General Requirements of Understanding the Six Sigma

A Typical Calculation for a sigma capability

Step	Action	Equations	Your Calculations
1	What process do you want to consider?	N/A	Billing
2	How many units were put through the process?	N/A	2167
3	Of the units that went into the process how many came out OK?	N/A	2059
4	Compute the yield for the process defined in Step 1.	Step 3/Step 2	2059/2167 = .9502
5	Compute the defect rate based on Step 4.	1 − step 4	1 − .9502 = .0498
6	Determine the number of potential things that could create a defect.	Number of CTQ characteristics	18
7	Compute the defect rate per CTO characteristic.	Step 5/Step 6	.00498/18 = .0028
8	Compute the defects per million opportunities (DPMO).	Step 7 x 1,000,000	.0028 x 1,000,000 = 2,800
9	Convert the DPMO (Step 8) into a sigma value. You may use a conversion chart or calculate the number.	N/A	4.3
10	Draw conclusions.	N/A	Little better than average performance

Cascading the Y = f(X)

Level 1 $Y = f(X_1, X_2, \ldots X_n)$

$\downarrow$

Level 2 $y = f(x_1, x_2, \ldots x_n)$

$\downarrow$

Level 3 $yi = f(x_i, x_{ii}, x_n)$

Where:

Y is influenced by a number of potential Xs.
The y is the new requirement based on X_1's and so on. The X_1 is further examined for more potential xs.
The y_i is yet another requirement of the customer based on x_1's and so on.
The x_i is further examined for more potential xs.

Example: High level application of a "meal in the restaurant":

Level 1 Y = a good meal in the restaurant is depended on X1 = price, X2 = service, X3 = satisfaction

Level 2 y = the result in satisfaction (which is the X3) is depended upon x1 = quality, and x2 = food selection

Level 3 yi = the result in satisfaction (X3) with quality (which is the x2) is depended upon x_i = availability of food, xii = management

Level 4 and so on

1. Translating the Voice of the Customer (VOC) to Requirements (CTQs)				
Level	**VOC**	**Key Issues**	**Requirements**	
			Good	Bad

2. Understanding Inputs and Outputs

Process input variables	Process output variables

3. Cause and Effect Matrix								
Rating of importance to customer								
	1	2	3	4	5	6	7	
Process inputs (Xs) CTPs	**Process outputs (Ys), CTC, CTD, CTQ**							**Total**

4. Project Charter	
Project title:	Key roles: Name: Title: Task:
Problem statement:	Timing: Start: End:
Company's impact:	ROI: Expected benefit:
Project scope statement: Project goal:	Team members:
Project location:	Process owner:

5. Project Plan Milestone Chart

Cycle of project	Time line in weeks of months				
Project start					
Define					
Measure					
Analyze					
Improve					
Control					
Project finish					

6. Process and Boundary Development		
Process name	**Starting point**	**Ending point**
1		
2		
3		
4		

7. Input, Process and Output Measures

Input measures	Process measures	Output measures

8. Computing the Cost of Quality	
Currently measured	**Not measure—at this time**
Scrap:	Increased maintenance:
Warranty expense:	Lot sales:
Inspection costs:	Customer dissatisfaction:
Overtime:	Downtime:
	Engineering and product:
	Development errors:
	Bill of material inaccuracy:
	Rejected raw materials:
Internal failure	**Appraisal**
Scrap:	Inspection:
Rework:	Testing:
Supplier scrap:	Quality audit:
Supplier rework:	Initial cost and maintenance of test equipment:
External failure	**Prevention**
Cost to customer:	Quality planning:
Warranty cost:	Process planning:
Complaint adjustments:	Process control:
Returned material:	Training:

9. Six Key Areas to Address When Improving the Cost of Quality	
Key drivers	**Basic issue**
1. Basic organizational capabilities:	Skills and tools required to implement improvements in business processes are lacking.
2. Industrial process variations:	Poor industrial process capabilities result in high COPO (rework, scrap, field failure). Customer demands are frequently not passed on to engineering. Inefficient front-end engineering.
3. Business process variations:	Product cost estimation is often widely off the mark, resulting in poor financial performance and incorrect manufacturing decisions.
4. Engineering/design process and documentation	Engineering systems, design processes, and documentation are often inadequate and flawed.
5. Quality of specifications:	Specifications sent to suppliers/subcontrators vary considerably in their quality, resulting in poor-quality parts.
6. Supplier capabilities:	Lack of quality suppliers, resulting in poor-quality parts/services, late deliveries, higher parts/service costs, etc..

10. Checksheet Development

Name:		**Date:**
Defect type	Frequency	Comments

11. Data Collection Plan

What			Why	Who	How	When	Where
Needed measures	Operational definition	Formula or formulae	Purpose of data	Individual responsible for the collection	Method of selection	Date, time, or frequency	Source

12. FMEA Form

Process or product name:	FMEA team	Prepared by:	Original date:	Revised date:	Page __ of __	FMEA number:
Responsible:						

Process step	Potential failure mode	Effect	SEV	Class	Causes	OCC	Controls	DET	RPN	Actions received	Actions taken	SEV	OCC	DET	RPN

13. Repeatability and Reproducibility Study (Gauge R&R)—Long Form

Reapeatability and reproducibility data collection sheet

	1	2	3	4	5	6	7	8	9	10	11	12
Appraiser	A-				B-				C-			
Sample #	1st trial	2nd trial	3rd trial	Range	1st trial	2nd trial	3rd trial	Range	1st trial	2nd trial	3rd trial	Range
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
Totals												

	A	B	C
Sum			
Xbar			
$Rbar_A$ / $Rbar_B$ / $Rbar_C$			

$Rbar_A$	
$Rbar_B$	
$Rbar_C$	
$\bar{\bar{R}}$	

# Trials	D_4
2	3.267
3	2.574

$(\bar{\bar{R}}) \times (D_4) = UCL_R$*

(_) x (___) = ___

Max. Xbar	
Min. Xbar	
Rxbar	

* Limit of individual Rs. Circle those that are beyond this limit, identify the cause, and correct. Repeat these readings using the same appraiser and unit as originally used or discard values and reaverage and recompute R and the limiting value UCL_F from the remaining observations.

Notes ____

____

____

13. Repeatability and Reproducibility Report (cont.)

Part no. & name ______________ Gage name ______________ Date ______________

Characteristic ______________ Gage no. ______________ Performed by ______________

Specification ______________ Gage type ______________

From data sheet: $\bar{\bar{R}}$ = ________ Rxbar = ________

Measurement unit analysis

Repeatability error variation (RPT)

RPT = (R) x (K_1)

= (___) x (___) = ________

n = number of parts
r = number of trials

Trials	2	3
K_1	4.56	2.7

Reproducibility error variation (RPD)

RPD = (Rxbar) x (K_2)*

= (___) x (___)

= ________

Operators	2	3
K_2	3.56	2.7

Repeatability and reproducibility (R&R)

$$R\&R = \sqrt{(RPT)^2 \times (RPD)^2}$$

$$= \sqrt{(\_\_\_)^2 \times (\_\_\_)^2} = \_\_\_\_\_\_\_\_$$

Note: All calculations are based upon predicting 5.15 sigma (99% of the area under normal curve)

% Tolerance analysis

% RPT = 100 ((RPT)^2 / [(R&R) x (tolerance)])

= 100 ((___) / [9___) x (___)])

= ________

% RPD = 100 ((RPD)^2 / [(R&R) x (tolerance)])

= 100 ((___) / [9___) x (___)])

= ________

% R&R = (%RPT) + (%RPD)

= (___) + (___)

= ________

* A negative value under the square root sign causes the appraiser variation to default to zero.

13A. An Alternative Evaluation to the R&R—Long Form

Part no. & name ____________ Gage name ____________ Date ____________

Characteristic ____________ Gage no. ____________ Performed by ____________

Specification ____________ Gage type ____________

From data sheet: $\bar{\bar{R}}$ = ________ $\bar{X}_{Diff}$ = ________ R_p = ________

Measurement unit analysis	% Total variation

Repeatability - equipment variation (EV)

$EV = \bar{\bar{R}} \times K_1$

= ___ x ___

= ________

Trials	K_1
2	4.56
3	3.05

%EV = 100 x [EV / TV]

= 100 x [___ / ___]

= ___%

Reproducibility - appraiser variation (AV)

$AV = \sqrt{(\bar{X}_{Diff} \times K_2)^2 - (EV^2 / (n \times r))}$

$= \sqrt{(\_\_\_ \times \_\_\_)^2 - (\_\_\_^2 / (\_\_\_ \times \_\_\_))}$

= ________

Appraisers	2	3
K_2	3.65	2.70

%AV = 100 x [AV / TV]

= 100 x [___ / ___]

= ___%

n = number of parts
r = number of trials

Repeatability - reproducibility (R&R)

$R\&R = \sqrt{(EV^2 \times AV^2)}$

$= \sqrt{\_\_\_^2 \times \_\_\_^2}$

= ________

%R&R = 100 x [R&R / TV]

= 100 x [___ / ___]

= ___%

Parts	K_1
2	3.65
3	2.70
4	2.30
5	2.08
6	1.98
7	1.82
8	1.74
9	1.67
10	1.62

Part variation (PV)

$PV = R_p \times K_3$

= ___ x ___

= ________

%PV = 100 x [PV / TV]

= 100 x [___ / ___]

= ___%

Total variation (TV)

$TV = \sqrt{(R\&R^2 \times PV^2)}$

$= \sqrt{\_\_\_^2 \times \_\_\_^2}$

= ________

$R \times K_1$

All calculations are based upon predicting 5.15 sigma (99.0% of the area under the normal distribution curve).

K_1 is $5.15/d_2$, where d_2 is dependant on the number of trials (m) and the number of parts times the number of operators (g) which is assumed to be greater than 15. the d_2 values may be found in the *MSA* 3rd edition of the AIAG or Duncan's book on *Quality Control and Industrial Statistics*.

AV - If a negative value is calculated under the square root sign, the appraiser variation (AV) defaults to zero (0).

K_2 is $5.15/d_2$*, where d2* is dependant on the number of operators (m) and (g) is 1, since there is only one range calculation.

K_3 is $5.15/d_2$*, where d2* is dependant on the number of parts (m) and (g) is 1, since there is only one range calculation.

13B. Gage Repeatability and Reproducibility Report

Part no. & name ____________ Gage name ____________ Date ____________

Characteristic ____________ Gage no. ____________ Performed by ____________

Specification ____________ Gage type ____________

From data sheet: $\bar{\bar{R}}$ = ________ $\bar{X}_{Diff}$ = ________ R_p = ________

Measurement unit analysis	% Total variation
Repeatability - equipment variation (EV) $EV = \bar{\bar{R}} \times K_1$ = ___ x ___ = ________	$\%EV = 100 \times [EV / TV]$ = 100 x [___ / ___] = ___%
Reproducibility - appraiser variation (AV) $AV = \sqrt{(\bar{X}_{Diff} \times K_2)^2 - (EV^2 / (n \times r))}$ $= \sqrt{(\_\_\_ \times \_\_\_)^2 - (\_\_\_^2 / (\_\_\_ \times \_\_\_))}$ = ________ n = number of parts r = number of trials	$\%AV = 100 \times [AV / TV]$ = 100 x [___ / ___] = ___%
Repeatability - reproducibility (GRR) $GRR = \sqrt{(EV^2 \times AV^2)}$ $= \sqrt{\_\_\_^2 \times \_\_\_^2}$ = ________	$\%GRR = 100 \times [GRR / TV]$ = 100 x [___ / ___] = ___%
Part variation (PV) $PV = R_p \times K_3$ = ___ x ___ = ________	$\%PV = 100 \times [PV / TV]$ = 100 x [___ / ___] = ___%
Total variation (TV) $TV = \sqrt{(GRR^2 \times PV^2)}$ $= \sqrt{\_\_\_^2 \times \_\_\_^2}$ = ________	$ndc = 1.41 \times (PV/GRR)$ = 4.41 x [___ / ___] = ________

Trials	K_1
2	0.8862
3	0.5908

Appraisers	2	3
K_2	0.7071	0.5231

Parts	K_3
2	0.7071
3	0.5231
4	0.4467
5	0.4030
6	0.3742
7	0.3534
8	0.3375
9	0.3249
10	0.3146

For information on the theory and constants used in the form see *MSA Reference Manual*, 3rd edition. AIAG.

14. Repeatability and Reproducibility Study (Gauge R&R)—Short Form

Parts	Operator A	Operator B	Range
1			
2			
3			
4			
5			
		Sum of percentage	

D_2 values for distribution of R

Parts	2 operators	3 operators	
1	1.41	1.91	
2	1.28	1.81	
3	1.23	1.77	
4	1.21	1.75	
5	1.19	1.74	

R-bar = $\frac{\sum R}{n}$; RR error = $(\frac{\overline{R}}{d_2}) \times 5.15$; R&R = $\frac{RR\ Error}{Tolerance} \times 100\%$

15. Attribute Gage Study

Operation title:	Gage name:
Characteristics:	**Gage number:**

	Name	Data
Operator A		
Operator B		
Operator C		

Attribute Legend

A	Accept
B	Bad
D	Defect
G	Go
G	Good
NG	No go

Known attribute		Operator A		Operator B		Operator C		Score
Sample ID	Attribute	Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2	
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								

continued

15. Attribute Gage Study (cont.)									
Known attribute		**Operator A**		**Operator B**		**Operator C**		**Score**
Sample ID	Attribute	Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2	
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
Score via trial								
Score via operator								
Results summary:								
% appraiser effectiveness								
Operator A								
Operator B								
Operator C								
% Effectiveness								
Total								

16. 5S Observation Summary

5S summary report:		Score results: (X/100)
Shift:	Area/department:	
5S target objective:		
Historical 5S success(es):		
Priority items that need attention	**Existing situation: score**	**Future situation: score**
1		
2		
3		
4		
5		

17. Control Plan

Department:	Prepared by:	Page___ of ___	Document number:
Process:	Approved by:	Revision date:	Other:
Location:		Supercedes:	

Employee check	Character-istics	CTQ or critical level (CL)	Require-ment	Measure-ment methods	Sample size	Frequency	Who measures	Where recorded	Decision rule or corrective action	Reference number

18. Simplified Control Plan					
Project title:			**Date:**		
Task/action to be accomplished	Specific steps to be taken	Responsible person for task	Starting data	Finish date	Deliverables

19. Sources of Data				
	Y (CTQ)	X_1	X_2	X_n
Existing data				
Needed data				

20. Main Effect and Interaction Set Up

	Orthogonal array (set up of experiment with appropriate levels)			**Individual factors and or interactions**			**Response** (it may be a single or a multiple response)
Level effect +							
Level effect -							
Main effect difference							

21. Criteria Matrix (Evaluating Improvements)

Desirable criteria	**Alternatives**				
	Weights	Alternative 1		Alternative 2	
		Score	Weighted score	Score	Weighted score
	Totals				

22. A Form That May Be Used to Direct Effort and Resources

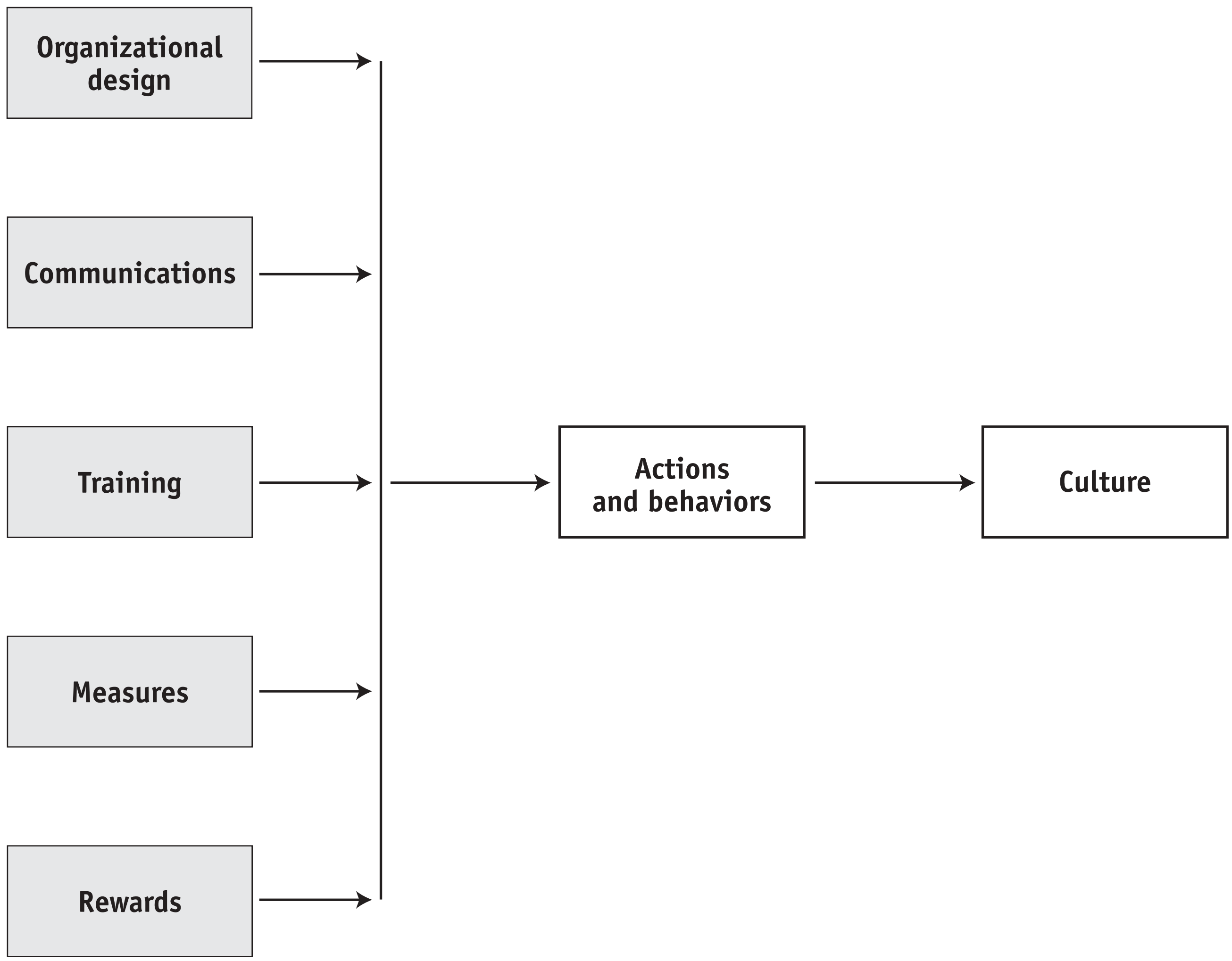
Part name:

Functional area	Present cost	High	Low
X			
Y			
Total cost			

23. Payoff Matrix

		Effort	
		Low	High
Benefit	High		
	Low		

24. Understanding Systems and Structures for the Six Sigma Methodology



25. Problem Statement

According to...	Definition of the problem	Unit of measure	Source of data/ Data type

26. Understanding the Operational Definition of the Problem

Problem statement and project definition (original):

Customer:

CTQs:

Nonconformance or variation (I will reduce…):

Data needed and units of measurement (relating to the nonconformance):

Current performance and reduction goal:

Potential benefits (COPQ):

Project scope, limits, and boundaries:

Potential team members:

Problem statement and project definition (final):

27. Gage Control Plan

Gage ID:	Department:	MSA reference:	Page ___ of ___
Gage name:	Gage location:	Calibration proceedure:	Document #:
Gage type:	Storage:	Date:	Revision #:

Baseline	Date	Resolution	Bias	Linearity	Calibration		GR&R		Remarks
					Date	By	%R&R	P/T	

28. Work Breakdown Structures (WBS)

Task #	Task name	Predecessor	Duration

29. Who Does What in the Project

Stakeholder	Wants, needs, and concerns	Relationship to the project					
		Impacted	Authority	Expertise	Influence	Resources	Other

30. How the Work Gets Done					
Who needs information	Message forum	Message frequency	Message goal	Best way to present message	Who delivers the message

31. Exploring the Values of the Organization	
Priority	**Description of what is valued**

32. Risk Identification & Mitigation

Risk element	Risk management	Risk score	Mitigation plan	

33. Competition Matrix

Customer needs	Priority	Competitor A	Competitor B	Best in class	Best in class performance
Total impact					

34. CTQ Matrix and Assessment of Design Risk

Customer needs	Importance	Performance	Measure-ment	Target	USL	LSL	Date type	Defect rate	Map to critical X	Impact on customer	Impact on company	Take away

35. Design Scorecard

CTQ	Measure-ment	Data type	Target	USL	LSL	Sigma	DPMO

36. Pugh Matrix				
CTQs & business needs	Pugh priority	Concept A	Concept B	Concept n
Sum of positives				
Sum of negatives				
Sum of sames				
Weighted positives				
Weighted negatives				
Next score				

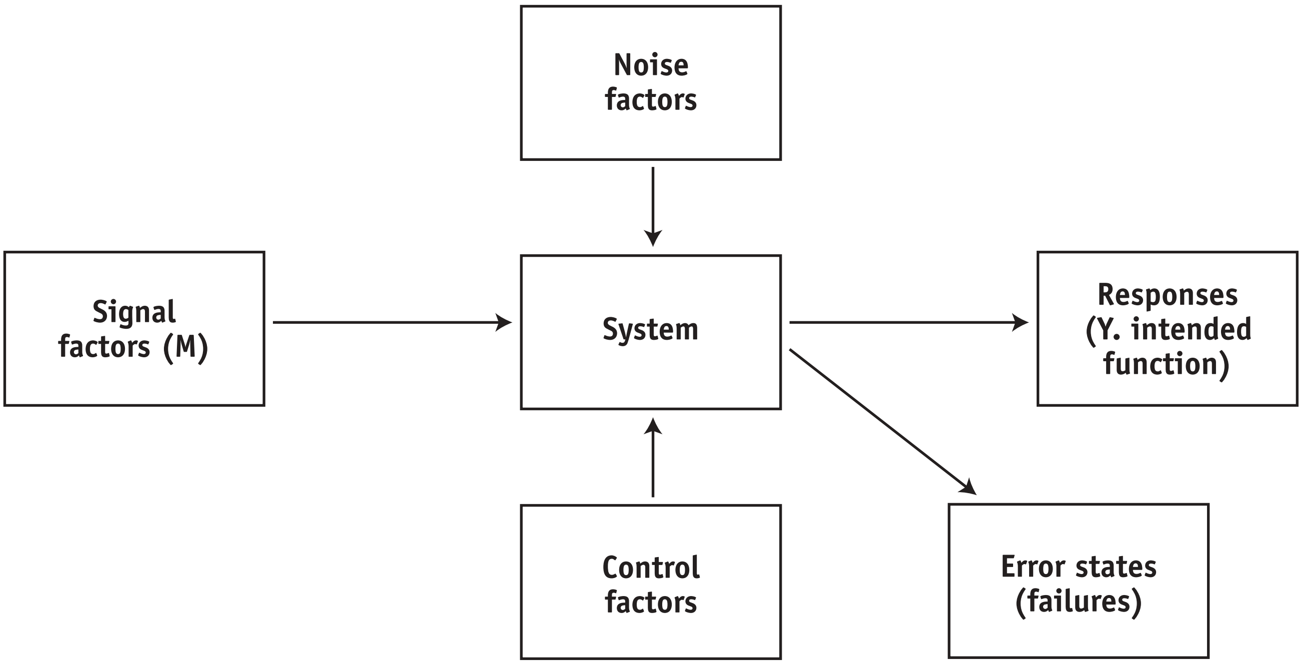
37. Scorecard: Critical to Satisfaction (CTS) Items

Project Description:

Date:

CTSs	Units	Range		Contribution to variability		Specs		Sample statistics			Z-score	
		Min.	Max.	Capability	%	LSL	USL	μ	σ	Conf.	σ shift	DPM

38. P-Diagram


Noise factors
Signal factors (M)
System
Responses (Y. intended function)
Control factors
Error states (failures)

39. Translating Language Data to Numeric Data		
Steps	**Language data**	**Numeric data**
Convert information to data		
Find the underline message		
Identify the structure		
Weighted positives		
Evaluate importance plan appropriate actions		

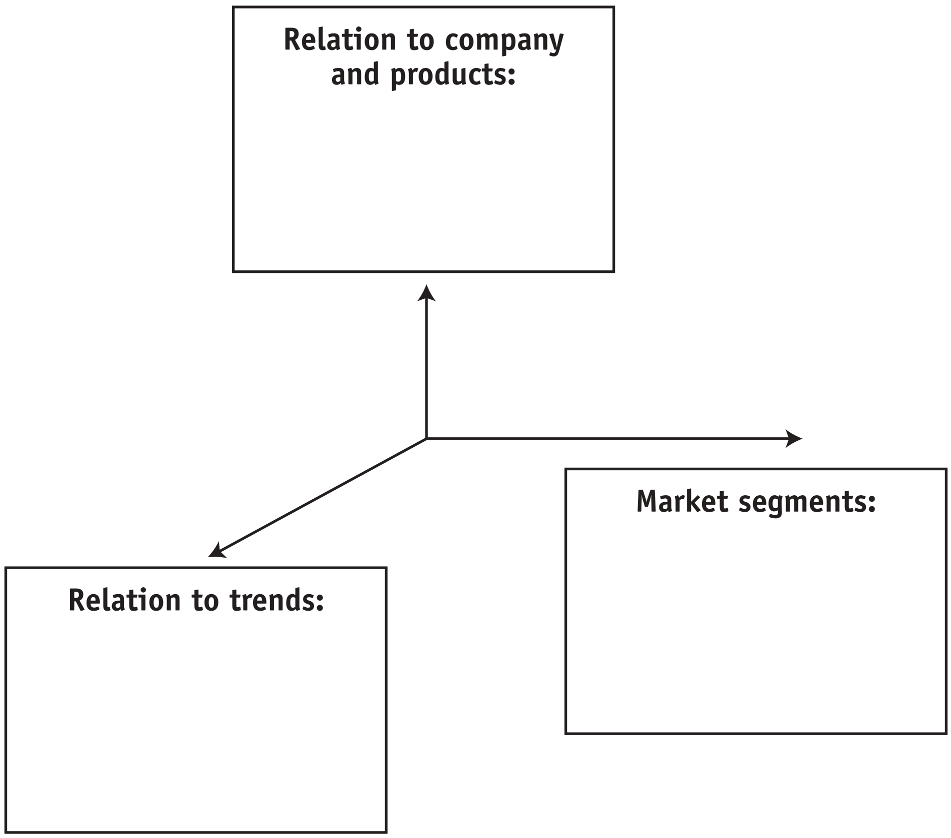
40. Brand Profiler							
Attribute	Attribute class	Priority	Primary brand positioning	Nameplate brand positioning	Program specifics		Present nameplate entry
					Target objectives	Status	
Usage experience							

Attribute differentiation:	Product attribute leadership strategy:

41. Status of Items Critical to Satisfaction and Relationship to Customer Satisfaction (may be used at each stage of the DCOV model)

CTS or surrogate	Units	T.F. or Y/N	Status		Competitor (BIC)		Target: initial			Target: aged			Customer satisfaction improvement
			μ	σ	μ	σ	μ	LSL	USL	μ	LSL	USL	

42. Customer Dimensions



43. Reliability and Robustness Checklist

Functional requirement life target (CTSs)	Design parameters (number and name)	Tests (number, name, and strategy)	Error states and their management

44. Design Verification (DV) Test Plan

Test (name, type, and frequency)	Objective	Expected results	Real outcome of test

45. Triple 5-Why Analysis Worksheet

For each root cause selected in step 5, use this table to determine technical, detection, and systematic root causes.

	Define problem										Root causes		Corrective Actions
1. Use this path for the technical root causes being investigated.		Why?		Why?		Why?		Why?		Why?		A	A. What was done to correct the problem?
	Ask "why" at least 5 times before accepting that you have reached the real root cause.												
2. Use this path to investigate why the problem was not detected.		Why?		Why?		Why?		Why?		Why?		B	B. What was one to improve detection?
	Examine the escape point in your process map to find the root cause for detection failure.												
3. Use this path to investigate the systematic root.		Why?		Why?		Why?		Why?		Why?		C	C. What was done to change the system?
	Apply this systematic root cause process during your System Prevent investigation.												

Lessons learned:

Investigated by: ______________________

Completed by: ______________________

46. Project Proposal Worksheet

Proposal name: **Black belt:**

Proposal #: **Date:**

Part name:			Carl lines affected:			Current function rating:	Proposed function rating:
Part number:			Volumes:			Current value ration:	Proposed value rating:
Present condition (please describe):			Proposal description:			Advantages:	
						Disadvantages:	
1. Cost savings per part—material	2. Cost savings—labor	3. Number of parts per vehicle	4. Annual volume	5. Lifetime volume	Weight reduction	Savings as % of piece cost	If all actions completed, implementation date:
6. Tooling cost	7. Engineering cost	8. Annual savings [(1+2)*3*4]	First year savings [8-(6+7)]	Lifetime savings [(1+2)*3*5-(6+7)]	Payback period (mos.): [(6+7)/8]^12	Evaluation rank (circle selection): Immediately OK Needs examination Not accepted Next iteration	

47. Action Plan Worksheet

Workshop subject: **Date:**
Proposal #:

	What needs to be done (be specific)	Who does it (name of person responsible)	Possible roadblocks (names of people most likely to get in the way)	How to overcome	Completion date	Cost to complete
Design						
Samples						
Evaluation & engineering judgement						
Tooling						
Other						

48. Cost/Function Worksheet

Blackbelts:	Project:	Customer requirements:	Workshop dates:

#	Part/ operation	Cost	Function (active verb/measurable noun)									
			1	2	3	4	5	6	7	8	9	10

49. Process Sequence Flowchart

Blackbelts:	Project:	Customer requirements:	Workshop dates:

#	Who does it What happens									Cost per event	Time per event	Labor rate

50. Cost Index Worksheet

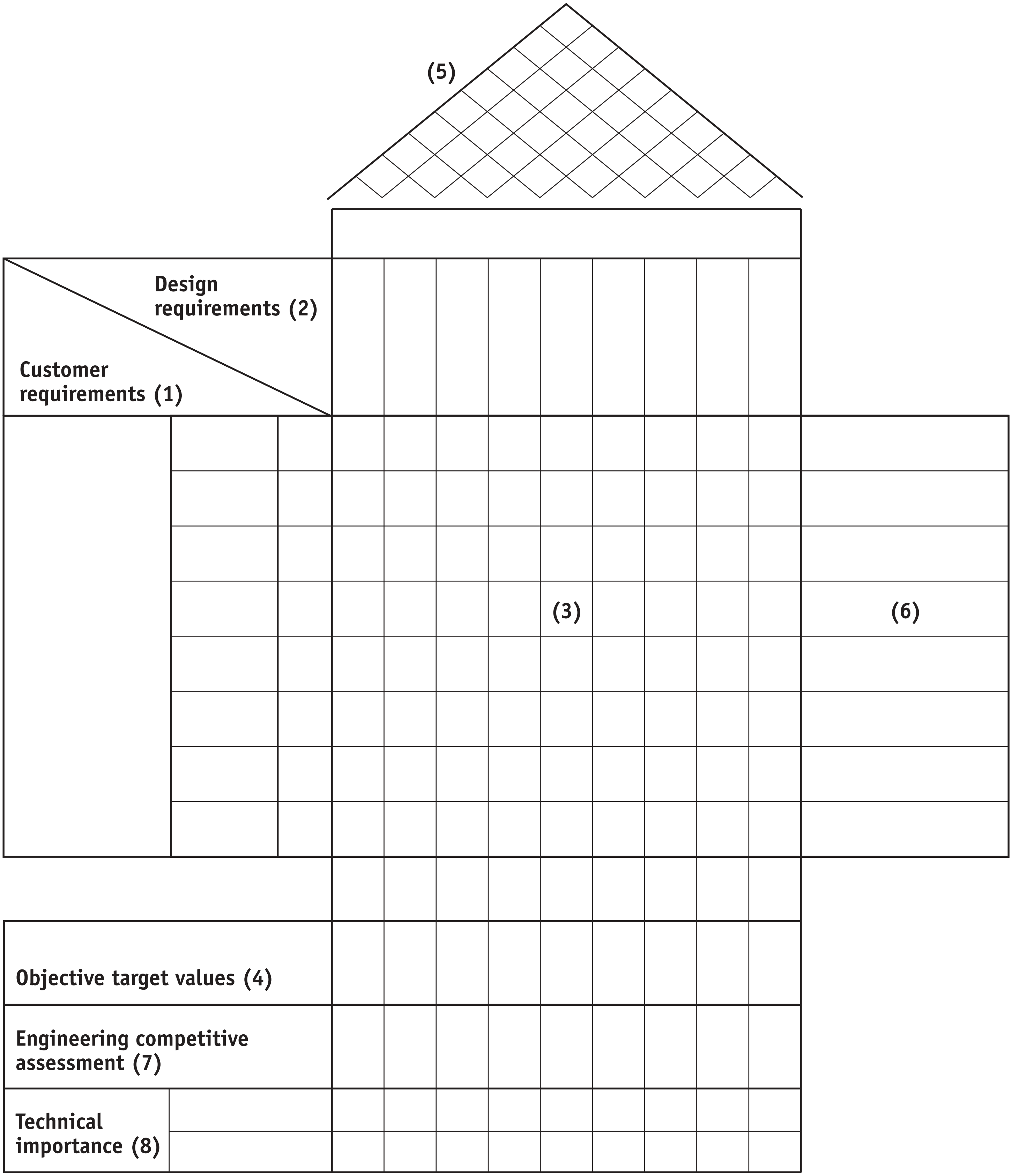
Team members:	**Project:**	**Customer needs:**	**Workshop date:**

Model / Component		Ours		Competitor 1		Competitor 2		Competitor 3		Competitor 4		Comments
Part	**Sketch** →											
	Material											
	Size											
	Weight											

51. Manufacturer Information Gathering Worksheet

Information required	Person responsible		Comment
	Manufacturer	OEM	
Bill of materials (complete parts list)			
Material cost			
Labor cost			
Freight & packaging costs			
Material flow/inventory costs			
Inspection costs			
Scrap & rework costs			
Any other cost components			
Original tooling costs			
Tooling capacity			
Standard volume			
Process description with detailed costs			
Video of process (mfg. & ass'y.)			
Process flow charts			
Plant layout drawings			
Detail part drawing			
Material specifications			
Assembly drawing			
Photos of parts and/or processes			
Competitive parts			
Test/government requirements			
Warranty information			
List of suppliers' suppliers' phone #s			
Invitation to employees & supervisors			
Conference room & equipment			

52. QFD Block Diagram



1. Customer requirements (focus on functionality) 2. Engineering requirements (based on customer's functionality) 3. Weighted relationship of customer functionalities 4. Realistic target goals 5. Relationship of engineering requirements 6. Competitive cost relationship 7. Engineering competitive evaluation 8. Technical priority

53. Function Identification Worksheet

Team members:	**Workshop dates:**
Project:	

Listing of functions performed

Active verb	Measurable noun

54. Function Diagram

Blackbelt(s):	**Company:**

Why? → ← How?

Project	**Date:**

55. Alternative Action Plan

Legend
I Initiate action and monitor performance
W Perform work
C Consultation required
R Review/comment/summarize/recommend
A Approve action or make decision
D Make final decision if "A's" do not agree
N Must be notified of decision

Title:

Objective:

Number:

Prepared by:

Date:

Number	Steps to be taken	Characteristic of step taken												Dates		Resources required or anticipated obstacles	
		A	B	C	D	E	F	G	H	I	J	K	L	Start	Stop		

56. Competitive Evaluation

Product/market:

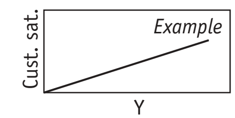
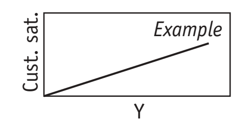
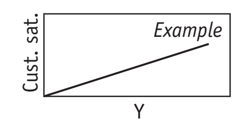
Please rank each company. 10 is best, 1 is worst.

Key reasons to buy		Weight	Company	Competitors		
				1	2	3

57. Critical to Satisfaction (CTS) Scorecard

Project description:

Status of critical to satisfaction (CTS) items and relationship to customer satisfaction

CTS metric[1]	Units	T.F.? Y/N	Status		Competitor/BIC		Target: initial condition			Target: aged			Associated customer satisfaction improvement	Customer satisfaction graphical view
			mean: μ	s.d.: σ	mean: μ	s.d.: σ	mean: μ	LSL	USL	mean: μ	LSL	USL		
														
														
														

[1] Include reference to test or procedure for obtaining this measurement.
Verification strategy will be captured in Reliability & Robustness Checklist.

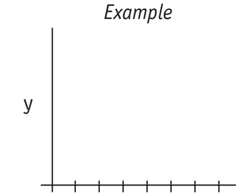
58. Design & Manufacturing Scorecard

Project description:

Performance Y or y		Transfer function		Specification			Estimated performance capability			6σ score			Actual capability		
Characteristic	Units	Y/N	Formula (below)	Target	LSL	USL	mean μ	s.d. σ	Confidence/ comments	z_{st}	σ shift	DPM_T	mean μ	s.d. σ	Confidence/ comments
				0							1.50				

Variables: y's or x's			Range		Contribution to variability		Specification		Sample/database statistics			6σ score			Capability: graphical view
No.	Characteristic	Units	Min.	Max.	Sensitivity	%	LSL	USL	mean μ	s.d. σ	Confidence/ comments	z_{st}	σ shift	DPM_T	____Prediction? ____Actual result?
1													1.50		
2													1.50		
3													1.50		
4													1.50		
5													1.50		
6													1.50		
7													1.50		
8													1.50		
9													1.50		
10													1.50		
11													1.50		
12													1.50		
13													1.50		
14													1.50		
15													1.50		
Variables: n's, or signals, etc.															
17															
18															
19															
20															
21															

Example



x-axis: variable such as speed, torque, temp, cycles, time, etc.

#REFI

#REFI

#REFI

#REFI

Cell shading key

- Enter data
- Enter formula (refer to cells J12, J13, ... representing x_1, x_2, ...)
- Do not enter data (ciruclation)
- Do not enter data (ciruclation)

Confidence ratings

High (H)	Mean & s.d. estimates based on cutomer-correlated model or same parts
Med (M)	Mean & s.d. estimates based on partial customer correlation or surrogate parts
Low (L)	Mean & s.d. estimates made without customer correlation or no process data available

Robustness assessment

Product	Range	mean: μ	s.d. : σ	S/N ratio	Beta
Present design					
Benchmark					
Process	**Range**	**mean: μ**	**s.d. : σ**	**S/N ratio**	**Beta**
Present design					
Benchmark					

Performance section

Transfer function: Y/N	Has transfer function been identified? Yes/No
Transfer function: Enter formula	Type in the Excel formula here, referring to the appropriate cells
Specification	Targets and spec limits based on customer needs
Estimated performance capability	Calculated using the transfer function and the listed means & s.d.'s of the variables

Variables section: y's: technical metrics; x's: control factors; n's: noise factors

Characteristics	Name of variable being measured
Units	Units in which the characteristic is measured
Range: min. & max.	Design range (range in which nominal values of the characteristic can be set) or range of the noise space
Contribution to variability:	
Sensitivity	Amount of change in performance with respect to change in variables, i.e., sensitivity of Δy Δx
%	Contribution of the characteristic to variability in the performance (y)

Variables section (cont.)

USL	Upper spec. limit
LSL	Lower spec. limit
mean	Sample average or assumed population mean
s.d.	Standard deviation (may include mfg. and/or usage variation)
Confidence/comments	Qualitative confidence rating for data: see Confidence Ratings table. Short/long-term indication
z	z-score calculated from USL, LSL, mean, and s.d.; z_{st} represents "unshifted," i.e. short term score
σ-shift	"Shift" of mean used in the DPM calculation; default is 1.5; (-1.5 for items with no USL)
DPM	Defects per million, calculated using the σ-shift indicated to represent defects over the "long term"
Graphical view	If performance over the range of some variable is important, include a graph such as the one shown
Robustness assessment	Results from steps D and E, indicate results using range, mean, and s.d., or S/N and Beta

59. Reliability and Robustness Demonstration Matrix

Program:	**Project:**	**System:**
Date:	**Team lead:**	**Supplier lead:**

Define requirements						**Design for robustness**				**Verify design**			
Qualify history analysis				SDS and/or DVP		VM condition [here we ID the high impact noise factors]		Critical metric	Range	Reliability demonstration			
Criteria	Component	High impact error state	VM number	VM description	VM target	Number	Name			Demonstrated result	Risk assessment	Issues	Finish date

60. Assessment of Six Sigma Status

Desired direction

Six sigma category	Manufacturing commitment	Obsession with excellence	Organization is customer driven	Customer satisfaction	Training	Employee involvement	Use of insentives	Use of tools
5	Is continual improvement a natural behavior even for the routine tasks?	Is there a constant improvement in quality, cost, and productivity?	Is the primary goal to satisfy the customer?	Are customer maintaining a long term relationship?	Is appropriate and applicable training available among employees?	Are employees proud to participate? Are employees self directed? Are effective teams utilized in appraising and preventing of problems?	Are incentives appropriate and applicable for the entire team?	Is statistics used as a common language throughtout the organization?
4	Is focus on improving the system?	Are cross functional teams used?	Is customer feedback used in decision making?	Is improvement for value to the customer inherent in all routine behaviors of management?	Is top management aware of the six sigma methodology and apply it appropriately?	Is manager the key decision with employees following his lead?	Are incentives appropriate and applicable for individuals in the team?	Is it at least some statistics and SPC used?
3	Is appropriate resources applied to training?	Is six sigma supported by executives and managers?	Are appropriate and applicable tools and methodologies identified and used for identifying the wants, needs in the design?	Is there a verification of using the customer's feedback to improve processes and/ or complaints?	Are there ongoing training proposals?	Is the manager asking for input before a decision is made?	Is there a quality related selection and promotion criteria for employees?	Is it at least some SPC used to reduce variation?
2	Is there a policy of balancing long term goals with short term objectives?	Is there an executive steering committee set up? Is there a Champion for specific areas designated?	Are you sure that the customer's wants and needs are known?	Do you know how the customer is rating you?	Is there a big picture training plan developed?	Is the manager the key person for decision making? Is the manager the person who decides and then asks his employees for ideas?	Is there an effective employee suggestion program in place?	Is it at least some SPC used in key processes?
1	Traditional approach to quality control—very ineffective Emphasis is on inspection Quality is found only in manufacturing facilities.							

Benchmarking matrix

The desired direction is always at the higher level.
For your organization you may modify this to reflect your own needs.

61. A Typical Design FMCA Form

Part number (1):	**Production release date (4):**
Assembly number (2):	**Page (5): ___of ___**
Responsible engineer (3):	**Date (6):**

Line number (7)	Cross-reference number (8)	Circuit location (9)	Enter the part/ component number/ name (10)	Function(s) & specification(s) (11)	Potential failure mode(s) (12)	System effect (0=unsafe conditions) (13)	Unsafe (14)	Cause(s) of failure (15)	Internal or external counter measures (controls) (16)	Severity (17)	Base failure rate λB (18)	Failure mode ration (19)	Effectiveness (20)	Risk priority number (RPN) (21)

Where:

1. Part number. Enter the part number under consideration
2. Assembly number. Enter the number on the part or drawing or part list.
3. Responsible engineer. Enter the name of the responsible engineer.
4. Production release date. Enter the date the product is to be released for production.
5. Page. Enter the FMCA page number.
6. Date. Enter the date the page was worked on. Or, enter the revision date, if it is a revised FMCA.
7. Line number. Identify the part for which the FMCA is to be conducted.
8. Crossreference number. Enter the number if there is a crossreference with other parts or assemblies.
9. Circuit location. Describe the location of the part on the circuit.
10. Enter the part/component number/name. Enter the appropriate name.
11. Function(s) and specification(s). Describe the funtion(s) the part is to perform and the specification(s) required. Make the description as clear and concise as possible. Be sure you include all functions. Include pertinent information about the product specification, such as operating current range, operating voltage range, operating environment, and everything else that is applicable and appropriate.
12. Potential failure mode(s). A failure mode is a design flaw or change in the product which prevents it from functioning properly. The typical failure modes are a short circuit, open circuit, leak, loosening. The failure mode is expressed in physical terms of what the customer will experience.
13. System effect. The system effect is what a system or a module might experience as a result of the failure mode. List all conceivable effects, including unsafe conditions or violations of government regulation. A typical system effect is a system shut down or a failure of a section of the product.
14. Unsafe. Enter 0 for unsafe end product condition.
15. Cause of failure. The ROOT CAUSE—not the symptom—is the real cause. Examples: insufficient/inaccurate voltage, firmware errors, missing instruction on drawings.
16. Internal or external counter measures (controls). Identify the controls and/or measures established to prevent or detect the cause of the failure mode. Examples: perform a derating analysis, perform transient testing, perform specific testing, identify specific inspection and manufacturing specifications.
17. Severity. An estimate of how severe the sub-system and/or the end product will behave as a result of a given failure mode. Severity levels are being scaled from 1 to 10. Number 10 is to be used for a definite unsafe condition, and number 0 is to be used for a neglibible severity (nuisance). Usually this rating, at this stage, is very subjective rating.
18. Base failure rate (λB). A subjective estimate of failure rate (probability of failure in a billion hours). This is also called inherent failure rate.
19. Failure ratio. A subjective likelihood in comparison to the other failure modes. The sum of all failure rates for a part/component should be equal to 10 percent.
20. Effectiveness. A subjective estimate of how effectively the prevention or detection measure eliminates potential failure modes. A typical ranking is the following:
    - 1 = The prevention or detection measure is foolproof.
    - 2-3 = Probability of failure occurrence is low.
    - 4-6 = Probability of occurrence is moderate.
    - 7-9 = Probability of occurrence is high.
    - 10 = Very high probability. The prevention/detection measure is ineffective.
21. Risk priority number (RPN). The product of severity, base failure rate, failure mode ratio, and effectiveness.

62. A Typical Process FMCA Form

Operation name (1):	Sub-assembly number (4):	Production release date (7):
Work station (2):	Supplier (5):	Page (8): ___of ___
Responsible engineer (3):	Original date (6):	Revised date (9):

Line number (10)	Cross-reference number (11)	Circuit location (12)	Enter the part/ component number/ name (13)	Operational steps (14)	Potential failure mode(s) (15)	Cause(s) of failure (16)	Internal or external counter measures (controls) (17)	Severity (18)	PPM (19)	Effectiveness (20)	Risk priority number (RPN) (21)

Where:

1. Operation name. Enter the name of the operation
2. Work station. Enter the name or number of the work station.
3. Responsible engineer. Enter the name of the responsible engineer.
4. Sub-assembly number. Enter the sub-assembly name or number.
5. Supplier. Indicate where the process is performed.
6. Original date. Enter the date that the FMCA is due and or completed.
7. Production release date. Enter the date the product is to be released for production.
8. Page. Enter the FMCA page number
9. Revised date. Enter the date of the revision date.
10. Line number. Identify the part for which the FMCA is to be conducted.
11. Crossreference number. Enter the number if there is a crossreference with other parts or assemblies.
12. Circuuit location. Describe the location of the part on the circuit.
13. Enter the part/component number/name. Enter the appropriate name.
14. List all steps of operation in the process. A good tool to use for this is the Process Flow Diagram.
15. Potential failure modes(s). A process-related failure mode is a deviation from specification caused by a change in the variables influencing the process. Examples: damaged board, misaligned, discolored, missing, bent, etc.
16. Cause of failure. The ROOT CAUSE—not the symptom—is the real cause of the failure. Examples: transient, human error, machine out of tolerance, ESD equipment failure.
17. Internal or external counter measures (controls). Identify the controls and/or measures established to prevent or detect the cause of the failure mode. Examples: verify tooling to its specification, effective incoming inspection, testing, etc.
18. Severity. A subjective estimate of how severe the sub-system and/or the end product will behave as a result of a given failure mode. Severity levels are being scaled from 1 to 10. Number 10 is to be used for a definite unsafe condition, number 1 is to be used for a negligible severity (nuisance).
19. PPM. The percent failure per 1 million parts.
20. Effectiveness. A subjective estimate of how effectively the prevention or detection measure eliminates potential failure modes. A typical ranking is the following:
    - 1 = The prevention or detection measure is foolproof.
    - 2-3 = Probability of failure occurrence is low.
    - 4-6 = Probability of occurrence is moderate.
    - 7-9 = Probability of occurrence is high.
    - 10 = Very high probability. The prevention/detection measure is ineffective.
21. Risk priority number (RPN). The product of severity, PPM, and effectiveness.

63. Dynamic Control Plan with FMEA

Company: ______________________
Division/plant: ______________________
Department: ______________________
Process: ______________________
Operation: ______________________
Machine: ______________________
Station: ______________________

Part name: ______________________
Part number: ______________________
Contol plan orig. date: ______________________
FMEA orig. date: ______________________
Control plan rev. date: ______________________
FMEA rev. date: ______________________
Page ___ of ___ pages

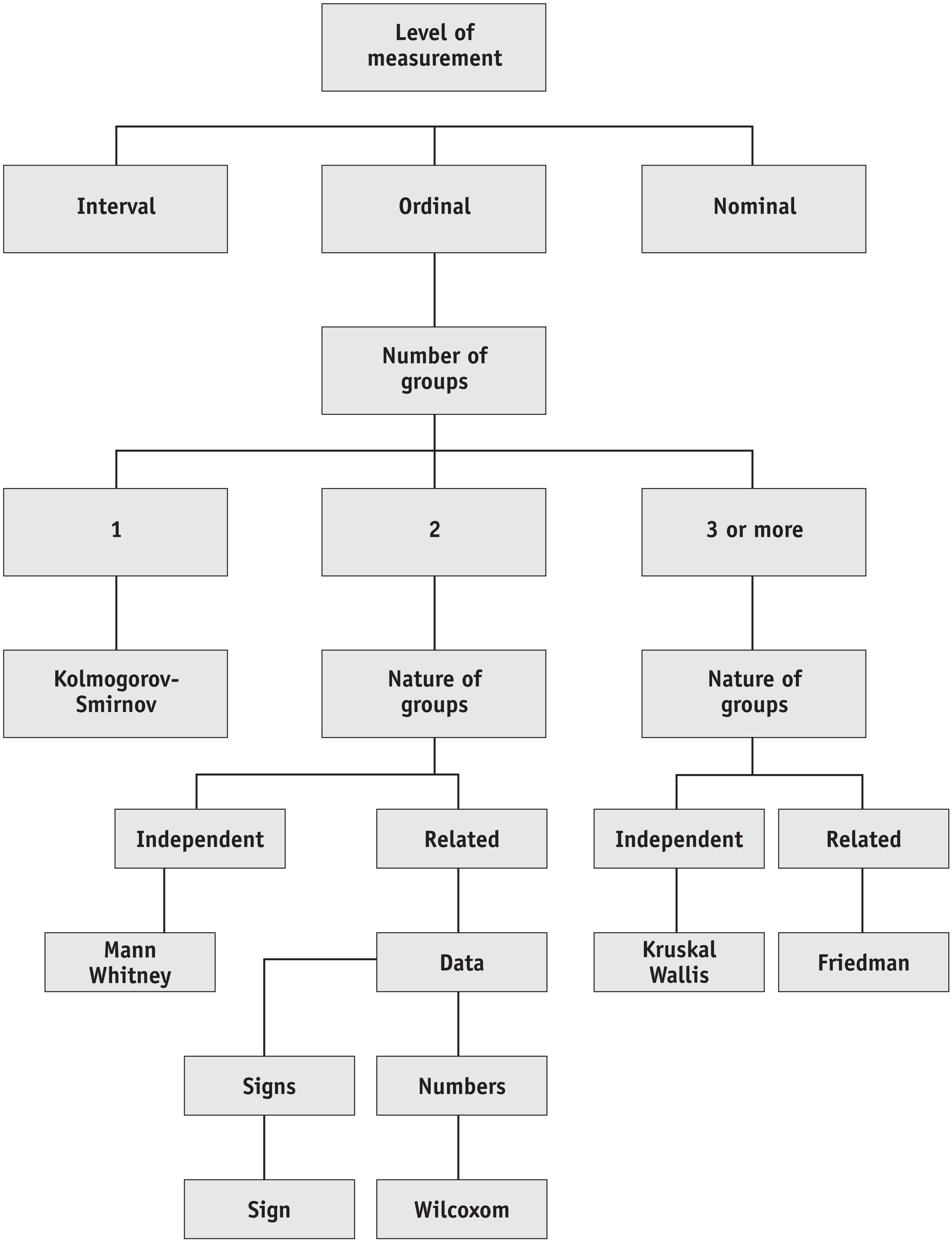
Authorized control plan by: ______________________
Authorized FMEA by: ______________________
Contol plan leader: ______________________
FMEA leader: ______________________
FMEA members: ______________________
____
____

Char #	Charac-teristic description (product & process)	Spec	Type	IMP	Failure mode	Effects of failure	SEV	Causes of failure	OCC	Current controls	DET	RPN	Recom-mended actions	Actions taken	SEV	OCC	DET	RPN	Respon-sible person	Control factor	Class	Contol method	Tool	Gage, desc., master, detail	Other*

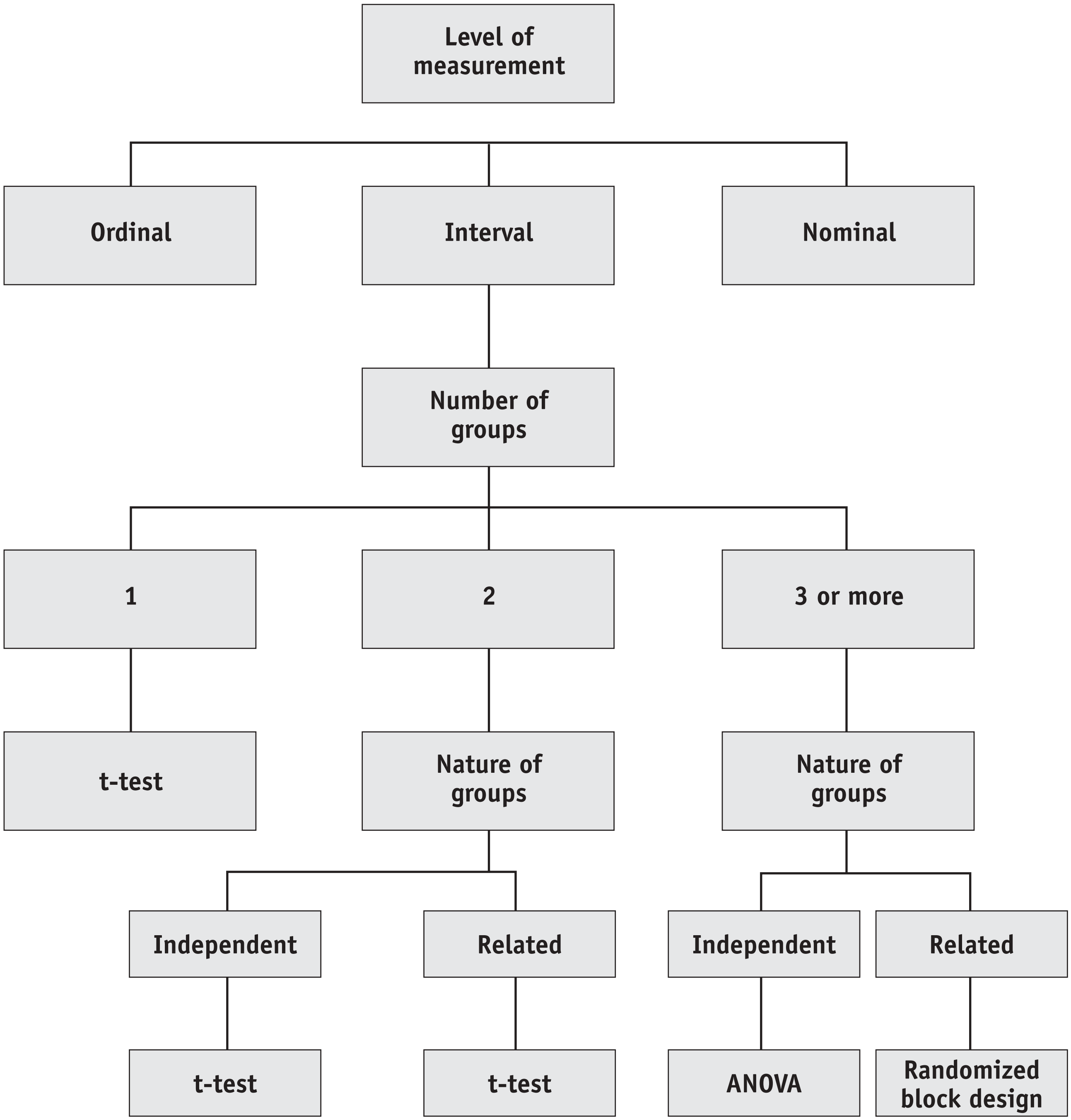
*Typical other items may include:

GR&R & date	Cp/cpk (target) & date	Reaction plans	Inpection requirements	Sampling requirements

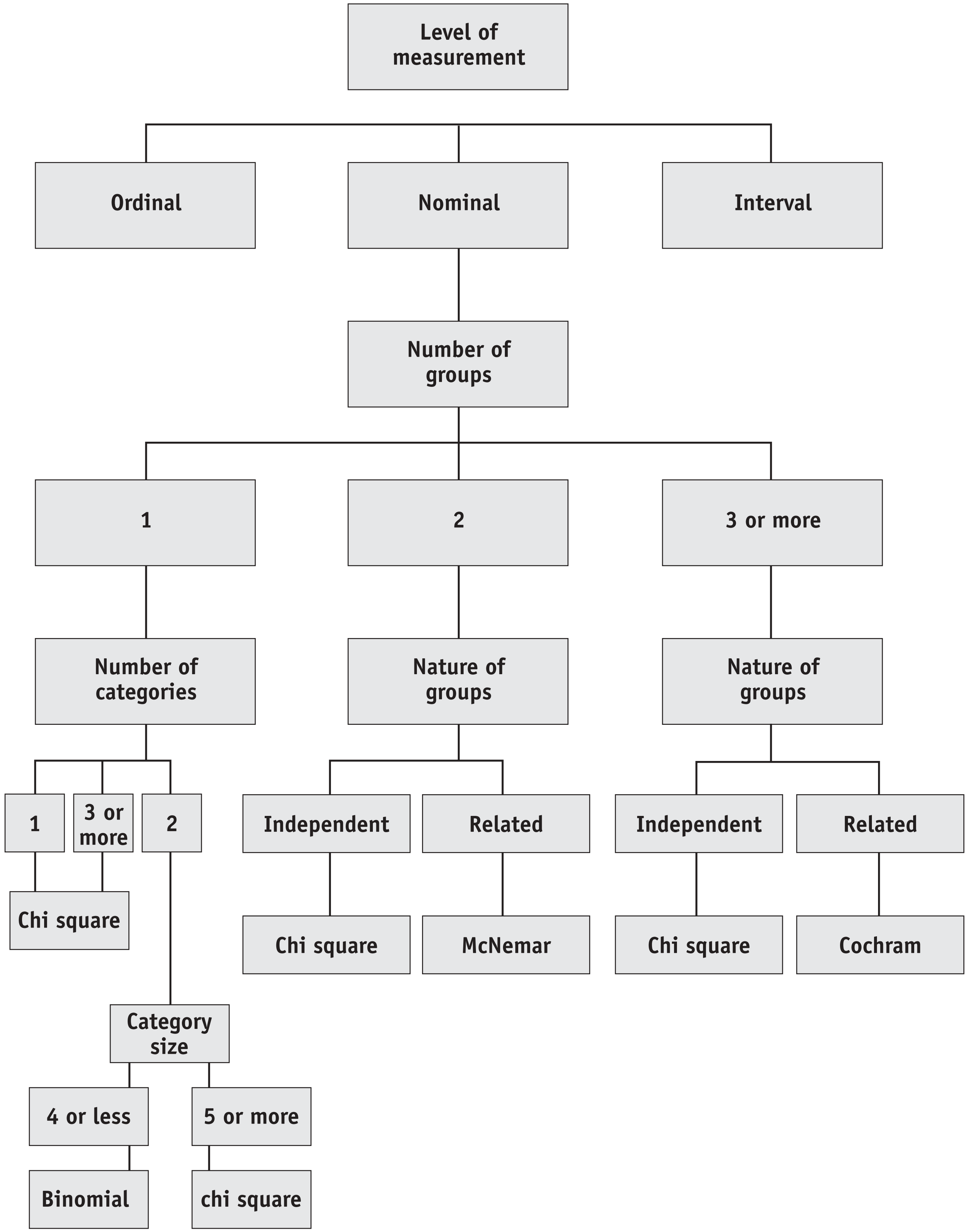
64. Selection of Statistical Techniques Based on Ordinal Data



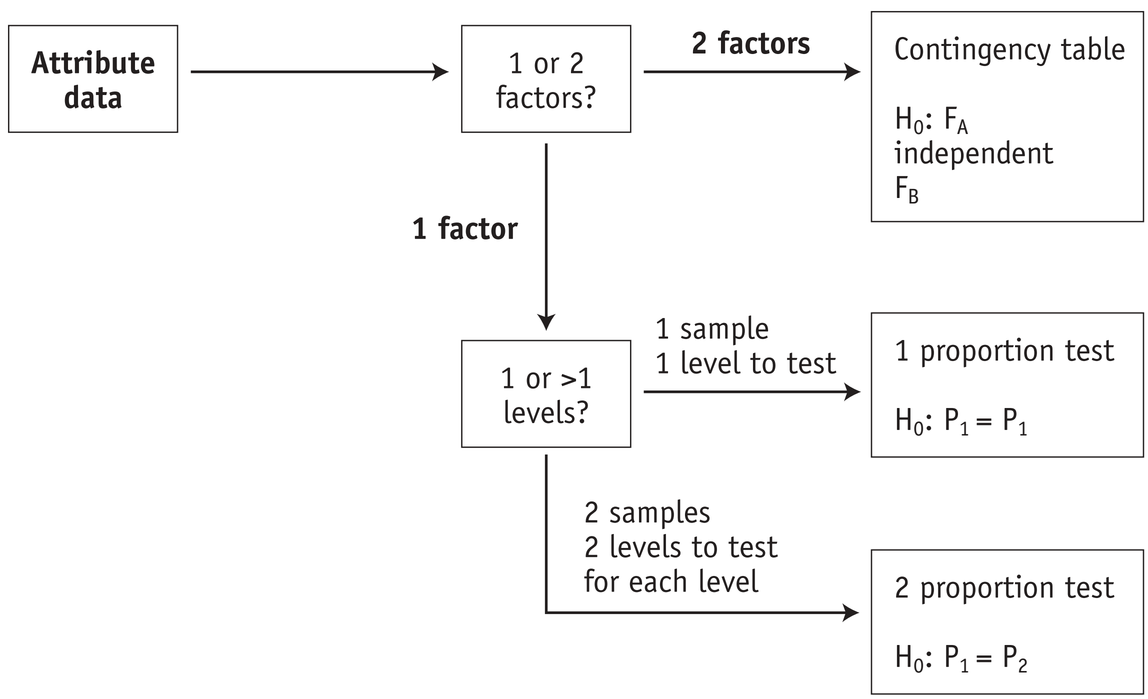
65. Selection of Statistical Techniques Based on Interval Data



66. Selection of Statistical Techniques Based on Nominal Data



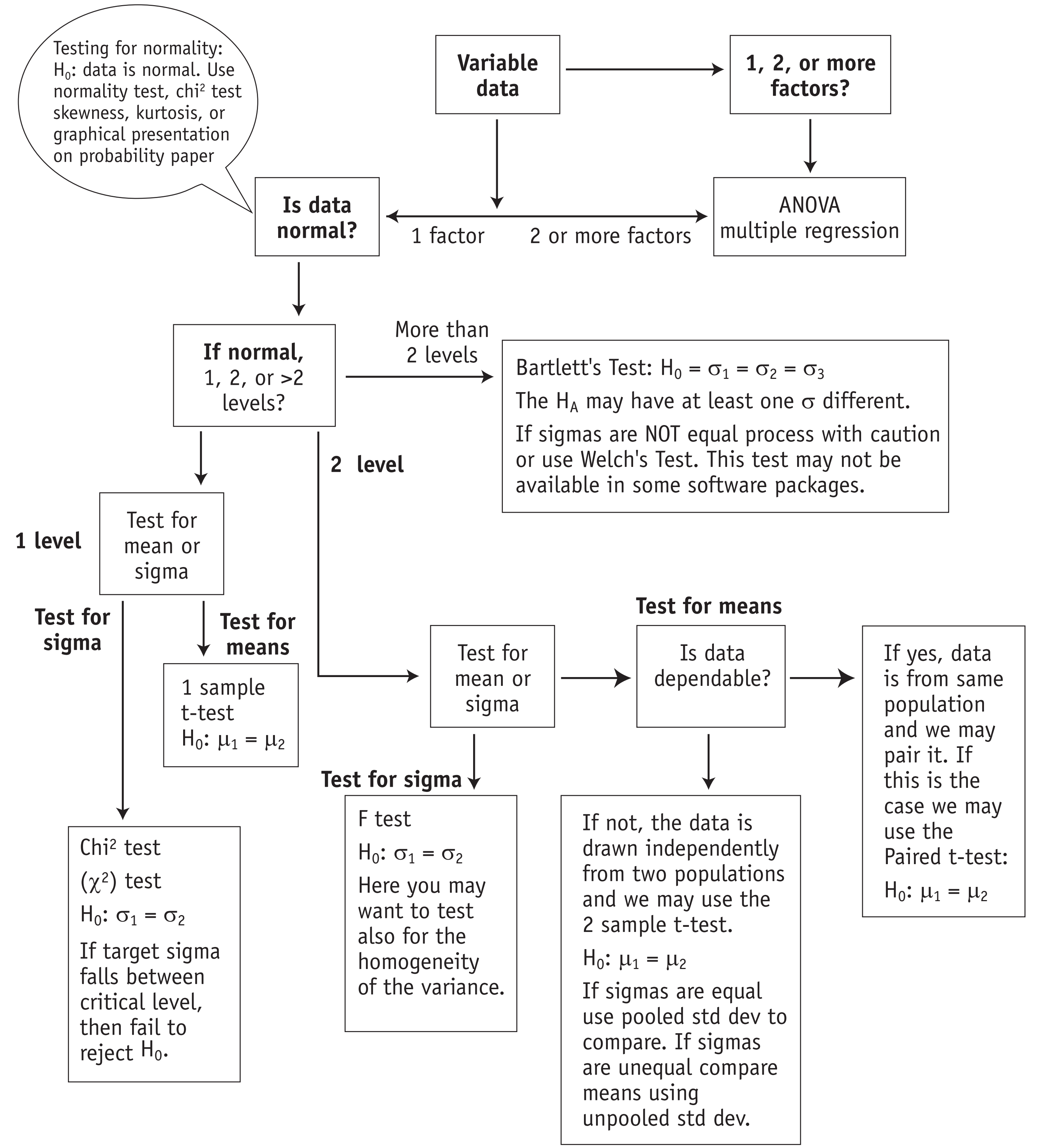
67. Hypothesis Testing Roadmap



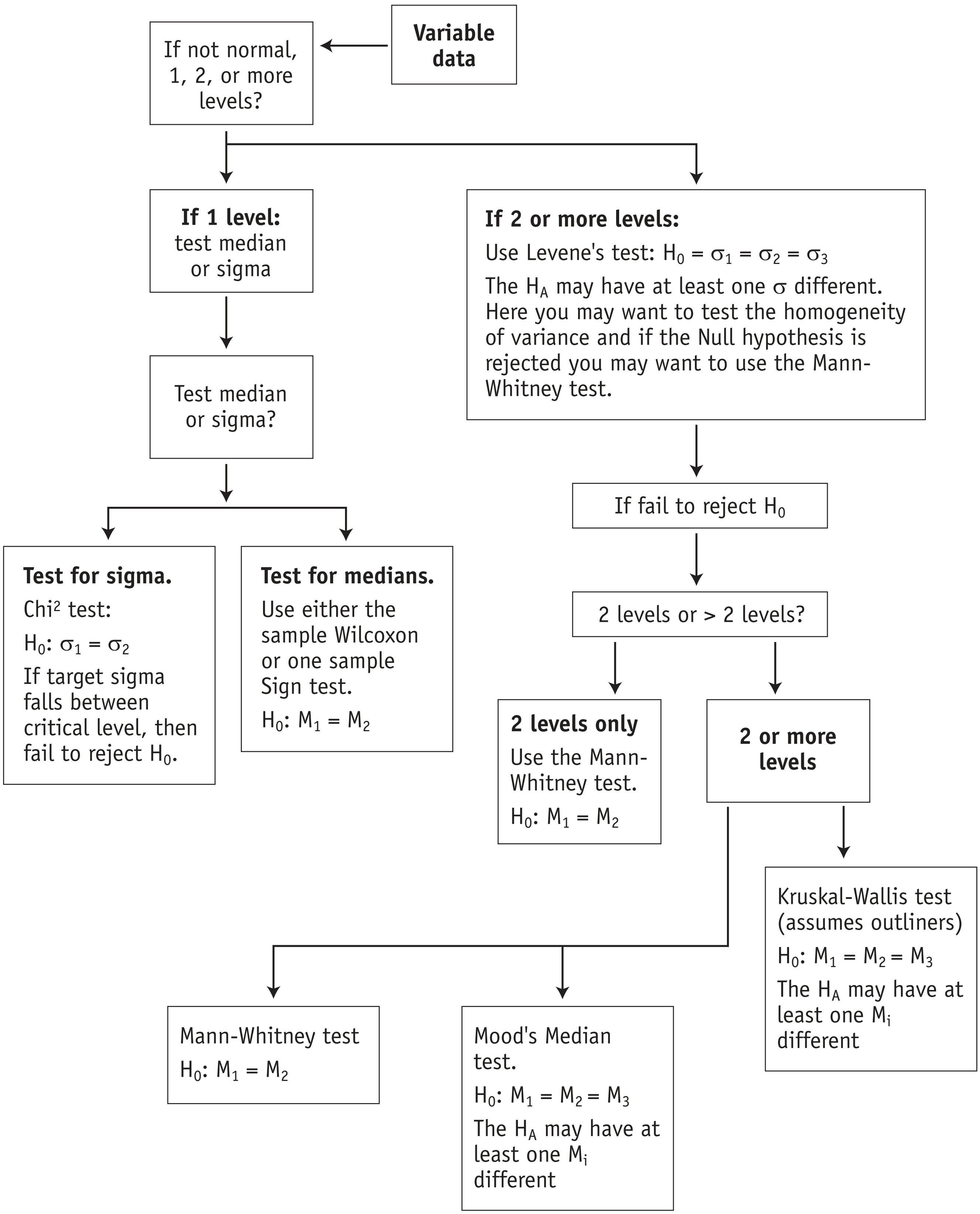
Special note: In all case of hypothesis testing the evaluation is based on the level of probability set on a *a-priori* bases. Usually that is set on a p or alpha (α) = .05, 01, or .001 with the appropriate sample size.

The actual evaluation is: If p value is greater than the *a-priori* criteria, then we fail to reject the Null (H_0) hypothesis. If p value is less than the *a-priori* criteria we then reject the null hypothesis. In all cases make sure that the evaluation is based on a *a-priori* criteria and not on a *post priori* visual inspection of the results.

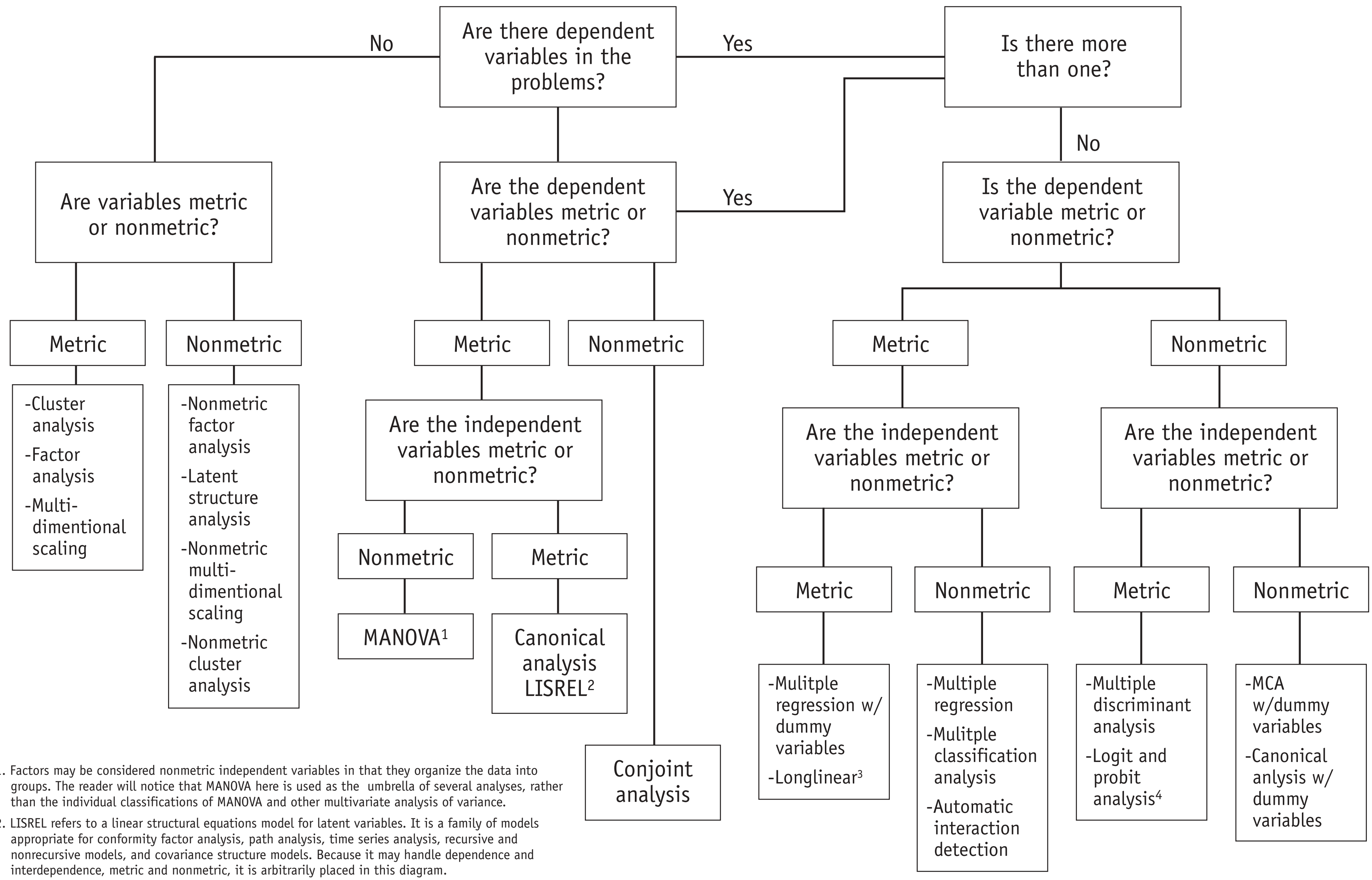
67. Hypothesis Testing Roadmap (cont. a)



67. Hypothesis Testing Roadmap (cont. b)



68. A Selection Guide for Some Common Multivariate Techniques



1. Factors may be considered nonmetric independent variables in that they organize the data into groups. The reader will notice that MANOVA here is used as the umbrella of several analyses, rather than the individual classifications of MANOVA and other multivariate analysis of variance.
2. LISREL refers to a linear structural equations model for latent variables. It is a family of models appropriate for conformity factor analysis, path analysis, time series analysis, recursive and nonrecursive models, and covariance structure models. Because it may handle dependence and interdependence, metric and nonmetric, it is arbitrarily placed in this diagram.
3. The dependent variable is matric only when we consider that the number of cases in the crosstabulation cell are used to calculate the logs.
4. The independent variable is matric only in the sense that a transformed proportion is used.

69. The Process of Problem Solving—Concern Analysis

Process steps	1. Major or complex concern	2. Sub-concern breakdown	3. Potential impact	Timing	Trend	4. Determine process
1. List concerns 2. Breakdown into precise manageable sub-concerns 3. Prioritize: –Impact: $ lost, organizational effects –Timing: Who's deadlines can we do nothing about? –Trend: Is it stable, predictable, consistant? 4. Determine process: –Past: Cause problem solving –Now: Choice decision making –Future: Implement planning	**A.**					
	B.					
	C.					

70. The Process of Problem Solving—Problem Solving

1. Problem statement:

2. Description and or questions	What is a problem	What is not a problem	3. Differences about the IS (for only new and relevent data)	4. Changes about the differences	Date
What: is the nonconforming object? is the nonconformance? ***Where:*** is the nonconformance object observed? on the object is the observed nonconformance? ***When:*** in the life cycle of the object does the nonconformance occur? are the nonconforming objects observed? If so, how and when? what is the pattern? ***Magnitude:*** How many objects are nonconforming? How much of the objects are nonconforming? What is the trend, if any?					

5. Potential causes from changes and differences:

6. Examine potential causes against each is and is not for most likely cause (make sure you list as many inconsistancies and assemptions):

7. Document cause either through a cause and effect diagram or:

Who: ____________________

How: ____________________

Where: ____________________

When: ____________________

71. The Process of Problem Solving—Decision Making Alternatives

1. Decision statement:

2. Objectives			**5. Alternatives**								
			A			**B**			**C**		
3. Required from objective sheets or planning summary sheets			*Data:*	**6. Yes/no**		*Data:*	**6. Yes/no**		*Data:*	**6. Yes/no**	
Process steps	*Desired*	**4. Value**	*Data:*	**7. Score**	**8. Value score**	*Data:*	Score	Value score	*Data:*	Score	Value score
4. Value the desired objectives from 10-1 scale 5. Estimate alternatives 6. Test alternatives against required objectives (yes/no) 7. Score alternatives against each desired objective 8. Multiply value x score = value score 9. Add all value scores											
				9. Total value score			**9. Total value score**			**9. Total value score**	

72. The Process of Problem Solving—Decision Making Risks

1. Potential alternative	**Alternative A**			**Alternative B**				
Process Steps	**2. Risks**	**3. Likelihood**	**4. Impact**	Risks	Likelihood	Impact	**5. Assess impact**	**6. Prioritize and select best alternative**
1. List highest value score alternatives 2. List risks if we go with a particular alternative 3. Assess likelihood of each risk occuring based on high, medium or low level 4. Assess impact of each risk if occurs based on high, medium, or low level 5. Identify items with both likelihood and impact as high 6. Select best alternative for benefit versus risks								

73. The Process of Problem Solving—Planning

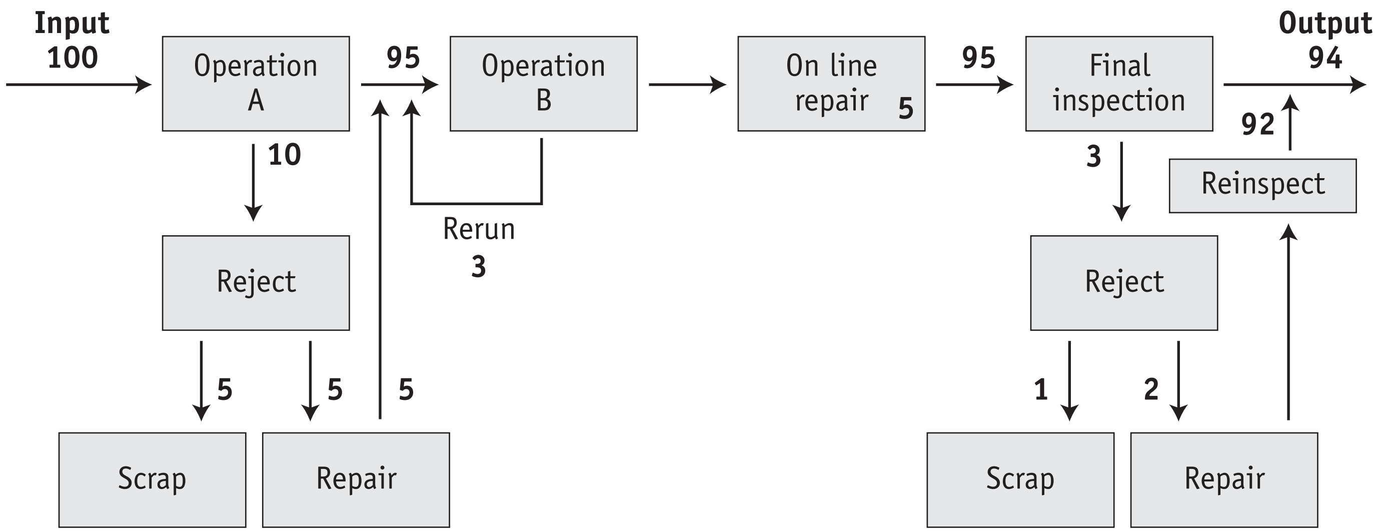
1. Plan statement:

Process Steps	**2.** Components and or steps	**3.** Set in chronological order	**4.** Precise potential problems of vital components	**5.** Precise potential problems of vital components	**6.** Likelihood	Impact	**7.** Probable cause(s)	**8.** Likelihood H-M-L	**9.** Plan for preventive action against cause(s)	**10.** Plan for contingent action against the precise potential problem's effects	**11.** Feedback points assign individually, date and system
2. List component or steps of plan 3. Number components in chronological order 4. Identify vital components (root cause(s) that will most likely cause us to fail) 5. Identify precise potential probability of vital components 6. Assess each precise potential probability for likelihood and impact 7. Probably cause(s) of precise potential problems 8. Assess likelihood of each probable cause 9. Plan for preventive action 10. Plan for contingent action 11. Feedback points (who, when, and how of progress reporting)											

74. Control Chart Constants											
Sample size	Estimating σ_x			X Chart		Median Chart	Individual X Chart	R Chart		s Chart	
n	d_2	d_3	c_4	A_2	A_3	A_2	E_2	D_3	D_4	B_3	B_4
2	1.128	0.853	0.7979	1.880	2.659	1.880	2.660	0.000	3.267	0.000	3.267
3	1.693	0.888	0.8862	1.023	1.954	1.187	1.772	0.000	2.574	0.000	2.568
4	2.059	0.880	0.9213	0.729	1.628	0.796	1.457	0.000	2.282	0.000	2.266
5	2.326	0.864	0.9400	0.577	1.427	0.691	1.290	0.000	2.114	0.000	2.089
6	2.534	0.848	0.9515	0.483	1.287	0.548	1.184	0.000	2.004	0.030	1.970
7	2.704	0.833	0.9594	0.419	1.182	0.508	1.109	0.076	1.924	0.118	1.882
8	2.847	0.820	0.9650	0.373	1.099	0.433	1.054	0.136	1.864	0.185	1.815
9	2.970	0.808	0.9693	0.337	1.032	0.412	1.010	0.184	1.816	0.239	1.761
10	3.078	0.797	0.9727	0.308	0.975	0.362	0.975	0.223	1.777	0.284	1.761
11	3.173	0.787	0.9754	0.285	0.927		0.945	0.256	1.744	0.321	1.679
12	3.258	0.778	0.9776	0.266	0.886		0.921	0.284	1.716	0.354	1.646
13	3.336	0.770	0.9794	0.249	0.850		0.899	0.308	1.692	0.382	1.618
14	3.407	0.762	0.9810	0.235	0.817		0.881	0.329	1.671	0.406	1.594
15	3.472	0.755	0.9823	0.223	0.789		0.864	0.348	1.652	0.428	1.572
16	3.532	0.749	0.9835	0.212	0.763		0.849	0.364	1.636	0.448	1.552
17	3.588	0.743	0.9845	0.203	0.739		0.836	0.379	1.621	0.466	1.534
18	3.640	0.738	0.9854	0.194	0.718		0.824	0.392	1.608	0.482	1.518
19	3.689	0.733	0.9862	1.187	0.698		0.813	0.404	1.596	0.497	1.503
20	3.735	0.729	0.9869	0.180	0.680		1.803	0.414	1.586	0.510	1.490
21	3.778	0.724	0.9876	0.173	0.663		0.794	0.425	1.575	0.523	1.477
22	3.819	0.720	0.9882	0.167	0.647		0.786	0.434	1.566	0.534	1.466
23	3.858	0.716	0.9887	0.162	0.633		0.778	0.443	1.557	0.545	1.455
24	3.895	0.712	0.9892	0.157	0.619		0.770	0.452	1.548	0.555	1.445
25	3.931	0.709	0.9896	0.153	0.606		0.763	0.459	1.541	0.565	1.435

75. An Example of First Run Capability

You may want to use this to identify the "hidden factory"



Where:

N = Number of input pieces, units, transactions = 100

W = Waste

Operation A scrap	5
Operation A repair	5
Operation B rerun	3
On line repair	5
Final inspection:	
Scrap	1
Repair	2
Total W	**21**

Therefore,

FRC = {(N-W)/N} X 100% = {(100-21)/100} X 100% = 79%

76. Guide for Choosing Control Charts