K.V.P Consulting

Multi Disciplines Surrounding (MDS)

Understanding Variation that Extends Statistical Process Control

Organizational Background and Process ROI

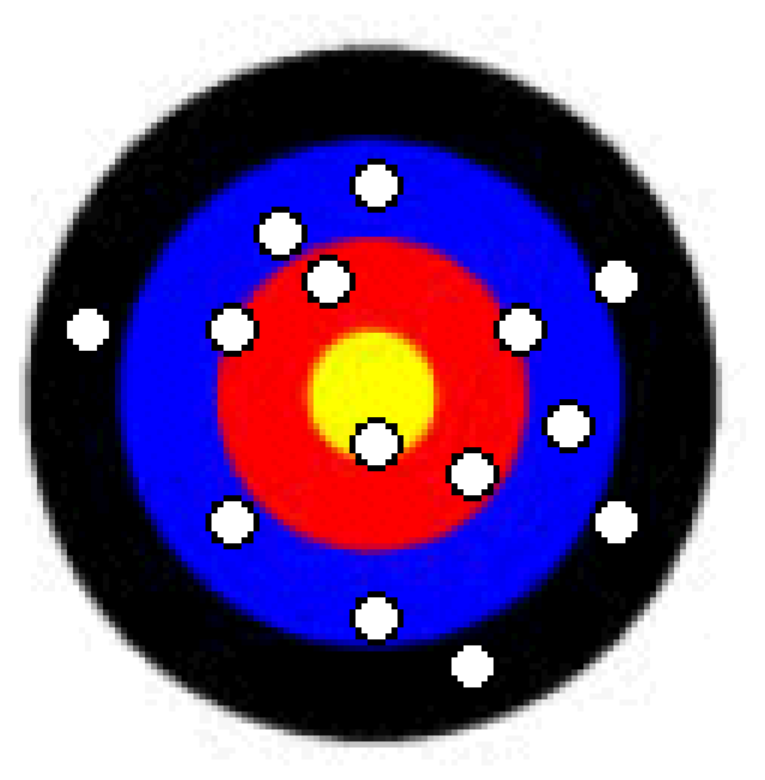
Project Idea and Proposal Preposition Development

- If an average developer day cost is ~7000
- The total Program effort was 10220 day (100%)
- The testing phase was 1480 day (14.5%)
- Defect that are the result of documentation are 69% of all defects

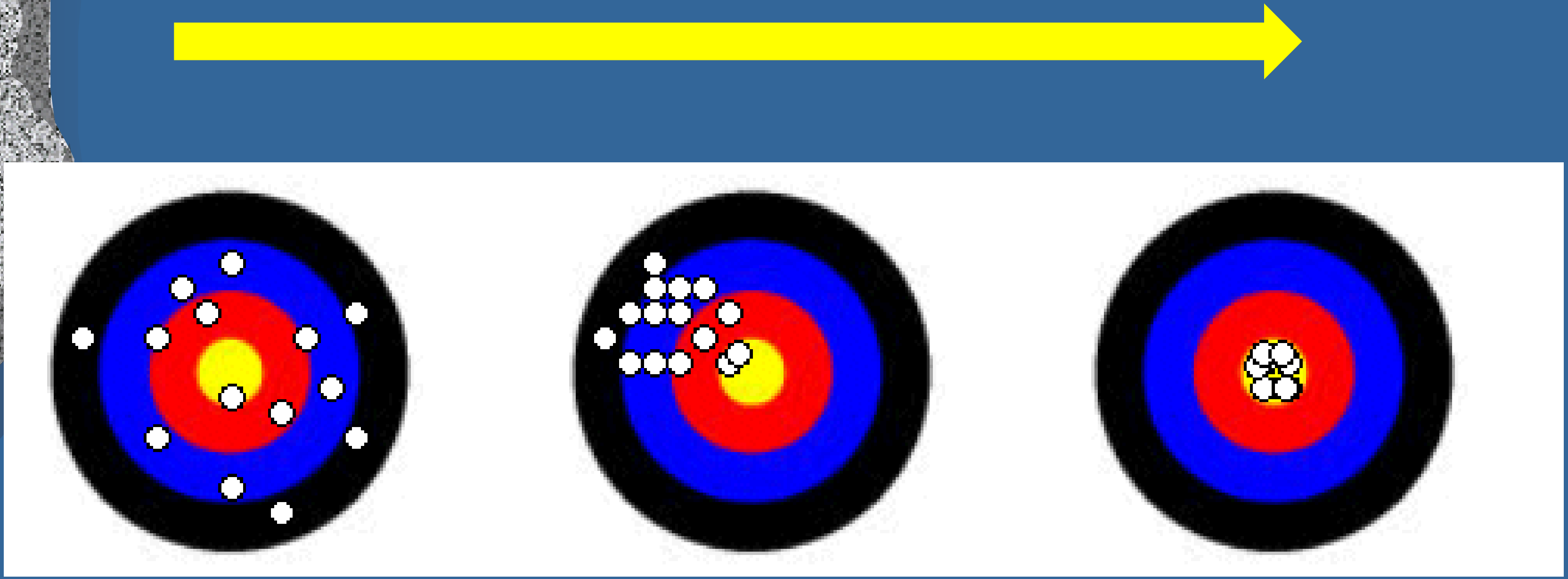
- If we will assume the to correct 69% of all defects will take around 40% of th testing duration; ☞ means that:
    - that will be 740 day
    - With the overall cost of 518000
- However to add 100 review days in the static tests and another 20 of code inspection will end with the cost of 2100000

- And still we have saved at least 3080000 (440 days)
- Means that we ware able to reduce 4.5% of the project time

Our Business Process



Our Improvement Target

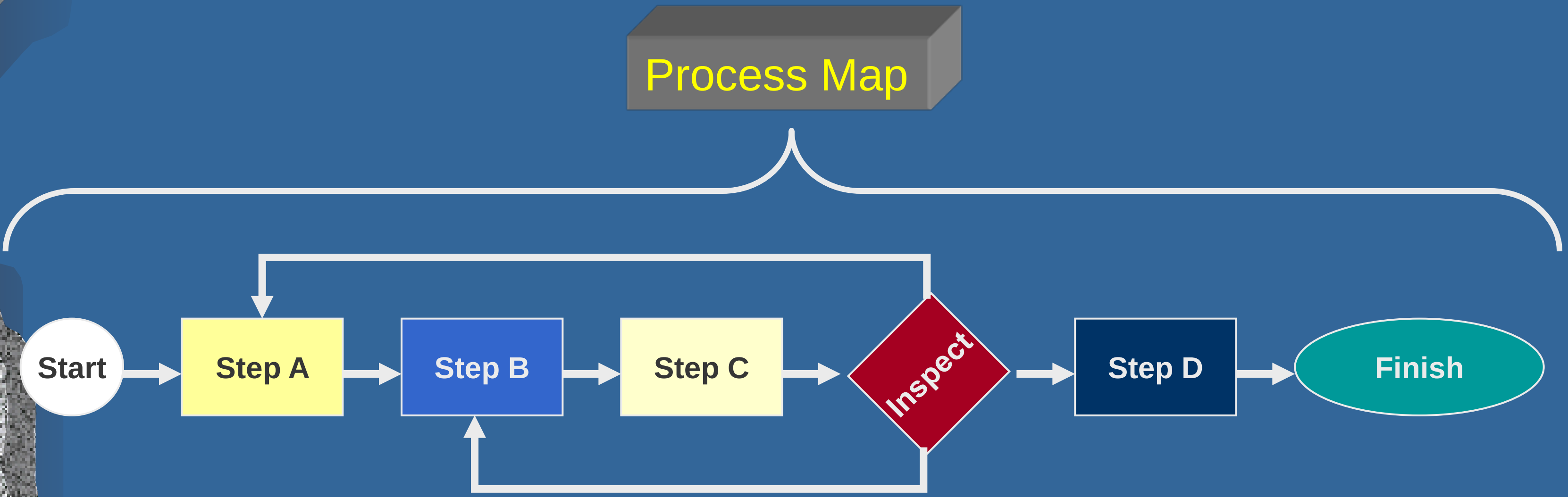


Covered Topics

- Process Map
- Statistical Process Control
- Basic Metrics
- Selection Tree for Control Charts and Visualizing the Data
- Control Charts Calculating and parameters
- Understanding Variation
- Case study – first phase
- Reducing Variation
- Case study – Second phase

Process Maps

- The purpose of process maps is to:
  - Identify the complexity of the process
  - Communicate the focus of problem solving
- Process maps are ***living*** documents and must be changed as the process is changed
  - They represent what is currently happening, not what you think is happening.
  - They should be created by the people who are closest to the process



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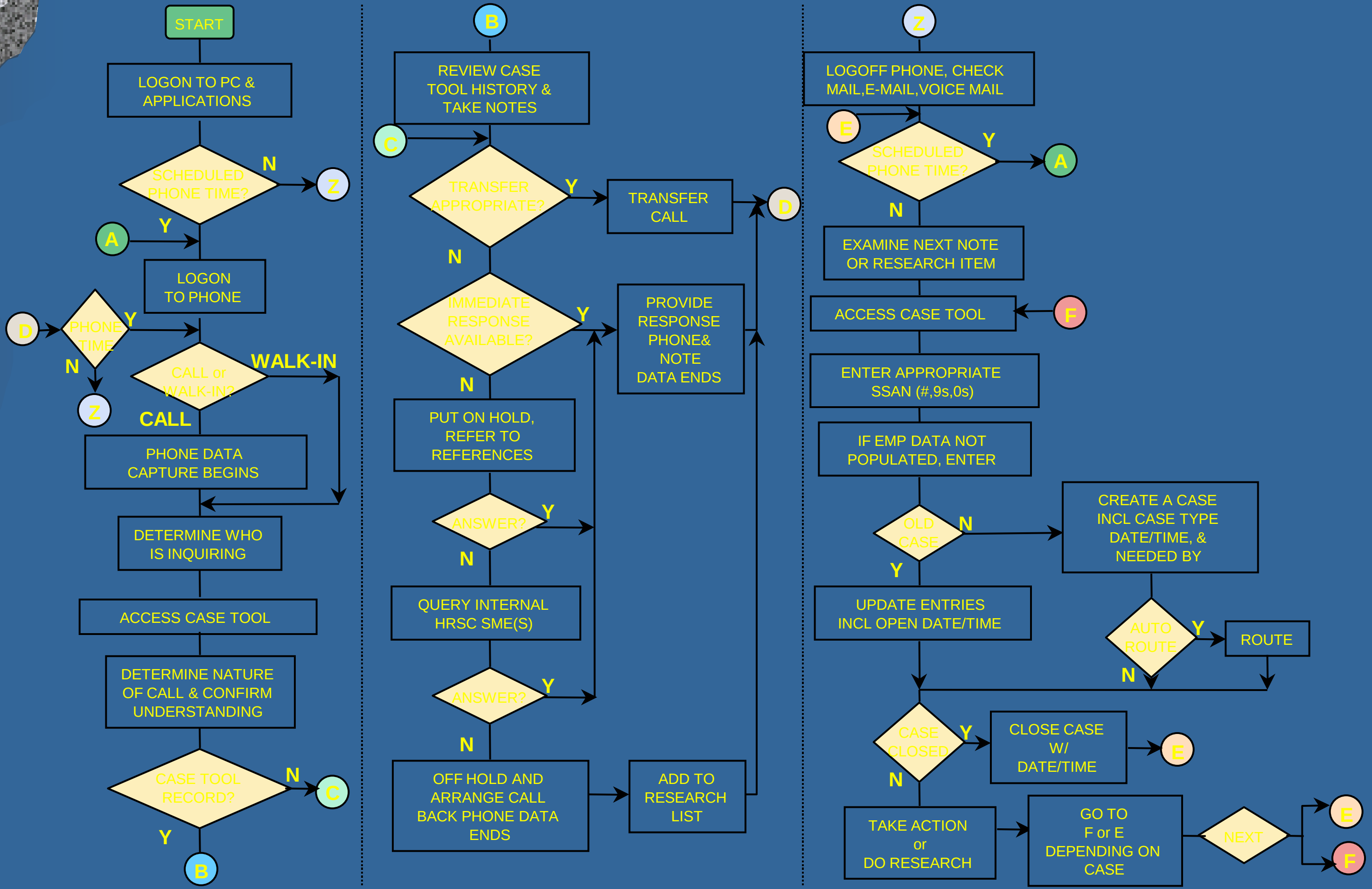
Support Center.
Process Map Example



START

LOGON TO PC & APPLICATIONS

SCHEDULED PHONE TIME?

N

Z

A

Y

LOGON TO PHONE

D

PHONE TIME

Y

N

Z

CALL or WALK-IN?

WALK-IN

CALL

PHONE DATA CAPTURE BEGINS

DETERMINE WHO IS INQUIRING

ACCESS CASE TOOL

DETERMINE NATURE OF CALL & CONFIRM UNDERSTANDING

CASE TOOL RECORD?

N

C

Y

B

B

REVIEW CASE TOOL HISTORY & TAKE NOTES

C

TRANSFER APPROPRIATE?

Y

TRANSFER CALL

D

N

IMMEDIATE RESPONSE AVAILABLE?

Y

PROVIDE RESPONSE PHONE& NOTE DATA ENDS

N

PUT ON HOLD, REFER TO REFERENCES

ANSWER?

Y

N

QUERY INTERNAL HRSC SME(S)

ANSWER?

Y

N

OFF HOLD AND ARRANGE CALL BACK PHONE DATA ENDS

ADD TO RESEARCH LIST

Z

LOGOFF PHONE, CHECK MAIL,E-MAIL,VOICE MAIL

E

SCHEDULED PHONE TIME?

Y

A

N

EXAMINE NEXT NOTE OR RESEARCH ITEM

ACCESS CASE TOOL

F

ENTER APPROPRIATE SSAN (#,9s,0s)

IF EMP DATA NOT POPULATED, ENTER

OLD CASE

N

CREATE A CASE INCL CASE TYPE DATE/TIME, & NEEDED BY

Y

UPDATE ENTRIES INCL OPEN DATE/TIME

AUTO ROUTE

Y

ROUTE

N

CASE CLOSED

Y

CLOSE CASE W/ DATE/TIME

E

N

TAKE ACTION or DO RESEARCH

GO TO F or E DEPENDING ON CASE

NEXT

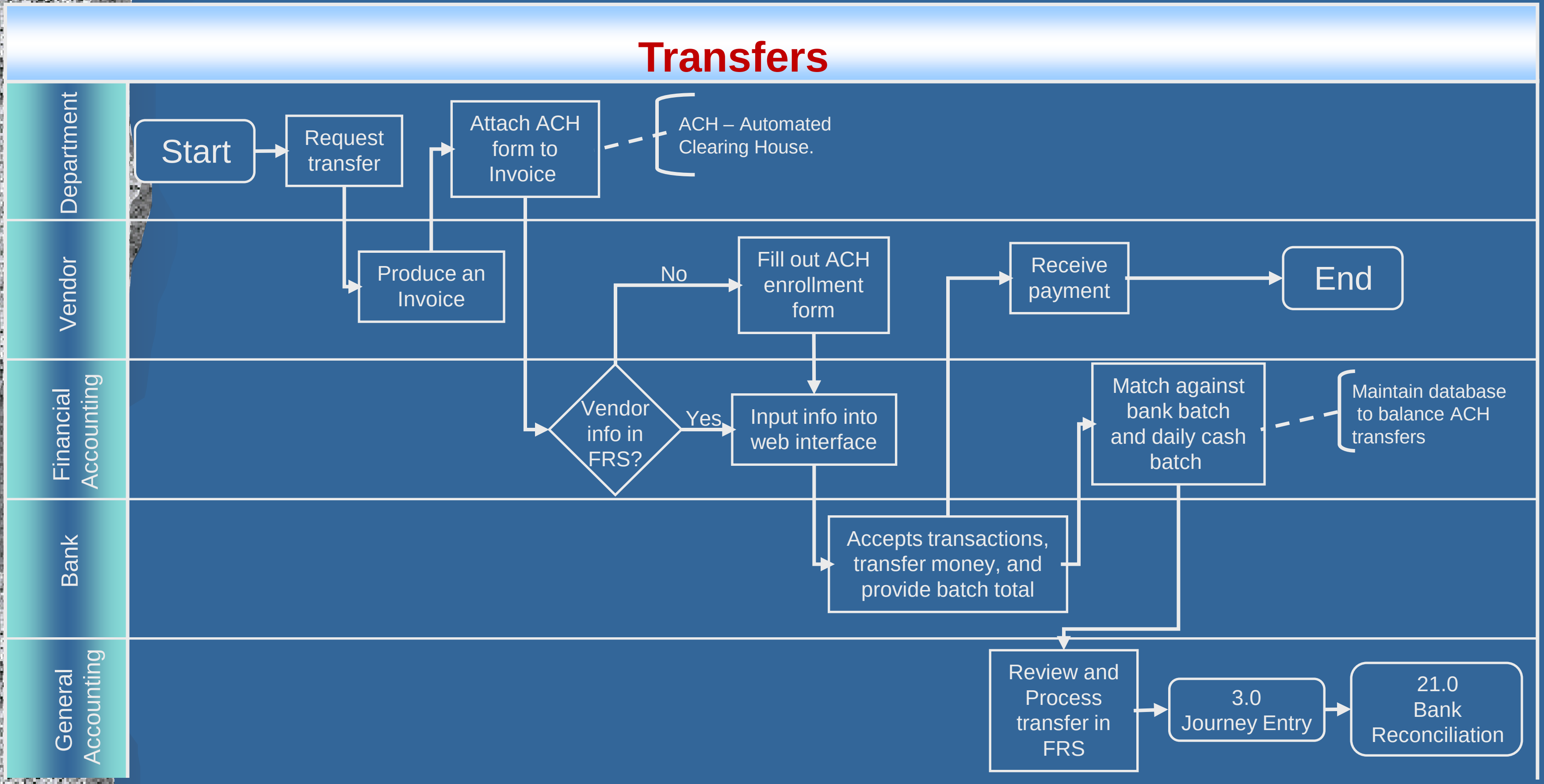
E

F

Cross Functional Process Map

When multiple departments or functional groups are involved in a complex process it is often useful to use cross functional process maps

Draw in either vertical or horizontal swim lanes and label the functional groups and draw the process map



Transfers

Department

Vendor

Financial Accounting

Bank

General Accounting

Start

Request transfer

Attach ACH form to Invoice

ACH – Automated Clearing House.

Produce an Invoice

Vendor info in FRS?

No

Fill out ACH enrollment form

Yes

Input info into web interface

Accepts transactions, transfer money, and provide batch total

Receive payment

End

Match against bank batch and daily cash batch

Maintain database to balance ACH transfers

Review and Process transfer in FRS

3.0 Journey Entry

21.0 Bank Reconciliation

STATISTICAL PROCESS CONTROL

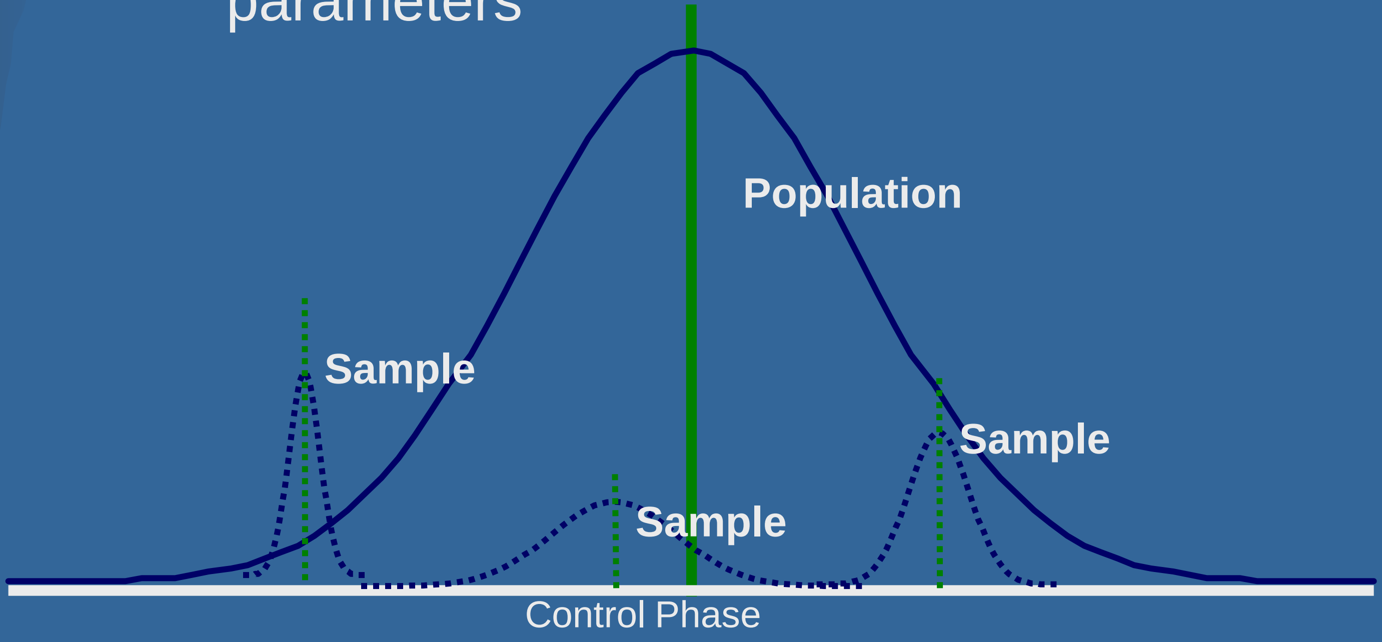
SPC Overview: Collecting Data

Population:

- An entire group of objects that have been made or will be made containing a characteristic of interest

Sample:

- A sample is a subset of the population of interest
- The group of objects actually measured in a statistical study
- Samples are used to estimate the true population parameters



Purpose of Statistical Process Control

Every process has Causes of Variation known as:

- Common Cause: Natural variability
- Special Cause: Unnatural variability
  - Assignable: Reason for detected Variability
  - Pattern Change: Presence of trend or unusual pattern

SPC is a basic tool to monitor and improve variation in a process.

SPC is used to detect special cause variation telling us the process is “out of control” but does NOT tell us why.

SPC gives a glimpse of ongoing process capability AND is a visual management tool.

Elements of Control Charts

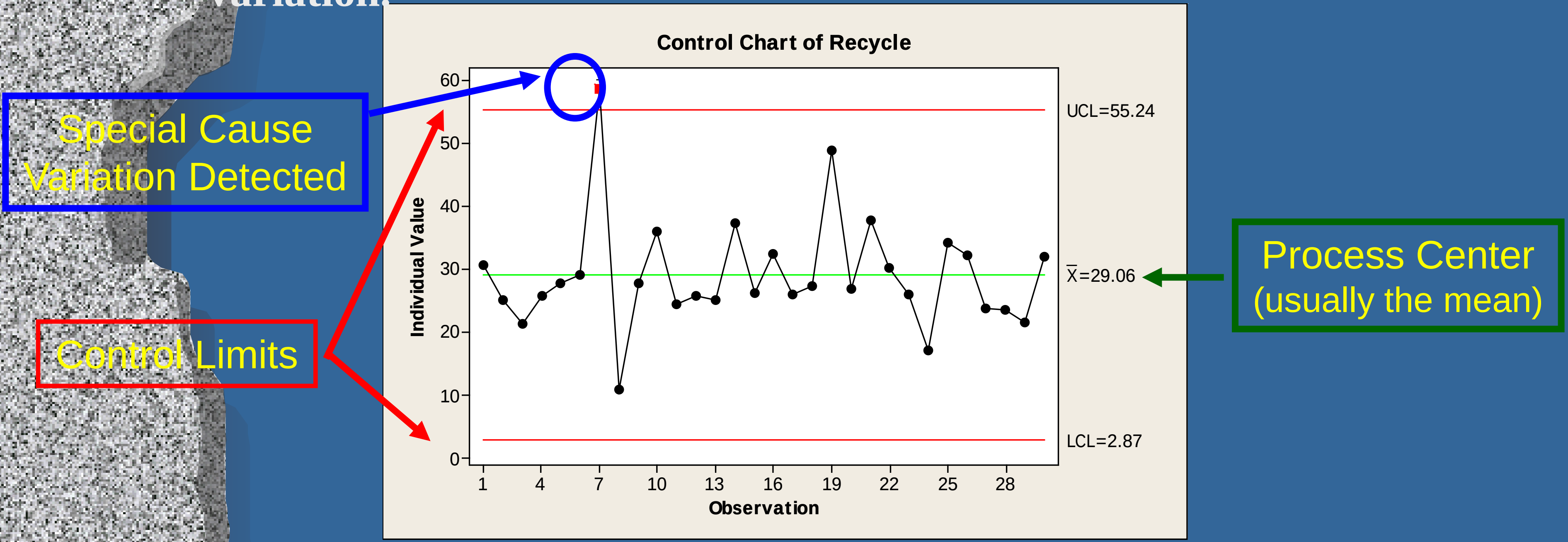
Developed by Dr Walter A. Shewhart of Bell Laboratories from 1924

Graphical and visual plot of changes in the data over time

- This is necessary for visual management of your process.

Control charts were designed as a methodology for indicating change in performance, either variation or mean/median.

Charts have a central line and control limits to detect special cause variation.



Special Cause Variation Detected

Control Limits

Process Center (usually the mean)

Understanding the Power of SPC

Control charts indicate when a process is “out of control” or exhibiting special cause variation but NOT why!

SPC charts incorporate upper and lower control limits.

- The limits are typically +/- 3 σ from the centerline.
- These limits represent 99.73% of natural variability for normal distributions.

Control limits describe the process variability and are unrelated to customer specifications. (Voice of the Process instead of Voice of the Customer)

- An undesirable situation is having control limits wider than customer specification limits. This will exist for poorly performing processes with a Cp less than 1.0

Many SPC charts exist and selection must be appropriate for effectiveness.

General Steps for Constructing Control Charts

- Select characteristic (critical “X” or CTQ) to be charted.
- Determine the purpose of the chart.
- Select data-collection points.
- Establish the basis for sub-grouping (only for Y’s).
- Select the type of control chart.
- Determine the measurement method/criteria.
- Establish the sampling interval/frequency.
- Determine the sample size.
- Establish the basis of calculating the control limits.
- Set up the forms or software for charting data.
- Set up the forms or software for collecting data.
- Prepare written instructions for all phases.
- Conduct the necessary training.

Focus of Six Sigma and the Use of SPC

$$Y=F(x)$$

To get results, should we focus our behavior on the Y or X?

Y	X_1 . . . X_N
Dependent	Independent
Output	Input
Effect	Cause
Symptom	Problem
Monitor	Control

If we find the “vital few” X’s, first consider using SPC on the X’s to achieve a desired Y?

BASIC METRICS

In any process improvement endeavor, The ultimate objective is to make the process:

- **Better:** *DPU, DPMO, RTY*
  (there are others, but they derive from these basic three)
- **Faster:** *Cycle Time*
- **Cheaper:** *COPQ*

If you make the process better by *eliminating* defects you will make it faster
If you choose to make the process faster, you will have to eliminate defects to be as fast as you can be
If you make the process better or faster, you will necessarily make it cheaper

Cycle Time Defined

Think of Cycle Time in terms of your product or transaction in the eyes of the customer of the process:

- It is the time required for the product or transaction to go through the entire process, from beginning to end
- It is not simply the "touch time" of the value-added portion of the process

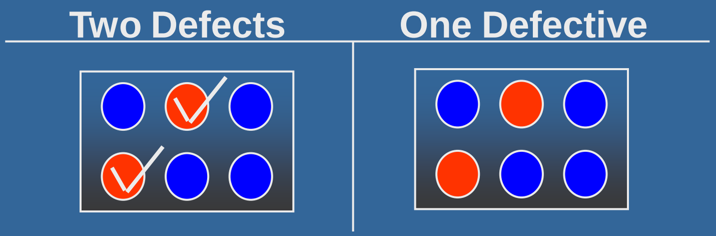
What is the cycle time of the process you mapped?

Is there any variation in the cycle time? Why?

Defects Per Unit (DPU)

Six Sigma methods quantify individual defects and not just defectives

- Defects account for all errors on a unit
  - A unit may have multiple defects
  - An incorrect invoice may have the wrong amount due *and* the wrong due date
- Defectives simply classifies the unit bad
  - Doesn't matter how many defects there are
  - The invoice is wrong, causes are unknown
- A unit:
  - Is the measure of volume of output from your area.
  - Is observable and countable. It has a discrete start and stop point.
  - It is an individual measurement and not an average of measurements.



$$\text{DPU} = \frac{\#\text{ of defects}}{\#\text{ of units}}$$

or average defects

First Time Yield

FTY is the traditional quality metric for yield

- Unfortunately, it does not account for any necessary rework

$$\text{FTY} = \frac{\text{Total Units Passed}}{\text{Total Units Tested}}$$

Units in = 50
Units Out = 50

Process A (Grips)

Defects Repaired 4

Units in = 50
Units Out = 50

Process B (Shafts)

Defects Repaired 3

Units in = 50
Units Out = 50

Process C (Club Heads)

Defects Repaired 2

=

Units Passed = 50
Units Tested = 50

Final Product (Set of Irons)

FTY = 100 %

Rolled Throughput Yield

RTY is a more appropriate metric for problem solving

$$RTY = X_1 * X_2 * X_3$$

- It accounts for losses due to rework steps

Units in = 100
Units Out = 100
RTY = 0.6

Process A (Grips)

Defects Repaired
4

Units in = 100
Units Out = 100
RTY = 0.7

Process B (Shafts)

Defects Repaired
3

Units in = 100
Units Out = 100
RTY = 0.8

Process C (Club Heads)

Defects Repaired
2

=

Units Passed = 100
Units Tested = 100

Final Product (Set of Irons)

RTY = 33.6 %

RTY Estimate

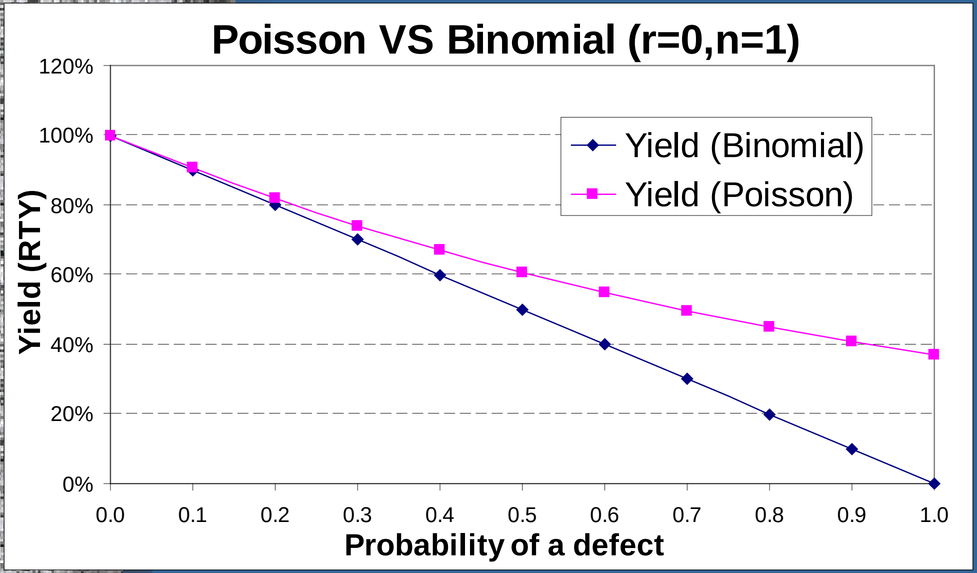
- In many organizations the long term data required to calculate RTY is not available, we can however estimate RTY using a known DPU as long as certain conditions are met.
- The Poisson distribution generally holds true for the random distribution of defects in a unit of product and is the basis for the estimation.
    - The best estimate of the proportion of units containing no defects, or RTY is:

*The mathematical constant **e** is the base of the natural logarithm.*
e ≈ 2.71828 18284 59045 23536 02874 7135

$$RTY = e^{-dpu}$$

Deriving RTY from DPU

The Binomial distribution is the true model for defect data, but the Poisson is the convenient model for defect data. The Poisson does a good job of predicting when the defect rates are low.



Probability of a defect	*Yield (Binomial)*	*Yield (Poisson)*	*% Over Estimated*
0.0	100%	100%	0%
0.1	90%	90%	0%
0.2	80%	82%	2%
0.3	70%	74%	4%
0.4	60%	67%	7%
0.5	50%	61%	11%
0.6	40%	55%	15%
0.7	30%	50%	20%
0.8	20%	45%	25%
0.9	10%	41%	31%
1.0	0%	37%	37%

Binomial

$$Y = \frac{n!}{r!(n-r)!} p^r q^{n-r}$$

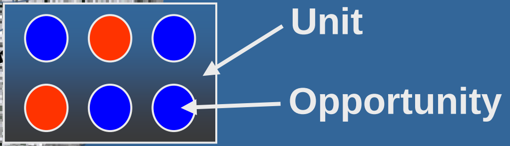
n = number of units
r = number of predicted defects
p = probability of a defect occurrence
q = 1 - p

Poisson

$$Y = \frac{(np)^r e^{-np}}{r!}$$

For low defect rates (p < 0.1), the Poisson approximates the Binomial fairly well.

Deriving RTY from DPU - Modeling



- For the unit shown above the following data was gathered:
  - 60 defects observed
  - 60 units processed
- What is the DPU?

$$DPU = \frac{\text{\# of defects}}{\text{\# of units}} = \frac{60}{60} = 1.0$$

- What is probability that any given opportunity will be a defect?

$$P(\text{defect}) = \frac{1}{10} = 0.1$$

- What is the probability that any given opportunity will NOT be a defect is:

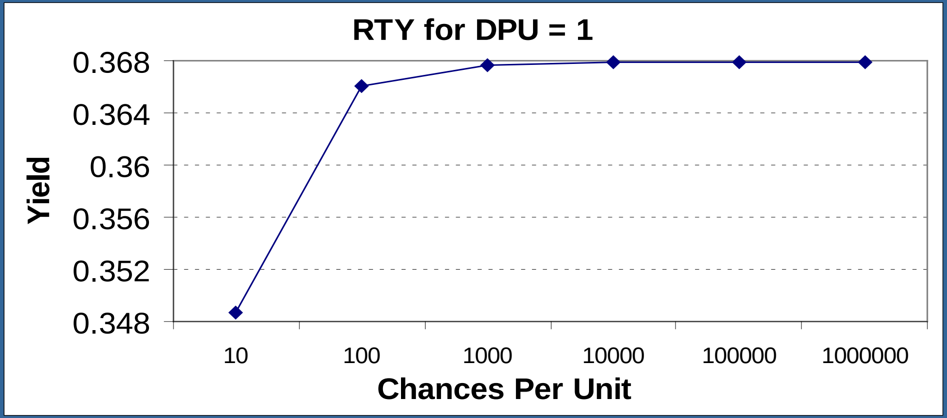
$$P(\text{no defect}) = \frac{9}{10} = 0.9$$

- The probability that all 10 opportunities on single unit will be defect-free is:

$$P(0) = 0.9^{10} = 0.3486$$

Basic Question: *What is the likelihood of producing a unit with zero defects?*

$$DPU = \frac{\text{\# of defects}}{\text{\# of units}} = \frac{60}{60} = 1.0$$



Opportunities	P(defect)	P(no defect)	RTY (Prob defect free unit)
10	0.1	0.9	0.34867844
100	0.01	0.99	0.366032341
1000	0.001	0.999	0.367695425
10000	0.0001	0.9999	0.367861046
100000	0.00001	0.99999	0.367877602
1000000	0.000001	0.999999	0.367879257

If we extend the concept to an infinite number of opportunities, all at a DPU of 1.0, we will approach the value of 0.368.

RTY Prediction — Poisson Model

- Use the binomial to estimate the probability of a discrete event (good/bad) when sampling from a relatively large population, $n > 16$, & $p < 0.1$.
- When r=0, we compute the probability of finding zero defects per unit (called “rolled throughput yield”).
- The table to the right shows the proportion of product which will have
  - 0 defects (r=0)
  - 1 defect (r=1)
  - 2 defects (r=2), etc…

When DPU=1

$$Y = \frac{(dpu)^{r} e^{-dpu}}{r!}$$

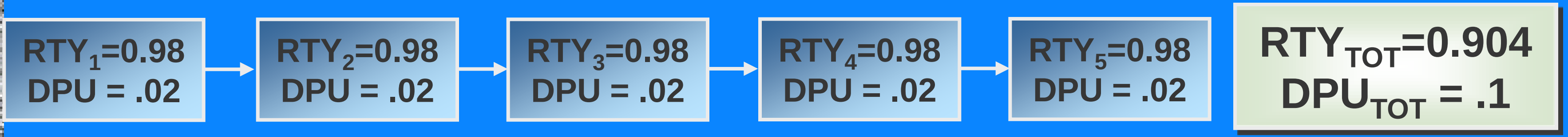
r	p[r]
0	0.3679
1	0.3679
2	0.1839
3	0.0613
4	0.0153
5	0.0031
6	0.0005
7	0.0001
8	0.0000

- When, on average, we have a process, with 1 defect per unit, then we say there is a 36.79% chance of finding a unit with zero defects. There is only a 1.53% chance of finding a unit with 4 defects.
- When r=1, this equation simplifies to:
- To predict the % of units with zero defect (i.e., RTY):
  - count the number of defects found
  - count the number of units produced
  - compute the dpu and enter it in the dpu equation:

Six Sigma Metrics – Calculating DPU

The DPU for a given operation can be calculated by dividing the number of defects found in the operation by the number of units entering the operational step.

100 parts built
2 defects identified and corrected
dpu = 0.02
So RTY for this step would be e-.02 (.980199) or 98.02%.



RTY_1=0.98
DPU = .02

RTY_2=0.98
DPU = .02

RTY_3=0.98
DPU = .02

RTY_4=0.98
DPU = .02

RTY_5=0.98
DPU = .02

RTY_{TOT}=0.904
DPU_{TOT} = .1

If the process had only 5 process steps with the same yield the process RTY would be: 0.98 * 0.98 * 0.98 * 0.98 * 0.98 = 0.903921 or 90.39%. Since our metric of primary concern is the COPQ of this process, we can say that in less than 9% of the time we will be spending dollars in excess of the pre-determined standard or value added amount to which this process is entitled.

Note: RTY's must be multiplied across a process, dpu's are added across a process.

Focusing our Effort – FTY vs. RTY

Assume we are creating two products in our organization that use similar processes.

Product A

FTY = 80%

Product B

FTY = 80%

How do you know what to work on?

Focusing our Effort – FTY vs. RTY

Let’s look at the DPU of each product assuming equal opportunities and margin…

Product B

DPU 100 / 100 = 1 DPU

Product A

DPU 200 / 100 = 2 DPU

Now, can you tell which to work on?

“the product with the highest DPU?” …think again!

How much more time and/or raw material are required?
How much extra floor space do we need?
How much extra staff or hours required to perform the rework?
How many extra shipments are we paying for from our suppliers?
How much testing have we built in to capture our defects?

Selection and Design of Control Charts

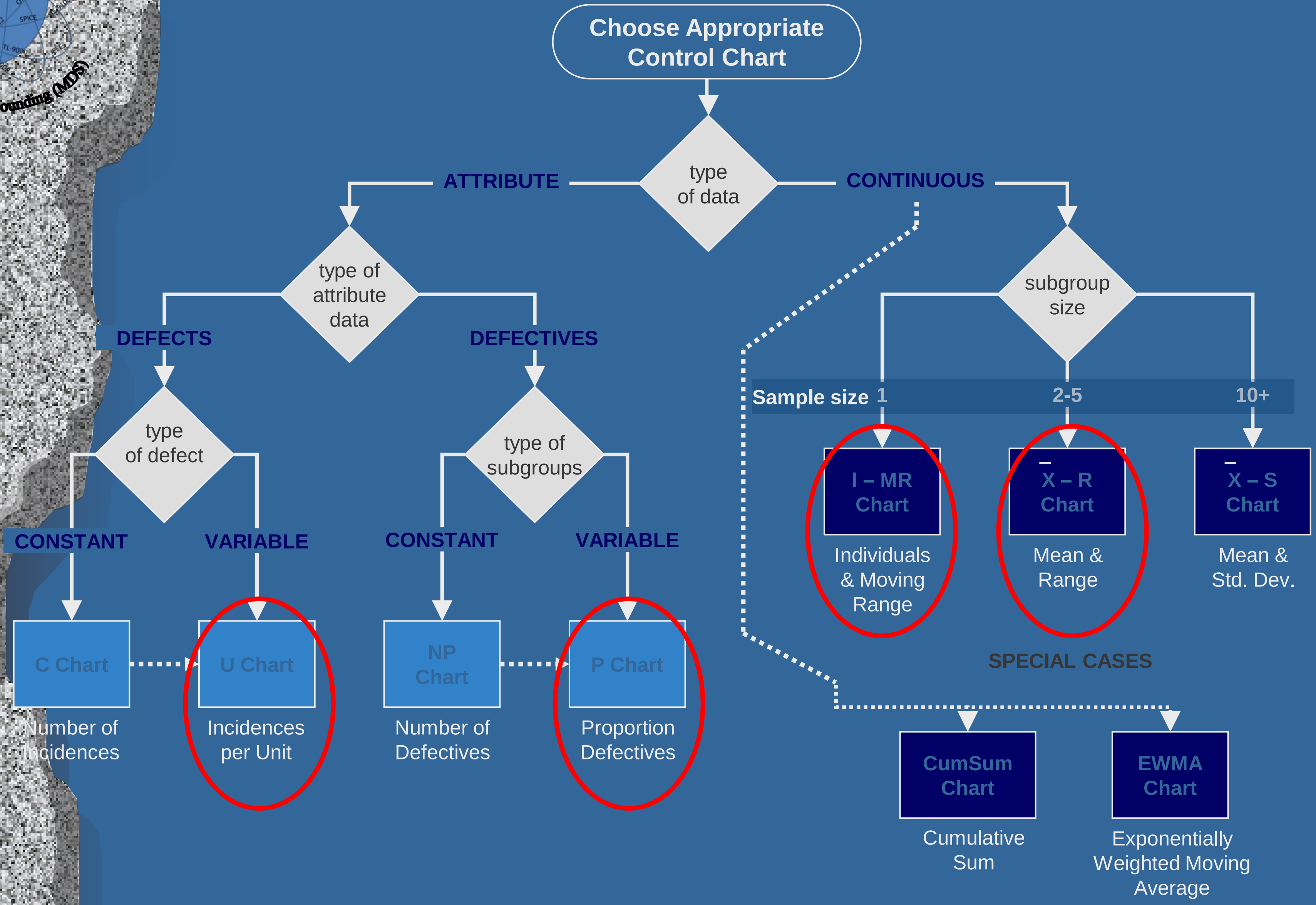
Visualizing the Data

Two Types of Data

- **Attribute Data**: noting the presence or absence of some characteristic or attribute in each of the units in the group under consideration:
  - Either **classifying** how many units do (or do not) possess the quality attribute,
  - or **counting** how many such events occur in the unit, group, or area.

- **Continuous Data** (sometimes called variables data): measuring and recording the numerical magnitude of a quality characteristic for each of the units in the group under consideration.

SPC Selection Process



Choose Appropriate Control Chart

type of data

ATTRIBUTE

type of attribute data

DEFECTS

type of defect

CONSTANT

C Chart

Number of Incidences

VARIABLE

U Chart

Incidences per Unit

DEFECTIVES

type of subgroups

CONSTANT

NP Chart

Number of Defectives

VARIABLE

P Chart

Proportion Defectives

CONTINUOUS

subgroup size

Sample size 1 | 2-5 | 10+

I – MR Chart

Individuals & Moving Range

$\bar{X}$ – R Chart

Mean & Range

$\bar{X}$ – S Chart

Mean & Std. Dev.

SPECIAL CASES

CumSum Chart

Cumulative Sum

EWMA Chart

Exponentially Weighted Moving Average

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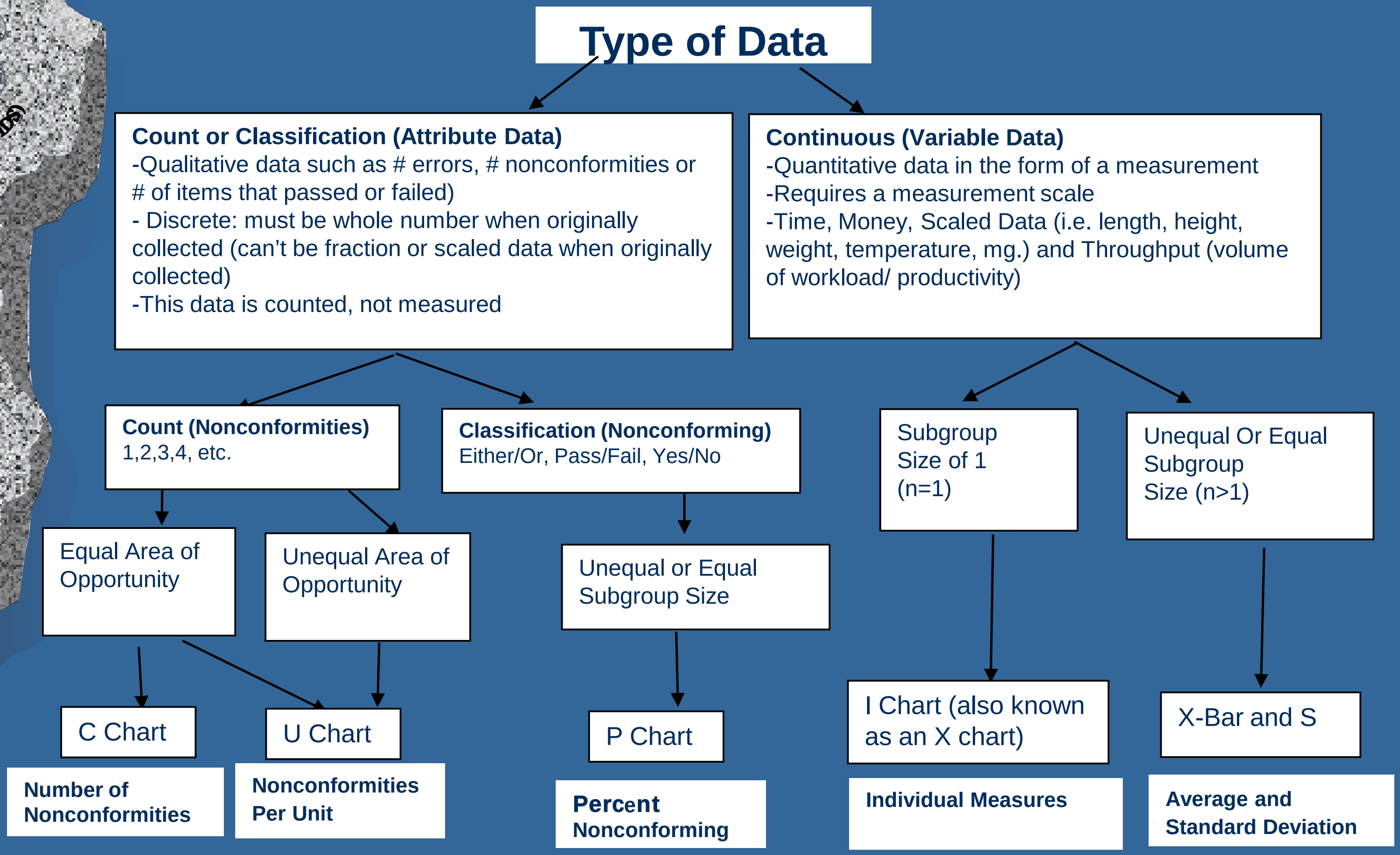
Chart Selection



Type of Data

Count or Classification (Attribute Data)
-Qualitative data such as # errors, # nonconformities or # of items that passed or failed)
- Discrete: must be whole number when originally collected (can’t be fraction or scaled data when originally collected)
-This data is counted, not measured

Continuous (Variable Data)
-Quantitative data in the form of a measurement
-Requires a measurement scale
-Time, Money, Scaled Data (i.e. length, height, weight, temperature, mg.) and Throughput (volume of workload/ productivity)

Count (Nonconformities)
1,2,3,4, etc.

Equal Area of Opportunity

Unequal Area of Opportunity

C Chart

Number of Nonconformities

U Chart

Nonconformities Per Unit

Classification (Nonconforming)
Either/Or, Pass/Fail, Yes/No

Unequal or Equal Subgroup Size

P Chart

Percent Nonconforming

Subgroup Size of 1 (n=1)

I Chart (also known as an X chart)

Individual Measures

Unequal Or Equal Subgroup Size (n>1)

X-Bar and S

Average and Standard Deviation

Other types of control charts for count/classification data:
1. NP (for classification data)
2. T-chart [time (or event, items, etc.) between rare events]
3. Cumulative sum (CUSUM)
4. Exponentially weighted moving average (EWMA)
5. Geometric distribution chart (G chart for count data)
6. Standardized control chart

Other types of control charts for continuous data:
7. X-bar and Range
8. Moving average
9. Median and range
10. Cumulative sum (CUSUM)
11. Exponentially weighted moving average (EWMA)
12. Standardized control chart

The choice of a control chart depends on the question you are trying to answer and the type of data collected

Type of Chart	**Process: Medication Production Analysis**
X bar & R Chart	What is the Turn around time (TAT) for a daily sample of 4 product assembly orders?
X bar & S Chart	What is the TAT for a all the engineering work orders filled each day?
Individuals Chart (X or I)	How many engineering work orders do we process each week?
C-Chart	Using a sample of 100 engineering work orders each week, how many errors (defects) are observed?
U-Chart	Out of all engineering work orders each week, how many errors (defects) are observed?
P-Chart	For all engineering work orders each week, what percentage are not filled correctly (1 or more mistakes)?

Understanding Variable Control Chart Selection

Type of Chart	*When do you need it?*
Average & Range or S (Xbar and R or Xbar and S) Most common	Production is higher volume; allows process mean and variability to be viewed and assessed together; more sampling than with Individuals chart (I) and Moving Range charts (MR) but when subgroups are desired. Outliers can cause issues with Range (R) charts so Standard Deviation charts (S) used instead if concerned.
Individual and Moving Range	Production is low volume or cycle time to build product is long or homogeneous sample represents entire product (batch etc.); sampling and testing is costly so subgroups are not desired. Control limits are wider than Xbar charts. Used for SPC on most inputs.
Pre-Control	Set-up is critical, or cost of setup scrap is high. Use for outputs
Exponentially Weighted Moving Average	Small shift needs to be detected, often because of autocorrelation of the output results. Used only for individuals or averages of Outputs. Infrequently used because of calculation complexity.
Cumulative Sum Less Common	Same reasons as EWMA (Exponentially Weighted Moving Range) except the past data is as important as present data.

Understanding Attribute Control Chart Selection

Type of Chart	*When do you need it?*
P	**Need to track the fraction of defective units; sample size is variable and usually > 50**
nP	**When you want to track the number of defective units per subgroup; sample size is usually constant and usually > 50**
C	**When you want to track the number of defects per subgroup of units produced; sample size is constant**
U	**When you want to track the number of defects per unit; sample size is variable**

Detection of Assignable Causes or Patterns

Control charts indicate special causes being either assignable causes or patterns.

The following rules are applicable for both variable and attribute data to detect special causes.

These four rules are the only applicable tests for Range (R), Moving Range (MR), or Standard Deviation (S) charts.

- 1point more than 3 standard deviations from the center line.
- 6 points in a row all either increasing or all decreasing.
- 14 points in a row alternating up and down.
- 9 points in a row on the same side of the center line.

Detection of Assignable Causes or Patterns

These remaining four rules are only for variable data to detect special causes.

- 2 out of 3 points greater than 2 standard deviations from the center line on the same side.
- 4 out of 5 points greater than 1 standard deviation from the center line on the same side.
- 15 points in a row all within 1standard deviation of either side of the center line.
- 8 points in a row all greater than 1standard deviation of either side of the center line.

Recommended Special Cause Detection Rules

- If implementing SPC manually without software initially, the most visually obvious violations are more easily detected. SPC on manually filled charts are common place for initial use of defect prevention techniques.

- These 3 rules are **visually** the most easily detected by personnel.
  - 1point more than 3 standard deviations from the center line.
  - 6 points in a row all either increasing or all decreasing.
  - 15 points in a row all within 1standard deviation of either side of the center line.

Recommended Special Cause Detection Rules

- Dr. Shewhart that worked with the Western Electric Co. was credited with the following 4 rules referred to as Western Electric Rules.
  - 1point more than 3 standard deviations from the center line.
  - **8** points in a row on the same side of the center line.
  - 2 out of 3 points greater than 2 standard deviations from the center line on the same side.
  - 4 out of 5 points greater than 1 standard deviation from the center line on the same side.
- You might notice the Western Electric rules vary slightly. The importance is to be consistent in your organization and decide what rules you will use to detect special causes.
- VERY few organizations use all 8 rules for detecting special causes.

SPC Center Line and Control Limit Calculations

Calculate the parameters of the Individual and MR control charts with the following:

Centerline

$$\bar{X} = \frac{\sum_{i=1}^{k} x_i}{k} \qquad \overline{MR} = \frac{\sum_{i}^{k} R_i}{k}$$

Control Limits

$$UCL_x = \bar{X} + E_2\overline{MR} \qquad UCL_{MR} = D_4\overline{MR}$$

$$LCL_x = \bar{X} - E_2\overline{MR} \qquad LCL_{MR} = D_3\overline{MR}$$

Where:

Xbar: Average of the individuals, becomes the centerline on the Individuals chart

Xi: Individual data points

k: Number of individual data points

R_i : Moving range between individuals, generally calculated using the difference between each successive pair of readings

MRbar: The average moving range, the centerline on the range chart

UCL_X: Upper control limit on individuals chart

LCL_X: Lower control limit on individuals chart

UCL_{MR}: Upper control limit on moving range

LCL_{MR} : Lower control limit on moving range (does not apply for sample sizes below 7)

E_2, D_3, D_4: Constants that vary according to the sample size used in obtaining the moving range

$$\hat{\sigma}\ \text{(st. dev. Estimate)} \frac{\text{MRbar}}{\text{d2}} =$$

(computed above)

(table of constants for subgroup

SPC Center Line and Control Limit Calculations

Calculate the parameters of the Xbar and R control c harts with the following:

Centerline

$$\bar{\bar{X}} = \frac{\sum_{i=1}^{k} \bar{x}_i}{k} \qquad \bar{R} = \frac{\sum_{i}^{k} R_i}{k}$$

Control Limits

$$UCL_{\bar{x}} = \bar{\bar{X}} + A_2\bar{R} \qquad UCL_R = D_4\bar{R}$$

$$LCL_{\bar{x}} = \bar{\bar{X}} - A_2\bar{R} \qquad LCL_R = D_3\bar{R}$$

Where:

$\bar{\bar{X}}_i$: Average of the subgroup averages, it becomes the centerline of the control cha

$\bar{X}_i$: Average of each subgroup

k: Number of subgroups

R_i : Range of each subgroup (Maximum observation – Minimum observation)

Rbar: The average range of the subgroups, the centerline on the range chart

UCL_X: Upper control limit on average chart

LCL_X: Lower control limit on average chart

UCL_R: Upper control limit on range chart

LCL_R : Lower control limit range chart

A_2, D_3, D_4: Constants that vary according to the subgroup sample size

$\hat{\sigma}$ (st. dev. Estimate) $\frac{\text{Rbar}}{\text{d2}} =$ (computed above) / (table of constants for subgrou

SPC Center Line and Control Limit Calculations

Calculate the parameters of the Xbar and S control charts with the following:

Centerline

$$\overline{\overline{X}} = \frac{\sum_{i=1}^{k} \overline{x}_i}{k} \qquad \overline{S} = \frac{\sum_{i=1}^{k} s_i}{k}$$

Control Limits

$$UCL_{\overline{x}} = \overline{\overline{X}} + A_3\overline{S} \qquad UCL_S = B_4\overline{S}$$

$$LCL_{\overline{x}} = \overline{\overline{X}} - A_3\overline{S} \qquad LCL_S = B_3\overline{S}$$

Where:

$\overline{\overline{X}}_i$: Average of the subgroup averages, it becomes the centerline of the control chart

$\overline{X}_i$: Average of each subgroup

k: Number of subgroups

s_i : Standard deviation of each subgroup

Sbar: The average s.d. of the subgroups, the centerline on the S chart

UCL_X: Upper control limit on average chart

LCL_X: Lower control limit on average chart

UCL_S: Upper control limit on S chart

LCL_S : Lower control limit S chart

A_3, B_3, B_4: Constants that vary according to the subgroup sample size

$\hat{\sigma}$ (st. dev. Estimate) $= \frac{\text{Sbar}}{\text{c4}}$ (computed above) (table of constants for subgrou

SPC Center Line and Control Limit Calculations

Calculate the parameters of the P control charts with the following:

Centerline

$$\bar{p} = \frac{\text{Total number of defective items}}{\text{Total number of items inspected}}$$

Control Limits

$$\mathrm{UCL}_p = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n_i}}$$

$$\mathrm{LCL}_p = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n_i}}$$

Where:

$\bar{p}$: Average proportion defective (0.0 – 1.0)

n_i: Number inspected in each subgroup

LCL_p: Lower control limit on p chart

UCL_p: Upper control limit on p chart

Since the Control Limits are a function of sample size, they will vary for each sample

SPC Center Line and Control Limit Calculations

Calculate the parameters of the **nP** control charts with the following:

Centerline

$$\overline{np} = \frac{\text{Total number of defective items}}{\text{Total number of subgroups}}$$

Control Limits

$$UCL_{np} = \overline{n}_i\overline{p} + 3\sqrt{n_i p(1-p)}$$

$$LCL_{np} = \overline{n}_i\overline{p} - 3\sqrt{n_i p(1-p)}$$

Where:

np: Average number defective items per subgroup

ni: Number inspected in each subgroup

LCL_{np}: Lower control limit on nP chart

UCL_{np}: Upper control limit on nP chart

Since the control limits AND center line are a function of sample size, they will vary for each sample

SPC Center Line and Control Limit Calculations

Calculate the parameters of the U control charts with the following:

Centerline

$$\bar{u} = \frac{\text{Total number of defects Identified}}{\text{Total number of Units Inspected}}$$

Control Limits

$$\mathrm{UCL}_u = \bar{u} + 3\sqrt{\frac{\bar{u}}{n_i}}$$

$$\mathrm{LCL}_u = \bar{u} - 3\sqrt{\frac{\bar{u}}{n_i}}$$

Where:

$\bar{u}$:	Total number of defects divided by the total number of units inspected.
n_i:	Number inspected in each subgroup
LCL_u:	Lower control limit on u chart.
UCL_u:	Upper control limit on u chart.

Since the control limits are a function of sample size, they will vary for each sample

SPC Center Line and Control Limit Calculations

Calculate the parameters of the C control charts with the following:

Centerline

$$\bar{c} = \frac{\text{Total number of defects}}{\text{Total number of subgroups}}$$

Control Limits

$$UCL_c = \bar{c} + 3\sqrt{\bar{c}}$$

$$LCL_c = \bar{c} - 3\sqrt{\bar{c}}$$

Where:

c: Total number of defects divided by the total number of subgroups.
LCL_c: Lower control limit on c chart.
UCL_c: Upper control limit on c chart.

SPC Center Line and Control Limit Calculations

Calculate the parameters of the

Exponentially Weighted Moving Average (**EWMA**)

control charts with the following:

Centerline

$$Z_t = \lambda X_t + (1-\lambda) Z_{t-1}$$

Control Limits

$$UCL = \overline{X} + 3\frac{\sigma}{\sqrt{n}}\sqrt{(\frac{\lambda}{2-\lambda})[1-(1-\lambda)^{2t}]}$$

$$LCL = \overline{X} - 3\frac{\sigma}{\sqrt{n}}\sqrt{(\frac{\lambda}{2-\lambda})[1-(1-\lambda)^{2t}]}$$

Where:

Z_t: EWMA statistic plotted on control chart at time t

Z_{t-1}: EWMA statistic plotted on control chart at time t-1

λ: The weighting factor between 0 and 1 – suggest using 0.2

σ: Standard deviation of historical data (pooled standard deviation for subgroups – MRbar/d2 for individual observations)

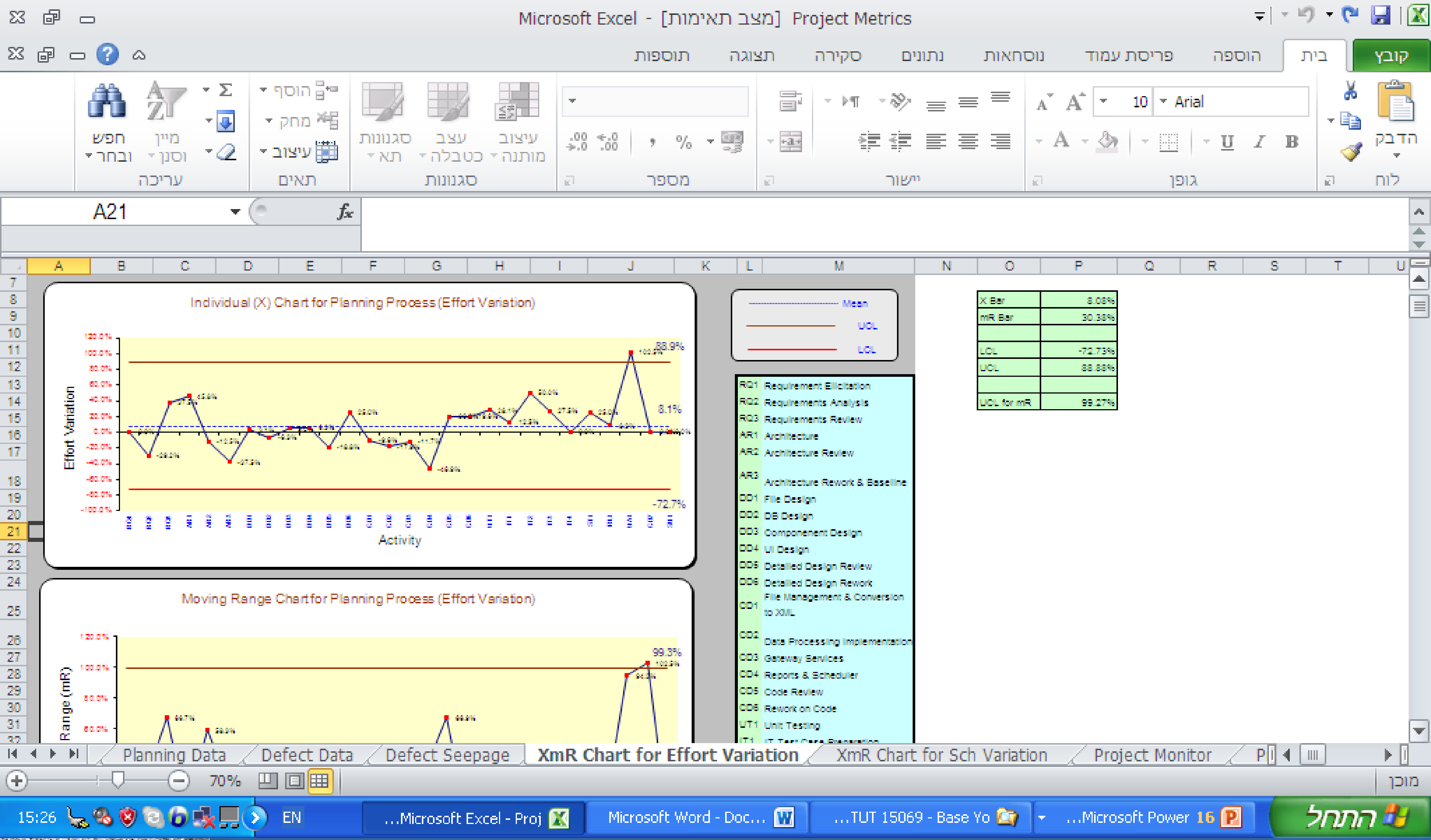
X_t: Individual data point or sample averages at time t

UCL: Upper control limit on EWMA chart

LCL: Lower control limit on EWMA chart

n: Subgroup sample size

K V P Consulting



X Bar	8.08%
mR Bar	30.38%
LCL	-72.73%
UCL	88.88%
UCL for mR	99.27%

RQ1	Requirement Elicitation
RQ2	Requirements Analysis
RQ3	Requirements Review
AR1	Architecture
AR2	Architecture Review
AR3	Architecture Rework & Baseline
DD1	File Design
DD2	DB Design
DD3	Componenent Design
DD4	UI Design
DD5	Detailed Design Review
DD6	Detailed Design Rework
CD1	File Management & Conversion to XML
CD2	Data Processing Implementation
CD3	Gateway Services
CD4	Reports & Scheduler
CD5	Code Review
CD6	Rework on Code
UT1	Unit Testing
IT1	IT Test Case Preparation

UNDERSTANDING VARIATION

Sources of Variation

- Variation exists in all processes.
- Variation can be categorized as either:
  - Common or Random causes of variation, or
    - Random causes that we cannot identify
    - Unavoidable, e.g. slight differences in process variables like diameter, weight, service time, temperature
  - Assignable causes of variation
    - Causes can be identified and eliminated: poor employee training, worn tool, machine needing repair

Process Capability

Product Specifications

- Preset product or service dimensions, tolerances: bottle fill might be 16 oz. ±.2 oz. (15.8oz.-16.2oz.)
- Based on how product is to be used or what the customer expects

Process Capability – Cp and Cpk

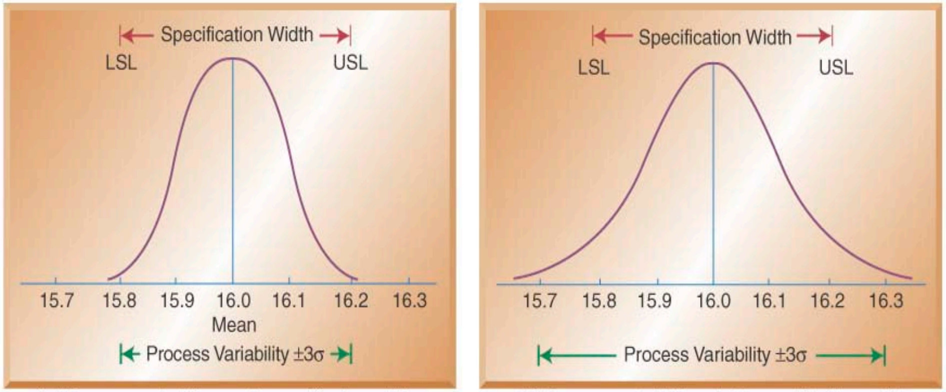
- Assessing capability involves evaluating process variability relative to preset product or service specifications
- **Cp** assumes that the process is centered in the specification range

$$\mathbf{Cp} = \frac{\textbf{specification width}}{\textbf{process width}} = \frac{\mathbf{USL - LSL}}{\mathbf{6\sigma}}$$

- **Cpk** helps to address a possible lack of centering of the process

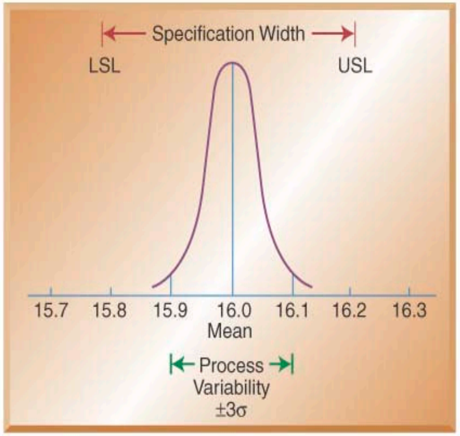
$$\mathbf{Cpk} = \mathbf{min}\left(\frac{\mathbf{USL - \mu}}{\mathbf{3\sigma}}, \frac{\mathbf{\mu - LSL}}{\mathbf{3\sigma}}\right)$$

Relationship between Process Variability and Specification Width



(a) Process variability meets specification width

(b) Process variability outside specification width



(c) Process variability within specification width

- **Three possible ranges** for **Cp**
  - **Cp = 1, as in Fig. (a), process variability just meets specifications**
  - **Cp ≤ 1, as in Fig. (b), process not capable of producing within specifications**
  - **Cp ≥ 1, as in Fig. (c), process exceeds minimal specifications**
- **One shortcoming, Cp assumes that the process is centered on the specification range**
- **Cp=Cpk when process is centered**

Measures of Variation

Measures of Variation include:

- The range
- The Variance
- The Standard Deviation
- The Mean Absolute Deviation

The standard deviation is just the square root of the variance

Measures of Variation

Standard Deviation of a Population

We will label the population variance to be σ^2

And define $\sigma^2 = \Sigma_i (x_i - \mu)^2 / N$

Where

μ is the population mean

N is the size of the population

$\Sigma_i (x_i - \mu)^2$ is the sum of the squares of the difference between each item in the population and the mean.

Measures of Variation

Suppose a student receives the following quiz grades:

{82, 68, 74, 86, 90, 88, 62, 75, 80, 55}

For this student, these grades are the total population of her scores that are used to calculate her mean or average grade. We obtain:

$$\mu = (82 + 68 + 74 + 86 + 90 + 88 + 62 + 75 + 80 + 55)/10$$

$$= 760/10 = 76$$

The mean of this population is 76

Measures of Variation

Having obtained the mean, we can now calculate the variance

{82, 68, 74, 86, 90, 88, 62, 75, 80, 55} and $\mu = 76$

$$\sigma^2 = \Sigma_i (x_i - \mu)^2/N$$

$$= \{(82-76)^2 + (68-76)^2 + (74-76)^2 + (86-76)^2 + (90-76)^2 +$$

$$(88-76)^2 + (62-76)^2 + (75-76)^2 + (80-76)^2 + (55-76)^2 \}/10$$

$$= (36 + 64 + 4 +100 + 196 + 144 + 196 + 1 + 16 + 441)/10$$

$$= 119.8$$

Measures of Variation

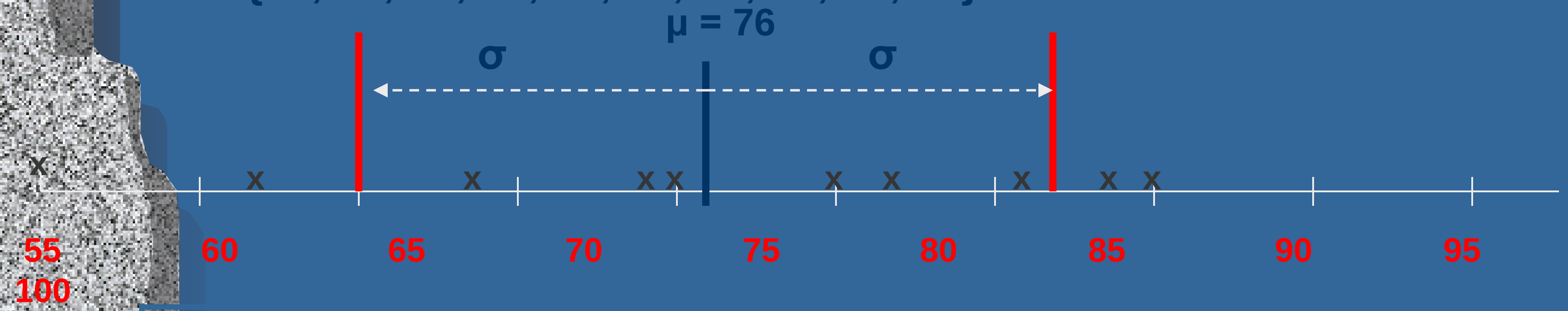
We find the standard deviation in this population data by taking the square root of the variance.

$$\sigma^2 = \Sigma_i (x_i - \mu)^2/N = 119.8$$

$$\sigma = (119.8)^{½} = 10.94$$

If we display the data on a dot plot, we can visualize the use of the standard deviation as a measure of variation in the data

{82, 68, 74, 86, 90, 88, 62, 75, 80, 55}



Mean = 76

Measures of Variation

Chebyshev’s Theorem

The proportion of <u>any</u> set of data lying within K standard deviations of the mean is always *at least* $1 - 1/K^2$, for all K greater than or equal to 2.

Chebyshev’s Inequality tells us that in any statistical distribution at least ¾ of the values will lie within 2 standard deviations of the mean, and at least 8/9 of all values will lie within 3 standard deviations of the mean.

In the previous example we found $\mu = 76$ and $\sigma = 10.94$

$\mu - 2\sigma = 76 - 2(10.94) = 54.12$

$\mu + 2\sigma = 76 + 2(10.94) = 97.88$

We find that 100% of the values lie within 2σ of the mean

CASE STUDY – FIRST PHASE

REDUCING VARIATION

Selecting improvements to implement

- High-level objective evaluation of all potential improvements
  - Impact of each improvement
  - Cost to implement each improvement
  - Time to implement each improvement
- Balance desire with quantifiable evaluation
  - Engineering always wants the gold standard
  - Sales always wants inventory
  - Production always wants more capacity

Impact of the improvement

- Time frame of improvements
  - Long-term vs. Short-term effectiveness
    - If a supplier will lose a major customer because of defects, the short term benefit will prevail first.
- Effectiveness of the improvement types
  - Removing the root cause of the defect
  - Monitoring/flagging for the condition that produces a defect
  - Inspecting to determine if the defect occurred
  - Training people not to produce defects

Cost to implement improvement

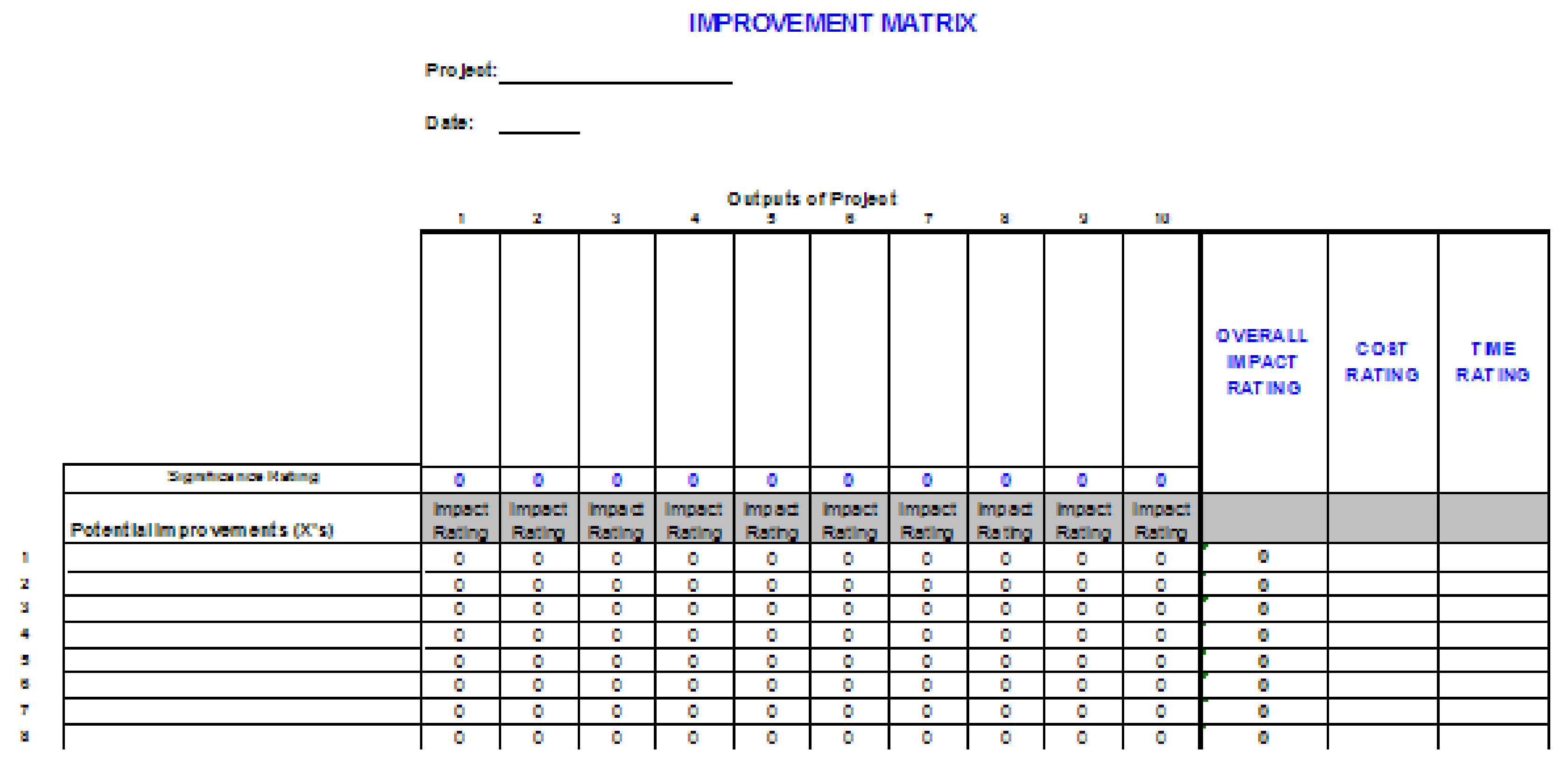
- Initial cost to implement improvement
  - Cost to train existing work force
  - Cost to purchase any new materials necessary for improvement
  - Cost of resources used to build improvement
  - Any capital investments required
- On-going costs to sustain improvement
  - Future training, inspection, monitoring, and material costs

Time to implement improvement:

- Technical time constraints
  - What is the minimum time it would take to implement?
    - Time to build/create improvement, time to implement improvement
- Political time constraints
  - What other priorities are competing for the technical time to build the improvement?
- Cultural time constraints
  - How long will it take to gain support from necessary stakeholders?

The clock’s ticking……

Improvement Selection Matrix



IMPROVEMENT MATRIX

Project: ____________________

Date: _______

Outputs of Project

		1	2	3	4	5	6	7	8	9	10	OVERALL IMPACT RATING	COST RATING	TIME RATING
	Significance Rating	0	0	0	0	0	0	0	0	0	0			
	Potential Improvements (X's)	Impact Rating	Impact Rating	Impact Rating	Impact Rating	Impact Rating	Impact Rating	Impact Rating	Impact Rating	Impact Rating	Impact Rating			
1		0	0	0	0	0	0	0	0	0	0	0		
2		0	0	0	0	0	0	0	0	0	0	0		
3		0	0	0	0	0	0	0	0	0	0	0		
4		0	0	0	0	0	0	0	0	0	0	0		
5		0	0	0	0	0	0	0	0	0	0	0		
6		0	0	0	0	0	0	0	0	0	0	0		
7		0	0	0	0	0	0	0	0	0	0	0		
8		0	0	0	0	0	0	0	0	0	0	0		

Solution Matrix.xls

Improvement Selection Matrix

Impact Ratings	
7	X's are removed from impacting the process output.
6	Continual control and adjustment of critical X's impacting the process output.
5	Continual control of critical X's prevents defects in the process output from X.
4	Defect detection of the process output prevents unknown defects from leaving the process.
3	Process inspection or testing is improved to find defects better.
2	Process is improved with easier control of a critical X impacting the process output.
1	Personnel are trained about X's impact on the process output.
0	X's have no impact on the process output.

Improvement Selection Matrix

Cost to Implement Ratings	
7	Improvement Costs are minimal with upfront and ongoing expenses.
6	Improvement Costs are low and can be expensed with no capital authorization and recurring expenses are low.
5	Improvement Costs are low and can be expensed with no capital authorization and recurring expenses are higher.
4	Medium capital priority because of relative ranking of return on investment.
3	Low capital priority because of relative ranking of return on investment.
2	High capital and ongoing expenses make a low priority for capital investment.
1	High capital and/or expenses without acceptable return on investment.
0	Significant capital and ongoing expenses without alignment with business priorities.

Improvement Selection Matrix

Time to Implement Ratings	
7	Less than a week to get in place and workable.
6	7 - 14 days to get in place and workable.
5	2 - 8 weeks to get the improvement in place and workable.
4	2 - 3 months to get the improvement in place and workable.
3	3 - 6 months to get the improvement in place and workable.
2	6 - 9 months to get the improvement in place and workable.
1	9 - 12 months to get the improvement in place and workable.
0	Over a year to get the improvement in place and workable. All above times include time for approvals process.

Example of Completed Solution Selection Matrix

		Outside noises do not interfer with speakers	Coffee is hot and rich tasting	Plenty of bottled water available	Food choices include "healthy choices"	OVERALL IMPACT RATING	COST RATING	TIME RATING	OVERALL RATING
	Significance Rating	**10**	**9**	**8**	**9**				
	Potential Improvements	Impact Rating	Impact Rating	Impact Rating	Impact Rating				
1	**Hotel staff monitors room**	2	2	6	0	**86**	**7**	**7**	**4214**
2	**Mgmt visits/leaves ph #**	2	0	4	0	**52**	**7**	**7**	**2548**
3	**Replace old coffee makers/coffee**	0	7	0	0	**63**	**3**	**6**	**1134**
4	**Menus provided with nutrition info**	0	0	0	4	**36**	**5**	**5**	**900**
5	**Comp. gen. "quiet time" scheduled**	6	0	0	0	**60**	**3**	**3**	**540**
6	**Dietician approves menus**	0	0	0	7	**63**	**5**	**2**	**630**

Improvement Selection Matrix Output

Improvements with the higher overall rating should be given first priority.

Keep in mind that long time frame capital investments, etc. should have parallel efforts to keep delays from further occurring.

Implementing Solutions in Your Organization

Implementation plans should emphasize the need to:

- Organize the tasks and resources
- Establish realistic time frames and deadlines
- Identify actions necessary to ensure success

Components of an implementation plan include:

- Work breakdown structure
- Influence strategy for priorities and resourcing
- Risk management plan
- Audit results for completion and risks.

All solutions must be part of Control Plan Document.

What is a Control Plan?

- Written summary describing systems used for
- monitoring/controlling process or product variation
- Document allowing team to formally document all control
- methods used to meet project goal
- Living document to be updated as new measurement systems and control methods are added for continuous improvement

What is a Control Plan?

- Often used to create concise operator inspection sheet
- NOT a replacement of information contained in detailed operating, maintenance, or design instructions
- ESSENTIAL portion of final project report
  - Final projects are organizationally dependent
    - Informal or formal
  - Filed as part of project tracking mechanism for organization
    - Track benefits
    - Reference for unsustained results

WHO Should Create a Control Plan

The team working on the project!!!!

ANYONE who has a role in defining, executing or changing the process:

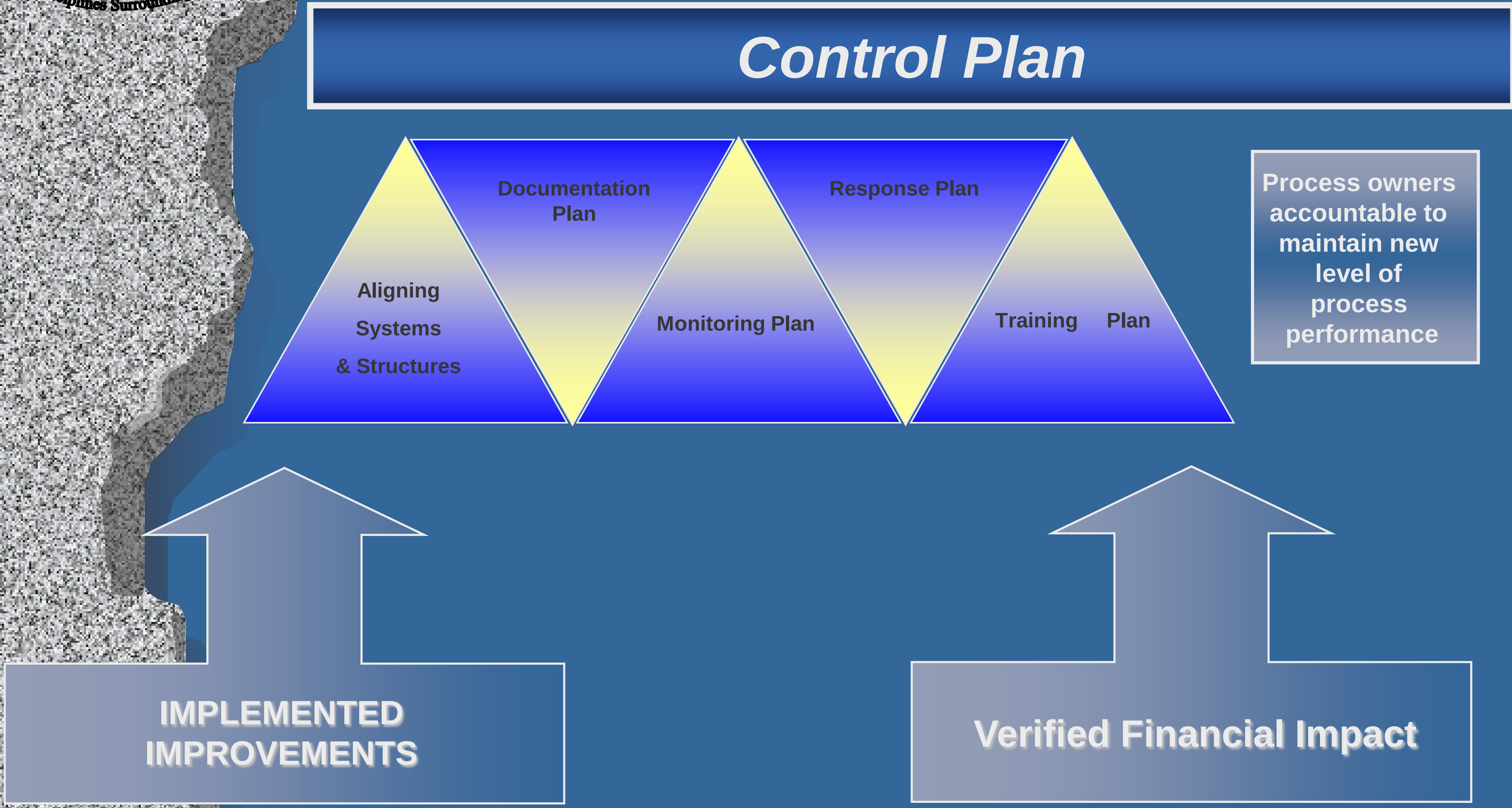
- Associates
- Technical Experts
- Supervisors
- Managers
- Site Manager
- Human Resources

Why Do We Need a Control Plan?

Project results need to be sustained.

- Control Plan requires operators/engineers, managers, etc. to follow designated control methods to guarantee product quality throughout system
- Allows to move onto other projects!
- Prevents need for constant heroes in an organization who repeatedly solve the same problems
- Control Plans are becoming more of a customer requirement

Control Plan Elements



Control Plan

Documentation Plan

Response Plan

Aligning Systems & Structures

Monitoring Plan

Training Plan

Process owners accountable to maintain new level of process performance

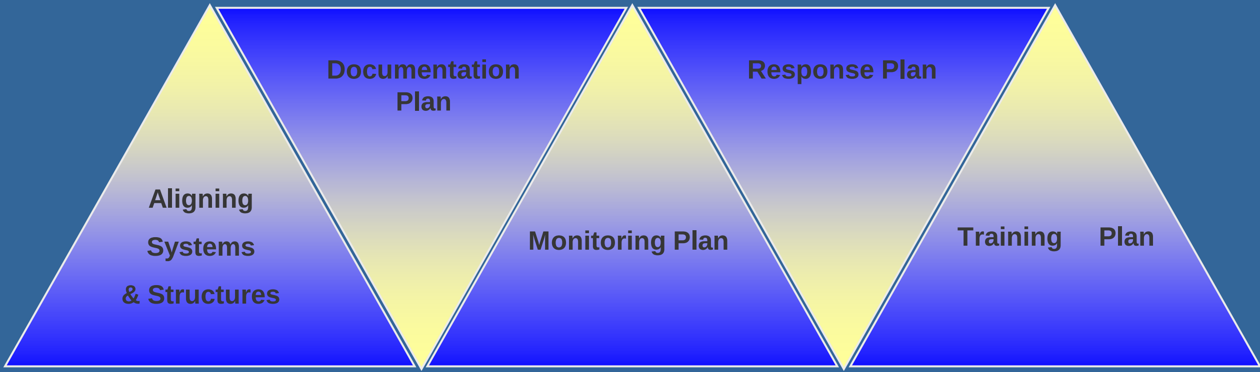
IMPLEMENTED IMPROVEMENTS

Verified Financial Impact

Control Plan Information

The team develops the Control Plan by utilizing all available information from the following:

- Results from the Measure, Analyze and Improve Phases
- Lessons learned from similar products and processes
- Team’s knowledge of the process
- Design FMEAs
- Design reviews
- Defect Prevention Methods selected



Documentation Plan

Response Plan

Aligning Systems & Structures

Monitoring Plan

Training Plan

Training Plan

Who/What organizations require training?

- Those impacted by the improvements
  - People who are involved in the process impacted by the improvement
  - People who support the process impacted by the improvement
- Those impacted by the Control Plan
  - Process owners/managers
  - People who support the processes involved in the Control Plan
  - People who will make changes to the process in the future

Training Plan

Who will complete the training?

- Immediate training
  - The planning, development and execution is a responsibility of the project team
  - Typically some of the training is conducted by the project team
- Qualified trainers
  - Typically owned by a training department or process owner
  - Those who are responsible for conducting the on-going training must be identified

Specific training materials need developing.

- PowerPoint, On the Job checklist, Exercises, etc.

Training Plan

When will training be conducted?

What is the timeline to train everyone on the new process(es)?

What will trigger ongoing training?

- New employee orientation?
- Refresher training?
- Part of the response plan when monitoring shows performance degrading?

Documentation
Plan

Documentation Plan

Documentation is necessary to ensure that what has been learned from the project is shared and institutionalized:

- Used to aid implementation of solutions
- Used for on-going training

This is often the actual Final Report some organizations use.

Documentation must be kept current to be useful

Documentation Plan

Documentation Plan

Items to be included in the documentation plan:

- Process documentation
  - Updated Process maps/flowcharts
  - Procedures (SOP’s)
  - FMEA
- Control Plan documentation
  - Training manuals
  - Monitoring plan—process management charts, reports, sops
  - Response plan—FMEA
  - Systems and structures—job descriptions, performance management objectives

Documentation Plan

Documentation Plan

Assigning responsibility for documentation plan:

- Responsibility at implementation
  - Black belt ensures all documents are current at hand off
  - Black belt ensures there is a process to modify documentation as the process changes in place
  - Black belt ensures there is a process in place to review documentation on regular basis for currency/accuracy
- Responsibility for ongoing process (organizationally based)
  - Plan must outline who is responsible for making updates/modifications to documentation as they occur
  - Plan must outline who is responsible to review documents—ensuring currency/accuracy of documentation

Documentation Plan

Documentation Plan

Documentation Plan Outline

Document	Items Necessary	Immediate Responsibility	Update/ Modification Responsibility	Review Responsibility

Monitoring Plan

Monitoring Plan

Purpose of a monitoring plan:

- Assures gains are achieved and sustained
- Provides insight for future process improvement activities

Development of a monitoring plan:

- Belt is responsible for the development of the monitoring plan
- Team members will help to develop the plan
- Stakeholders must be consulted
- Organizations with financial tracking would monitor results.

Monitoring Plan

Monitoring Plan

Sustaining the monitoring plan:

- Functional managers will be responsible for adherence to the monitoring plan
  - They must be trained on how to do this
  - They must be made accountable for adherence

Monitoring Plan

Monitoring Plan

Tests:

- When to Sample
  - After training
  - Regular intervals
  - Random intervals (often in auditing sense)
- How to Sample
- How to Measure

Monitoring Plan

Monitoring Plan

Statistical process control:

- Control charts
  - Posted in area where data collected
  - Plot data points real time
    - Act on Out of Control Response with guidelines from the Out of Control Action Plan (OCAP).
    - Record actions taken to achieve in-control results.
  - Notes impacting performance on chart should be encouraged
- Establishing new limits
  - Based on signals that process performance has changed

Response Plan

Monitoring Plan

FMEA is a great tool to use for the monitoring plan

#	Process Function (Step)	Potential Failure Modes (process defects)	Potential Failure Effects (Y's)	SEV	Clas	Potential Causes of Failure (X's)	OCC	Current Process Controls	DET	RPN	Recommend Actions	Responsible Person & Target Date	Taken Actions	SEV	OCC	DET	RPN
1																	
2																	
3																	
4																	
5																	
6																	

- Allows process manager and those involved in the process to see the entire process and how everyone contributes to a defect free product/service.
- Provides the means to keep the document current—reassessing RPNs as the process changes

Monitoring Plan

Monitoring Plan

Check Lists/Matrices

- Key items to check
- Decision criteria; decision road map
- Multi-variable tables

Visual Management

- Alerts or signals to trigger action.
  - Empty bins being returned to when need stock replenished
  - Red/yellow/green reports to signal process performance
- Can be audible also.

Response Plan

Response plans—outline process(es) to follow when there is a defect or Out of Control from monitoring:

- Out of control point on control chart
- Non random behavior within control limits in control chart
- Condition/variable proven to produce defects present in process
- Check sheet failure
- Automation failure

Response to poor process results are a must in training.

Response plans are living documents updated with new information as it becomes available

Response Plan

Response Plan

Components of response plan:

- The triggers for a response
    - What are the failure modes to check for?
    - Usually monitor the highest risk x's in the process
- The recommended response for the failure mode
- The responsibilities for responding to the failure mode
- Documentation of response plan being followed in a failure mode
- Detailed information on the conditions surrounding the failure mode

Response Plan – Abnormality Report

Response Plan

- Detailed documentation when failure modes occur.
- Provide a method for on-going continuous improvement.
- Reinforce commitment to eliminating defects.
- Fits with ISO 9000 standard of having a CAR or Corrective Action Request.
- Method to collect frequency of corrective actions.

Current Situation	Process					
	Metric					
	Signal					
	Situation Code					
	Detailed Situation					
Investigation of Cause	Date					
	Code of Cause					
	Corrective Action					
Root Cause Analysis	Who To Be Involved					
	What To Be Done					
	Date for completion of analysis					
	Date for implementation of permanent prevention					

Aligning Systems and Structures

Systems and structures are the basis for allowing people to change their behaviors permanently:

- Performance goals/objectives
- Policies/procedures
- Job descriptions
- Incentive compensation
- Incentive programs, contests, etc

Aligning
Systems
& Structures

There are long- and short-term strategies for alignment of systems and structures

Aligning Systems and Structures

Aligning
Systems
& Structures

- Get rid of measurements that do not align with desired behaviors
- Get rid of multiple measures for the same desired behaviors
- Implement measures that align with desired behaviors currently not motivated by incentives
- Change management must consider your process changes and how the process will respond?
- Are the hourly incentives hurting your chance of success?

Project Sign Off

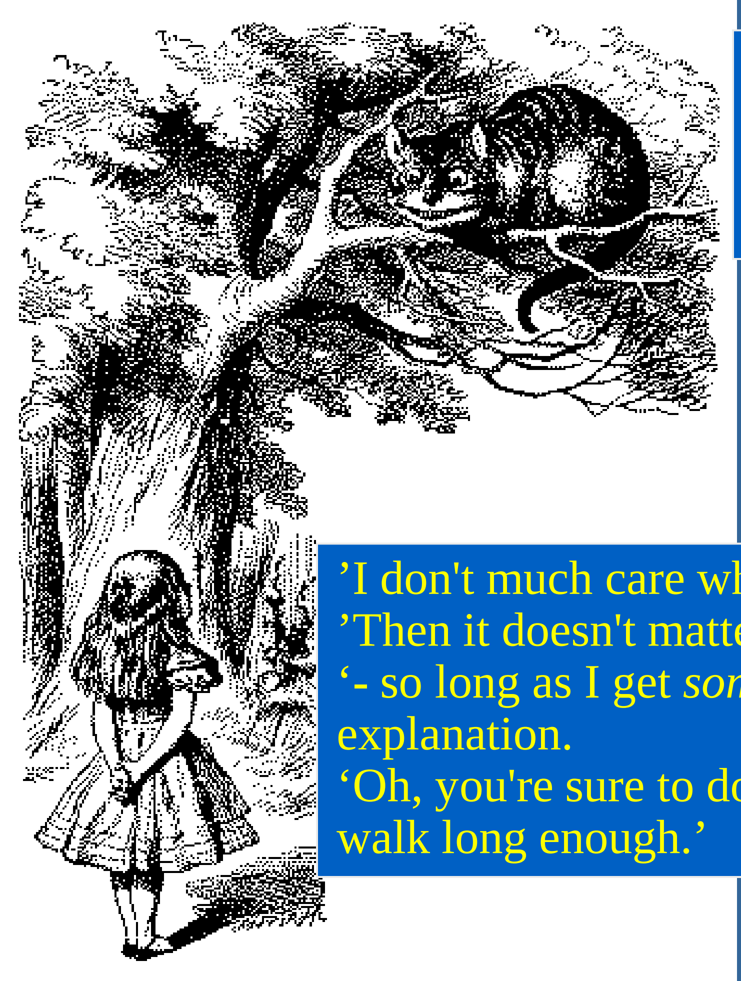
Aligning
Systems
& Structures

Best method to assure acceptance of Control Plan is having supervisors and management for the area involved.

- Meeting for a summary report
- Specific changes to the process highlighted
- Information where Control Plan is filed

CASE STUDY – SECOND PHASE

Why to Monitor Processes



‘Cheshire Puss,’ she began, … `Would you tell me, please, which way I ought to go from here?’
‘That depends a good deal on where you want to get to,' said the Cat.

’I don't much care where –’ said Alice.
’Then it doesn't matter which way you go,' said the Cat.
‘- so long as I get *somewhere*,' Alice added as an explanation.
‘Oh, you're sure to do that,' said the Cat, ‘if you only walk long enough.’

Tell me where you want to be and I will show (measure) you the way

Center	
min	0%
max	100%
ave	50%
sample Projects	104
% From ORG	100.00%
Sample Practices	19629
% From Sample	100.00%
is 0	2649
% of is 0	13.50%
>4	9147
% of >4	46.60%
<4	7828
% of <4	39.88%
is 4	2654
% of is 4	13.52%
>6	4818
% of >6	24.55%
mean	#NUM!
median	4
mode	8
VAR	7.279

Areas

	A1	A2	A3	A4	A5	A6	A7
min	0%	0%	0%	0%	0%	0%	0%
max	100%	100%	100%	100%	100%	100%	100%
ave	50%	50%	37.5%	62.5%	50%	50%	75%
sample Projects	22	6	3	13	23	13	24
% From ORG	21.15%	5.77%	2.88%	12.50%	22.12%	12.50%	23.08%
Sample Practices	3733	957	647	2069	4961	2914	4348
% From Sample	19.02%	4.88%	3.30%	10.54%	25.27%	14.85%	22.15%
is 0	526	127	154	195	914	378	355
% of is 0	14.09%	13.27%	23.80%	9.42%	18.42%	12.97%	8.16%
>4	1575	476	213	1092	1850	1413	2528
% of >4	42.19%	49.74%	32.92%	52.78%	37.29%	48.49%	58.14%
<4	1626	347	322	705	2358	1165	1305
% of <4	43.56%	36.26%	49.77%	34.07%	47.53%	39.98%	30.01%
is 4	532	134	112	272	753	336	515
% of is 4	14.25%	14.00%	17.31%	13.15%	15.18%	11.53%	11.84%
>6	779	211	82	579	775	733	1659
% of >6	20.87%	22.05%	12.67%	27.98%	15.62%	25.15%	38.16%
mean	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!
median	4	4	4	5	4	4	6
mode	2	6	0	6	0	6	8
VAR	7.058	6.898	6.750	6.853	6.654	7.142	7.265

Configuration Management

	min	max	ave	samp	>4	% of >4	<4	% of <4	is 4	% of is 4	>6	% of ≥6	mean	median	mode	VAR
Identify Configuration Items	0%	75%	37.5%	104	12	12%	82	79%	10	10%	0	0%	#NUM!	3	3	1.97
Establish a Configuration Management System	0%	100%	37.5%	104	10	10%	81	78%	13	13%	1	1%	#NUM!	3	3	2.21
Create or Release Baselines	0%	100%	37.5%	104	8	8%	82	79%	14	13%	1	1%	#NUM!	2	2	1.94
Track Change Requests	0%	87.5%	25%	103	8	8%	88	85%	7	7%	1	1%	#NUM!	2	0	2.90
Control Configuration Items	0%	62.5%	25%	104	2	2%	94	90%	8	8%	0	0%	#NUM!	2	2	1.67
Establish Configuration Management Records	0%	62.5%	12.5%	104	1	1%	98	94%	5	5%	0	0%	#NUM!	1	0	1.69
Perform Configuration Audits	0%	87.5%	12.5%	104	4	4%	96	92%	4	4%	1	1%	#NUM!	1	0	2.05

Integrated Project Management

	min	max	ave	samp	>4	% of >4	<4	% of <4	is 4	% of is 4	>6	% of ≥6	mean	median	mode	VAR
Establish the Project’s Defined Process	0%	75%	2	46	3	7%	37	80%	6	13%	0	0%	#NUM!	2	2	2.47
Use Organizational Process Assets for Planning Project Activities	0%	75%	2	46	2	4%	40	87%	4	9%	0	0%	#NUM!	2	0	2.38
Establish the Project's Work Environment	0%	100%	6	42	29	69%	7	17%	6	14%	18	43%	#NUM!	6	8	5.37
Integrate Plans	0%	87.5%	2	46	7	15%	33	72%	6	13%	1	2%	#NUM!	2	0	3.94
Manage the Project Using the Integrated Plans	0%	87.5%	2	46	8	17%	36	78%	2	4%	1	2%	#NUM!	2	0	4.25
Contribute to the Organizational Process Assets	0%	50%	1	46	0	0%	42	91%	4	9%	0	0%	#NUM!	1	0	1.63
Manage Stakeholder Involvement	0%	87.5%	3	46	17	37%	23	50%	6	13%	4	9%	#NUM!	4	1	5.51
Manage Dependencies	0%	87.5%	3	46	9	20%	35	76%	2	4%	1	2%	#NUM!	2	2	3.54
Resolve Coordination Issues	0%	87.5%	3	46	13	28%	28	61%	5	11%	2	4%	#NUM!	3	2	3.87

Requirements Management

SP 1.4 Maintain Bidirectional Traceability of Requirements

max		ave	samp	>4	% of >4	<4	% of <4	is 4	% of is 4	>6	% of >6	mean	median	mode	VAR
0%	100%	62.5%	104	66	63%	20	19%	18	17%	23	22%	#NUM!	6	6	3.75

Requirements Management

SP 1.5 Identify Inconsistencies Between Project Work and Requirements

max		ave	samp	>4	% of >4	<4	% of <4	is 4	% of is 4	>6	% of >6	mean	median	mode	VAR
0%	100%	62.5%	104	65	63%	24	23%	15	14%	37	36%	#NUM!	6	6	5.19

Technical Solution

SP 3.1 Implement the Design

min	max	ave	samp	>4	% of >4	<4	% of <4	is 4	% of is 4	>6	% of >6	mean	median	mode	VAR
25%	100%	75%	35	30	86%	3	9%	2	6%	16	46%	5.759	6	6	2.85

Validation

SP 2.2 Analyze Validation Results

min	max	ave	samp	>4	% of >4	<4	% of <4	is 4	% of is 4	>6	% of >6	mean	median	mode	VAR
0%	100%	62%	39	19	49%	6	15%	14	36%	8	21%	#NUM!	4	4	3.71

Verification

SP 3.2 Analyze Verification Results

min	max	ave	samp	>4	% of >4	<4	% of <4	is 4	% of is 4	>6	% of >6	mean	median	mode	VAR
0%	100%	62.5%	39	20	51%	12	31%	7	18%	12	31%	#NUM!	5	7	5.13

Organizational Background and Process ROI

Project Idea and Proposal Preposition Development

- If an average developer day cost is ~7000
- The total Program effort was 10220 day (100%)
- The testing phase was 1480 day (14.5%)
- Defect that are the result of documentation are 69% of all defects

- If we will assume the to correct 69% of all defects will take around 40% of th testing duration; ☞ means that:
  - that will be 740 day
  - With the overall cost of 518000
- However to add 100 review days in the static tests and another 20 of code inspection will end with the cost of 2100000

- And still we have saved at least 3080000 (440 days)
- Means that we ware able to reduce 4.5% of the project time

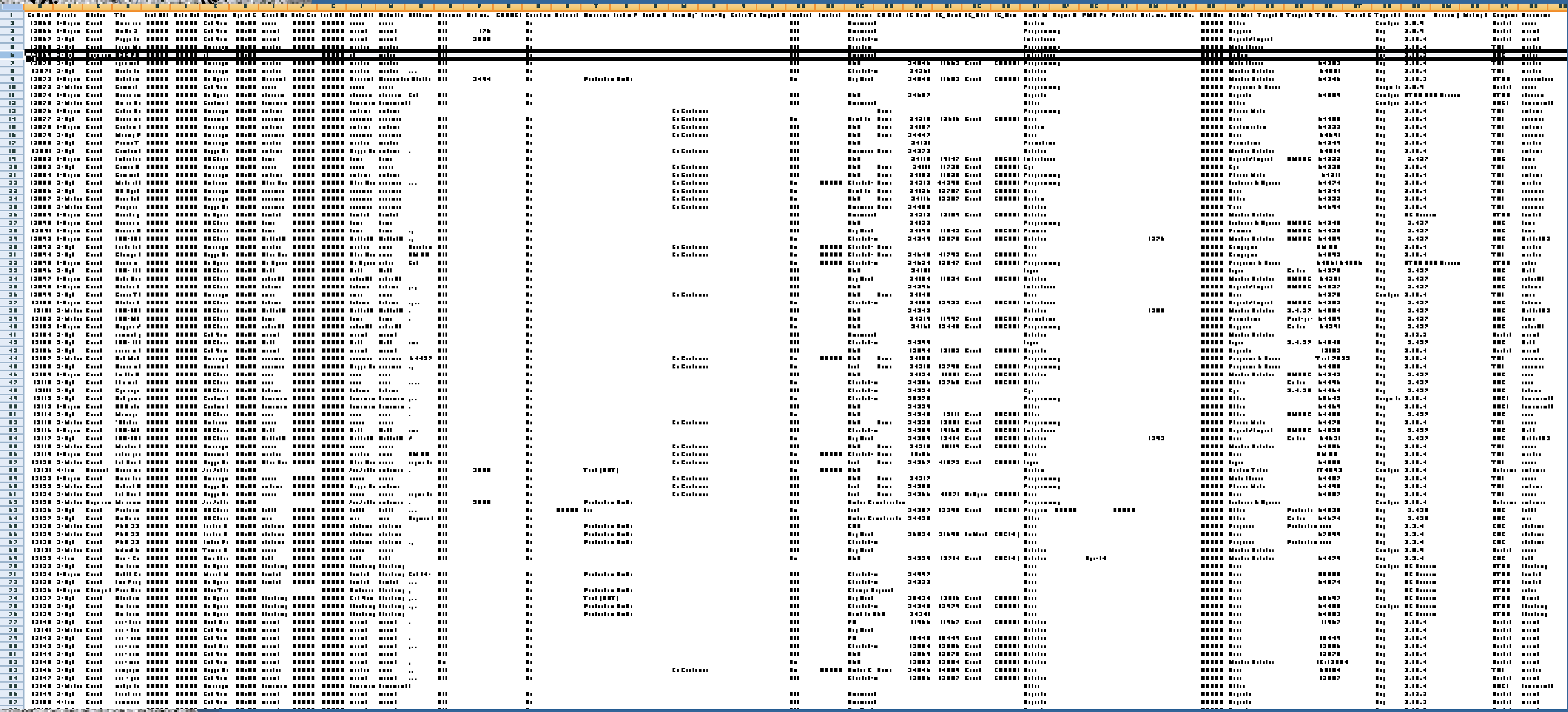
Questions ?

Contact

Kobi Vider
K.V.P Consulting
Kobi.Vider@hotmail.com
KobiVP@aol.com
Phone: +972522946676

“which way I ought to go from here”

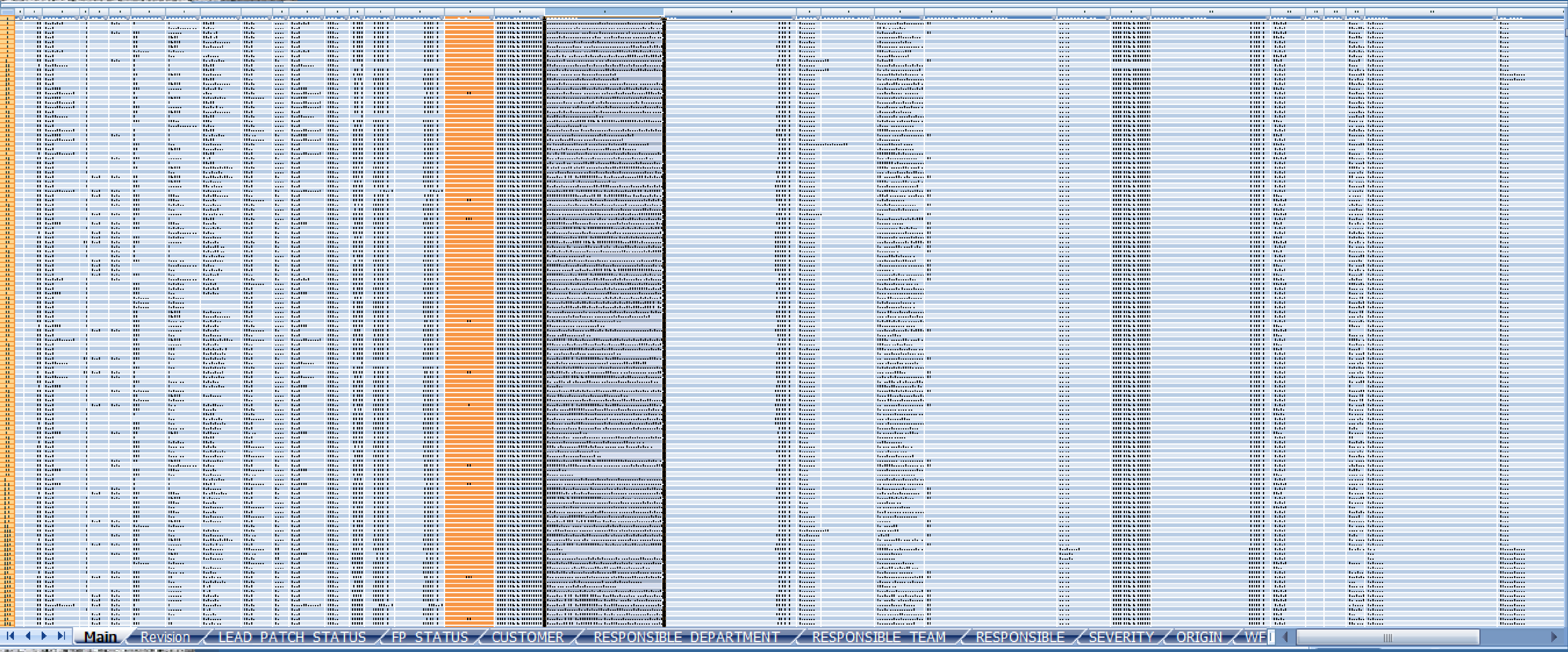
Call Center – Calls Database



~45000 Records
With
22 Attributes

"which way I ought to go from here"

Bug Database



~33000 Records
With
36 Attributes