Improving Hurricane Mitigation Using Statistics-Based Engineering

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Summary

Hurricanes and typhoons are important events for nations in the Caribbean, South Pacific, and the Indian Ocean, where they appear yearly, are vastly feared, and highly destructive. This paper presents several applications of statistics-based engineering methods to design, development and improvement of weather-related (hurricane) problems. Several real life examples are presented and discussed.

Outline

- Introduction: about the author
- Basic Quality Engineering tools
- The three basic analysis phases:
  - Before the Event
  - During the Event
  - After the Event
- Some specific examples
- Conclusions
- Questions?

About the Presenter

- Cuban Expatriate (came to US at age 35)
  - Lived under Castro regime for 22 years
  - H.S., military service, college, professional life
  - Mathematical statistician; University of Havana
  - Worked at: petroleum , construction, agriculture
- Arrived to US during Mariel Boatlift (1980)
  - Completed PhD in IE/OR at Syracuse U (1990)
  - Retired Emeritus from SUNY
  - Research/Adjunct Professor, S.U.
  - Senior Engineer, Illinois Inst. of Tech. Res. Inst. (IITRI)

International Educator

- Fulbright Senior Scholar:
  - Mexico (1994, 2000, 2003), Dominican Republic (2004, twice), Ecuador (2007), Colombia (2020)
- Fundayacucho: Venezuela (1998)
- Created/Directs Juarez Lincoln Marti Project
  - http://web.cortland.edu/matresearch/
  - Faculty development workshops (Spain, Mexico, Ecuador, Peru, Brazil, Puerto Rico
  - Hundreds of textbooks donated to universities
  - Brought sixteen Latin Amer. faculty to US congresses

Covid-19 Pro-Bono Work

- Wrote/Hangued 14+ papers in the web:
  - https://www.researchgate.net/publication/349008991_Commented_Summary_of_a_Year_of_Work_in_Covid-19_Statistical_Modeling
  - Widely read, especially in Third World countries:
  - https://web.cortland.edu/matresearch/SELECTEDREADINGSRESEARCHGATE.pdf
- Wrote/Hangued Covid-19 Systems Design paper
  - https://www.researchgate.net/publication/352998703_Quality_Engineering_Methodology_in_Covid-19_Systems_Design_and_Improvement?channel=doi&linkId=60e35fa7299bf1ea9ee373ec&showFulltext=true
- Wrote /Hangued paper on Hurricane Mitigation

Applied Statistics Experience

Technical Experience:

- **Statistical data analysis and design of experiments**
- **Statistical process control/quality control/Six Sigma**
- **System reliability modeling and data analysis**
- **System simulation, optimization & performance evaluation**
- **Quality systems assessments, planning & control**
- **Professional Training in all of the above areas.**

Institutions where author has worked:

- **AFOSR/Rome Laboratory: Advanced Design Experiments**
- **AMPTIAC: Advanced Materials and Processes Anal. Ctr.**
- **RAC: Reliability Analysis Center/SRC: Systems Rel. Ctr**
- **DACS: Data and Analysis Center for Software**
- **IITRI: IIT Research Institute/Alion Sciences**

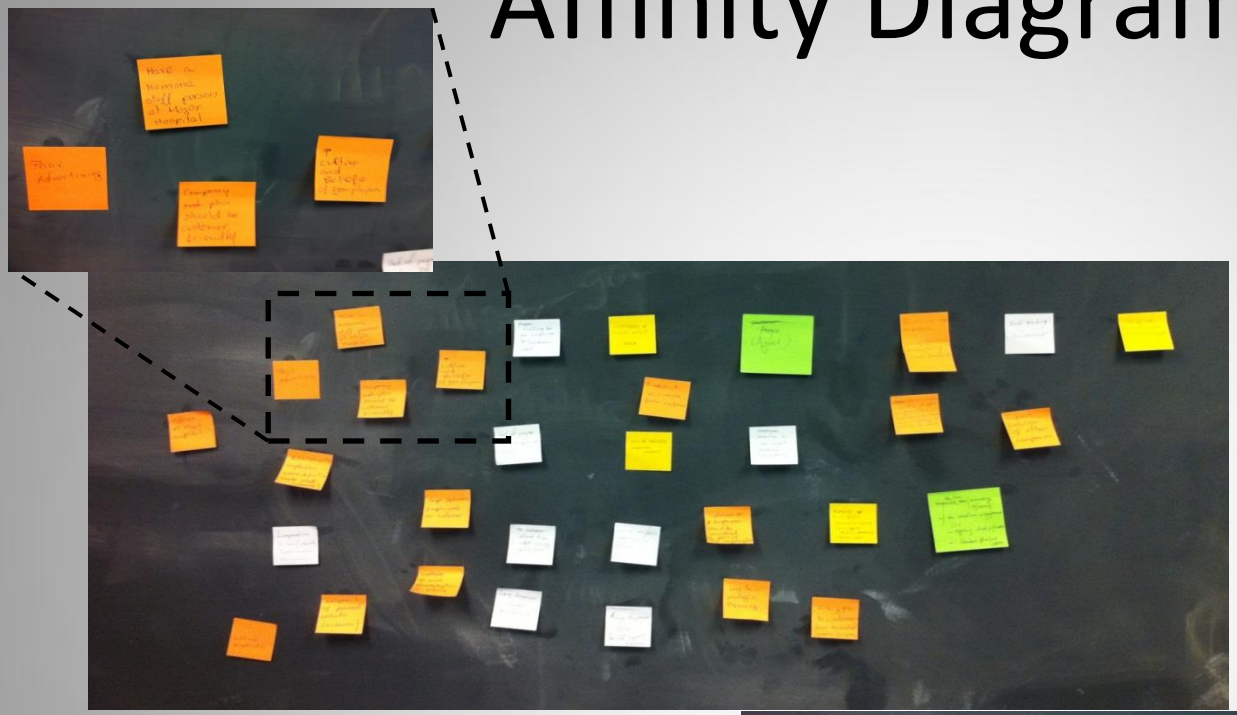
Professional Credentials:

- **Ph.D. in Industrial Engineering/Operations Research**
- **Certified Quality and Reliability Engineer, ASQ**
- **Senior Member, ASQ; Past Regional Director; Member ASA**
- **Chartered Statistician Fellow, Royal Statistical Society**

Basic Quality Tools

- **Cause-and-Effect Diagrams**
  - Aka Fishbone / Ichikawa Diagram
- **Check Sheets**
- **Histograms**
- **Box Plots**
- **Pareto Charts**
- **Scatter Diagrams**
- **Flow Charts**

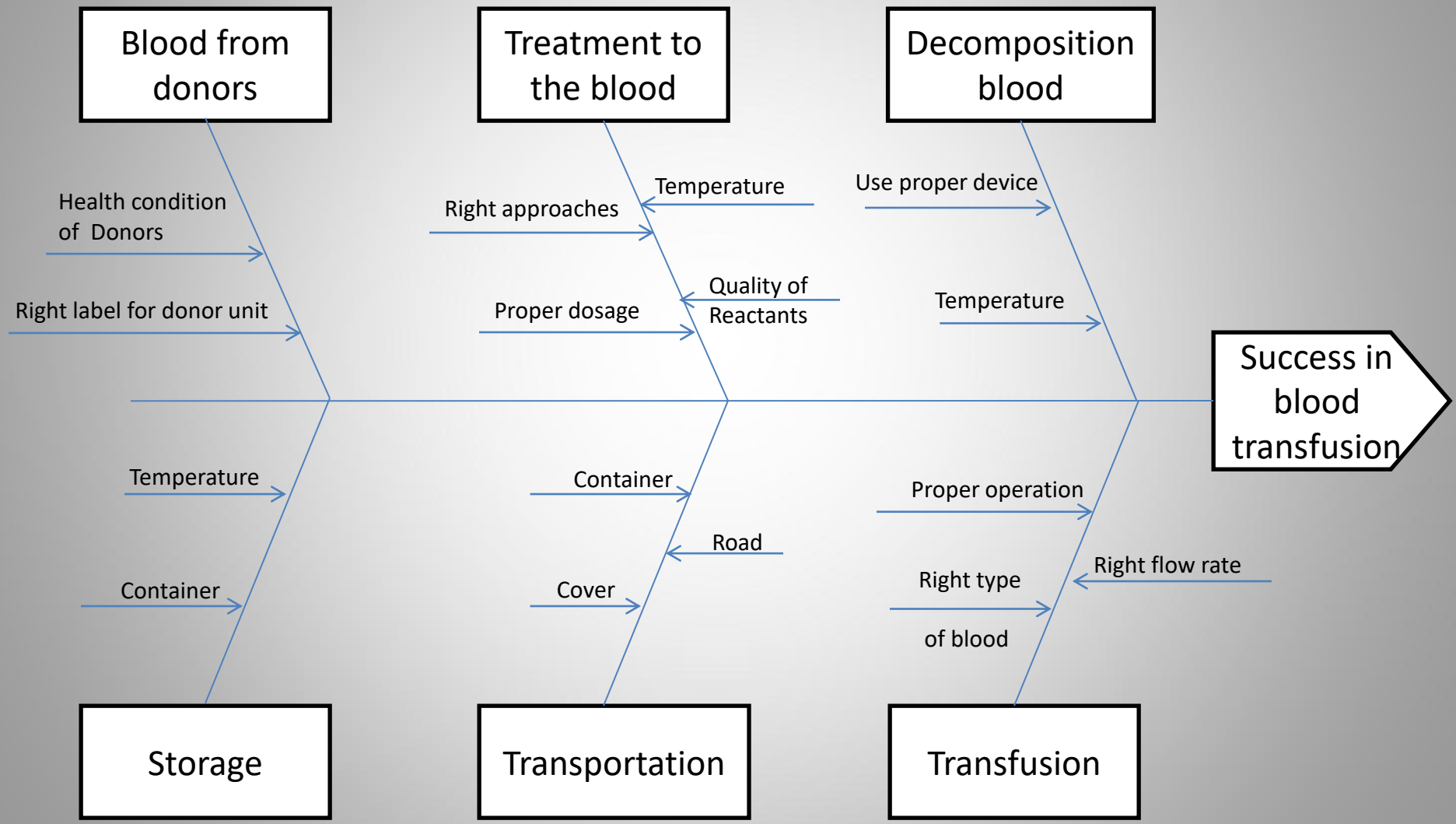
Affinity Diagram Process



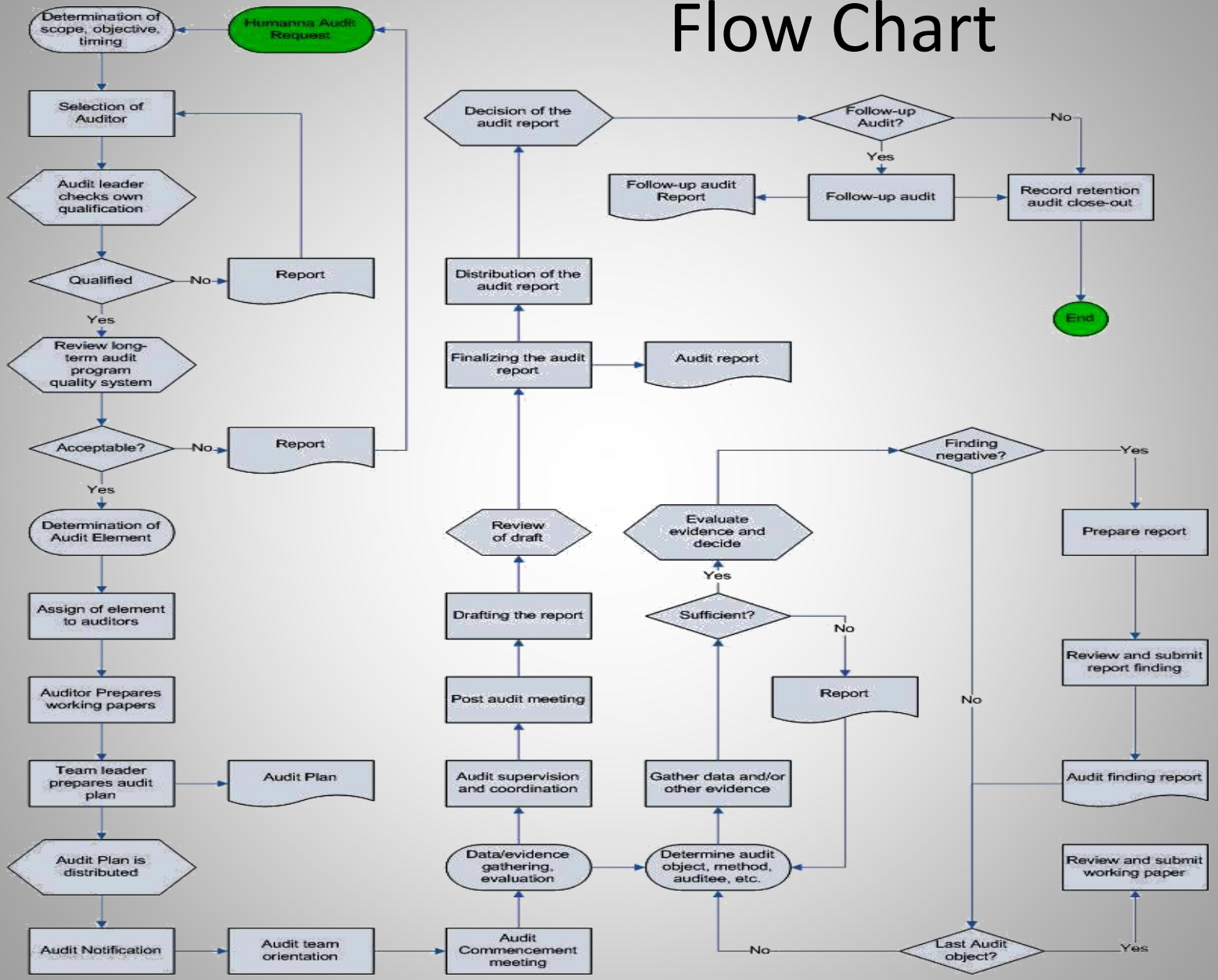
1st Step

2nd & 3rd Step

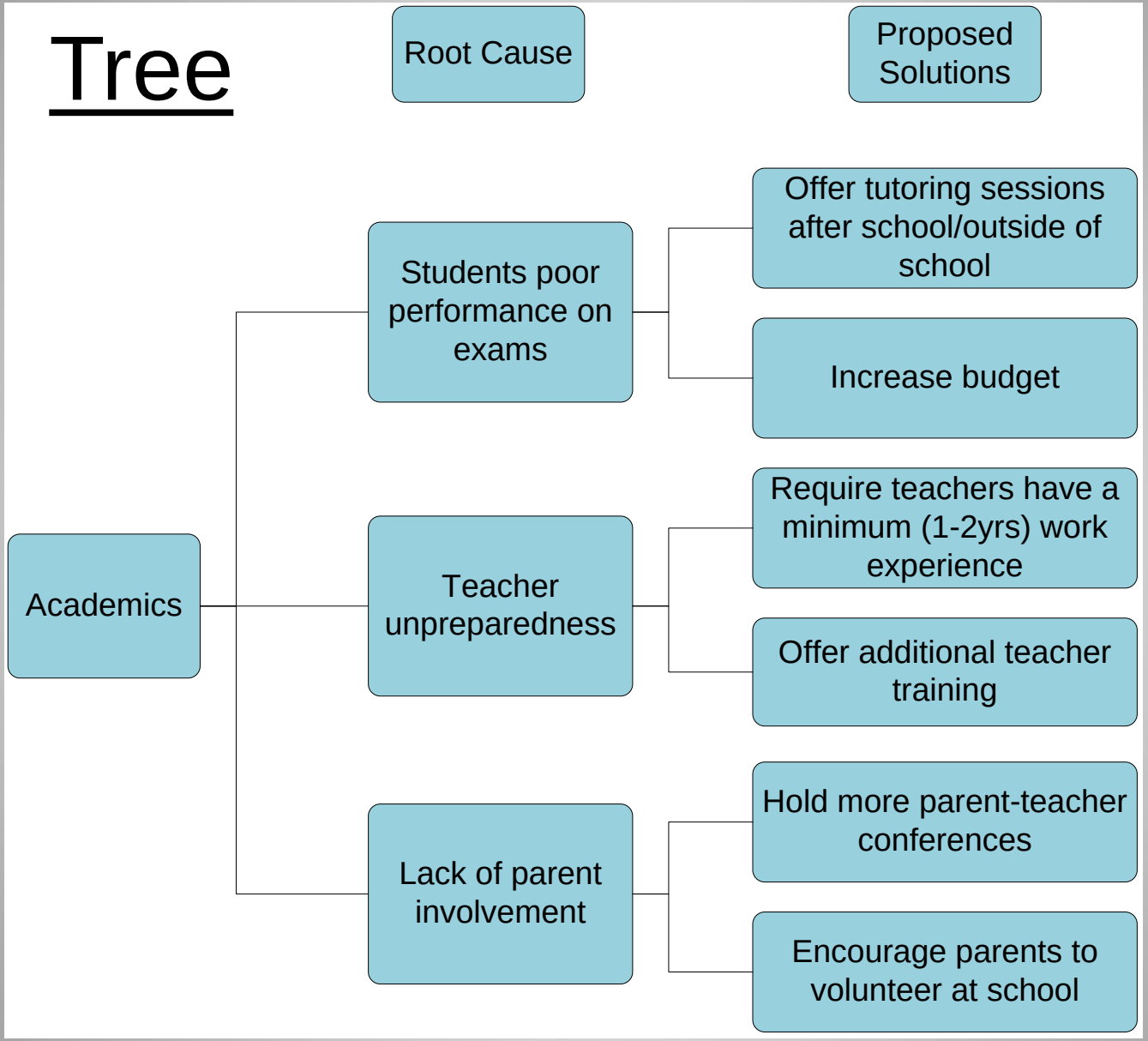
FISHBONE CHART



Flow Chart


Determination of scope, objective, timing
Humanna Audit Request
Selection of Auditor
Audit leader checks own qualification
Qualified
No
Report
Yes
Review long-term audit program quality system
Acceptable?
No
Report
Yes
Determination of Audit Element
Assign of element to auditors
Auditor Prepares working papers
Team leader prepares audit plan
Audit Plan
Audit Plan is distributed
Audit Notification
Audit team orientation
Audit Commencement meeting
Data/evidence gathering, evaluation
Audit supervision and coordination
Post audit meeting
Drafting the report
Review of draft
Distribution of the audit report
Finalizing the audit report
Audit report
Decision of the audit report
Follow-up Audit?
No
Yes
Follow-up audit Report
Follow-up audit
Record retention audit close-out
End
Finding negative?
Yes
Prepare report
Review and submit report finding
Audit finding report
Review and submit working paper
Last Audit object?
No
Yes
Determine audit object, method, auditee, etc.
Gather data and/or other evidence
Sufficient?
No
Report
Yes
Evaluate evidence and decide

Tree



Check Sheet

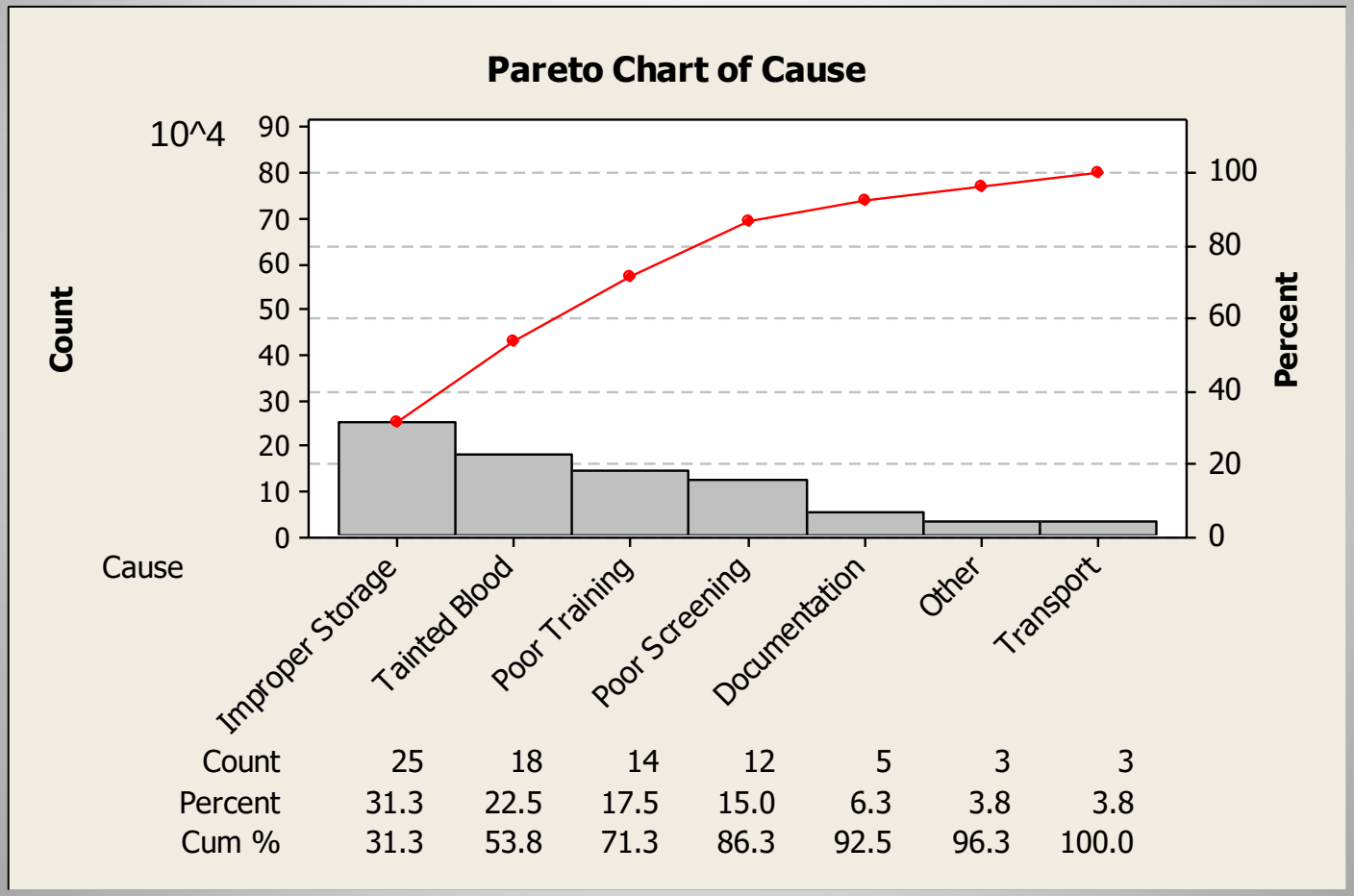
- **A structured, prepared form for collecting and analyzing data**
- **This is a generic tool that can be adapted for a wide variety of purposes**
- **Characteristic of a check sheet is that data is recorded by making checks on it**

Customer interview checklist

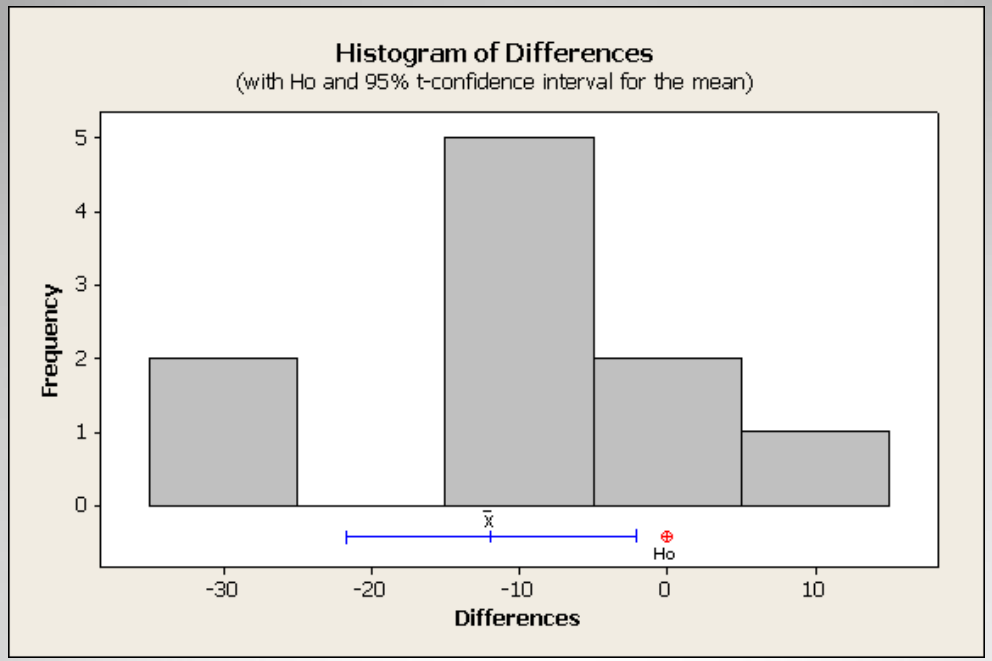
How long have you had a policy with Humana?	(a) Less than 1 month (b) 1 to 6 months (c) 6 months to 1 year (d) 1 to 3 years (e) Over 3 years
Overall, how satisfied are you, with Humana insurance company?	(a) Extremely satisfied (b) Very satisfied (c) Somewhat satisfied (d) Unsatisfied (e) Very unsatisfied
How likely are you to renew your insurance policy/policies with Humana?	(a) Definitely (b) Probably (c) Might or might not (d) Probably not (e) Definitely not
Would you recommend Humana insurance service to your friends and family?	(a) Definitely (b) Probably (c) Might or might not (d) Probably not (e) Definitely not
Have you ever had occasion to file a claim?	(a)Yes (b) No
What is the most important reason for you to have health insurance?	(a) To protect against high medical bills (b) To pay for everyday health care expenses
What is the highest amount you would be willing to pay for various aspects of health insurance monthly?	(a)200$ or less (b)Greater than 200$ and less than 300$ (c) Greater than 300$ and less than 400$ (d) do not know
What is the highest amount you would be willing to pay for a doctor visit co-pay?	(a)20$ or lower (b) Higher than 20$ and lower than 40$ (c) Higher than 40$ and lower than 60$ (d) do not know
What is the highest amount you would be willing to pay for prescription drug co-pay?	(a)10$ or lower (b) Higher than 10$ and lower than 20$ (c) Higher than 20$ and lower than 40$ (d) do not know
What is the highest amount you would be willing to accept for deductibles?	(a)50$ or lower (b) Higher than 50$ and lower than 100$ (c) Higher than 100$ and lower than 200$ (d) do not know
What factors would you consider when choosing or evaluating a health insurance plan? (Multiple choice)	(a)Cost of health plan (b) choice of doctors (c)Range of benefits

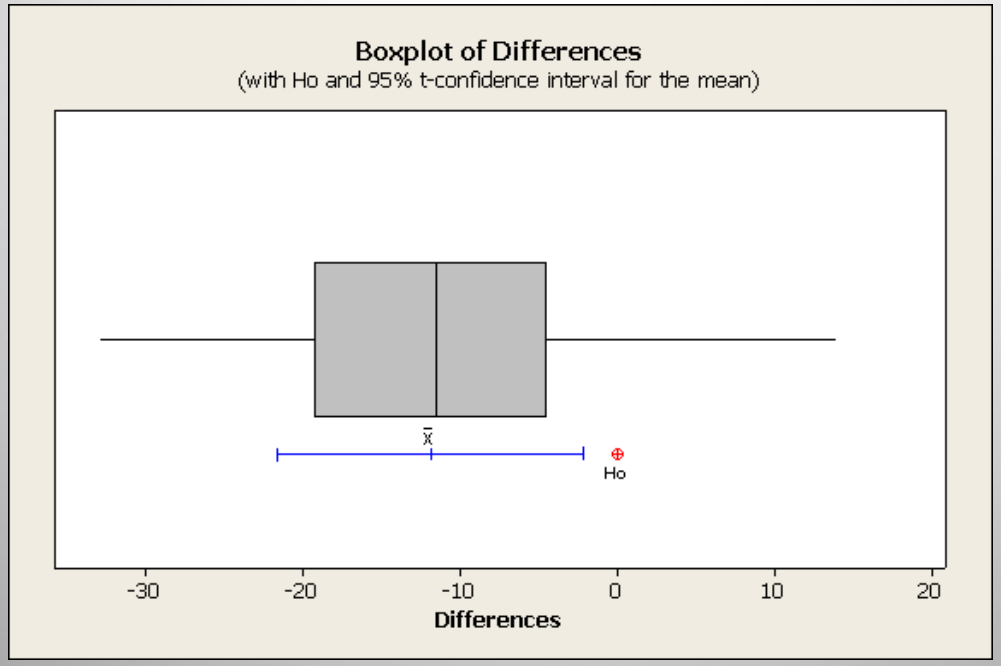
Pareto Chart

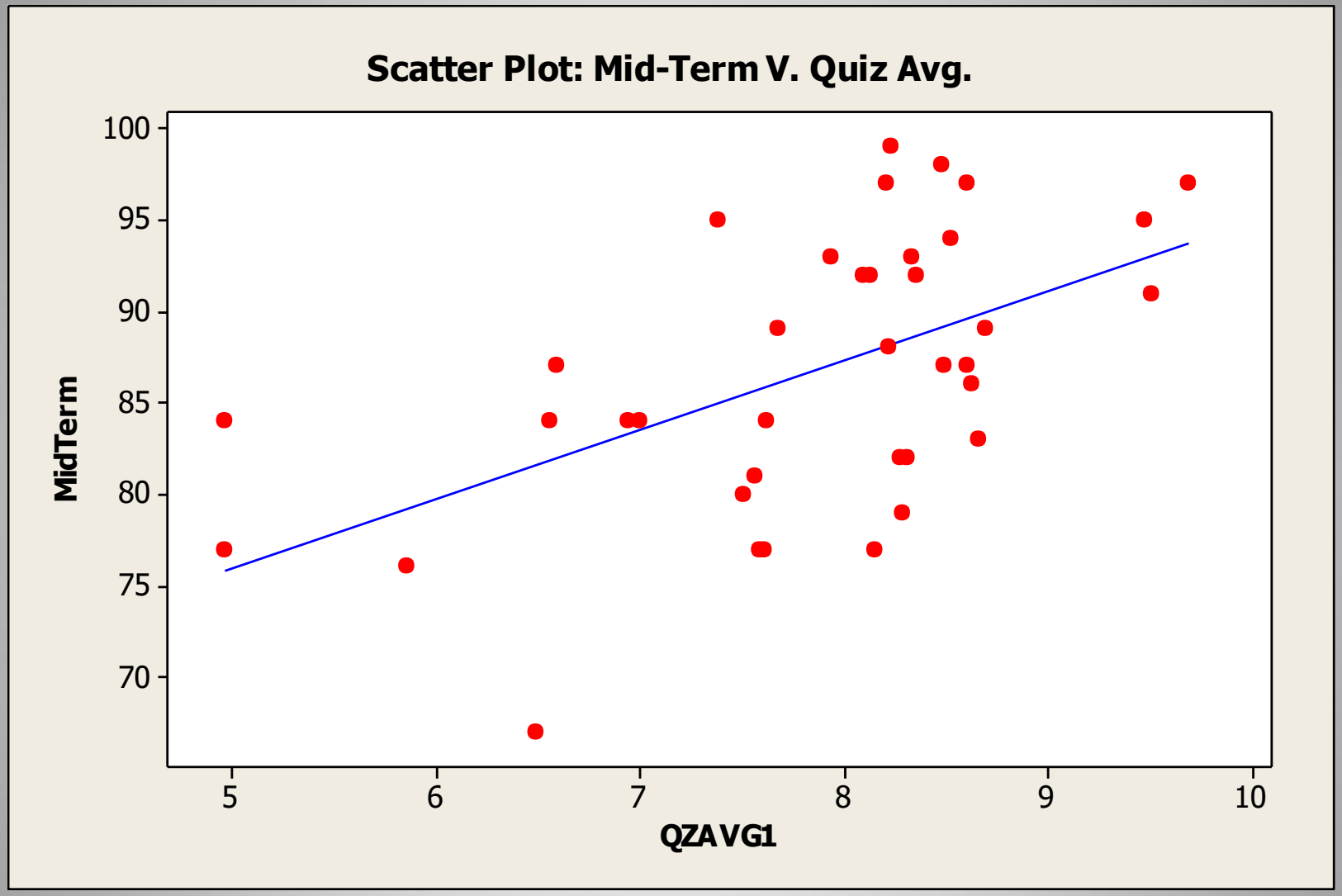
800,000 TOTAL UNITS



Count	25	18	14	12	5	3	3
Percent	31.3	22.5	17.5	15.0	6.3	3.8	3.8
Cum %	31.3	53.8	71.3	86.3	92.5	96.3	100.0


Histogram of Differences
(with Ho and 95% t-confidence interval for the mean)
Frequency
0
1
2
3
4
5
X̄
Ho
-30
-20
-10
0
10
Differences


Boxplot of Differences
(with Ho and 95% t-confidence interval for the mean)
X̄
Ho
-30
-20
-10
0
10
20
Differences

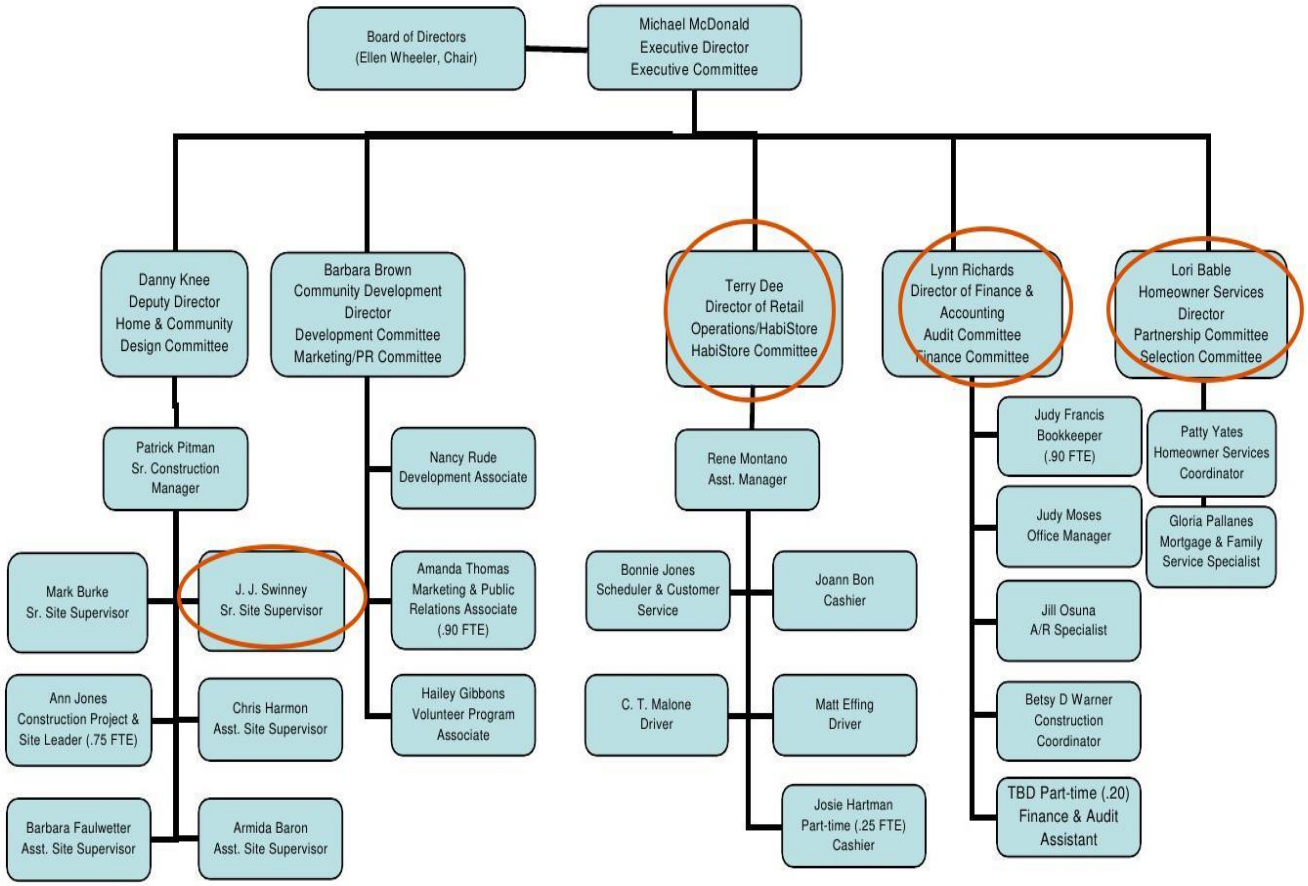

Scatter Plot: Mid-Term V. Quiz Avg.
MidTerm
100
95
90
85
80
75
70
5
6
7
8
9
10
QZAVG1

Matrix Diagram

- **Relationship between two, three or four groups of information**
  - **Strength**
  - **Roles played by various individuals or measurements**

What Happened? Proximate Cause	**Why did this happen?** Contributing Factors	**Risk Reduction Strategy** Action Plan
Receiving Complaints Increasing	1. No proper Documentation for complaints 2. not recording valuable information 3. no follow up on action against complaints 4. no learnt lesson 5. High delay in response time	-implementation of a proper Customer Relation Management System - Training customer service Employee to satisfy the customers better that before - record issues and use lessons for future improvement (reoccurring issues) - prepare fast response procedure for first-time issues
Addressing of customer needs by NOT trained personnel	6. Insufficient training programs 7. Not effective training programs 8. no qualification plan or procedure for trainer persons or contractors	- Prepare a qualification Plan for trainers - develop training programs - develop a training scope for each activity, which includes who have to learn what before doing it
Not following the customer complaint; believing its out of contacted employee scope duties	9.Confusing/Insufficient Information to customer. 10. No Clear Scope of duty for employee 11. Not enough sympathy with customer 12. not trained employee for anger management	- Make the policies more clear - Prepare a procedure to ensure new customers understands their rights - define duty scope of each employee - Make sympathy as a part of scope of duty - define sympathy limits - train employee for anger management
Low contributions of employees	13. No motivation for contribution	- Rewards and incentives for contribution - create more intimate working environment - Let them know how much their contribution is important, and how can effect their working condition
Not completely compliant with the standards	14. No prepared procedure in accordance with Standards 15. No regular audit 16. no tool to measure and monitor compliance	- revise all the existing procedures and make sure they are in-compliance with standard - create standard procedures for every job and activity - do a regular internal audit to make sure procedure are followed - measure performance of procedures, and feedback from reviews and audit to modify them as needed

Organization Chart



1.53 FTEs added since FY09_10 Budget

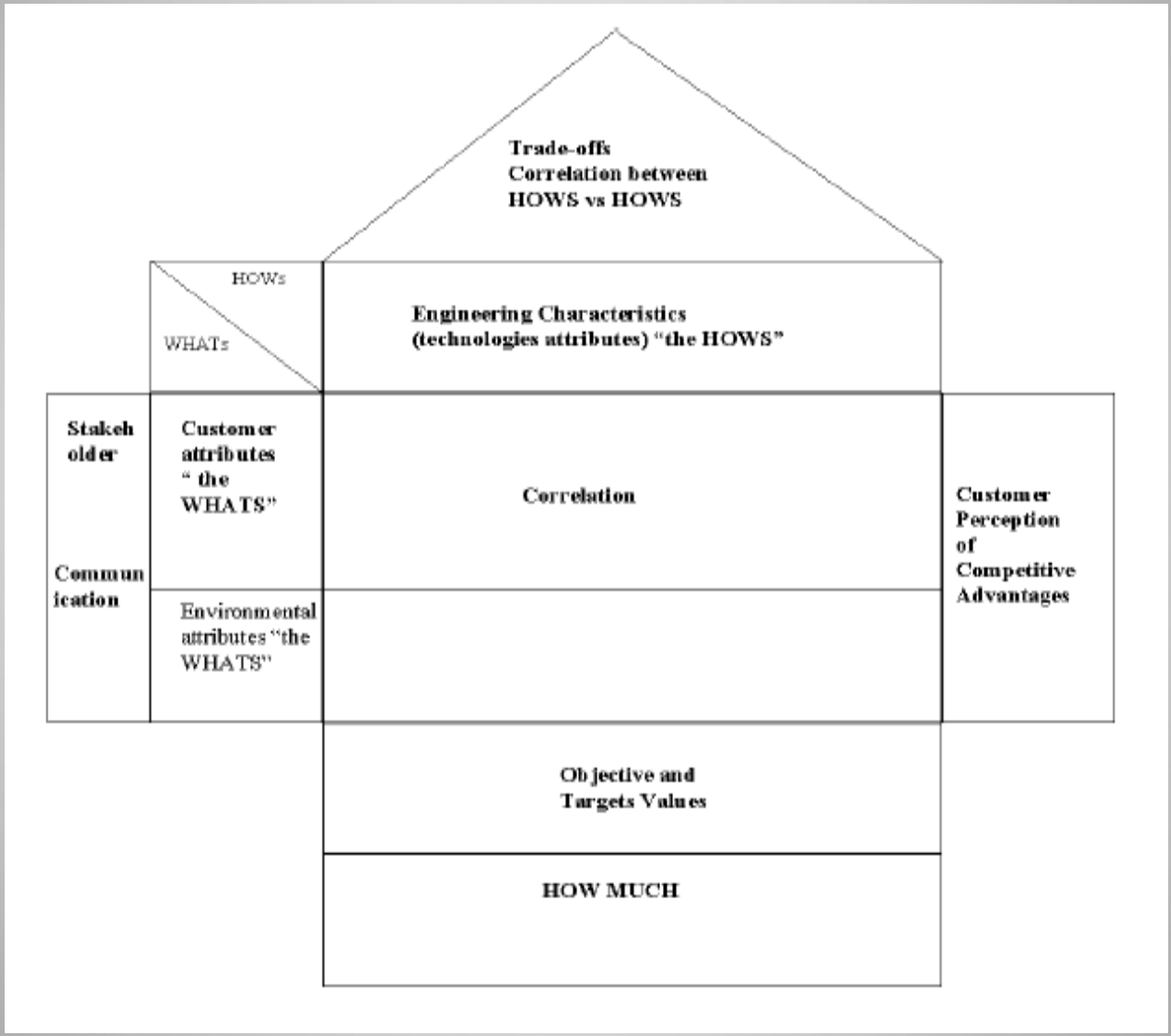
5S System: Kaizen Principles

- **Sort**: keep only necessary things
- **Set in order**: arrange efficiently
- **Shine**: maintain cleanliness/avoid clutter
- **Standardize**: proceed consistently
- **Sustain**: cooperative working environment

More Complex Methods

- Quality Function Deployment/QFD
- Value Stream Maps/VSM
- Six Sigma/DMAIC
- Control Charts/SPC
- Process Capability

A skeleton for a House of Quality

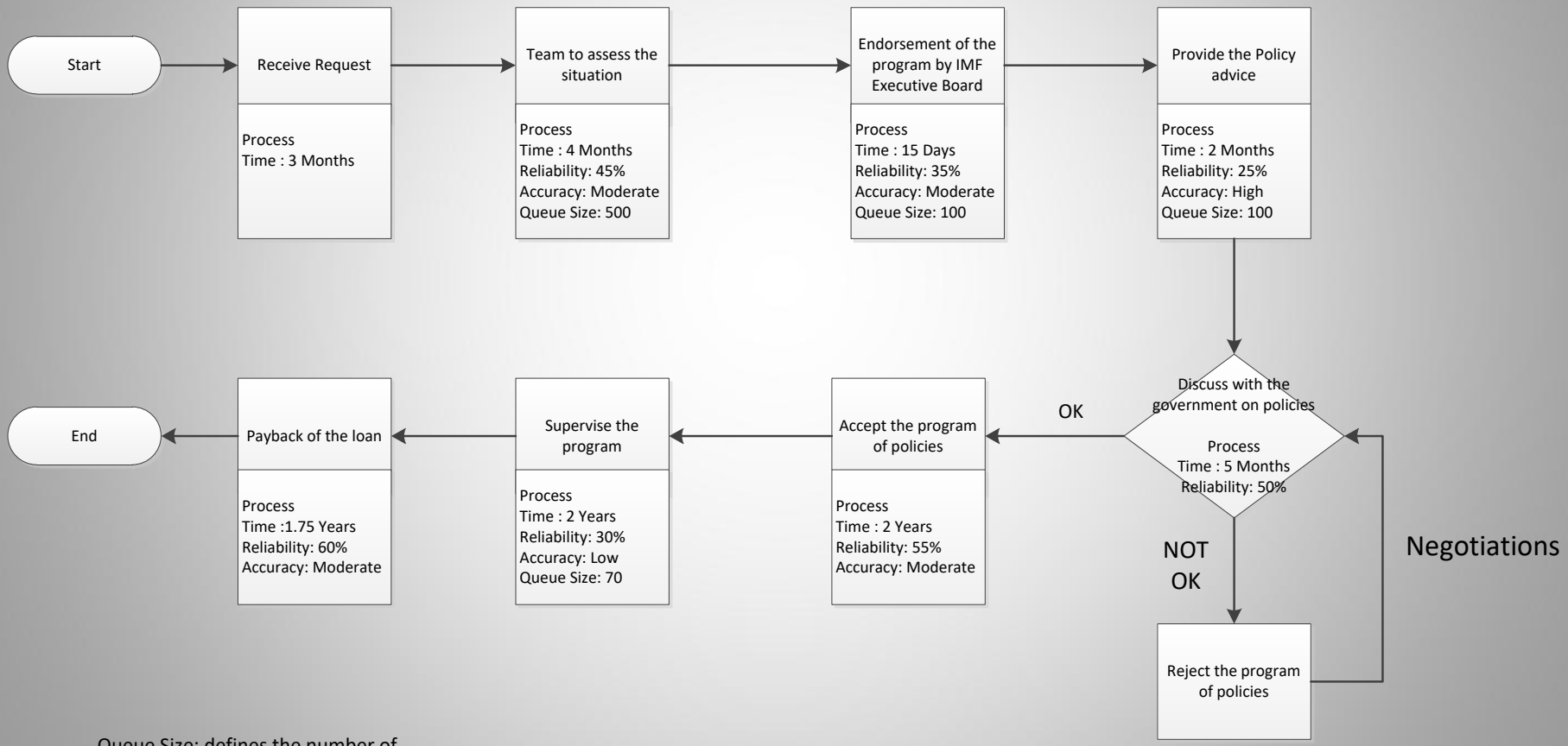


Value Stream Map (VSM)

- Lean manufacturing technique used to analyze and design the flow to bring a product from conception through delivery to the customer.
- It consists of all activities (both value added and non-value added) to deliver a product, in Present as well as in Future (new design) states.

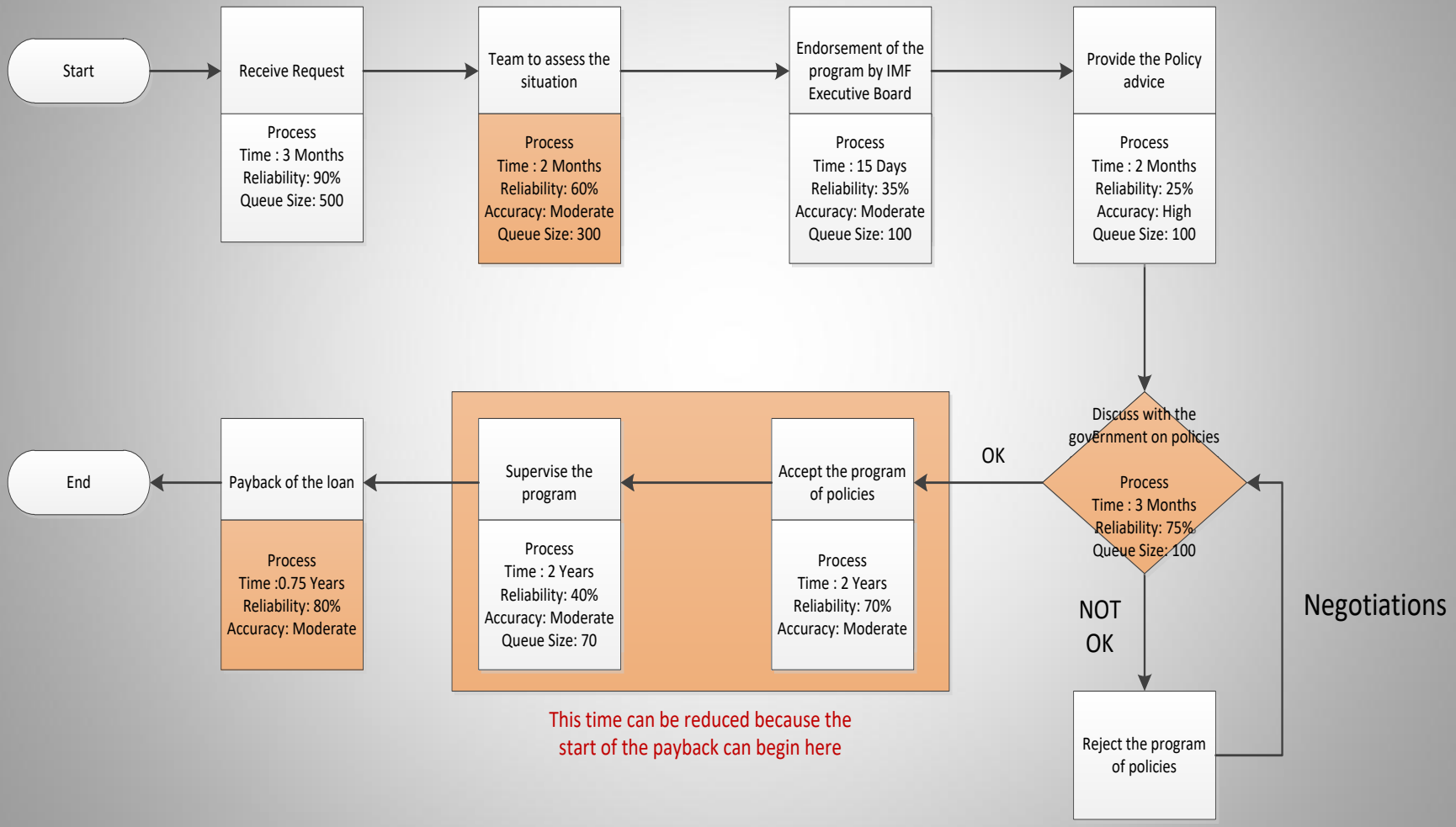
Current State

The Process is IMF's "Stand-By Arrangements" lending option



Queue Size: defines the number of documents impending for review per month

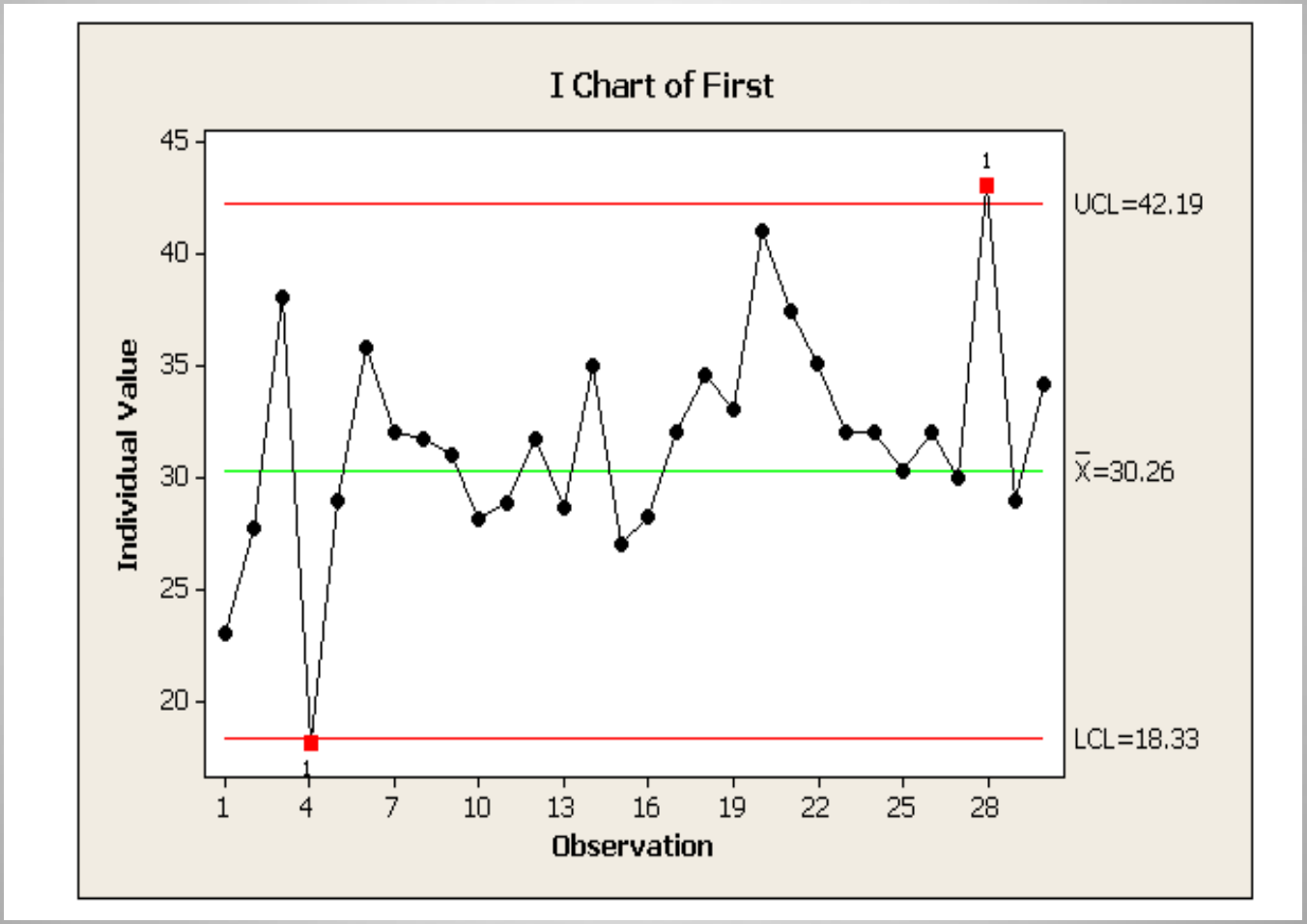
Final State


Start
Receive Request
Process
Time : 3 Months
Reliability: 90%
Queue Size: 500
Team to assess the situation
Process
Time : 2 Months
Reliability: 60%
Accuracy: Moderate
Queue Size: 300
Endorsement of the program by IMF Executive Board
Process
Time : 15 Days
Reliability: 35%
Accuracy: Moderate
Queue Size: 100
Provide the Policy advice
Process
Time : 2 Months
Reliability: 25%
Accuracy: High
Queue Size: 100
Discuss with the government on policies
Process
Time : 3 Months
Reliability: 75%
Queue Size: 100
OK
NOT OK
Negotiations
Reject the program of policies
Accept the program of policies
Process
Time : 2 Years
Reliability: 70%
Accuracy: Moderate
Supervise the program
Process
Time : 2 Years
Reliability: 40%
Accuracy: Moderate
Queue Size: 70
Payback of the loan
Process
Time :0.75 Years
Reliability: 80%
Accuracy: Moderate
End
This time can be reduced because the start of the payback can begin here

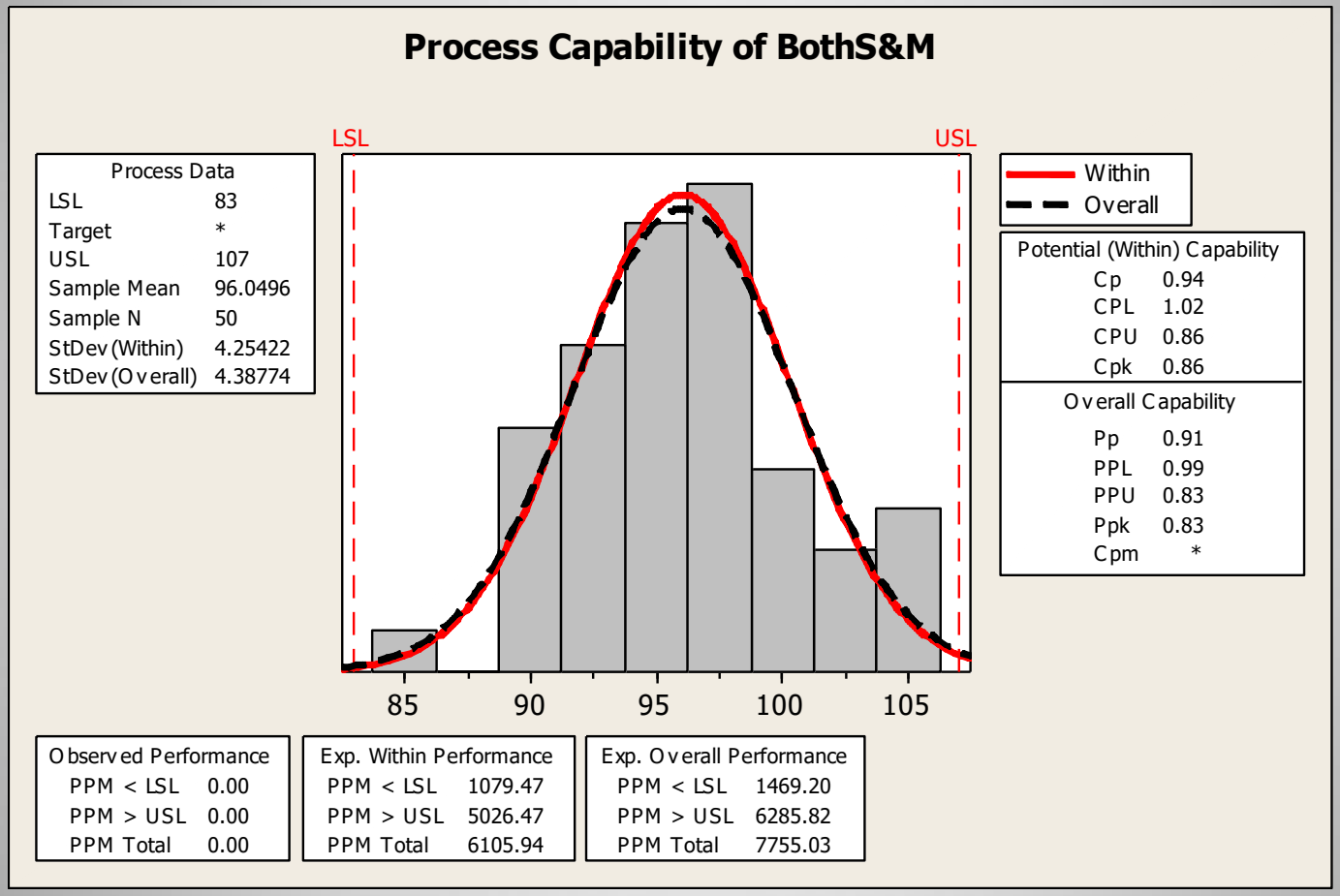
Quality Control Methods

- Addresses Sporadic Problems
  - Acceptance Sampling
  - SPC Control Charts
- Detects issues, corrects them and
  - returns the system
  - To Original Status

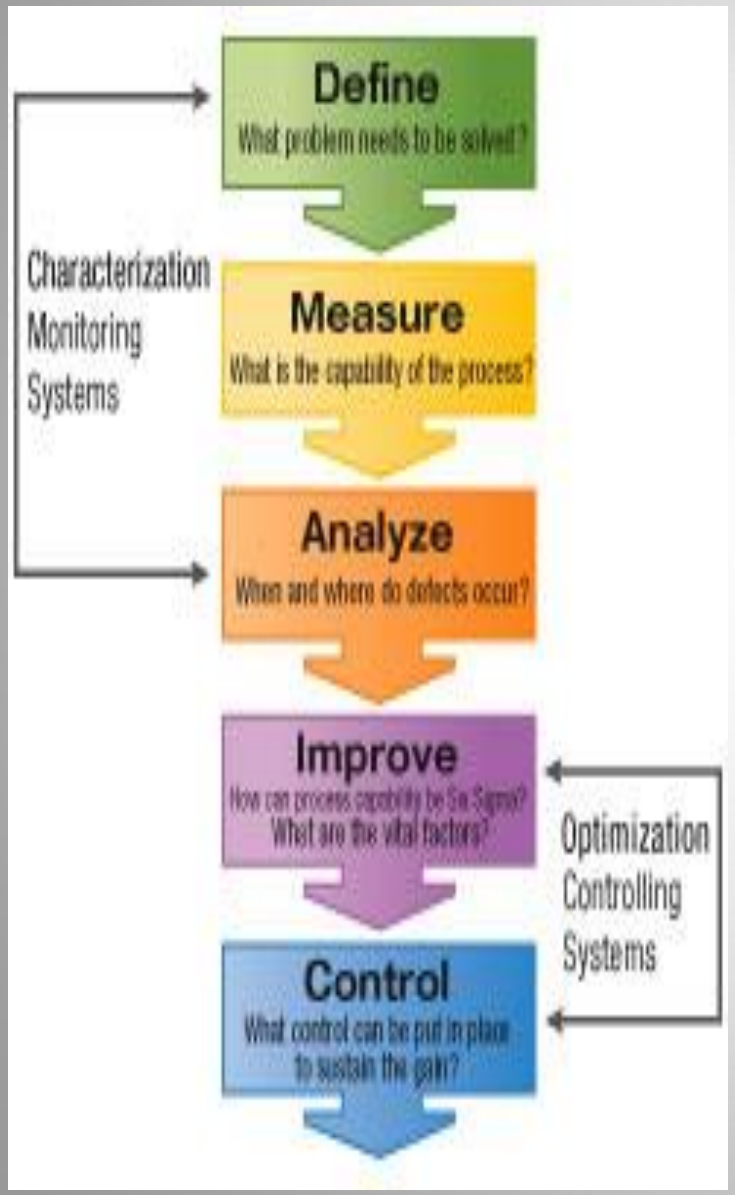
Control Chart for Number of Errors



Process Capability Analysis



Six Sigma DMAIC: Addresses Chronic Problems



DEFINE
Problem and project goals.

MEASURE
Current process followed.

ANALYZE
Cause and effect relationships .

IMPROVE
Improve Process using special techniques.

CONTROL
Make correction and implement control system.

Quality Engineering Methodology in Hurricane Mitigation

Paper Url

https://www.researchgate.net/publication/354322771_Quality_Engineering_Methodology_in_Hurricane_Mitigation_Procedures

Hurricane Mitigation Phases

Broadly speaking, *we need to address three different phases*, in order *to prepare for a hurricane* strike. These are: **before, during and after the hurricane lands**. We review them, next.

Before Mitigation Phase

Before, *meaning up to several months or even a year*, requires an in-depth assessment of the terrain affected by the *three main fallouts of a hurricane*: *wind, rain and surge*. *Wind* affects tall structures. We need to assess and reinforce their strength, pull them down, protect surrounding structures from their possible collapse, etc. *Rain* will pour during hours; where will all that water go? If there is poor drainage there is only one possibility: up!

Before Phase (cont.)

There will be flooding, that will threaten lives and weaken structures. If the region is *close to the sea* there is a possible *surge*, adding to the rain water flooding. Then, we need to consider evacuating the inhabitants.

Before Phase (cont.)

We need to estimate the number of people to evacuate, and establish how this will be done (road, air, water?). It implies estimating the number of vehicles (buses, boats, planes) that will be used, including travel time, as well as the capacity of routes (roads, bridges, canals, airports, etc.) to ensure there is sufficient capability to move all evacuees out of danger, before the storm hits.

Before Phase (cont.)

- It is necessary to establish where all these evacuees will be lodged (for several days) and provide for them: food, water, beds, medical and safety personnel and equipment, electrical power (the first element lost as the storm hits), etc.
- We need to establish an array of warehouses, where equipment and material will be stored, to minimize supply chains to provision them. We need to organize a contingent (firemen, medics, police, etc.) that will stay on location, to help those that will not be evacuated, as well as in the evacuation sites, including support material.

Before Phase (end)

All *this information is obtained* from interviews, brainstorming sessions, studies, etc. done with subject matter experts, *before the hurricane hits* the site. It will be consolidated and analyzed via Ichikawa and Process Flow Charts.
Then, such information will be used *to draft a master plan* to be implemented at the time of imminent threat of a hurricane.

During Hurricane Phase

The *master plan will be implemented*. For safety and precaution, *key parts* of it should have *back-ups or redundancy* –remember Murphy's laws: *if anything can go wrong, it will*! This period may last several days. For, after the hurricane passes through, this team must stay to *clean up the debris, re-establish* electrical power and water supply, and provide all other essential services before the evacuees can return and resume a semi-normal life, again.

After Hurricane Phase

After the hurricane is gone and evacuees are back, *reconstruction* and *root-cause analysis* needs to be done. In spite of all the planning and forward thinking, *some things may have not worked*, or *worked poorly*, or we may have *forgotten or miss-calculated* some issues. This is the time to *go back to the drawing* board and *revise, redo*, etc. the *plans, for the next iteration*.

All these activities will be illustrated through several student projects.

Hurricanes in Louisiana and NYC

**Sandy* hits a *heavily populated urban area* (New York City) and *its surge floods* the city's underworld: subway stations, basements, streets etc., thus disabling electrical power stations and cutting the electricity off elevators of high rise buildings, public transportation systems, etc.
**Katrina* hits a *smaller, less populated* city (New Orleans), situated *in the delta of an immense river* (Mississippi), whose *levies yield to the surge* from the river and allows *complete flooding* of the urban area.
**Student Group QE final report PPT* based on the Katrina, LA and Sandy, NY hurricanes can be found in:
https://web.cortland.edu/matresearch/2017WeatherDisasterMgmtFinPres.pdf

Hurricane Harvey in Texas

This project analyses one of the most devastating and costly hurricanes of recent times. *Houston, Texas* is a heavily populated and industrial (*refineries*) urban area that becomes partially flooded when a *large reservoir gives in and floods* an improperly situated residential area. The PPT and project follows the same organization and parts as Katrina and Sandy. In addition to shedding more light on how QE methods are implemented, it includes an example and analysis of Harvey's expensive economic impact, on the faulty elements that increased damages, and suggests some improvements. This is one of our most complete and detailed hurricane student projects received. The PPT for hurricane Harvey, TX, student group project is found in:
https://web.cortland.edu/romeu/HurricaneHarveyPptS2018.pdf

Conclusions

*We want to *encourage weather disaster professionals to use statistics-based QE* procedures, and to *undertake joint work with quality, reliability, logistics, and industrial and operations research engineers*. And to use these methods not only *after weather disaster* systems have been designed and implemented, but also *during the time that these systems* are being *designed/prepared.*

**Statistics-based weather disaster* systems *analysis* can also *be used as part of a weather disaster course*, or as part of an *applied modeling and analysis graduate course in an industrial engineering, operations research, or applied statistics department*.