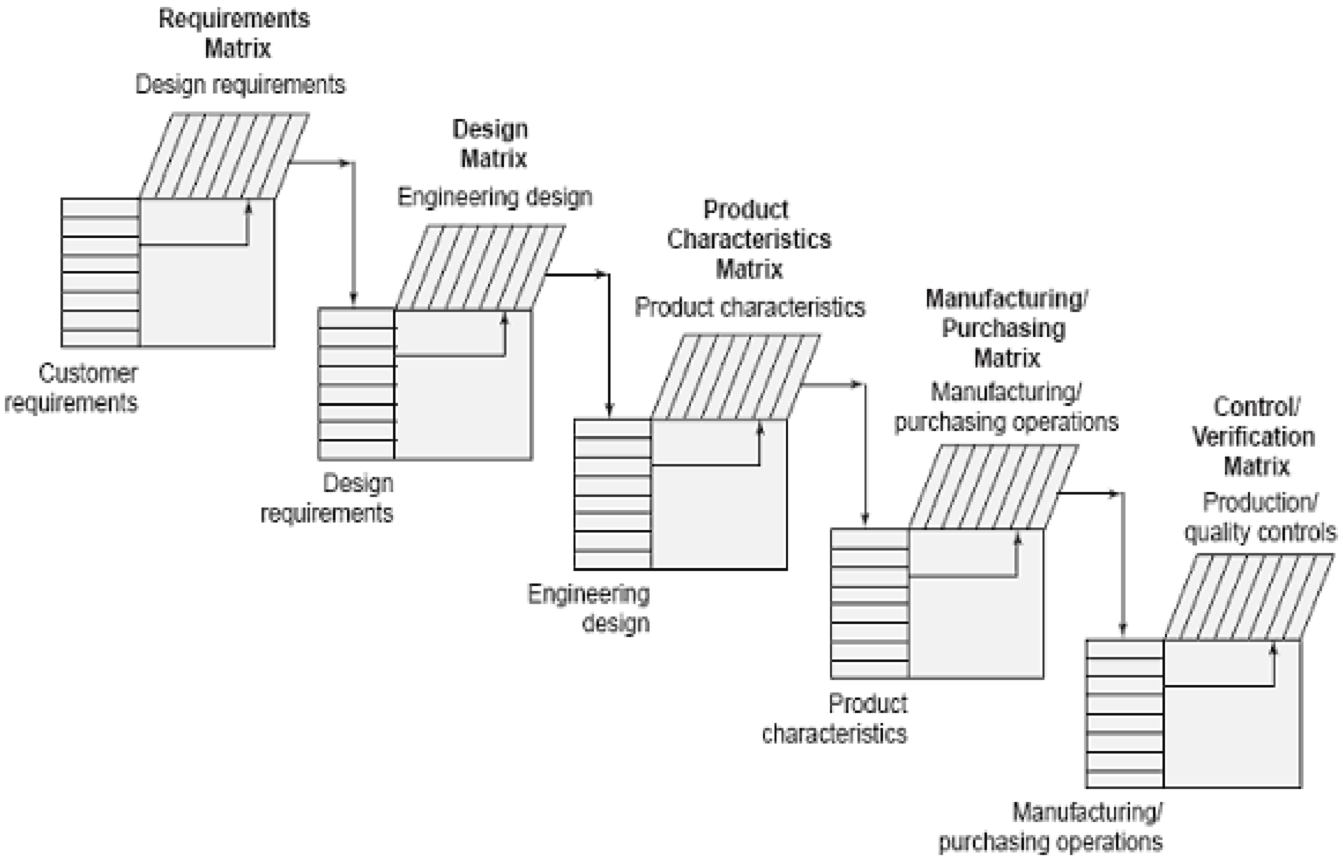


		Functional Requirements					
Direction of Improvement		◎	↑	◎	↑	◎	↑
Priority	**Customer Requirements**	Social distancing and testing kits	Demand forecasting	Stable internet servers and connectivity	Quality of testing kits	Food supply	Travel restrictions
10	Protection from COVID-19	9			3		3
9	Adequate testing kits	9			9		
8	Availability of essential goods		9			9	
7	Availability of adequate hospital beds		9				
6	Continued operation			3			3
5	IT services and online platforms			9			
4	Quarantine centers	3			3	9	
2	Travel permits for essential workers						9
CTQ Priority Score		183	135	63	123	106	66
Relative Weight		27%	20%	9%	18%	16%	10%

LEGEND	
Trade-offs	
Positive	✚
Negative	▬
Direction of Improvement	
Maximize	↑
Target	◎
Minimize	↓
Relationship	Weight
Strong	9
Moderate	3
Weak	1

Design for Six Sigma – Design Phase

Figure 2 — Waterfall relationship of QFD matrices



Matrix Cascade for Implementing Lockdown

<u>Customer Requirements</u>

- Public welfare

<u>Design Requirements</u>

- Protection for COVID-19
- ➢ Availability and continued operation

<u>Engineering Design</u>

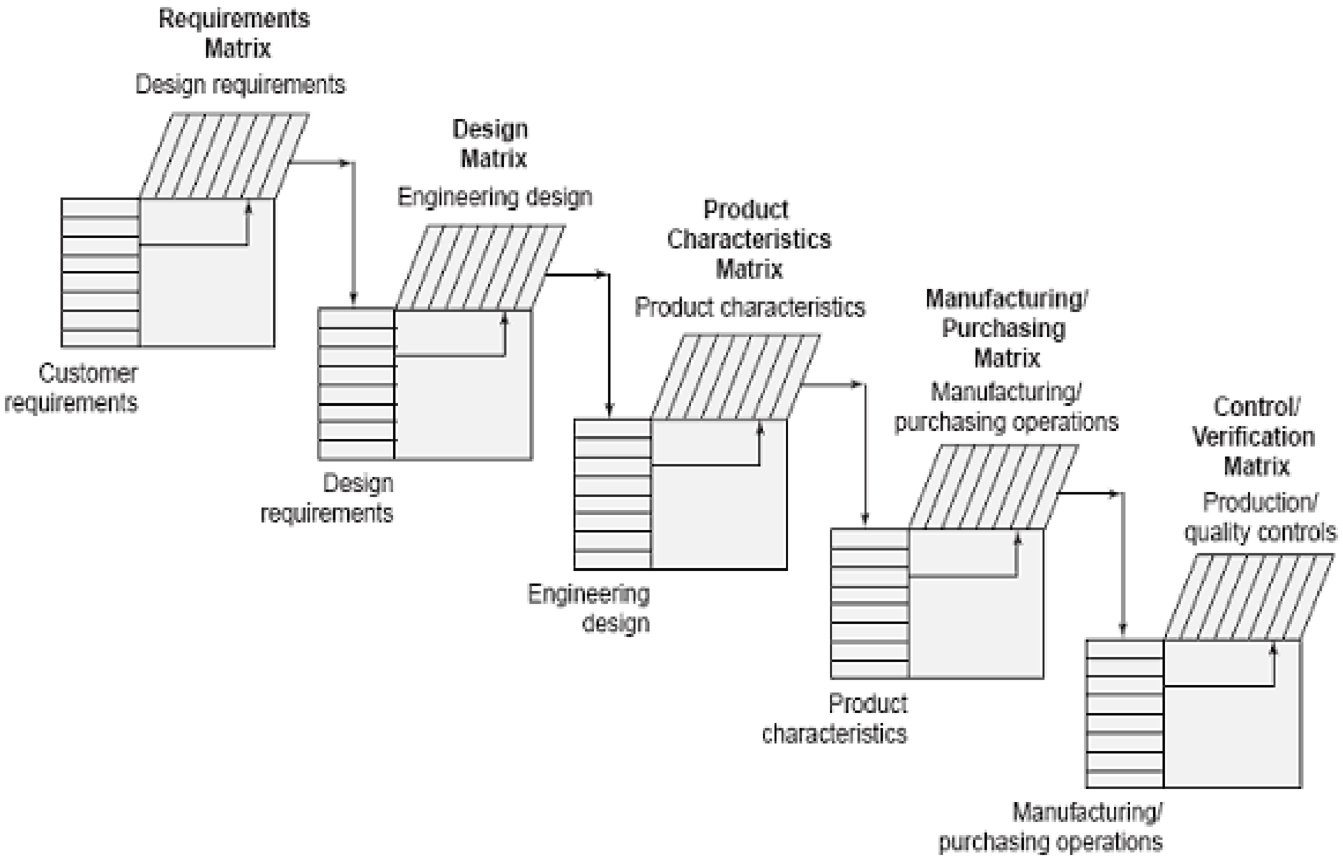
- Testing kits, hand sanitizers, masks, social distancing
- ➢ IT services, good and efficient supply chain

<u>Product Characteristics</u>

- Instructions to use testing kits, groups of 10 people or less
- ➢ Stable internet services, strategic placement of warehouses

Design for Six Sigma – Design Phase

Figure 2 — Waterfall relationship of QFD matrices



Matrix Cascade for Implementing Lockdown

Manufacturing/Purchasing Operations

- Raw materials for testing kits, social distance markings
- ➢ Collaboration between service providers, portable warehouses

Production/Quality Controls

- Quality analysis plan for testing kits, 6-feet distance
- ➢ Traceability and configuration for IT services

Design for Six Sigma – Verification Phase

Failure Modes and Effects Analysis (FMEA) for Verification						
Failure	**Root Cause**	**Severity**	**Probability of Occurrence**	**Probability of Detection**	**RPN**	**Corrective Action**
Shortage of masks	Manufacturing shutdown, delayed deliveries	9	5	9	405	Order in advance, collaboration with other companies for production
IT services failure	Server overload, cyber attack	9	7	8	**504**	Efficient cybersecurity, backup servers
Faulty quality analysis for testing kits	Low quality material	8	3	6	144	Maintain multiple reliable vendors
People traveling without travel permits	Urgent emergencies, students traveling back home	7	7	8	392	Maintain emergency stores in local neighborhoods, planned departure of students

Design for Six Sigma – Verification Phase

Design with Control and Verification Measures		
Factor	**Design**	**Control and Verification Measures**
Online working platforms	Good internet speed and connectivity for students and employees	Daily internet speed and configuration tests for schools and businesses
Stockpile of medical equipment	Adequate supply of medicines and testing kits with backup inventory	Daily auditing of inventory and back orders
Stockpile of food	Efficient demand forecasting with backup inventory	Daily auditing of inventory and back orders, city-wide demand analysis of food requirements
Quarantine centers	Proper treatment and adequate space for infected patients	Daily sanitization of space and preparation of makeshift quarantine centers if needed
Social distance mandates	Mandatory wearing of masks, group sizes no more than 10	Recommendation of following social distancing guidelines and wearing masks by non-medical volunteers

Statewide COVID-19 Lockdown

Design of Experiment (DOE)

Design of Experiment

What is Design of Experiment?

- **Design of Experiments (DOE)** is a powerful technique used for exploring new processes, gaining increased knowledge of existing processes, and optimizing these processes for achieving world-class performance.
- DOE allows the manipulation of multiple input factors which can determine the contribution of and the interaction between factors that can impact the reliability and capability of the process.
- This statistical approach can be implemented at any time during the process but is mostly applied to conducted experiments before the process is finalized.

Design of Experiment

Here is the full table for the Design of Experiments analysis which will be discussed in detail in the following slides.

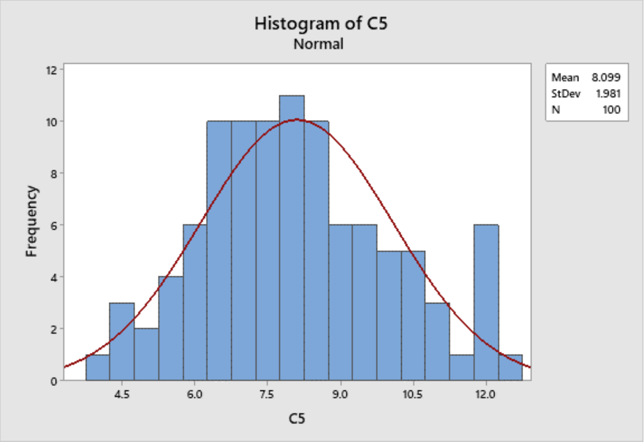
Design of Experiments Analysis: Part I												
Factorial Experiments 2^3 (Three Replications/Treatment)								Run Results				
Run	A	B	C	AB	AC	BC	ABC	G2	G3	G4	Average	Variance
1	-1	-1	-1	1	1	1	-1	-2.42320006	1.7217139	-1.065570	-0.589	4.465
2	1	-1	-1	-1	-1	1	1	0.72755043	6.86826589	3.719142	3.772	9.429
3	-1	1	-1	-1	1	-1	1	-0.75185569	0.72100834	-0.580239	-0.204	0.649
4	1	1	-1	1	-1	-1	-1	11.6355325	13.4964973	12.037245	12.390	0.959
5	-1	-1	1	1	-1	-1	1	4.1222552	8.61166612	7.750157	6.828	5.676
6	1	-1	1	-1	1	-1	-1	17.995741	13.5711024	15.445649	15.671	4.932
7	-1	1	1	-1	-1	1	-1	12.094647	9.99694852	11.093057	11.062	1.101
8	1	1	1	1	1	1	1	15.0225992	20.1942574	18.309584	17.842	6.850
TotSum								58.42	75.18	66.71	66.77	34.06
SumY+	49.67	41.09	51.40	36.47	32.72	32.09	28.24			TotAvg	8.346	
SumY-	17.10	25.68	15.37	30.30	34.05	34.68	38.53					
AvgY+	12.42	10.27	12.85	9.12	8.18	8.02	7.06					
AvgY-	4.27	6.42	3.84	7.58	8.51	8.67	9.63					
Effect	**8.14**	**3.85**	**9.01**	**1.54**	**-0.33**	**-0.65**	**-2.57**					
Var+	5.543	2.390	4.640	4.488	4.224	5.461	5.651					
Var-	2.973	6.126	3.876	4.028	4.291	3.054	2.864					
F	0.536	2.563	0.835	0.897	1.016	0.559	0.507					
Variance of Model		4.26		StdDv	**2.063**							
Variance of Effect		0.71		StdDv	0.84							
Student T (0.025;DF) =				2.473								
C.I. Half Width =				**2.083**								

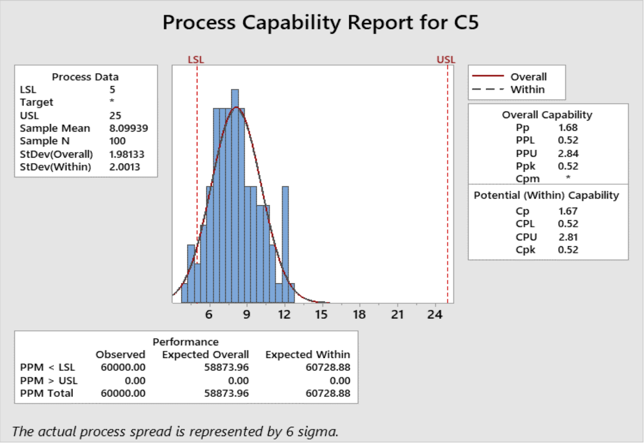
NOTE: The process has an average of 8.346 units with a standard deviation of 2.063 and a confidence interval half-width of 2.083 units.

Design of Experiment

Design of Experiment Process

Step 1 Determine the capability of the process before improvement.





The specifications for implementing an effective lockdown are: ***5 for the lower specification limit (LSL), 25 for the upper specification limit (USL)****.*

Before improvement, the process capability ratio C_{pk} is:

$$C_{pk} = min\left(\frac{\bar{x}-LSL}{3\sigma}, \frac{USL-\bar{x}}{3\sigma}\right) = min\left(\frac{8.346-5}{3(2.063)}, \frac{25-8.346}{3(2.063)}\right)$$
$$= min(0.541, 2.691) = 0.541$$

Since the calculated C_{pk} is less than the minimum acceptable value of 1.33, ***this process is unacceptable****.*

Our group decided to develop a DOE analysis to investigate improvement measures. The potential process capability ratio C_p is:

$$C_p = \frac{USL-LSL}{6\sigma} = \frac{25-5}{6(2.063)} = 1.615$$

Since the calculated C_p is greater than the minimum acceptable value of 1.33, ***this process is acceptable if and only if the process is centered****.*

Design of Experiment

Design of Experiment Process

Step 2 Acquire the inputs and outputs being investigated.

*There are three factors that can impact **the effectiveness of implementing an effective lockdown due to COVID-19**:*

a. ***percentage of people staying home***
b. ***percentage of transportation shut down***
c. ***percentage of the food industry shut down***

*The response from these three factors is **reaching an infection rate of less than 5%**.*

Design of Experiment

Design of Experiment Process

Step 3 Create a design matrix for the factors being investigated.

Design of Experiments Analysis: Part I							
Factorial Experiments 2^3 (Three Replications/Treatment)							
Run	**A**	**B**	**C**	**AB**	**AC**	**BC**	**ABC**
1	-1	-1	-1	1	1	1	-1
2	1	-1	-1	-1	-1	1	1
3	-1	1	-1	-1	1	-1	1
4	1	1	-1	1	-1	-1	-1
5	-1	-1	1	1	-1	-1	1
6	1	-1	1	-1	1	-1	-1
7	-1	1	1	-1	-1	1	-1
8	1	1	1	1	1	1	1

Design of Experiment

Design of Experiment Process

Step 4 For each input, determine the extreme but realistic high and low levels to investigate.

Data Manipulation							
Factor	**Low**	**High**	**Unit**	**Range**	**MidPt**	**Val(-)**	**Val(+)**
A	40	80	%	40	60	-1	1
B	30	60	%	30	45	-1	1
C	30	50	%	20	40	-1	1

The design is a 2^3 factorial with 3 replications.

Design of Experiment

Design of Experiment Process

Step 5 Perform each experiment and record the results.

Design of Experiments Analysis: Part I												
Factorial Experiments 2^3 (Three Replications/Treatment)								Run Results				
Run	**A**	**B**	**C**	**AB**	**AC**	**BC**	**ABC**	**G2**	**G3**	**G4**	**Average**	**Variance**
1	-1	-1	-1	1	1	1	-1	-2.42320006	1.7217139	-1.065570	-0.589	4.465
2	1	-1	-1	-1	-1	1	1	0.72755043	6.86826589	3.719142	3.772	9.429
3	-1	1	-1	-1	1	-1	1	-0.75185569	0.72100834	-0.580239	-0.204	0.649
4	1	1	-1	1	-1	-1	-1	11.6355325	13.4964973	12.037245	12.390	0.959
5	-1	-1	1	1	-1	-1	1	4.1222552	8.61166612	7.750157	6.828	5.676
6	1	-1	1	-1	1	-1	-1	17.995741	13.5711024	15.445649	15.671	4.932
7	-1	1	1	-1	-1	1	-1	12.094647	9.99694852	11.093057	11.062	1.101
8	1	1	1	1	1	1	1	15.0225992	20.1942574	18.309584	17.842	6.850

Design of Experiment

Design of Experiment Process

Step 6 Calculate the effects of each factor and of the interactions.

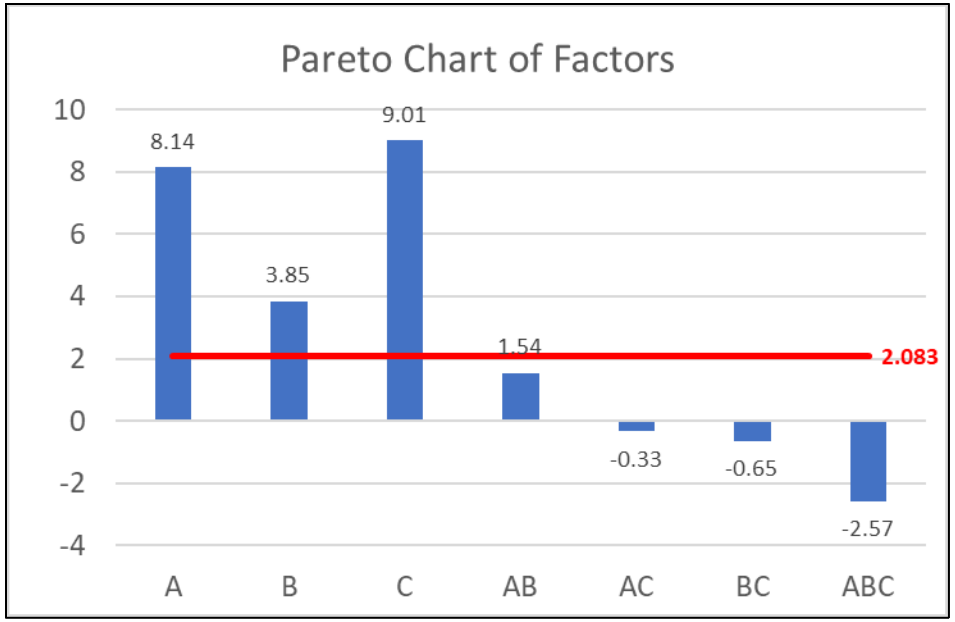
Design of Experiments Analysis: Part I							
Factorial Experiments 2^3 (Three Replications/Treatment)							
Factors	**A**	**B**	**C**	**AB**	**AC**	**BC**	**ABC**
SumY+	49.67	41.09	51.40	36.47	32.72	32.09	28.24
SumY-	17.10	25.68	15.37	30.30	34.05	34.68	38.53
AvgY+	12.42	10.27	12.85	9.12	8.18	8.02	7.06
AvgY-	4.27	6.42	3.84	7.58	8.51	8.67	9.63
Effect	**8.14**	**3.85**	**9.01**	**1.54**	**-0.33**	**-0.65**	**-2.57**
Var+	5.543	2.390	4.640	4.488	4.224	5.461	5.651
Var-	2.973	6.126	3.876	4.028	4.291	3.054	2.864
F	0.536	2.563	0.835	0.897	1.016	0.559	0.507

Design of Experiment

Design of Experiment Process

Step 7 Determine the significance of the effects for each factor and for each interaction by comparing them with the confidence interval half-width (must be greater than 2.083 units to be significant) in the table or the Pareto chart.

Design of Experiments Analysis: Part I							
Factorial Experiments 2^3 (Three Replications/Treatment)							
Factors	**A**	**B**	**C**	**AB**	**AC**	**BC**	**ABC**
Effect	**8.14**	**3.85**	**9.01**	**1.54**	**-0.33**	**-0.65**	**-2.57**
Signific.	**Yes**	**Yes**	**Yes**	**No**	**No**	**No**	**No**
LwrLimit	6.06	1.77	6.93	-0.54	-2.42	-2.73	-4.66
UprLimit	10.23	5.94	11.09	3.63	1.75	1.43	-0.49



Design of Experiment

Design of Experiment Process

Step 8 Determine the regression equation for the process.

For the three replications, the regression parameters from the significant factors are:

$$a_0 = \overline{x} = 8.346 \qquad a_1 = \frac{1}{2}(Eff_A) = \frac{1}{2}(8.144) = 4.072$$

$$a_2 = \frac{1}{2}(Eff_B) = \frac{1}{2}(3.852) = 1.926 \qquad a_3 = \frac{1}{2}(Eff_C) = \frac{1}{2}(9.008) = 4.504$$

The regression parameters are half of the effects because the half-width of the confidence interval is being considered. Thus, the regression equation is:

$$Response = a_0 + a_1A + a_2B + a_3C = 8.346 + 4.072A + 1.926B + 4.504C$$

Design of Experiment

Design of Experiment Process

Step 9 Determine the new mean and target value for the process.

Coding the Data			De-Coding back	
Factor	**Coded**	**Data**	**Data**	**Coded**
A	1	80	80	1
B	0.6	54	54	0.6
C	1	50	50	1

To accomplish this goal, our group decided to change the coded values of factors A and C to the maximum of its range as well as the coded value of factor B to 0.6 times of its range. Thus, the new mean $\bar{x}_2$ with these changes will be:

$$\bar{x}_2 = 8.346 + 4.072(1) + 1.926(0.6) + 4.504(1) = 18.078$$

Our target value T is calculated as:

$$T = \bar{x}_2 + \frac{1}{2}(USL - LSL) = 18.078 + \frac{1}{2}(25 - 5) = 28.346$$

Design of Experiment

Design of Experiment Process

Step 10 Determine the capability of the process after improvement.

Coding the Data			De-Coding back	
Factor	**Coded**	**Data**	**Data**	**Coded**
A	1	80	80	1
B	0.6	54	54	0.6
C	1	50	50	1

Using the new mean and the target value, our group then verified that the newly achieved Taguchi process capability ratio C_{pm} is:

$$C_{pm} = \frac{USL - LSL}{6\sqrt{\sigma^2 + (T - \bar{x}_2)^2}} = \frac{25-5}{6\sqrt{(2.063)^2 + (18.346 - 18.078)^2}} = \mathbf{1.602}$$

*Since the calculated C_{pm} is greater than the minimum acceptable value of 1.33, **this process is acceptable**.*

Design of Experiment

Design of Experiment Process

Step 10 Determine the capability of the process after improvement.

Coding the Data			De-Coding back	
Factor	**Coded**	**Data**	**Data**	**Coded**
A	1	80	80	1
B	0.6	54	54	0.6
C	1	50	50	1

Thus, our group can perform the corresponding DOE unit transformations with coded values to obtain the real values by applying the formulas to the corresponding coded values:

$$\textbf{Real } \boldsymbol{A} = 0.5 \cdot A \cdot Range_A + MidPt_A = 0.5(1)(40) + 60 = \mathbf{80\%}$$
$$\textbf{Real } \boldsymbol{B} = 0.5 \cdot B \cdot Range_B + MidPt_B = 0.5(0.6)(30) + 45 = \mathbf{54\%}$$
$$\textbf{Real } \boldsymbol{C} = 0.5 \cdot C \cdot Range_C + MidPt_C = 0.5(1)(20) + 40 = \mathbf{50\%}$$

Design of Experiment

Factorial Analysis in Minitab

Coded Coefficients

Term	Effect	Coef	SE Coef	T-Value	P-Value	VIF
Constant		8.346	0.421	19.82	0.000	
A	8.144	4.072	0.421	9.67	0.000	1.00
B	3.852	1.926	0.421	4.57	0.000	1.00
C	9.008	4.504	0.421	10.69	0.000	1.00
A*B	1.543	0.771	0.421	1.83	0.086	1.00
A*C	-0.333	-0.166	0.421	-0.39	0.698	1.00
B*C	-0.650	-0.325	0.421	-0.77	0.452	1.00
A*B*C	-2.574	-1.287	0.421	-3.06	0.008	1.00

Model Summary

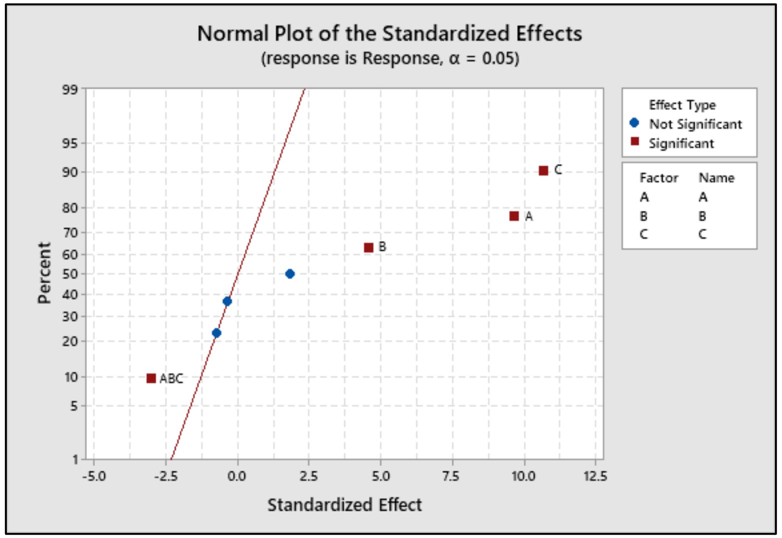
S	R-sq	R-sq(adj)	R-sq(pred)
2.06344	93.80%	91.09%	86.06%

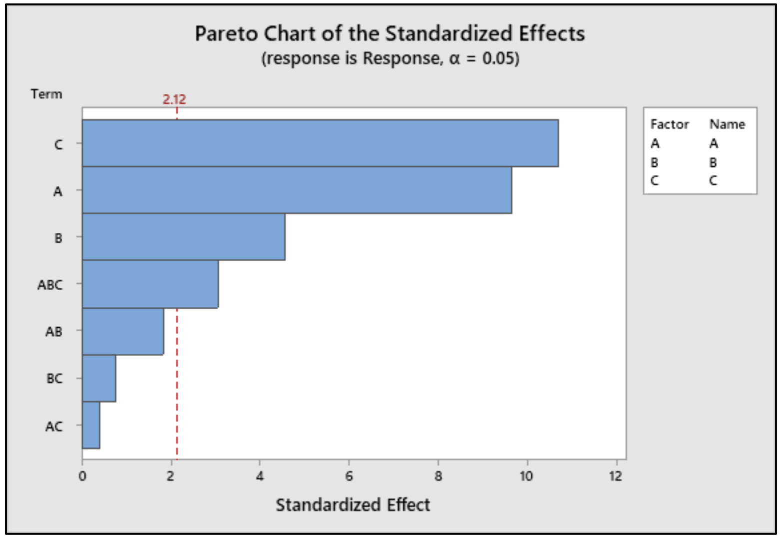
Analysis of Variance

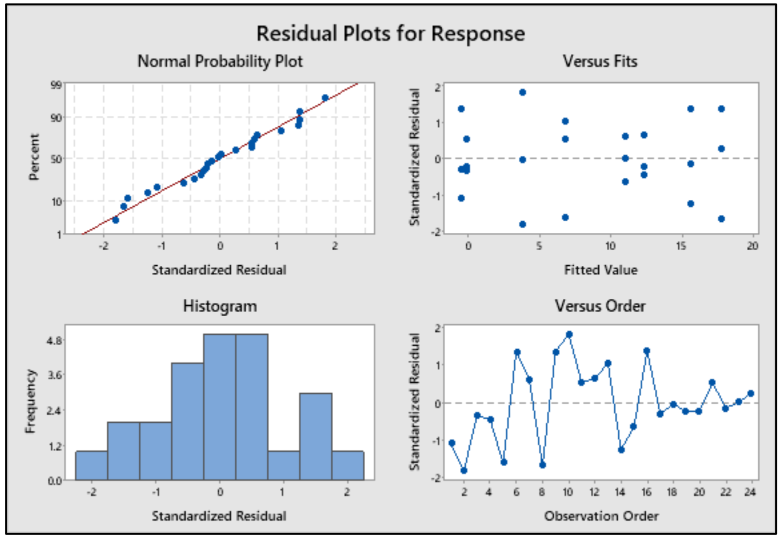
Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	7	1031.15	147.307	34.60	0.000
Linear	3	973.93	324.644	76.25	0.000
A	1	397.99	397.986	93.47	0.000
B	1	89.03	89.031	20.91	0.000
C	1	486.91	486.915	114.36	0.000
2-Way Interactions	3	17.47	5.825	1.37	0.288
A*B	1	14.28	14.278	3.35	0.086
A*C	1	0.66	0.664	0.16	0.698
B*C	1	2.53	2.532	0.59	0.452
3-Way Interactions	1	39.75	39.745	9.33	0.008
A*B*C	1	39.75	39.745	9.33	0.008
Error	16	68.12	4.258		
Total	23	1099.28			

Design of Experiment

Factorial Analysis in Minitab



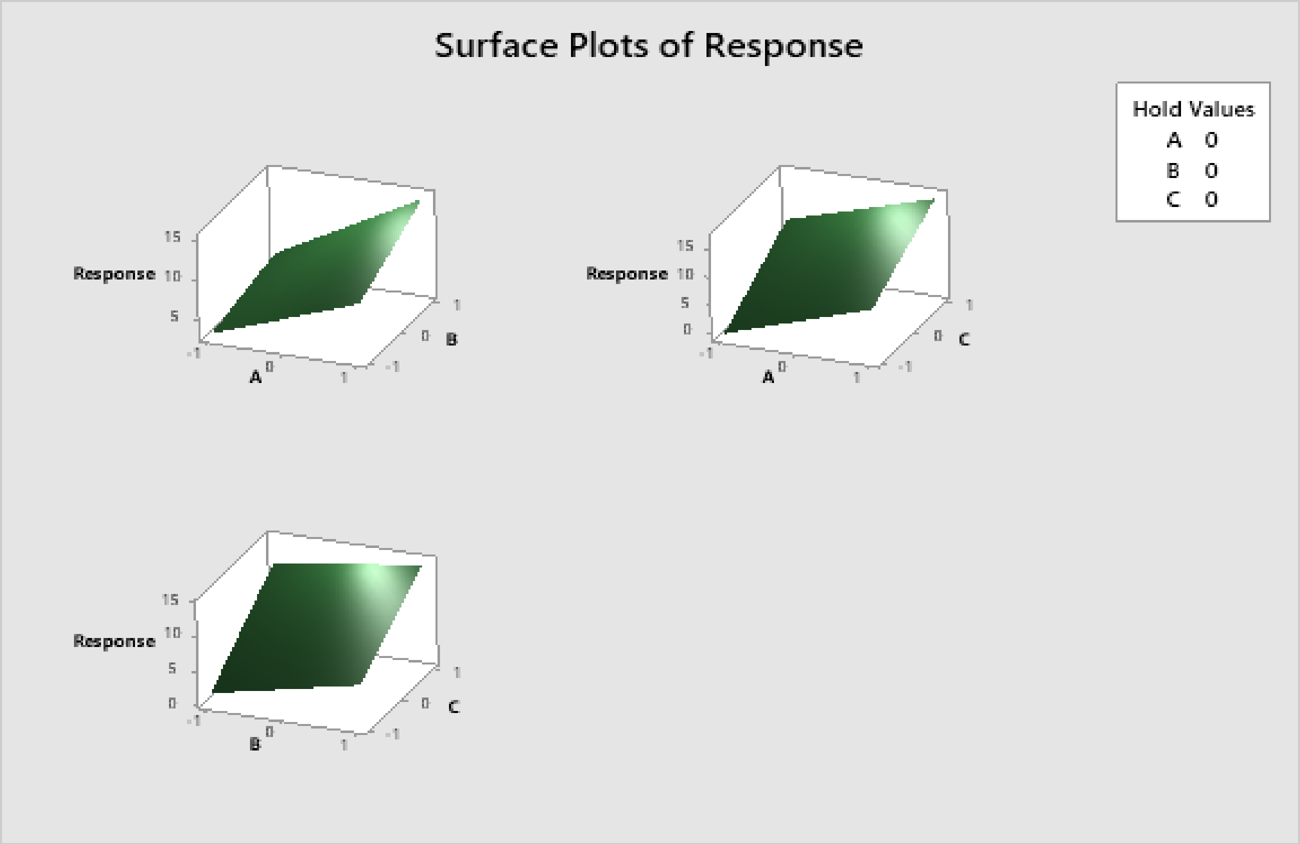




It is evident that the percentage of people staying at home (Factor A), the percentage of transportation shutdown (Factor B), and the percentage of food industry shutdown (Factor C) are significant as their P-values are less than 0.05.

Design of Experiment

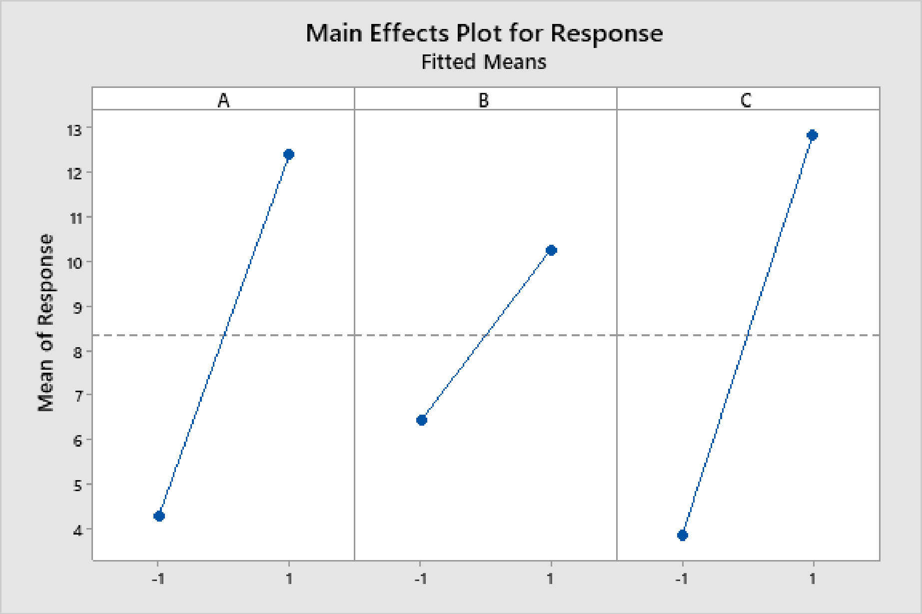
Factorial Analysis in Minitab

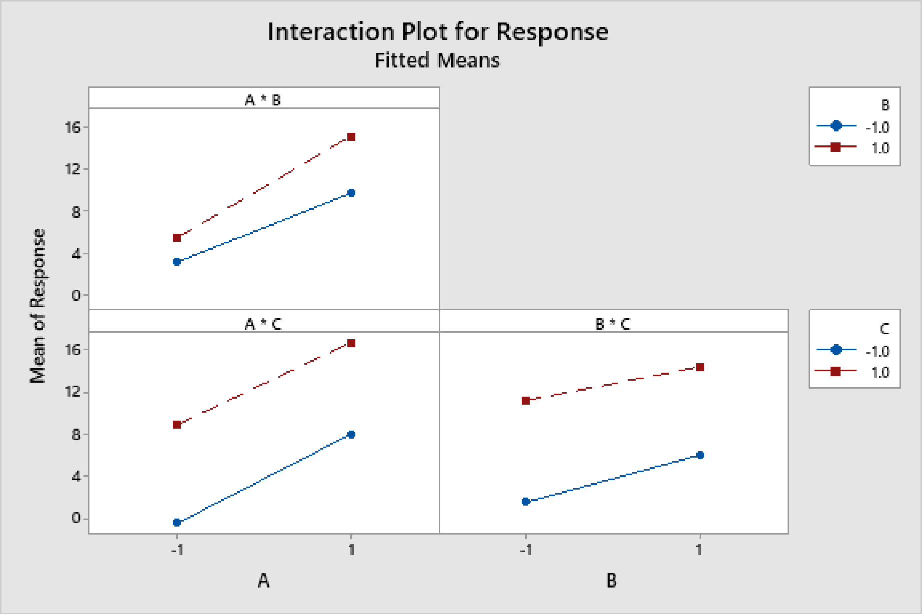


Design of Experiment

Factorial Analysis in Minitab

An analysis on the main effects and interactions for the response variable is performed in Minitab, giving the following results:





- Factors A and C have a quicker rise in response and are more significant compared to Factor B.
- The Factor A-Factor B interaction is not parallel and is more significant compared to the Factor A-Factor C interaction and the Factor B-Factor C interaction.

Design of Experiment

Factorial Analysis in Minitab

A regression analysis on our data for the response variable is performed in Minitab, giving the following results:

Regression Equation

Response	=	8.346 + 4.072 A + 1.926 B + 4.504 C

Model Summary

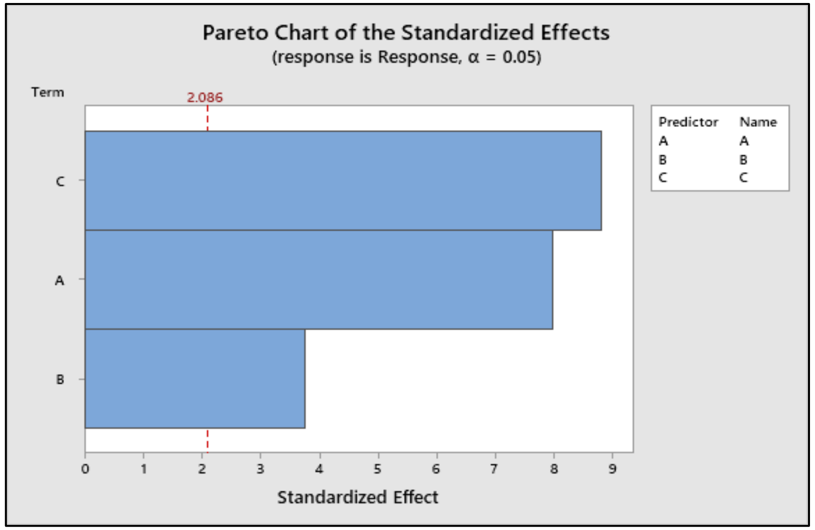
S	R-sq	R-sq(adj)	R-sq(pred)
2.50344	88.60%	86.89%	83.58%

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	3	973.93	324.644	51.80	0.000
A	1	397.99	397.986	63.50	0.000
B	1	89.03	89.031	14.21	0.001
C	1	486.91	486.915	77.69	0.000
Error	20	125.34	6.267		
Lack-of-Fit	4	57.22	14.305	3.36	0.035
Pure Error	16	68.12	4.258		
Total	23	1099.28			

Coefficients

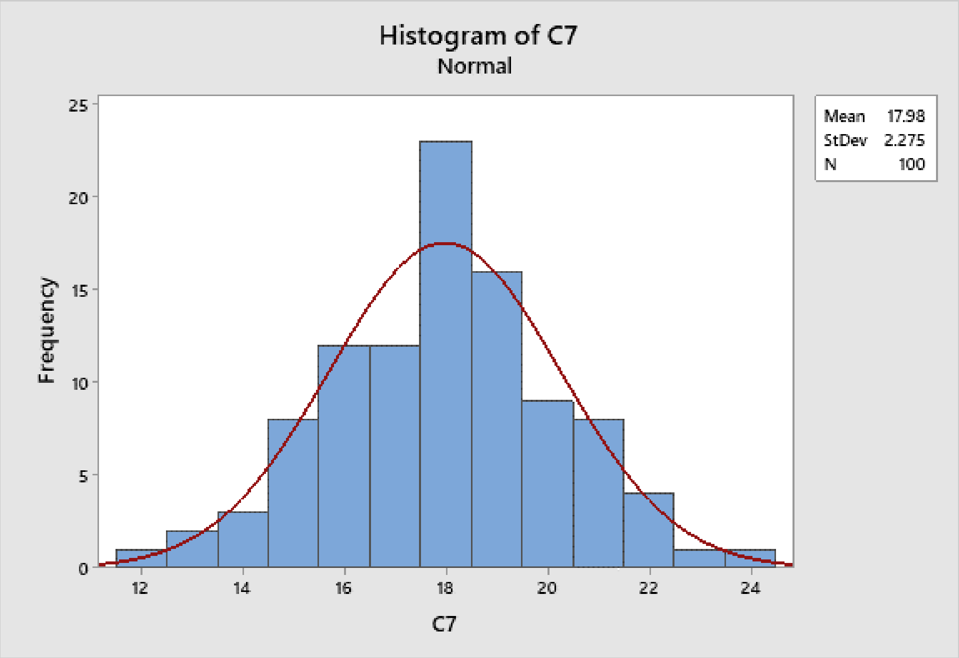
Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	8.346	0.511	16.33	0.000	
A	4.072	0.511	7.97	0.000	1.00
B	1.926	0.511	3.77	0.001	1.00
C	4.504	0.511	8.81	0.000	1.00

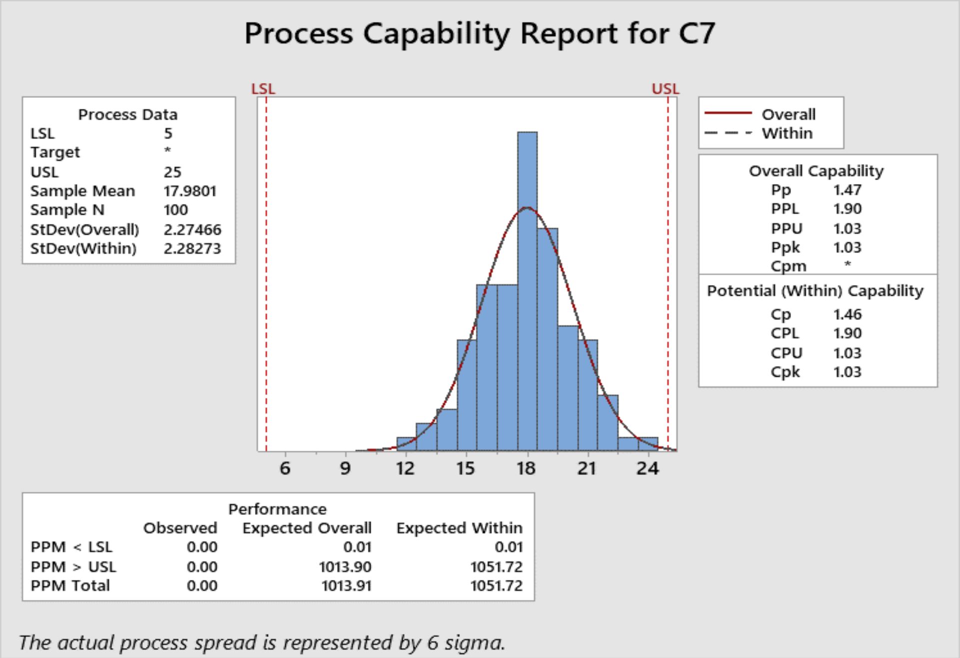


Comparing our regression analysis on Minitab to our Design of Experiment in Excel, our group was able to obtain the same results in both analyses.

Design of Experiment

Conclusion





Thus, to implement an effective lockdown (i.e. an infection rate of less than 5%), our group would want **80%** of people to follow stay-at-home restrictions, **54%** of transportation shut down, and **50%** of the food industry shut down.

Statewide COVID-19 Lockdown

Supply Chain Management

Supply Chain Management

What is Supply Chain Management?

- Supply chain management (SCM) is the active management of supply chain activities to maximize customer value and achieve a sustainable competitive advantage.
- It represents a conscious effort by the supply chain firms to develop and run supply chains in the most effective and efficiency ways possible.
- Supply chain activities cover everything from product development, sourcing, production, and logistics as well as the information systems needed to coordinate these activities.

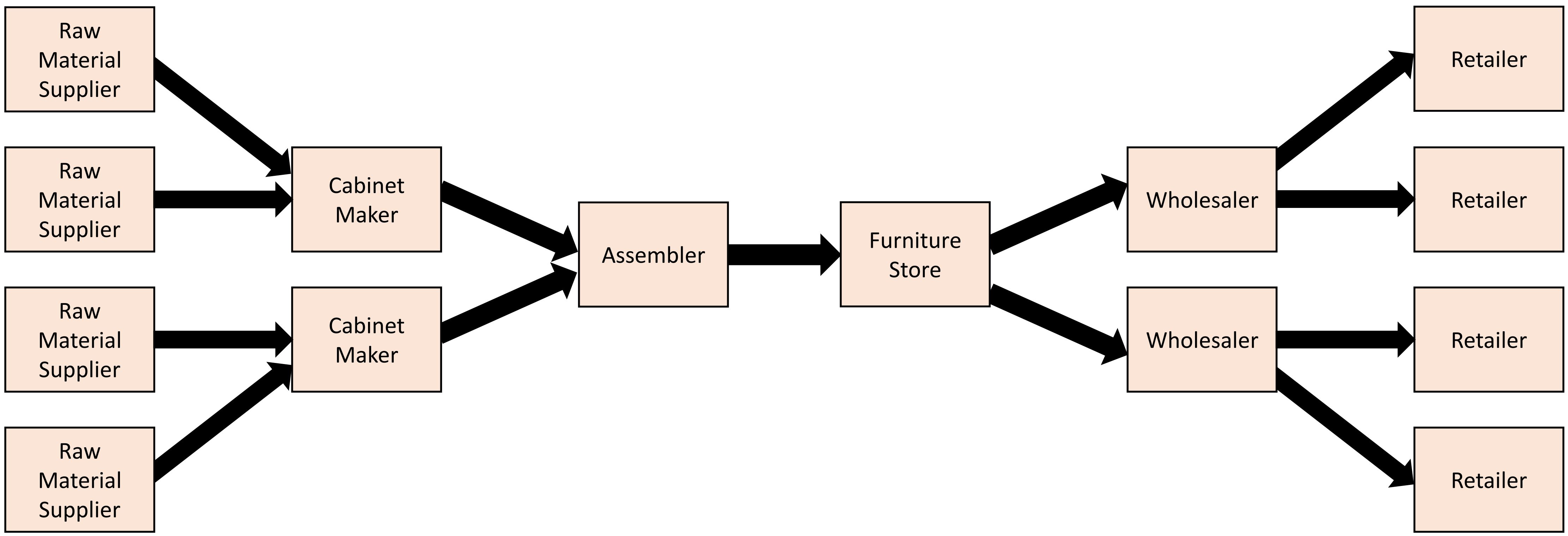
Supply Chain Management

Importance of Supply Chain Management

- SCM can boost:
  - Customer service
  - Reduce operating costs
  - Improve a company's financial position
- Other benefits include:
  - Reduced inventory costs
  - Better information sharing between partners
  - Improved process integration
  - Improved quality

Supply Chain Management

Supply Chain Network



Supply Chain Management

Supply Chain Game Problem Definition

The supply chain game gives a better understanding of the flow of materials and costs involved. Assume you manage a store that sells furniture. Your furniture supplier assembles it, by receiving the parts from his own supplier who cuts and prepares the necessary parts of wood. The weekly supply chain flow information is as follows:

Item	Cabinet Maker	Assembler	Furniture Store
Production/Sale	0 to N1	0 to N2	0 to N3
Inventory Max	9	10	8
Cost of Inventory	1	2	5
Cost of Overflow	3	4	10
Cost of Shortage	7	6	7
Random/Selection	**Judgement**	**Judgement**	**Distribution J**

$$N1 = 7 + Group\ Num$$
$$N2 = 8 + Group\ Num$$
$$N3 = 6 + Group\ Num$$

We must determine how many items produced weekly by the cabinet maker and assembler, the amount of inventory in the furniture store weekly, and the costs per subsystem and for the entire system. Assume that inventories are initially full and weekly sales are random.

Supply Chain Management

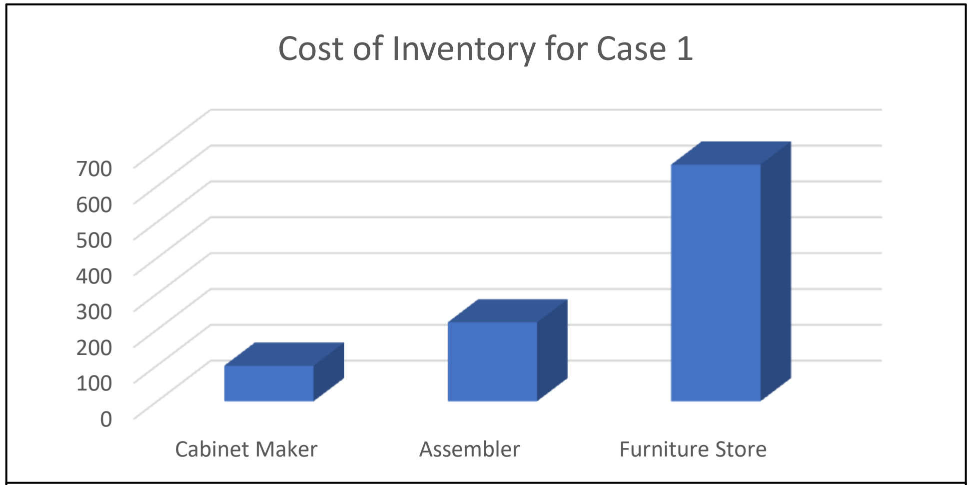
Case 1 – Limitation on Maximum Inventory

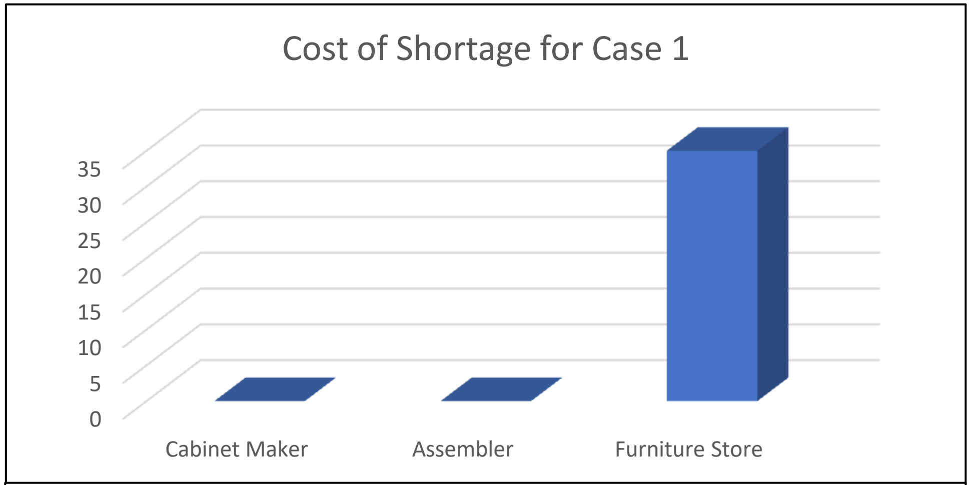
Item	Cabinet Maker	Assembler	Furniture Store
Minimum Production Sale	0	0	0
Maximum Production Sale	8	9	7
Inventory Max	9	10	8
Cost of Inventory	$1	$2	$5
Cost of Overflow	$3	$4	$10
Cost of Shortage	$7	$6	$7
Random / Selection	Judgement	Judgement	Distribution J

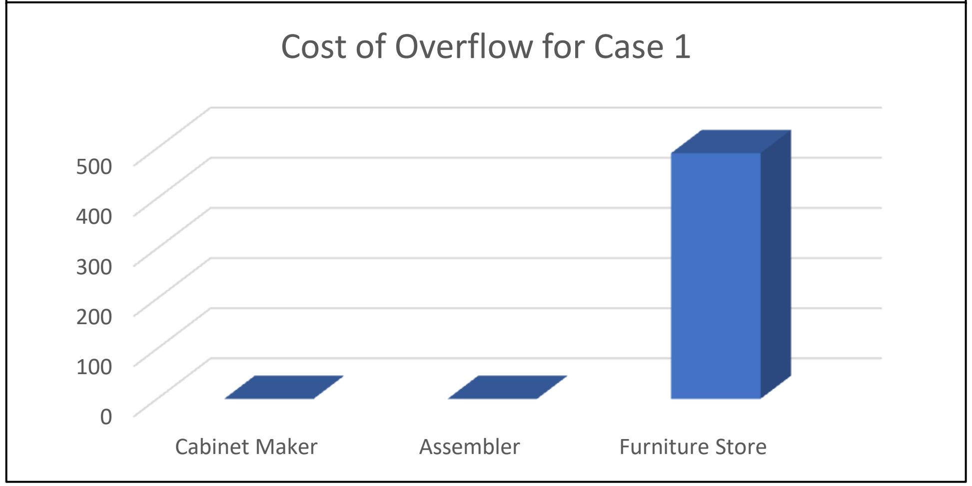
	Week	0	1	2	3	4	5	6	7	8	9	10
Furniture Store	Demand		6	6	4	5	1	4	1	5	0	5
	Planned Receipt		5	5	5	5	5	5	5	5	5	5
	Total Units		13	12	11	12	12	16	17	21	21	26
	Inventory	8	7	6	7	7	11	12	16	16	21	21
	Overflow		0	0	0	0	3	4	8	8	13	13
	Shortage		1	2	1	1	0	0	0	0	0	0
	Cost of Inventory	$40	$35	$30	$35	$35	$55	$60	$80	$80	$105	$105
	Cost of Overflow		$0	$0	$0	$0	$30	$40	$80	$80	$130	$130
	Cost of Shortage		$7	$14	$7	$7	$0	$0	$0	$0	$0	$0
	Total Cost	$1,185										
Assembler	Production		5	5	5	5	5	5	5	5	5	5
	Planned Receipt		5	5	5	5	5	5	5	5	5	5
	Total Units		15	15	15	15	15	15	15	15	15	15
	Inventory	10	10	10	10	10	10	10	10	10	10	10
	Overflow		0	0	0	0	0	0	0	0	0	0
	Shortage		0	0	0	0	0	0	0	0	0	0
	Cost of Inventory	$20	$20	$20	$20	$20	$20	$20	$20	$20	$20	$20
	Cost of Overflow		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Cost of Shortage		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Total Cost	$220										
Cabinet Maker	Production		5	5	5	5	5	5	5	5	5	5
	Planned Receipt		5	5	5	5	5	5	5	5	5	5
	Total Units		14	14	14	14	14	14	14	14	14	14
	Inventory	9	9	9	9	9	9	9	9	9	9	9
	Overflow		0	0	0	0	0	0	0	0	0	0
	Shortage		0	0	0	0	0	0	0	0	0	0
	Cost of Inventory	$9	$9	$9	$9	$9	$9	$9	$9	$9	$9	$9
	Cost of Overflow		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Cost of Shortage		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Total Cost	$99										
System Total Cost		**$1,504**										

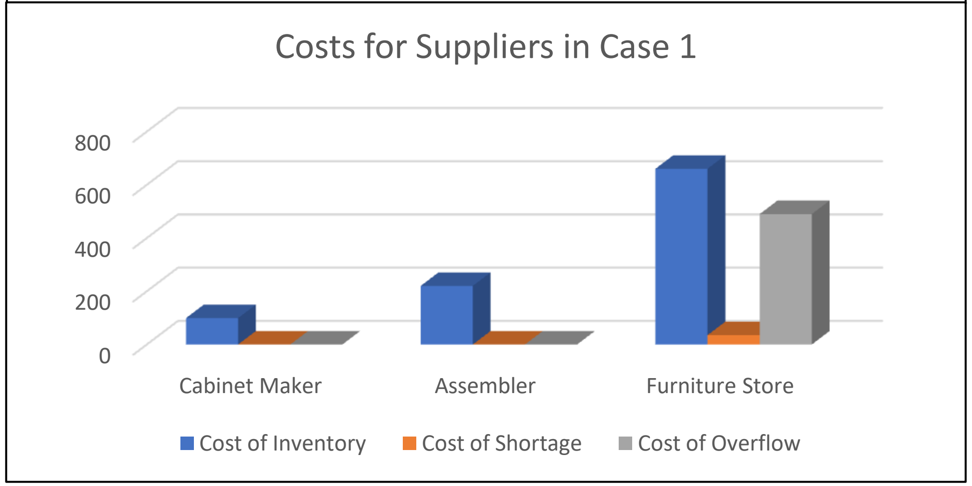
Supply Chain Management

Case 1 – Limitation on Maximum Inventory









Supply Chain Management

Case 2 – No Limitation on Maximum Inventory

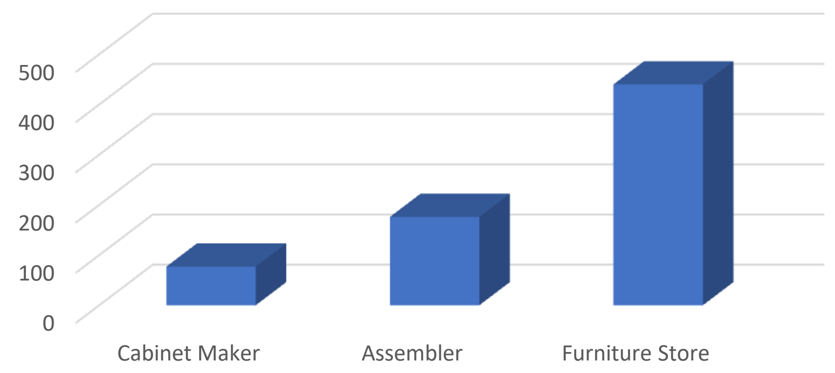
Item	Cabinet Maker	Assembler	Furniture Store
Minimum Production Sale	0	0	0
Maximum Production Sale	8	9	7
Inventory Max	**7**	**8**	**4**
Cost of Inventory	$1	$2	$5
Cost of Overflow	$3	$4	$10
Cost of Shortage	$7	$6	$7
Random / Selection	Judgement	Judgement	Distribution J

	Week	0	1	2	3	4	5	6	7	8	9	10
Furniture Store	Demand		6	6	4	5	1	4	1	5	0	5
	Planned Receipt		5	5	5	5	5	5	5	5	5	5
	Total Units		9	8	7	8	8	12	13	17	17	22
	Inventory	4	3	2	3	3	7	8	12	12	17	17
	Overflow		0	0	0	0	3	4	8	8	13	13
	Shortage		1	2	1	1	0	0	0	0	0	0
	Cost of Inventory	$20	$15	$10	$15	$15	$35	$40	$60	$60	$85	$85
	Cost of Overflow		$0	$0	$0	$0	$30	$40	$80	$80	$130	$130
	Cost of Shortage		$7	$14	$7	$7	$0	$0	$0	$0	$0	$0
	Total Cost	$965										
Assembler	Production		5	5	5	5	5	5	5	5	5	5
	Planned Receipt		5	5	5	5	5	5	5	5	5	5
	Total Units		13	13	13	13	13	13	13	13	13	13
	Inventory	8	8	8	8	8	8	8	8	8	8	8
	Overflow		0	0	0	0	0	0	0	0	0	0
	Shortage		0	0	0	0	0	0	0	0	0	0
	Cost of Inventory	$16	$16	$16	$16	$16	$16	$16	$16	$16	$16	$16
	Cost of Overflow		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Cost of Shortage		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Total Cost	$176										
Cabinet Maker	Production		5	5	5	5	5	5	5	5	5	5
	Planned Receipt		5	5	5	5	5	5	5	5	5	5
	Total Units		12	12	12	12	12	12	12	12	12	12
	Inventory	7	7	7	7	7	7	7	7	7	7	7
	Overflow		0	0	0	0	0	0	0	0	0	0
	Shortage		0	0	0	0	0	0	0	0	0	0
	Cost of Inventory	$7	$7	$7	$7	$7	$7	$7	$7	$7	$7	$7
	Cost of Overflow		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Cost of Shortage		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Total Cost	$77										
System Total Cost		$1,218										

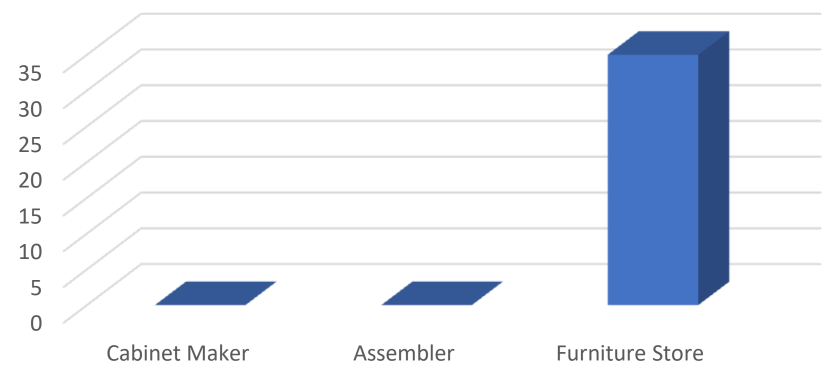
Supply Chain Management

Case 2 – No Limitation on Maximum Inventory

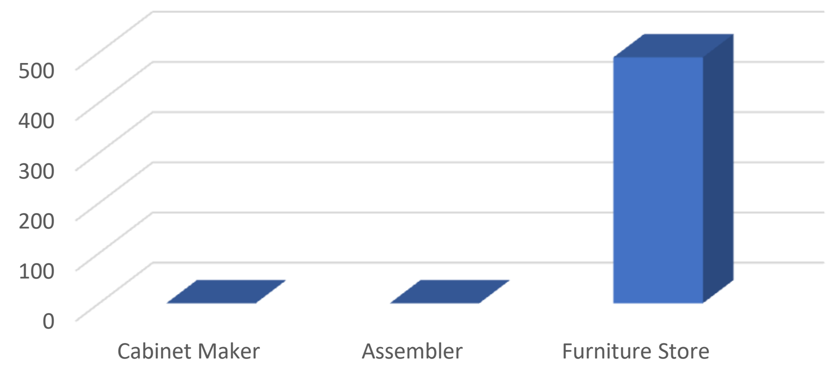
Cost of Inventory for Case 2



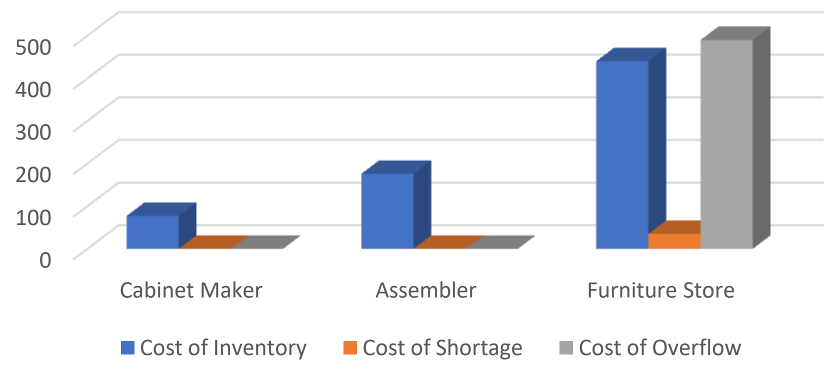
Cost of of Shortage for Case 2



Cost of Overflow for Case 2

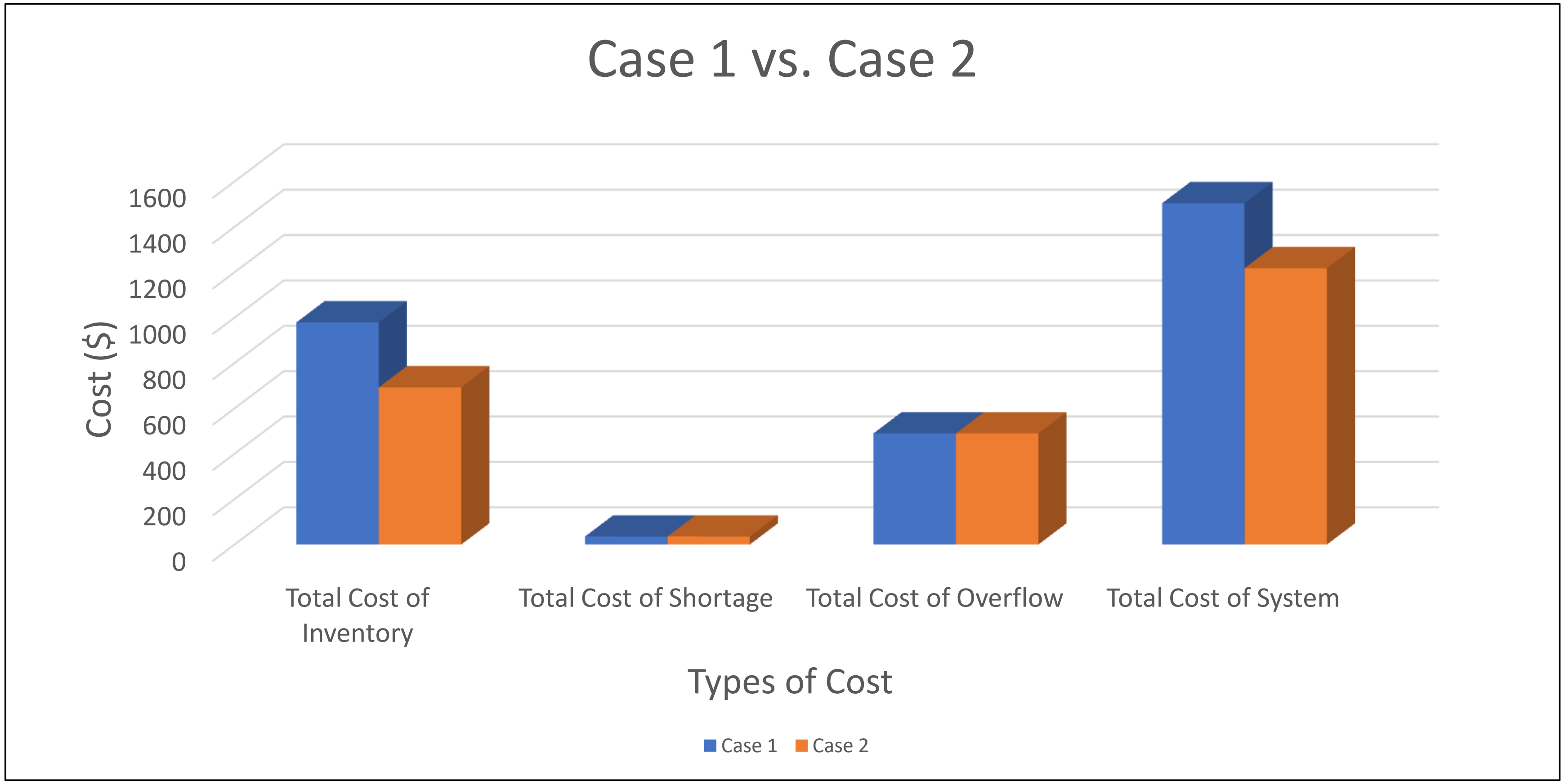


Cost for Suppliers in Case 2



Supply Chain Management

Comparison of Case 1 and Case 2



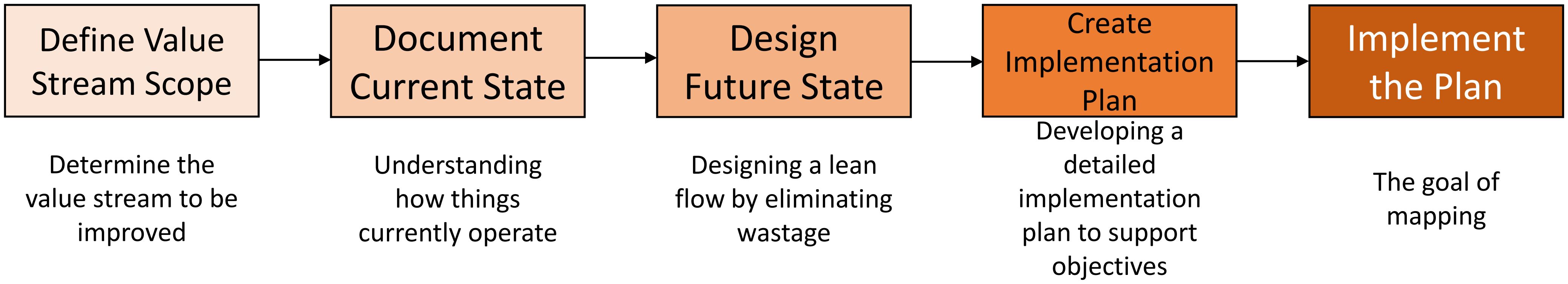
Statewide COVID-19 Lockdown

Value Stream Mapping (VSM)

Value Stream Mapping

What is Value Stream Mapping?

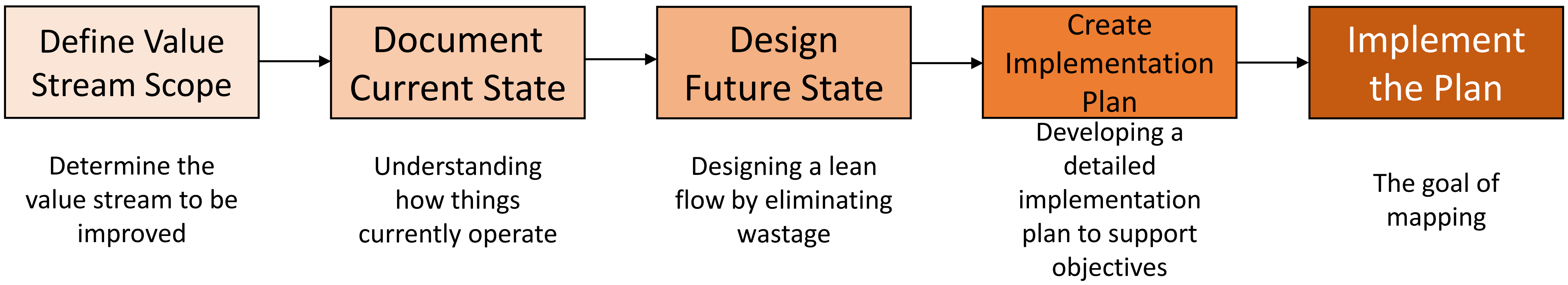
- A Value Stream Map (VSM) consists of all activities (both value added and non-value added) to bring a product from conception through delivery to the customer.
- Value stream mapping is a lean manufacturing technique used to analyze and design the flow of materials and information required to bring a product or service to a customer.



Value Stream Mapping

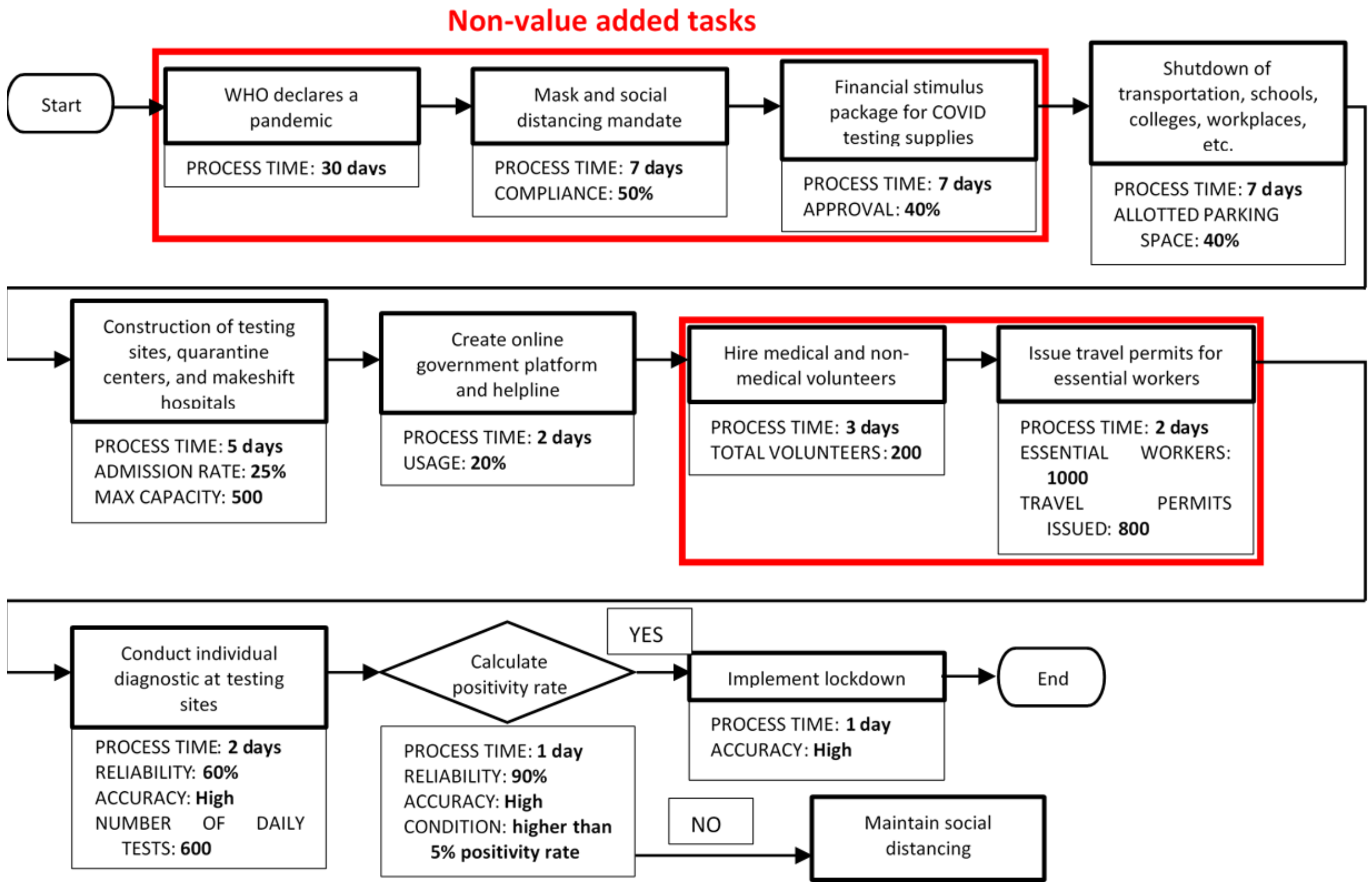
Objectives of Value Stream Mapping

- Identify and reduce waste in steps critical to the process
- Provide the means to see the material, process, and information flows
- Support the prioritization of continuous improvement activities at the value stream



Value Stream Mapping

Current-State Value Stream Map



Value Stream Mapping

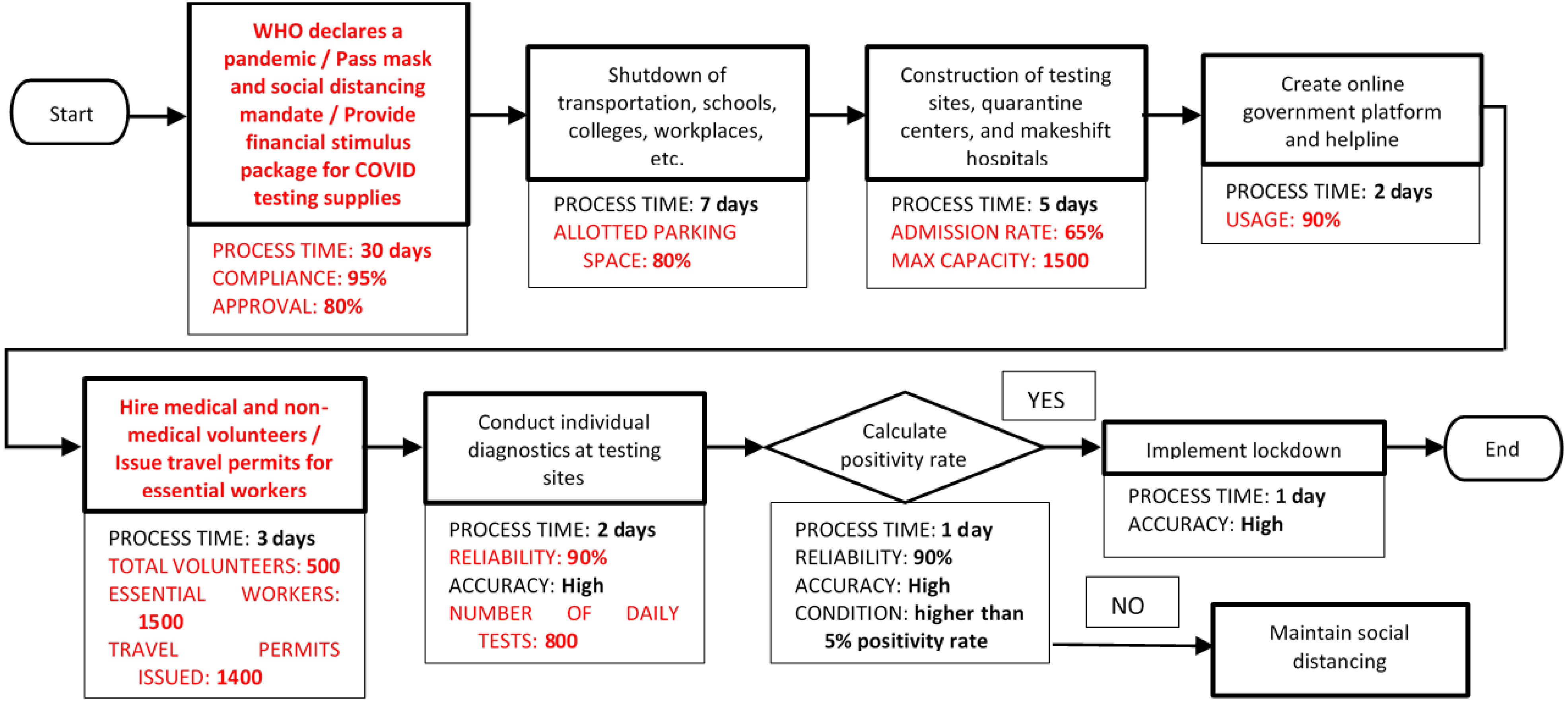
Current-State Value Stream Map

- Total process time length: **67 days**

- Non-value-added tasks
  1. WHO declaration of a pandemic
     - Process time: **30 days**
  2. Compliance with mask and social distancing mandates
     - Process time: **7 days**
     - Compliance: **50 %**
  3. Approval for financial stimulus package for COVID testing supplies
     - Process time: **7 days**
     - Approval: **40 %**
  4. Hiring process of medical and non-medical volunteers
     - Process time: **3 days**
     - Number of volunteers: **200**
  5. Issuance of travel permits for essential workers
     - Process time: **2 days**
     - Number of essential workers: **1000**
     - Travel permits issued: **800**

Value Stream Mapping

Future-State Value Stream Map



Value Stream Mapping

Future-State Value Stream Map

- Total process time length: **51 days**

- Combine steps 1, 2, and 3 as one step in process
  - WHO declaration of a pandemic + Compliance with mask and social distancing mandates + Approval for financial stimulus package for COVID testing supplies
    - Process time: **30 days**
    - Compliance: **50 % → 90 %**
    - Approval: **40 % → 80 %**
- Increased allotted parking space from 40% to 80% for shutdown of transportation, schools, colleges, workspaces, etc.
- Increased admission rate from 25% to 65% and maximum capacity from 500 to 1500 for testing sites, quarantine centers, and makeshift hospitals
- Increased usage from 20% to 90% for online government platforms and helpline

Value Stream Mapping

Future-State Value Stream Map

- Total process time length: **51 days**

- Combine steps 7 and 8 as one step in process
  - Hiring process of medical and non-medical workers + Issuance of travel permits for essential workers
    - Process time: **3 days**
    - Number of volunteers: **200 → 500**
    - Number of essential workers: **1000 → 1500**
    - Travel permits issued: **800 → 1400**
- Increased reliability from 60% to 90% and number of daily tests from 600 to 800 for conducting individual diagnostics at testing sites

Statewide COVID-19 Lockdown

Measurement System Analysis (MSA)

Measurement System Analysis

What is Measurement System Analysis?

- **Measurement System Analysis (MSA)** – the range of analysis techniques that can help to identify and measure the sources of error in data.
- Measurement system comprises of people, devices, procedures, standards, and training.
- MSA is relevant because the measurement system could have introduced errors and bias to the data which may not reflect the actual process data.

Measurement System Analysis

Gage Repeatability and Reproducibility (Gage R&R)

- The type of study typically implemented in Measurement System Analysis (MSA) is gage repeatability and reproducibility (gage R&R).
  - **Repeatability** – the variation in measurements obtained by a measure instrument when used several times by an appraiser
  - **Reproducibility** – the variation in measurements made by different appraisers using the same measuring instrument
- There are two types of gage R&R studies: **continuous and attribute**.
- The measurement is considered:

Acceptable if:	**% Study Variance < 10%**	**% Contribution < 1%**
Marginally acceptable if:	**10% < % Study Variance < 30%**	**1% < % Contribution < 9%**
Unacceptable if:	**% Study Variance > 30%**	**% Contribution > 9%**

Measurement System Analysis

Gage R&R Study Problem Statement

The state government are proposing to implement a statewide lockdown due to COVID-19 and has hired our group to evaluate their system quality. The government's lockdown implementation involves cooperation with everyone throughout the state.

In the study, the government selected three operators for the first process and two inspectors for the second process. The three operators selected for the study are transport service providers, food distributors, and everyday citizens. Our group would like to implement a gage R&R study to evaluate the quality of this measurement system.

Measurement System Analysis

Continuous Gage R&R Study – Dataset

Part	Operator	Measurement
1	A	0.29
1	A	0.41
1	A	0.64
2	A	-0.56
2	A	-0.68
2	A	-0.58
3	A	1.34
3	A	1.17
3	A	1.27
4	A	0.47
4	A	0.5
4	A	0.64
5	A	-0.8
5	A	-0.92
5	A	-0.84
6	A	0.02
6	A	-0.11
6	A	-0.21
7	A	0.59
7	A	0.75
7	A	0.66
8	A	-0.31
8	A	-0.2
8	A	-0.17
9	A	2.26
9	A	1.99
9	A	2.01
10	A	-1.36
10	A	-1.25
10	A	-1.31

Part	Operator	Measurement
1	B	0.08
1	B	0.25
1	B	0.07
2	B	-0.47
2	B	-1.22
2	B	-0.68
3	B	1.19
3	B	0.94
3	B	1.34
4	B	0.01
4	B	1.03
4	B	0.2
5	B	-0.56
5	B	-1.2
5	B	-1.28
6	B	-0.2
6	B	0.22
6	B	0.06
7	B	0.47
7	B	0.55
7	B	0.83
8	B	-0.63
8	B	0.08
8	B	-0.34
9	B	1.8
9	B	2.12
9	B	2.19
10	B	-1.68
10	B	-1.62
10	B	-1.5

Part	Operator	Measurement
1	C	0.04
1	C	-0.11
1	C	-0.15
2	C	-1.38
2	C	-1.13
2	C	-0.96
3	C	0.88
3	C	1.09
3	C	0.67
4	C	0.14
4	C	0.2
4	C	0.11
5	C	-1.46
5	C	-1.07
5	C	-1.45
6	C	-0.29
6	C	-0.67
6	C	-0.49
7	C	0.02
7	C	0.01
7	C	0.21
8	C	-0.46
8	C	-0.56
8	C	-0.49
9	C	1.77
9	C	1.45
9	C	1.87
10	C	-1.49
10	C	-1.77
10	C	-2.16

Measurement System Analysis

Continuous Gage R&R Study – Results

Two-Way ANOVA Table With Interaction

Source	DF	SS	MS	F	P
Part	9	88.3619	9.81799	492.291	0.000
Operator	2	3.1673	1.58363	79.406	0.000
Part * Operator	18	0.3590	0.01994	0.434	0.974
Repeatability	60	2.7589	0.04598		
Total	89	94.6471			

α to remove interaction term = 0.05

Two-Way ANOVA Table Without Interaction

Source	DF	SS	MS	F	P
Part	9	88.3619	9.81799	245.614	0.000
Operator	2	3.1673	1.58363	39.617	0.000
Repeatability	78	3.1179	0.03997		
Total	89	94.6471			

- Part-operator variation is not significant **(P-value = 0.974 > 0.05)**. Part and operator variations are significant **(P-value = 0.000 > 0.05)**.

Variance Components

Source	VarComp	%Contribution (of VarComp)
Total Gage R&R	0.09143	7.76
Repeatability	0.03997	3.39
Reproducibility	0.05146	4.37
Operator	0.05146	4.37
Part-To-Part	1.08645	92.24
Total Variation	1.17788	100.00

- The percent contribution for part-to-part variation is 92.24% **(=1.0864/1.17788)**, which is larger than the percent contribution for operator variation of 4.37%. **Part-to-part variability contributes most to total process variability.**

Gage Evaluation

Source	StdDev (SD)	Study Var (6 × SD)	%Study Var (%SV)
Total Gage R&R	0.30237	1.81423	27.86
Repeatability	0.19993	1.19960	18.42
Reproducibility	0.22684	1.36103	20.90
Operator	0.22684	1.36103	20.90
Part-To-Part	1.04233	6.25396	96.04
Total Variation	1.08530	6.51180	100.00

- Percent study variation for total gage R&R is 27.86% (which is between 10% and 30%) indicates **the process is acceptable depending on the application, cost of measuring device, cost of repair, other factors.**

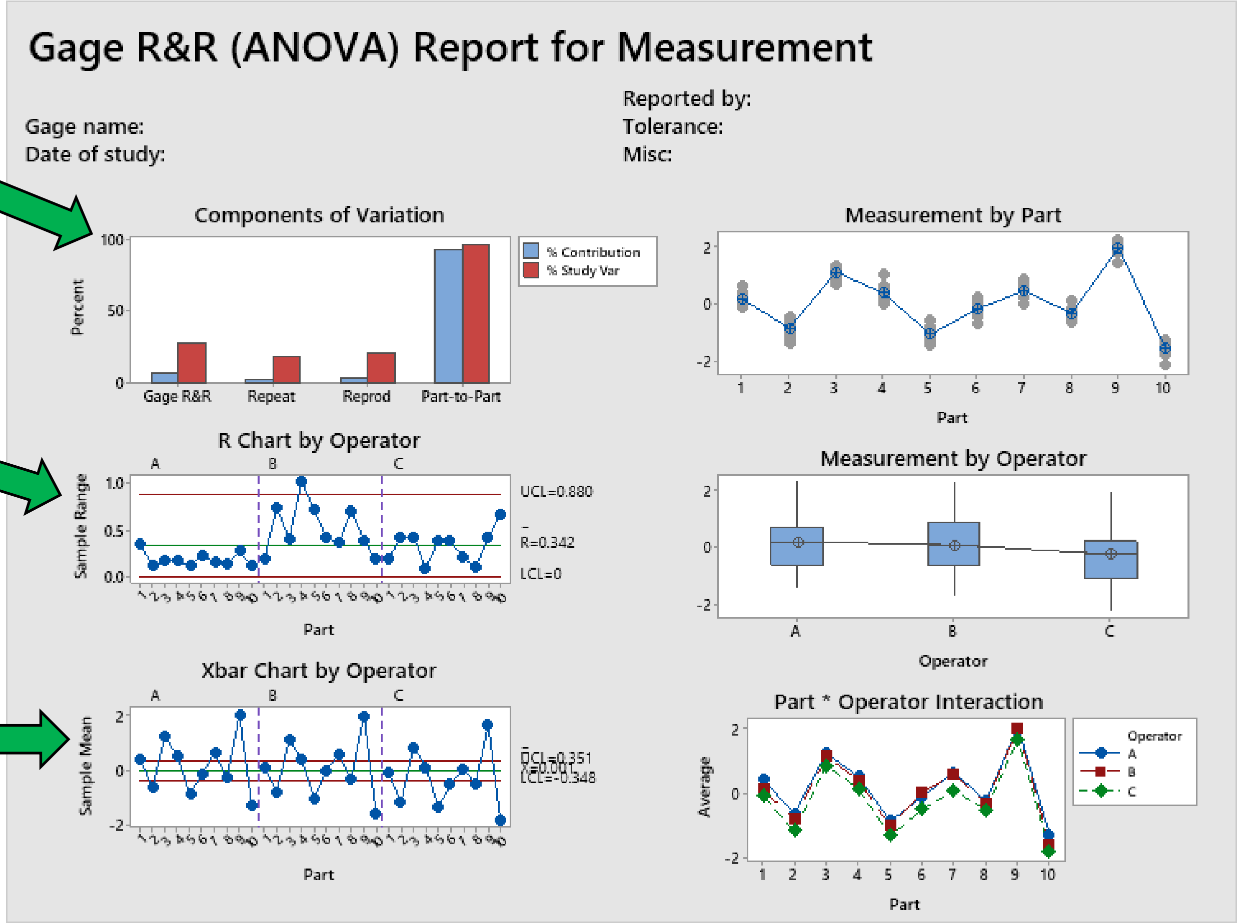
Measurement System Analysis

Continuous Gage R&R Study – Results

The percentage contribution of part-to-part is larger than total gage R&R, thus **the variation is mostly due to difference between parts.**

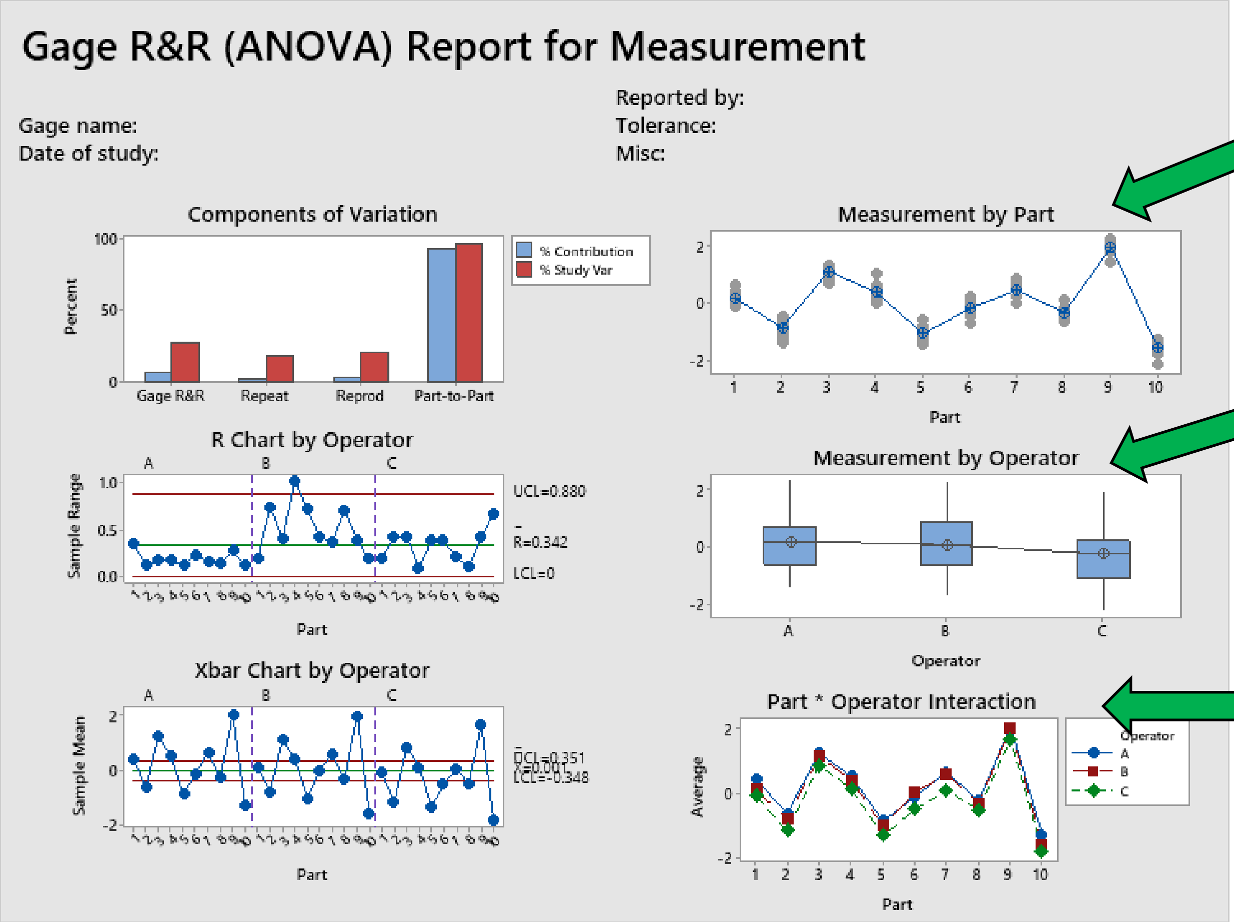
The range of subgroups indicate whether the operators could measure consistently over time as all points should fall within the control limits. **Operator B measures just one point outside the upper control limit.**

The means of subgroups indicate whether the parts are measured consistently over time as all points should fall outside the control limits. **More variation between part averages is expected as most points fall outside the control limits.**



Measurement System Analysis

Continuous Gage R&R Study – Results



It must be determined whether multiple measurements for each part are about the same. **Parts 4 and 10 have the largest variation.**

It must be determined whether there is difference in the total average measurements between operators. **Operator C has a slightly lower average for measurements but is like those of Operators A and B.**

The trend of measurements for each operator indicate whether there is difference in average measurements for each part between operators. **Operator C measures consistently higher on some parts and lower on other parts which adds bias to measurements.**

Measurement System Analysis

Attribute Gage R&R Study – Dataset

Sample	Attribute	Inspector	Result
1	go	1	go
2	no	1	no
3	no	1	no
4	no	1	no
5	no	1	no
6	no	1	no
7	no	1	no
8	no	1	no
9	no	1	no
10	no	1	no
11	no	1	no
12	no	1	no
13	no	1	no
14	no	1	no
15	go	1	go
16	go	1	go
17	go	1	no
18	no	1	no
19	go	1	go
20	no	1	no

Sample	Attribute	Inspector	Result
1	go	1	go
2	no	1	no
3	no	1	no
4	no	1	no
5	no	1	no
6	no	1	no
7	no	1	no
8	no	1	no
9	no	1	no
10	no	1	no
11	no	1	no
12	no	1	no
13	no	1	no
14	no	1	no
15	go	1	go
16	go	1	go
17	go	1	no
18	no	1	no
19	go	1	go
20	no	1	no

Sample	Attribute	Inspector	Result
1	go	2	go
2	no	2	no
3	no	2	no
4	no	2	no
5	no	2	no
6	no	2	no
7	no	2	no
8	no	2	no
9	no	2	no
10	no	2	no
11	no	2	no
12	no	2	no
13	no	2	no
14	no	2	no
15	go	2	go
16	go	2	go
17	go	2	no
18	no	2	no
19	go	2	go
20	no	2	no

Sample	Attribute	Inspector	Result
1	go	2	go
2	no	2	no
3	no	2	no
4	no	2	no
5	no	2	no
6	no	2	no
7	no	2	no
8	no	2	no
9	no	2	no
10	no	2	no
11	no	2	no
12	no	2	no
13	no	2	no
14	no	2	no
15	go	2	go
16	go	2	no
17	go	2	go
18	no	2	no
19	go	2	go
20	no	2	no

Measurement System Analysis

Attribute Gage R&R Study – Results

Within Appraisers

Assessment Agreement

Appraiser	# Inspected	# Matched	Percent	95% CI
1	20	20	100.00	(86.09, 100.00)
2	20	18	90.00	(68.30, 98.77)

 # Matched: Appraiser agrees with him/herself across trials.

Fleiss' Kappa Statistics

Appraiser	Response	Kappa	SE Kappa	Z	P(vs > 0)
1	go	1.0000	0.223607	4.47214	0.0000
	no	1.0000	0.223607	4.47214	0.0000
2	go	0.6875	0.223607	3.07459	0.0011
	no	0.6875	0.223607	3.07459	0.0011

▲ **Within appraisers, appraiser 1 has a perfect agreement between trials (Kappa value = 1) and appraiser 2 has strong association between trials (Kappa value = 0.6875).**

Each Appraiser vs Standard

Assessment Agreement

Appraiser	# Inspected	# Matched	Percent	95% CI
1	20	19	95.00	(75.13, 99.87)
2	20	18	90.00	(68.30, 98.77)

 # Matched: Appraiser's assessment across trials agrees with the known standard.

Assessment Disagreement

Appraiser	# no / go	Percent	# go / no	Percent	# Mixed	Percent
1	1	20.00	0	0.00	0	0.00
2	0	0.00	0	0.00	2	10.00

 # no / go: Assessments across trials = no / standard = go.
 # go / no: Assessments across trials = go / standard = no.
 # Mixed: Assessments across trials are not identical.

Fleiss' Kappa Statistics

Appraiser	Response	Kappa	SE Kappa	Z	P(vs > 0)
1	go	0.856631	0.158114	5.41781	0.0000
	no	0.856631	0.158114	5.41781	0.0000
2	go	0.856631	0.158114	5.41781	0.0000
	no	0.856631	0.158114	5.41781	0.0000

▲ **For each appraiser against the standard, both appraisers have a near perfect agreement between trials (Kappa values = 0.856631).**

Between Appraisers

Assessment Agreement

# Inspected	# Matched	Percent	95% CI
20	18	90.00	(68.30, 98.77)

 # Matched: All appraisers' assessments agree with each other.

Fleiss' Kappa Statistics

Response	Kappa	SE Kappa	Z	P(vs > 0)
go	0.84375	0.0912871	9.24282	0.0000
no	0.84375	0.0912871	9.24282	0.0000

▲ **Between appraisers, the responses have a near perfect agreement between trials (Kappa value = 0.84375).**

Measurement System Analysis

Attribute Gage R&R Study – Results

All Appraisers vs Standard

Assessment Agreement

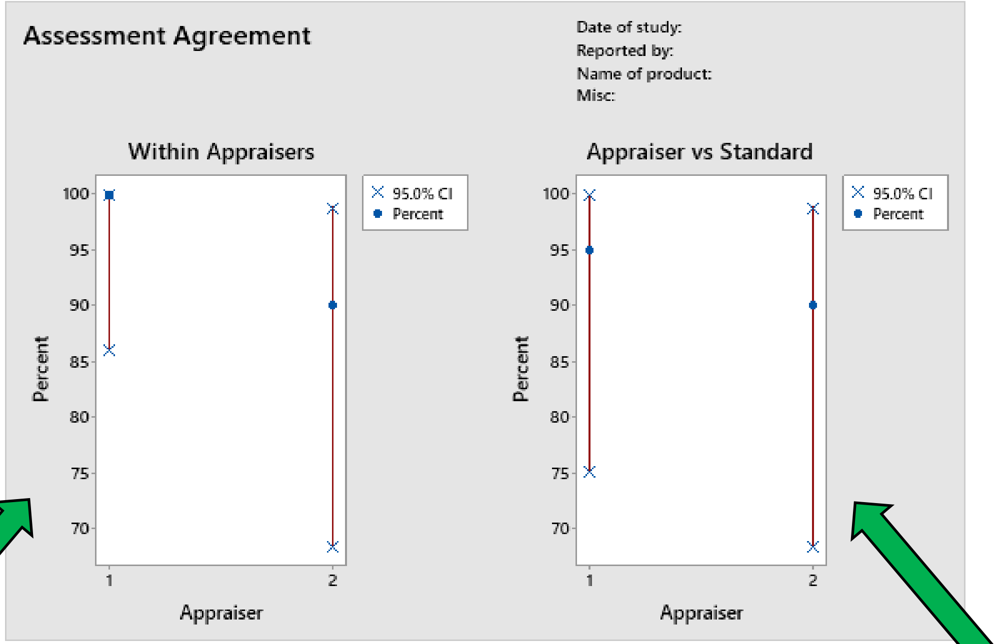
# Inspected	# Matched	Percent	95% CI
20	18	90.00	(68.30, 98.77)

 # Matched: All appraisers' assessments agree with the known standard.

Fleiss' Kappa Statistics

Response	Kappa	SE Kappa	Z	P(vs > 0)
go	0.856631	0.111803	7.66194	0.0000
no	0.856631	0.111803	7.66194	0.0000

- **For all appraisers against the standard, the responses have a near perfect agreement between trials (Kappa value = 0.856631).**



Rating consistency for each appraiser is represented by the blue dot. **Appraiser 1 has the most consistent ratings with approximately 100% consistency, while appraiser 2 has the least consistent ratings with a lower consistency.**

Rating correctness for each appraiser is represented by the blue dot. **Appraiser 1 has the most correct ratings, while appraiser 2 has the least correct ratings.**

Statewide COVID-19 Lockdown

Acceptance Sampling

Acceptance Sampling

<u>What is Acceptance Sampling?</u>

- **Acceptance sampling** – a statistical method that assesses the quality of a lot by randomly picking samples from a lot
- Accept or reject lot based on information from samples
- An approach between no inspection and full inspection
- Determine the quality of lot with a certain level of statistical certainty without evaluating all samples in lot

Acceptance Sampling

Sampling Plan

- Five parameters to consider in creating an acceptance sampling plan:
  - **Producer's risk (α probability)** – the probability of deciding that the alternative hypothesis (H_1) is true when in fact the null hypothesis (H_0) is true
  - **Consumer's risk (β probability)** – the probability of deciding that the null hypothesis (H_0) is true when in fact the alternative hypothesis (H_1) is true
  - **Acceptable quality level (AQL)** – the percent defective that is the base line requirement for the quality of the producer's product
  - **Lot tolerance percent defective (LTPD)** – a pre-specified high defect level that would be unacceptable to the consumer
  - **Lot size (N)** – the total number of products tested

Acceptance Sampling

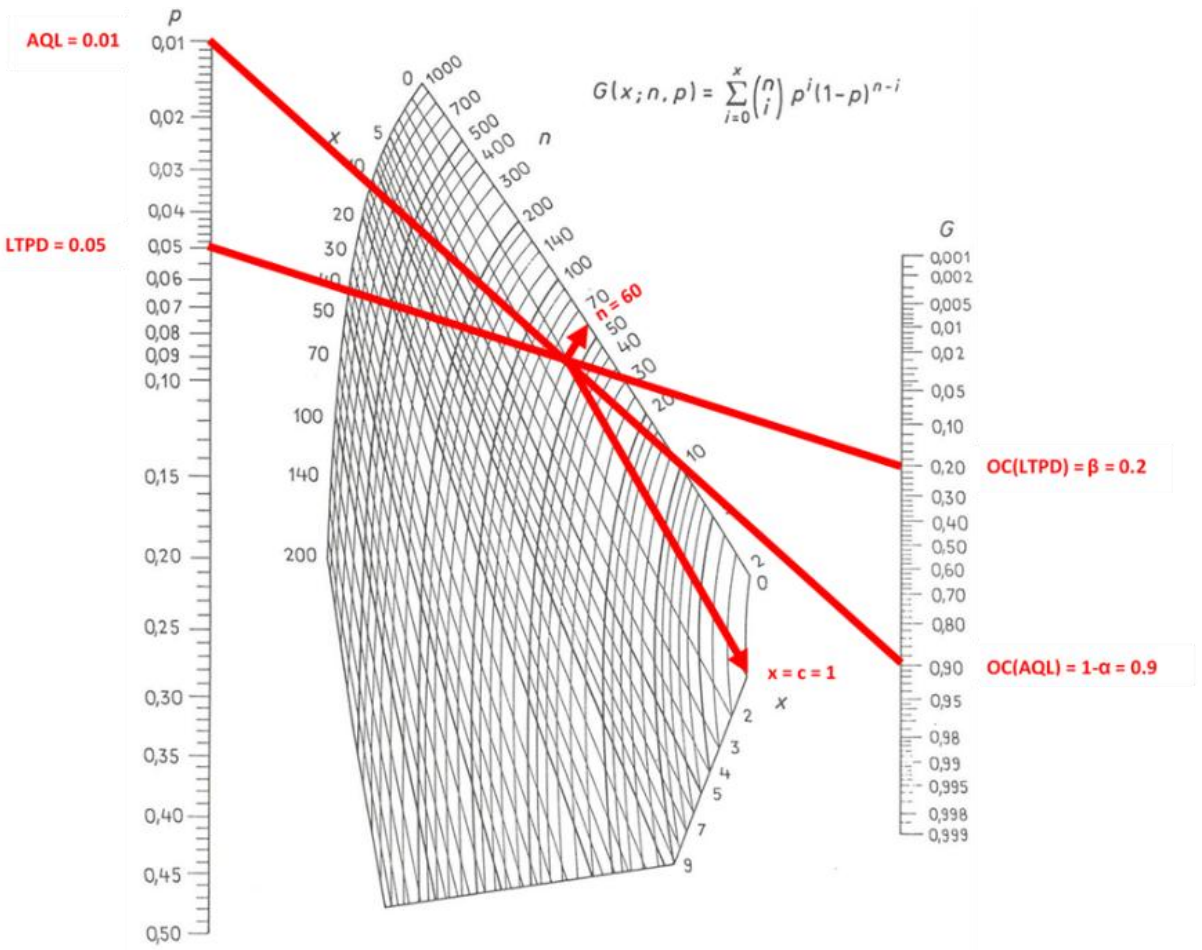
Nomogram for Binomial Distributions

- For a very large lot size N with a sampling plan of producer's risk α, consumer's risk β, acceptable quality level, and lot tolerance percent defective, the sample size n and the accepted number of defectives c can be determined by a nomogram.
- Procedure in determining n and c on nomogram from sampling plan:
    1. Draw a line connecting AQL on the left side with $1 - \alpha$ on the right side
    2. Draw another line connecting LTPD on the left side with β on the right side
    3. The point of intersection of the two lines gives n and c

Acceptance Sampling

Our Sampling Plan and Nomogram

Acceptance Sampling Plan	
Parameter	Value
AQL	0.01
LTPD	0.05
α	0.1
β	0.2
N	1000



Acceptance Sampling

OC, AOQ, and ATI Curves

- **Operating characteristic (OC) curve** – the probability curve for sampling plan that shows the probabilities of accepting lots with various LTPDs with probability of acceptance P_a and is based on the binomial distribution

$$P_a = \sum_{d=0}^{c} \frac{n!}{d!(n-d)!} p^d (1-p)^{n-d}$$

- **Average outgoing quality (AOQ) curve** – the average defective rate in a released lot with a correlation between the quality of incoming and outgoing materials, assuming reject lots are 100% inspected and all defectives are removed

$$AOQ = \frac{P_a p(N-n)}{N}$$

- **Average total inspection (ATI) curve** – the average inspection rate in a lot with a correlation between the quality of incoming materials and the number of items needed to be inspected

$$ATI = n + (1 - P_a)(N - n)$$

Acceptance Sampling

Binomial Distribution in Minitab

Method

Acceptable Quality Level (AQL)	0.01
Producer's Risk (α)	0.1
Rejectable Quality Level (RQL or LTPD)	0.05
Consumer's Risk (β)	0.2

- Our acceptance sampling plan with AQL, LTPD, α, and β are shown.

Generated Plan(s)

Sample Size	86
Acceptance Number	2

Accept lot if number of defects in 86 items ≤ 2; Otherwise reject.

Defects Per Unit	Probability Accepting	Probability Rejecting	AOQ	ATI
0.01	0.944	0.056	0.00862	137.6
0.05	0.197	0.803	0.00902	819.6

- The values obtained for sample size n and the accepted number of defectives c are 86 and 2, respectively. In context for implementing a lockdown our group would test 86 people if they are infected with COVID-19 and 2 people would be the minimum accepted number for the lot being analyzed. The probability of acceptance, the probability of rejection, the AOQ, and the ATI are shown for AQL and LTPD.

Average Outgoing Quality Limit(s) (AOQL)

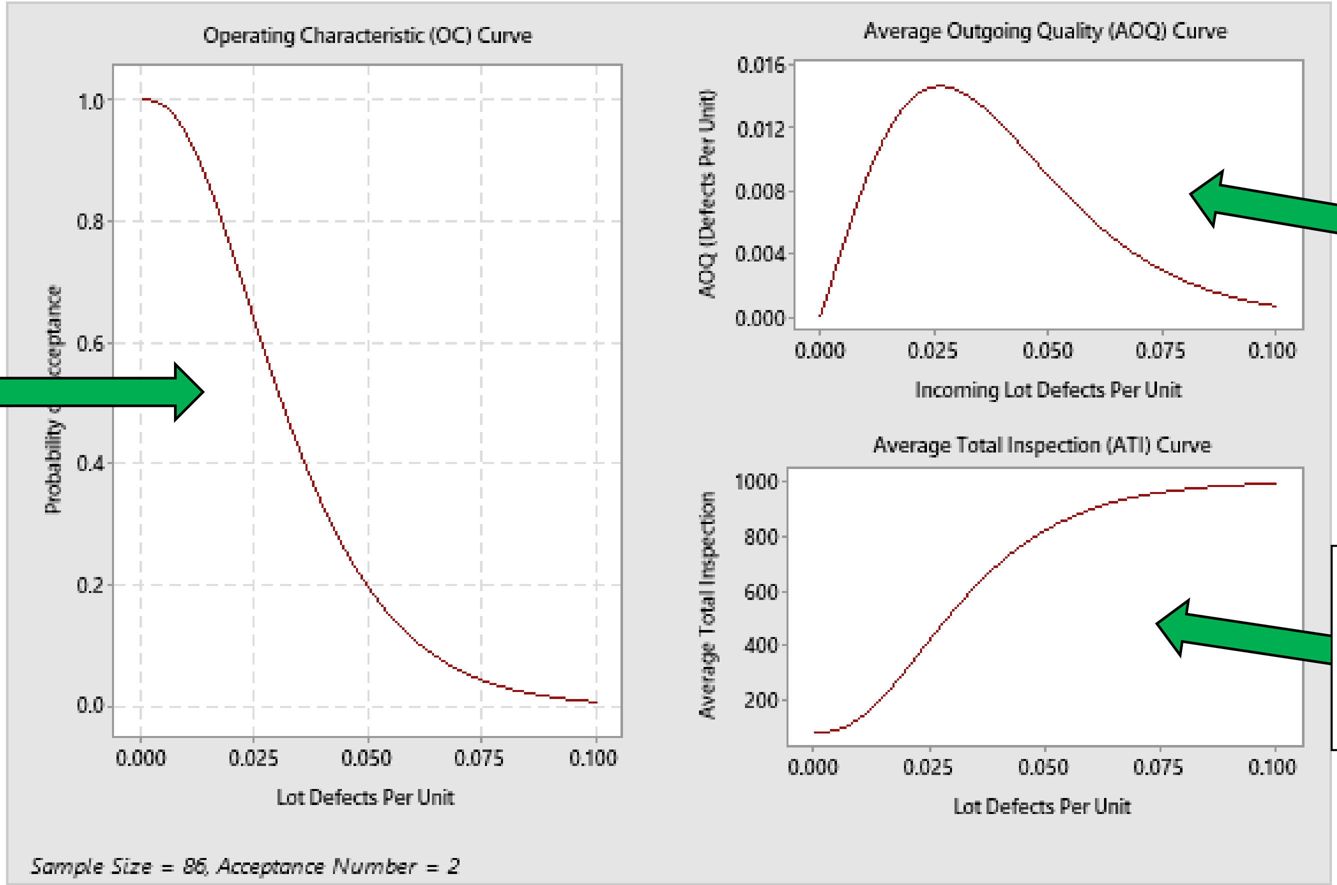
AOQL	At Defects per Unit
0.01457	0.02639

- The AOQ limit is the worst possible quality that results from the rectifying inspection program. Here, the AOQ limit is 0.01457 when the defects per unit is 0.02639.

Acceptance Sampling

Binomial Distribution in Minitab

The probability of acceptance for each lot decreases as the fraction of defective lots per unit increases.



Outgoing lot quality is accepted with a low fraction of incoming defectives or rejected and eliminated/ replaced with a high fraction of incoming defectives. The AOQ limit is the maximum of the AOQ curve.

The average total inspection for each lot increases as the fraction of defective lots per unit increases.

Acceptance Sampling

Binomial Distribution in Excel

OC, AOQ, and ATI for Implementing a Lockdown						
n	60			86		
c	1			2		
N	1000			1000		
P_d	P_a	AOQ	ATI	P_a	AOQ	ATI
0	1.000000	0	60	1.000000	0	86
0.01	0.878767	0.00826	173.9593	0.944466	0.008632	136.7579
0.02	0.661904	0.012444	377.8103	0.752698	0.013759	312.034
0.03	0.459211	0.01295	568.3419	0.521236	0.014292	523.5904
0.04	0.302233	0.011364	715.9009	0.326512	0.011937	701.5679
0.05	0.191553	0.009003	819.9398	0.190008	0.008683	826.3329
0.06	0.117923	0.006651	889.1522	0.104476	0.005729	904.5087
0.07	0.070894	0.004665	933.3594	0.054888	0.003512	949.8325
0.08	0.041771	0.003141	960.735	0.027762	0.00203	974.6259
0.09	0.024181	0.002046	977.27	0.013591	0.001118	987.5781
0.1	0.013777	0.001295	987.0495	0.006465	0.000591	994.0913
0.11	0.007736	0.0008	992.7286	0.002996	0.000301	997.2613
0.12	0.004284	0.000483	995.9727	0.001356	0.000149	998.7604
0.13	0.002342	0.000286	997.7982	0.000600	7.13E-05	999.4512
0.14	0.001265	0.000166	998.8111	0.000260	3.33E-05	999.762
0.15	0.000675	9.51E-05	999.3657	0.000111	1.52E-05	999.8989
0.16	0.000356	5.35E-05	999.6656	0.000046	6.75E-06	999.9578
0.17	0.000185	2.96E-05	999.8257	0.000019	2.93E-06	999.9827
0.18	0.000096	1.62E-05	999.9102	0.000008	1.25E-06	999.9931
0.19	0.000049	8.69E-06	999.9542	0.000003	5.2E-07	999.9973
0.2	0.000025	4.61E-06	999.977	0.000001	2.12E-07	999.9989

Excel Formulas for Calculations:

Probability of Acceptance

$$P_a = BINOMDIST(c, n, p, 1)$$

Average Outgoing Quality

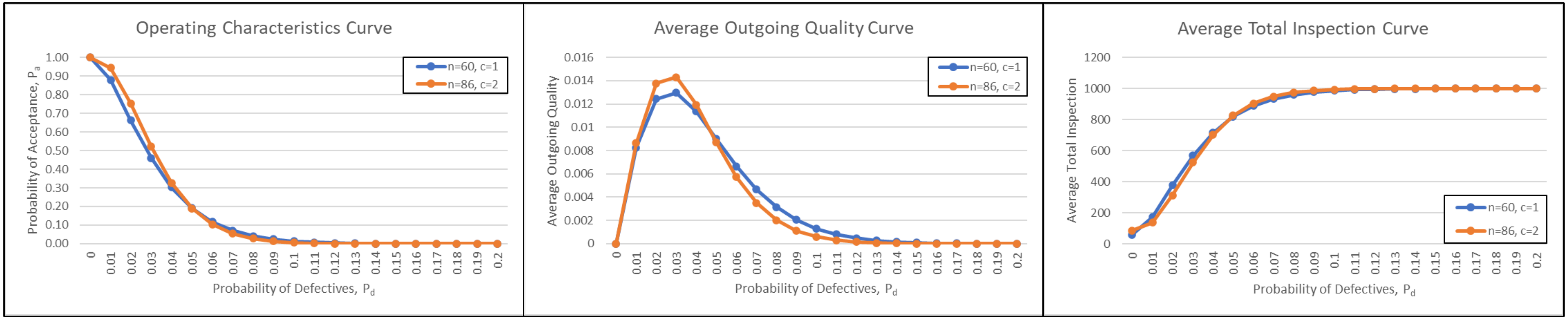
$$AOQ = \left(P_a * p * (N - n)\right)/N$$

Average Total Inspection

$$ATI = n + (1 - P_a) * (N - n)$$

Acceptance Sampling

Binomial Distribution in Excel



Comparing the OC, AOQ, and ATI curves for n and c between the binomial nomogram method ($n = 60, c = 1$) and Minitab ($n = 86, c = 2$), both are approximately equal. Although it is difficult to exactly obtain n and c from the binomial nomogram method, our group had to approximate those values.

Statewide COVID-19 Lockdown

Statistical Process Control (SPC)

Statistical Process Control

What is Statistical Process Control?

- **Statistical process control (SPC)** – a technique that enables the stability of the process and the type of variation involved to be understood
- Detects changes in process average, changes in process variation, and one-off changes
- There are three types of data that can be analyzed in SPC:
  - **Continuous data** – a type of data resulting from measuring a product or service characteristic
  - **Count data** – a type of data resulting from counting things
  - **Attribute data** – a type of data resulting from classifying things

Statistical Process Control

Types of SPC Control Charts

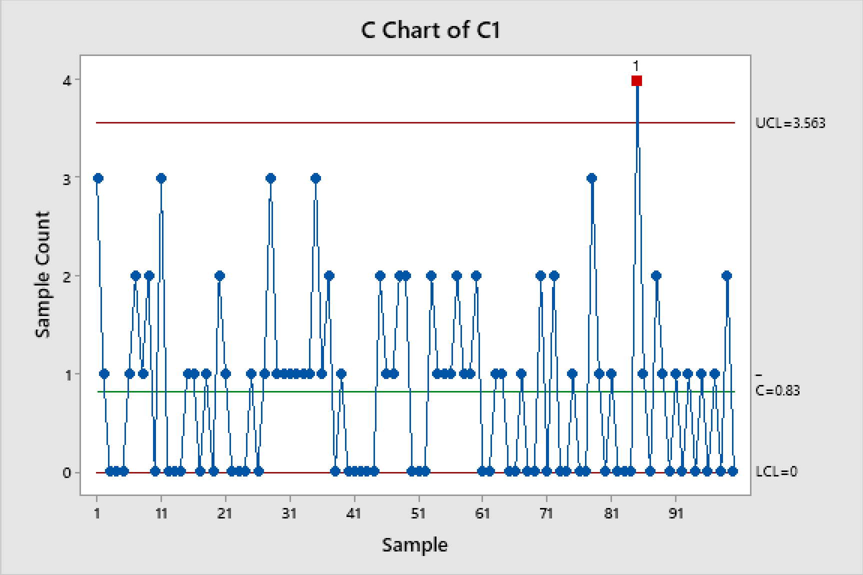
- Continuous data
  - I-MR **chart** – a control chart that analyzes individual data points
  - $\bar{X}$-R **chart** – a control chart that analyzes the averages of small subgroups (of size 2 to 9)
  - $\bar{X}$-S **chart** – a control chart that analyzes the averages of large subgroups (of size 10 or more)
- Count data
  - U **chart** – a control chart that analyzes counts or defects per unit of a variable subgroup size
  - C **chart** – a control chart that analyzes counts or defects per unit of a constant subgroup size
- Attribute data
  - P **chart** – a control chart that analyzes proportions or percentages of a variable subgroup size
  - NP **chart**– a control chart that analyzes proportions or percentages of a constant subgroup size

Statistical Process Control

Attribute Statistical Process Control

- ➢Binomial distribution for daily COVID-19 positivity rate
- ➢Attribute: counting the number of people infected with COVID-19 per 100 people

Positivity Rate of COVID-19 Cases per Day									
D 1-10	**D 11-20**	**D 21-30**	**D 31-40**	**D 41-50**	**D 51-60**	**D 61-70**	**D 71-80**	**D 81-90**	**D 91-100**
3	3	1	1	0	0	0	0	1	1
1	0	0	1	0	0	0	2	0	0
0	0	0	1	0	2	1	0	0	1
0	0	0	1	0	1	1	0	0	0
0	1	1	3	2	1	0	1	4	1
1	1	0	1	1	1	0	0	1	0
2	0	1	2	1	2	1	0	0	1
1	1	3	0	2	1	0	3	2	0
2	0	1	1	2	1	0	1	1	2
0	2	1	0	0	2	2	0	0	0

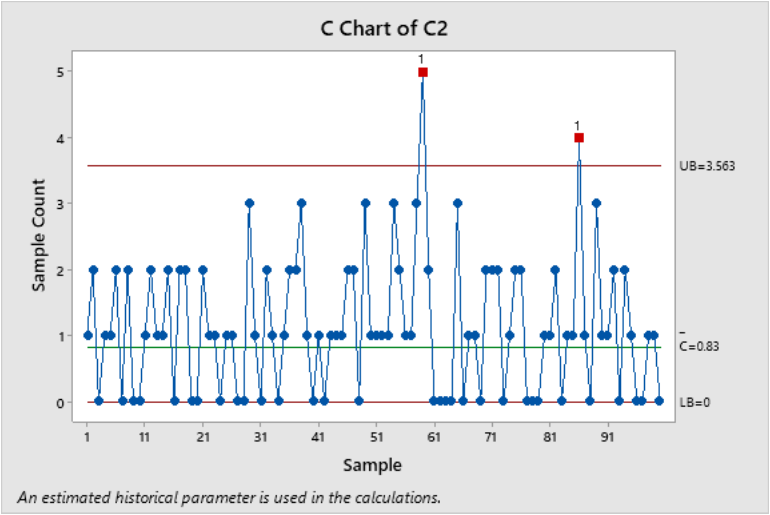


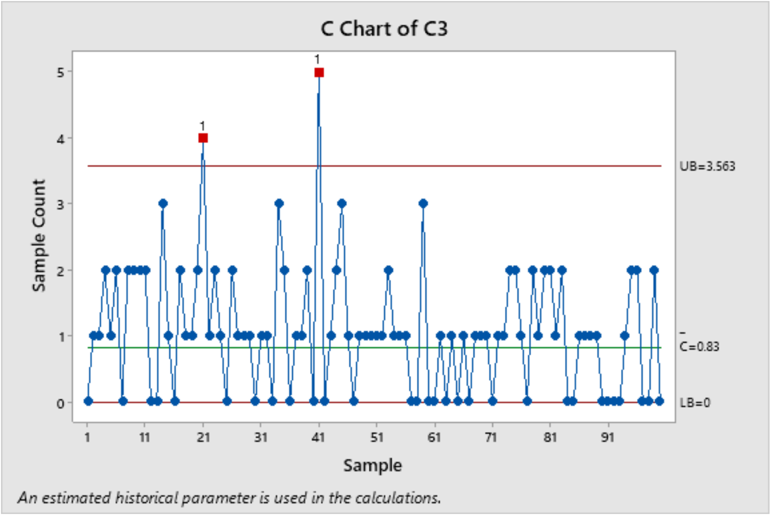
Within a 100-day period, the daily average COVID-19 positivity rate is 0.83% (denoted as $\overline{C}$).

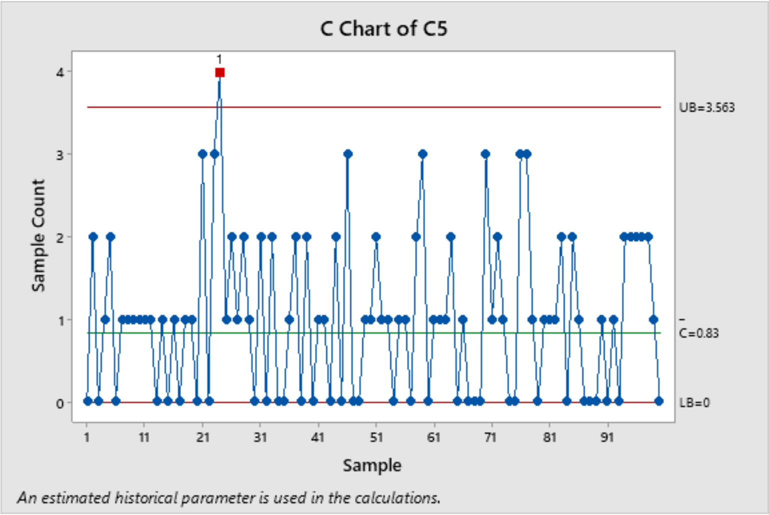
Statistical Process Control

Attribute Statistical Process Control

- Binomial distribution for daily COVID-19 positivity rate



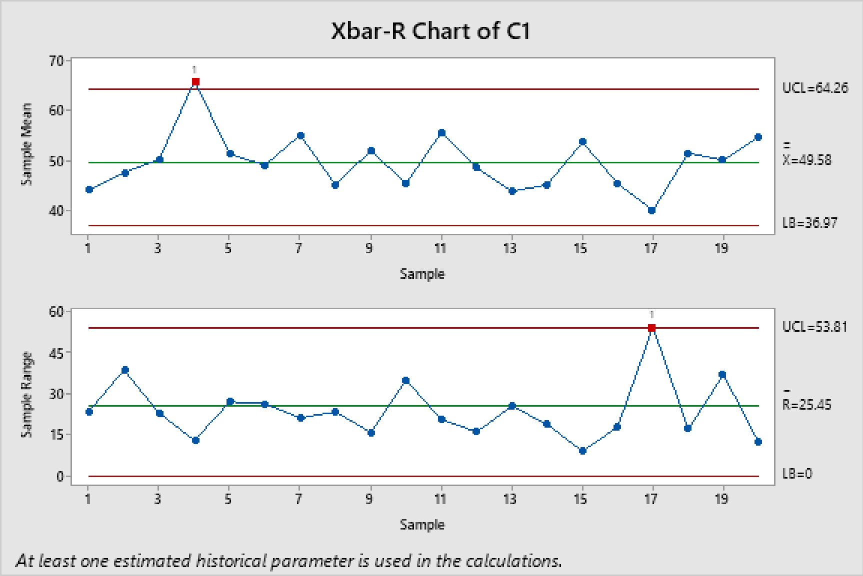




Statistical Process Control

<u>Variable Statistical Process Control</u>

- ➢Normal distribution for daily percentage of social distancing compliance
- ➢Continuous variable: percentage of people complying with social distancing guidelines



Percentage of Social Distancing Compliance per Day									
D 1-10	**D 11-20**	**D 21-30**	**D 31-40**	**D 41-50**	**D 51-60**	**D 61-70**	**D 71-80**	**D 81-90**	**D 91-100**
32.237	39.0082	46.1854	49.2164	49.4968	45.2431	45.6511	51.9666	26.6458	41.4112
36.7944	57.2059	51.4532	54.8669	55.7082	58.9915	46.0228	50.6957	60.8995	56.8945
47.7146	53.8007	62.4974	69.3469	61.4685	49.6313	35.886	51.5273	6.7863	29.5022
47.1068	61.6451	35.6614	53.0237	47.1204	57.982	32.9617	53.8816	56.3437	66.2395
55.5753	38.9603	59.8161	48.4042	45.7741	65.6502	58.1827	59.5019	48.9122	55.7261
41.7914	57.2708	64.7067	51.4885	51.7856	47.272	40.6409	51.8596	41.9396	50.2816
58.521	67.5194	44.218	28.2864	41.4098	54.2163	49.6948	39.3572	52.3737	50.01
29.3883	67.2231	38.5626	45.9133	29.0935	48.9921	56.013	34.3703	58.8012	62.0295
39.8327	66.8985	45.7501	47.9183	63.8141	38.337	41.4281	48.7757	52.1092	57.6127
67.7725	70.0525	51.6197	51.0453	40.09	53.2492	37.3106	52.0728	51.4682	53.0801

Statistics

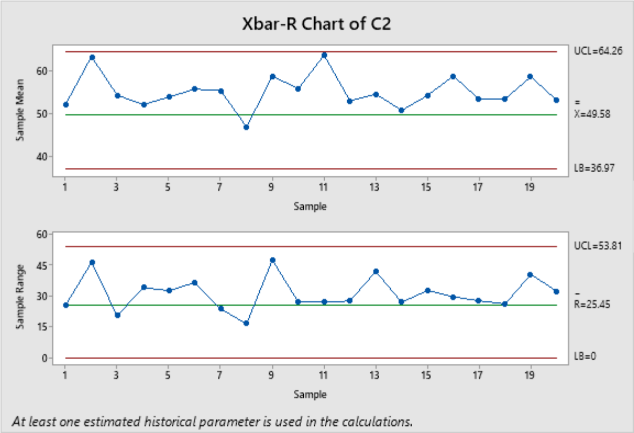
Variable	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3	Maximum
C1	100	0	49.58	1.09	10.94	6.79	41.83	50.87	57.13	70.05

Within a 100-day period, the daily average percentage of social distancing compliance is 49.58% (denoted as $\overline{X}$) with a standard deviation of 10.94%.

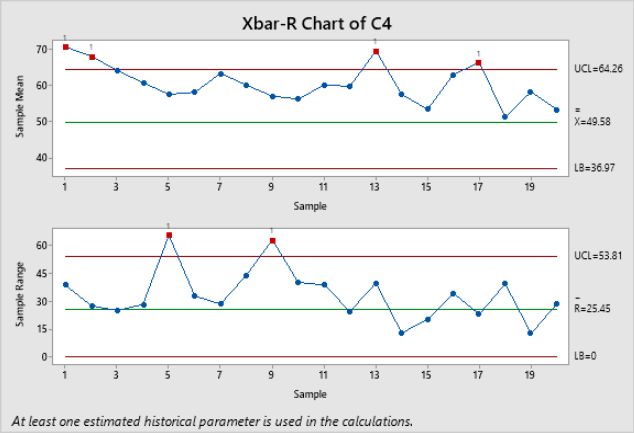
Statistical Process Control

Variable Statistical Process Control

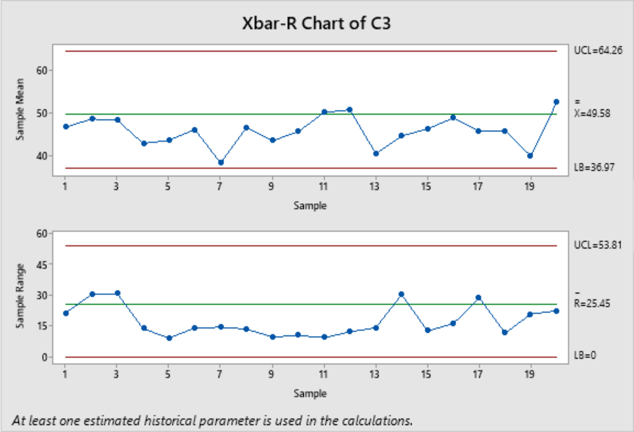
➢Normal distribution for daily percentage of social distancing compliance



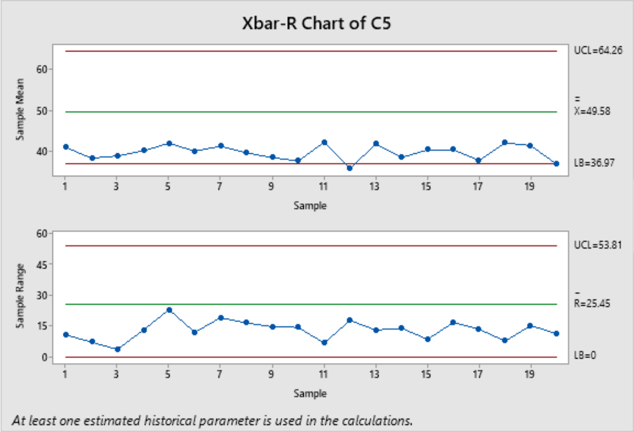
◀ $\mu = 55, \sigma = 12$



◀ $\mu = 60, \sigma = 15$



◀ $\mu = 45, \sigma = 8$



◀ $\mu = 40, \sigma = 5$

Statewide COVID-19 Lockdown

Conclusions

Conclusions

- Our project was to implement an effective state-wide lockdown and the condition we considered to implement a lockdown was positivity rate more than 5%.

- Initially we performed the design of experiment to understand the capability of the process and the significant factors that would contribute majorly to the lockdown.

- Once the process was capable, we made a value stream map to understand the total number of days it will take to complete the entire process and created a future state value stream map with an intention to reduce the total duration of the process. The total duration was reduced from 67 days to 51 days.

- Gauge R&R analysis was performed to see if there are any errors while the same process is being repeated all over the state. Part to part variability was the most significant indicating that different COVID-19 testing sites have different practices.

Conclusions

- After analyzing our measurement system, we created statistical process control charts considering Binomial distribution for COVID-19 cases and normal distribution for percentage of people complying with the social distancing guidelines. The control charts indicated that the process was under control over time since people have started taking the lockdown and social distancing guidelines seriously.

- Hence, to make a final decision on whether to implement a state-wide lockdown we calculate the positivity rate which includes a capable process, correct measurement system with less variability and statistically controlled process with few out of control events during the entire process.

Thank you!

Questions? Comments?