Epidemic Prevention Operation

Zika Virus Spread control

Group – 2

Satish Chiluvuri

Benliu He

Jupeng Di

Weijie Lin

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1.BACKGROUND

Epidemic Prevention Operation- Zika virus spread control project is a part of Product Quality Engineering (MFE-634) course work, completed under the guidance of professor J.L Romeu. The purpose of this project is to utilize quality control and improvement tools to control/ improve the prevention process.

Zika is spread mostly by the bite of an infected Aedes species mosquito (Ae. aegypti and Ae. albopictus). These mosquitoes bite during the day and night, Zika can be passed from a pregnant woman to her fetus. Infection passed during pregnancy can cause certain birth defects and there is no vaccine or medicine for Zika.

Local mosquito-borne Zika virus transmission has been reported in the continental United States. Many people infected with Zika virus won't have symptoms or will only have mild symptoms. The most common symptoms of Zika includes fever, rash, headache and body pains.

Our project mainly focuses on methods to identify and control Zika virus spread in united states

2 INTRODUCTION

2.1 Zika Virus Background

Although the first case of Zika Virus was identified in 1947 in Uganda, and many outbreaks have been recorded in Africa during last couple decades. However, it never caught the attention of the public until early 2015 during its outbreak in Brazil.

Many people infected with Zika virus won't have symptoms or will only have mild symptoms. The most common symptoms of Zika are

- Fever
- Rash
- Headache
- Joint pain
- Muscle pain

Zika virus can be transmitted through mosquito bites, sexual activity and mother to fetus. Due to its likelihood to cause Microcephaly, it is important for women with pregnancy to adopt prevention method when travel to Zika spreading regions.

According to data published by Center for Disease Control and Prevention(CDC), from the Zika outbreak in Brazil in 2015 to April 2017, there are total of 5,264 cases reported in United States. Within all cases, 4,963 were travel related, 224 cases acquired through local mosquito transmission and 77 cases acquired by other routes. (Data see appendix) Due to the high percentage of travel related Zika cases reported in U.S. our team decide to focus on ways to improve border and transportation terminal inspections to control the Zika virus spreading in United States.

2.2 Mission Statement and Mission Scope

Using methods of Productivity and Quality Analysis to identify improve potential problems existing in current Zika Virus spread control processes.

What is in our scope?

- Center for Disease Control (CDC)
- Transportation Terminals/Centers Administrations.
- Within United States of America

What is out of scope?

- Cost Control for Vaccine Research.
- Potential Ethical Issues Involved with Virus Eradication.

3.COPQ ASSESSMENT

3.1 COPQ Introduction

Cost of Poor Quality or COPQ is a methodology that allows an organization to determine the extent to which its resources are used for activities that prevent poor quality, that appraise the quality of the organization's products or services, and that result from internal and external failures. In our case, it is important for us to determine damages caused by poor inspection quality and target more vulnerable processes within current border and terminal inspection procedures.

Process (Passive)	Internal Failure	External Failure	Appraisal	Prevention
Passengers' Arrival		Illegal Immigration	Board Patrol, Board Inspection Station, 'Wall'	Board Protection
Passenger Screening	Uneducated/In-Sufficient Staff Insufficient Equipments		Staffs Equipments	Staff Training
Possible Zika Infected Passengers' Transportation	Insufficient Vehicles, Uneducated Staff	Passengers' Resistance	Vehicles Equipments	Training
Zika Virus Test	Inadequate Knowledge and Equipment	Passengers' Incorporation	Medical Equipment	Training
Inform Passenger Prevention Method	Inadequate Knowledge	Passengers' Incorporation		Training
Zika Patients' Treatment	Currently No Cure	Patients' Incorporation	Cure/Vaccine Research, Symptom Relief Medicine	Research

Table 1: COPQ Table for Terminal Inspection

As mentioned previously in topic overview, our project will focus on improving inspection at major border inspection stations and public transportation terminals and target its current weak processes.

From COPQ table, our team has identified 6 processes existed in current screening/inspection procedure with high likelihood of failure. Furthermore, we have also estimated potential damage cost might incurred by those failures.

4.SIX SIGMA

4.1 Six Sigma Introduction

Six Sigma is a set of techniques and tools for process improvement. It seeks to improve the quality of the output of a process by identifying and removing the causes of defects and minimizing variability in manufacturing and business processes.

It uses a set of quality management methods, mainly empirical, statistical methods, and creates a special infrastructure of people within the organization who are experts in these methods. Each Six Sigma project carried out within an organization follows a defined sequence of steps and has specific value targets, for example: reduce process cycle time, reduce pollution, reduce costs, increase customer satisfaction, and increase profits.

4.2 Implementation

In our project, we have followed the process of Six Sigma implementation, which are Define, Measure, Analyze, Improve, Control or DMAIC for short. The following list includes our deliverable for each phase

I. Define Phase

This phase identifies potential projects, selects and defines a project, and sets up the project team.

a. Cost of Poor Quality(COPQ)

Process (Passive)	Internal Failure	External Failure	Appraisal	Prevention
Passengers' Arrival		Illegal Immigration	Board Patrol, Board Inspection Station, 'Wall'	Board Protection
Passenger Screening	Uneducated/In-Sufficient Staff Insufficient Equipments		Staffs Equipments	Staff Training
Possible Zika Infected Passengers' Transportation	Insufficient Vehicles, Uneducated Staff	Passengers' Resistance	Vehicles Equipments	Training
Zika Virus Test	Inadequate Knowledge and Equipment	Passengers' Incorporation	Medical Equipment	Training
Inform Passenger Prevention Method	Inadequate Knowledge	Passengers' Incorporation		Training
Zika Patients' Treatment	Currently No Cure	Patients' Incorporation	Cure/Vaccine Research, Symptom Relief Medicine	Research

Table 2: COPQ

As introduced and explained in previous section, COPQ is part of Six Sigma analysis process. With the help of COPQ table, our team could identify potential failure existing in current system and facilitate following Six Sigma implementation process.

b. Quality Function Deployment(QFD)

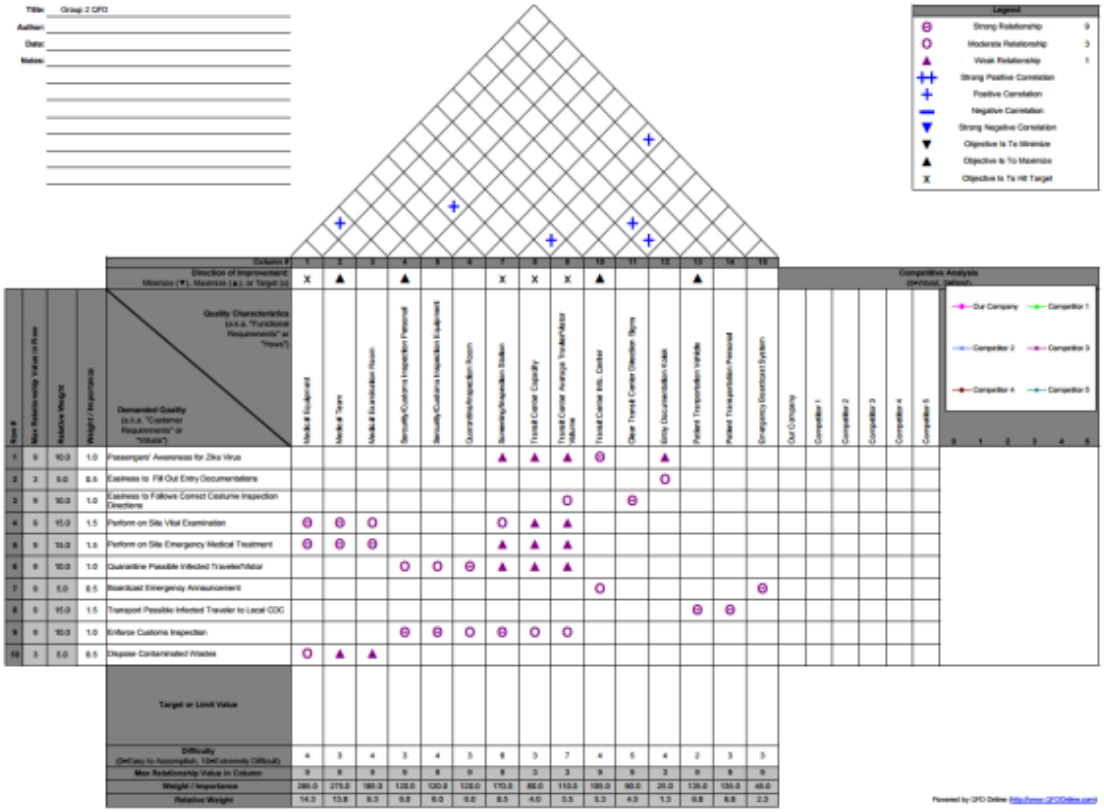


Figure 1: House of QFD

By design Quality Function Deployment(QFD) Chart, our team could specify technical requirements needed to improve our current process. Also by comparing technical requirements side by side with customer requirement, we could determine the interactions between two different types of requirement and devised and improve specific processes to meet both. Details of QFD chart will be explained in later section.

II. Measure Phase

This phase identifies key product parameters and process characteristics and measures the current process capability.

Deliverables: Verify the project need, Process map of current state, measure product feature, data collection plan and validate the measurement system.

a. Flow Chart

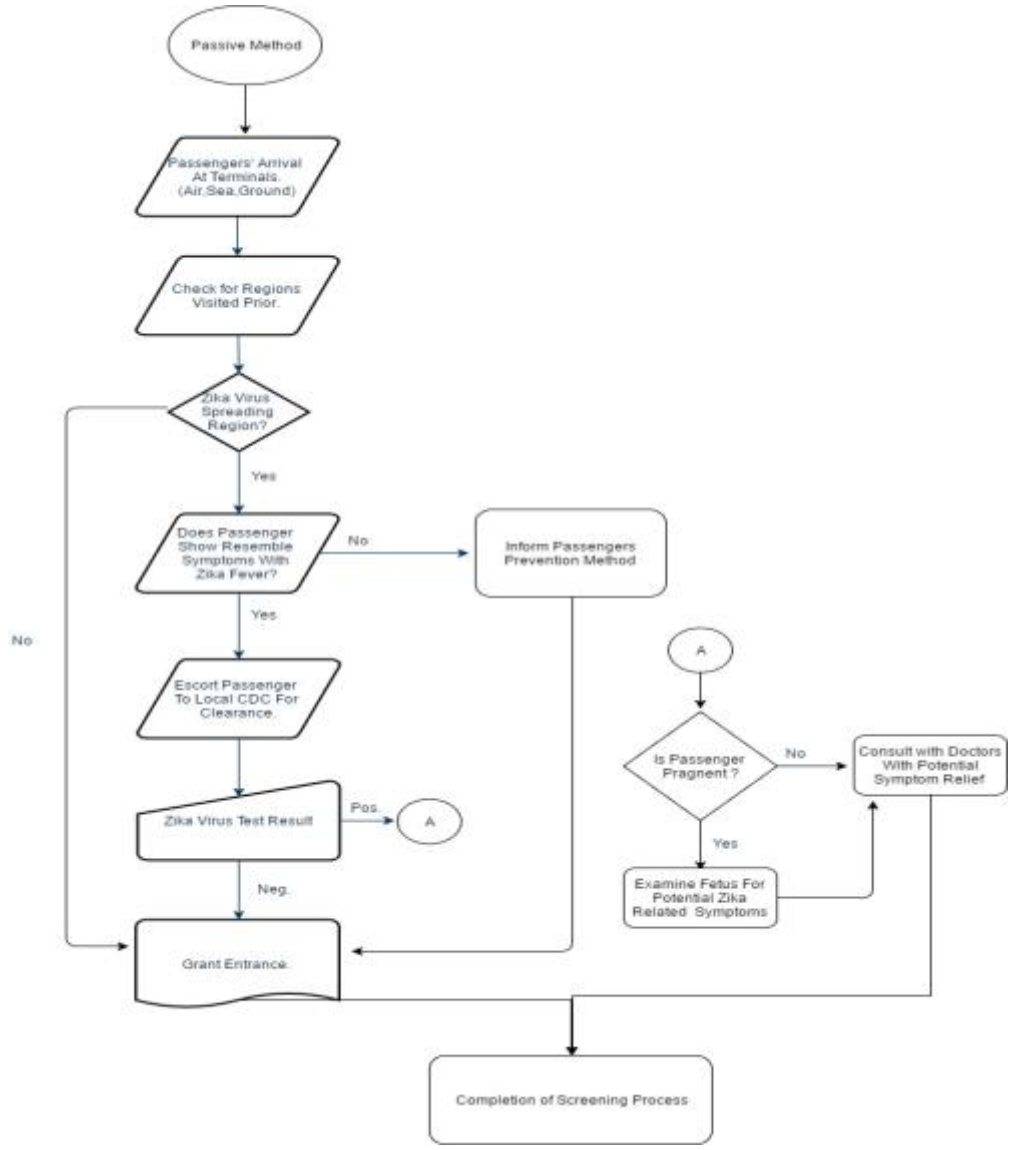


Figure 2: Flow Chart

To measure current inspection process, our team simulated current process with flow chart to facilitate Six Sigma process.

b. Process Capability Analysis(PCA)

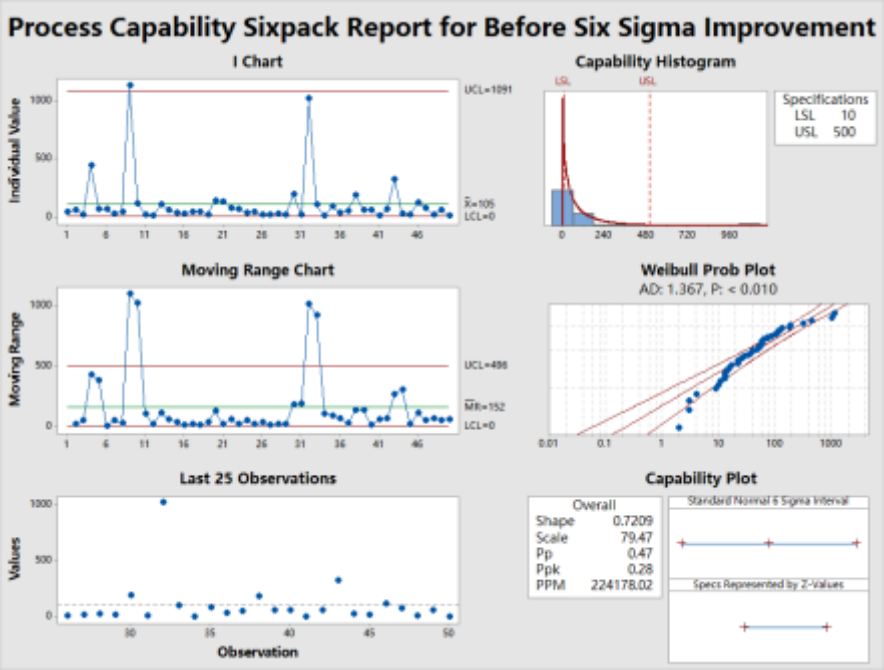


Figure 3: PCA Result

To analyze the performance of current inspection quality, PCA was implemented and case count data published from Center for Disease Control was used. Shown in 6 charts above, we have noticed high variance exists in total case count numbers from different states. By comparing CDC data with U.S. total border cross population for 50 states and U.S. total international flight data, we have noticed all highest case count states have highest cross border passengers count and international passengers count.

c. Gage R&R

To measure potential discrepancies existed in our current measuring tools and operators, Gage R&R analysis was implemented. The process and result will be explained further in later section.

There are two important aspects of a Gauge R&R:

- **Repeatability**: The variation in measurements taken by a single person or instrument on the same or replicate item and under the same conditions.
- **Reproducibility**: the variation induced when different operators, instruments, or laboratories measure the same or replicate specimen.

Gauge R&R addresses only the precision of a measurement system. It is common to examine the **P/T ratio** which is the ratio of the precision of a measurement system to the (total) tolerance of the manufacturing process of which it is a part

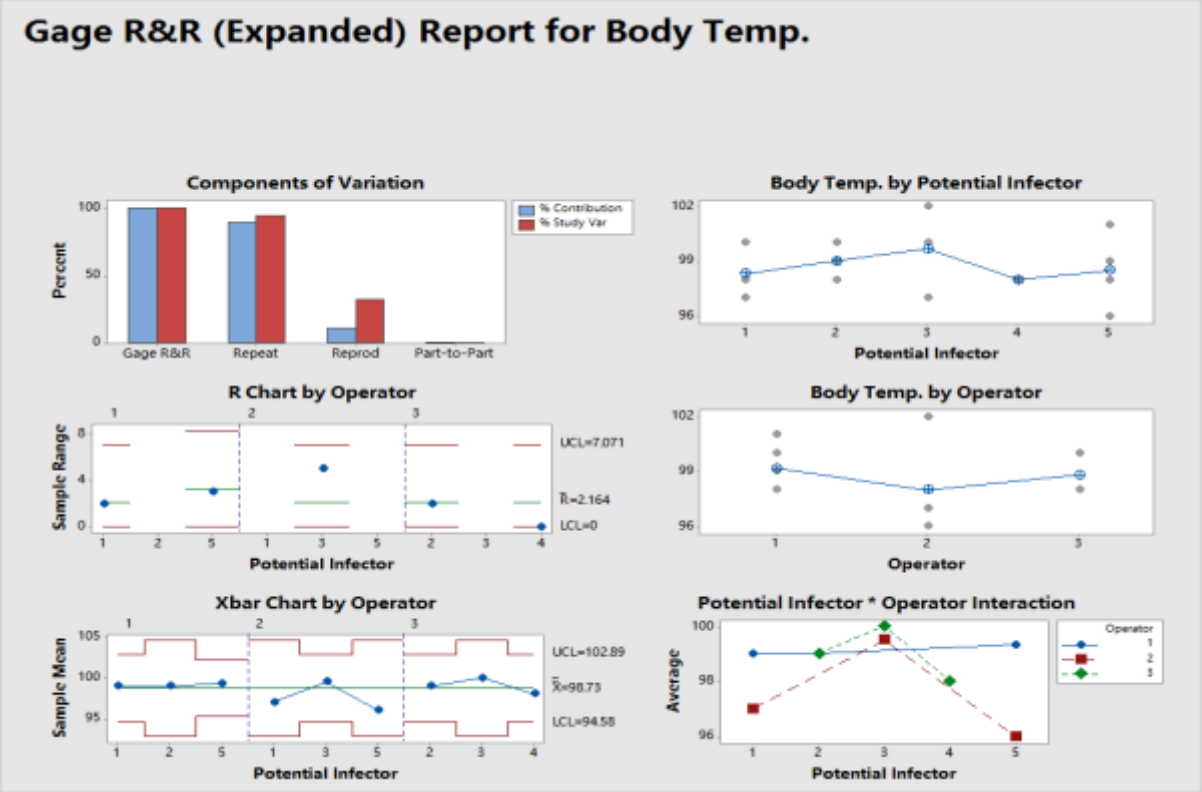


Figure 4: Gage R&R Result

III. Analyze Phase

This phase analyzes past and current performance data to identify the causes for variation and process performance.

a. Fishbone(Ishikawa)

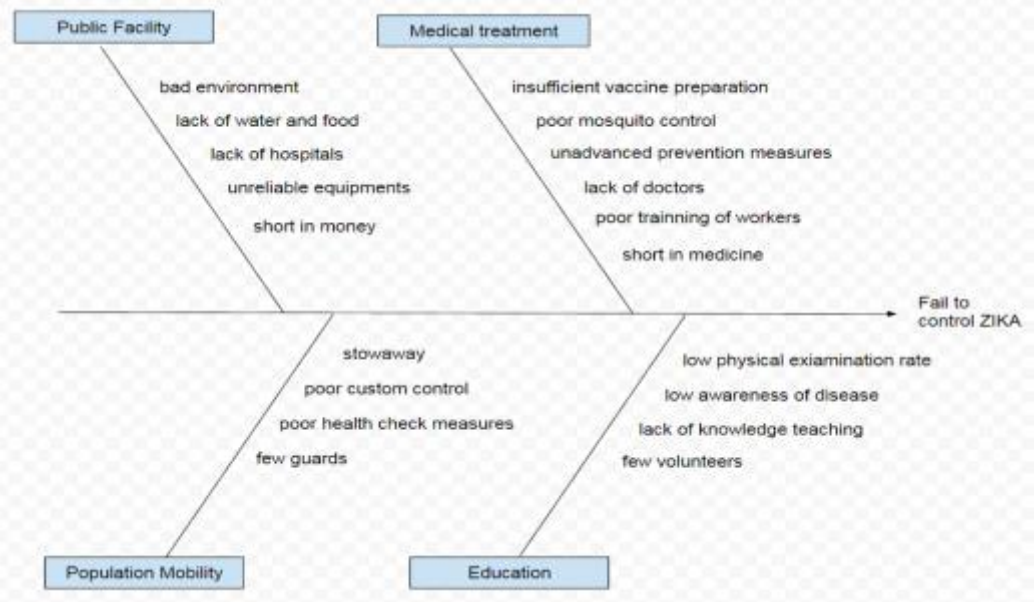


Figure 5: Ishikawa diagram

A fishbone diagram, also called a cause and effect diagram or Ishikawa diagram, is a visualization tool for categorizing the potential causes of a problem to identify its root causes. In our project, we have defined four major factors could lead to spreading control failure shown in the diagram above.

b. Statistical Process Control(SPC)

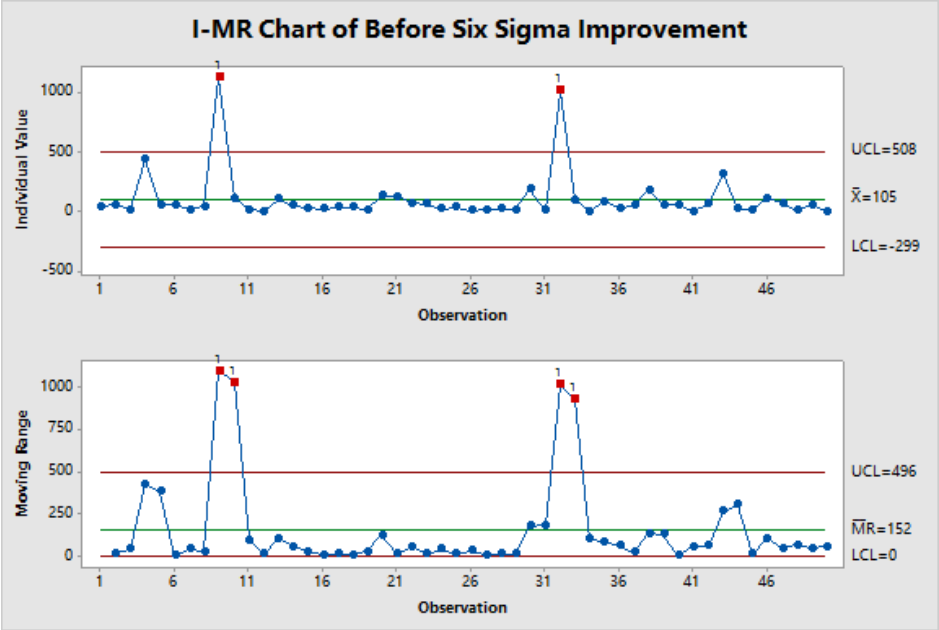


Figure 6: Before Six Sigma

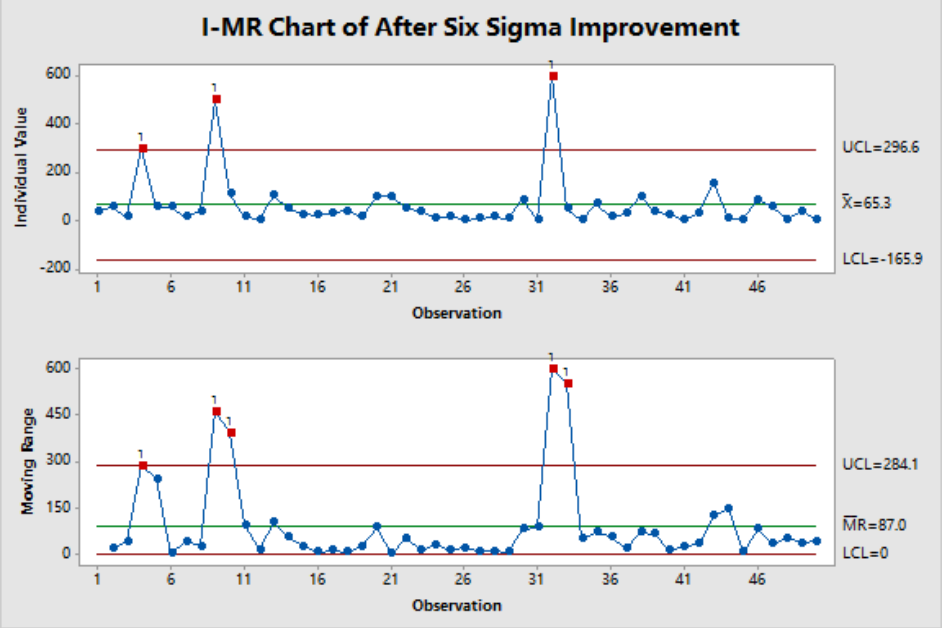


Figure 7: After Six Sigma

SPC Result

By apply SPC with CDC published case count data, we could find high variation exist in current inspection process. Such variation might cause by difference in passenger flow rate and passenger origins. SPC method and result will be discussed and explained further in later section.

IV. Improvement Phase

This phase designs a remedy, proves its effectiveness and prepares an implementation plan.

I. Process Capability Analysis(PCA)

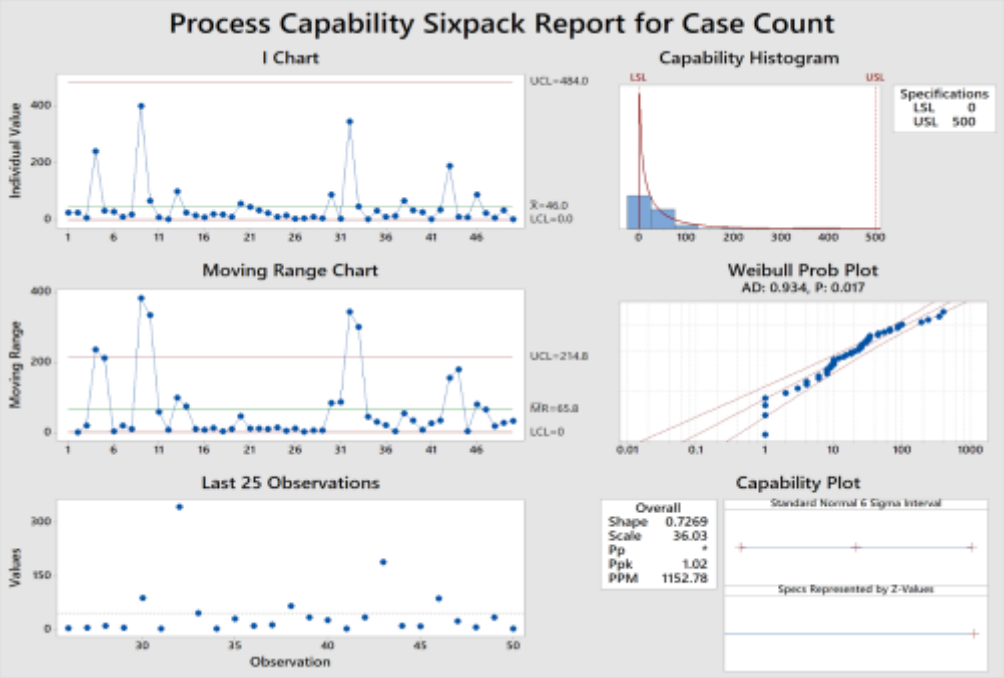


Figure 7: PCA After Improvement Result

By implement Six Sigma method, we hypothesized new data to represent potential improvement. From our data, we can see the variation has decreased compared with previous result.

V. Control Phase

In this phase, we design and implement certain activities to sustain the gains of improvement.

- Validate Measure System
- Validate Medical Census Data
- Skill and Knowledge of Zika
- Implement Zika Virus Education at Transportation Centers
- Adequate Medical Equipment at Transportation Centers
- Adequate Medical Training for Transportation Center Employees
- Continuous Review and Improve

- Implement and Monitor the Screening Process at Transportation Centers
- Determine the Final Process Capability

To maintain potential improvement, control phase is crucial. The list above is list of concerns might lead to failures to maintain the improvement from Six Sigma process.

5.QUALITY FUNCTION DEPLOYMENT

5.1 Quality Function Deployment introduction

Quality function deployment (QFD) is a method developed to transform the voice of the customer [VOC] into engineering characteristics for a product. Yoji Akao, the original developer, described QFD as a "method to transform qualitative user demands into quantitative parameters, to deploy the functions forming quality, and to deploy methods for achieving the design quality into subsystems and components, and ultimately to specific elements of the manufacturing process.".

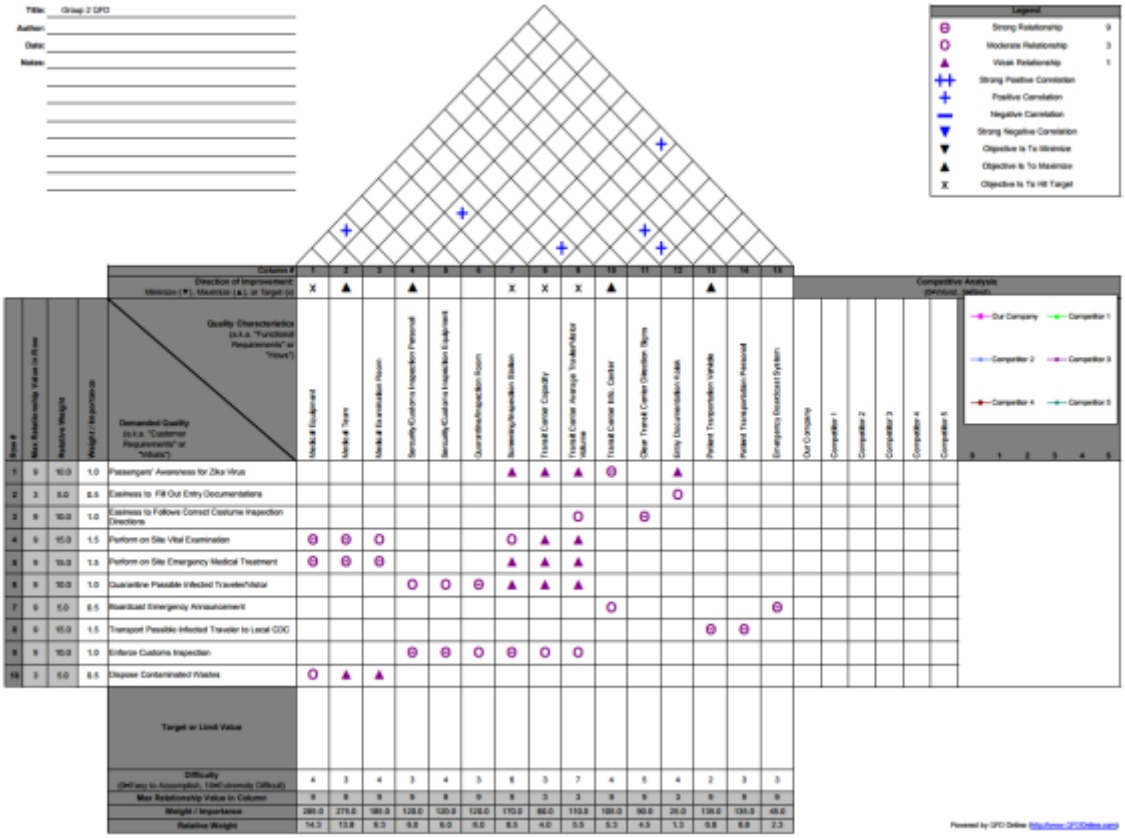


Figure 8: overview of Zika virus control QFD

5.2 Elements in the house of quality

In the vertical line of the QFD, there are demand quality (customer requirements) of control Zika virus. For easily control Zika spreading, we list the passenger's awareness for Zika virus, easiness to fill out entry documentations and easiness to follows correct costume inspection directions. In the emergency, we consider quarantining the infected visitors and broadcast the emergency and transport the infected people. After that, service of enforce customs inspection and dispose the wastes are also list in the demand quality. In the horizontal line is the quality characteristics (functional requirements) associated with the problems we raised. These are medical equipment's, medical team, medical examination room, security team and equipment's and so on.

6.DOE/EXPERIMENTAL DESIGN

6.1 Introduction of Design of experiments

DOE is used to set up and analyze a framework where multiple factors, levels and replicates can be combined and analyzed. The goal of a DOE is to determine how a response is affected by both individual factors and the interactions between each factor.

The most commonly used terms in the DOE methodology include: controllable and uncontrollable input factors, responses, hypothesis testing, blocking, replication and interaction.

- Controllable input factors are input parameters that can be modified in an process.
- Uncontrollable input factors are those parameters that cannot be altered.
- Responses are the elements of the process outcome that gage the desired effect.

6.2 Steps of DOE

The controllable input factors can be modified to optimize the output. The relationship between the factors and responses is shown in figure below.

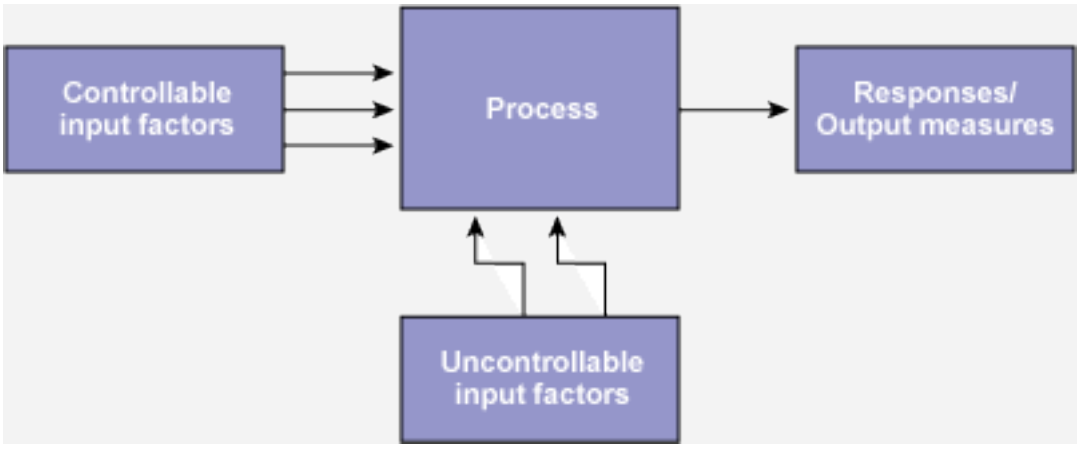


Figure 9: Process Factors and Responses

Hypothesis testing It helps to determine the significant factors using statistical methods. There are two possibilities in a hypothesis statement:

- Null hypothesis
- Alternative hypothesis

The null hypothesis is valid if the testing is true. The alternative hypothesis is true if the testing not valid. Testing is done at a level of significance, which is based on a probability.

This assignment deals with analysis of 2*3 full factorial design and the design of experiments is performed using

- Excel
- Minitab
- Quality Companion.

Given below is the data set with three factors

- Time
- Catalyst
- Temperature

Data Set 2: Groups 2, 4, 6 and 8

Row	Time	Temp	Catalyst	Cost
1	50	200	A	31.7457
2	20	200	A	31.0513
3	50	200	B	36.8941
4	50	150	B	32.6394
5	20	150	A	27.5306
6	50	150	A	29.3841
7	20	200	B	34.6241
8	20	150	B	30.5424
9	50	200	A	32.3437
10	50	150	B	33.0854
11	50	200	B	37.4261
12	20	200	B	35.2461
13	50	150	A	28.7501
14	20	150	B	30.2104
15	20	150	A	28.0646
16	20	200	A	30.7473

Table 3: (Data for DOE Design)

Step 1: To begin with Each factor has two levels high and low

Factors	Low (-)	High (+)
Time	20	50
Temperature	150	200
Catalyst	A	B

Table 4: (Design of Experiments Factors)

Step 2: Total Number of runs: 2*2^3 = 16

- As the given data has replicates, we ignored the effect of replicates and performed DOE for 8 runs

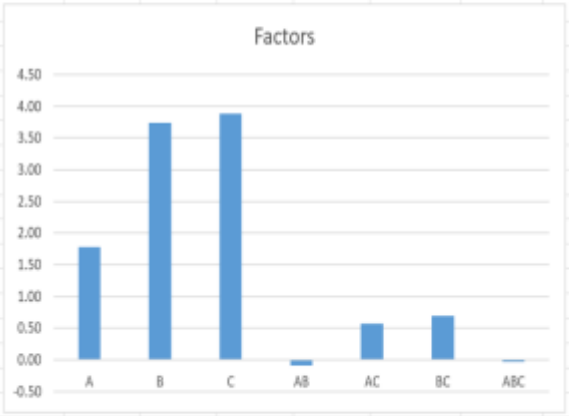
Step 3: Begin assigning values to the factors i.e. assign (+1) for high value of factor and (-1) for low value

Step 4: Record the response in the “Y1” column

Step 5: Repeat the experiment with “Y2” column

6.3 Design of Experiments in Excel

	Factorial Experiments							Run Results					Regression Residuals	
Run	A	B	C	AB	AC	BC	ABC	Y1	Y2	Avg.	Var.	RegEstim	Er-1	Er-2
1	1	1	-1	1	-1	-1	-1	31.75	32.34	32.045	0.179	32.66	-0.92	-0.32
2	-1	1	-1	-1	1	-1	1	31.05	30.75	30.899	0.046	32.66	-0.92	-0.32
3	1	1	1	1	1	1	1	36.89	37.43	37.160	0.142	30.98	0.07	-0.23
4	1	-1	1	-1	1	-1	-1	32.64	33.09	32.862	0.099	36.54	0.35	0.88
5	-1	-1	-1	1	1	1	-1	27.53	28.06	27.798	0.143	32.91	-0.27	0.18
6	1	-1	-1	-1	-1	1	1	29.38	28.75	29.067	0.201	27.15	0.38	0.92
7	-1	1	1	-1	-1	1	-1	34.62	35.25	34.935	0.193	29.02	0.36	-0.27
8	-1	-1	1	1	-1	-1	1	30.54	30.21	30.376	0.055	34.86	-0.23	0.39
TotSum								254.41	255.87	255.143	1.069	31.03	-0.49	-0.82
SumY+	131.13	135.04	135.33	127.38	128.72	128.96	127.50							
SumY-	124.01	120.10	119.81	127.76	126.42	126.18	127.64							
AvgY+	32.78	33.76	33.83	31.84	32.18	32.24	31.88							
AvgY-	31.00	30.03	29.95	31.94	31.61	31.55	31.91							
Effect	**1.78**	**3.73**	**3.88**	**-0.10**	**0.57**	**0.69**	**-0.03**							
Var+	0.155	0.140	0.122	0.130	0.107	0.170	0.111							
Var-	0.109	0.125	0.142	0.135	0.157	0.095	0.154							
F	0.705	0.890	1.161	1.043	1.462	0.559	1.384							



Regression Estimations							
RegCoef	A	B	C	AB	AC	BC	Constant
Estimat.	0.89	1.87	1.94	-0.05	0.29	0.35	31.89
Var. of Model		0.13		StdDv	0.37		
Var. of Effect		0.02		StdDv	0.15		
Student T (0.025;DF) =				2.473			
C.I. Half Width =				**0.369**			

Factor	A	B	C	AB	AC	BC	ABC
Signific.	Yes	Yes	Yes	No	Yes	Yes	No

Table 5: Excel DOE Analysis

Figure above shows Excel DOE analysis, the regression model generated is described in following equation. Also, as C.I. Half Width value for factor AC is great than its Effect, factor AC is not significant, thus in our regression model, this factor will not be considered.
Equation:1

Y = 31.89 + 0.89*Time+ 1.87*Temp + 1.94*Catalyst +0 .29 Time*Catalyst + 0.35Temp*Catalyst

6.4 Mini Tab DOE

To perform Minitab DOE analysis, a framework must be generated using Minitab Factorial Creation. Figure below is the Factorial Design table generated from Minitab. Also, the Responses(Cost), are added next to corresponding runs.

With Factorial Design Table generated, we can perform DOE analysis using Minitab, Table 6 Below shows the Minitab Result.

↓	C1	C2	C3	C4	C5	C6	C7	C8
	StdOrder	RunOrder	CenterPt	Blocks	Time	Temp	Catalyst	Cost
1	15	1	1	1	-1	1	1	31.7457
2	6	2	1	1	1	-1	1	31.0513
3	14	3	1	1	1	-1	1	36.8941
4	16	4	1	1	1	1	1	32.6394
5	12	5	1	1	1	1	-1	27.5306
6	10	6	1	1	1	-1	-1	29.3841
7	3	7	1	1	-1	1	-1	34.6241
8	11	8	1	1	-1	1	-1	30.5424
9	4	9	1	1	1	1	-1	32.3437
10	8	10	1	1	1	1	1	33.0854
11	1	11	1	1	-1	-1	-1	37.4261
12	5	12	1	1	-1	-1	1	35.2461
13	2	13	1	1	1	-1	-1	28.7501
14	13	14	1	1	-1	-1	1	30.2104
15	9	15	1	1	-1	-1	-1	28.0646
16	7	16	1	1	-1	1	1	30.7473

Table 6: 2*2^3 Factorial Design

Interpretation from P - value:

The 'P' value column below we see that there is only 1 Term where we would fail to reject the null hypothesis. The interaction between Time and Temp (Time*Temp) has a p-value of 0.605 which is above our alpha value of .05 (95% confidence). The assessment of the experiment is governed by interactions between some factors. A summary is shown below.

From the P value, we can determine the effect of 6 different factors, shown in table below.

Factor	Has Effect?
Time	Yes
Temp	Yes
Catalyst	Yes
Time * Temp	No
Time * Catalyst	Yes
Temp * Catalyst	Yes

Factorial Regression: Cost versus Time, Temp, Catalyst

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	6	132.199	22.0332	189.99	0.000
Linear	3	128.924	42.9746	370.56	0.000
Time	1	12.623	12.6226	108.84	0.000
Temp	1	55.920	55.9201	482.18	0.000
Catalyst	1	60.381	60.3811	520.65	0.000
2-Way Interactions	3	3.276	1.0919	9.42	0.004
Time*Temp	1	0.033	0.0333	0.29	0.605
Time*Catalyst	1	1.336	1.3362	11.52	0.008
Temp*Catalyst	1	1.906	1.9063	16.44	0.003
Error	9	1.044	0.1160		
Lack-of-Fit	1	0.006	0.0058	0.04	0.837
Pure Error	8	1.038	0.1297		
Total	15	133.243			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.340548	99.22%	98.69%	97.52%

Coded Coefficients

Term	Effect	Coef	SE Coef	T-Value	P-Value	VIF
Constant		31.8903	0.0851	374.58	0.000	
Time	1.7764	0.8882	0.0851	10.43	0.000	1.00
Temp	3.7390	1.8695	0.0851	21.96	0.000	1.00
Catalyst	3.8853	1.9426	0.0851	22.82	0.000	1.00
Time*Temp	-0.0912	-0.0456	0.0851	-0.54	0.605	1.00
Time*Catalyst	0.5780	0.2890	0.0851	3.39	0.008	1.00
Temp*Catalyst	0.6903	0.3452	0.0851	4.05	0.003	1.00

Alias Structure

Factor	Name
A	Time
B	Temp
C	Catalyst

Aliases

I
A
B
C
AB
AC
BC

Regression Equation in Uncoded Units

Cost = 31.8903 + 0.8882 Time + 1.8695 Temp + 1.9426 Catalyst - 0.0456 Time*Temp
+ 0.2890 Time*Catalyst + 0.3452 Temp*Catalyst

Table 7: Mini Tab Result

Equation 2:

Y = 31.89 + 0.89*Time+ 1.87*Temp + 1.94*Catalyst +0 .29 Time*Catalyst + 0.35Temp*Catalyst

Figure 10 to 13 are chart generated from Minitab analysis to visually demonstrate the results, the graph in figure 5 shows the effectiveness of each factors by measuring its distance to the straight line, if it is too close, means the factor have no effect on its response.

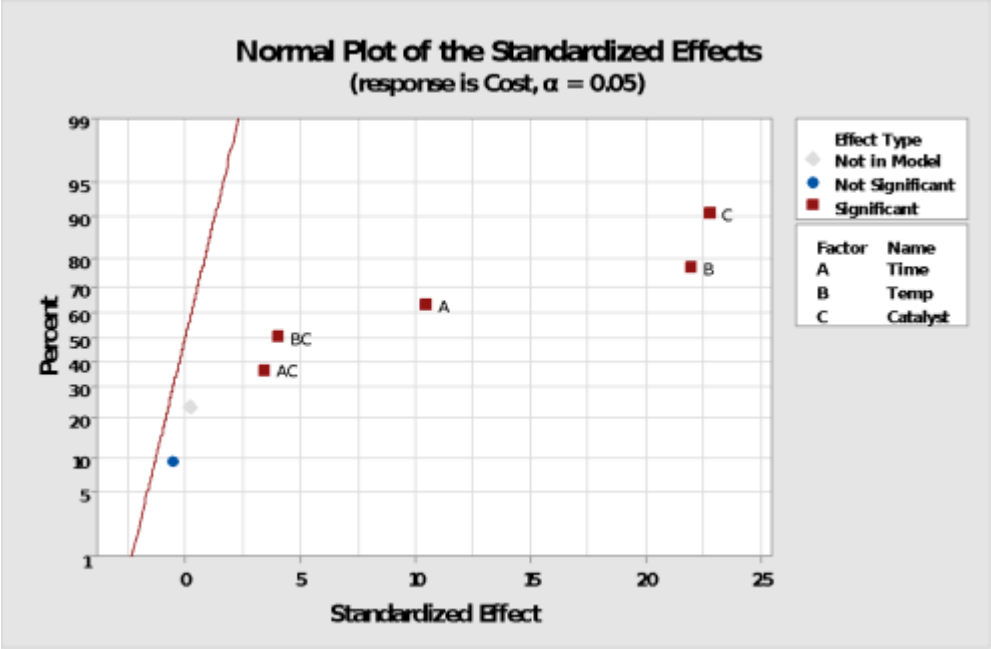


Figure 10: Normal Plot of Effects

Similar with figure 10, figure 11 below also shows the effectiveness by comparing its T value, if the T value is higher than required C.I., it means such factor has no effect on the response.

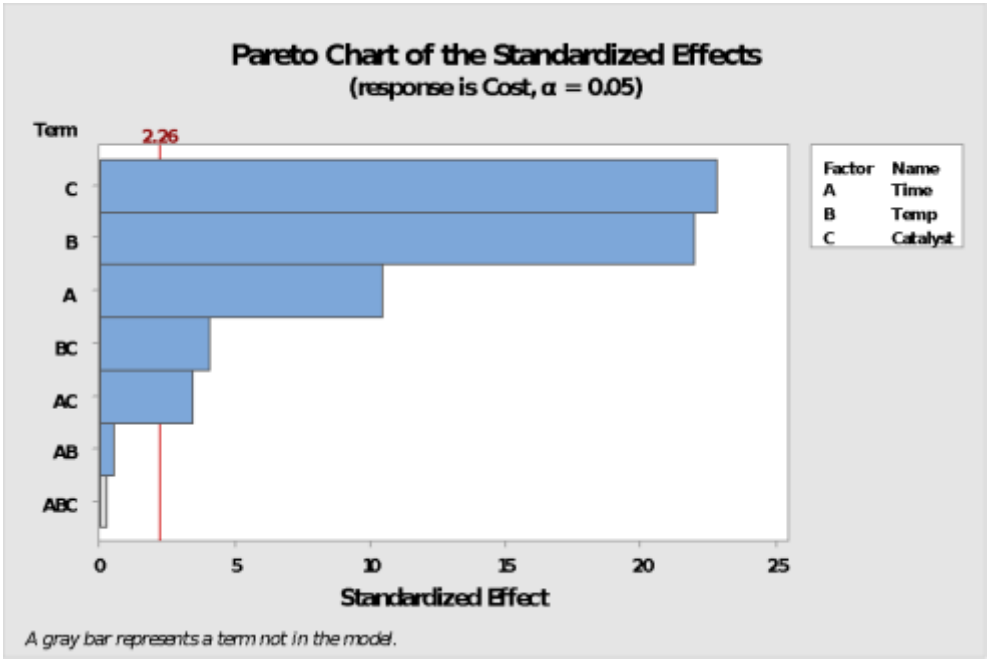


Figure 11: Pareto Chart of Effect

Figure 12 show the effectiveness of each factor, if the slope of each factor is greater than 0, means such factor has effect on the response.

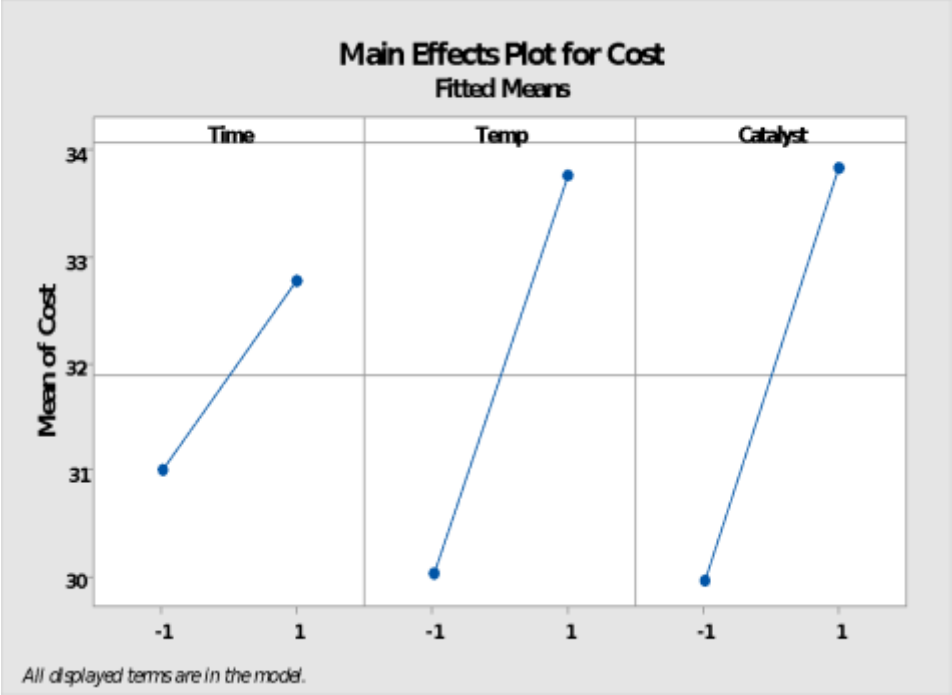


Figure 12: Response and Effect Chart

Figure below shows the effectiveness on the response of interactions between factors, as shown in figure, due to the parallel line of interaction Time*Temp, it indicates that interaction Time*Temp has no effect on the response.

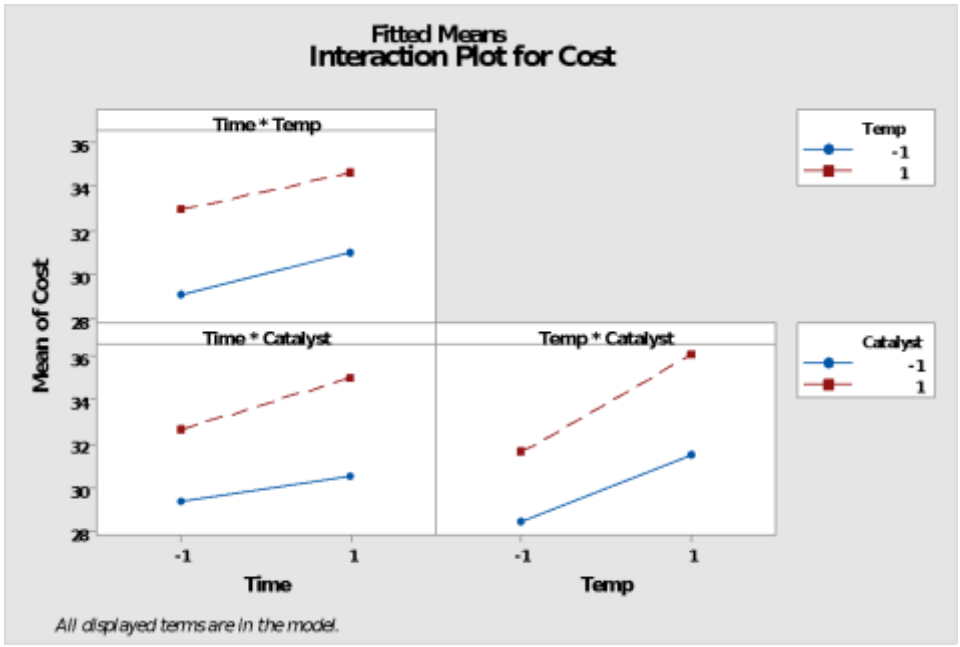


Figure 13: Interaction Chart

6.5 Mini Tab Regression Model

Figure below shows the factorial table for regression analysis. Compared with DOE factorial table, there are only 8 runs for regression design, whereas replication response has a separate column.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
	StdOrder	RunOrder	CenterPt	Blocks	Time	Temp	Catalyst	Time*Temp	Time*Catalyst	Temp*Catalyst	Time*Temp*Catalyst	Cost 1	Cost 2	Avg.
1	1	1	1	1	-1	-1	-1	1	1	1	-1	27.53	28.06	27.798
2	2	2	1	1	1	-1	-1	-1	-1	1	1	29.38	28.75	29.067
3	3	3	1	1	-1	1	-1	-1	1	-1	1	31.05	30.75	30.899
4	4	4	1	1	1	1	-1	1	-1	-1	-1	31.75	32.34	32.045
5	5	5	1	1	-1	-1	1	1	-1	-1	1	30.54	30.21	30.376
6	6	6	1	1	1	-1	1	-1	1	-1	-1	32.64	33.09	32.862
7	7	7	1	1	-1	1	1	-1	-1	1	-1	34.62	35.25	34.935
8	8	8	1	1	1	1	1	1	1	1	1	36.89	37.43	37.160
9														

Table 8: Regression Factorial Table

The Result of regression is shown below, compared with Excel and DOE result, the Time*Temp interaction also has a high P value. Furthermore, the regression equation is described in equation 3.

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	31.8927	0.0173	1848.86	0.000	
Time	0.8907	0.0173	51.64	0.012	1.00
Temp	1.8670	0.0173	108.23	0.006	1.00
Catalyst	1.9405	0.0173	112.49	0.006	1.00
Time*Temp	-0.0480	0.0173	-2.78	0.220	1.00
Time*Catalyst	0.2870	0.0173	16.64	0.038	1.00
Temp*Catalyst	0.3472	0.0173	20.13	0.032	1.00

Regression Equation

```
Avg. = 31.8927 + 0.8907 Time + 1.8670 Temp + 1.9405 Catalyst - 0.0480 Time*Temp
       + 0.2870 Time*Catalyst + 0.3472 Temp*Catalyst
```

Table 9: Regression Model

Equation 3:

Y = 31.89 + 0.89*Time+ 1.87*Temp + 1.94*Catalyst +0 .29 Time*Catalyst + 0.35Temp*Catalyst

6.6 Standard deviation regression

-	C1	C2	C3	C4	C5	C6	C7	C8	C9
	Row	Time	Temp	Catalyst	Cost	Cost 2	AVG.	STD.Dev	LogStd
1	1	1	1	-1	31.7457	32.3437	32.0447	0.422850	-0.373814
2	2	-1	1	-1	31.0513	30.7473	30.8993	0.214960	-0.667641
3	3	1	1	1	36.8941	37.4261	37.1601	0.376181	-0.424603
4	4	1	-1	1	32.6394	33.0854	32.8624	0.315370	-0.501180
5	5	-1	-1	-1	27.5306	28.0646	27.7976	0.377595	-0.422974
6	6	1	-1	-1	29.3841	28.7501	29.0671	0.448306	-0.348426
7	7	-1	1	1	34.6241	35.2461	34.9351	0.439820	-0.356725
8	8	-1	-1	1	30.5424	30.2104	30.3764	0.234759	-0.629377
9									

Table 10: Worksheet for STDEV regression

Figure Above shows the Minitab Worksheet used for log standard and Factor regression, the regression result is shown in figure below.

```
       S    R-sq  R-sq(adj)  R-sq(pred)
0.142683  23.48%      0.00%        0.00%


Coefficients

Term         Coef  SE Coef  T-Value  P-Value   VIF
Constant  -0.4656   0.0504    -9.23    0.001
Time       0.0536   0.0504     1.06    0.348  1.00
Temp       0.0099   0.0504     0.20    0.854  1.00
Catalyst  -0.0124   0.0504    -0.25    0.818  1.00


Regression Equation

LogStd = -0.4656 + 0.0536 Time + 0.0099 Temp - 0.0124 Catalyst
```

Table 11: Regression Result

As shown in Table 11, the P value of regression for each factor is high, which will reject the hypothesis indicating no significant factors.

6.7 Process Capability

From data given, we only have access to average data from each run and its replication, thus we could not determine the data collecting method is capable or not. To improve future

performance result, more run should be performed to gather more accurate data and reduce the variance.

6.8 Conclusion

From three different DOE method, we performed, all of them generated similar result as shown in table below.

Excel	Y = 31.89 + 0.89*Time+ 1.87*Temp + 1.94*Catalyst +0 .29 Time*Catalyst + 0.35Temp*Catalyst
DOE	Y = 31.89 + 0.89*Time+ 1.87*Temp + 1.94*Catalyst +0 .29 Time*Catalyst + 0.35Temp*Catalyst
Regression	Y = 31.89 + 0.89*Time+ 1.87*Temp + 1.94*Catalyst +0 .29 Time*Catalyst + 0.35Temp*Catalyst

7.SUPPLY CHAIN AND LEAN/VSM

7.1 Introduction

Lean supply chain management is not exclusively for those companies who manufacture products, but by businesses who want to streamline their processes by eliminating waste and nonvalue added activities. Companies have several areas in their supply chain where waste can be identified as time, costs or inventory. To create a leaner supply chain companies must examine each area of the supply chain.

Product	Level	Week	1	2	3	4	5	6	7	8	9	10	Total
Medical Department	0	Demand(J1)	6	8	5	3	4	8	8	5	2	5	54
		Planned Receipt	6	6	6	6	6	6	6	6	6	6	60
		Total Units	14	14	12	13	14	14	12	10	11	14	128
		Inventory	8	6	7	8	8	6	4	5	8	8	68
		Overflow	0	0	0	2	2	0	0	0	1	1	6
		Shortage	0	0	0	0	0	0	0	0	0	0	0
		Cost of Inventory	40	30	35	40	40	30	20	25	40	40	340
		Cost of Overflow	0	0	0	20	20	0	0	0	10	10	60
		Cost of Shortage	0	0	0	0	0	0	0	0	0	0	0
Medical Transportation	1	Production	6	6	6	6	6	6	6	6	6	6	60
		Planned Receipt	6	6	6	6	6	6	6	6	6	6	60
		Total Units	16	16	16	16	16	16	16	16	16	16	160
		Inventory	10	10	10	10	10	10	10	10	10	10	100
		Overflow	0	0	0	0	0	0	0	0	0	0	0
		Shortage	0	0	0	0	0	0	0	0	0	0	0
		Cost of Inventory	20	20	20	20	20	20	20	20	20	20	200
		Cost of Overflow	0	0	0	0	0	0	0	0	0	0	0
		Cost of Shortage	0	0	0	0	0	0	0	0	0	0	0
Medicene Factory	2	Production	6	6	6	6	6	6	6	6	6	6	60
		Planned Receipt	6	6	6	6	6	6	6	6	6	6	60
		Total Units	15	15	15	15	15	15	15	15	15	15	150
		Inventory	9	9	9	9	9	9	9	9	9	9	90
		Overflow	0	0	0	0	0	0	0	0	0	0	0
		Shortage	0	0	0	0	0	0	0	0	0	0	0
		Cost of Inventory	9	9	9	9	9	9	9	9	9	9	90
		Cost of Overflow	0	0	0	0	0	0	0	0	0	0	0
		Cost of Shortage	0	0	0	0	0	0	0	0	0	0	0
											Total Cost of I		630

Table 12: Supply chain

7.2. Improvement

As we are working for the CDC and Homeland security, we need a large amount of medicine for the Zika virus control. From the information we can see, large amount of waste could cost by the overflow and shortage, to save the medical fund, we can lean the supply chain.

Product	Level	Week	1	2	3	4	5	6	7	8	9	10	Total
Medical Department	0	Demand(J1)	6	8	5	3	4	8	8	5	2	5	54
		Planned Receipt	5	5	5	5	5	5	5	5	5	5	50
		Total Units	11	10	7	7	9	10	9	5	5	8	81
		Inventory	5	2	2	4	5	2	0	0	3	3	26
		Overflow	0	0	0	0	0	0	0	0	0	0	0
		Shortage	0	0	0	0	0	0	1	0	0	0	1
		Cost of Inventory	25	10	10	20	25	10	0	0	15	15	130
		Cost of Overflow	0	0	0	0	0	0	0	0	0	0	0
		Cost of Shortage	0	0	0	0	0	0	7	0	0	0	7
Medical Transportation	1	Production	5	5	5	5	5	5	5	5	5	5	50
		Planned Receipt	5	5	5	5	5	5	5	5	5	5	50
		Total Units	10	10	10	10	10	10	10	10	10	10	100
		Inventory	5	5	5	5	5	5	5	5	5	5	50
		Overflow	0	0	0	0	0	0	0	0	0	0	0
		Shortage	0	0	0	0	0	0	0	0	0	0	0
		Cost of Inventory	10	10	10	10	10	10	10	10	10	10	100
		Cost of Overflow	0	0	0	0	0	0	0	0	0	0	0
		Cost of Shortage	0	0	0	0	0	0	0	0	0	0	0
Medicene Factory	2	Production	5	5	5	5	5	5	5	5	5	5	50
		Planned Receipt	5	5	5	5	5	5	5	5	5	5	50
		Total Units	10	10	10	10	10	10	10	10	10	10	100
		Inventory	5	5	5	5	5	5	5	5	5	5	50
		Overflow	0	0	0	0	0	0	0	0	0	0	0
		Shortage	0	0	0	0	0	0	0	0	0	0	0
		Cost of Inventory	5	5	5	5	5	5	5	5	5	5	50
		Cost of Overflow	0	0	0	0	0	0	0	0	0	0	0
		Cost of Shortage	0	0	0	0	0	0	0	0	0	0	0
												Total Cost of Ir	280
												Total cost of O	0

Table 13: Supply chain Improvement

7.3 Conclusion

After lean the supply chain, we can simply save much cost by change the plan of inventory and receipt. This can then optimize the cost of overflow and shortage.

7.4 Value Stream Map

VSM is a lean manufacturing technique used to analyze and design the flow of materials and information required to bring product or service to a consumer.

Purpose:

- Develop a common understanding of the current process
- Create a baseline to measure improvements against
- Define a vision of the future process
- Design and implementation plan for improvements

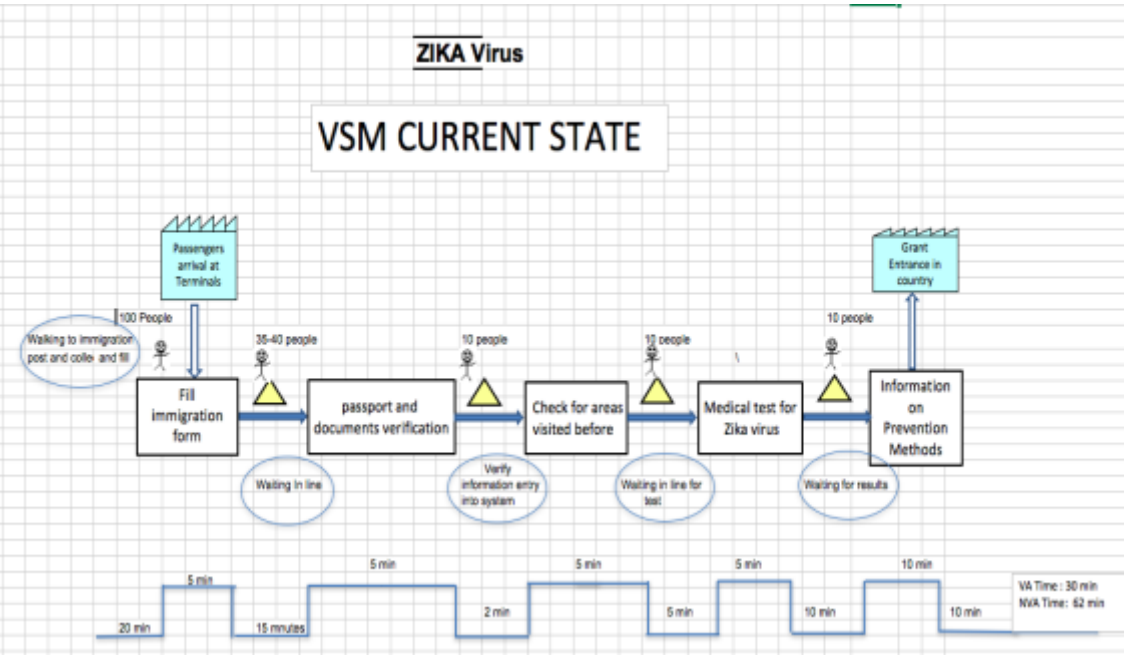


Figure 14: Current VSM

7.5 Future Value Stream Map

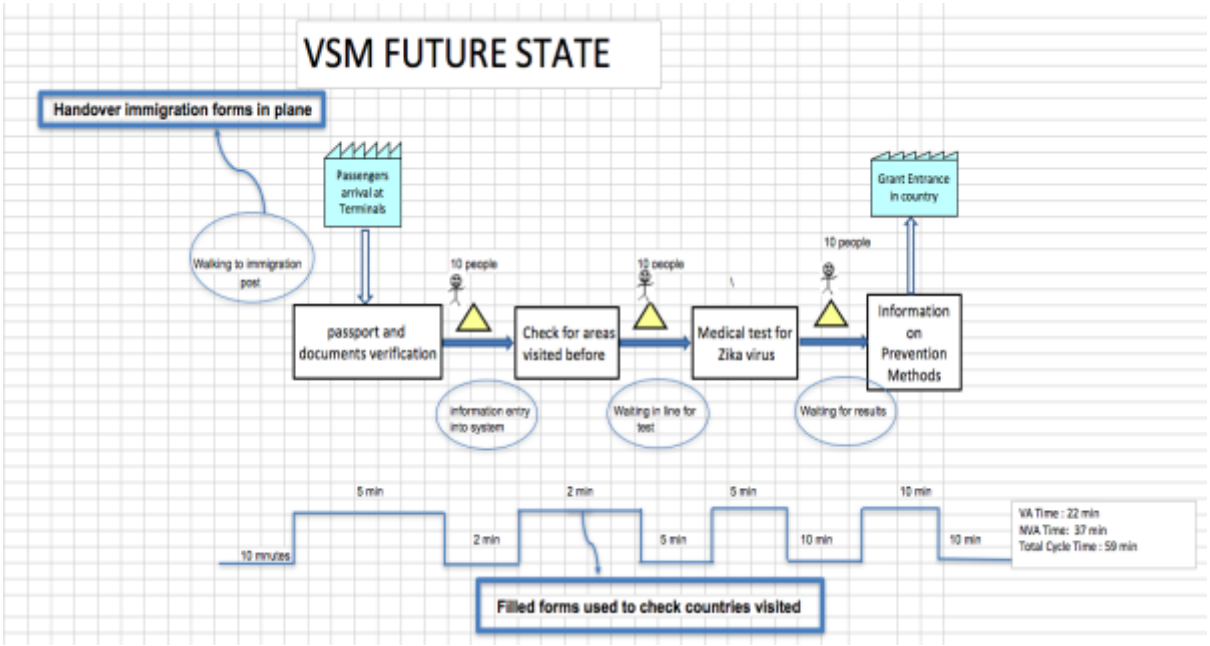


Figure 15: Future VSM

8. GAGE R&R METROLOGY MSA STUDY

8.1 Introduction

ANOVA 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 viability of the measurement system.

8.2 Gage R&R Study - ANOVA Method

Measurement System Analysis is an evaluation method to measure instruments and process utilized in obtaining the results. Especially, Gage R&R is a measuring tool used to determine the level of variability within the measurements based on the implemented measuring system.

In out topic ZITA Virus, Gage R&R can be utilized to evaluate the level of variability in the number of people detected at terminals using medical equipment and doctors.

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 * Ope	18	0.3590	0.0199	0.434	0.974
Repeatability	60	2.7589	0.04598		
Total	89	94.6471			

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			

Gage R&R

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

Study Var Source	%Study Var Std Dev (SD)	(6 * SD)	(%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

Number of Distinct Categories = 4

8.3 Attribute Agreement Analysis

Attribute Agreement Analysis. Overview. Attribute Agreement Analysis is used to assess the agreement between the ratings made by appraisers and the known standards.

There are two primary ways to assess attribute agreement:

- The percentage of the agreement between the appraisals and the standard
- The percentage of the agreement between the appraisals and the standard adjusted by the percentage of agreement by chance (known as the kappa statistics)

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

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
```

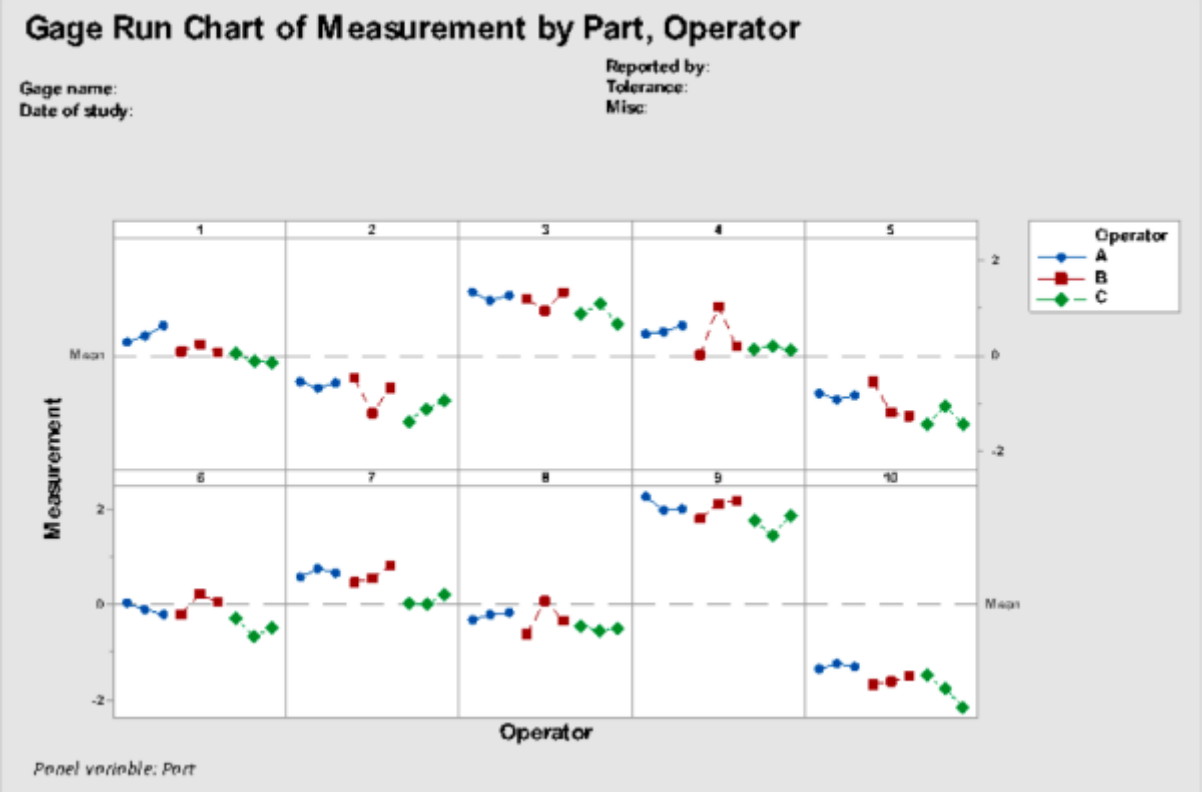


Figure 16: Gage R&R

Descriptive Statistics: Measurement

Results for Part = 1

Variable	Operator	N	N*	Mean	SE Mean	St Dev	Minimum	Q1
Measurement	A	3	0	0.447	0.103	0.178	0.290	0.290
	B	3	0	0.1333	0.0584	0.1012	0.0700	0.0700
	C	3	0	-0.0733	0.0578	0.1002	-0.1500	-0.1500

Variable	Operator	Median	Q3	Maximum
Measurement	A	0.410	0.640	0.640
	B	0.0800	0.2500	0.2500
	C	-0.1100	0.0400	0.0400

Results for Part = 2

Variable	Operator	N	N*	Mean	SE Mean	St Dev	Minimum	Q1
Measurement	A	3	0	-0.6067	0.0371	0.0643	-0.680	-0.680
	B	3	0	-0.790	0.223	0.387	-1.220	-1.220
	C	3	0	-1.157	0.122	0.211	-1.380	-1.380

Variable	Operator	Median	Q3	Maximum
Measurement	A	-0.5800	-0.5600	-0.5600
	B	-0.680	-0.470	-0.470
	C	-1.130	-0.960	-0.960

Results for Part = 3

Variable	Operator	N	N*	Mean	SE Mean	St Dev	Minimum	Q1
Measurement	A	3	0	1.2600	0.0493	0.0854	1.1700	1.170
	B	3	0	1.157	0.117	0.202	0.940	0.940
	C	3	0	0.880	0.121	0.210	0.670	0.670

Variable	Operator	Q3	Maximum
Measurement	A	1.3400	1.3400
	B	1.340	1.340
	C	1.090	1.090

Results for Part = 4

Variable	Operator	N	N*	Mean	SE Mean	St Dev	Minimum	Q1
Measurement	A	3	0	0.447	0.103	0.178	0.290	0.290
	B	3	0	0.1333	0.0584	0.1012	0.0700	0.0700
	C	3	0	-0.0733	0.0578	0.1002	-0.1500	-0.1500

Variable	Operator	Median	Q3	Maximum
Measurement	A	0.410	0.640	0.640
	B	0.0800	0.2500	0.2500
	C	-0.1100	0.0400	0.0400

Results for Part = 5

Variable	Operator	N	N*	Mean	SE Mean	St Dev	Minimum	Q1
Measurement	A	3	0	0.447	0.103	0.178	0.290	0.290
	B	3	0	0.1333	0.0584	0.1012	0.0700	0.0700
	C	3	0	-0.0733	0.0578	0.1002	-0.1500	-0.1500

Variable	Operator	Median	Q3	Maximum
Measurement	A	0.410	0.640	0.640
	B	0.0800	0.2500	0.2500
	C	-0.1100	0.0400	0.0400

Results for Part = 6

Variable	Operator	N	N*	Mean	SE Mean	St Dev	Minimum	Q1
Measurement	A	3	0	-0.6067	0.0371	0.0643	-0.680	-0.680
	B	3	0	-0.790	0.223	0.387	-1.220	-1.220
	C	3	0	-1.157	0.122	0.211	-1.380	-1.380

Variable	Operator	Median	Q3	Maximum
Measurement	A	-0.5800	-0.5600	-0.5600
	B	-0.680	-0.470	-0.470
	C	-1.130	-0.960	-0.960

Results for Part = 7

Variable	Operator	N	N*	Mean	SE Mean	St Dev	Minimum	Q1
Measurement	A	3	0	1.2600	0.0493	0.0854	1.1700	1.170
	B	3	0	1.157	0.117	0.202	0.940	0.940
	C	3	0	0.880	0.121	0.210	0.670	0.670

Variable	Operator	Q3	Maximum
Measurement	A	1.3400	1.3400
	B	1.340	1.340
	C	1.090	1.090

Results for Part = 8

Variable	Operator	N	N*	Mean	SE Mean	St Dev	Minimum	Q1
Measurement	A	3	0	0.447	0.103	0.178	0.290	0.290
	B	3	0	0.1333	0.0584	0.1012	0.0700	0.0700
	C	3	0	-0.0733	0.0578	0.1002	-0.1500	-0.1500

Variable	Operator	Median	Q3	Maximum
Measurement	A	0.410	0.640	0.640
	B	0.0800	0.2500	0.2500
	C	-0.1100	0.0400	0.0400

Results for Part = 9

Variable	Operator	N	N*	Mean	SE Mean	St Dev	Minimum	Q1
Measurement	A	3	0	1.2600	0.0493	0.0854	1.1700	1.170
	B	3	0	1.157	0.117	0.202	0.940	0.940
	C	3	0	0.880	0.121	0.210	0.670	0.670

Variable	Operator	Q3	Maximum
Measurement	A	1.3400	1.3400
	B	1.340	1.340
	C	1.090	1.090

Results for Part = 10

Variable	Operator	N	N*	Mean	SE Mean	St Dev	Minimum	Q1
Measurement	A	3	0	-0.6067	0.0371	0.0643	-0.680	-0.680
	B	3	0	-0.790	0.223	0.387	-1.220	-1.220
	C	3	0	-1.157	0.122	0.211	-1.380	-1.380

Variable	Operator	Median	Q3	Maximum
Measurement	A	-0.5800	-0.5600	-0.5600
	B	-0.680	-0.470	-0.470
	C	-1.130	-0.960	-0.960

Descriptive Statistics: Measurement

Variable	Part	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median
	1	9	0	0.1689	0.0846	0.2537	-0.1500	-0.0350	0.0800
	2	9	0	-0.851	0.110	0.329	-1.380	-1.175	-0.680
	3	9	0	1.0989	0.0760	0.2281	0.6700	0.9100	1.1700
	4	9	0	0.367	0.108	0.325	0.0100	0.125	0.200
	5	9	0	-1.064	0.103	0.309	-1.460	-1.365	-1.070
	6	9	0	-0.1856	0.0922	0.2765	-0.6700	-0.3900	-0.2000
	7	9	0	0.454	0.102	0.305	0.0100	0.115	0.550
	8	9	0	-0.3422	0.0741	0.2222	-0.6300	-0.5250	-0.340
	9	9	0	1.9400	0.0832	0.2495	1.4500	1.7850	1.9900
	10	9	0	-1.5711	0.0934	0.2802	-2.1600	-1.7250	-1.500

Variable	Part	Q3	Maximum
	1	0.3500	0.6400
	2	-0.570	-0.470
	3	1.3050	1.3400
	4	0.570	1.030
	5	-0.820	-0.560
	6	0.0400	0.2200
	7	0.705	0.830
	8	-0.1850	0.0800
	9	2.1550	2.2600
	10	-1.3350	-1.2500

Descriptive Statistics: Measurement

Variable	Operator	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median
Measurement	A	30	0	0.190	0.180	0.989	-1.360	-0.605	0.155
	B	30	0	0.0683	0.194	1.063	-1.680	-0.643	0.0750
	C	30	0	-0.254	0.187	1.024	-2.160	-1.085	0.220

Variable	Operator	Q3	Maximum
Measurement	A	0.683	2.260
	B	0.858	2.190
	C	0.203	1.870

Based on the results seen above, it can be determined that the measurement system utilized effectively because the Gage R&R variation is extremely low 27.86and the Part to Part variation is extremely high(96.04).

9. ACCEPTANCE SAMPLING PLAN

9.1 Introduction

In the process of preventing Zika virus from spreading. Vaccine quality is important. Some of them may be damaged during transportation. Some may have other quality problems. So, we designed acceptance sampling plan to check the quality of vaccine before using them.

9.2 Determining sample size

Assuming our lot size of vaccine is 1500. The manufacturer calls for an AQL of 5 defective vaccines per 100 and an LTPD of 15 defective vaccines per 100 as follow:

AQL = 0.05	α = 0.05
LPTD = 0.15	β = 0.1

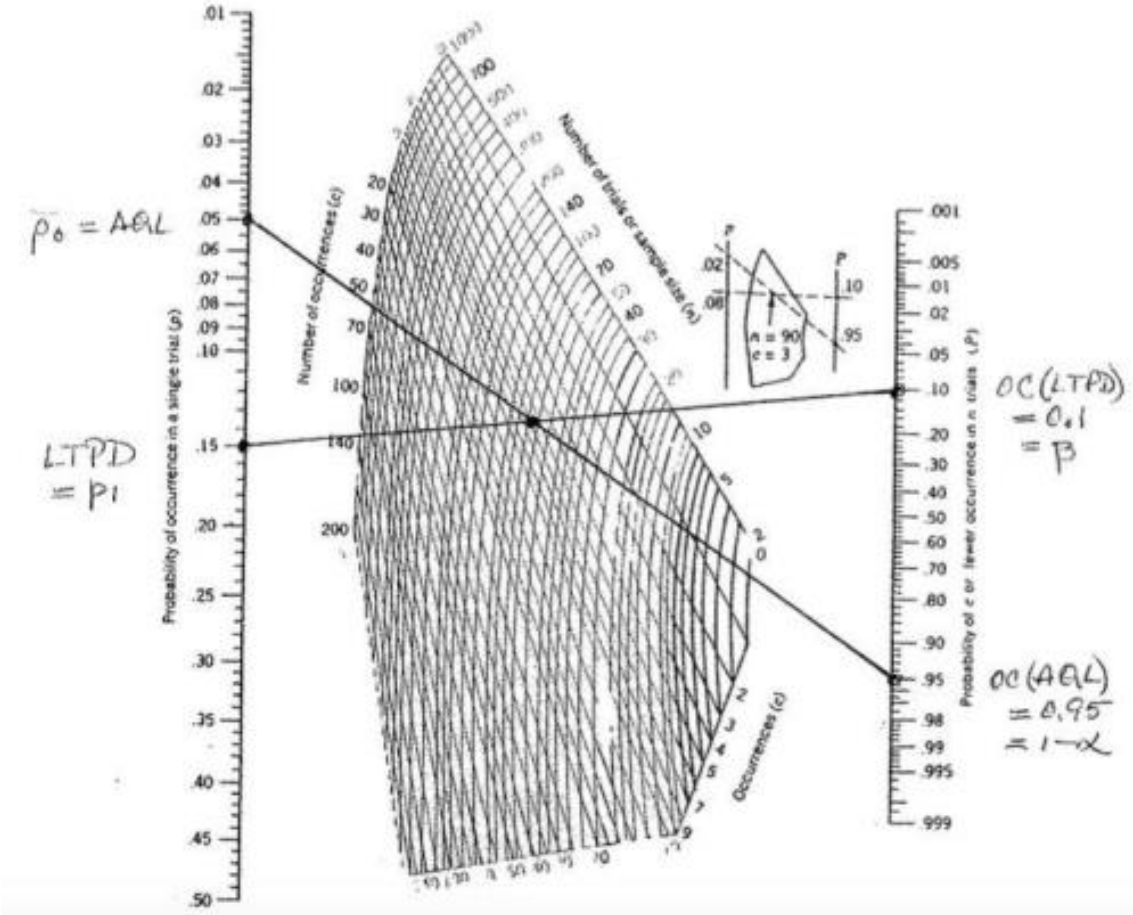


Figure 17: OC curve nomograph

In the acceptance sampling, we are looking for the most appropriate sampling size and best number of defective. For this purpose, we try two methods to find out n (sampling size) and c (number of defective) and compared them to determine the better result. First, we use the binomial nomograph as the figure showed.

We connected AQL and 1 - α as well as LTPD and β. The intersection of two line is the guess value which is n = 80, c = 7 and then according to this set of values we can calculate the OC data.

Second, ANSI/ASQC Z1.4 can also be used to guess the value of sampling size and number of defective. Since our lot size is 1500 and we choose II as our inspection level which is widely used, the code letter is going to be K as the figure showed.

Table I—Sample size code letters

(See 9.2 and 9.3)

Lot or batch size	Special inspection levels				General inspection levels		
	S-1	S-2	S-3	S-4	I	II	III
2 to 8	A	A	A	A	A	A	B
9 to 15	A	A	A	A	A	B	C
16 to 25	A	A	B	B	B	C	D
26 to 50	A	B	B	C	C	D	E
51 to 90	B	B	C	C	C	E	F
91 to 150	B	B	C	D	D	F	G
151 to 280	B	C	D	E	E	G	H
281 to 500	B	C	D	E	F	H	J
501 to 1200	C	C	E	F	G	J	K
1201 to 3200	C	D	E	G	H	K	L
3201 to 10000	C	D	F	G	J	L	M
10001 to 35000	C	D	F	H	K	M	N
35001 to 150000	D	E	G	J	L	N	P
150001 to 500000	D	E	G	J	M	P	Q
500001 and over	D	E	H	K	N	Q	R

Table 14: ANSI/ASQC Code

After we determine the code letter together with AQL, guess value of sample size and number of defective that n = 125 and c = 12can be found using the master table of normal inspection as the figure showed.

Sample size code letter	Sample size	Acceptable quality level (normal inspection)																												
		0.010	0.015	0.025	0.040	0.065	0.10	0.15	0.25	0.40	0.65	1.0	1.5	2.5	4.0	6.5	10	15	25	40	65	100	150	250	400	650	1000
		Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re
A	2	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	0 1	↓	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	30 31	↓	↓	↓
B	3	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	0 1	↑	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	30 31	44 45	↓	↓	↓	↓
C	5	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	0 1	↑	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
D	8	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	0 1	↑	↓	1 2	↑	↓	2 3	3 4	5 6	7 8	10 11	14 15	21 22	30 31	44 45	↓	↓	↓
E	13	↓	↓	↓	↓	↓	↓	↓	↓	↓	0 1	0 1	↓	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↓	↓	↓	↓	↓	↓	↓	↓
F	20	↓	↓	↓	↓	↓	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
G	32	↓	↓	↓	↓	↓	↓	↓	0 1	↑	↓	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
H	50	↓	↓	↓	↓	↓	↓	0 1	↑	↓	1 2	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
J	80	↓	↓	↓	↓	↓	0 1	↑	↓	1 2	2 3	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
K	125	↓	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	3 4	5 6	7 8	10 11	14 15	21 22	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
L	200	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	5 6	7 8	10 11	14 15	21 22	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
M	315	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
N	500	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
P	800	↓	0 1	↑	1 2	↓	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
Q	1250	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
R	2000	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓

↓ = use first sampling plan below arrow. If sample size equals or exceeds lot or batch size, do 100% inspection.

↑ = use first sampling plan above arrow.

Table 15: AQL

Obviously, we can also obtain the OC data by using this sample size and number of defective.

Now we can two set of OC data. The following graph is the comparison two OC curve made by their OC data.

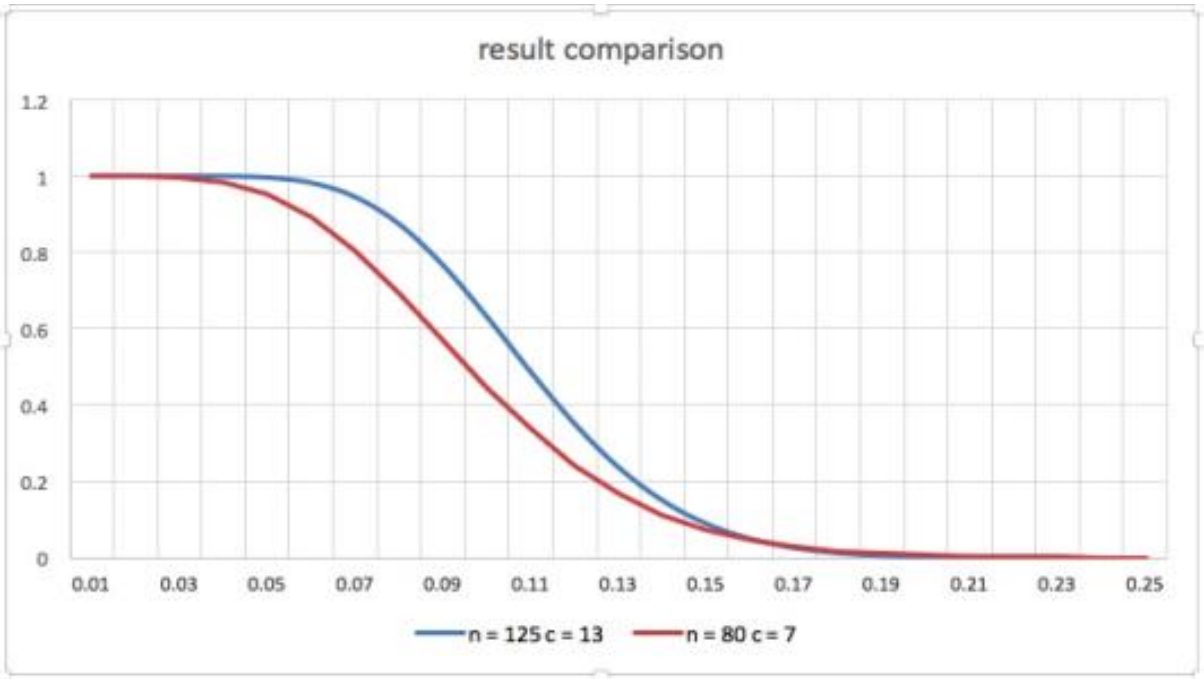


Figure 18: OC Curve results

Vertical axis represents probability of acceptance while horizontal axis stand for PD. According to the graph, n = 80 is better than n = 125. So, if we choose to use acceptance sampling. n = 80 c = 7 will be used.

9.3 Modify the sample size

The OC curve can be modifying to better performance by slightly regulating n and c.

Minitab can create a sampling plan based on the same input (AQL, LTPD, alpha and beta). Like what we did above. Below is the output for Minitab as well as the oc curve.

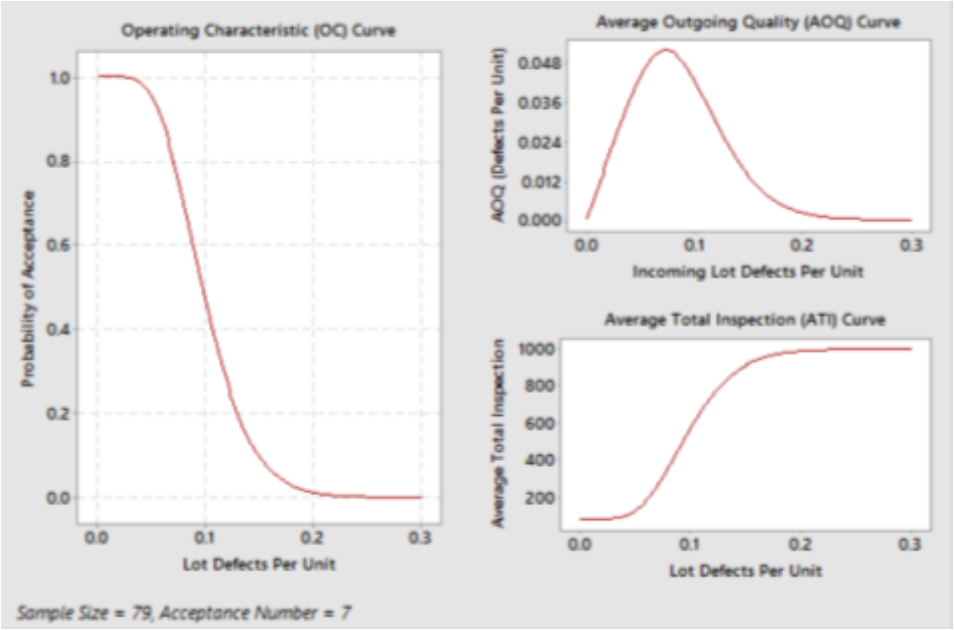


Figure 19: Minitab results

To test the oc curve and sampling plan we can use Minitab Bernoulli random number generator. Below is a Minitab session showing the output of the random number generation. Notice that according to our plan we will accept lots 95% of the time when the lot defect rate is at or less than 5%.

a. **Verify that your sampling plan accepts the lot.**

Data Display									
0	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	0	0
0	0	0	1	0	0	1	0	0	0
0	0	0	0	0	0	0	1	0	0
0	0	0	1	1	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0							

The sum of the defective is 6

Data Display						
0	0	0	0	0	1	0
0	0	0	0	0	0	0
0	0	0	1	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	1	0	0	0	0	0
0	0	0				

The sum of the defective is 5

b. Verify that sample is rejected.

Data Display						
0	0	0	0	0	0	0
0	1	0	0	0	0	0
0	1	0	0	1	0	0
0	1	0	1	0	1	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0				

The sum of the defective is 10

Data Display						
0	1	0	1	0	1	1
0	1	0	0	0	0	0
0	1	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	1	0
0	0	0	1	0	0	0
0	0	0				

The sum of the defective is 11

9.4 Economic of inspection

In this part, we are going to analyze the cost of inspection. In our case, it can be either no inspection or acceptance sampling inspection or 100% inspection which depending on the cost

including the cost of inspection, the cost of damage cost incurred if a defective slip through inspection and so on. The calculation formula is placed on the following:

Scheme	Cost
No inspection	NpA
acceptance sampling inspection	nI + (N - n) pAPa + (N - n) (1 - Pa) I
100% inspection	NI

where the meaning of parameters is list below:

N = number of items in lot = 1500
n = number of items in sample = 80
p = proportion defective in lot = 0.05
A = damage cost incurred if a defective slip through inspection = 50
I = inspection cost per item = 1.5
Pa = probability that lot will be accepted by sampling plan = 0.95
The break-even point Pb = I / A = 3%

Scheme	Cost
No inspection	3750
Acceptance sampling inspection	3599
100% inspection	2250

9.5 Conclusion

Since the cost of 100% inspection is lowest, in terms of economic, we are going to use 100% inspection. However, we also prepared the scheme of acceptance sampling plan if necessary.

10. STATISTICAL PROCESS CHART

10.1 introduction

Methods of statistical process control(SPC) have been in existence for over eighty years now in industrial statistics (Shewhart, Wald, Deming, etc.). SPC methods are used, among other things, to detect when a stable process, defined as one with a fixed mean level and a fixed variation, departs from stability. SPC is also used to assess the quality of a product that we are either producing ourselves or trying to acquire from a supplier. The first objective falls within 'quality control'(QC) procedures while the second falls within 'acceptance sampling' methods

10.2 Attribute SPC

Binomial n (inspections) =30, p=0.07, where n (trials) =100

Tries	Increment	p	Data Generated (Number of defectives in each inspection)
1	0%	0.07	7 7 8 7 3 6 8 8 6 3 5 8 6 9 5 5 6 2 7 6 11 7 6 7 6 7 8 8 4 6
2	20%	0.084	10 8 9 12 8 8 10 9 10 5 9 9 7 6 5 9 6 9 6 7 11 5 10 4 9 9 5 10 4 8
3	40%	0.098	8 6 4 10 11 14 8 15 13 11 9 12 13 7 10 8 7 9 7 6 11 15 8 7 8 10 5 11 3 13
4	60%	0.112	12 16 8 13 8 9 9 9 17 10 8 10 13 13 8 17 12 12 10 14 12 10 9 10 11 10 12 19 15 8

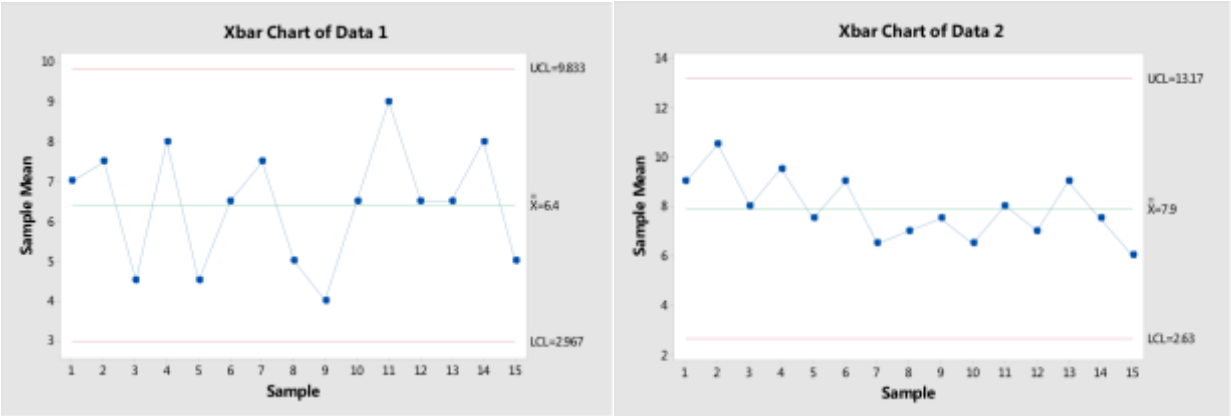


Figure 20: X bar charts for data sets 1 and 2

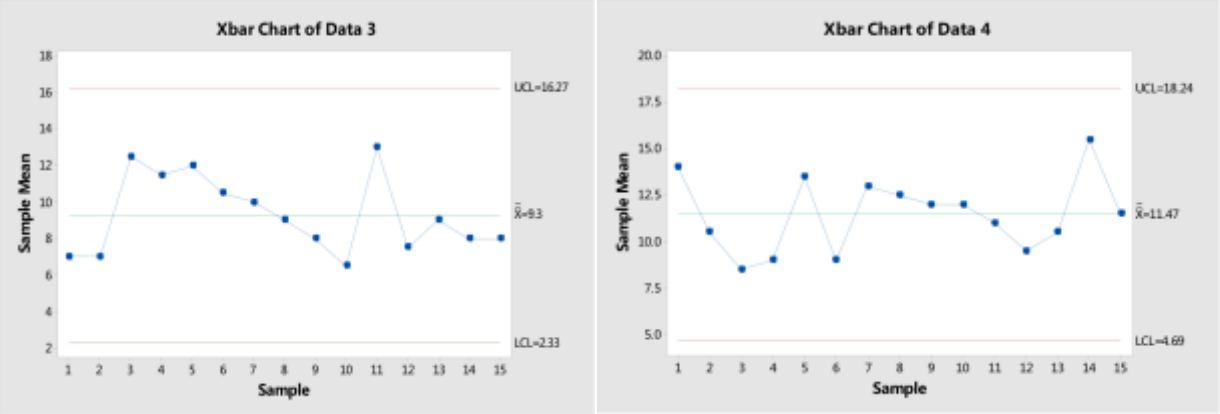


Figure 20: X bar charts for data sets 3 and 4

From chart 1 to 4, as we increase p by 20% each time data stays within range of UCL and LCL, indicates consistency exists in process.

10.3 Variable SPC

Normal (3 observations), μ=52, σ=12

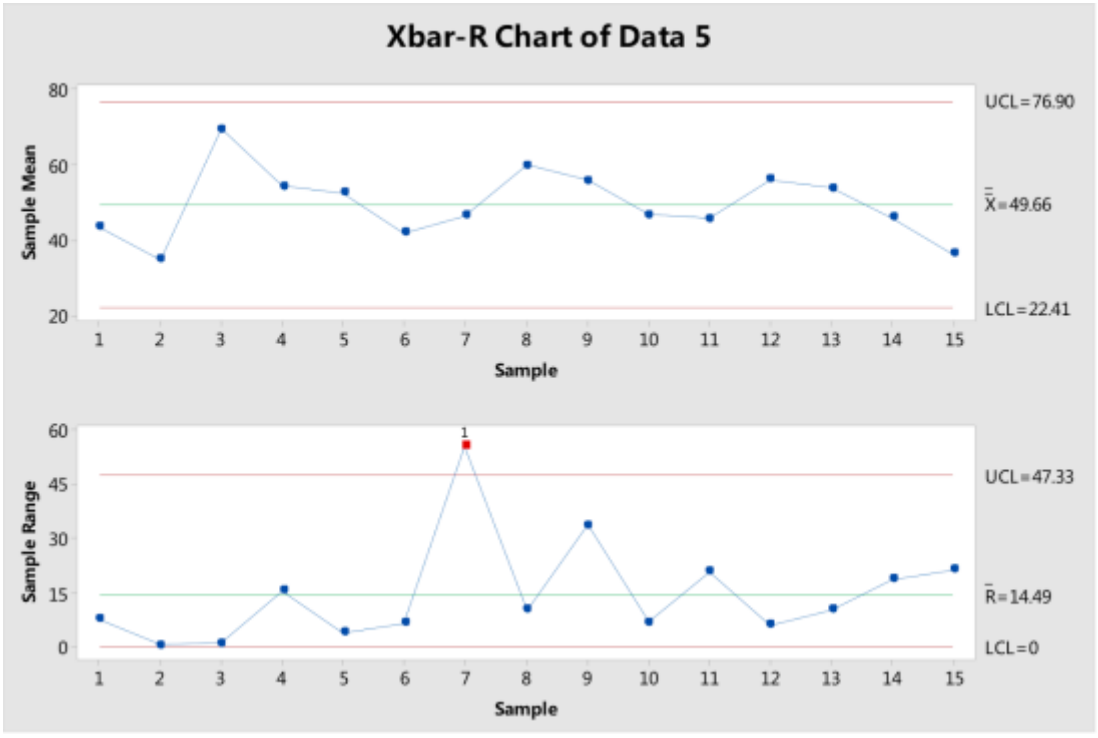


Figure 20: X bar charts for data set 5

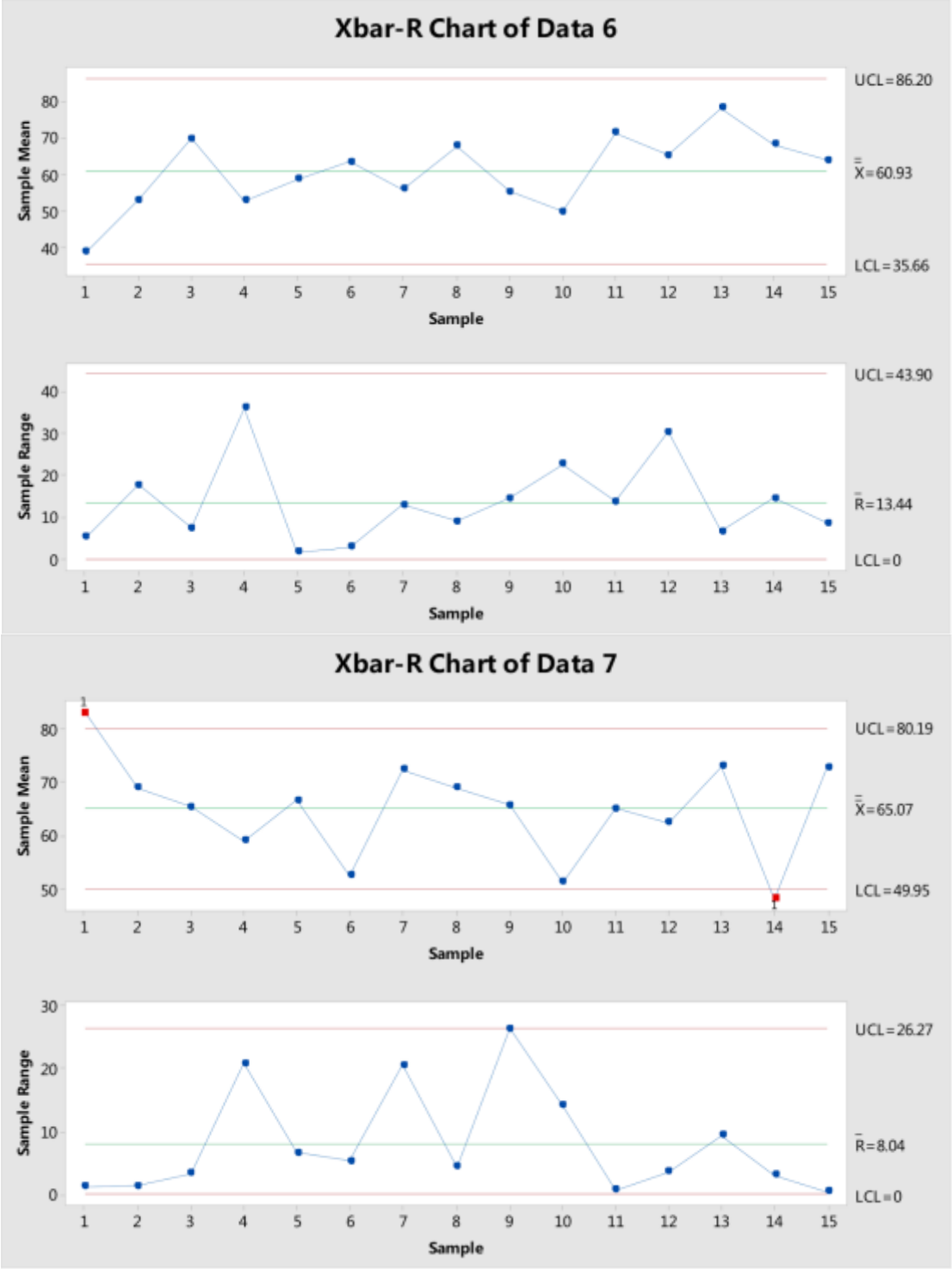


Figure 20: X bar charts for data sets 6 and 7

From Bar-R chart of data set 4-8, as we increase μ by 20% each time we can identify the increase in variation with the increase of μ. Furthermore, in data set 7, data has exceeded UCL and LCL in same dataset. The Cause of variation should be investigated.

Tries	1	2	3
Increment	0%	20%	40%
μ	52	62.4	72.8
Data Generated (10 sets of 7 observations, 70 in total)	39.7096 47.3191 35.2742 34.6846 70.0955 68.9663 62.1570 46.7323 50.6723 54.6434 45.3216 38.7994 74.1313 18.8547 65.0000 54.8624 39.1687 72.6342 50.2686 43.4251 56.0244 35.4563 59.0924 53.2157 58.9422 48.8499 36.9210 55.4400 47.1434 25.8841	41.5743 36.3583 44.4444 61.9348 66.1858 73.5709 70.8987 35.0268 57.9687 59.6316 62.1278 64.8716 62.3263 49.6005 72.3590 63.5379 62.5369 48.2434 61.1891 38.7647 78.2403 64.6765 50.3067 80.4567 74.9353 81.3605 75.5836 61.1804 68.1979 59.8158	81.7288 58.7906 93.5965 85.2169 86.2106 81.5164 70.5592 86.3558 89.9566 86.8557 57.5546 77.7476 63.4420 74.8916 73.7023 93.2894 75.6148 55.4351 61.3816 72.7320 69.3118 81.2613 71.8486 55.7383 84.2316 69.8183 69.6551 65.9754 77.4436 61.7261

Table 16: Operational sampling data

11. RELIABILITY ANALYSIS AND ESTIMATION

Even though Center for Disease Control and Department of Homeland Security are working together to prevent spread of Zika virus. The transmission and risks associated are originated from different sources. To pinpoint the sources of transmission and causes for Zika virus. We performed reliability analysis using Failure Mode Effect Analysis and Fault Tree Analysis.

11.1 Failure Mode Effect Analysis

FMEA is a step by step approach for identifying all possible failures in a design, manufacturing or assembly process, or product or service. it is one of the most important and most widely used tool of reliability analysis.

FMEA is useful for:

1. Removing causes of failures.
2. Developing system that can mitigate the effects of failures.
3. Prioritize and focus on high risk failures.

We performed FMEA for Zika Virus spread function and based on RPN value we decided that Mosquito is major contributor for Zika virus spread

FUNCTION	FAILURE MODE	EFFECT	CAUSE	OCCURRENCE	SEVERITY	DETECTION	RPN	ACTIONS
ZIKA VIRUS SPREAD CONTROL	Pregnancy	Infant death	Body fluids	4	8	6	192	Medication
	Mosquitos	Rapid Spread	Unhygienic	7	8	7	392	Use repellants
	Travel	Transmission	Travel to affected areas	5	7	7	245	Avoid affected areas
	Sex	Transmission	Semen	6	5	4	120	Use Condoms

Table 17: FMEA

Failure modes according to RPN

1. Mosquitos
2. Travelling to areas effected
3. Pregnancy and sex

11.2 Failure Tree Analysis

FTA is a top down failure assessment technique useful in identifying safety concerns, so that product analysis will identify the causes of product failures which may then be eliminated through good design practice.

Updated FTA reflects design changes and will assess whether previous problems have been eliminated, or new problems have been introduced.

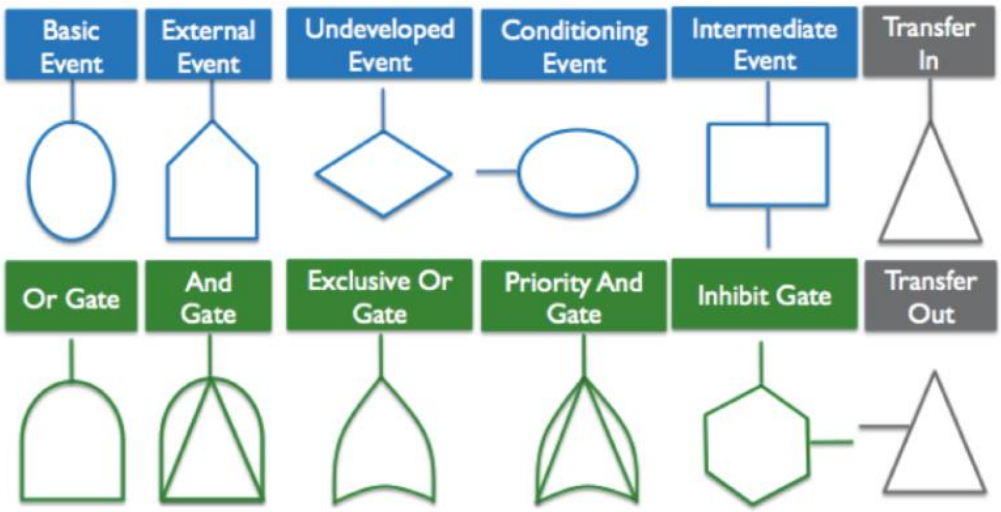


Figure 21: FTA Symbols

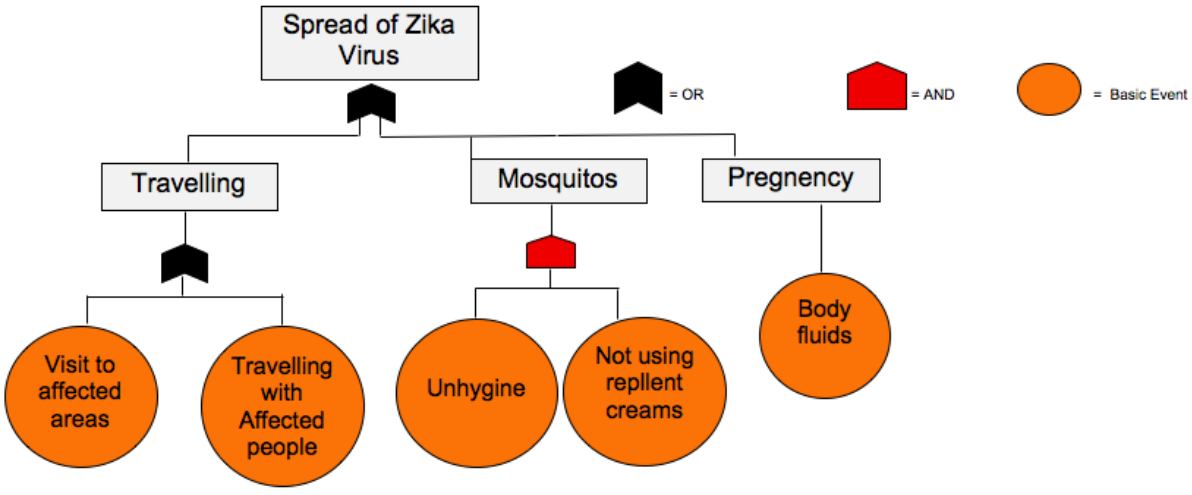


Figure 22: FTA for Zika virus

11.3 Reliability analysis

We performed reliability analysis on Patho Screen Field Scanner device which used for testing Zika virus. For which we generated a random exponential data using Minitab.

Data Generation and analysis

Group	Expo. MTTF
All others	7000

Table above shows value used to generate exponential distributed data, using Minitab, 20 rows of data was generated and shown in table below.

Exponential Distribution'						
5757.530	532.069	452.148	226.758	5235.895	610.626	71417.925
3751.760	1685.115	6104.074	9115.853	13728.832	2553.656	502.096
1287.201	1102.451	3865.193	2136.244	10386.943	1512.603	870.865

To calculate CI for Mean Time to Failure, Failure Rate Following Equations were used.

1. MFFT Interval=$(2 * \mathrm{T}/(\mathrm{X}^{2\left(2\mathrm{n},1-\frac{\mathrm{a}}{2}\right)}, 2 * \mathrm{T}/(\mathrm{X}^{2\left(2\mathrm{n},\frac{\mathrm{a}}{2}\right)})$
2. Failure Rate =$\frac{1}{\text{MFFT Interval}}$
3. Failure Rate Interval=$(\exp(-FR * T), \exp(-FR * T))$

11.3.1 Estimation based on reference data

a. 95% Confidence Interval for the Mean Time to Failure (MTTF) and Failure Rate (FR)

(2N,CI) = (40, 0.025) (40, 0.975)		Chi Square
		(59.342, 24.433)
MFFT Interval	2406.994217	5846.021807
Failure Rate	0.000415456	0.000171056
FR Interval	0.054574341	0.301979705

b. 90% Confidence BOUNDS for MTTF and FR

(2N,CI) = (40, 0.05) (40, 0.95)		Chi Square
		(66.766, 26.509)
MFFT Interval	2139.350131	5388.202151
Failure Rate	0.000467432	0.000185591
FR Interval	0.037929668	0.272767736

11.3.2 Estimation based on 5th failure

We have lowest to highest to truncate data after 5th failure, data shown below.

Q2 Data				
226.7586455	452.1482871	502.0962559	532.0690342	610.6265306

Sum of data = 2323.698753
T = 14536.22937

a. 95% Confidence Interval for the Mean Time to Failure (MTTF) and Failure Rate (FR)

(2N,CI) = (10, 0.025) (10, 0.975)		**Chi Square** (20.483, 3.247)
MFFT Interval	1419.345737	8953.636813
Failure Rate	0.00070455	0.000111686
FR Interval	0.007213148	0.457579234

b. 90% Confidence BOUNDS for MTTF and FR

(2N,CI) = (10, 0.05) (10, 0.95)		**Chi Square** (25.188, 3.94)
MFFT Interval	1154.218625	7378.796632
Failure Rate	0.000866387	0.000135523
FR Interval	0.002323434	0.387257988

11.3.3 Estimation based on Truncated" at Time = 0.2*MTTF

M = 20
MTTF =7000
0.2*MTTF*m = 28000

a. 95% Confidence Interval for the Mean Time to Failure (MTTF) and Failure Rate (FR)

(2N,CI) = (12, 0.05) (12, 0.95)		Chi Square
		(28.3, 5.229)
MFFT Interval	1978.798587	10709.50469
Failure Rate	0.000505357	0.000093375
FR Interval	7.15703E-07	0.073204382

b. 90% Confidence BOUNDS for MTTF and FR

(2N,CI) = (12, 0.025) (12, 0.975)		Chi Square
		(23.337, 4.404)
MFFT Interval	2399.622916	12715.71299
Failure Rate	3.57143E-05	3.57143E-05
FR Interval	0.778800783	0.778800783

11.4 Conclusion

Therefore, 95% of the times there is chance that scanner pass through warranty period without claim is between 66.7% and 26.5%.The goal was not meet, since the percentages obtained for reliability are less than 70%.

12 SUMMARY

1. **Six Sigma approach - guidelines for the project**

   Zika virus spread problem required step by step high level approach of quality improvement. By using the principles of six sigma, we could focus on the key areas where improvement was possible and the main factors that needed to be addressed in order to make this process of quality improvement effective.

2. **Cost of poor quality – COPQ helped us in deriving Contribution factors**

3. **Acceptance Sampling - Best size of the sample and acceptance criteria required for inspecting components**
   By using OC curves, we analyzed different types of sampling and inspections.

4. **Gage R&R - verification and validation of the system**

   We learnt that the measurement system is as important as the measurement itself. We used Gage R&R to ensure that the measurement system is in order. 3 operators performing two trials each worked on 10 parts taken from different lots and we found that the variation in results due to gage were minimal compared to variation due to parts.

5. **Reliability – Failure modes and Efficiency required**

   We used FMEA and FTA to determines the failure modes and basic components responsible for Zika virus spread. We have used reference data to test reliability of patho scanner.

13 REFERENCES

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