THE SIX SIGMA YELLOW BELT PRIMER

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Six Sigma Introduction (Continued)

Figure 2.1 illustrates the ±1.5 sigma shift and Table 2.2 provides some indications of possible defect levels.

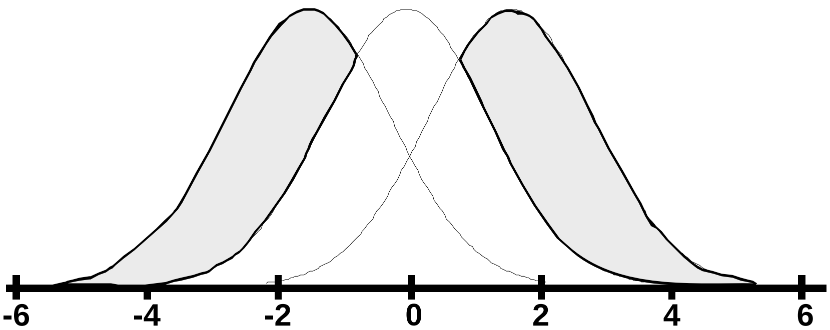

Figure 2.1 The ± 1.5 Sigma Shift

Sigma Level	ppm
6 sigma	3.4 ppm
5 sigma	233 ppm
4 sigma	6,210 ppm
3 sigma	66,810 ppm
2 sigma	308,770 ppm
1 sigma	697,672 ppm

Table 2.2 Defect Levels

Note that Table II in the Appendix provides defect levels at other sigma values. Various authors report slightly different failure rates based mainly upon rounding effects and slight miscalculations. Most of the differences occur at levels less than 3 sigma. However, in looking at this situation objectively, companies with less than 3 sigma capability and with ± 1.5 sigma shifts probably won't be around long enough to undertake a six sigma improvement effort anyway.

It should be noted that the term "six sigma" has been applied to many operations including those with non-normal distributions, for which a calculation of sigma would be inappropriate. The principle remains the same; deliver near perfect products and services by improving the process and eliminating defects. The end objective is to delight customers.

Six Sigma Training

The role of training, in the successful implementation of six sigma, is fundamental. The skills necessary for breakthrough improvements cannot be developed without proper training. Companies that have implemented successful six sigma programs found that training investments return significant benefits. Motorola®, for instance, has discovered a 10 to 1 payback for six sigma training investments. Extensive training is necessary for several levels of individuals and basic training is required for the entire organization.

Potential black belts may undertake a 4 month training program consisting of one week of instruction each month. A variety of software packages are used to aid in the presentation of projects, including Excel or MINITAB™ for the statistics portion. Potential black belts will receive coaching from a master black belt to guide them through a project. The completed project will typically require the trainee to use the majority of the tools presented during the training sessions.

Lesser amounts of training will qualify individuals for the green and yellow belt titles. It should be noted that ASQ's BOK and this Primer are major efforts in attempting to provide a more standardized training.

The diagram below outlines a high level training plan with special training for executives and master black belts. The relative volume of each diagram level represents the relative number of people receiving training.

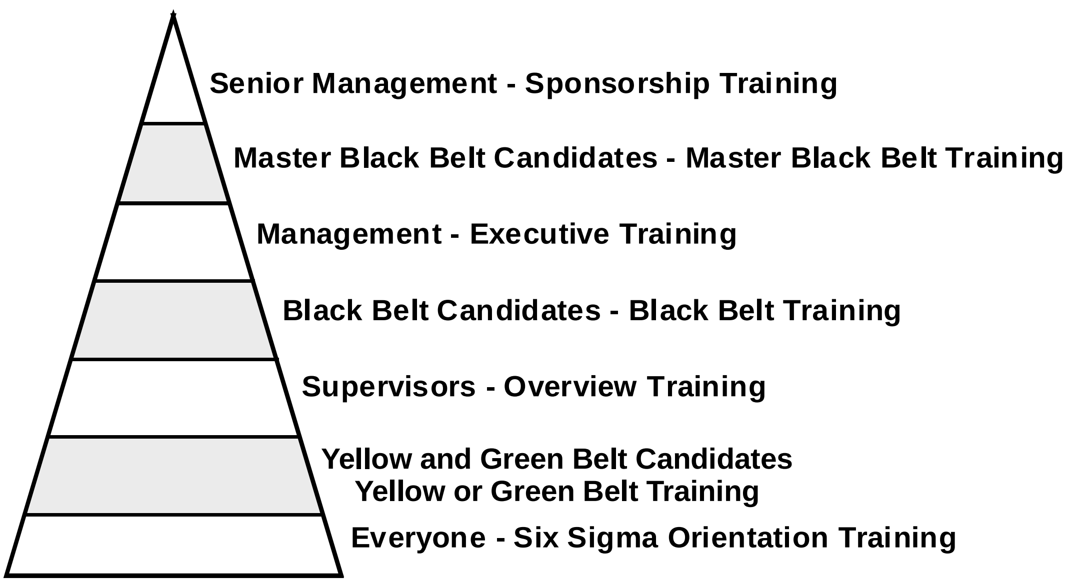

Figure 2.3 Six Sigma Training Pyramid

Six Sigma Training (Continued)

In some organizations, black belts are full time positions that report directly to management sponsors, who, in turn, assign specific projects to them. These assignments may or may not include a process improvement team. Green belts and yellow belts within the normal organizational structure and are typically assigned to process improvement teams as needed. Black belts have specific mentoring responsibilities, including the development of individuals assigned to them.

In other organizations, black belts continue in their normal assignments and participate in process improvement teams as needed. In this structure, black belts and green belts act as internal consultants and are pulled into teams when their specific skills are needed. Black belts are typically responsible for mentoring 1 to 3 green belts or black belt candidates.

Many organizations have a structure that fits somewhere in between the two previous models. Master black belts are responsible for coaching and training black belts in order to make the best use of their skills. Master black belts also train and coach management in order to help them support the black belt program.

Rewards and Reinforcement

Rewards and reinforcement may be one of the hardest parts of successfully institutionalizing a six sigma program. Black belts, green belts, and yellow belts must have positive career paths in order to encourage the best candidates to commit to the extensive training and development required. Especially now that black belt skills are in demand, it is important to recognize the accomplishments of black belts by tangible and intangible means.

It is also important that yellow, green, and black belts experience the rewards of achieving significant savings for the company. At the same time, all other team members must be recognized for their contribution to performance improvements. To only reward the black belts for improvements that were achieved by teams, creates resentment and isolates the black belts from team members.

Six Sigma Foundations

Listed below are some well-known gurus and what they have contributed to the business and technical foundations of six sigma. This list is far from inclusive.

Guru	Contribution
Philip B. Crosby	Senior management involvement 4 absolutes of quality management Quality cost measurements
W. Edwards Deming	Plan-do-study-act (wide usage) Top management involvement Concentration on system improvement Constancy of purpose
Armand V. Feigenbaum	Total quality control/management Top management involvement
Kaoru Ishikawa	4M (5M) or cause-and-effect diagram Companywide quality control (CWQC) Next operation as customer
Joseph M. Juran	Top management involvement Quality trilogy (project improvement) Quality cost measurement Pareto analysis
Walter A. Shewhart	Assignable cause vs. chance cause Control charts Plan-do-check-act (as a design approach) Use of statistics for improvement
Genichi Taguchi	Loss function concepts Signal to noise ratio Experimental design methods Concept of design robustness
Bill Smith	First introduced the term "six sigma"
Mikel Harry	The main architect of six sigma
Forrest Breyfogle III	Author of *Implementing Six Sigma*

Table 2.4 Major Contributors to the Six Sigma Knowledge Bank

Phase Reviews (Continued)

Project status reviews involve collecting and disseminating project performance information to provide stakeholders with information about how resources are being used to achieve the objectives, as stated in the project plan.

Examples of project performance topics include:

- **Status reporting:** **This describes how the project now stands. For example, status reporting includes the scheduled cost and budget metrics.**
- **Progress or tollgate reporting:** **This describes what the project team has accomplished. For example, percent schedule or project completion can be compared to the percent of items still in progress.**
- **Forecasting:** **This is a prediction of future project status and progress.**
- **Progress status reporting:** **This provides information on project scope, schedule, costs, quality, issues, and risks.**
- **Lessons learned:** **The cause of variances, the reasoning behind corrective actions, and other project lessons should be documented so they become part of the historical database for both the completion of the current project and future projects.**

Post-Project Retrospectives

Typically, post project reviews are utilized to improve the efficiency and effectiveness of all functional groups involved in the product life cycle (PLC) through the application of lessons learned." Key elements of a lessons learned program include:

- **Establish/maintain an experience and lessons learned history**
- **Identify practices/activities to promote/or to eliminate**
- **Identify areas for improvement**
- **Implement measures for improvement action plan implementation**
- **Identify and publish lessons learned**

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A STATE OF STATISTICAL CONTROL IS NOT A NATURAL STATE FOR A MANUFACTURING PROCESS. IT IS INSTEAD AN ACHIEVEMENT, ARRIVED AT BY ELIMINATING ONE BY ONE, BY DETERMINED EFFORT, THE SPECIAL CAUSES OF EXCESSIVE VARIATION.

W. EDWARDS DEMING

Improve & Control Phases

The Improve and Control Phases are described in the following topic areas:

- **Improvement Techniques**
- **Control Tools & Documentation**

Improvement Techniques

Improvement Techniques is described in the following topic areas:

- **Kaizen/Kaizen Blitz**
- **PDCA Cycle**
- **Cost Benefit Analysis**

Kaizen

Kaizen is Japanese for continuous improvement (Imai, 1997)[4]. The word kaizen is taken from the Japanese kai "change" and zen "good." This is usually referred to as incremental improvement, but on a continuous basis and involving everyone. Western management is enthralled with radical innovations. They enjoy seeing major breakthroughs, the "home runs" of business. Kaizen is an umbrella term for:

- Productivity
- Total quality control
- Zero defects
- Just-in-time production
- Suggestion systems

(Imai, 1997)[4]

PDSA

Deming (1986)[3] was somewhat disappointed with the Japanese PDCA adaption. He proposed a Plan-Do-Study-Act continuous improvement loop (actually a spiral), which he considered principally a team oriented, problem solving technique. The team objective is to improve the input and the output of any stage. The team can be composed of people from different areas of the plant, but should ideally be composed of people from one area or stage in the plant's operation.

1. Plan - What could be the most important accomplishment of this team? What changes might be desirable? What data is needed? Does a test need to be devised? Decide how to use any observations.

2. Do - Carry out the change or test decided upon, preferably on a small scale.

3. Study - Observe the effects of the change of the test.

4. Act - Study the results. What was learned? What can one predict from what was learned? Will the result of the change lead to either (a) improvement of any, or all stages and (b) some activity to better satisfy the internal or external customer? The results may indicate that no change at all is needed, at least for now.

5. Repeat step 1 with new knowledge accumulated.

6. Repeat step 2 and onward.

Deming (1986)[3]

As noted with other problem solving techniques, everyone on the team has a chance to contribute ideas, plans, observations and data which are incorporated into the consensus of the team. The team may take what they have learned from previous sessions and make a fresh start with clear ideas. This is a sign of advancement.

Both PDCA and PDSA are very helpful techniques in product and/or process improvement projects. They can be used with or without a special cause being indicated by the use of statistical tools.

Cost-Benefit Analysis

Project cost-benefit analysis is a comparison to determine if a project will be (or was) worthwhile. The analysis is normally performed prior to implementation of project plans and is based on time-weighted estimates of costs and predicted value of benefits. The cost-benefit analysis is used as a management tool to determine if approval should be given for the project go-ahead. The actual data is analyzed from an accounting perspective after the project is completed to quantify the financial impact of the project.

The sequence for performing a cost-benefit analysis is:

1. Identify the project benefits.
2. Express the benefits in dollar amounts, timing, and duration.
3. Identify the project cost factors including materials, labor, and resources.
4. Estimate the cost factors in terms of dollar amounts and expenditure period
5. Calculate the net project gain (loss).
6. Decide if the project should be implemented (prior to starting), or if the project was beneficial (after completion).
7. If the project is not beneficial using this analysis, but it is management's desire to implement the project, what changes in benefits and costs are possible to improve the cost-benefit calculation?

Return on Assets (ROA)

Johnson (1982)[6] gives an equation for return on assets (ROA) as:

$$\text{ROA} = \frac{\text{Net Income}}{\text{Total Assets}}$$

Where the net income for a project is the expected earnings and total assets is the value of the assets applied to the project.

Additionally, a calculation of the return on investment is widely used:

$$\text{ROI} = \frac{\text{Net Income}}{\text{Investment}}$$

Where: net income for a project is the expected earnings and investment is the value of the investment in the project.

Internal Rate of Return (IRR) Method

The internal rate of return (IRR) is the interest or discount rate, I or r, that results in a zero net present value, NPV = 0, for the project. This is equivalent to stating that time weighted inflows equal the time weighted outflows. The equation for IRR from Johnson (1982)[6] is :

$$NPV = 0 = \sum_{t=0}^{n} \frac{CF_t}{(1 + r)^t}$$

The IRR is that value of r which results in NPV being equal to 0, and is calculated by an iterative process. Once calculated for a project, the IRR is then compared with other projects and investment opportunities for the organization. The projects with the highest IRR are approved, until the available investment capital is allocated.

Most real projects would have an IRR in the range of 5% to 25% per year. Managers, given the opportunity to accept a project which has calculated values for IRR higher than the company's return on investment (ROI), will normally approve them, assuming the capital is available.

The above equations for net present value and internal rate of return have ignored the effects of taxes. Some organizations make investment decisions without including taxes, while others look at the after tax results.

Payback Period Method

The payback period is the length of time necessary for the net cash benefits or inflows to equal the net costs or outflows. The payback method generally ignores the time value of money, although the calculations can be done taking this into account. The main advantage of the payback method is the simplicity of calculation. It is also useful for comparing projects on the basis of a quick return on investment. A disadvantage is that cash benefits and costs beyond the payback period are not included in the calculations.

Organizations using the payback period method will set a cut-off criteria, such as 1, 1-1/2, or 2 years maximum for approval of projects. Uncertainty in future status and effects of projects, or rapidly changing markets and technology tend to reduce the maximum payback period accepted for project approval. If the calculated payback period is less than the organization's maximum payback period, then the project will be approved. For projects with an initial investment and fixed annual cash inflow, the payback period is calculated as follows from Johnson (1982)[6]:

$$\text{Payback Period} = \frac{\text{Initial (\& Incremental) Investment}}{\text{Annual (or Monthly) Cash Inflow}}$$

Steps for Constructing $\bar{X}$- R Charts

1. Determine the sample size (n = 3, 4, or 5) and the frequency of sampling.
2. Collect 20 to 25 sets of time - sequenced samples (60 to 100 data points).
3. Calculate the average for each set of samples, equals $\bar{X}$.
4. Calculate the range for each set of samples, equals R.
5. Calculate $\bar{\bar{X}}$ (the average of all the $\bar{X}$'s). This is the center line of the $\bar{X}$ chart.
6. Calculate $\bar{R}$ (the average of all the R's). This is the center line of the R chart.
7. Calculate the control limits:

$\bar{X}$ Chart: $UCL_{\bar{X}} = \bar{\bar{X}} + A_2\bar{R}*$

$LCL_{\bar{X}} = \bar{\bar{X}} - A_2\bar{R}*$

R Chart: $UCL_R = D_4\bar{R}$

$LCL_R = D_3\bar{R}$

* Note: $A_2\bar{R}$ can be shown to be identical in value to $3S_{\bar{X}}$

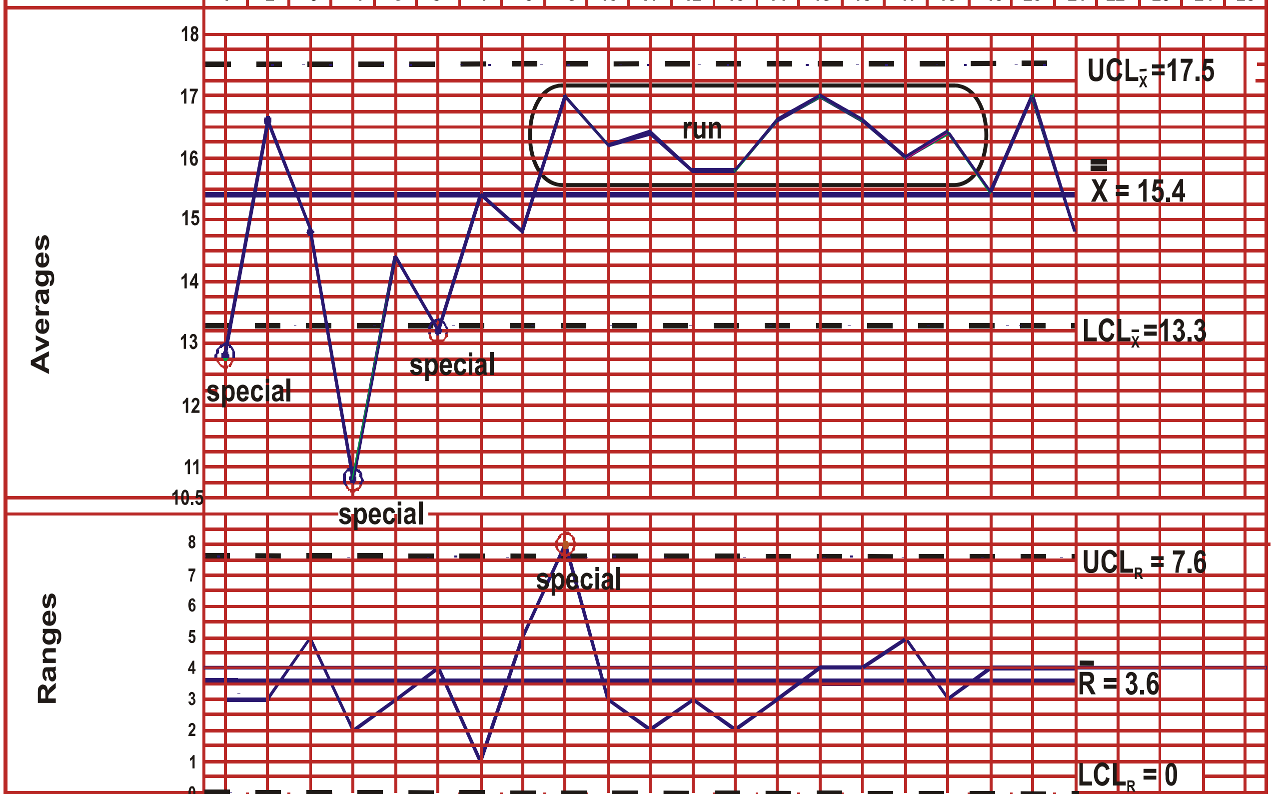
8. Plot the data and interpret the chart for special or assignable causes.

n	A_2	D_3	D_4	d_2
2	1.88	0	3.27	1.13
3	1.02	0	2.57	1.69
4	0.73	0	2.28	2.06
5	0.58	0	2.11	2.33
6	0.48	0	2.00	2.53

Table 7.7 Common Factors used for $\bar{X}$ - R Control Limits

$\bar{X}$- R Control Chart

			Chart No. 1
Product Name: Tablets	Process Closure Department		Operator Bill
Variable: Removal Torques	Specification Limits: LSL = 10 LBS USL = 22 LBS	Units of Measure: LBS	

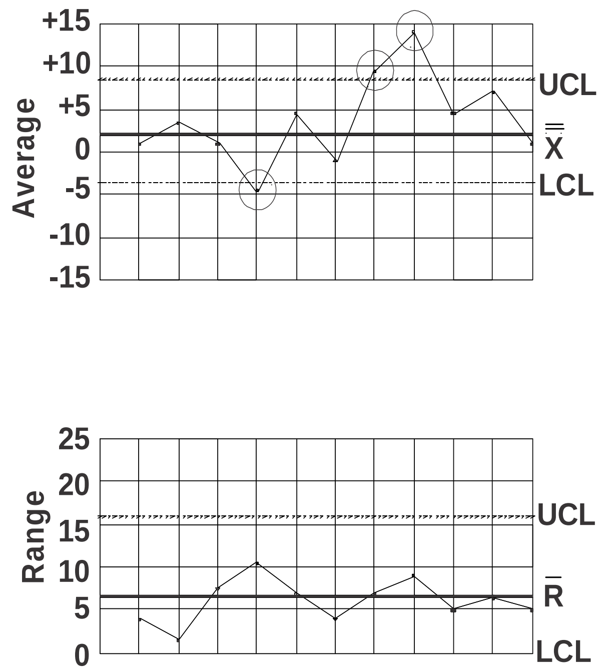


		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Date Start 1/12/98		1/12																1/13								
Time		7:05	7:10	7:35	8:10	8:15	9:10	9:12	9:33	11:40	11:43	12:05	13:05	13:45	13:55	14:20	14:55	7:00	7:55	9:00	9:12	9:32				
Sample Measurement	1	12	15	13	10	13	15	15	15	22	16	16	15	17	16	17	19	16	16	17	19	14				
	2	12	17	18	12	16	12	16	17	17	15	18	16	15	15	19	17	19	15	13	18	17				
	3	13	16	14	11	14	13	15	16	15	17	16	17	16	18	17	15	16	17	17	17	16				
	4	15	17	14	10	15	15	16	14	17	15	16	17	15	18	15	15	15	16	15	15	14				
	5	12	18	15	11	14	11	15	12	14	18	16	14	16	16	17	17	14	18	14	16	13				
Total		64	83	74	54	72	66	77	74	85	81	82	79	79	83	85	83	80	82	76	85	74				
Average $\bar{x}$		12.8	16.6	14.8	10.8	14.4	13.2	15.4	14.8	17	16.2	16.4	15.8	15.8	16.6	17	16.6	16	16.4	15.2	17	14.8				
Range R		3	3	5	2	3	4	1	5	8	3	2	3	2	3	4	4	5	3	4	4	4				

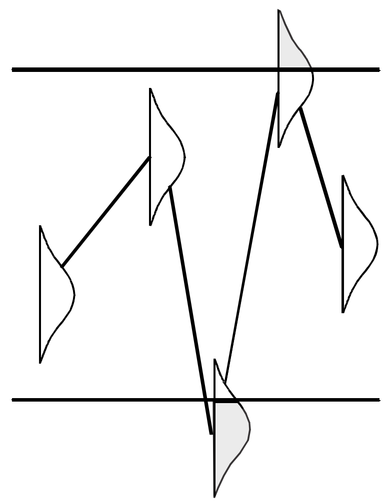
Figure 7.8 An $\bar{X}$- R Chart for Closure Removal Torques

This was a start up process. The process started smoothing out from data set number 10 on. If continued, the chart would need new control limits from that point.

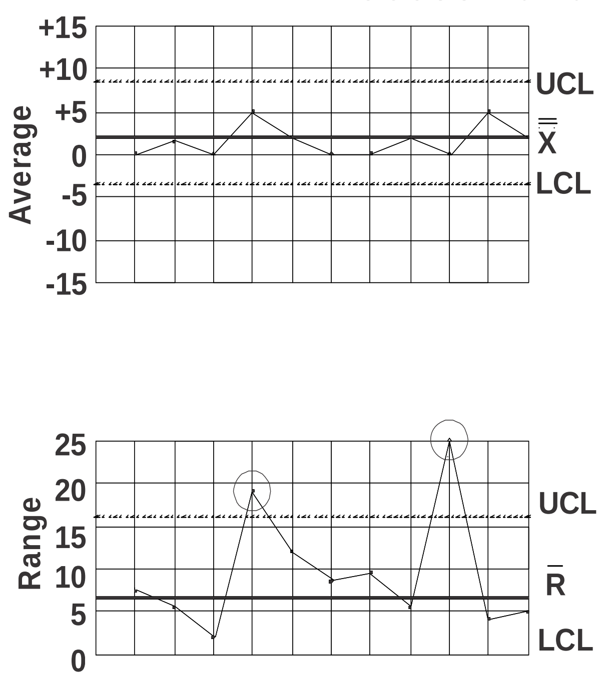
1. Process Average Out-of-control



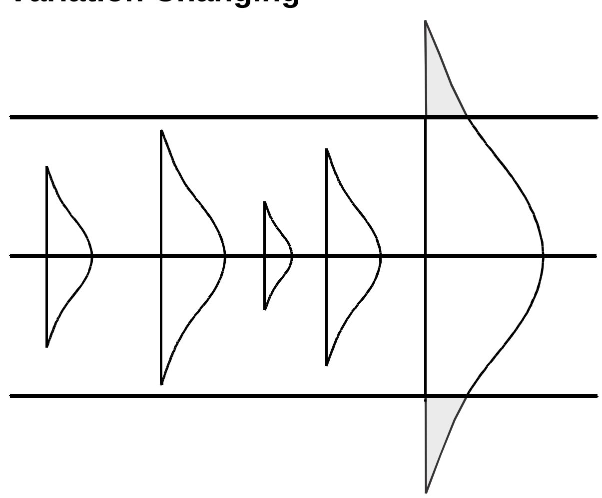
Average Shifting
Variation Stable



2. Process Variation Out-of-control



Average Stable
Variation Changing



7.45. If a company were to evaluate why some customers refused to purchase a newly released product, what Deming cycle phase would apply?

a. Plan
b. Do
c. Study
d. Act

7.46. Production and schedule boards could display which of the following?

a. Machine downtime and kanban records
b. Productivity and quality trends
c. Safety records and jidohkas
d. Jidohkas and kanban cards

7.47. Which of the following charts have upper control limits, but frequently have lower control limits of zero?

a. X-bar and individual charts
b. c charts and u charts
c. p charts and np charts
d. R and sigma charts

7.48. The design of a control plan for a particular part incorporates information from a variety of sources such as flow charts, QFD, FMEAs, designed experiments, and statistical studies. It is a tool to monitor and control the part or process. If used properly, the control plan avoids which of the following problems?

a. Becoming a substitute for written operator instructions
b. Having a listing of the critical Xs and Ys of the process
c. Error proofing the process through various control plans
d. Being used as evidence of installed controls

7.49. When investigating TPM, which of the following would be considered one of the six big negative contributors to equipment effectiveness?

a. Set-up and adjustment
b. Fast speeds
c. Few machine shut downs
d. Work cell arrangement

7.50. The Japanese techniques that complement the visual factory concept are:

a. Kanban, poka-yoke, 5S
b. Poka-yoke, muda, andon boards
c. 5-Whys, andon boards, TPM
d. 5S, kanban, muda

7.51. A centered X-bar and R control chart has been observed to have an upper control limit of 90 and a lower control limit of 70. The sample size was noted to be 5. Determine the average range for each sample subgroup.

a. 21.34
b. 20.00
c. 17.24
d. 13.70

7.52. On a control plan form, the key output variable is often designated as:

a. X
b. Y
c. X or Y
d. A special characteristic

7.53. Which of the following control charts would best fit a process in which measurement data on a product is easily obtained?

a. Run charts
b. Median charts
c. X-bar and R charts
d. p charts

7.54. What is the importance of the reaction plan in a control plan?

a. It describes what will happen if a key variable goes out of control
b. It indicates that a new team must be formed to react to a problem
c. It lists how often the process should be monitored
d. It defines the special characteristics to be monitored

7.55. Which of the following is a normally accepted control chart interpretation rule violation?

a. Five or more consecutive points out of 20 above or below the centerline
b. Six or more consecutive points, upward or downward, in more than 20 plot points
c. Two of five consecutive points in zone 3
d. Ten points in a row in zone 1

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