# Mudslide Mitigation

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Apr 30, 2020

# Problem Statement

- Extremely rapid surging flow
- Significant proportion of clay
- Cause serious damage
- Happens in a short time

# Problem Statement

*mudslide  usually occurs quickly and with great uncertainty, leaving a short response time, so it is easy to cause problems in the disaster management process.*

- Mudslide is difficult to predict and prevent
- Extreme weather conditions hampered escape and rescue efforts
- As a result of the lack of early training, when the disaster occurred personnel confusion
- Emergency supplies are in short supply
- Reconstruction after the disaster is difficult

# Previous case

*Tibes, Ponce, Puerto Rico*

Caused by heavy rainfall from Tropical Storm Isabel in 1985. The mudflow destroyed more than 100 homes and claimed an estimated 300 lives.

# Previous case

*Zhouqu, Gansu, China*

Occurred at 12 midnight on 8 August 2010. It was caused by heavy rainfall and flooding in Gansu Province.

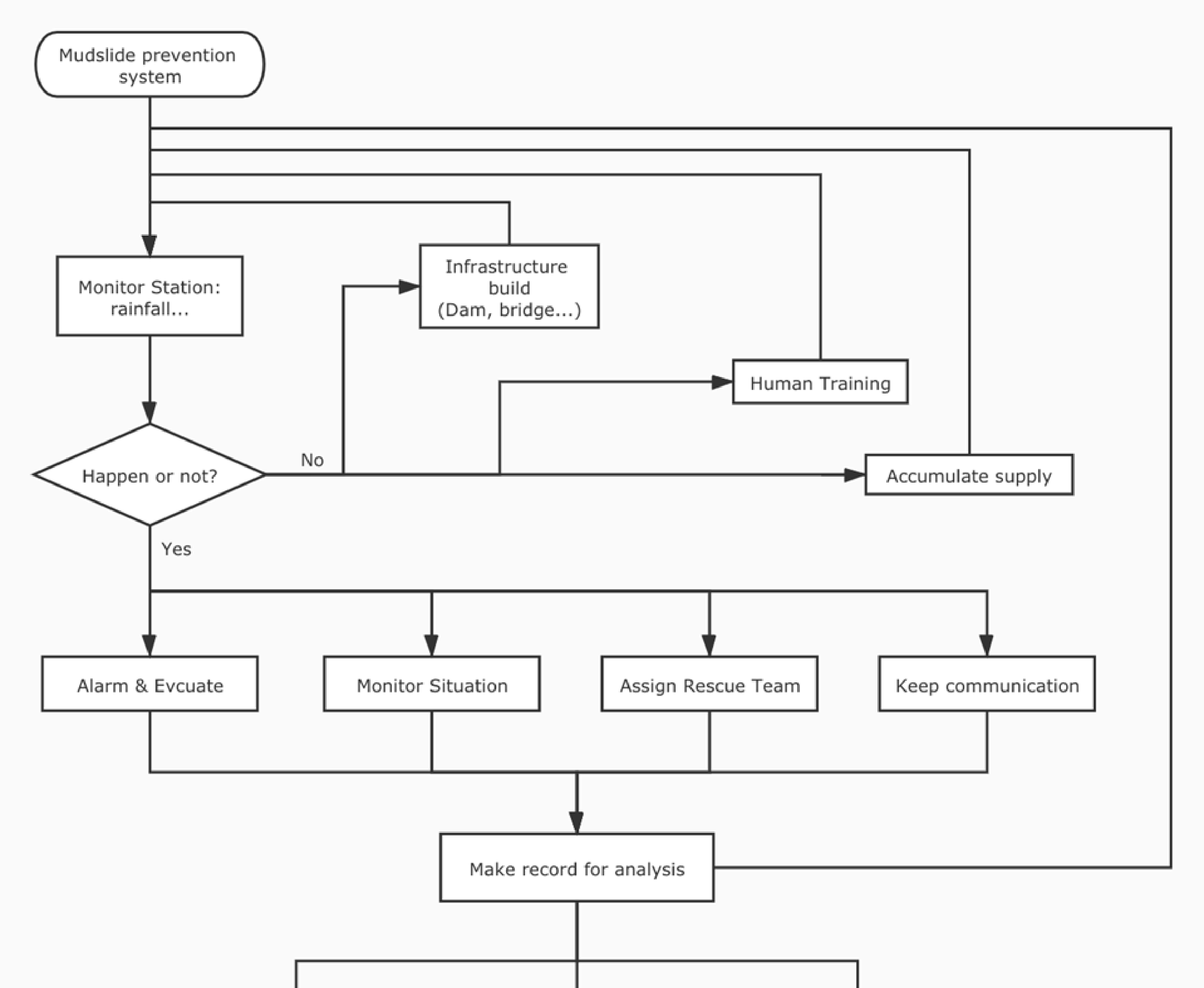
This mudslides killed more than 1,471 people as of 21 August 2010, while 1,243 others have been rescued and 294 remain missing.

Around 1,800,000 cubic metres (64,000,000 cu ft) of mud and rocks swept through the town

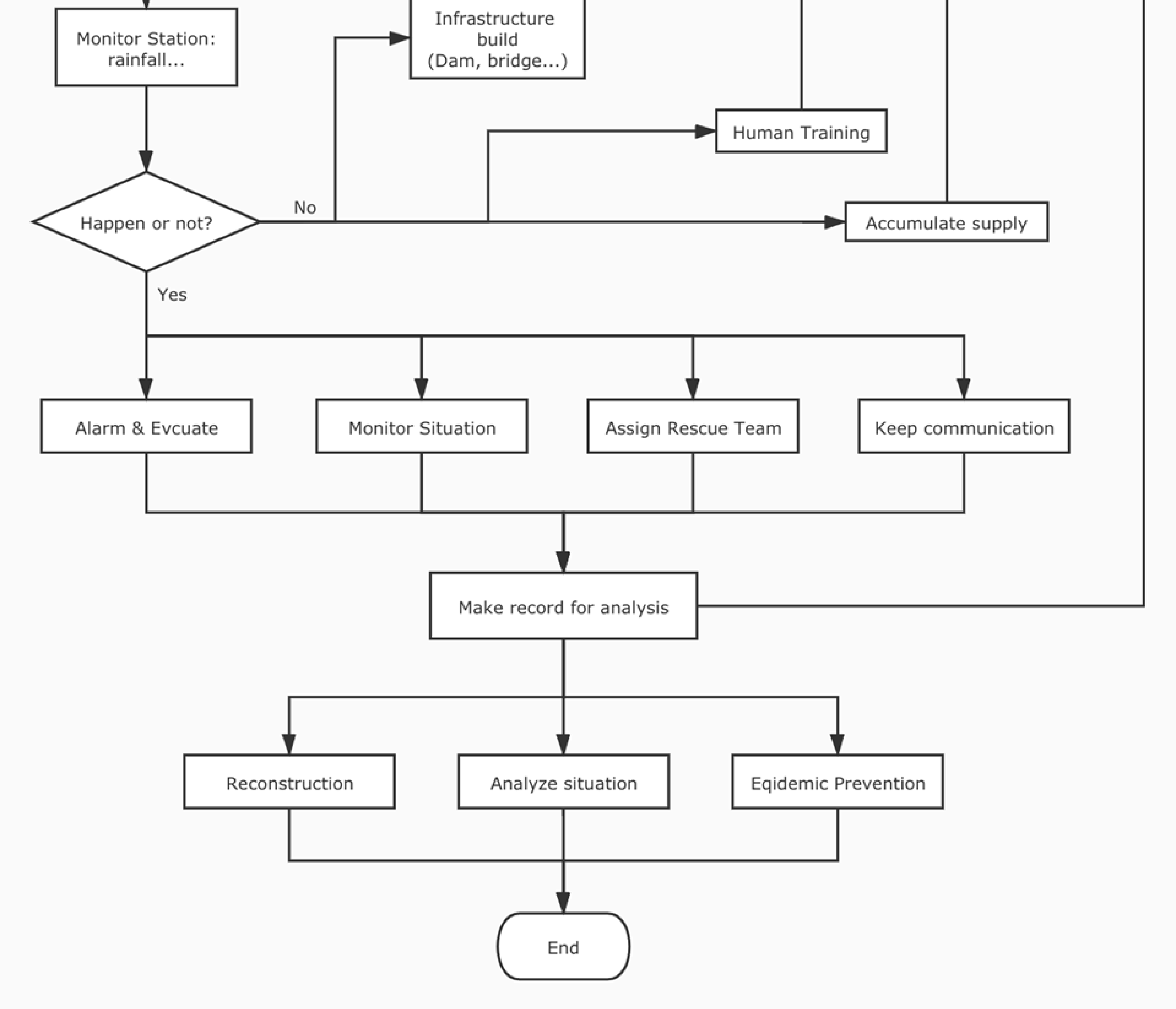
# Brainstorming Session

| Before | During | After |
|---|---|---|
| Detection | Alarm | Reconstruction |
| Preparation | Monitoring | Analyze |
| Training | Rescue | Epidemic prevention |
| | Communication | |

# Flow chart

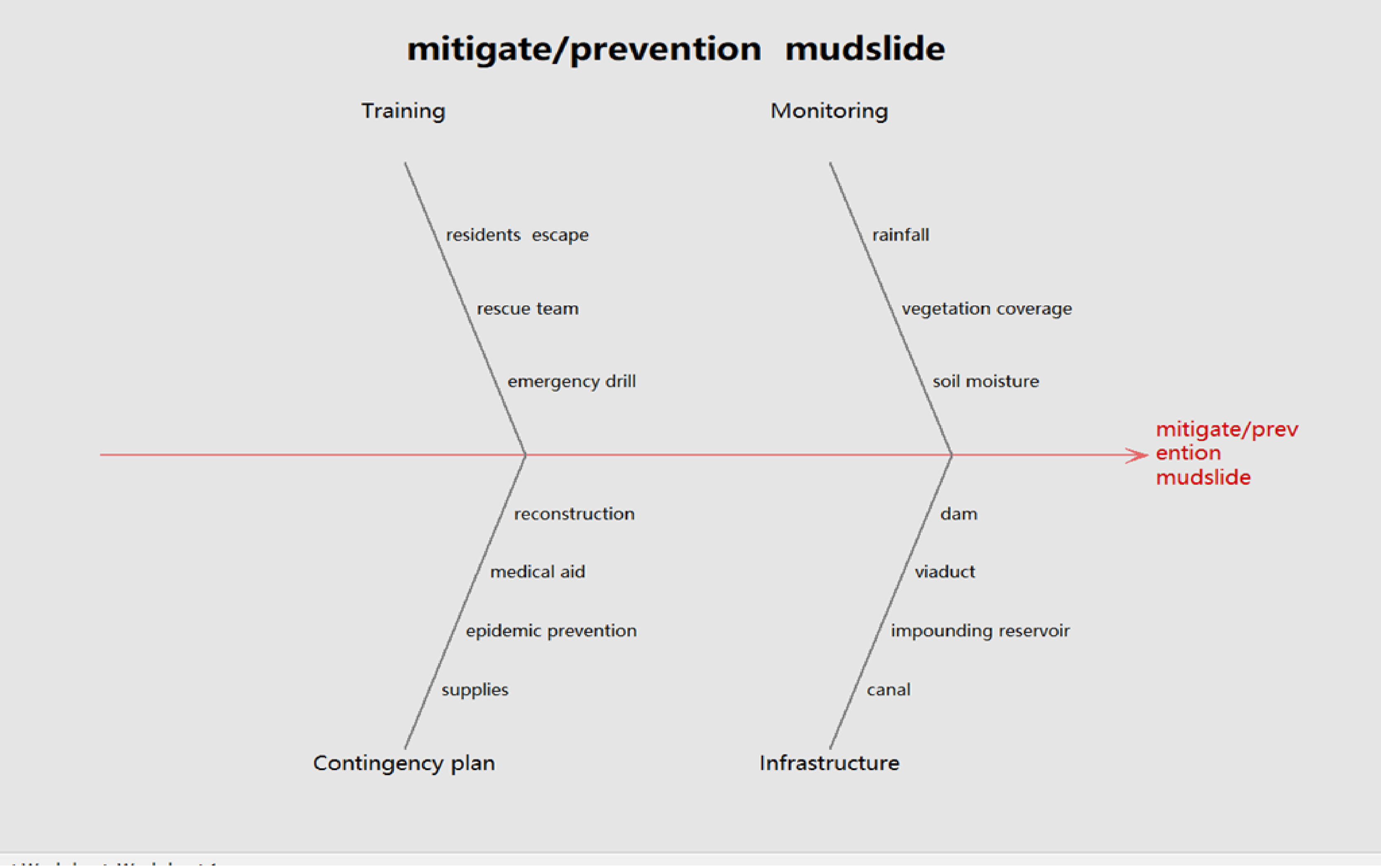

Mudslide prevention system
Monitor Station: rainfall...
Infrastructure build (Dam, bridge...)
Human Training
Happen or not?
No
Accumulate supply
Yes
Alarm & Evcuate
Monitor Situation
Assign Rescue Team
Keep communication
Make record for analysis

# Flow cha



Monitor Station: rainfall...
Infrastructure build (Dam, bridge...)
Human Training
Happen or not?
No
Accumulate supply
Yes
Alarm & Evcuate
Monitor Situation
Assign Rescue Team
Keep communication
Make record for analysis
Reconstruction
Analyze situation
Eqidemic Prevention
End

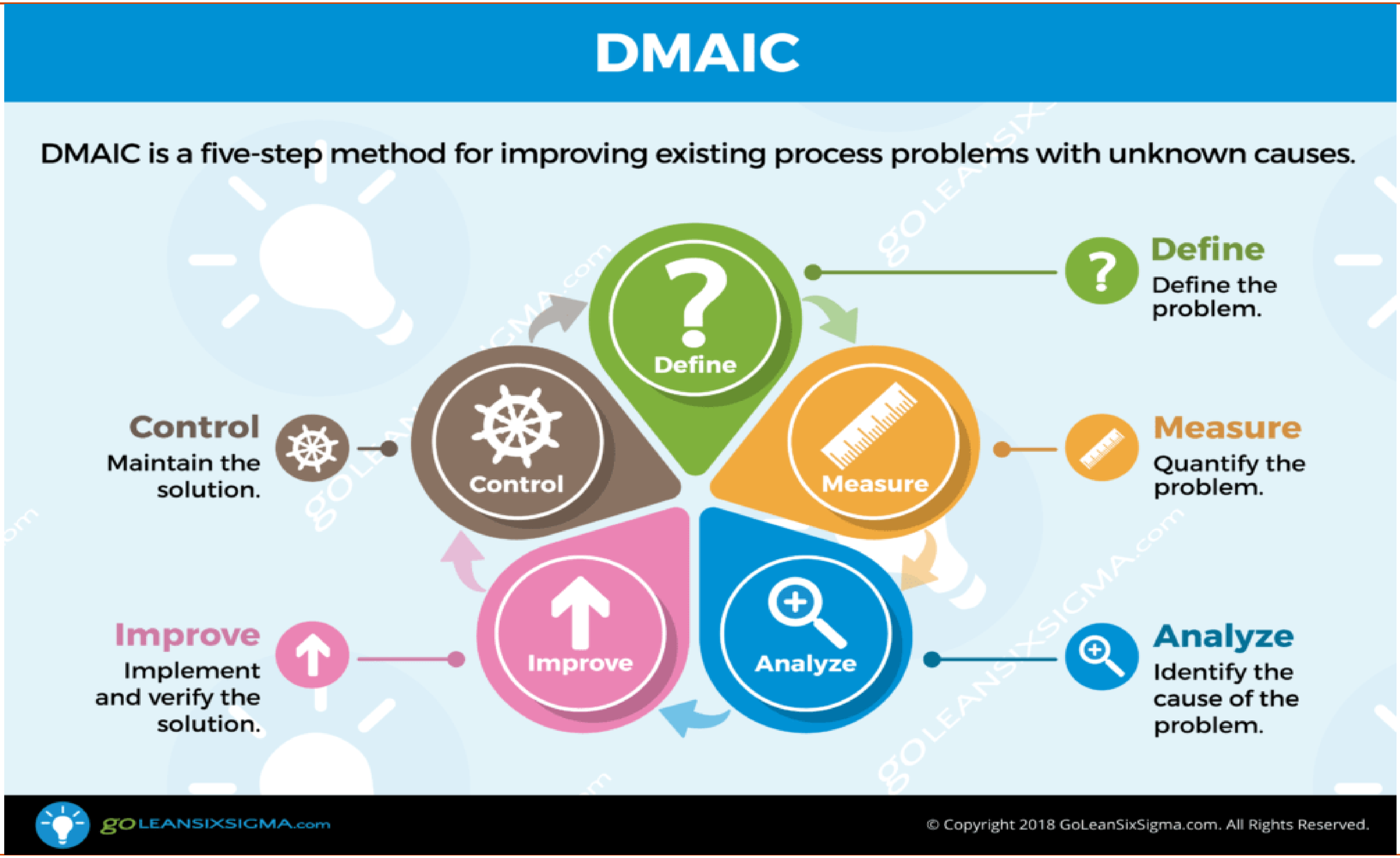
# Fishbone chart



# COPQ

| Cost of Poor Quality | | | | |
|---|---|---|---|---|
| **Process** | **Internal Failure Costs** | **External Failure Costs** | **Appraisal Costs** | **Prevention Costs** |
| Monitoring Mud Slide | Failure of equipment | Breach of duty | Rules | Inspect and equipment maintaining |
| Local hospital prepared | Failure of equipment/lack of doctors and room | Destroyed/electricity ruin | Monitoring | Improve medical service and electricity back up |
| Infrastructure | Lack of Dam, bridge, cannel, sludge storage | Few workers | Monitoring | Infrastructure building |
| Evacuation people/ Transfer injured | Lack of vehicle/ambulance | Roads be destroyed | Method(human training) and spare place, amount of the vehicle | Train people how to get to safe place and evacuation method |
| Keeping Communication | No enough signal base stations | Signal interference | Signal base stations maintaining | Pay more on advanced and stable equipment |
| Epidemic Prevention | Too late to transfer dead people and animals | No enough vehicle | Laws | Emergency epidemic p revention plan(training firefighte rs) |

# 6 SIGMA


DMAIC
DMAIC is a five-step method for improving existing process problems with unknown causes.
Define
Measure
Analyze
Improve
Control
Define
Define the problem.
Measure
Quantify the problem.
Analyze
Identify the cause of the problem.
Improve
Implement and verify the solution.
Control
Maintain the solution.
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# Define

*Problem Statement*

- Dams are unable to stop or slow down the mudslide;
- Capability of canal is not enough for mudslide to flow;
- Insufficient food and medical supplies;
- People cannot evacuate in time.

# Measure

*Data Collection*

| | Where will data be collected | Who will provide the data | How often |
|---|---|---|---|
| Amount of Rainfall | | Weather Department | Every time it rains |
| Moisture of soil on mountains | On the mountain | Geology Department | Before and during rain |
| Amount of mud flushed down the mountain | In the canal | Reconstruction Team | After the mudslide |
| Local population | | Local government | Every year |
| Amount of supplies (food, medicine, etc.) used during a single mudslide | | Local government | After the mudslide |

# Gage R&R Analysis

## *Gage R&R--ANOVA Method*

### Gage R&R Study - ANOVA Method

#### Two-Way ANOVA Table With Interaction

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

*α to remove interaction term = 0.05*

#### Two-Way ANOVA Table Without Interaction

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

### Gage R&R

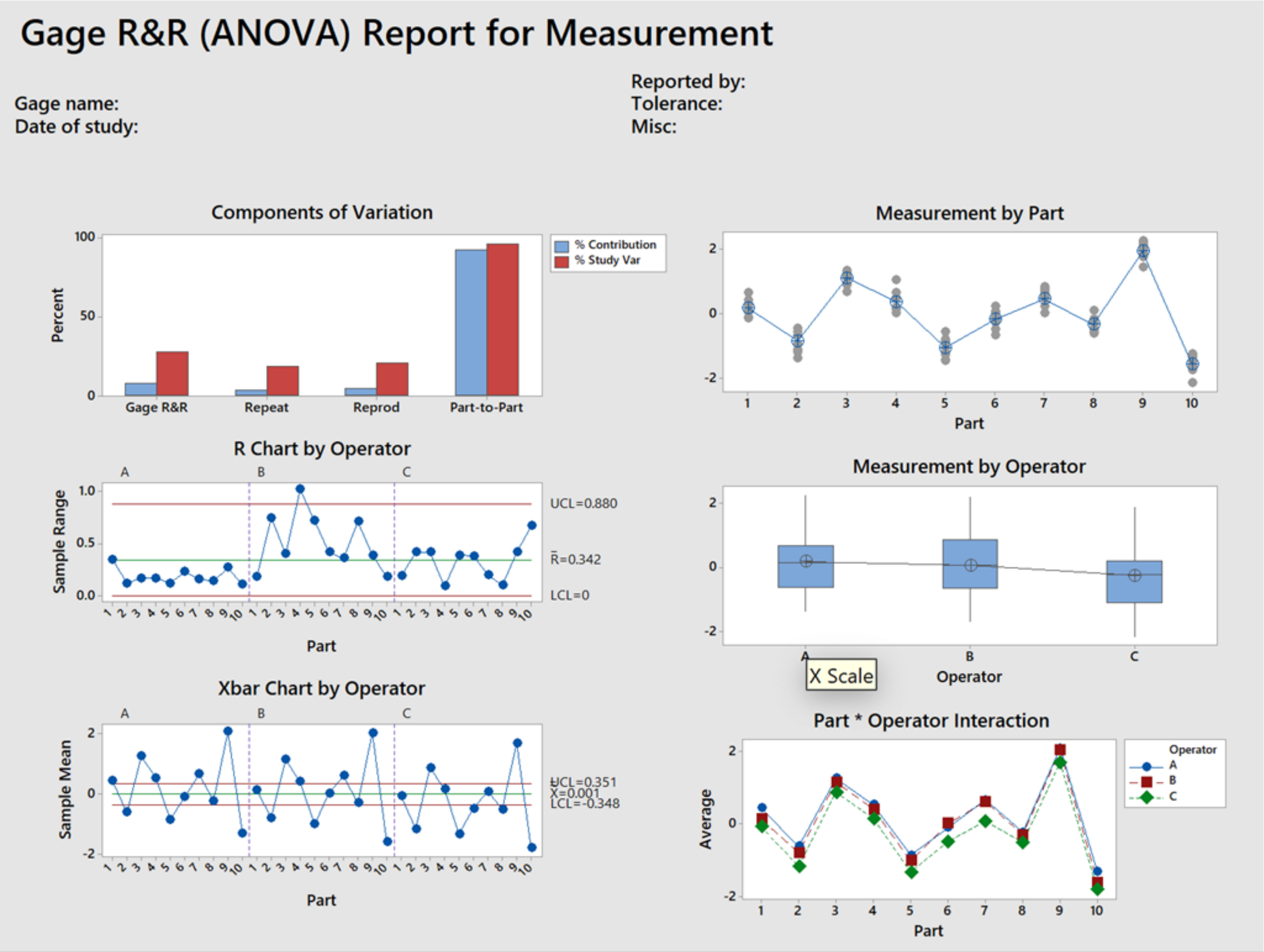
#### Variance Components

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

#### Gage Evaluation

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

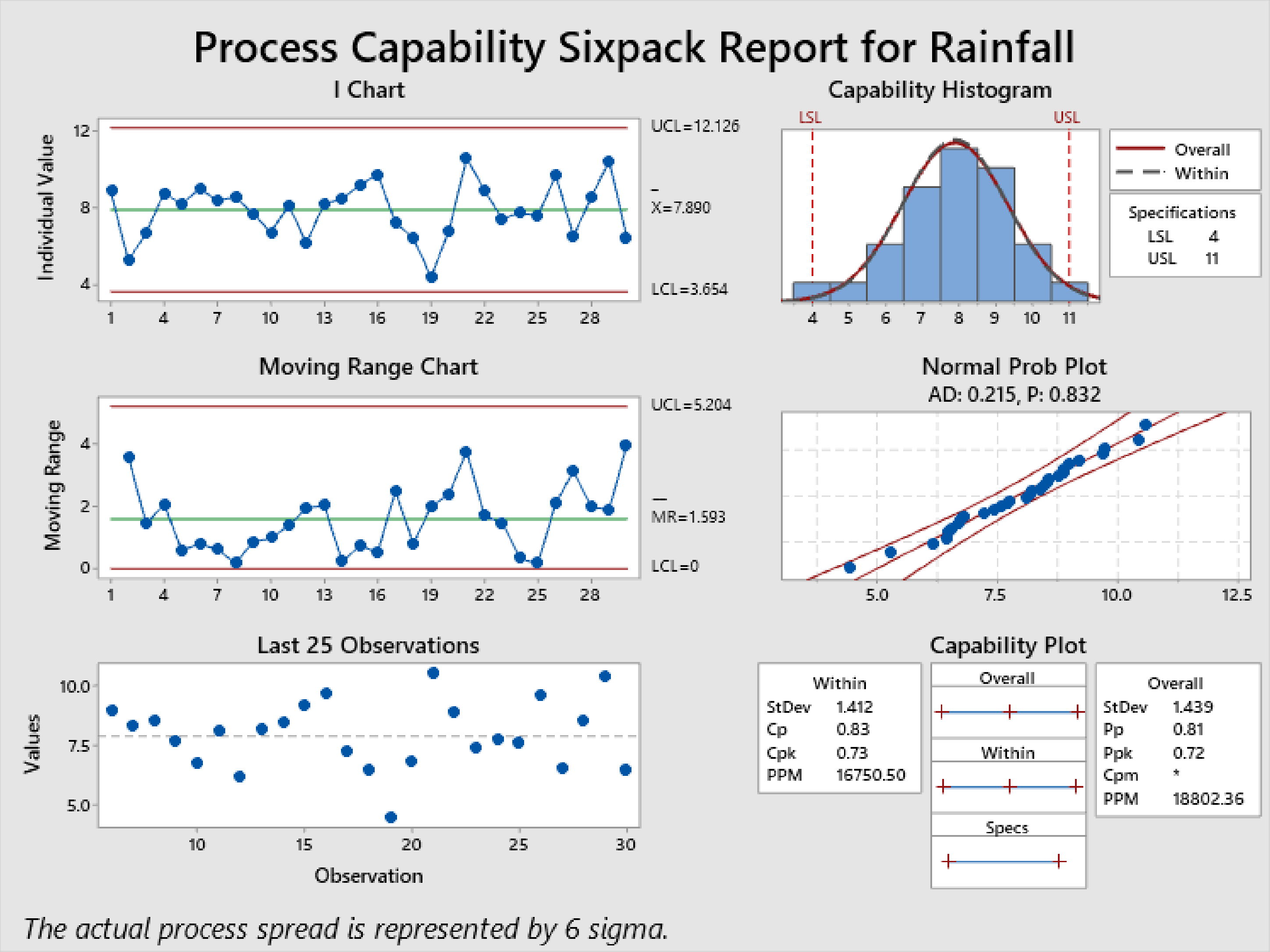
# Gage R&R Analysis



# Analyse

| Rainfall (inches) | | |
|---|---|---|
| 8.86707 | 8.114762 | 10.57913 |
| 5.265968 | 6.174741 | 8.882498 |
| 6.696338 | 8.212439 | 7.4181 |
| 8.773968 | 8.44493 | 7.74245 |
| 8.183697 | 9.180771 | 7.575326 |
| 8.984158 | 9.717632 | 9.678482 |
| 8.367323 | 7.22412 | 6.550373 |
| 8.551716 | 6.426168 | 8.538369 |
| 7.709114 | 4.423975 | 10.43627 |
| 6.727064 | 6.797707 | 6.462808 |

# Analyse


Process Capability Sixpack Report for Rainfall
I Chart
Individual Value
UCL=12.126
X̄=7.890
LCL=3.654
Capability Histogram
LSL
USL
Overall
Within
Specifications
LSL 4
USL 11
Moving Range Chart
Moving Range
UCL=5.204
MR̄=1.593
LCL=0
Normal Prob Plot
AD: 0.215, P: 0.832
Last 25 Observations
Values
Observation
Capability Plot
Within
StDev 1.412
Cp 0.83
Cpk 0.73
PPM 16750.50
Overall
Within
Specs
Overall
StDev 1.439
Pp 0.81
Ppk 0.72
Cpm *
PPM 18802.36
The actual process spread is represented by 6 sigma.

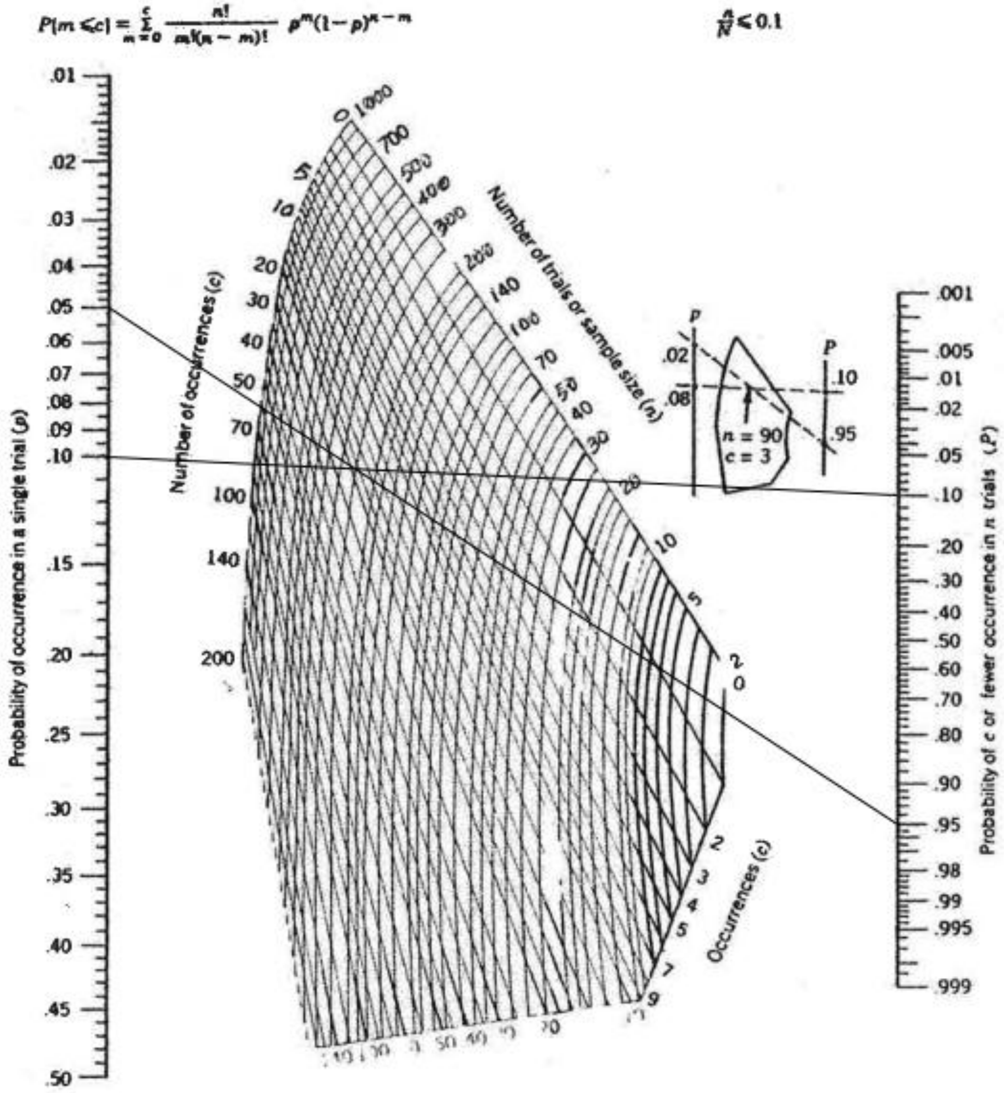
# Acceptance Sampling

AQL=0.05

LTPD=0.1

α=0.05

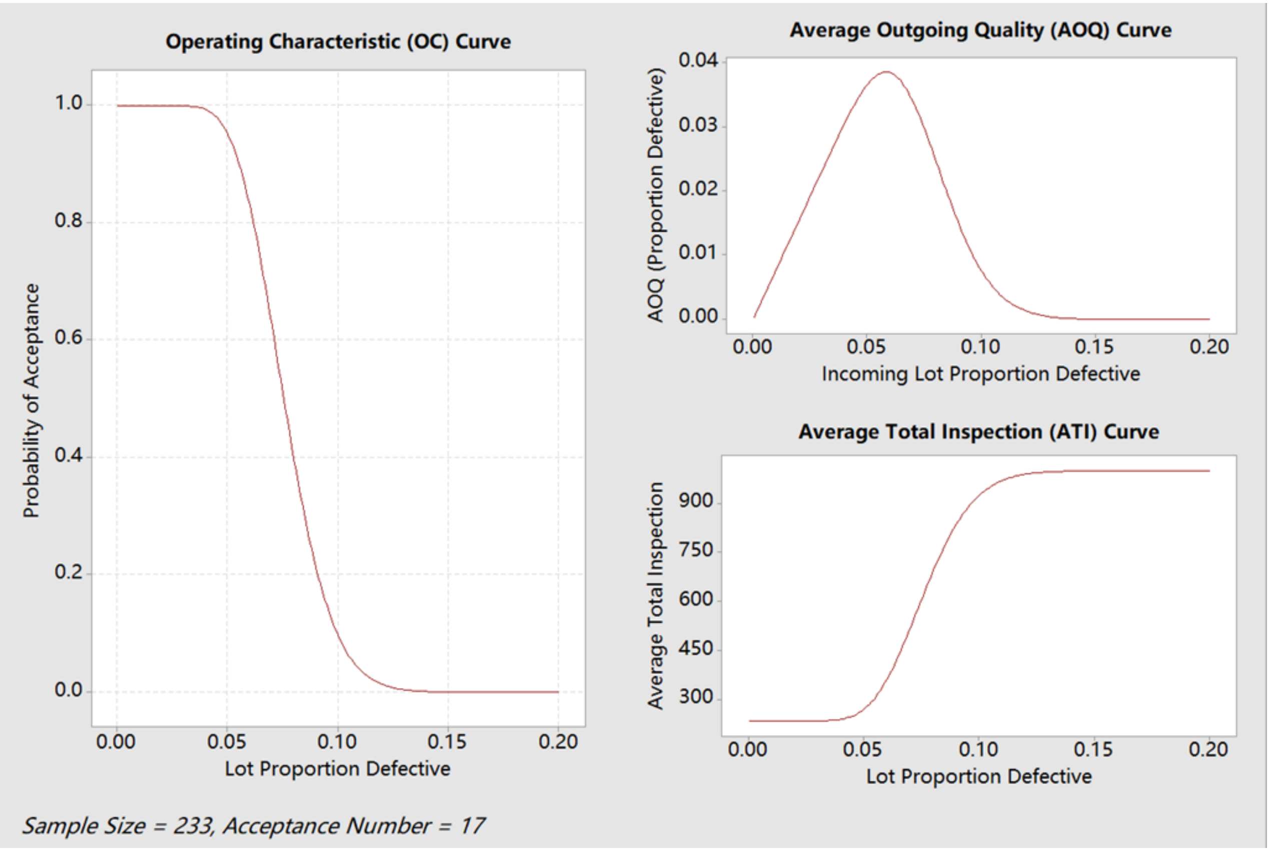
β=0.1



# Operating Charateristic Curve(OC Curve)

*An OC curve visualizes the probability for a sampling plan, showing the probability of accepting a lot given the percent defectiveness.*

*This probability is calculated using a binomial distribution.*



# Operating Charateristic Curve(OC Curve)

## Acceptance Sampling by Attributes

Measurement type: Go/no go
Lot quality in proportion defective
Lot size: 1000
Use binomial distribution to calculate probability of acceptance

### Method

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

### Generated Plan(s)

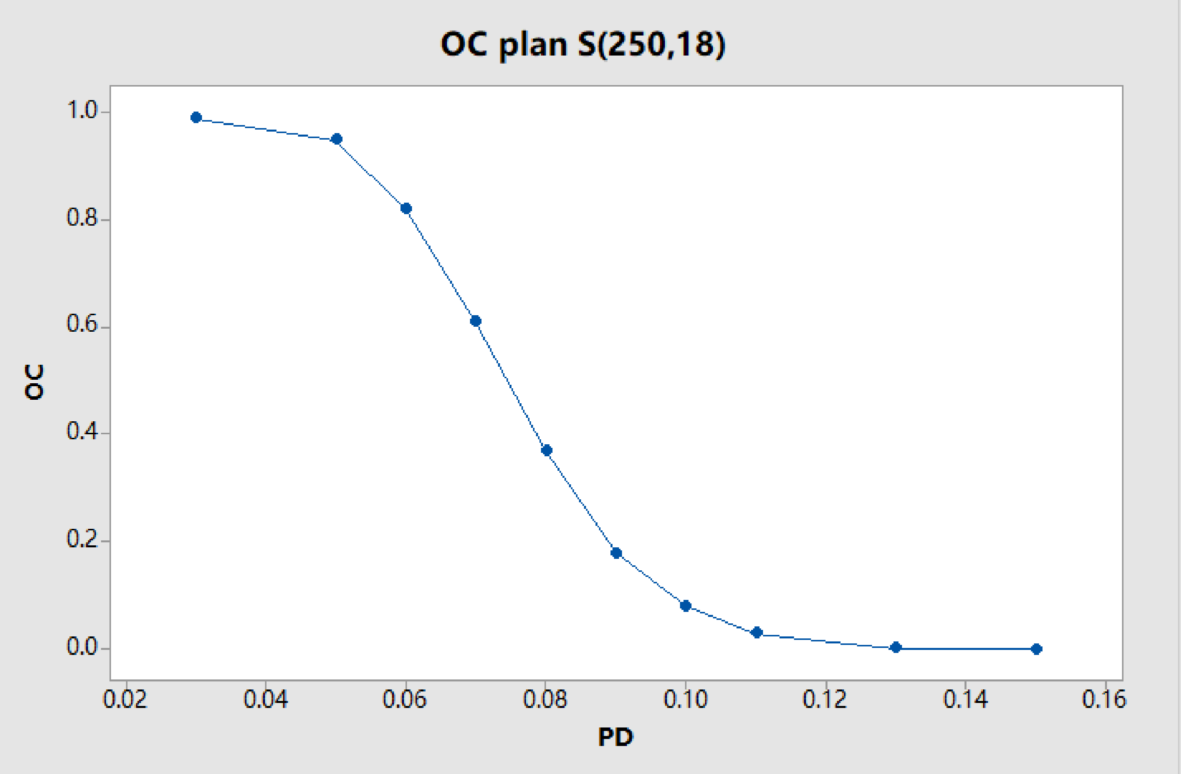
| | |
|---|---|
| Sample Size | 233 |
| Acceptance Number | 17 |

Accept lot if defective items in 233 sampled ≤ 17; Otherwise reject.

| Proportion Defective | Probability Accepting | Probability Rejecting | AOQ | ATI |
|---|---|---|---|---|
| 0.05 | 0.954 | 0.046 | 0.03658 | 268.3 |
| 0.10 | 0.099 | 0.901 | 0.00758 | 924.2 |

### Average Outgoing Quality Limit(s) (AOQL)

| AOQL | At Proportion Defective |
|---|---|
| 0.03855 | 0.05815 |




Graphs - Acceptance Sampling by Attributes

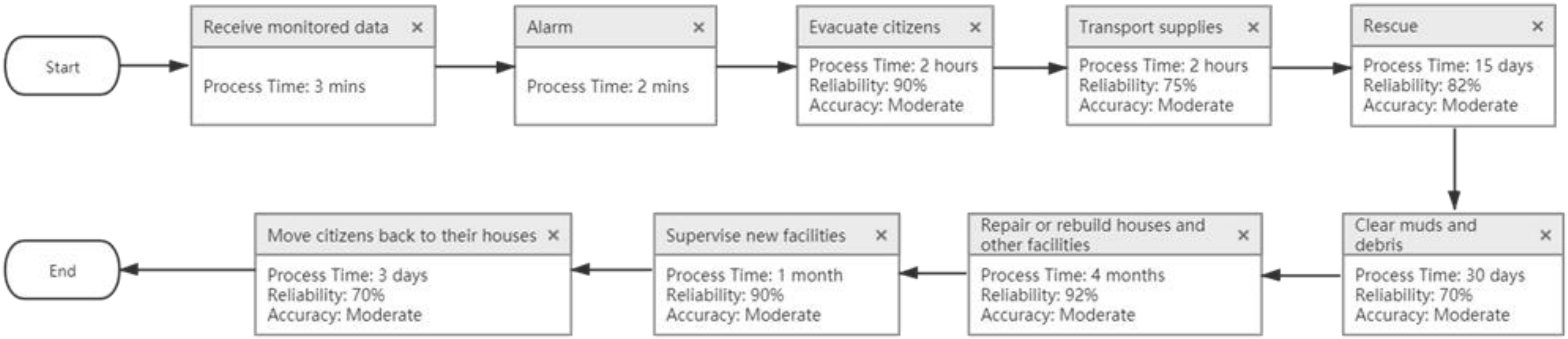
# Improve

*Provide solutions to the problem*

- Improvement Strategy
- Design of Experiments (DOE)
- Value Stream Map (VSM)
- Reliability Analysis
- List of remedies selected

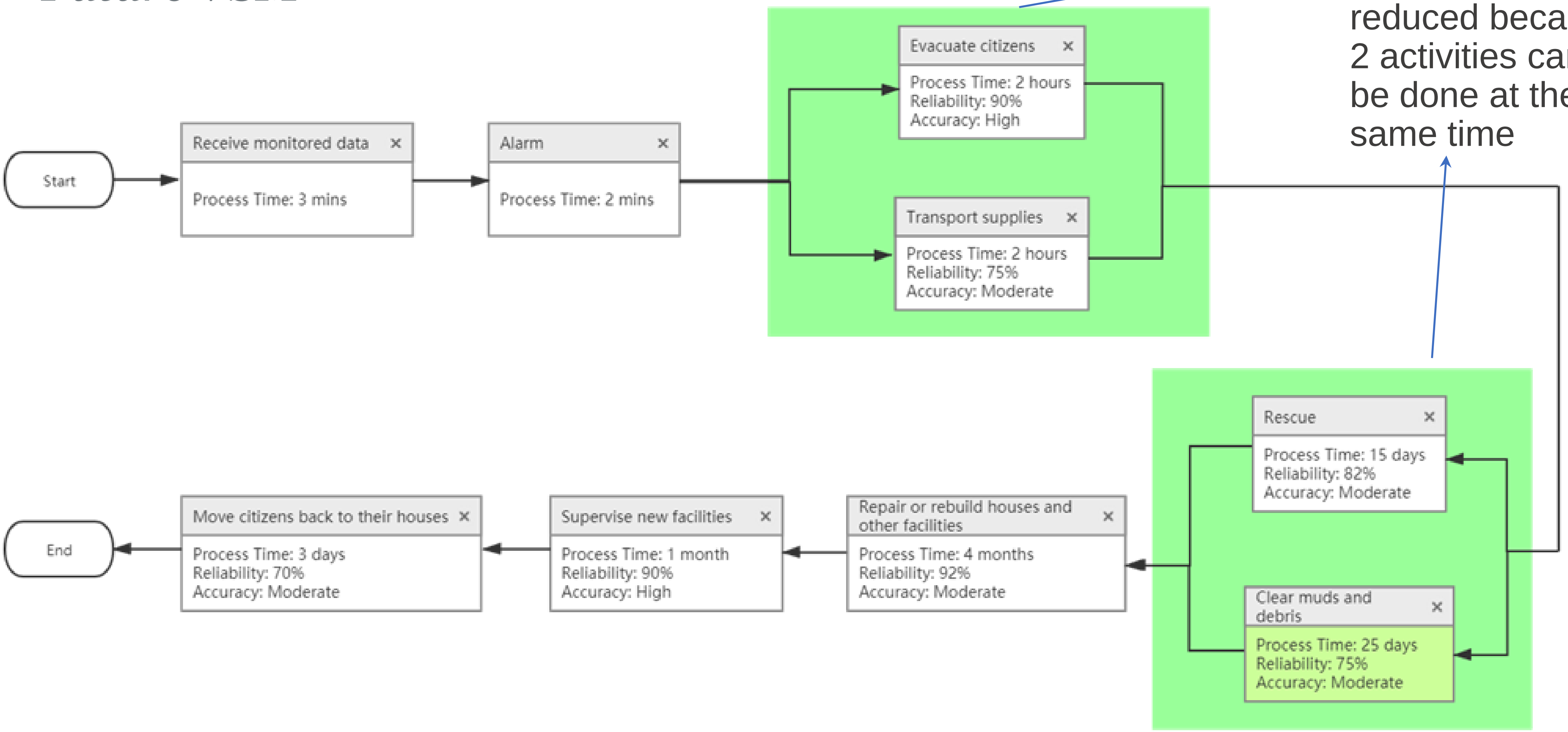
# VSM

*Current VSM*



# VSM

*Future VSM*




The time can be reduced because 2 activities can be done at the same time

# Design of Experimental

*For this experiment we are conducting a full factorial design. That is we have 3 factors (Time, Temp and Catalyst) each of which have two levels and 2 replicates.*

*The concept of coding is used to both differentiate between high and low values and to determine later values. Coding is simple taking either the High or Low value subtracting the midpoint, divided by the range and then multiplying times two. This normalization is done to ensure a standardized combination of factors.*

| Factor | Low level | High level |
|---|---|---|
| **time** | 20 | 50 |
| **temp** | 150 | 200 |
| **catalyst** | A | B |

| | Low level 20-34 | High level 35-50 |
|---|---|---|
| **time** | **-1** | **1** |
| | **Low level 150-174** | **High level 174-200** |
| **temp** | **-1** | **1** |
| | **Low level A** | **High level B** |
| **catalyst** | **-1** | **1** |

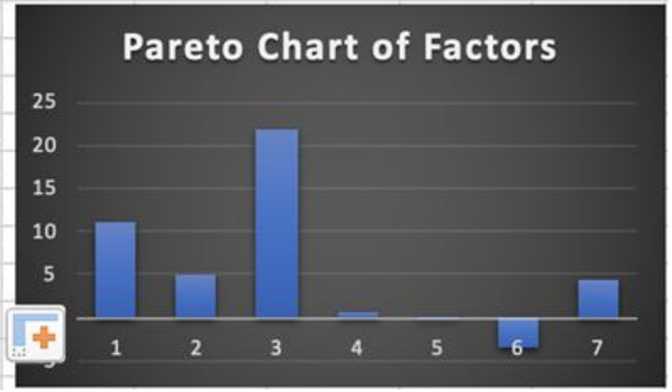
# DOE DATA AND CODING

| Factorial Experiments 2^3 (DOE) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Runs | A | B | C | AB | AC | BC | ABC | Y1 | Y2 |
| 1 | -1 | -1 | -1 | 1 | 1 | 1 | -1 | 0.51817 | -0.49313 |
| 2 | 1 | -1 | -1 | -1 | -1 | 1 | 1 | 6.988546 | 8.020517 |
| 3 | -1 | 1 | -1 | -1 | 1 | -1 | 1 | 5.674872 | 6.574334 |
| 4 | 1 | 1 | -1 | 1 | -1 | -1 | -1 | 6.500394 | 13.32876 |
| 5 | -1 | -1 | 1 | 1 | -1 | -1 | 1 | 15.67002 | 14.22132 |
| 6 | 1 | -1 | 1 | -1 | 1 | -1 | -1 | 15.96954 | 19.63775 |
| 7 | -1 | 1 | 1 | -1 | -1 | 1 | -1 | 16.34648 | 9.913479 |
| 8 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 20.72943 | 21.31062 |

# Excel DOE

*Excel can be used to create the framework for this experiment. Below we have created an experiment design where we have our 3 factors, our 2 levels and our 16 runs. Note that Y1 and Y2 represent the responses for the runs.*

| | | | Factorial Experiments 2^3 (DOE-ASQ) | | | | | | Run Results | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Run | A | B | C | AB | AC | BC | ABC | | Y1 | Y2 | Avg. | Var. |
| 1 | -1 | -1 | -1 | 1 | 1 | 1 | -1 | | 0.51817 | -0.49313 | 0.01252 | 0.511365 |
| 2 | 1 | -1 | -1 | -1 | -1 | 1 | 1 | | 6.988546 | 8.020517 | 7.504531 | 0.532482 |
| 3 | -1 | 1 | -1 | -1 | 1 | -1 | 1 | | 5.674872 | 6.574334 | 6.124603 | 0.404516 |
| 4 | 1 | 1 | -1 | 1 | -1 | -1 | -1 | | 6.500394 | 13.32876 | 9.914578 | 23.3133 |
| 5 | -1 | -1 | 1 | 1 | -1 | -1 | 1 | | 15.67002 | 14.22132 | 14.94567 | 1.049371 |
| 6 | 1 | -1 | 1 | -1 | 1 | -1 | -1 | | 15.96954 | 19.63775 | 17.80364 | 6.727862 |
| 7 | -1 | 1 | 1 | -1 | -1 | 1 | -1 | | 16.34648 | 9.913479 | 13.12998 | 20.69173 |
| 8 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 20.72943 | 21.31062 | 21.02003 | 0.168893 |
| TotSum | | | | | | | | | 88.39745 | 92.51365 | 90.45555 | 53.39952 |
| SumY+ | 56.24278 | 50.18919 | 66.89932 | 45.89279 | 44.9608 | 41.66706 | 49.59483 | | | | | |
| SumY- | 34.21277 | 40.26636 | 23.55623 | 44.56276 | 45.49475 | 48.78849 | 40.86072 | | | | | |
| AvgY+ | 28.12139 | 25.09459 | 33.44966 | 22.9464 | 22.4804 | 20.83353 | 24.79742 | | | | | |
| AvgY- | 17.10638 | 20.13318 | 11.77812 | 22.28138 | 22.74738 | 24.39425 | 20.43036 | | | | | |
| Effect | 11.01501 | 4.961412 | 21.67154 | 0.665018 | -0.26698 | -3.56072 | 4.367055 | | | | | |
| Var+ | 7.685635 | 11.14461 | 7.159463 | 6.260733 | 1.953159 | 5.476117 | 0.538815 | | | | | |
| Var- | 5.664244 | 2.20527 | 6.190417 | 7.089146 | 11.39672 | 7.873763 | 12.81106 | | | | | |
| F | 1.356869 | 5.053626 | 1.15654 | 0.883143 | 0.171379 | 0.695489 | 0.042059 | | | | | |



# Minitab DOE

*Minitab can be used to create the framework for this experiment. Below minitab has created a an experiment where we have our 3 factors, our 2 levels and our 16 runs. Note that minitab has randomized the order in which each run is take place. In addition we use coded values in minitab as well.*

| ↓ | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 |
|---|---|---|---|---|---|---|---|---|
| | StdOrder | RunOrder | CenterPt | Blocks | time | temp | catalyst(AorB) | cost |
| 2 | 7 | 2 | 1 | 1 | -1 | 1 | 1 | 16.3465 |
| 3 | 10 | 3 | 1 | 1 | 1 | -1 | -1 | 8.0205 |
| 4 | 9 | 4 | 1 | 1 | -1 | -1 | -1 | -0.4931 |
| 5 | 15 | 5 | 1 | 1 | -1 | 1 | 1 | 9.9135 |
| 6 | 4 | 6 | 1 | 1 | 1 | 1 | -1 | 6.5004 |
| 7 | 2 | 7 | 1 | 1 | 1 | -1 | -1 | 6.9885 |
| 8 | 1 | 8 | 1 | 1 | -1 | -1 | -1 | 0.5182 |
| 9 | 12 | 9 | 1 | 1 | 1 | 1 | -1 | 13.3288 |
| 10 | 8 | 10 | 1 | 1 | 1 | 1 | 1 | 20.7294 |
| 11 | 11 | 11 | 1 | 1 | -1 | 1 | -1 | 6.5743 |
| 12 | 16 | 12 | 1 | 1 | 1 | 1 | 1 | 21.3106 |
| 13 | 3 | 13 | 1 | 1 | -1 | 1 | -1 | 5.6749 |
| 14 | 6 | 14 | 1 | 1 | 1 | -1 | 1 | 15.9695 |
| 15 | 14 | 15 | 1 | 1 | 1 | -1 | 1 | 19.6377 |
| 16 | 5 | 16 | 1 | 1 | -1 | -1 | 1 | 15.6700 |

# Minitab DOE

The below minitab analysis of the DOE shows each of the three effects as well as the interactions (combinations) of effects.

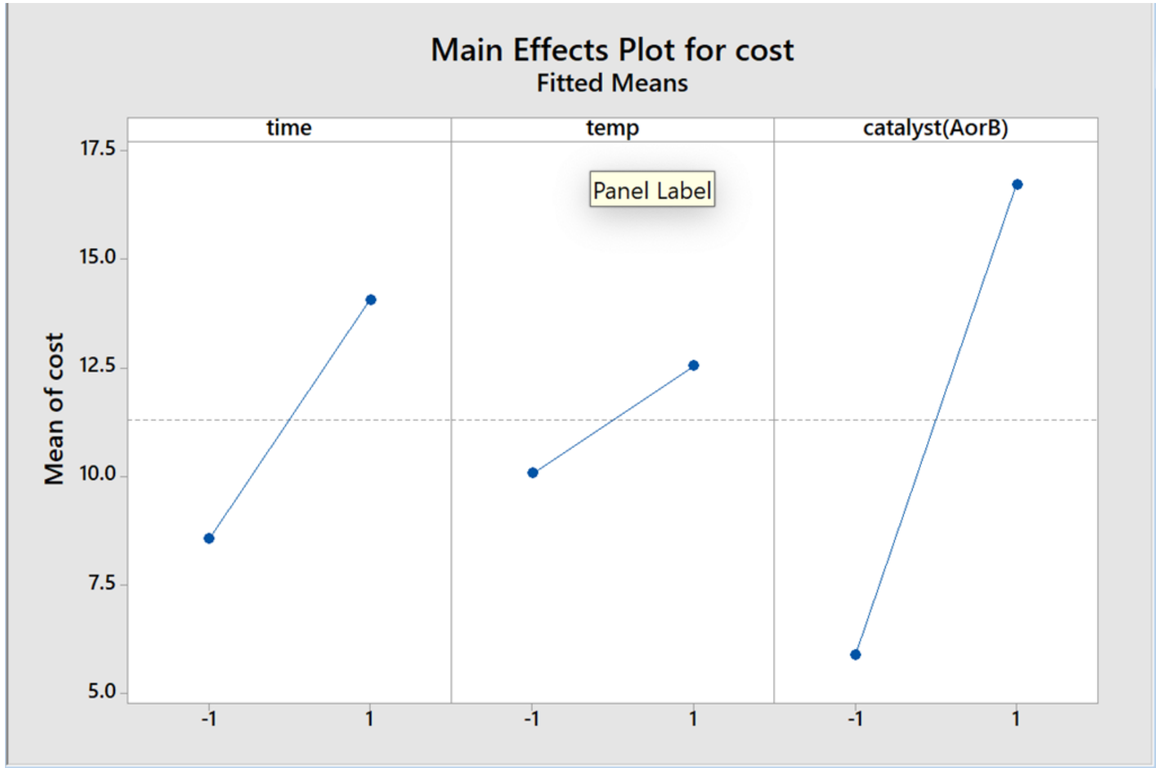
| Term | Effect | Coef | SE Coef | T-Value | P-Value | VIF |
|---|---|---|---|---|---|---|
| Constant | | 11.307 | 0.646 | 17.51 | 0.000 | |
| time | 5.508 | 2.754 | 0.646 | 4.26 | 0.003 | 1.00 |
| temp | 2.481 | 1.240 | 0.646 | 1.92 | 0.091 | 1.00 |
| catalyst(AorB) | 10.836 | 5.418 | 0.646 | 8.39 | 0.000 | 1.00 |
| time*temp | 0.333 | 0.166 | 0.646 | 0.26 | 0.803 | 1.00 |
| time*catalyst(AorB) | -0.133 | -0.067 | 0.646 | -0.10 | 0.920 | 1.00 |
| temp*catalyst(AorB) | -1.780 | -0.890 | 0.646 | -1.38 | 0.205 | 1.00 |
| time*temp*catalyst(AorB) | 2.184 | 1.092 | 0.646 | 1.69 | 0.129 | 1.00 |

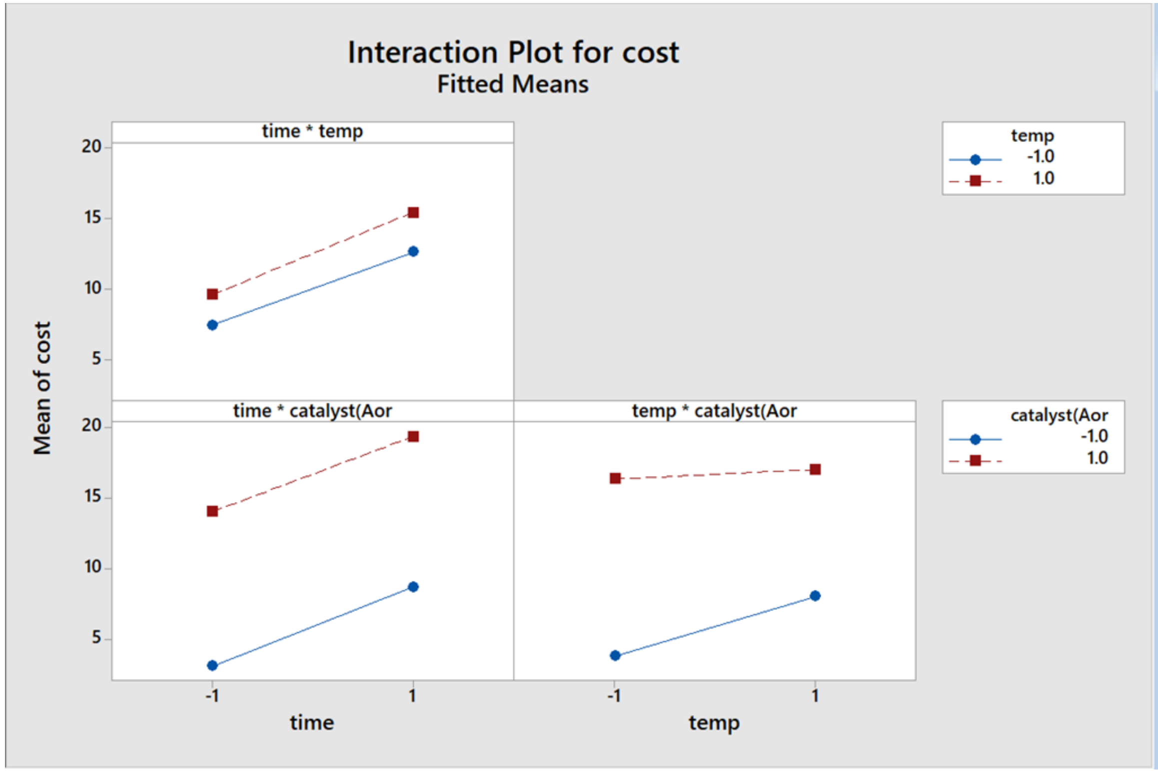
| Factor | Has Effect? |
|---|---|
| Time | YES |
| Temp | NO |
| Catalyst | YES |
| Time * Temp | NO |
| Time * Catalyst | NO |
| Temp * Catalyst | NO |
| Time*Temp*Catalyst | NO |

The interaction between Time and Temp (Time*TemP) has a p-value of 0.589 which is above our alpha value of .05 (95% confidence). We make the assessment that the experiment is governed by effects from each factor as well as interactions between some factors.

# DOE Interpretation using graphs

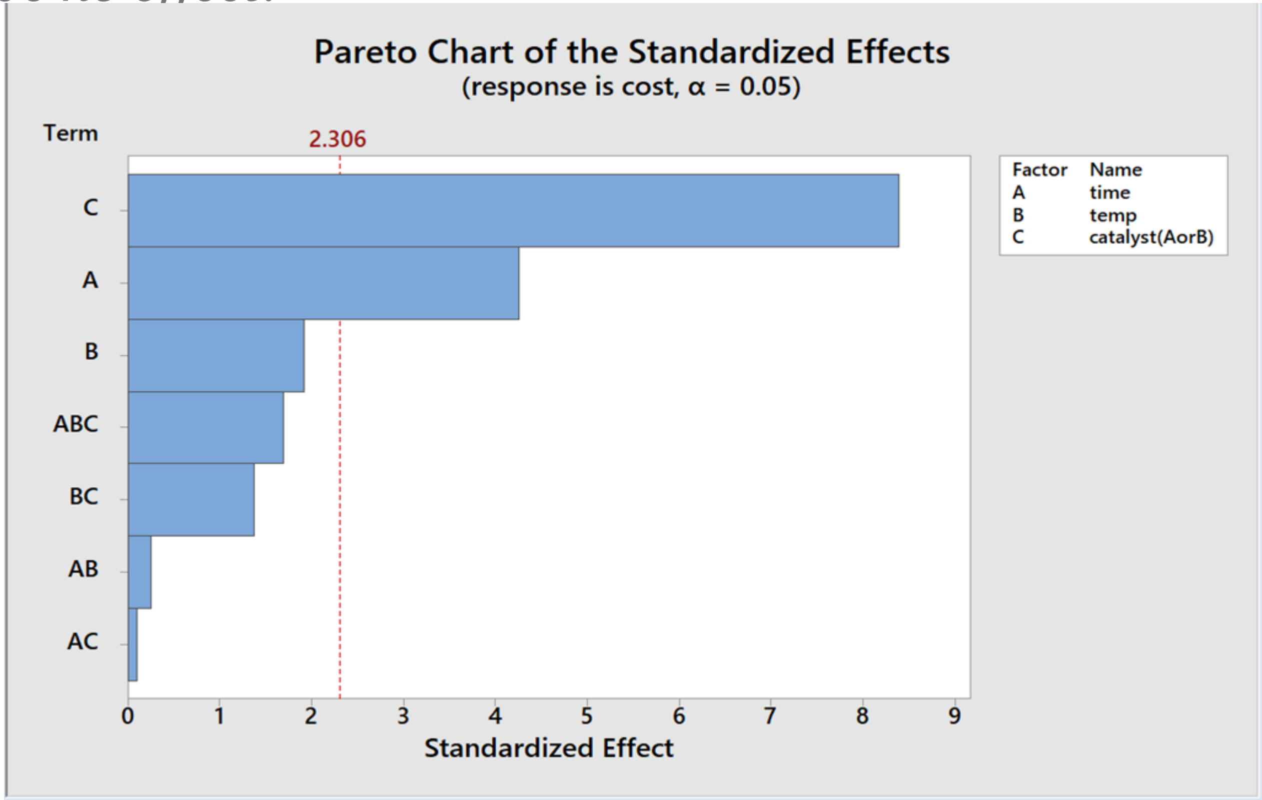
*Minitab graphs can give us the same information as the numerical analysis shown above. Below are graphs for each factor as well each interactions.*



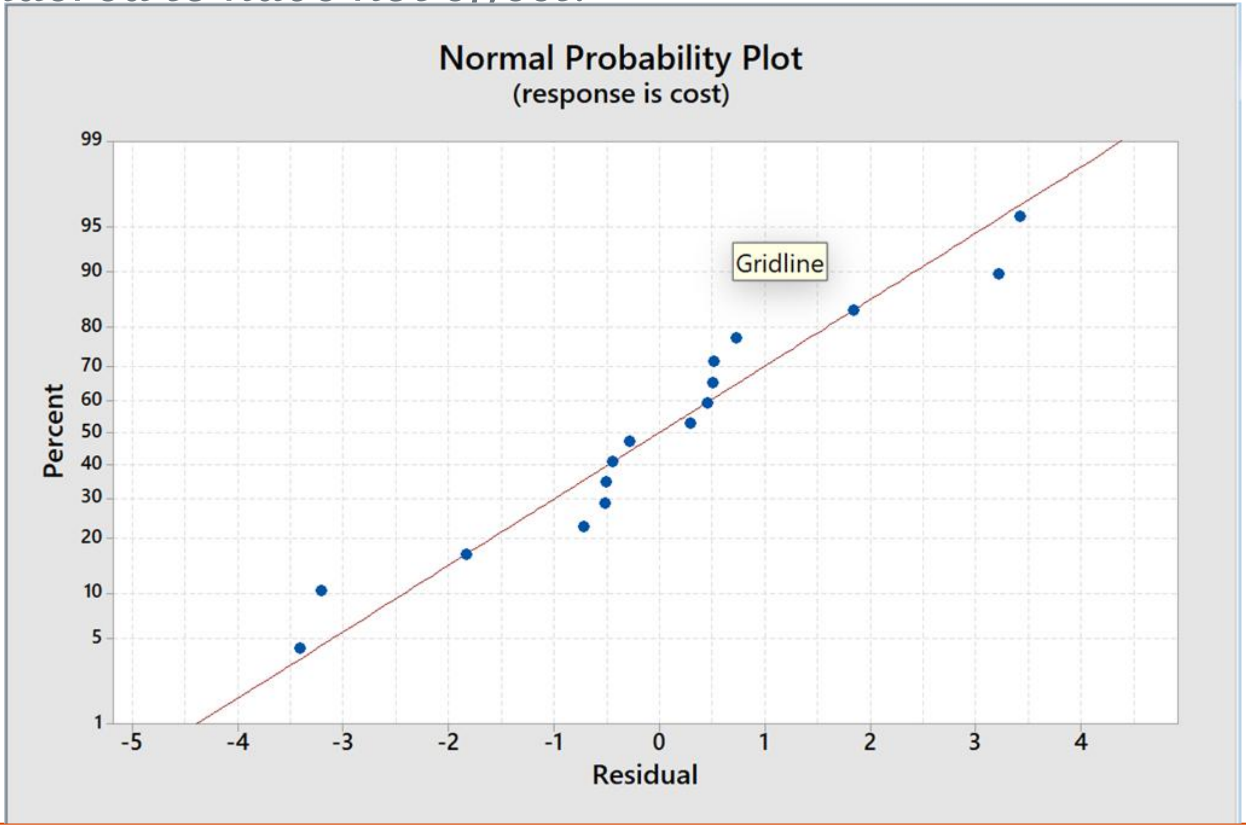
# DOE Interpretation using graphs

*This graphs is Pareto chart. With the pareto chart we see a boundary line this line is a 95% confidence boundary. Factors and interactions that go beyond this line are assumed to have and effect, factors and interactions that do not pass this line are assumed to have no effect.*



# DOE Interpretation using graphs

*Similarly in the graph to the right in the above figure there is a blue line and several dots representing the factors and interactions. The dots that are red and a distance form the line are considered to have an effect while the dot(s) that are black and near the line are considered to have not effect.*



# DOE Estimated cofficients

*Minitab automatically calculates the constants and coefficients we need for our predictive equation. Similar to what we did in Excel. The below table displays the minitab calculated values for this experiment.*

| Term | Coef |
|---|---|
| Constant | 11.307 |
| time | 2.754 |
| temp | 1.240 |
| catalyst(AorB) | 5.418 |
| time*temp | 0.166 |
| time*catalyst(AorB) | -0.067 |
| temp*catalyst(AorB) | -0.890 |
| time*temp*catalyst(AorB) | 1.092 |

*Combine the Constant along with the coefficients to determine the predictive equation.*

cost = 11.307 + 2.754 time + 1.240 temp + 5.418 catalyst(AorB) + 0.166 time*temp
- 0.067 time*catalyst(AorB) - 0.890 temp*catalyst(AorB)
+ 1.092 time*temp*catalyst(AorB)

# Reliability

*According to our design of the Mudslide Prevention System, it has the following five subsystems:*

*(1) monitoring system;*

*(2) infrastructure building team;*

*(3) supply management team;*

*(4) rescue team;*

*(5) communication maintaining group.*

*If our Mudslide prevention System requires a Reliability of 95%, we need reliability of 99% to each subsystem:*

*R(IICU) = R(D)*R(N)*R(SS)*R(V)*R(A)E = 0.99^5 = 0.95099*

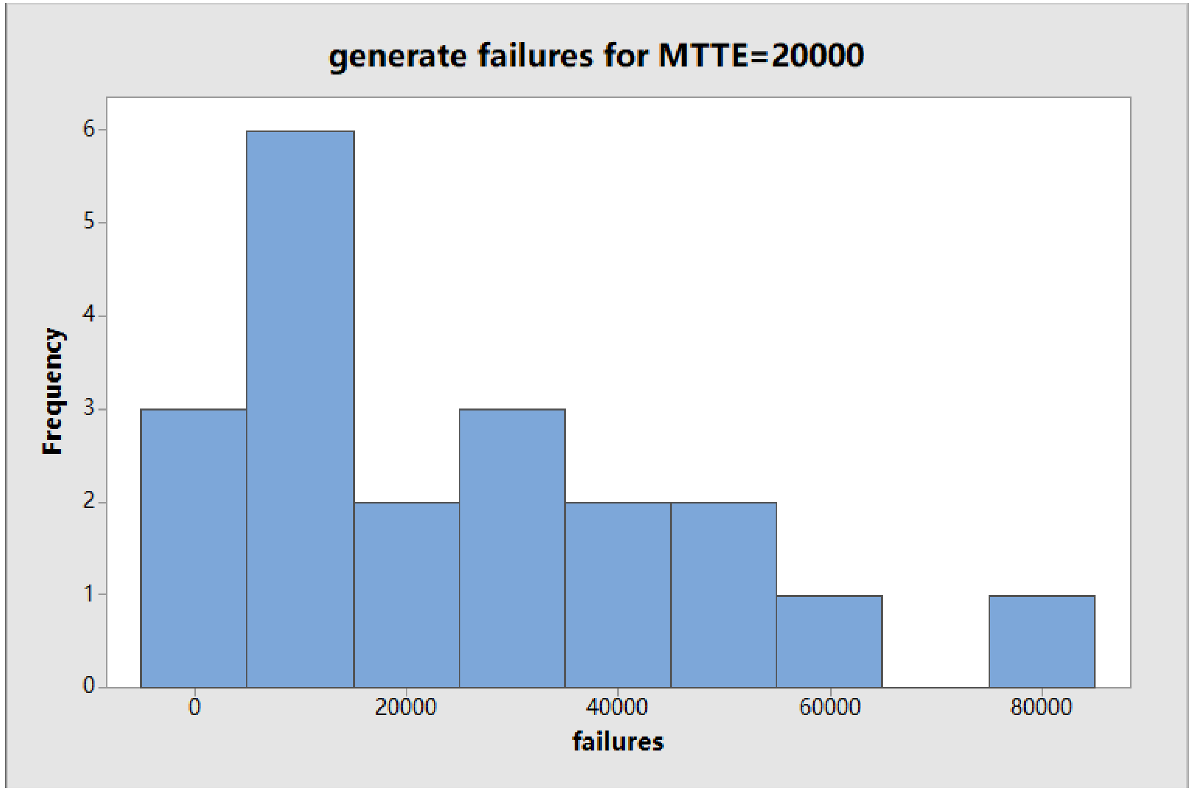
Generate data

| | Failures | | |
|---|---|---|---|
| 1 | 46462.9 | 11 | 17649.7 |
| 2 | 38890.2 | 12 | 38423.9 |
| 3 | 8386.1 | 13 | 22927.1 |
| 4 | 10016.1 | 14 | 6426.1 |
| 5 | 2340.1 | 15 | 1392.1 |
| 6 | 33690.7 | 16 | 25150.1 |
| 7 | 58067.6 | 17 | 6714.9 |
| 8 | 48176.9 | 18 | 7339.8 |
| 9 | 34743.3 | 19 | 84.3 |
| 10 | 6551.9 | 20 | 77648.8 |
| | | SUM | **491082.6** |
| | | AVG | 24554.13 |

# Reliability

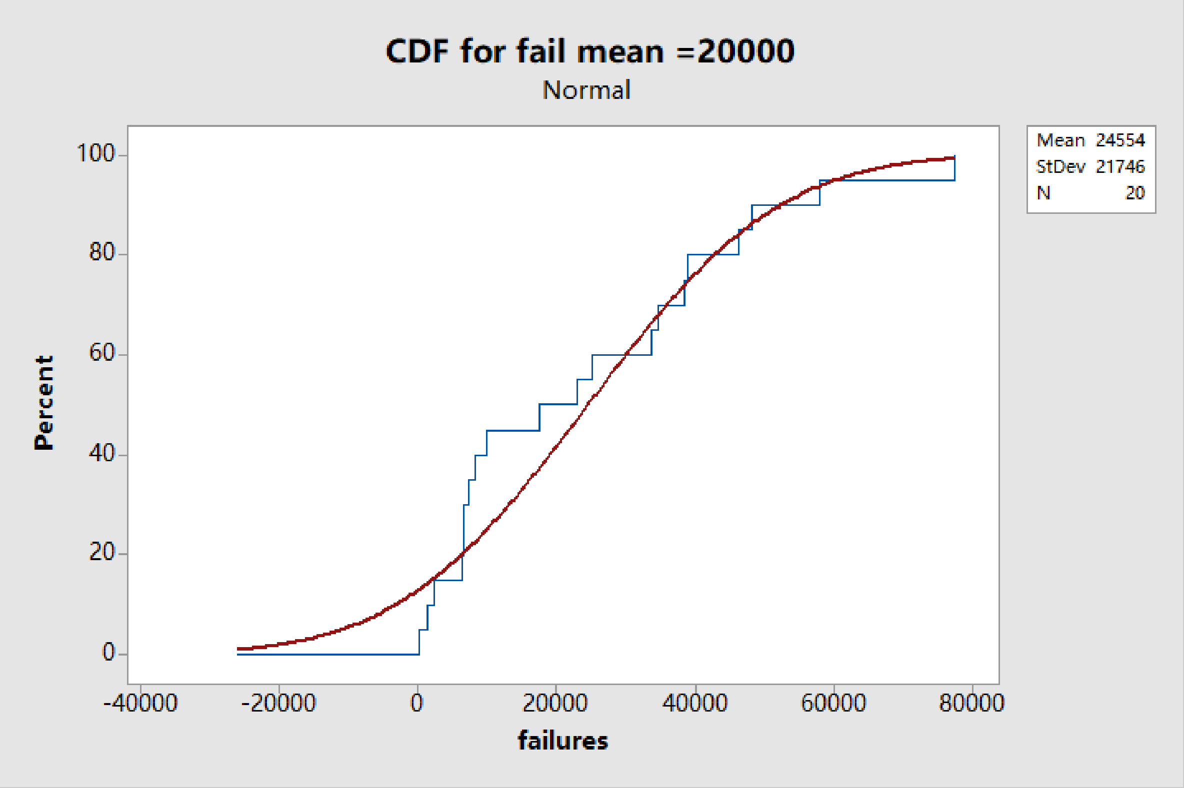
*Example of monitoring system: receiving and assessing a lot of n = 20 vibration detectors.*

*Generate the lives (time to failure) of n=20 vibration detectors, as Exponential with Mean Time Between Failures: MTBF = 20K hours*



# Reliability

*The diagram below is the cumulative distribution function (CDF). According our data (after sorted), 20% of the failure are less than 6426.1, the last 10% of the failure are greater than 58067.6.*



# Reliability

*If we want to define a Ventilator non-stop work time of 5000 hrs(= 83.3 hrs = 3.5 days):*

*95% CI for Reliability on this Mission Time (working without stopping for sched maintenance):[ 0.29 ; 0.61 ]*

*Since the upper internal is 0.61, that means there are 40% of the time our vibration dectectors are not working. Such reliability is not acceptable, so we will decrease Mission (maint.) time to 480 min = 8 hours*

*95% CI for Reliability on this Mission Time : [ 0.891; 0.953 ]*

# Reliability

*But we do not have the time nor the resources to wait for the Complete sample of n = 20 vibration dectectors to have a failure. We will stop our test at the First Failure Xk: k = 1 (assume we stop testing at time=84.3)*

*Then we calculate a new 95% CI of the mean is [457, 66,600]*

*We have reduced testing time from 77648 to 84 min, but paid a price of a much larger CI.*

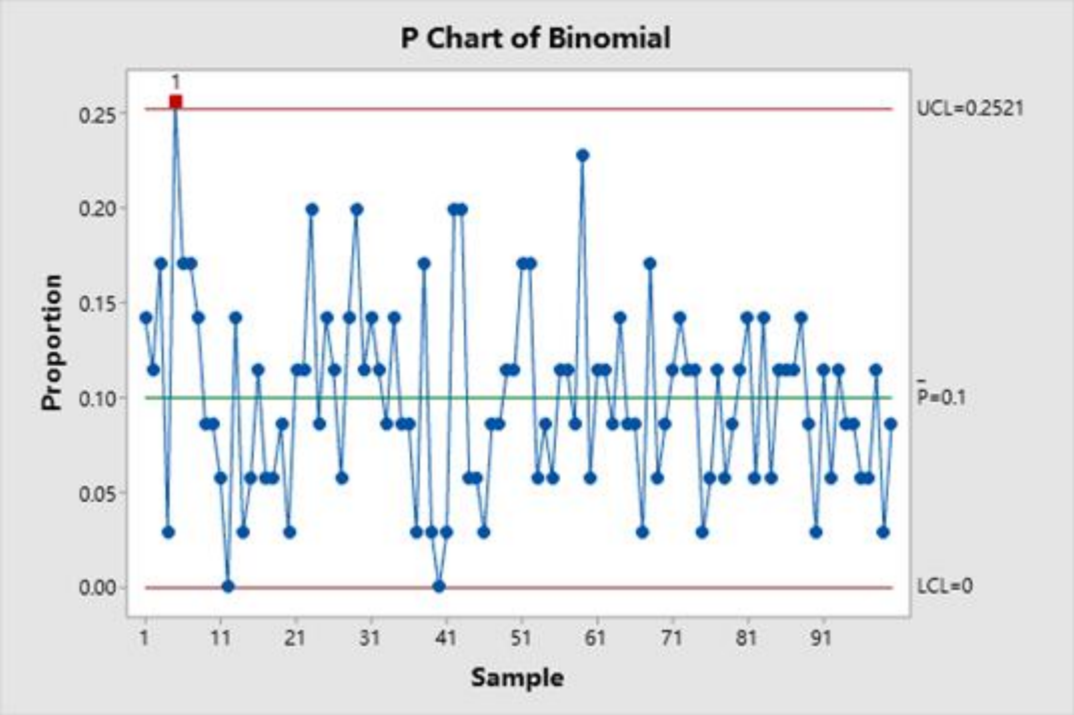
# Control

*Strategies to control the improvement:*

- Document the improved process
- Regular maintenance of facilities built for mudslide
- Making checklist to see if all supplies are available
- Regular evacuation training for citizens

# Attribute SPC

*One point more than 3.00 standard deviations from center line. Test Failed at points: 5. We can see that percentage is very high at that point, which means the process is unstable. But the mean is going down, and the situation is under control.*



# Conclusion

We use the methods of Brainstorming , COPQ, fishbone chart, flowchart, let us discover the methods and steps in mitigating mudslide disasters and determine the direction of improvement. Use gage R&R and OC curve to analyze rainfall data, and use VSM and DOE methods to adjust and improve the disaster relief plan to reduce the recovery period. Using reliability analysis reduces equipment testing time and makes the system more reliable. Lastly, we use control chart to control the performance of our system.

# Thanks for listening!