DEFINE

* = most critical phase!

- team roles defined
- team operational procedures established
- team charter complete
- VOC + "voice of the business analysis"
- critical measures of quality (SMART KPIs) + measures of process chosen
- process described (e.g. maps/VSM)
- "Quick wins" identified

MEASURE

- CLT, distributions (N, Poiss, Weib, Binomial)
- Process Capability Studies
- Process Performance Measures (DPU, DPMO, RTY)
- Process Capability Calculations!

ANALYZE

- Regression + Correlation
- Sample Size Calculations
- Probability Calc's (Regular + on FTA Diagrams)
- → χ^2 test for change in variance/stdev!!
- Hypothesis Tests for Means, Proportions
- Logit/Probit/χ^2 for O and E
- Nonparametrics

IMPROVE

- DOE to understand influence of factors, best treatments
- choose appropriate exper. objectives, assumpt.
- Waste reduction via Kanban/Pull, 5S, Std Wk, Poka-Yoke, Kaizen
- Cycle Time Reduction via SMED, contin. flow mfg (CFM)
- Kaizen, Blitz, TOC
- Plan to implement improvements (pilots, simulations, Commun.)
- Risk (e.g. expected profit p. 351, SWOT, feasibility, RPN)

SIGMA LEVELS

*shifted by 1.5

Level	DPMO	% defective	% Yield	Short term C_{pk}	Long term C_{pk}
1	691,462	69%	31%	0.33	−0.17
2	308,538	31%	69%	0.67	0.17
3	66,807	6.7%	93.3%	1.00	0.5
4	6,210	0.62%	99.38%	1.33	0.83
5	233	0.023%	99.977%	1.67	1.17
6	3.4	0.00034%	99.99966%	2.0	1.5
7	0.019	0.0000019%	99.9999981%	2.33	1.83

* processes USUALLY do not perform as well in the LONG TERM as they do in the short term

BASIS of 1.5σ SHIFT

* Sigma levels and DPMOs assume that the process mean will shift toward the critical specification limit by 1.5 over long term

* Thus 3.4 DPMO actually corresponds to a 4.5 sigma process

* To get a SIGMA LEVEL from a DPMO:

$$6\sigma = 0.8406 + \sqrt{29.37 - 2.221\,\mathrm{Ln}(\mathrm{DPMO})}$$

(or look at XII-3 TABLE!)

CONTROL

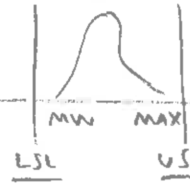
- SPC [Wecs/Minitab Rules p. 351 Kubiak]
- Control charts
- SHORT RUN charting when production lot size is small (10-20 pcs.) or sample size small (X-27)
- TPM, Visual Factory
- check to ensure MEASUREMENT INSTRUMENTS have ACCURACY 1/10 of specific. TOLERANCE (also called 10:1 rule) (this is <10% error)
- Control Plans
- Training Plans

Process Capability

Process capability studies for PPAP should be based on data from a SIGNIFICANT production run of 300 consecutive pieces.

What are P_R + P_p?
(need stdev + spec limits to calculate)

CAPABLE PROCESS has
min > LSL
max < USL



can estimate STDEV from a control chart using $\sigma_R = \frac{\bar{R}}{d_2}$

where do you get them?
cust reqs, ind stds, engr dept

$MSE = SSE / N-t$

DF for ERROR SUM OF SQUARES is # tests − # treatment

IS THE PROCESS STABLE? no, if points outside control limits, trends, cycles, oscillation, points on one side of center

control chart RULES p. X-35

Process variability in a PILOT RUN likely < in ongoing process variability GREATER over longer runs, hence 1.5 sigma shift

specification range = USL − LSL

POTENTIAL CAPABILITY $C_p = \frac{USL - LSL}{6\sigma}$

$C_{p,lower} = \frac{Mean - LSL}{3\sigma}$

$C_{p,upper} = \frac{USL - Mean}{3\sigma}$

CAPABILITY RATIO $C_R = 1/C_p$

Dials on the Washing Machine

... 1 of one F assoc. w/ L of another F

← LEVELS
← FACTORS

Treatments = Combinations of Specific Factor Levels

LATIN SQUARES are special designs with two and only two blocking factors. Each treatment appears only once in each row and once in each column. (Solutions to sudoku are Latin squares.) it is a ONE FACTOR DESIGN. and ALWAYS n x n. {treatment efx only; NO intxn's}
- uses ANOVA table to eval. statist. significance of factors
- calculates an F

Ex. Fuel company wants to test fuel efficiency of 4 diff. blends of gasoline and want to exclude (or block) variability due to CARS and DRIVERS.

= fractional factorial

- "Full Factorial" Alternative would have required 4 x 4 x 4 = 64 observations instead of just 16. (often used for AGRICULTURE studies)

To IMPROVE PRECISION of a designed experiment when the experimental material is not homogeneous, use BLOCKING to exclude variability due to that.

BLOCKING factors are usually OUTSIDE experimenter's control

BALANCED means EQUAL # TRIALS CONDUCTED for each FACTOR.

RANDOMIZED BLOCK design means each GROUP in the experiment has EXACTLY ONE measmt of each TREATMENT:
- each BLOCK contains all TREATMENTS
- randomization is restricted to within blocks.

or FACTOR of 4 if its HUGE

$n = L^F$ [Levels to the Lim Factors Fly]

L = # levels (settings on dials)

F = # factors (dials)

Calculate MAIN EFFECTS

Exper. #	Temp	Time	Oil	$\boxed{EV}$
2	−	−	−	60
3	+	−	−	72
5	−	+	−	54
8	+	+	−	68

(# exper's = 4)

$\frac{\sum +'s - \sum -'s}{\frac{1}{2}\ \#\ exper's}$ is the MAIN EFFECT of the variable you're looking at

EXPERIMENTAL RESIDUALS must be:
- normally distributed
- independent of one another
- constant variance

LATIN 1 factor
GRECO-LATIN 2 factors
HYPO-GRECO-LATIN 3 factors

MULTIPLE REPLICATIONS provide you with an estimate of experimental error

Financial Analysis

Goals of 6σ projects can be to:

- result in (overall) revenue growth
- increase market share
- increase margins

$$\text{RoI} = \frac{\text{Income Generated As Result of Project}}{\text{Cost of Doing Project}} \times 100\%$$

$$\text{NPV} = \text{Amount to be Rcvd at End of Time Period} \left(1 + \text{interest rate}\right)^{-\text{years}}$$

if payments are staggered, add up NPV of each return to get NPV of the income stream

IRR = this is the discount rate that CAUSES NPV = 0.

Should EXCEED cost of capital % to be productive!

$$\text{Payback period} = \frac{\text{initial investment } \$}{\$ \text{ repaid per yr}} = x \text{ yr}$$

* time value of money NOT factored in to payback period calculation

EVOP is GOOD Because:
Conservative, Little Scrap, Only Few vars chgd, less staff reqd

Selecting a 6σ Project

- MUST further organizational goals
- all else being equal, projects with the greatest contribution to the bottom line receive the highest priority

Advantages of MANUAL TA
ease of use, low cost, hands on feel, best for monitoring, EASIER TO LEARN, not good for lg proj

JURAN'S TRILOGY
Q Planning → Budgeting
Q Control → Cost Control
Q Improvement → Cost Reduc, Profit ↑

MEDIAN TESTS
Mood's Median Test
Mann-Whitney Test
Kruskal-Wallis Test

$$k = \frac{\text{cost of def. prod}}{(\text{tolerance})^2} = \frac{A}{\Delta^2}$$

TAGUCHI LOSS FXN

$$L(y) = k(y-m)^2$$

m → target
y → output value

$$k = \frac{\text{Consumer loss } \$}{\left(\text{max. deviation from target allowed by consumer}\right)^2}$$

BALANCED SCORECARD includes
business performance metrics, strategy metrics, financial metrics, stakeholder metrics

A GOOD 6σ project will:

- be short term (< 4-6 mo) + scoped well
- impact a key business goal or process
- cross-functional or cross-business line impact
- produce QUANTIFIABLE results
- address improved customer satisfaction or reduced dissatisfaction
- be data driven and apply statistical thinking + decision making

If P(car starting) = 0.6, and we have two cars, what's P(at least one starts)?

$$P(A \cup B) = P(A) + P(B) - P(A \cap B)$$
$$= 0.6 + 0.6 - (0.6 \times 0.6)$$
$$= 1.2 - 0.36 = \underline{0.84}$$

Substituting 2σ boundaries for 3σ boundaries will INCREASE the alpha risk of Rejecting H_0 when in fact it is true

Visual Factory includes
- Kanban
- Tool boards
- Andon boards
- SS

(not poka-yoke)

IF SAMPLE SIZE SMALL, USE t TABLE TO CALCULATE CONFIDENCE LIMITS!

e.g. $\bar{y} \pm Z_{\alpha/2}\sigma_{\bar{y}}$ $\quad \sigma_{\bar{y}} = \frac{s}{\sqrt{n}}$

$$\downarrow$$

$$\bar{y} \pm t_{\alpha/2}\,\sigma_{\bar{y}}$$

EXACT metrics are not determined at the DEFINE step

CALCULATE STDEV BY HAND:
- Calculate mean
- Create list of deviations
- Square all deviations
- add up all squares of deviations
- divide that by n-1
- take SQRT to get STDEV

LIMIT GAGES
- ring
- radius
- gage blocks

NOT verniers

CTQ Tree: Strategic Goal

$\downarrow$

Project objectives

$\downarrow$

1-D CTQ's

$\downarrow$

Constituents

Custome expectations
B – E – D – U
basic, expected, desired, unantic.

PERT is EVENT-oriented
CPM is ACTIVITY-based

critical path is LONGEST path

Kano analysis/Kano Model
① DISSATISFIERS – must be
② SATISFIERS – more is better
③ DELIGHTERS (latent)

When the NATURAL PROCESS LIMITS are compared to the specification range, you may:
① Do NOTHING
② CHANGE THE SPEC
③ CENTER THE PROCESS
④ REDUCE VARIABILITY
⑤ ACCEPT LOSSES

HYPERGEOM – sample is LARGE comp. to POP SIZE WITHOUT replacement
or need P(success)(f=1)

PROCESS CAPABILITY

$C_{pk} = \text{Min}(C_{pk\,upper}, C_{pk\,lower})$

$C_{pk\,upper} = \dfrac{USL - \bar{x}}{3\sigma}$

$C_{pk\,lower} = \dfrac{\bar{x} - LSL}{3\sigma}$

MULTIVARI
POSITIONAL = WITHIN part
CYCLICAL = Part to Part
TEMPORAL = over time
TOTAL VARIANCE = PROCESS VAR + MEAS. VAR
$\sigma_T^2 = \sigma_p^2 + \sigma_m^2$

Poisson Distribution
use when p<0.1 and n large
mean = variance
Used to Model
DEFECT COUNTS
+ RATES (arrivals/hr)
Variance = mean

Exponential Distribution
used to Model things with
CONSTANT FAILURE RATE
mean = stdev of Distrib!

$f(x) = \dfrac{1}{\theta} e^{-\frac{x}{\theta}} = \lambda e^{-\lambda x}$

θ = mean
λ = failure rate
Variance = mean^2

Lognormal
mean = $e^{(\mu + \frac{\sigma^2}{2})}$

variance = $(e^{2\mu + \sigma^2})(e^{\sigma^2} - 1)$

take MEAN of indiv value and STDEV of indiv. value
→ "scale" parameter
→ "location" parameter
insert them into Eqn on pg. VII-47

γ is 3rd Param
Weibull P VII-49
TIME to FAIL, MTTR, MATERIAL STRENGTH
3-param:
$f(t) = \frac{\beta}{\eta}\left(\frac{t-\gamma}{\eta}\right)^{\beta-1} e^{\left(-\frac{(t-\gamma)}{\eta}\right)^{\beta}}$

Flexi Prom
β = shape parameter, η = scale (width of distrib)
γ = location param. (no failures below this pt)
if $\beta = 1$, W(mean) = characteristic life

$\beta = 1$	E
$\beta = 2$	Ray
$3 < \beta < 4$	N

POKA-YOKE = Error Proofing
STANDARD WORK = takt, ergonomics, part flow, maint. proc., routine (IV-44)

LOGIT (p. VIII-41)
odds = $\dfrac{p}{1-p} = \dfrac{p(\text{success})}{p(\text{failure})}$

logit probability = Ln(odds) = L
logit equation $p = \dfrac{e^L}{1 + e^L}$

PROBIT (p. VIII-44)
– for destructive testing, survivability
– b coeff. of Logit and Probit differ by 1.814.
– mean of ZERO, variance of 1

TOC (Kubiak p. 344)
5 steps to sys improvement:
1) Identify process of concern. Throughput prob usually assoc w/ WIP
2) Exploit. Use kaizen to improve rate of process.
3) Subordinate. All sys processes should be SLOWED DOWN (via rope) to speed of SLOWEST PROCESS (drum) and amount of WIP (buffer) is determined by dependability of individual process.
4) Elevate system rate by new equipment or new technology if it's still not good.
5) Repeat move to new limiting constraint.

TOC has significant impact on THROUGHPUT, INVEN, or EXP

$\boxed{\text{thruput}} \rightarrow \boxed{\text{inventory}} \rightarrow \boxed{\text{op expense}}$
money coming in → money tied up → money going out

COMBINATIONS tell how many UNIQUE ways you can arrange n objects taking them in groups of r at a time.

$C_r^n = \dfrac{n!}{r!(n-r)!}$

Pick 1 from a grp of 5: $C_1^5 = \dfrac{5!}{1!(5-1)!} = 5$

Pick 2 from a grp of 8: $C_2^8 = \dfrac{8!}{2!(8-2)!} = \dfrac{40320}{1440} = 28$

Pick 1 from a grp of 5 AND 2 from a grp of 8:
$C_1^5 \times C_2^8 = 5 \cdot 28 = 140$

VI-40

		CT
NOMINAL	– categorical	Mode
ORDINAL	– rank ordered; Likert scale	Mode, Med (NOT Mean)
INTERVAL	– scaled variable, e.g. Celsius (fails ratio test)	Mode, Med, or Mean
RATIO	– physical measurement, mass, time, weight, energy; 2 hr = 2 x 1 hr	

$$\chi^2 = \sum_{\text{all cells}} \frac{(O-E)^2}{E}$$

$$df = (\text{rows}-1)(\text{cols}-1)$$

SAMPLE VARIANCE $\quad s^2 = \dfrac{\sum (y-\bar{y})^2}{n-1}$

STDEV $\quad s = \sqrt{s^2}$

or STDEV $= \sqrt{\text{VARIANCE}}$

TOLERANCE LIMITS

$$\bar{y} \pm 3s$$

STDEV are NOT additive...
but VARIANCES are!

$$\sigma_{\text{stack of parts}} = \sqrt{\sigma_A^2 + \sigma_B^2 + \sigma_C^2}$$

PORTER'S 5 Forces

1. bargaining power of CUSTOMERS
2. " " of SUPPLIERS
3. THREAT of new entrants
4. Threat of substitute
5. intensity of competitive rivalry

# of EXPERIMENTAL RUNS needed

$$n = L^F$$

L = # of levels (setting on dials)
F = # of factors (dials)

Coefficient of contingency is the DEGREE of RELATIONSHIP among items in a contingency table:

$$C = \sqrt{\frac{\chi^2}{\chi^2 + N}}$$

$N \rightarrow$ total counts in contingency table or "grand frequency total"

C never > 1

C = f(# rows, # cols)

$$\text{Max } C = \sqrt{\frac{k-1}{k}}$$

where k is smaller of rows or cols.

$$E = \frac{(\text{col. total})(\text{row total})}{\text{grand total}}$$

Correlation coeff φ of conting. table

$$\varphi = \sqrt{\frac{\chi^2}{N(k-1)}} \qquad 0 < \varphi < 1$$

only if χ^2_{calc} is significant

Correlation coefficient of a SCATTER

$$r = 1 - \frac{\text{Sum of Squared Errors}}{\text{Sum of Squares Total}} = 1 - \frac{SSE}{SST} = \frac{SST - SSE}{SST}$$

Coefficient of variation

$$COV = \frac{\text{stdev}}{\text{mean}}(100\%)$$

don't correct for sample size

χ^2 for Reducing Variation Studies

OLD process ≈ POPULATION
NEW process ≈ SAMPLE

$$\chi^2 = (n-1)\frac{\text{stdev}_{samp}^2}{\text{stdev}_{pop}^2} = (n-1)\frac{\text{var}_{samp}}{\text{var}_{pop}}$$

WASTE ELIM = Kanban/Pull, 5S, Standard Work, Poka-yoke, Kaizen

LINEAR REGRESSION

$y = mx + b$

$y = \beta_1 x + \beta_0$

Approximate slope β_1 by $\dfrac{S_{xy}}{S_{x^2}}$

$$S_{xy} = \sum xy - \frac{\sum x \sum y}{n}$$

$$S_{x^2} = \sum x^2 - \frac{(\sum x)^2}{n}$$

CI on Slope β_1 p. VIII-11

Estimate VARIAB. of RANDOM ERRORS w/ σ_ε^2 p. VIII-9

use average $(\bar{x}, \bar{y})$ as test point in line eqn. to get intercept β_0

CHARACTERISTIC LIFE using Weibull:

- if shape param $\beta = 1$ then W(mean) = charac. life
- as β increases, VARIANCE of W decreases
- if location param $\delta = \emptyset$ characteristic life = scale param $\theta + \delta$
- if location param $\delta, \gamma = \emptyset$ the scale param θ & η equals characteristic life

* BEWARE of ROUNDING errors! + extrapol.
* REDUCE HIGHER ORDER TERM USING TRANSFORMATION!!

Inferences about μ, σ unknown

$H_0: \mu = \mu_0$

$H_a: \begin{cases} \mu > \mu_0 \\ \mu < \mu_0 \\ \mu \neq \mu_0 \quad \text{two-tailed} \end{cases}$

T.S. $t = \dfrac{\bar{y} - \mu_0}{s/\sqrt{n}}$

Sample size if Margin of error known:

ONE TAIL

$n = \dfrac{\sigma^2}{ME^2}(z_{\alpha/2} + z_\beta)^2$

TWO TAILS

$n = \sigma^2 \dfrac{(z_{\alpha/2} + z_\beta)^2}{ME^2}$

R.R. For a probability α of a Type I Error and $df = n-1$,

Reject H_0 if $\begin{cases} t_{calc} > t_\alpha \\ t_{calc} < t_\alpha \\ |t_{calc}| > \underbrace{t_{\alpha/2}}_{\text{From Lookup}} \end{cases}$

$100(1-\alpha)\%$ CI: $\bar{y} \pm t_{\alpha/2} \dfrac{s}{\sqrt{n}}$

$\beta = P\left[z < z_\alpha - \dfrac{|\mu_0 - \mu_a|}{\sigma_{\bar{y}}}\right] \quad \sigma_{\bar{y}} = \dfrac{s}{\sqrt{n}}$

Power $= 1 - \beta$; use $z_{\alpha/2}$ if two tailed test

Caveats: if data values are SKEWED, efficiency of this procedure is suspect

$df = n - 1$ p-value $= P[t_{df} > t_{calc}]$

Inferences about $\mu_1 - \mu_2$ INDEP. SAMPLES!

ALt. WILCOXON RANK SUM TEST

$H_0: \mu_1 - \mu_2 = D_0$

$H_a: \begin{cases} \mu_1 - \mu_2 > D_0 \\ \mu_1 - \mu_2 < D_0 \\ \mu_1 - \mu_2 \neq D_0 \quad \text{(two tailed)} \end{cases}$

T.S. $t = \dfrac{\bar{y}_1 - \bar{y}_2 - D_0}{s_p\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$ EQUAL VARIANCES

$s_p = \sqrt{\dfrac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}}$

$s_1^2 = \dfrac{1}{n-1}\left[\sum y^2 - \dfrac{(\sum y)^2}{n}\right]$

Reject H_0 if $\begin{cases} t_{calc} > t_\alpha \\ t_{calc} < t_\alpha \\ |t_{calc}| > t_{\alpha/2} \end{cases}$

T.S. $t' = \dfrac{\bar{y}_1 - \bar{y}_2 - D_0}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$ UNEQUAL VARIANCE

$df = \dfrac{(n_1 - 1)(n_2 - 1)}{(n_2 - 1)c^2 + (1-c)^2(n_1 - 1)}$ where $c = \dfrac{s_1^2/n_1}{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}$

Caveats: both random variables must be normally distributed

CI: $(\bar{y}_1 - \bar{y}_2) \pm t_{\alpha/2} s_p \sqrt{\dfrac{1}{n_1} + \dfrac{1}{n_2}}$

$df = n_1 + n_2 - 2$

Inference about Population Variance σ^2

CI for $100(1-\alpha)\%$:

$$\frac{(n-1)s^2}{\chi^2_u} < \sigma^2 < \frac{(n-1)s^2}{\chi^2_L}$$

IMPORTANT!

χ^2_u ↓ upper tail val; χ^2_L ↓ lower tail val

* get these from χ^2 table (p. A-6 etc)

H_0: $\sigma^2 = \sigma_0^2$ (specified)

H_a: $\begin{cases} \sigma^2 > \sigma_0^2 \\ \sigma^2 < \sigma_0^2 \\ \sigma^2 \neq \sigma_0^2 \text{ (two tailed)} \end{cases}$

Alternatives: Levene's test, Bartlett's test

T.S. $\chi^2 = \dfrac{(n-1)s^2}{\sigma_0^2}$

Reject H_0 if

$\chi^2_{calc} > \chi_u^2$ (upper tail value for $df = n-1$ and $a = \alpha$)

$\chi^2_{calc} < \chi_L^2$ (lower tail value for $df = n-1$ and $a = 1-\alpha$)

$\chi^2_{calc} > \chi_u^2$ $df = n-1$ AND $a = \alpha/2$

OR

$\chi^2_{calc} < \chi_L^2$ $df = n-1$ AND $a = 1-\frac{\alpha}{2}$

Ex.

Comparing two population variances (F test).

H_0: $\sigma_1^2 = \sigma_2^2$

H_a: $\begin{cases} \sigma_1^2 > \sigma_2^2 \\ \sigma_1^2 \neq \sigma_2^2 \text{ (two tail)} \end{cases}$

T.S. $F = \dfrac{s_1^2}{s_2^2}$

Reject H_0 if

$\begin{cases} F_{calc} > F_{table},\ a = \alpha,\ df_1 = n_1 - 1,\ df_2 = n_2 - 1 \\ F_{calc} > F_{table},\ a = \frac{\alpha}{2},\ df_1 = n-1,\ df_2 = n_2 - 1 \end{cases}$

CI for $100(1-\alpha)\%$:

$$\frac{s_1^2}{s_2^2} F_L < \frac{\sigma_1^2}{\sigma_2^2} < \frac{s_1^2}{s_2^2} F_u$$

$F_L = \dfrac{1}{F_{df1,df2}}$ $\quad F_u = F_{df2,df1}$

One proportion z-test

H_0: $\pi = \pi_0$

H_a: $\begin{cases} \pi > \pi_0 \\ \pi < \pi_0 \\ \pi \neq \pi_0 \text{ (two tailed)} \end{cases}$

T.S. $z = \dfrac{\hat{\pi} - \pi_0}{\sigma_{\hat{\pi}}}$ $\quad \sigma_{\hat{\pi}} = \sqrt{\dfrac{\pi_0(1-\pi_0)}{n}}$

Reject H_0 if:

$\begin{cases} z_{calc} > z_\alpha \\ z_{calc} < -z_\alpha \\ |z_{calc}| > z_{\alpha/2} \end{cases}$

100(1 − α)% CI:

$\hat{\pi} \pm z_{\alpha/2}\sigma_{\hat{\pi}}$ where

$\hat{\pi} = \dfrac{y}{n}$ and $\sigma_{\hat{\pi}} = \sqrt{\dfrac{\pi(1-\pi)}{n}}$

(*) Sample size:

$$n = \frac{z_{\alpha/2}^2\,\pi(1-\pi)}{E^2}$$

2E is width of ENTIRE CI

USE $\pi = 0.5$ to GENERATE MOST CONSERVATIVE SAMPLE SIZE ESTIMATE!

Ex. If a product yields 90% recovery before improvement, and you want to know if 2% chg has been made at 95%, (*) $n = \dfrac{(1.96)^2(0.9)(0.1)}{(0.02)^2} = 864$

Two proportion z-test

H_0: $\pi_1 - \pi_2 = \varnothing$

H_a: $\begin{cases} \pi_1 - \pi_2 > 0 \\ \pi_1 - \pi_2 < 0 \\ \pi_1 - \pi_2 \neq 0 \text{ (two tailed)} \end{cases}$

T.S. $z = \dfrac{\hat{\pi}_1 - \hat{\pi}_2}{\sigma_{\hat{\pi}_1 - \hat{\pi}_2}}$ $\quad = \sqrt{\pi(1-\pi)\left(\dfrac{1}{n_1} + \dfrac{1}{n_2}\right)}$

Estimate π using $\hat{\pi} = \dfrac{y_1 + y_2}{n_1 + n_2}$

Reject H_0 if:

$\begin{cases} z_{calc} > z_\alpha \\ z_{calc} < -z_\alpha \\ |z_{calc}| > z_{\alpha/2} \end{cases}$

100(1 − α)% CI:

$$(\hat{\pi}_1 - \hat{\pi}_2) \pm z_{\alpha/2}\,\underbrace{\sigma_{\hat{\pi}_1 - \hat{\pi}_2}}_{\sqrt{\frac{\pi_1(1-\pi_1)}{n_1} + \frac{\pi_2(1-\pi_2)}{n_2}}}$$

Level of Confidence = $(1-\alpha)$ Risk

α Risk = 1 − Level of confidence

TYPE I SPC ERRORS occur when we treat a behavior as a special cause of variation when in fact it is NOT – no change has really occurred in the process.

→ OVERCONTROL.

TYPE II SPC ERRORS occur when we DON'T treat a behavior as a special cause when in fact, it is.

→ UNDERCONTROL.

POWER = chance I will CORRECTLY reject H_0.

In general, as α increases, β decreases and Power $1-\beta$ increases.

POWER HIGHER for PARAMETRIC TESTS!

If a small change in the PROCESS MEAN truly exists, but we don't detect it because our sample size is too small, that's a Type II Error.

SAME AS: H_0 is false, but we don't reject it.

For α if you're willing to be WRONG 5% of the time (or 1 in 20) at the 95% level of significance, this means:

- 5% of the time you will say there is a real difference between the mean/proportions when in fact there is not, OR
- 5% of the time you will Reject H_0 when you shouldn't have!

α = LEVEL of SIGNIFICANCE = Risk of a Type I Error

TYPE I α	TYPE II β
H_0 rejected when IN FACT it is TRUE	H_0 NOT rejected when it should have been – it's FALSE!