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MFE 634: Productivity and Quality Engineering

RE-OPENING OF SCHOOLS IN NEW YORK STATE

GROUP 4

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1. Overview of the Project

1.1 Introduction

The most important step for school administrators to take before reopening in-person services and facilities are **planning and preparing**.

For the school administrators to have a seamless reopening of schools, a few good strategic Emergency Operation Plans were developed:

- Monitor local COVID-19 data.
- Adopt mitigation strategies to promote healthy behaviors.
- Examine accessibility of information and resources to reduce spread of COVID-19.
- Assess student' special needs.

Based on the above EOP's, we will be evaluating this project

1.2 Background

With an onset of COVID-19 pandemic, there had been a chaos in the operations of schools. Keeping that in mind, we are trying to reopen schools safely, reliably, and seamlessly.

For this analysis, the school area taken into consideration for planning of re-opening schools is the Greater Syracuse area – Onondaga County and the schools considered are:

High Schools	Middle & Pre-K-8 Schools	Elementary Schools
Corcoran	Brighton Academy	Bellevue Elementary School
Henninger	Clary Middle School	Delaware Primary
Institute of Technology (ITC)	Ed Smith Pre-K-8 School	Dr. Weeks Elementary School
Nottingham	Expeditionary Learning Middle	Franklin Elementary School
PSLA @ Fowler	Frazer Pre-K-8 School	LeMoyne Elementary School
	Grant Middle School	McKinley-Brighton Elementary
Alternative Programs	Huntington Pre-K-8 School	Meachem Elementary School
Adult Education	HW Smith Pre-K-8 School	Montessori @ Lemoyne
Elmcrest	Lincoln Middle School	Porter Elementary School
McCarthy @ Beard	Roberts Pre-K-8 School	Salem Hyde Elementary School
Oasis Academy	Syracuse Latin	Seymour Dual Language Academy
PFLA	Syracuse STEM @ Blodgett	STEAM @ Dr. King
		Van Duyn Elementary School
		Webster Elementary School

Figure 1: Schools in Greater Syracuse, NY

The complete analysis done in this project is solely based on the data from CDC. The data is devised; and models are strategized for process analysis lastly, efforts are put in to implement a robust model for reopening of schools.

1.3 Affinity Diagram

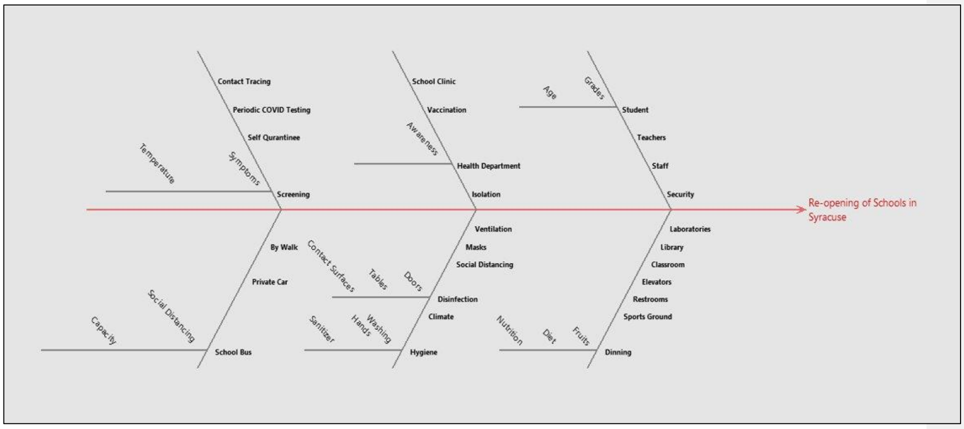
Affinity diagram helps gather various brainstorming ideas, opinions and issues and organizes them into groupings based on the various relationships. The affinity diagram deduced for re-opening of schools is shown as follows:

Table 1: Affinity Diagram

MEASUREMENTS	MATERIALS	MAN	ENVIRONMENT	METHODS	MACHINES
School Clinic	Dinning	Students	Screening	Ventilation	By Walk
Vaccination	Nutrition	Faculty	Symptoms	Masks	Private Car
Health Department	Diet	Staff	Temperature	Social Distancing	School Bus
Awareness	Fruits	Security	Self-quarantine	Disinfection	Social Distance
Isolation/ Quarantine	Sports Ground		Periodic COVID Testing	Doors, Tables, Contact Surfaces	Capacity
	Restrooms		Contact Tracing	Climate	
	Classroom			Hygiene	
	Elevators			Washing Masks	
	Laboratories & Library			Sanitizer	

1.4 Ishikawa Chart

Based on the Affinity Diagram, we derived an Ishikawa Chart; the Ishikawa Chart shows the causes of an event, this helps in quality control and determine which resources need to be used at what specific time. Depending on the Ishikawa Chart, we selected five major qualities based on which we carried out our analysis.



1.5 Process Flow Chart

A summarized process flow chart designed for re-opening of schools efficiently and smoothly:

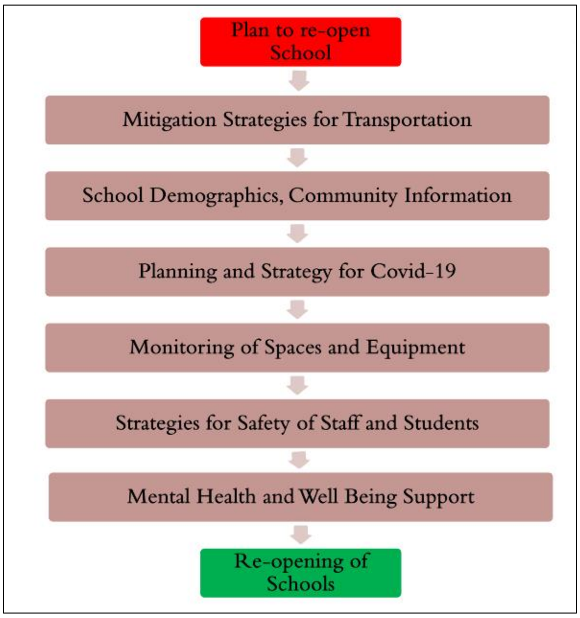


Figure 2: Process Flow

A detailed process flow chart for re-opening of schools is as depicted:

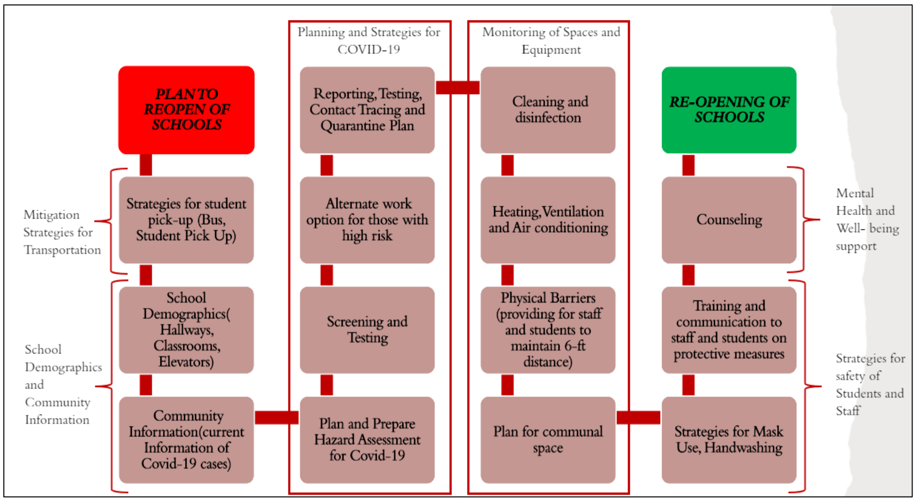


Figure 3: Detailed Process Flowchart

1.6 Organizational Flow Chart

To implement the above processes smoothly and efficiently, the organizational chart below portrays the crucial individuals that are required to re-open schools:

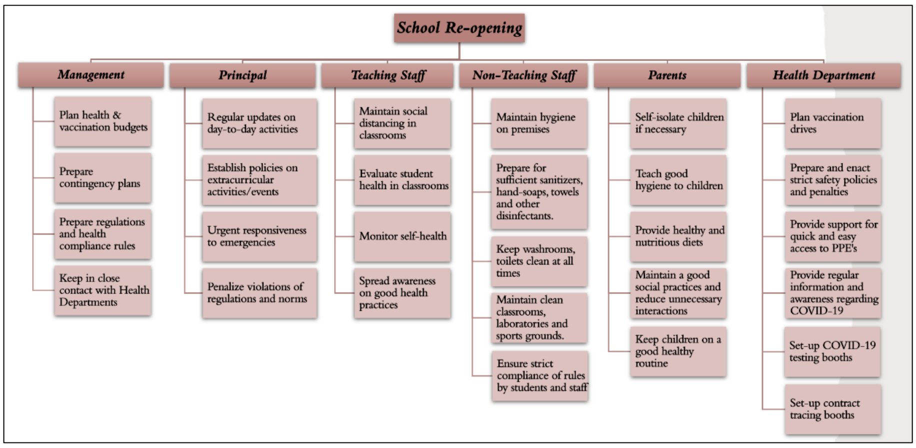


Figure 4: Organizational Flow Chart

2. Assessment and Analysis of COPQ

2.1 Definition

The cost of poor quality is the annual monetary loss of products and processes that are not achieving their quality objectives. To understand various failures to reopen schools, we carried out COPQ based on five categories which might have a crucial role to play. The five main categories considered are: **Hygiene, Social Distancing, PPE's, COVID Testing and Tracing and Personnel**.

2.2 Categories of Cost of Poor Quality

There are four categories COPQ can be divided into –

1. **Internal Failure Costs**: The cost of deficiencies discovered before delivery that are associated with the failure to meet explicit requirements or implicit needs of customers which also includes avoidable process losses and inefficiencies that occur even when requirements and neds are met.
2. **External Failure Costs**: The costs associated with the deficiencies that are found after the customer receives the product which also includes the opportunities for sales revenue.
3. **Appraisal Costs**: The costs incurred to determine the degree of conformance to quality requirements.
4. **Prevention Costs**: The costs incurred to keep failure and appraisal costs to a minimum.

Table 2: COPQ Analysis of Reopening of Schools

COPQ	***Internal Failures***	***External Failures***	***Appraisal Failures***	***Prevention Failures***
Hygiene	1. Not washing hands before and after meals 2. Improper Ventilation	1. Insufficient cleaning materials 2. Unclean utensils and takeaway boxes 3. Usage of unsanitary equipment	1. Periodic checklists for cleaning equipment inclusive of checking expiration 2. Food quality checks	1. Quality checks by health department 2. Sufficient inventory for hygiene related materials
Social Distancing	1. Students and faculty ignoring the 6 feet gap 2. Overcrowding of spaces	1. Lack of open spaces	1. Proper planning for classroom capacities, social distancing practices	1. Awareness on social distancing protocols and repercussions

PPEs	1. No usage of masks, face-shields, gloves	1. Shortage of PPEs from supplier	1. Quality checks of PPEs received in the facility 2. Demand Planning for PPEs	1. Awareness on wearing PPEs and their consequences for not wearing them
COVID Testing & Tracing	1. Lack of testing technology 2. Lack of testing materials 3. Lack of testing sites 4. Lack of contact tracing system	1. Improper disposals of used testing materials 2. Lack of training to handle highly contagious samples	1. Training of employees for testing, tracing, and equipment handling 2. Proper database management for testing, tracing	1. Proper checklists for every equipment and material 2. Barcodes for sample classification and error-proofing
Personnel	1. Lack of knowledge for using online class platforms 2. Lack of awareness on safety measures and precautions 3. Shortage of health personnel	1. Lack of surveillance for maintaining safety measures. 2. Software malfunctions	1. Proper training for online classes to faculty and students 2. Scrutiny for maintain safety measures	1. Simplified steps for connecting over internet for online classes 2. Proper resource allocation for health staff

3. Six Sigma (DMAIC/DFSS)

3.1 Introduction to Six Sigma

Six-sigma is a powerful quality tool used to reduce the variation in different processes and prevent any deficiencies and discrepancies in the process. In midst of a pandemic, it is evident that there will be several variations causing discrepancies in the process of re-opening schools, which will hinder the fulfilment of the objectives set for this project. Therefore, an approach towards incorporating the six sigma tools is a welcome move for this project, this will not only ensure re-opening of schools at 100% capacity but also will ensure the decrease in spread of infection. Six sigma focuses on 6 phases, being Define, Measure, Analyze, Identify and Control. In brief, this tool will allow to reopen the schools by identifying the problems posed for the fulfilment of the objective in the first phase, after which we can measure the extent of the problems identified in the second phase, then using the tools of six-sigma we can conduct a thorough analysis from the up-to-date data for the state of re-opening schools, spread of infection and current state of the number of team members defined in the six verticals of the organizational flowchart. This data then gives the ability to implement various improvements in the identified problem areas in the fourth phase and that is when a set of checklists can be formulated in order to keep a check on the various improvements implemented as this will ensure that the re-opening of schools at a 100% capacity while keeping the spread of infection at a minimum is never compromised.

Phase 1 – Define

The goal of this phase is to identify potential projects, select and define a project while setting up a project team. It includes problem identification and the probable business case associated with it.

a. Business Case:

The goal is 100% re-opening of schools in Onondaga District – Syracuse by June 2021 while maintaining a safe and secure in-person schooling experience to students and staff while also avoiding health safety and hygiene lapses that would incur large financial losses and legal consequences.

b. Problem Statement:

By June 2021, a 100% re-opening of Schools in Syracuse Onondaga District requires the total number of COVID 19 positive cases less than 5% of the total number of student enrollments.

c. Communication Plan:

A plan of communication between the various stakeholders is also tabulated, as shown in Table 3, this gives clear instructions to every team member as to what mode of communication to use and the frequency of communicating with rest of the teams.

Table 3: Communication Plan

Version:	**1**				
Date:	**03-07-2021**				
Stakeholder Name	**Method**	**Purpose**	**Team member responsible**	**Frequency**	**Notes**
	(email updates, invite to tollgate, phone call, send slides)	**(why & what)**	**(or sponsor)**	**(dates)**	
Management	e-mail updates, invite to tollgates, scheduled meetings, phone calls	critical approvals, project updates	Shreya	at tollgate, monthly	Interaction as needed
Principal	e-mail updates, invite to tollgates, scheduled meetings, phone calls	information, execution	Shreya	at tollgate	Participate in weekly meetings
Parents	e-mail updates, send slides, invite to tollgates, weekly meetings, phone calls	regular information, execution, keep updated	Saad	weekly, at tollgate	Closely Involved
Teachers	e-mail updates, invite to tollgates, scheduled meetings	process information	Saad	As needed	Participate in weekly meetings
Students	e-mail updates, scheduled meetings	process information	Dhanesh	As needed	Interaction as needed
Health Department	e-mail updates, invite to tollgates, scheduled	key updates, legal procedures	Manas	As needed	Interaction as needed

	meetings, phone calls				

d. Stakeholder Analysis

To understand the impact of the stakeholders for ensuring the success of the objectives set, a table consisting of the very same information is put together. Table 4 describes influence, an action plan, and the attitude of the stakeholder towards the project.

Table 4: Stakeholder Analysis

Version :	*1*	*Keep the Stakeholder Analysis Confidential*				
Date:	*03/07/2021*					
Stakeholder Name	***Stakeholder impact on project***	***Stakeholder level of influence on success of project***	***Stakeholders current attitude towards project***		***Stakeholder score (H=3, M=2, L=1,***	***Action Plan for Stakeholder***
	(H, M, L)	*(H, M, L)*	*(+, 0, -)*	*Comments*	*+=1, 0=2, -=3)*	
Management	H	H	+	Driving the project, interested in the outcome	9	
Principal	H	H	+	Driving project	9	Avoid getting influenced or carried away in a direction towards personal objectives.
Parents	M	M	+	Supports project, interested in outome	4	
Teachers	L	L	0	Familiar with project and objective	2	
Students	L	H	-	key priority and crucial to the project outcome	9	Be ready for any obstacles regarding design/process flows and operations.
Health Department	L	H	+	Driving the project, interested in the outcome	3	

e. SIPOC Chart:

The important elements of this project must be identified so that the scope this project can be defined. Table 5 defines the various suppliers involved, the inputs required from the stakeholders, the requirements of the process the process steps, the outputs to be expected and the requirements of the customer and the customers that are being served, this will ensure a proper flow in terms of equipment, manpower and streamlined processes for re-opening schools at a 100% capacity.

Table 5: SIPOC

SIPOC: Re-opening of Schools						
S	I	Process Requirements	P	O	Customer Requirements	C
Suppliers	Inputs		Process	Outputs		Customers
NIH	COVID 19 guidelines & mandates		Refer COVID 19 guidelines	Accurate COVID 19		Teachers
CDC	Virus related information & vaccine updates		Evaluate Virus related risks	Accurate virus propagation and prevention information		Parents
Mayor's Office	State-wide info on restrictions and policies		Understand & Assess state-wide restrictions	Correspond and plan better COVID contingency strategies		Students
Syracuse Dept. of Health	Permissions & grants related to School activities		Get Approvals from State Health Dept.	Quick Policy approvals and outbreak containment support		
SUNY Upstate Hospital	Vaccination, Rapid Testing and Screening facilities and services		Collaborate with SUNY Upstate Hospital	Quick testing, results and vaccination drives		
PPE Manufacturers	Masks, Sanitizers, Face-shields, Gloves			Sufficient inventory of protective materials		
Management	Updated directions to the respective school authorities		Procure sufficient PPE materials	Ability to implement effective strategies		
Principal	Execute orders and enact protocols for smooth learning		Enforce regulations and prevention procedures	Enact rules and drive good hygiene and social practices		

f. Critical to Quality Characteristics (CTQC) Chart:

To convert the requirements into a measurable form of specifications, a preliminary analysis is conducted to understand the critical measures that can hinder the various quality characteristic. For this project we can formulate that the main CTQC would be the infection rate of the virus amongst, the students and staff alike as shown in Figure 5.

Customers	Need	Drivers	CTQC's
▪ Management ▪ Principal ▪ Teachers ▪ Parents ▪ Students	▪ Low positive cases ▪ Avoid out-breaks ▪ Sufficient PPE's ▪ Vaccination ▪ Rapid Testing & Screening	▪ Accurate Information ▪ Practical strategies ▪ Quick Implementations ▪ Efficient Inventory Management ▪ Detailed Risk Analysis and Control Planning	▪ Infection rate ▪ Number of positive cases/per unit period ▪ Inventory cycle count ▪ Physical inventory (demand rate vs supply rate) ▪ Turns ratio

Figure 5: CTQC Chart

Phase 2 – Measure

The goal of this phase is to measure the **process** to determine its current performance and quantify the problem. It consists of documenting the process and planning for Data Collection.

a. **Risk Assessments:** First, the major risk factor must be traced, over here, the Fig. 6 indicates the steps on the working of the virus depending on the person's susceptibility towards the virus.

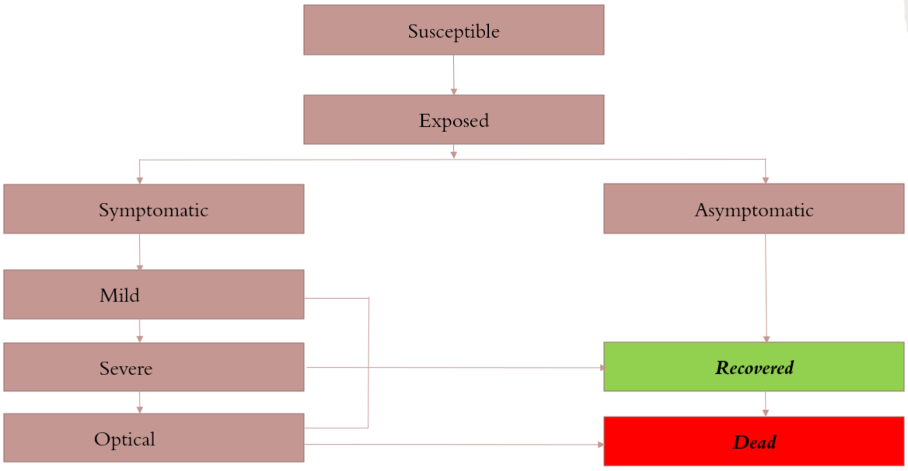


Figure 6: Risk Assessments

b. **Key Performance Indicators:** Based on the risk assessments and the identification of problems and defining the significant points from the grassroots level, we can define the major key performance indicators of this project, which will drive the success of the objectives set, these KPIs are indicated in the Fig. 7.

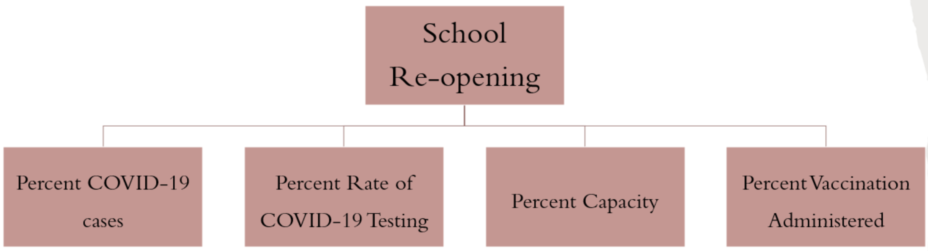


Figure 7: Key Performance Indicators

Phase 3 – Analyze

The Analyze Phase of **DMAIC** helps project teams identify problems in the production process that cause product defects. This phase of Six Sigma methodology is loaded with tools to help spot the problems in the production process and to determine if these problems are the root causes of defects.

a. Data Collection of infected cases in Oneida, Onondaga, and Oswego County -

Table 6: Data Collection

District	County	Enrolment	Total cases / 1000 students	Total cases	Students In-Person	Students remote	Staff
Sherrill	Oneida	1411	28.3	40	9	20	11
Waterville	Oneida	705	25.5	18	10	0	8
Oriskany	Oneida	653	23	15	1	3	11
New Hartford	Oneida	2565	22.2	57	18	24	15
Clinton	Oneida	1247	21.7	27	11	10	6
Sauquoit Valley	Oneida	942	20.2	19	7	5	7
Whitesboro	Oneida	3053	19	58	4	33	21
Remsen	Oneida	439	18.2	8	3	0	5
Adirondack	Oneida	1161	18.1	21	5	8	8
Westmoreland	Oneida	919	16.3	15	7	2	6
Holland Patent	Oneida	1241	16.1	20	5	6	9
NY Mills	Oneida	560	16.1	9	3	3	3
Camden	Oneida	2010	15.4	31	0	14	17
Rome	Oneida	5288	11.9	63	0	32	31
Utica	Oneida	9665	6	58	0	10	48
Skaneateles	Onondaga	1296	46.3	60	35	15	10
Solvay	Onondaga	1457	30.9	45	24	10	11
Lafayette	Onondaga	869	29.9	26	6	15	5
Westhill	Onondaga	1699	28.3	48	37	0	11
Baldwinsville	Onondaga	5333	28.1	150	93	24	33
West Genesee	Onondaga	4300	24.9	107	68	10	29
Liverpool	Onondaga	6836	24.4	167	108	16	43
Tully	Onondaga	738	24.4	18	15	3	0
North Syracuse	Onondaga	8248	22.3	184	102	41	41
Syracuse	Onondaga	20028	21.6	433	150	122	161
Fayetteville-Manlius	Onondaga	3993	20.8	83	39	11	33
Jordan-Elbridge	Onondaga	1020	19.6	20	12	3	5
Jamesville-DeWitt	Onondaga	2597	18.1	47	37	4	6
Lyncourt	Onondaga	393	17.8	7	3	1	3
Marcellus	Onondaga	1478	17.6	26	11	3	12
Onondaga	Onondaga	821	17.1	14	4	7	3
Fabius-Pompey	Onondaga	593	15.2	9	1	3	5
East Syracuse Minoa	Onondaga	3327	14.7	49	15	21	13
Central Square	Oswego	3574	22.9	82	26	32	24
Altmar-Parish-Williamstown	Oswego	450	22.2	10	6	1	3

Mexico	Oswego	2003	20.5	41	25	3	13
Fulton	Oswego	3226	20.1	65	45	1	19
Phoenix	Oswego	1644	13.4	22	10	4	8
Pulaski	Oswego	972	13.4	13	5	3	5
Hannibal	Oswego	1400	12.9	18	3	6	9
Oswego	Oswego	3528	9.9	35	16	3	16
Sandy Creek	Oswego	653	7.7	5	1	2	2

b. Pareto Analysis

Pareto principle is also known as 80/20 rule. In the graph, almost 66% and 14% of the total cases by county are from Onondaga and Oneida, respectively. Hence, for our project we will be concentrating on Onondaga County.

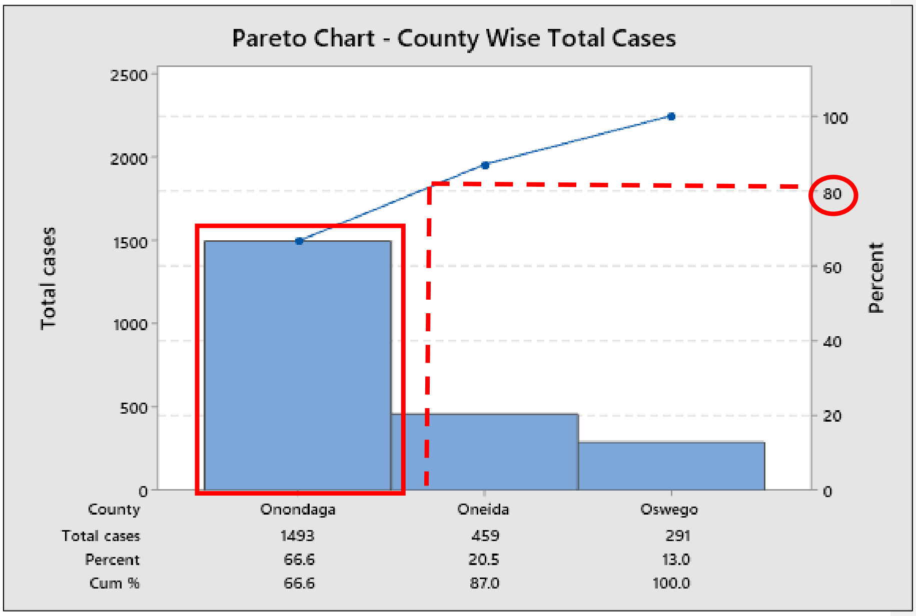


Figure 8: Pareto Analysis

c. Probability Plot –

Probability plot is an indicator whether the data is or is not of the normal distribution, the p-value is 0.005 which is lesser than the significance level of 0.05 and it hence it does not follow normal distribution. Therefore, this data is the converted into a normal distribution using the Box-Cox transformation.

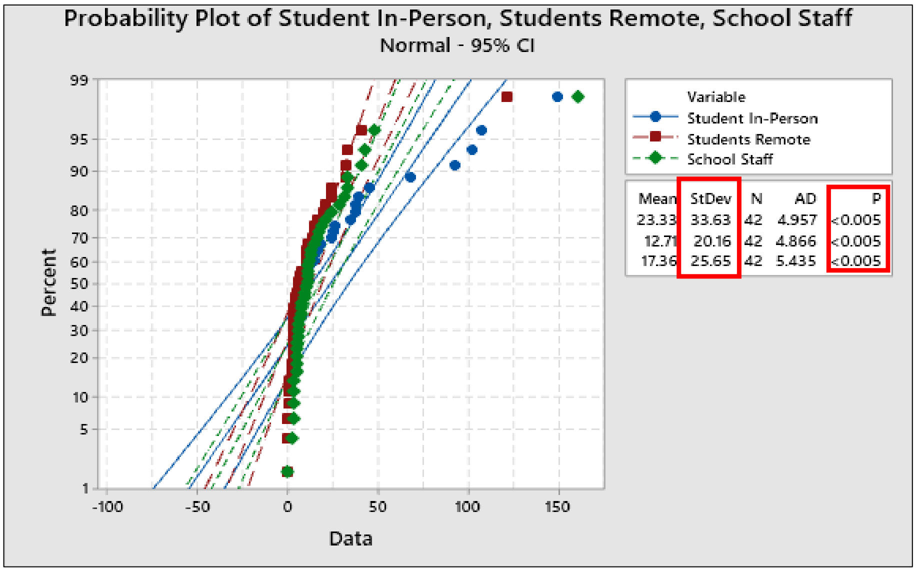


Figure 9: Probability Plot

d. Scatterplot –

Scatterplot gives us wide view of the number of infections amongst students taking in-person instruction, students studying remotely and the staff data at the beginning is quite inter-related but gradually shoots up indicating that the rate of infection amongst students taking in-person classes is higher than the students studying remotely and the staff of the schools.

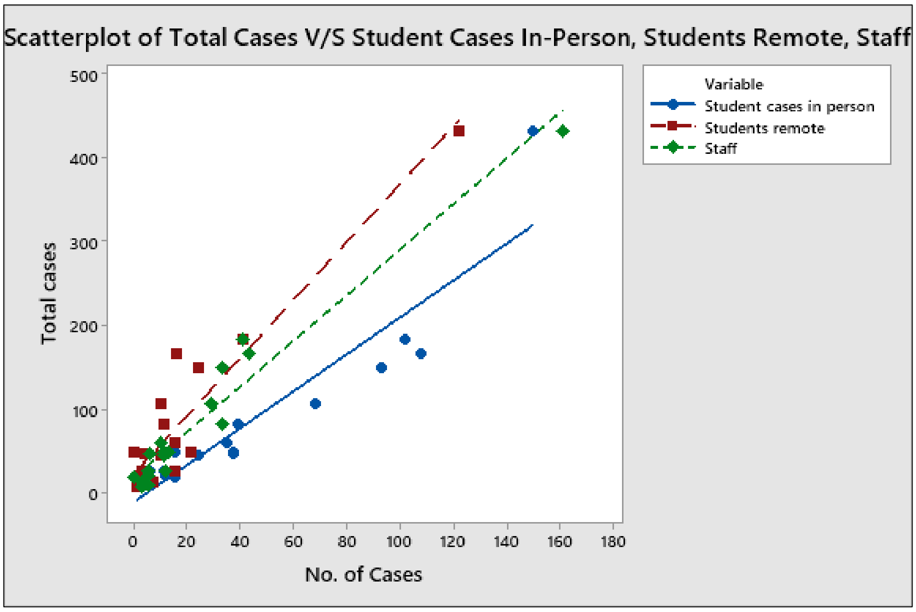


Figure 10: Scatterplot

e. Boxplot –

The box plot below indicates the data distribution of total cases in the three counties taken into account, Oneida, Onondaga, and Oswego. It clearly shows that Onondaga has the most cases and is the problem group, therefore the focus has to be on schools in Onondaga county. Also, Fig 11, indicates that the highest number of infections are from the students taking in-person classes in the Onondaga County. Therefore, the focus should shift to the reduction in rate of infection for re-opening of schools in Onondaga County.

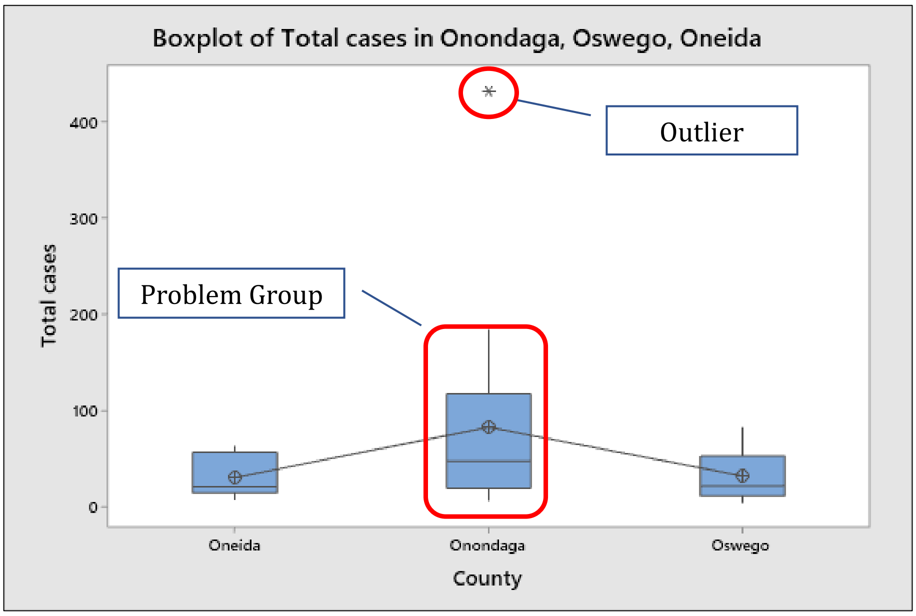


Figure 11: Box Plot of Total Cases in Onondaga, Oswego and Oneida

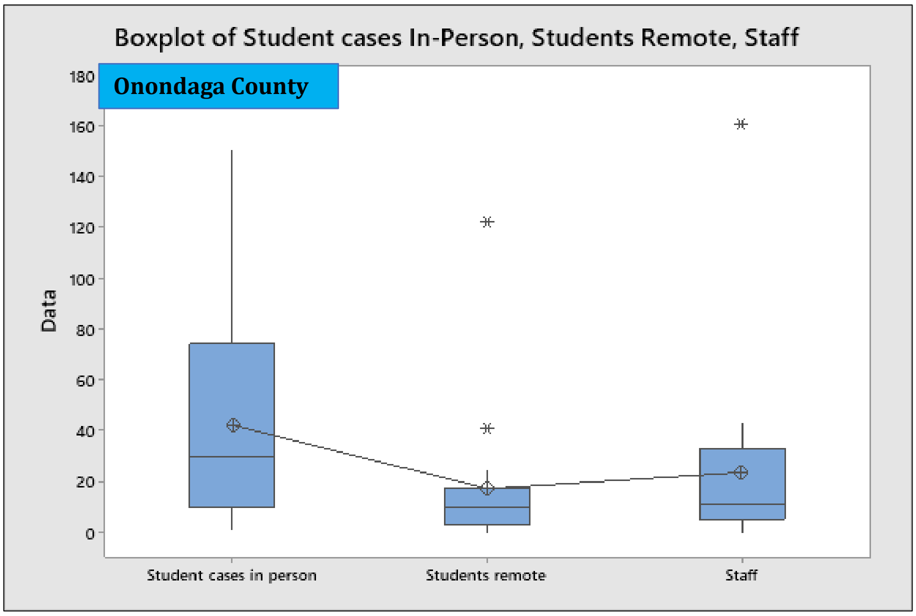


Figure 12: Boxplot of Students in-person, remote and Staff

f. Histogram:

The first three histograms, Fig. 13, Fig. 14, Fig 15, give us a data distribution of the number of cases occurring amongst students taking classes in-person, remotely and the staff over a given frequency. The last histogram, Figure 16 is the combination of the first three graphs therefore giving an overview of the number of cases and rate of infection.

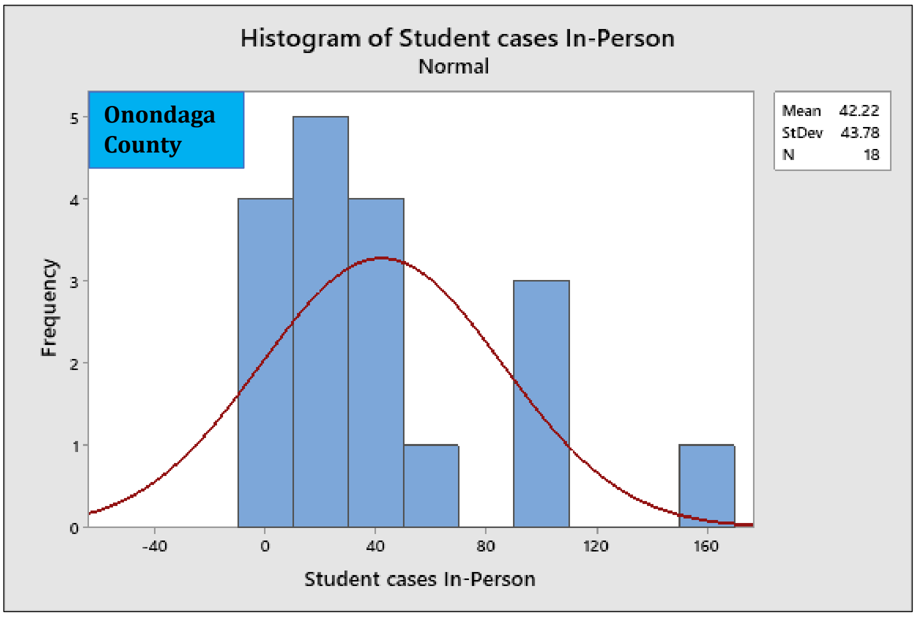


Figure 13: Histogram of Student Cases in-person

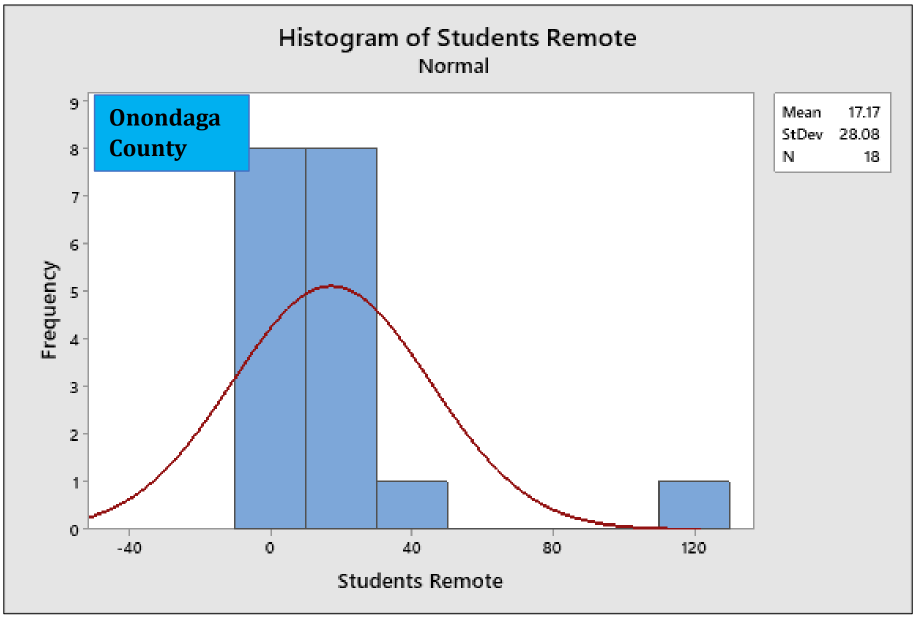


Figure 14: Histogram of Students Remote

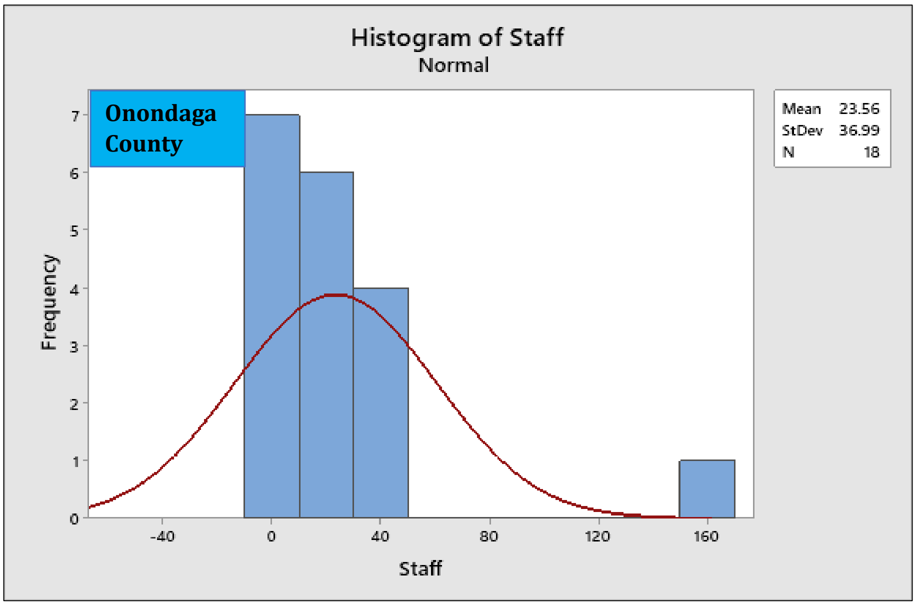


Figure 15: Histogram of Staff

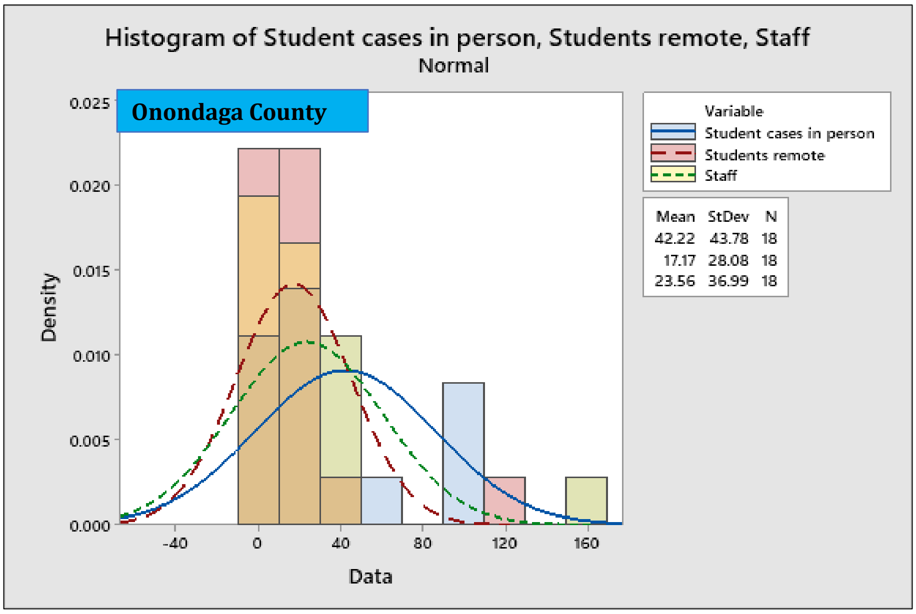


Figure 16: Histogram of student cases in-person, students remote, staff

g. I-MR Chart

The individual and moving range chart helps us to follow the variability in the process of re-opening of schools with respect to the number of cases amongst students and staff and tracks the rate of infection.

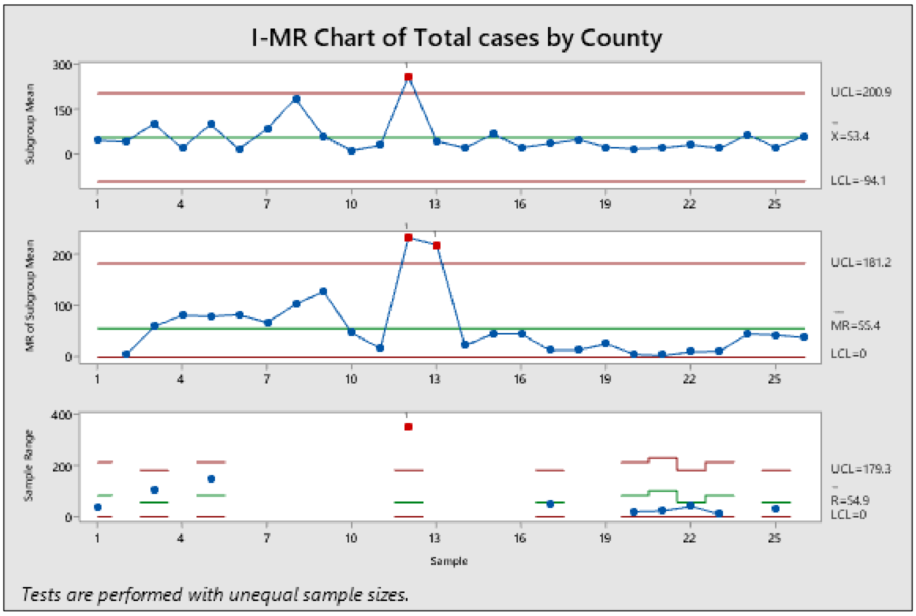


Figure 17: I-MR Chart

h. Capability Sixpack Report

The Capability sixpack report summarizes all the various data charts produces which makes it easier for comparison and understanding the data.

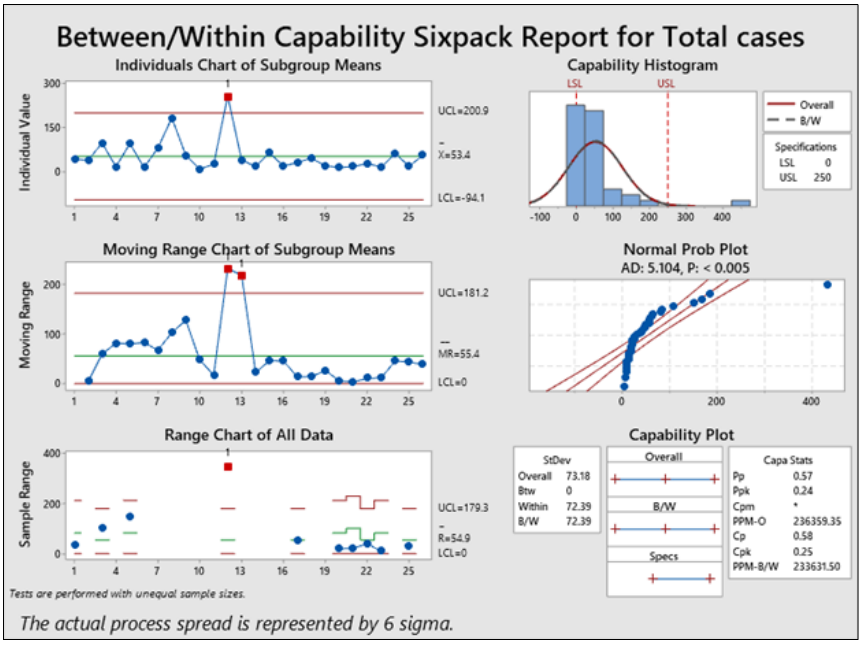


Figure 18: Between/Within Capability Sixpack Report for Total Cases

Phase 4 – Improve

The Improve Phase is where the team gets to solve the problem. They develop solutions, pilot the process changes, implement their ideas, and collect data to confirm they made a measurable difference.

Various solutions to apply for different problems -

1. Improvement strategies
    - Risk Assessment Plans and Recommendations
    - Critical Analysis and Contingency Planning
2. Failure Mode and Effect analysis
    - Detailed FMEA Chart
3. Design of Experiments
4. Poke-Yoke (Error Proofing)

Table 7: Error Proofing

Factor	Problem Description	Solution	Impact Score (H=5, M=3, L=1)
Hygiene	Improper ventilation	Revamp of ventilation system across the school	3
		Periodic check of air flow across the school and monitoring percentage of harmful gases in the air	
	Bad hygiene habits like not washing hands properly and not sanitizing any equipment before usage	Awareness programs and daily activities highlighting the importance of good hygiene	1
		Posters and awareness sheets to be put up across school	
	No checks for expiration of cleaning and sanitizing equipment	Checklists to be filled out daily for cleaning and sanitizing equipment	3
		Proper database management of every material arriving in the school	
PPEs	Improper usage of PPEs by faculty and students alike	Daily checks and penalties for improper usage	3
		Proper training and lessons on use of PPEs	
	Shortage of PPE	Demand planning of PPEs and proper distribution of the same across the school daily	5
		Database tracking of daily PPEs usage and wastage	
Covid Testing & Tracing	Lack of proper testing equipment and technology	Procurement of proper equipment and training of assigned personnel for the testing technology	5
		Checklists for using the equipment and including the	

		monitoring of the expiration of equipment	
Personnel	Software malfunctions	Strong periodic maintenance checks	3
		Immediate response by the IT team to any query raised by the members of the institution	
	Lack of healthcare professionals	Training given to non-medical staff for emergencies	5
		Proper resources provided to the healthcare professionals	

Phase 5 – Control

The Control Phase involves implementing the actual changes, whether they be physical, behavioral or both. In this phase we will present ways to help monitor the "new way" so that practices do not revert to the old way of doing things.

Table 8: General Checklist for Control of Errors

General Checklist for Control of Errors				
Sr. No.	Factor	Preventive Measure	Periodic Interval	Responsible Party
1	Hygiene	Check expiration dates of cleaning and sanitizing supplies	Daily	Non-teaching staff
2		Air flow check through vents in classrooms, hallways and public areas	Daily	Non-teaching staff
3		Daily database entry of new supplies arriving	Daily	Non-teaching staff
4	PPEs	Awareness programs on usage of PPEs and hygiene	Weekly	Teaching Staff
5		Checking proper usage of PPEs by members of the institution	Daily	Non-teaching staff
6		Demand planning, tracking, distribution and wastage of PPEs	Weekly	Management
7	Covid Testing & Tracing	Maintenance of all testing equipment and technology	Weekly	Health Department
8		Step wise handling and usage of the testing technology	Daily	Health Department
9		Database management of all the Covid-19 testing equipment &	Daily	Health Department

		technology inclusive f expiration date check		
10	Personnel	Maintenance of all servers and cloud systems for online classes	Weekly	Management
11		Briefing to trained non-medical personnel	Daily	Health Department
12		Resource allocation to all medical and non-medical personnel	Daily	Health Department

Table 9: Decision Tree for School Reopening

Indicator	**Lowest risk of transmission in schools**	**Lower risk of transmission in schools**	**Moderate risk of transmission in schools**	**Higher risk of transmission in schools**	**Highest risk of transmission in schools**
New cases per 100,000 population in the last 14 days	<5	5 to <20	20 to <50	50 to ≤ 200	>200
(For comparison to new thresholds, equivalent new cases per 100,000 in 7-day period shown in parentheses)	(2-3 in 7 days)	(3-9 in 7 days)	(10-24 in 7 days)	(25-100 in 7 days)	(>100 in 7 days)
RT-PCR diagnostic test result positivity rate in the last 14 days	<3%	3% to <5%	5% to <8%	8% to ≤ 10%	>10%

3.2 Design for Six Sigma

To develop a six-sigma plan that can be implemented, a design is formulated which will help a service or a product to be built from ground up, therefore, in order to implement the fundamentals of DMAIC we need to look into DFSS in order to ensure a safe and effective re-opening of schools. DFSS again has 6 phases with a variation being in the last two phases as that of DMAIC, Design and Verify. For this project, a list of design recommendations, as listed in Table 10, would be provided to be implemented and be converted into improvements once a though verification process is completed, as seen in Table 11.

Phase 4 – Design

Table 10: Design for Six Sigma

Factor	Design Recommendation (A: In-person sessions, B: Hybrid Sessions, C: Online Sessions
Hygiene	A. Installation of new and improved ventilation system across the school area.
	B. Introduction of proper database management system to track supplies, temperature checks of students, tests results and expiration dates of medical and sanitary equipment.
	C. Implementation of periodic checks of introduced systems across the school and proper documentation of the same.
PPEs	A. Formation of proper vigilance team to ensure usage of PPEs (like floor monitors) across the school to protect everyone from exposure to unnecessary germs.
	B. An interrupt-based system to be put into notify user of depletion of the PPEs stock to place an order for the next batch.
	C. Everyday passage of message and lessons of usage of PPEs in the mid of a pandemic.
Covid Testing & Tracing	A. Weekly safety and equipment handling training for medical teams and non-medical volunteers.
	B. Scheduled procurement for testing equipment's and proper maintenance checks of testing equipment.
	C. Training programs for volunteers in the contact-tracing team.
Personnel	A. Development of safety protocols for various everyday activities, like exiting the classroom, walking in hallways, using cafeteria, etc.
	B. Implementation of IT ticketing system, wherein anyone having an issue while using the online platform can raise a ticket, which the IT team should immediately solve.
	C. Remote solutions methods and an updated FAQs list circulated to all members of the institution.

Phase 5 – Verify

Table 11: Verify for Six Sigma

Factor	Verifications
Hygiene	A. Air flow checks through defined checklists and range for air type. B. Vigilant checks of proper maintenance for implemented database for supplies, expiration dates, test results, etc. C. Checks for posters and notices regarding covid-19 and hygiene care shared across to all members via emails.
PPEs	A. Checklists distributed to students, to be filled out before they enter school, checking the proper usage of PPEs. B. Physical checks for supplies of PPEs and not be dependent on the interrupt-based system. C. Database management containing information of members disobeying the PPE usage rules and evaluating penalties awarded to them and actions used to correct the behavior.
Covid Testing & Tracing	A. Checklist for dictating step wise usage of equipment like syringes, swabs and containers and for training sessions for medical and non-medical volunteers. B. Maintenance sessions using the interrupt-based system for testing equipment. C. Proper database maintenance of all traced contacts of current infected members of the institution.
Personnel	A. Checklists for daily following of safety protocols and weekly reviews of the same or based on the upcoming positive cases. B. Weekly meetings and passage of information to state and district medical personnel. C. Checklists for IT members for handling IT tickets and cleaning the same and checklist based for end user-friendly remote solutions and weekly updating of the FAQs section and remote solutions checklists.

4. Quality Function Deployment

4.1 Introduction

Quality function deployment is a powerful methodology which allows the supplier and engineer to listen to customer and respond to it appropriately to meet the customer's needs and expectations. Basically, in QFD, quality is a measure on how the product or service is performing in the eyes of the customer.

The House of Quality is defined as a Product Planning Matrix that is built to show how customer requirements relate directly to the ways and methods which can be used to achieve those requirements. It is considered the primary tool used during quality function deployment to facilitate group decision making.

4.2 House of Quality

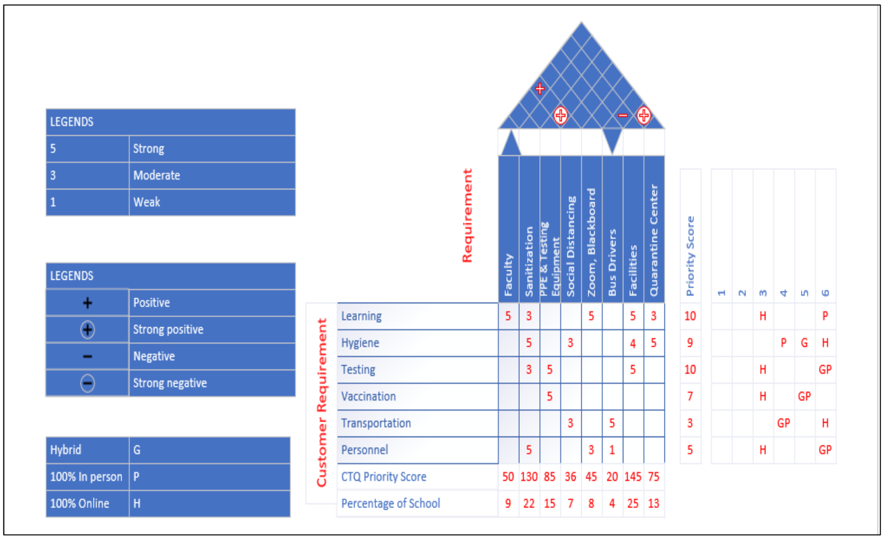


Figure 19: House of Quality

5. DOE/Experimental Design

In the following excel screenshot, we can see the 2^3 Factorial Experiment Analysis along with the results of the DOE simulation obtained through Minitab 19. Using these results, we could find the Average, Variance, and the Standard Deviation of the model. Furthermore, we can see the coefficients of the Effect variables A, B & C along with their interactions.

			Design of Experiments Analysis: Part II									
		Factorial Experiments 2^3 (Three Replications/Treatment)							Run Results			
Run	A	B	C	AB	AC	BC	ABC	Y1	Y2	Y3	Avg.	Var.
1	-1	-1	-1	1	1	1	-1	-2.50	-2.42	1.72	-1.066	5.828
2	1	-1	-1	-1	-1	1	1	3.56	0.73	6.87	3.719	9.446
3	-1	1	-1	-1	1	-1	1	-1.71	-0.75	0.72	-0.580	1.499
4	1	1	-1	1	-1	-1	-1	10.98	11.64	13.50	12.037	1.705
5	-1	-1	1	1	-1	-1	1	10.52	4.12	8.61	7.750	10.778
6	1	-1	1	-1	1	-1	-1	14.77	18.00	13.57	15.446	5.237
7	-1	1	1	-1	-1	1	-1	11.19	12.09	10.00	11.093	1.107
8	1	1	1	1	1	1	1	19.71	15.02	20.19	18.310	8.161
TotSum								66.52	58.42	75.18	66.71	43.76
SumY+	49.51	40.86	52.60	37.03	32.11	32.06	29.20					
SumY-	17.20	25.85	14.11	29.68	34.60	34.65	37.51					
AvgY+	12.38	10.21	13.15	9.26	8.03	8.01	7.30					
AvgY-	4.30	6.46	3.53	7.42	8.65	8.66	9.38					
Effect	8.08	3.75	9.62	1.84	-0.62	-0.65	-2.08					
Var+	6.137	3.118	6.321	6.618	5.181	6.135	7.471					
Var-	4.803	7.822	4.619	4.322	5.759	4.805	3.469					
F	0.783	2.509	0.731	0.653	1.111	0.783	0.464					
Var. of Model		5.47		StdDv	2.34	Mean	8.34					
Var. of Effect		0.91		StdDv	0.95							
Student T (0.025;DF) =				2.47								
C.I. Half Width =				2.36								

Figure 20: Simulation Model 2^3 Excel setup

Factors in consideration:

A	**Infection rate (in percent)**
B	**Vaccination administered (in percent)**
C	**PPE Inventory levels (in percent)**

With the given run results for the data sets according to groups, we found out the Mean and the Standard Deviation of the Run Results data set.

Mean	**8.33**
Standard Deviation	**2.34**

Using these values, we generated a random dataset for 100 values and found the following parameters:

Random Data Generated #1:

Normal dist. Data (8.33, 2.34)

3.258	6.584	8.232	10.003
3.586	6.587	8.337	10.128
4.022	6.682	8.446	10.129
4.562	6.800	8.483	10.129
4.754	6.858	8.855	10.169

5.054	6.918	8.862	10.494
5.076	7.111	8.895	10.513
5.102	7.237	8.994	10.557
5.113	7.291	8.996	10.888
5.331	7.309	9.007	10.897
5.402	7.328	9.020	11.099
5.515	7.363	9.061	11.166
5.679	7.392	9.138	11.304
5.818	7.433	9.204	11.316
5.887	7.464	9.231	12.057
5.943	7.743	9.231	12.192
5.985	7.790	9.266	12.226
5.993	7.852	9.448	12.290
6.011	8.001	9.572	12.445
6.105	8.035	9.608	12.552
6.120	8.075	9.670	12.669
6.166	8.100	9.721	12.926
6.420	8.129	9.806	13.068
6.471	8.157	9.847	13.105
14.767	8.178	9.897	13.895

Key Parameters:

LSL	**7**
USL	**27**
Range	**20**
Midpoint (MP)	**10**

Using the key parameters mentioned above, we generated the following Process Capability chart which shows that **almost 30% - 40%** of the data **falls outside of the LSL.** Also, the **Cp** value is **1.14** which is **less than 1.33**. This tells us that the process is **not in control.**

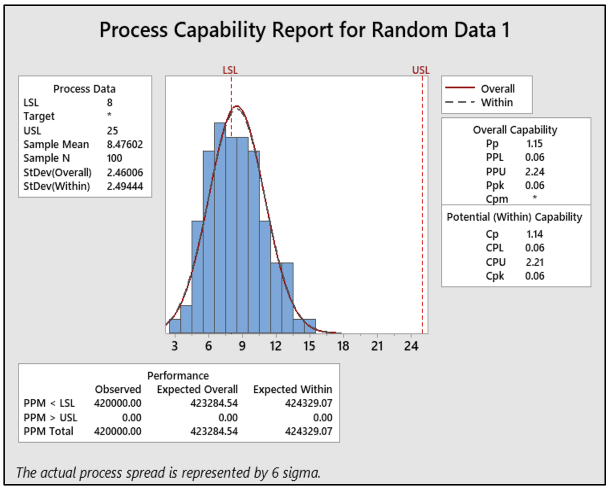


Figure 21: Before Improvement, Process Capability Chart

Hence, we now try to move the mean in such a way that this data is centered around a new mean and the entire data is within the LSL and USL.

We do this by assuming estimating a new **Target Mean (TM)** which is equal to **(LSL + MP).**

Therefore, **TM = 17.** This is done using the **Regression Equation** to analyze our new mean**.**

It is given by:

Response (Y) = Mean + a(1) * A + a(2) * B + a(3) * C

Where,

Effect A	**4.04**
Effect B	**1.88**
Effect C	**4.81**

a(1)	**0.48**
a(2)	**1**
a(3)	**1**

Therefore,

Y = 8.33 + 4.04 * (0.48) + 1.88 * (1) + 4.81 * (1)
= **16.95**

Taguchi Capability Ratio (C_{pm}):

$$C_{pm} = \frac{USL - LSL}{6\sqrt{\sigma^2 + (T - \mu)^2}}$$

$$C_{pm} = \frac{27 - 7}{6\sqrt{2.34^2 + (17 - 16.95)^2}}$$

$$\backslash\ C_{pm} = 1.42$$

Through the Taguchi Capability Ratio, we can verify that the **Capability ratio is now acceptable**.

Based on our conclusions from the Regression Analysis and the Taguchi Capability Ratio, we can now generate a new random dataset using the following parameters.

Mean	**17**
Standard Deviation	**2.34**

Using these values, we generated a random dataset for 100 values and found the following parameters:

Random Data Generated #2:

Normal dist. Data (17, 2.34)

17.256	16.993	14.550	17.986
17.278	13.972	18.256	16.193
15.271	21.695	18.316	13.827
18.233	18.341	17.017	15.533
17.829	16.147	14.555	20.507
15.873	18.601	13.252	15.407
18.872	19.504	22.621	18.412
16.810	15.048	16.339	13.733
14.382	14.376	17.653	18.750
13.873	15.264	18.799	14.996
17.936	17.956	16.797	19.876
18.142	20.031	17.514	20.998
16.936	15.926	18.514	16.093
16.623	17.333	14.503	19.797
18.910	18.989	18.673	18.690
12.302	18.229	20.401	16.044
14.571	18.123	20.312	15.555
16.550	13.851	17.869	19.971
17.256	20.330	15.827	16.993
17.000	16.136	18.998	18.450
15.107	15.794	17.875	15.510
15.753	20.512	19.419	16.073
16.304	19.326	16.377	13.438
13.747	13.409	17.470	16.804
15.360	15.429	18.144	16.563

New Parameters:

LSL	**7**
USL	**27**
Range	**20**
Midpoint	**10**
Target Mean	**17**

Using the new parameters mentioned above, we generated the following Process Capability chart which shows a perfect fit along with the data completely centred around the mean. All the data **falls within the estimated boundaries (LSL & USL) of the simulation.** Also, the **Cp** value is **1.55** which is **greater than 1.33**. This tells us that the process is **in control.**

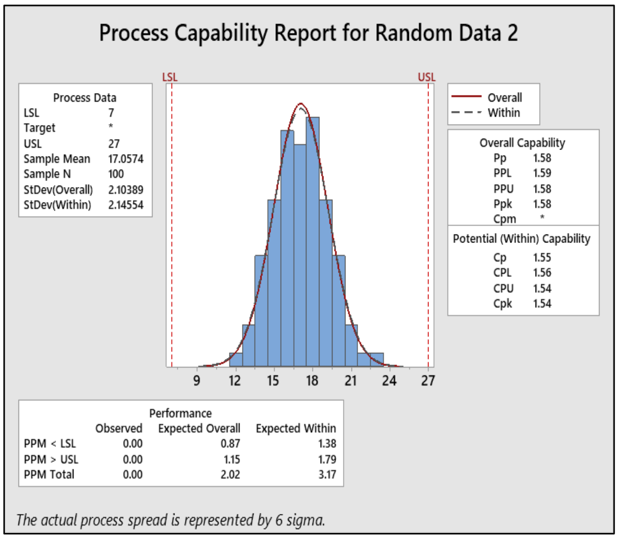


Figure 22: After Improvement, Process Capability Chart

Conclusion:

We can see the significant differences in the Process Capabilities before and after improvement using the DOE analysis.

Before Improvement	**After Improvement**
Cp = 1.14	Cp = 1.55

6. Supply Chain and VSM

6.1 Supply Chain and Lean/VSM

- Supply Chain Game – Excel Sheet provided

6.2 Value Stream Mapping

A value stream map will give us a clear picture of the number of steps a student has to take after re-opening of schools as compared to when schools were operating at 100% capacity in the normal way. This would give us the percentage of contamination and the percent of capacity across all the steps.

Sl. No.	Factor	Value Stream Mapping for Re-opening of Schools (Current) Criteria – Spread of Infection Assumption – 100% in-person classes			Value Stream Mapping for Re-opening of Schools (Future) Criteria – Spread of Infection Assumption – 50% in-person classes		
		Avg. TIME (in mins)	Avg. CAPACITY (in numbers)	Avg. Percent Contamination	Avg. TIME (in mins)	Avg. CAPACITY (in numbers)	Avg. Percent Contamination
1	Home	71	3	0.26	73	3	0.175
2	Travel	81	30	0.58	100	15	0.25
3	Campus	141	72	0.75	171	30	0.34
Total		**293**	**35**	**0.53**	**344**	**16**	**0.25**

Figure 23: VSM Comparisons

As per the VSM comparisons, we can deduce that the value stream mapping when the pandemic had just hit shows:

- Currently: Total time for the student is less and the capacity for each step is more this leads to a high percent contamination,
- Future Case: whereas when we re-open the school at 50% capacity as per the CDC recommended guidelines, the time taken increases, the capacity decreases but this leads to a decrease in the percent contamination by around 50%.

7. Gage R&R Metrology MSA study

7.1 Introduction

AVOVA Gauge R&R measures the amount of Variability induced in measurements by the measurement system itself and compares it to the total variability observed to determine the ability to successfully work with the measurement system.

From the following data, our Gage R&R considerations are as follows:

- Part – Student Population Sample Subset
- Operator – COVID-19 Screening Staff (A: Staff 1, B: Staff 2, C: Staff 3)
- Measurement – Infection Rate

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

The p-value is less than 0.05 which indicates that Part and Operator are statistically significant, and that the ***measurement system is capable.***

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			

Figure 24: Two-way ANOVA Table With Interaction

7.2 Results

Our measurement system is needs improvement. This is determined by looking at the sources of variation. The Gage R&R (the measurement system) accounts for 27.86% of observed variation, while the part-to-part variation accounts for 96.04% of observed variation. Minitab can detect 4 distinct categories, which indicates a lower set of categories/selection to achieve reliable results for this MSA. This is reinforced by the X-bar chart, in which more than 50% of the parts fall within the upper and lower control limits.

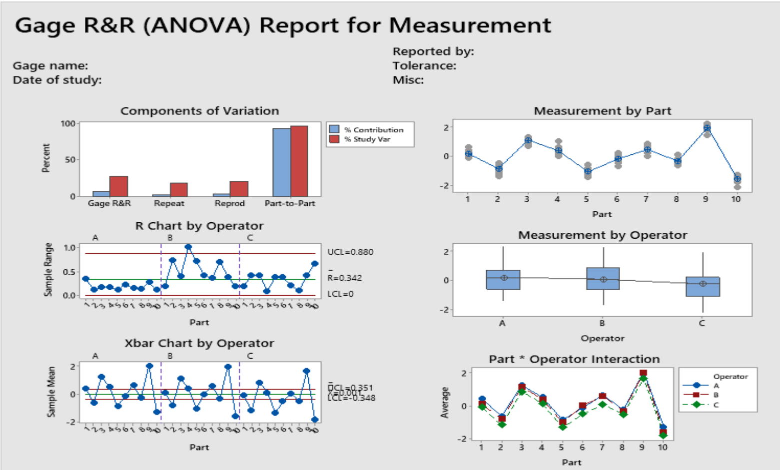


Figure 25: Gage R&R Report for Measurement

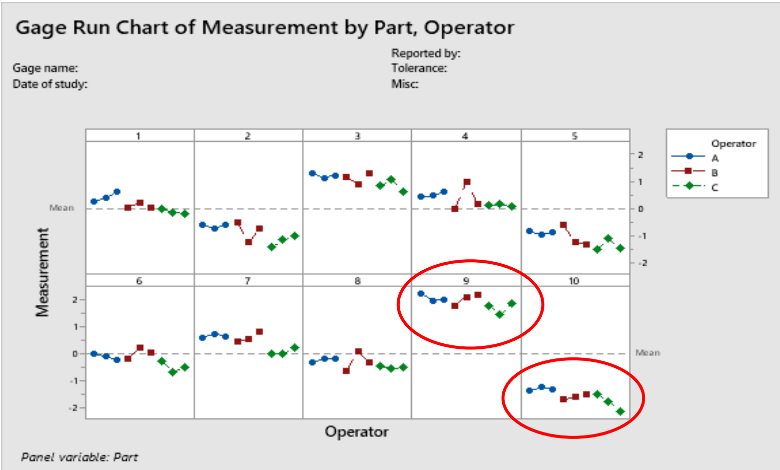


Figure 26: Gage Run Chart of Measurement by Part, Operator

8. Acceptance Sampling Plan

8.1 Introduction

Attribute Agreement Analysis is a method is used to assess whether the appraiser is consistent with themselves, with one another, and with known standard.

- Sample – Student Population Sample subset
- Attribute – Covid-19 test Result
    - GO – (Covid 19) Positive
    - NO – (Covid 19) Negative
- Inspector – Staff 1 and Staff 2

Attribute Agreement Analysis for Result

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

Figure 27: Attribute Agreement Analysis of Result

Kappa values range from −1 to +1. The higher the value of kappa, the stronger the agreement, as follows:

1. When Kappa = 1, perfect agreement exists.
2. When Kappa = 0, agreement is the same as would be expected by chance.

When Kappa < 0, agreement is weaker than expected by chance; this rarely occurs.

The Kappa value is 1 for Appraiser 1 which indicates perfect agreement within an appraiser between trials. Some of Appraiser 2's kappa values are close to 0.70. which might need to be investigated.

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

Figure 28: Each Appraiser v/s Standard

Most of the Kappa values are larger than 0.80, which indicates good agreement between each appraiser and the standard.

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

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

Figure 29: Between Appraisers

The Kappa values are larger than 0.80, which indicates good agreement between appraisers.

Statistical Process Control

9.1 Introduction

To track the performance of output of any process over time, we incorporate SPC (Statistical Process Control) and control charts. Control charts help in identifying common cause and special cause variation, this way we can take appropriate action on the process without over-controlling it. Quality Control Charts are powerful and easy to use facilities that can be used to custom design entirely new analytic procedures and add them permanently to the application.

Process is a collection of tasks which is inherently variable and large changes in performance causes larger problems. For our process, continuous data is the number of people and this data will follow normal distribution and when we examine the control chart (Xbar-R chart) we will get consistent range, mean, and control limits. Whereas attribute data is the number of people testing positive which is the defect count measurements, this data will follow Poisson distribution, and this will give us consistent mean and control limits via the control charts (C). Control charts do not show the comparison to specific limits but how is the performance of the process.

9.2 Poisson Distribution

To represent out defect counts we will use Poisson distribution. Therefore, we generate 100 defects using the random data generator in Minitab with a mean value of 5, therefore we would record an average of 5 positive cases.

Reference Data and Chart

Since, we are working with defect counts, which is an attribute data we will use the C chart to analyze and represent it. In the below chart we see that Minitab has created a lower and upper limit based on the calculation of the generated data, also the C-bar line is represented which equal to our mean. Since the C-chart represents the data, we require we can create new charts to show case the variance in our process.

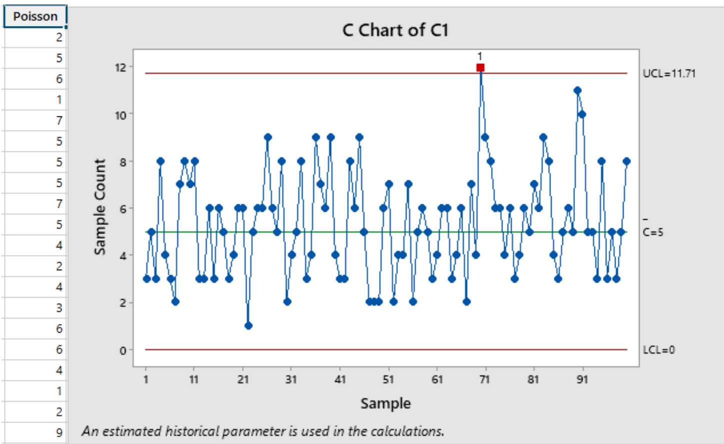


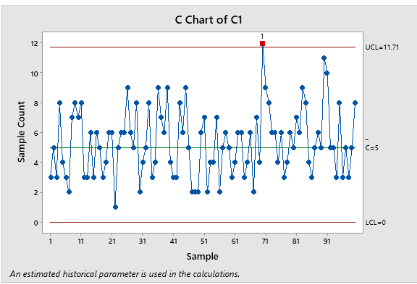
Figure 30: C Chart of C1

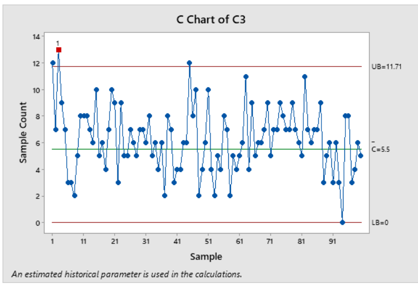
Detecting Process Changes

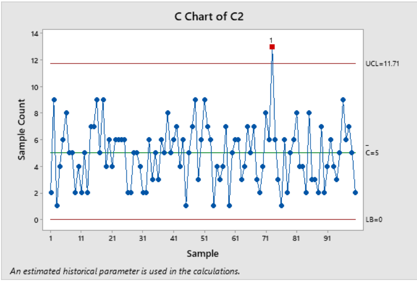
The four control charts below showcase the various data generated randomly in Poisson distribution with various means. It is evident that over various variances our process begins to become unstable. There are several ways we recognize this -

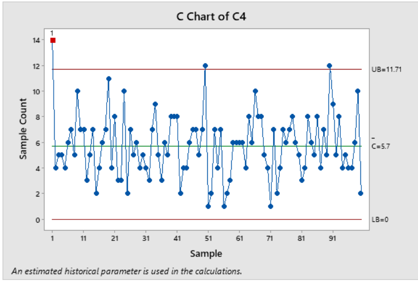
1. We see points that lie outside of the reference control limits (Upper & Lower Set Limits).

2. Minitab testing indicates various areas where points fall in patterns that indicated a problem.









The following are the four different mean values used for generating the data for the above chart. In each cases the control limit and the mean were set based on our reference control chart.

1. Mean = 5
2. Mean = 5.5
3. Mean = 5.7
4. Mean = 5.9

We see that over time the sampling plots are moving further away from the mean, therefore the process is not performing within controls.

9.3 Normal Distribution

To represent out defect counts we will use Normal distribution. Therefore, we generate 100 defects using the random data generator in Minitab with a mean value of 54 and standard deviation of 14, therefore over time an average of 54 people will get tested with a standard deviation of 14.

Reference Data and Chart

Since we are dealing with number of people getting tested, which is a continuous variable we will use an XBar-R chart to represent the data.

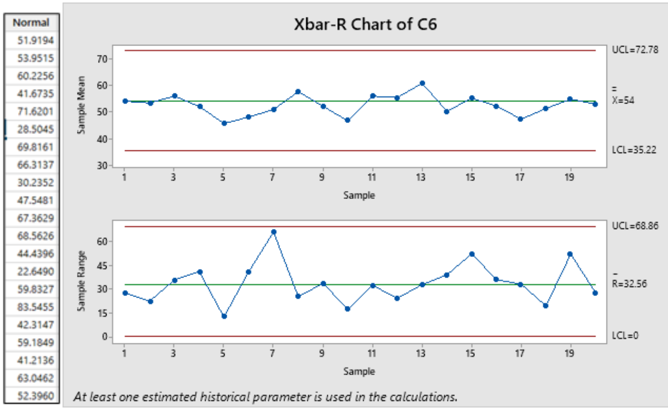


Figure 31: Xbar-R Chart

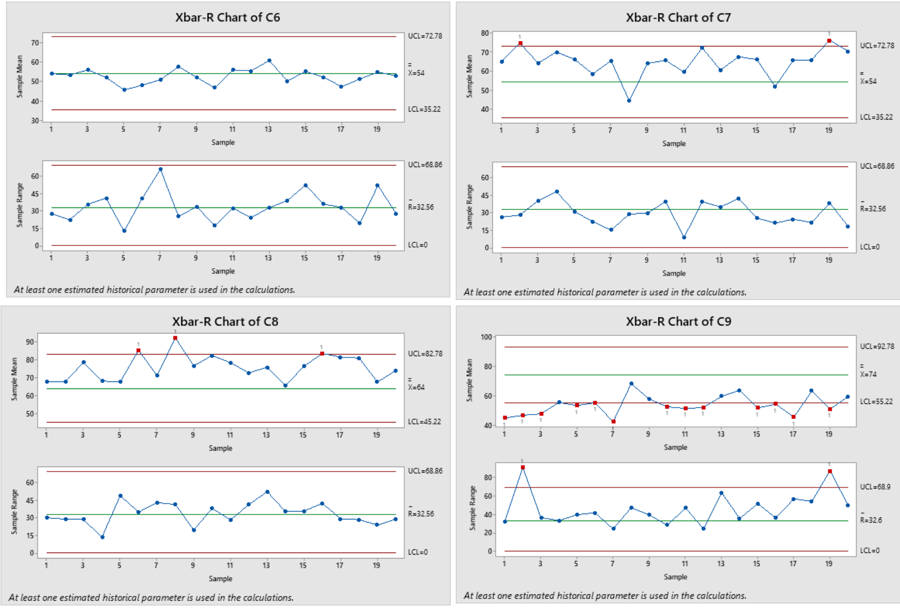
In the below chart we see that Minitab has created a lower and upper limit based on the calculation of the generated data, also the X-bar line and R-bar line is represented which equal to our mean of our samples and the mean of the ranges, respectively.

Since the Xbar-R-chart represents the data, we can now create new charts to show case the variance in our process.

Detecting Process Change

The four control charts below showcase the various data generated randomly in Normal distribution with various changes to the means and standard deviation. It is evident that over various variances our process begins to become unstable. There are several ways we recognize this -

1. We see points that lie outside of the reference control limits (Upper & Lower Set Limits).
2. Minitab testing indicates various areas where points fall in patterns that indicated a problem.



The following are the four different mean values used for generating the data for the above chart. In each cases the control limit and the mean were set based on our reference control chart.

1. Mean = 54, Standard Deviation = 14
2. Mean = 64, Standard Deviation = 14
3. Mean = 74, Standard Deviation = 14
4. Mean = 54, Standard Deviation = 20

We see that over time the sampling plots are moving further away from the mean, therefore the process is not performing within controls.

10. Reliability Analysis

10.1 OC Curves Introduction

One of the most useful tools in practical statistical applications is the Operating Characteristic Function (OC Function). The operating characteristic (OC) curve depicts the discriminatory power of an acceptance sampling plan. The OC curve plots the probabilities of accepting a lot versus the fraction defective. When the OC curve is plotted, the sampling risks are obvious. You should always examine the OC curve before using a sampling plan.

The OC Function depends on the PD (p), the sample size (n) and the acceptance number (c). This triple dependency yields one of the most important uses of the OC Function: deriving Acceptance Sampling Plan tables and "nomographs" to determine the best Plan (n, c), for a sample of size "n" and acceptance number "c", that provides a pre-established "confidence" in our acceptance test results, given the value of our parameter of interest (e.g., "p").

- α probability (also called producer's risk / probability of acceptance): the probability of deciding that the alternative hypothesis (H1) is true, when in fact the null (H0) is true (e.g., risk of rejecting the batch as defective, when it is spec-compliant)
- β probability (also called the consumer's risk / probability of failure): the probability of deciding that the null hypothesis (H0) is true, when the alternative (H1) is true (e.g., the risk of accepting a defective product)
- Acceptable Quality Level (AQL): a 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.

AQL	**0.01**	**n**	**70**
LTPD	**0.1**	**c**	**3**

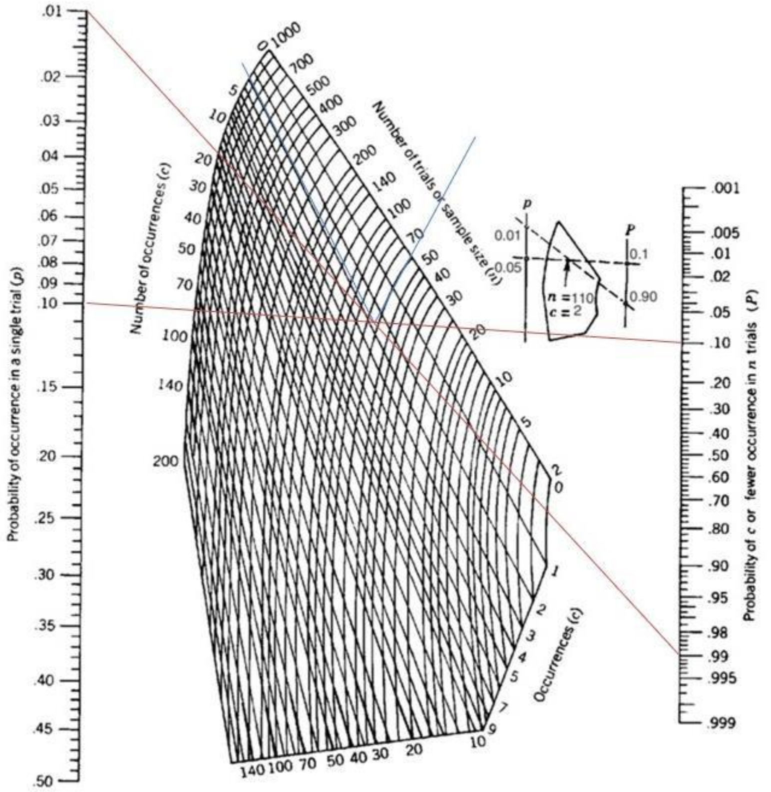


Figure 32: Nomograph

Using the nomograph and given values for AQL and LTPD, we get the values for **n and c as 70 and 3,** respectively.

Lot or Batch Size:	3500	Sampling Size (N)	200
Lot Code	**L**	**Ac = 0**	**Re = 1**

10.2 Cumulative Distribution Function

Binomial with n = 70 and P (failure) = 0.1 (or β)

1	0.0055000	0.9945000
2	0.0241813	0.9758187
3	0.0712306	0.9287694
4	0.1587945	0.8412055
5	0.2872216	0.7127784
6	0.4418098	0.5581902

7	0.5988517	0.4011483
8	0.7362634	0.2637366
9	0.8414427	0.1585573
10	0.9127309	0.0872691
11	0.9559359	0.0440641
12	0.9795386	0.0204614
13	0.9912391	0.0087609
14	0.9965322	0.0034678
15	0.9987279	0.0012721
16	0.9995665	0.0004335
17	0.9998625	0.0001375
18	0.9999593	0.0000407
19	0.9999887	0.0000113
20	0.9999971	0.0000029
21	0.9999993	0.0000007
22	0.9999998	0.0000002
23	1.0000000	0.0000000
24	1.0000000	0.0000000
25	1.0000000	0.0000000

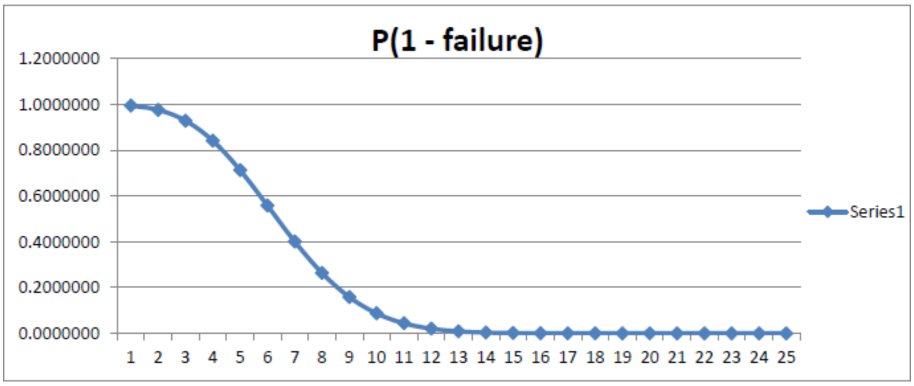


Figure 33: P(1-Failure)

10.3 Binomial Distribution – Excel

n	**70**	**c**	**3**

AQL → 0.01 ; 1-α → 0.99457

P_D	**P_A**
0	1.00000
0.01	0.99457
0.02	0.94810
0.03	0.84127

0.04	0.69289
0.05	0.53387
0.06	0.38851
0.07	0.26929
0.08	0.17902
0.09	0.11475
0.10	0.07123
0.12	0.02524
0.13	0.01448
0.14	0.00812
0.15	0.00446
0.16	0.00240
0.17	0.00127
0.18	0.00066
0.19	0.00034
0.2	0.00017
0.21	0.00008
0.22	0.00004
0.23	0.00002
0.24	0.00001
0.25	0.00000

LTPD → 0.10 ← AQL

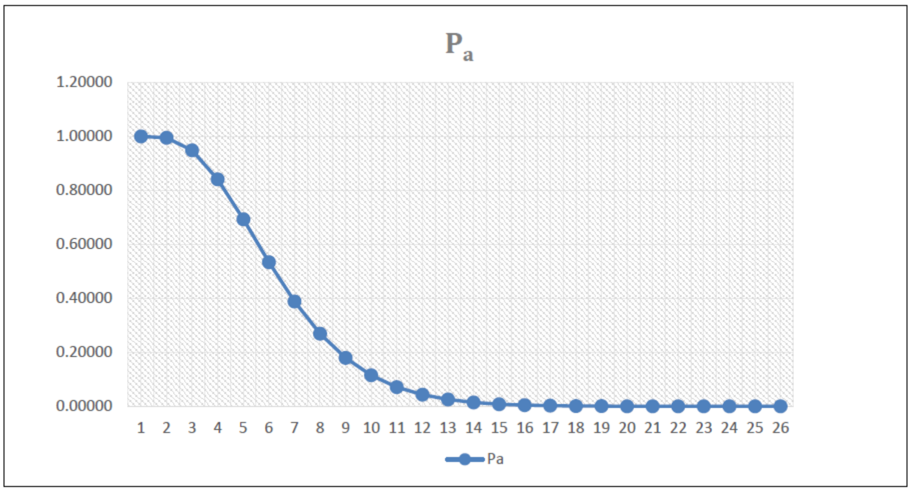


Figure 34: Pa Graph

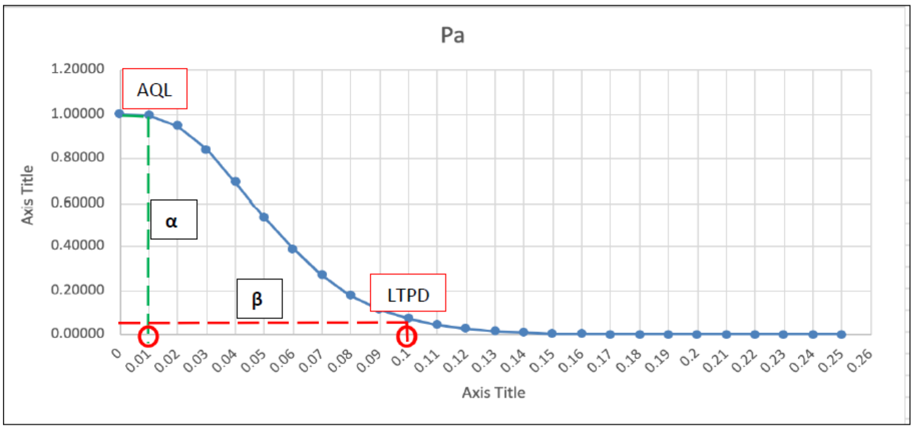


Figure 35: Pa

10.4 Binomial Distribution – Minitab

Using our specifications for lot size, AQL, LTPD, α, β, Minitab determines an appropriate sampling plan with a specific sampling size and acceptance number.

Acceptance Sampling by Attributes

Measurement type: Number of defects

Lot quality in defects per unit

Lot size: 3500

Use Poisson distribution to calculate probability of acceptance.

Method

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

Generated Plan(s)

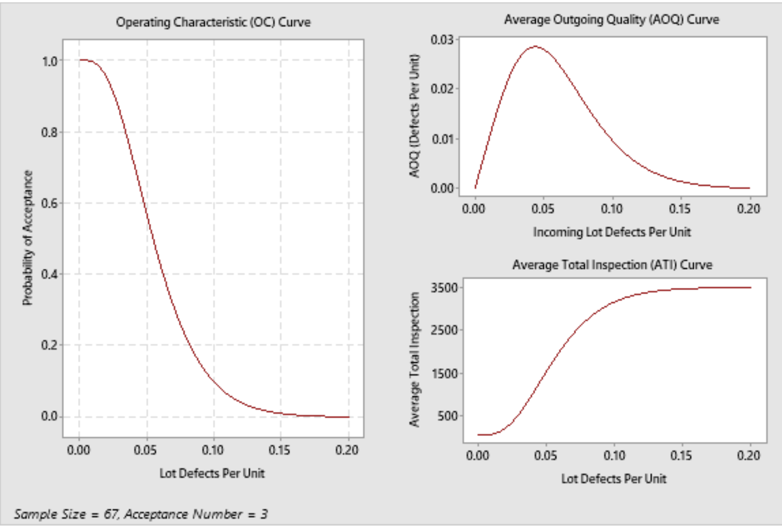
Sample Size	67
Acceptance Number	3

Accept lot if number of defects in 67 items ≤ 3; Otherwise reject.

Defects Per Unit	Probability Accepting	Probability Rejecting	AOQ	ATI
0.01	0.995	0.005	0.00976	84.0
0.10	0.099	0.901	0.00969	3160.8

Average Outgoing Quality Limit(s) (AOQL)

AOQL	At Defects per Unit
0.02844	0.04396



10.410.5 Test Data

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This binary data has been generated using Minitab's Bernoulli Distribution random data.

0	0	1	0	0
0	0	1	0	0
1	0	0	0	0
0	0	0	0	0
0	0	0	0	0

Interpretation –

Go (-ve for COVID-19 virus)	**0**
No-Go (+ve for COVID-19 virus)	**1**

The number of No-Go's: 3

~~10.5~~10.6 Failure Mode, Effects & Criticality Analysis

Failure Mode, Effects & Criticality Analysis (FMECA) is a method which involves quantitative failure analysis. The FMECA involves creating a series of linkages between potential failures (Failure Modes), the impact on the mission (Effects) and the causes of the failure (Causes and Mechanisms). The intent of the Failure Mode, Effects & Criticality Analysis methodology is to increase knowledge of risk and prevent failure.

Table 12: Failure Mode, Effects and Criticality Analysis

FUNCTION	***FAILURE MODE***	***EFFECTS***	***SEVERITY***	***CAUSES***	***RECOMMENDED ACTIONS***
HYGIENE	Improper ventilation	C	5	B	R
		N			P
	Not washing hands properly and not sanitizing any equipment before usage	B	0	S	A
					P
	No checks for expiration of cleaning and sanitizing equipment	L	6	P	C
		L		L	P
PPEs	Improper usage of PPEs by faculty and students alike	N	6	N	D
					P
	Shortage of PPE	L	5	I	D
					D
COVID TESTING AND TRACING	Lack of proper testing equipment and technology	L	9	I	P
					C
PERSONNEL	Software malfunctions	N	7	S	S
					I

	Lack of healthcare professionals	L	10	L	T
					P

~~10.6~~10.7 Criticality Analysis

Criticality analysis is a process by which assets are assigned a criticality rating based on their potential risk. Criticality Analysis are more difficult to perform for a functional FMEA due to the lack of detailed failure data at this level. If failure data is available, criticality numbers are developed as follows:

$$FAILURE\ MODE\ CRITICALITY\ NUMBER = \alpha\ (\%\ \text{of occurrence of each failure mode}) \times \text{frequency hours (rate of occurrence)} \times \text{hours of cycle} \times \beta\ (\text{probability that the failure effect will occur})$$

~~10.7~~10.8 Fault Tree Analysis

Fault tree analysis (FTA) is a graphical tool to explore the causes of system level failures. It uses Boolean logic to combine a series of lower-level events and it is basically a top-down approach to identify the component level failures that cause the system level failure to occur. Fault tree analysis consists of two elements "events" and "logic gates" which connect the events to identify the cause of the top undesired event.

~~10.8~~10.9 ~~10.6~~ Conclusion

We have concluded our Analysis for the Operating Characteristics on the reopening of schools in the Onondaga County. As we compare acceptance sampling results based on the batch size of 3500 students approximately, we find that for sample size of 67 students selected randomly must have an acceptance number of 3 (which denotes that the system in place to successfully reopens schools can have no more than 3 students tested positive out of 67 students tested). That bring us to 10% defect rate.

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Our results have been validated upon comparisons of results from excel spreadsheet, Minitab Acceptance Sampling by Attribute as well as random sampling using Bernoulli Distribution. We ascertain that for a sample size of 67 students no more than 3 students can test positive with an acceptance probability of 90% and rejection probability of 10%

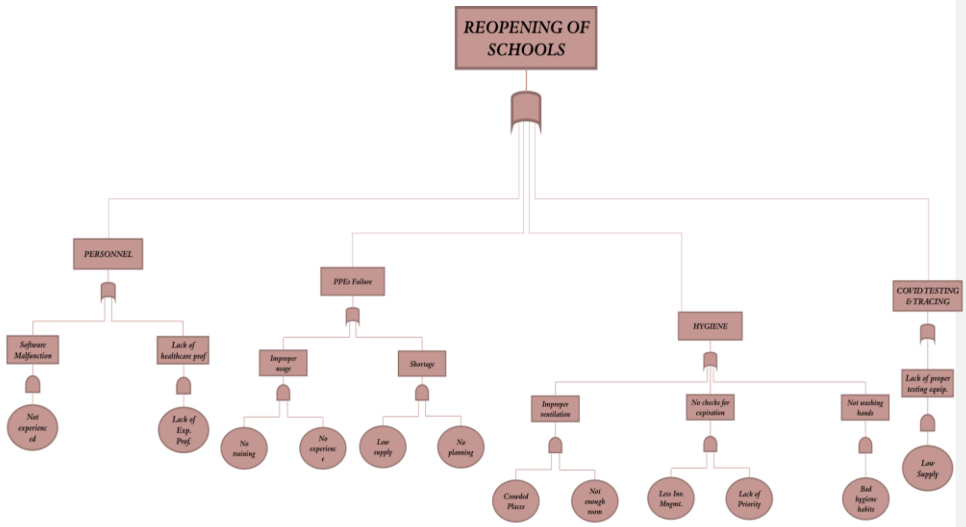

Figure 36: Fault Tree Analysis

11. Conclusion

- We tested accuracy of the data by checking the distributions, using various types of quality tools – histograms, box plots, pareto chart, scatter plot to analyze factors crucial to reopening of schools.
- We narrow it down to 5 different factors: PPE, Hygiene, Social Distancing, COVID Tracing and Tracking & Personnel
- From this we figure out that COVID tracking and tracing, PPE, social distancing are our main areas of focus.
- We conclude this from our Lean Six Sigma model and Design for Six Sigma to make sure that our reopening plan is right on track.
- We tried out the figure out the relationship between the factors by performing House of Quality and FMECA
- Moving forward, we conducted a Gage R&R to identify if our measurement system is accurate and we found that our measurement system is faulty. Attribute Agreement Analysis – Appraisals all okay

- Factorial Regression and OC Curves are to identify which factors are crucial to reopening of schools which also verifies our assessment of infection rate to be vital hence, to reopen schools we need to have an infection rate less than 5%