

Glossary of Six Sigma Terminology

A

Acceptance sampling plan. A specific plan that indicates the sampling sizes and the associated acceptance or non-acceptance criteria to be used. There are two types: attributes sampling and variables sampling. In attributes sampling, the presence or absence of a characteristic is noted in each of the units inspected. In variables sampling, the numerical magnitude of a characteristic is measured and recorded for each inspected unit; this involves reference to a continuous scale of some kind.

Action plan. The detail plan to implement the actions needed to achieve strategic goals and objectives (similar, but not as comprehensive as a project plan).

Affinity chart (diagram). Brainstorming tool used to gather large quantities of information from many people; ideas usually are displayed visually, then categorized into similar columns; columns are named giving an overall grouping of ideas. In other words, it is a management and planning tool used to organize ideas into natural groupings in a way that stimulates new, creative ideas. Also known as the “KJ” method.

Alpha (α) risk. The maximum probability of saying a process or lot is unacceptable when, in fact, it is acceptable (*see* Producer’s risk).

Analysis of means (ANOM). A statistical procedure for troubleshooting industrial processes and analyzing the results of experimental designs with factors at fixed levels. It provides a graphical display of data. Ellis R. Ott developed the procedure in 1967 because he observed that non-statisticians had difficulty understanding analysis of variance. Analysis of means is easier for quality practitioners to use, because it is an extension of the control chart. In 1973, Edward G. Schilling further extended the concept, enabling analysis of means to be used with normal distributions and attributes data where the normal approximation to the binomial distribution does not apply. This is referred to as analysis of means for treatment effects.

Analysis of results. The effect of each factor on the response of the system is determined. Using simple statistical techniques, the largest effects are isolated and a prediction equation is formulated to predict the behavior of the system more accurately.

Analysis of variance (ANOVA). A basic statistical technique for analyzing experimental data. It subdivides the total variation of a data set into meaningful component parts associated with specific sources of variation in order to test a hypothesis on the parameters of the model or to estimate variance components. There are three models: fixed, random and mixed.

Analytical thinking. Breaking down a problem or situation into discrete parts to understand how each part contributes to the whole.

Analyze. The third component of the DMAIC phase where process detail is scrutinized for improvement opportunities. Note that: 1. data is investigated and verified to prove suspected root causes and substantiate the problem statement, and 2. process analysis includes reviewing process maps for value-added/non-value-added activities.

Appraisal costs. Costs incurred to determine the degree of conformance to quality requirements.

Assignable causes (of variation). Significant, identifiable changes in the relationships of materials, methods, machines, measurement, mother nature and people (5M&P).

Attribute data. Go/no-go information. The control charts based on attribute data include fraction defective chart, number of affected units chart, count chart, count per-unit chart, quality score chart and demerit chart.

Availability. The ability of a product to be in a state to perform its designated function under stated conditions at a given time. Availability can be expressed by the ratio: $[\text{uptime}]/[\text{uptime} + \text{downtime}]$.

Average. *See* Mean.

Average chart. A control chart in which the subgroup average, X-bar, is used to evaluate the stability of the process level.

B

Bathtub curve. Also called life-history curve. A graphic demonstration of the relationship of life of a product versus the probable failure rate. Includes three portions: early or infant failure (break-in), a stable rate during normal use and wear out.

Bayes theorem. A theorem of statistics relating conditional probabilities.

Bell-shaped curve. A curve or distribution showing a central peak and tapering off smoothly and symmetrically to “tails” on either side. A normal (Gaussian) curve is an example.

Benchmarking. An improvement process in which a company measures its performance against that of best-in-class companies (or others who are good performers), determines how those companies achieved their performance levels and uses the information to improve its own performance. The areas that can be benchmarked include strategies, operations, processes and procedures.

Benefit-cost analysis. Collection of the dollar value of benefits derived from an initiative and the associated costs incurred and computing the ratio of benefits to cost.

Beta (β) risk. The maximum probability of saying a process or lot is acceptable when, in fact, it should be rejected (*see* Consumer’s risk).

Bias (in measurement). A characteristic of measurement that refers to a systematic difference. That systematic difference is an error which leads to a difference between the average result of a population of measurements and the true, accepted value of the quantity being measured.

Binomial distribution (probability distribution). Given that a trial can have only two possible outcomes (yes/no, pass/fail, heads/tails), of which, one outcome has probability p and

the other probability q ($p + q = 1$), the probability that the outcome represented by p occurs r times in n trials is given by the binomial distribution.

Black belt. A team leader, trained in the DMAIC process and facilitation skills, responsible for guiding an improvement project to completion. They are technically oriented individuals held in high regard by their peers. They should be actively involved in the organizational change and development process. Candidates may come from a wide range of disciplines and need not be formally trained statisticians or engineers. Six sigma technical leaders work to extract actionable knowledge from an organization's information warehouse. Successful candidates should understand one or more operating systems, spreadsheets, database managers, presentation programs and word processors. As part of their training, they will be required to become proficient in the use of one or more advanced statistical analysis software packages.

Block diagram. A diagram that shows the operation, interrelationships, and interdependencies of components in a system. Boxes, or blocks (hence the name) represent the components; connecting lines between the blocks represent interfaces. There are two types of block diagrams: a functional block diagram, which shows a system's subsystems and lower-level products, their interrelationships, and interfaces with other systems; and a reliability block diagram, which is similar to the functional block diagram, except it is modified to emphasize those aspects influencing reliability. Also known as a boundary diagram.

Brainstorming. A problem-solving tool that teams use to generate as many ideas as possible related to a particular subject. Team members begin by offering all their ideas; the ideas are not discussed or reviewed until after the brainstorming session. Another way of defining brainstorming, is a rapid pooling of ideas by a team of people before any discussion or judgment takes place.

Breakthrough. A method of solving chronic problems that results from the effective execution of a strategy designed to reach the next level of quality. Such change often requires a paradigm shift within the organization.

C

Calibration (of instrument). Adjusting an instrument using a reference standard to reduce the difference between the average reading of the instrument and the true value of the standard being measured, i.e. to reduce measurement bias.

Capability (of process). The uniformity of product which a process is capable of producing. Can be expressed numerically using C_p , C_r , C_{pk} , and $Z_{\max/3}$ when the data is normally distributed.

Capability ratio (C_p). Is equal to the specification tolerance width divided by the process capability.

Cause and effect diagram. A visually effective way of identifying and recording the possible causes of a problem and the relationships between them as they are suggested by the team. A pictorial diagram showing all the cause (process inputs) and effect (resulting problem being investigated) relationships among the factors that affect the process. In essence, it is a tool for analyzing process variables. It is also referred to as the Ishikawa diagram, because Kaoru Ishikawa developed it and the fishbone diagram, because the complete diagram resembles a fish skeleton (causes are the bones of the fish and the effect are shown as the head of the fish). Sometimes it is also called the feather diagram, because it resembles a feather. The diagram illustrates the main causes and subcauses leading to an effect (symptom). The cause and effect diagram is one of the seven tools of quality.

c-chart. For attributes data: a control chart of the number of defects found in a subgroup of fixed size. The c-chart is used where each unit typically has a number of defects.

Cell (of frequency distribution and/or histogram). For a sample based on a continuous variable, a cell is an interval into which individual data points are grouped. Also, a cell is a layout of workstations and/or various machines for different operations (usually in a U-shape) in which multitasking operators proceed, with a part, from machine to machine, to perform a series of sequential steps to produce a whole product or major subassembly.

Center line. For control charts: the horizontal line marking the center of the chart, usually indicating the grand average of the quantity being charted.

Central limit theorem. If samples of a population with size n are drawn, and the values of \bar{x} are calculated for each sample group, and the distribution of \bar{x} is found, the distribution's shape is found to approach a normal distribution for sufficiently large n . This theorem allows one to use the assumption of a normal distribution when dealing with \bar{x} . "Sufficiently large" depends on the population's distribution and what range of \bar{x} is being considered; for practical purposes, the easiest approach may be to take a number of samples of a desired size and *see* if their means are normally distributed. If not, the sample size should be increased.

Central tendency. A measure of the point about which a group of values is clustered; some measures of central tendency are mean, mode and median. Another way of saying it is the propensity of data collected on a process to concentrate around a value situated somewhere midway between the lowest and highest value.

Champion. An individual who has accountability and responsibility for many processes or who is involved in making strategic-level decisions for the organization. The champion ensures ongoing dedication of project resources and monitors strategic alignment (also referred to as a sponsor).

Change agent. The person who takes the lead in transforming a company into a quality organization by providing guidance during the planning phase, facilitating implementation and supporting those who pioneer the changes.

Characteristic. A dimension or parameter of a part that can be measured and monitored for control and capability. A property that helps to identify or to differentiate between entities and that can be described or measured to determine conformance or nonconformance to requirements.

Charter. A documented statement officially initiating the formation of a committee, team, project or other effort in which a clearly stated purpose and approval is conferred. It is the specific team document defining the context, specifics and plans of an improvement project; it includes business case; problem and goal statements; constraints and assumptions; roles; preliminary plan; and scope. Periodic reviews with the sponsor ensure alignment with business strategies; review, revise, refine periodically throughout the DMAIC process based on data.

Check sheet. A simple data-recording device. The check sheet is custom-designed for the particular use, allowing ease in interpreting the results and to reduce the likelihood of errors in recording data.. The check sheet is one of the seven tools of quality. Check sheets are often confused with data sheets and checklists. A sheet for the recording of data on a process or its product. (These may be: forms, tables, or worksheets facilitating data collection and compilation; allows for collection of stratified data. *See also* Stratification.) The check sheet is designed to remind the user to record each piece of information required for a particular study, and to reduce the likelihood of errors in recording data. The data from the check sheet can be typed into a computer for analysis when the data collection is complete. A check sheet is also a simple data-recording device.

Chi-square (χ^2). As used for goodness-of-fit: a measure of how well a set of data fits a proposed distribution, such as the normal distribution. The data is placed into classes and the observed frequency (O) is compared to the expected frequency (E) for each class of the proposed distribution. The result for each class is added to obtain a chi-square value. This is compared to a critical chi-square value from a standard table for a given α (alpha) risk and degrees of freedom. If the calculated value is smaller than the critical value, we can conclude that the data follows the proposed distribution at the chosen level of significance.

Coaching. A continuous improvement technique by which people receive one-on-one learning through demonstration and practice, and that is characterized by immediate feedback and correction.

Coded plan matrix. The levels of each factor within the plan matrix are represented by a code. The codes can be "1" and "2" or "−" and "+". The use of "−" and "+" is preferred as these simplify the use of the matrix when calculating the effect of each factor. Taguchi, on the other hand prefers the "1" and "2" designation.

Common cause. Normal, everyday influences on a process; usually harder to eliminate and require changes to the process. Problems from common causes are referred to as “chronic pain.”

Competence. Refers to a person’s ability to work in a team and perform a particular activity. Competence generally consists of skill, knowledge, experience and attitude components.

Competitive analysis. The gathering of intelligence relative to competitors in order to identify opportunities or potential threats to current and future strategy.

Concept (phase). The first of four sequential phases in the generic project life cycle. Also known as idea, economics, feasibility or prefeasibility phase.

Concerns. Number of defects (nonconformities) found on a group of samples in question.

Conducting the experiment. The experiment, once planned and designed, is performed by testing the system under investigation according to the combination of factor level settings determined by each experimental run.

Confidence interval. Range within which a parameter of a population (e.g., mean, standard deviation, etc.) may be expected to fall, on the basis of measurement, with some specified confidence level.

Confidence level. The probability set at the beginning of a hypothesis test that the variable will fall within the confidence interval. A confidence level of 0.95 is commonly used.

Confidence limits. The upper and lower boundaries of a confidence interval.

Confirmation run. An experiment performed under the optimal conditions predicted by the analysis of the results from the designed experiment. This test verifies, or otherwise, the quantitative knowledge of the system (which was determined through the analysis).

Conflict resolution. A process for resolving disagreements in a manner acceptable to all parties. To seek a solution to a problem, five methods in particular have been proven through confrontation, compromise, smoothing, forcing and withdrawal.

Conformance (of product). Adherence to some standard of the product’s properties. The term is often used in attributes studies of product quality (i.e. a given unit of the product is either in conformance to the standard or it is not).

Confounding. When interaction effects cannot be separated from the main effects, the main effects are said to be confounded with interactions.

Consensus. When all team members can support a decision and no member opposes it.

Constancy of purpose. Occurs when goals and objectives are properly aligned to the organizational vision and mission.

Constraint. A constraint may range from the intangible (e.g., beliefs, culture) to the tangible (e.g., posted rule prohibiting smoking, build-up of work-in-process awaiting the availability of a machine or operator).

Consumer’s risk. The maximum probability of saying a process or lot is acceptable when, in fact, it should be rejected. In a sampling plan, refers to the probability of acceptance of a lot, the quality of which has a designated numerical value representing a level that is sel-

dom desirable. Usually the designated value will be the lot tolerance percent defective (LTPD). Also called a beta risk or type II error.

Continuous data. The results of measuring a continuous variable. Any variable measured on a continuum or scale that can be infinitely divided—in fact, the measurement depends on the system used; primary types include time, dollars, size, weight, temperature and speed; also referred to as variable data.

Continuous process improvement. Includes the actions taken throughout an organization to increase the effectiveness and efficiency of activities and processes in order to provide added benefits to the customer and organization. It is considered a subset of total quality management and operates according to the premise that organizations can always make improvements. Continuous improvement can also be equated with reducing process variation.

Continuous variable. A variable that can assume any of a range of values; an example would be the measured size of a part.

Contract risk analysis. Analysis of the consequences and probabilities that certain undesirable events will occur and their impact on attaining the contract/procurement objectives.

Contrast. A contrast is a weighted average of the experiment's results (response data), where all the weights sum to zero. Each column of a contrast matrix represents the contrast for a factor or interaction.

Contrast matrix. When a coded plan matrix using the codes '−' and '+' is modified to show '−1' and '+1', it becomes known as a contrast matrix. Each column of the contrast matrix is known as a contrast and can be used to calculate the effect of the factor or the interaction attributable to that column.

Control. The last element of the DMAIC phase. Once solutions have been implemented, ongoing measures track and verify the stability of the improvement and the predictability of the process. Often includes process management techniques and systems including process ownership, cockpit charts and/or process management charts.

Control chart. A plot of some parameter of process performance, usually determined by regular sampling of the product, as a function (usually) of time or unit number or other chronological variable. The control limits are also plotted for comparison. The parameter plotted may be the mean value of a particular measurement for a product sample of specified size (x-bar chart), the range of values in the sample (R chart), the percent of defective units in the sample (p chart), etc. Another way to look at the control chart is to view it as a basic tool that consists of a graphical representation of data with upper and lower control limits on which values of some statistical measure for a series of samples or subgroups are plotted. It frequently shows a central line to help detect a trend of plotted values toward either control limit. It is used to monitor and analyze variation from a process to see whether the process is in statistical control.

Control limits. The limits within which the product of a process is expected (or required) to remain. If the process leaves the limits, it is said to be out of control. This is a signal that action should be taken to identify the cause and eliminate it if possible. Note: control limits are not the same as tolerance limits. Control limits always indicate the voice of

the process and the behavior of the process and they are always calculated. Tolerance limits, on the other hand, are always given.

Control plan. A document that may include the characteristics for quality of a product or service, measurements and methods of control.

COPQ. *See* Cost of poor quality.

Corrective action. Action taken to eliminate the root causes and symptoms of an existing deviation or nonconformity to prevent recurrence.

Correlation. Refers to the measure of the relationship between two sets of numbers or variables.

Correlation coefficient. Coefficient that indicates the strength of the association between any two metric variables. It is generally designated as r . When only two variables are compared the coefficient is thought of as the slope of the line as in the equation of $y = a + bx$.

Cost of poor quality (COPQ). The costs associated with providing poor-quality products or services. Dollar measures depicting the impact of problems (internal and external failures) in the process as it exists. It includes labor and material costs for handoffs, rework, inspection and other non-value-added-activity. In other words, the cost incurred from generating a defect; or a cost that would be avoided if, rather than a defect, the opportunity yielded a success.

Cost of quality (COQ). Costs incurred in assuring quality of a product or service. There are four categories of quality costs: internal failure costs (costs associated with defects found before delivery of the product or service); external failure costs (costs associated with defects found during or after product or service delivery); appraisal costs (costs incurred to determine the degree of conformance to quality requirements); and prevention costs (costs incurred to keep failure and appraisal costs to a minimum).

Counseling/coaching. The process of advising or assisting an individual concerning career plans, work requirements or the quality of work performed.

Count chart. A control chart for evaluating the stability of a process in terms of the count of events of a given classification occurring in a sample.

Count-per-unit chart. A control chart for evaluating the stability of a process in terms of the average count of events of a given classification per unit occurring in a sample.

Covariance. A measure of whether two variables (x and y) are related (correlated). It is given by the formula. $\sigma_{xy} = [\Sigma(x - \bar{X})(y - \bar{Y})]/n - 1$ where n is the number of elements in the sample

C_p . For process capability studies. C_p is a capability index defined by the formula: $C_p = \text{Tolerance}/6s$. C_p shows the process capability potential but does not consider how centered the process is. C_p may range in value from 0 to infinity, with a large value indicating greater potential capability. A value of 1.67 or greater, is considered an acceptable value of a C_p . Specifically in the six sigma methodology its value is expected to be greater than 2.0.

C_{pk} . A widely used process capability index. It is expressed as a ratio of the smallest answer of: $[USL - \bar{X}]/3\sigma$ or $[\bar{X} - LSL]/3\sigma$. If the C_{pk} has a value equal to C_p the process is centered on the nominal; if C_{pk} is negative, the process mean is outside the specification limits; if C_{pk} is between 0 and 1, then some of the six sigma spread falls outside the tolerance limits. If C_{pk} is larger than 1, the six sigma spread is completely within the tolerance limits. A value of 1.33 or greater is usually desired. Also known as $Z_{min}/3$. Special note: Capability in six sigma is a very important issue. Therefore, even though the above formulas are the generic ones, the practitioner for the six sigma project should be aware of the following conditions: For variable data: we use the C_p or C_{pk} for short term capability and for long capability we use the P_p or P_{pk} . The difference between the two is the calculation of the sigma in the denominator of the formula.

That is for C_{pk} we use $\hat{\sigma} = \frac{R}{d_2}$ and for P_{pk} we use the actual value of σ .

CQI. Continuous quality improvement.

C_r . For process capability studies: The inverse of C_p , C_r can range from 0 to infinity in value, with a smaller value indicating a more capable process.

Criteria. A statement that provides objectives, guidelines, procedures, and standards that are to be used to execute the development, design, and/or implementation portions of a project.

Criteria matrix. Decision-making tool used when potential choices must be weighed against several key factors (e.g., cost, ease to implement and impact on customer). Encourages use of facts, data and clear business objectives in decision making.

Critical path method (CPM). A scheduling technique using precedence diagrams for graphic display of the work plan. The method used to determine the length of a project and to identify the activities that are critical to the completion of the project. In other words, an activity-oriented project management technique that uses arrow-diagramming techniques to demonstrate both the time and cost required to complete a project. It provides one time estimate in normal time.

Critical to quality (CTQ) characteristic. A characteristic of a product, service or information that is important to the customer. CTQs must be measurable in either a quantitative manner (i.e., 3.00 mg, etc.) or qualitative manner (correct/incorrect, etc.).

Cross-functional team. A group consisting of members from more than one department that is organized to accomplish a project.

Culture (organizational). A system of values, beliefs, and behaviors inherent in an organization.

Cumulative sum chart (CuSum). A cumulative sum chart plots the cumulative deviation of each subgroup's average from the nominal value. The ordinate of each plotted point represents the algebraic sum of the previous ordinate and the most recent deviations from the target. That means, if the process consistently produces parts near the nominal, the CuSum chart shows a line which is essentially horizontal. If the process begins to

shift, the line will show an upward or downward trend. The CuSum chart is sensitive to small shifts in process level.

Customer. Anyone who receives a product, service or information from an operation or process. The term is frequently used to describe external customers—those who purchase the manufactured products or services that are the basis for the existence of the business. However, internal customers are customers who receive the intermediate or internal products or services from internal suppliers. In other words, a recipient of a product or service who is provided by a supplier.

Customer delight. The result achieved when customer requirements are exceeded in ways the customer finds valuable.

Customer requirements. Defines the needs and expectations of the customer; translated into measurable terms and used in the process to ensure compliance with the customers' needs.

Customer satisfaction. The result of delivering a product or service that meets customer requirements, needs, and expectations.

Customer service. The activities of dealing with customer questions; also sometimes the department that takes customer orders or provides post-delivery services.

Customer value. The market-perceived quality adjusted for the relative price of a product.

Cycle time. All time used in a process; includes actual work time and wait time.

Cycle time reduction. To reduce the time that it takes, from start to finish, to complete a particular process.

D

Data. Facts presented in descriptive, numeric or graphic form.

DCOV. The design for six sigma model: define, characterize, optimize and verify.

Decision matrix. A matrix used by teams to evaluate problems or possible solutions. For example, after a matrix is drawn to evaluate possible solutions, the team lists them in the far-left vertical column. Next, the team selects criteria to rate the possible solutions, writing them across the top row. Then, each possible solution is rated on a predetermined scale (such as 1-5) for each criterion and the rating recorded in the corresponding grid. Finally, the ratings of all the criteria for each possible solution are added to determine its total score. The total score is then used to help decide which solution deserves the most attention.

Defect. Any instance or occurrence where the product or service fails to meet customer requirements—however defined (we prefer the use of nonconformity). Also, any output of an opportunity that does not meet a defined specification; or a failure to meet an imposed requirement (intended or reasonable expectation for use, including safety considerations) on a single quality characteristic or a single instance of non-conformance to the specification. If the defect is in relation to safety, then they are often classified as follows: *Class 1*, critical, leads directly to severe injury or catastrophic economic loss; *Class 2*, serious, leads directly to significant injury or significant economic loss; *Class 3*, major, is related to major problems with respect to intended normal or reasonably foreseeable use; and *Class 4*, minor, is related to minor problems with respect to intended normal or reasonably foreseeable use (a defect may be also called a blemish, imperfection, or non-conformity).

Defective. Any unit with one or more nonconformities (defects). *See also* Defect.

Defective unit. A sample (part) which contains one or more defects, making the sample unacceptable for its intended, normal usage. *See also* Nonconforming unit.

Defect opportunity. A type of potential defect (nonconformity) on a unit of throughput (output) which is important to the customer; example: specific fields on a form that creates an opportunity for error that would be important to the customer.

Defects per million opportunities (DPMO). Calculation used in six sigma process improvement initiatives indicating the amount of defects in a process per one million opportunities; number of defects divided by (the number of units times the number of opportunities) = DPO, times 1 million = DPMO. *See also* DPO; Six sigma; Defect opportunity).

Defects per opportunity (DPO). Calculation used in process improvements to determine the amount of defects per opportunity; number of defects divided by (the number of units times the number of opportunities) = DPO. *See also* Defect; Defect opportunity,

Defects per unit (DPU). The number of defects counted, divided by the number of products or characteristics (units) produced.

Define. First element of the DMAIC phase that defines the problem/opportunity, process and customer requirements; because the DMAIC cycle is iterative, the process problem,

flow, and requirements should be verified and updated for clarity, throughout the other phases. *See also* Charter, Customer requirements, Process map, Voice of the customer.

Deliverable. A report or product of one or more tasks that satisfy one or more objectives and must be delivered to satisfy contractual requirements.

Demerit chart. A control chart for evaluating a process in terms of a demerit (or quality score), such as a weighted sum of counts of various classified nonconformities.

Deming Cycle. Also known as Deming Shewhart cycle. *See* Plan-do-check-act cycle.

Dependability. The degree to which a product is operable and capable of performing its required function at any randomly chosen time during its specified operating time, provided that the product is available at the start of that period. (Non-operation-related influences are not included.) Dependability can be expressed by the ratio: $[\text{time available}]/[\text{time available} + \text{time required}]$.

Deployment (to spread around). Used in strategic planning to describe the process of cascading plans throughout an organization.

Design. The creation of final approach for executing the project's work.

Design control. A system for monitoring project scope, schedule and cost during the project's design stage.

Design for six sigma (DFSS). Describes the application of six sigma tools to product development and process design efforts with the goal of designing in six sigma performance capability.

Design of experiment (DOE). A branch of applied statistics dealing with planning, conducting, analyzing and interpreting controlled tests to evaluate the factors and noises that control the value of a parameter or group of parameters. There are two approaches to DOE: the classical and the Taguchi approach. In both cases, however, the planning of an experiment to minimize the cost of data obtained and maximize the validity range of the results is the primary concern. Requirements for a good experiment include clear treatment comparisons, controlled fixed and experimental variables and maximum freedom from systematic error. The experiments should adhere to the scientific principles of statistical design and analysis. Each experiment should include three parts: the experimental statement, the design and the analysis. Examples of experimental designs include single/multi-factor block, factorial, latin square and nested arrangements.

Design review. Documented, comprehensive and systematic examination of a design to evaluate its capability to fulfill the requirements for quality.

Desired quality. Refers to the additional features and benefits a customer discovers when using a product or service that lead to increased customer satisfaction. If missing, a customer may become dissatisfied.

Development (phase). The second of four sequential phases in the generic project life cycle. Also known as planning phase.

Deviation. A nonconformance or departure of a characteristic from specified product, process, or system requirements.

Diagnostic journey and remedial journey. A two-phase investigation used by teams to solve chronic quality problems. In the first phase, the diagnostic journey, the team moves from the symptom of a problem to its cause. In the second phase, the remedial journey, the team moves from the cause to a remedy.

Dimensions of quality. Refers to different ways in which quality may be viewed, for example, meaning of quality, characteristics of quality, drivers of quality, etc.

Discrete data. Any data not quantified on an infinitely divisible scale. Includes a count, proportion, or percentage of a characteristic or category (e.g., gender, loan type, department, location, etc); also referred to as attribute data.

Discrete probability distribution. Means that the measured process variable takes on a finite or limited number of values; no other possible values exist.

Dispersion (of a statistical sample). The tendency of the values of the elements in a sample to differ from each other. Dispersion is commonly expressed in terms of the range of the sample (difference between the lowest and highest values) or by the standard deviation.

Dispersion analysis diagram. A cause and effect diagram for analysis of the various contributions to variability of a process or product. The main factors contributing to the process are first listed, then the specific causes of variability from each factor are enumerated. A systematic study of each cause can then be performed.

Disposition of nonconformity. Action taken to deal with an existing nonconformity; action may include: correction (repair), rework, re-grade, scrap, obtain a concession or amendment of a requirement.

Distribution. Describes the amount of potential variation in outputs of a process; it is usually described in terms of its shape, average and standard deviation.

DMAIC. The methodology (breakthrough strategy) used in the classical six sigma approach: define, measure, analyze, improve, control. It lends structure to process improvement and design or redesign applications, through a systematic process improvement/management system. Whereas, the DMAIC model is a process oriented approach, it must be separated from the DCOV model, which pertains to methodology used in the design for six sigma approach: define, characterize, optimize and verify.

Documentation. The collection of reports, user information and references for distribution and retrieval, displays, back-up information and records pertaining to the project.

Drivers of quality. Include customers, products/services, employee satisfaction, total organizational focus.

E

Effect plot. A line graph that visually depicts the difference between the response average at each factor level setting.

Effectiveness. Measures related to how well the process outputs meet the needs of the customer (e.g., on-time delivery, adherence to specifications, service experience, accuracy, value-added features, customer satisfaction level); links primarily to customer satisfaction.

Effects. General term that encompasses both main effects and interaction effects. It is a measure of the impact that a factor or interaction has on the response when levels are changed.

Efficiency. Measures related to the quantity of resources used in producing the output of a process (e.g., costs of the process, total cycle time, resources consumed, cost of defects, scrap, and/or waste); links primarily to company profitability.

Eighty-twenty (80-20) rule. *See* Pareto chart and Pareto analysis.

Employee involvement. A practice within an organization whereby employees regularly participate in making decisions on how their work areas operate, including making suggestions for improvement, planning, objectives setting and monitoring performance.

Empowerment. A condition whereby employees have the authority to make decisions and take action in their work areas, within stated bounds, without prior approval.

Estimate. An evaluation of all the costs of the elements of a project or effort as defined by an agreed-upon scope.

Event. An event is an identifiable single point in time on a project, task or group tasks. It may be the starting or the ending point of a task.

Evolutionary operations (EVOP). A procedure to optimize the performance of a process by making small, known variations in the parameters entering the process and observing the effects of the variation on the product. This seems identical to response surface methodology, except that it is done in a production situation rather than during process development, and the variations must therefore be kept small enough to meet product tolerances. In other words, the process of adjusting variables in a process in small increments in a search for a more optimum point on the response surface.

Executive education. Usually refers to the education (and training) provided to senior management.

Experimental design. A structured approach to gaining new knowledge, including that needed for quality improvement. The approach is based upon the systematic collection of information about a product or process. A formal plan that details the specifics for conducting an experiment, such as which responses, factors, levels, blocks, treatments and tools are to be used.

Experimental plan. This is determined by the number of factors, levels and experimental runs identified by the team. It involves choosing an orthogonal array on which to base the

experiment's design. This, in turn, gives the combination of factor level settings to be used for each experimental run.

Experimental run. A trial of the system with the factors fixed at one combination of levels.

Exponential distribution. A probability distribution mathematically described by an exponential function. Used to describe the probability that a product survives a length of time t in service, under the assumption that the probability of a product failing in any small time interval is independent of time. A continuous distribution where data are more likely to occur below the average than above it. Typically used to describe the break-in portion of the bathtub curve.

External customer. A person or organization who receives a product, a service, or information but is not part of the organization supplying it (*see also* Internal customer).

External failure. When defective units pass all the way through a process and are received by the customer.

External failure costs. Costs associated with defects found during, or after, delivery of the product or service.

F

F Distribution. The distribution of F , the ratios of variances for pairs of samples. Used to determine whether or not the populations from which two samples were taken have the same standard deviation. The F distribution is usually expressed as a table of the upper limit below which F can be expected to lie with some confidence level, for samples of a specified number of degrees of freedom.

F test. Test of whether two samples are drawn from populations with the same standard deviation, with some specified confidence level. The test is performed by determining whether F , as defined above, falls below the upper limit given by the F distribution table.

Factor analysis. A statistical technique that examines the relationships between a single dependent variable and multiple independent variables. For example, it is used to determine which questions on a questionnaire are related to a specific question such as "Would you buy this product again?"

Factors. Parameters or variables that may influence the performance of the product or process under investigation. Those factors believed to have the most impact are identified by the team and become the focus of attention for the experiment. Simply put, these factors become the things to change during the experiment.

Failure mode analysis (FMA). A procedure to determine which malfunction symptoms appear immediately before or after a failure of a critical parameter in a system. After all the possible causes are listed for each symptom, the product is designed to eliminate the problems.

Failure mode effects analysis (FMEA). A procedure in which each potential failure mode in every sub-item of an item is analyzed to determine its effect on other sub-items and on the required function of the item.

Failure mode effects and criticality analysis (FMECA). A procedure that is performed after a failure mode effects analysis to classify each potential failure effect according to its severity and probability of occurrence.

Failure rate. The average number of failures per unit time. Used for assessing reliability of a product in service.

False x-bar causes. For x-bar control charts: changes in the x-bar control chart which are not due to changes in the process mean, but to changes in the corresponding R-chart.

Fault tree analysis. A technique for evaluating the possible causes which might lead to the failure of a product. For each possible failure, the possible causes of the failure are determined; then the situations leading to those causes are determined; and so forth, until all paths leading to possible failures have been traced. The result is a flowchart for the failure process. Plans to deal with each path can then be made.

Feasibility. The assessment of capability of being completed; the possibility, probability and suitability of accomplishment.

Feather diagram. (See Cause and effect diagram).

Feedback–process. Using the results of a process to control it. The feedback principle has wide application. An example would be using control charts to keep production personnel informed on the results of a process. This allows them to make suitable adjustments to the process. Some form of feedback on the results of a process is essential in order to keep the process under control.

Figure of merit. Generic term for any of several measures of product reliability, such as MTBF, mean life, etc.

Fishbone diagram. (*See* Cause and effect diagram)

Fitness for use. A term used to indicate that a product or service fits the customer's defined purpose for that product or service.

Five whys. A persistent questioning technique to probe deeper to surface the root cause of a problem.

Flowchart (for programs, decision making, process development). A pictorial representation of a process indicating the main steps, branches and eventual outcomes of the process. Also called process map, activity flow. A graphical representation of the steps in a process, flowcharts are drawn to better understand processes. The flowchart is one of the seven tools of quality.

Force field analysis. A technique for analyzing the forces that aid or hinder an organization in reaching an objective. Identifies forces/factors supporting or working against an idea; restraining factors listed on one side of the page, driving forces listed on the other; used to reinforce the strengths (positive ideas) and overcome the weaknesses or obstacles.

Forecast. An estimate and prediction of future conditions and events based on information and knowledge available at the time of the forecast.

Formative quality evaluation. The process of reviewing the project data at key junctures during the project life cycle for a comparative analysis against the pre-established quality specifications. This evaluation process is ongoing during the life of the project to ensure that timely changes can be made as needed to protect the success of the project. Sometimes this is also called design review.

Fourteen (14) points. W. Edwards Deming's 14 management practices to help organizations increase their quality and productivity: 1) Create constancy of purpose for improving products and services. 2) Adopt a new philosophy. 3) Cease dependence on inspection to achieve quality. 4) End the practice of awarding business on price alone; instead, minimize total cost by working with a single supplier. 5) Improve constantly and forever every process for planning, production and service. 6) Institute training on the job. 7) Adopt and institute leadership. 8) Drive out fear. 9) Break down barriers between staff areas. 10) Eliminate slogans, exhortations and targets for the workforce. 11) Eliminate numerical quotas for the workforce and numerical goals for management. 12) Remove barriers that rob people of pride of workmanship and eliminate the annual rating or merit system. 13) Institute a vigorous program of education and self-improvement for everyone. 14) Put everybody in the company to work to accomplish the transformation.

Fraction defective chart (p chart). An attribute control chart used to track the proportion of defective units.

Fractional factorial experimentation. An experimental design that explores a fraction of all the possible combinations of all the levels of all the factors.

Frequency distribution. For a sample drawn from a statistical population, the number of times each outcome was observed.

Full factorial experimentation. An experimental design that explores all the possible combinations of all the levels of all the factors.

G

Gantt chart. A type of bar chart used in process/project planning and control to display planned work and finished work in relation to time. Also called a milestone chart.

Gap analysis. A technique that compares a company's existing state to its desired state (as expressed by its long-term plans) to help determine what needs to be done to remove or minimize the gap.

Gauge repeatability and reproducibility (GR&R). The evaluation of a gauging instrument's accuracy by determining whether the measurements taken with it are repeatable (when there is close agreement among a number of consecutive measurements of the output for the same value of the input under the same operating conditions) and reproducible (when there is close agreement among repeated measurements of the output for the same value of input made under the same operating conditions over a period of time).

Geometric dimensioning and tolerancing (GDT). A method to minimize production costs by considering the functions or relationships of part features in order to define dimensions and tolerances.

Go/no-go. State of a unit or product. Two parameters are possible: go conforms to specifications, and no-go does not conform to specifications.

Goal statement. Description of the intended target or desired results of process improvement or design/redesign activities; usually included in a team charter and supported with actual numbers and details, once data has been obtained.

Goodness-of-fit. Any measure of how well a set of data matches a proposed distribution. Chi-square is the most common measure for frequency distributions. Simple visual inspection of a histogram is a less quantitative, but equally valid, way to determine goodness-of-fit.

Grand average. Overall average of data represented on an x-bar chart at the time the control limits were calculated. Is denoted as $(\bar{\bar{X}})$.

Green belt. Green belts are six sigma team leaders capable of forming and facilitating six sigma teams and managing six sigma projects from concept to completion. Typically, green-belt training consists of five days of classroom training and is conducted in conjunction with six sigma team projects.

H

Half normal plots. These are very similar to normal plots in that they are a graphical way of determining which factors are likely to have a significant effect. The difference is that half normal plots use the absolute value of the contrasts (to ignore the sign) and a set of half normal scores (which are the positive half of a larger set of normal scores).

Heteroscedasticity. This is a condition where the variance of Y changes as the independent variable changes location. In other words, the variance of Y is correlated to the mean of Y . This is an observed condition generally when the independent variable of interest interacts with some other independent variable. As the interaction increases, so does the heteroscedasticity.

Histogram. A graphic representation of a frequency distribution. The range of the variable is divided into a number of intervals of equal size (called cells) and an accumulation is made of the number of observations falling into each cell. The histogram is essentially a bar graph of the results of this accumulation. A graphic summary of variation in a set of data. The pictorial nature of the histogram lets people *see* patterns that are difficult to *see* in a simple table of numbers. When raw numbers are plotted in a histogram, we refer to it as a frequency plot or distribution and we are concerned to *see* the “centeredness” of the sample or population as the case may be. The pictorial nature of the histogram lets people *see* patterns that are difficult to *see* in a simple table of numbers. The histogram is one of the seven tools of quality.

House of quality. A diagram (named for its house-shaped appearance) that clarifies the relationship between customer needs and product features. It helps correlate market or customer requirements and analysis of competitive products with higher level technical and product characteristics and makes it possible to bring several factors into a single figure. Also known as quality function deployment (QFD).

Hypergeometric distribution. A probability distribution for the probability of drawing exactly n objects type from a sample of N objects of which r are of the desired type. A discrete (probability) distribution defining the probability of r occurrences in n trials of an event, when there are a total of d occurrences in a population of N .

Hypothesis statement. A complete description of the suspected causes of a process problem.

I

Impact analysis. The mathematical examination of the nature of individual risks on the project, as well as potential structures of interdependent risks. It includes the quantification of their respective impact severity, probability and sensitivity to changes in related project variables including the project life cycle. To be complete, the analysis should also include an examination of the external status quo prior to project implementation, as well as the project's internal intrinsic worth as a reference baseline. A determination should also be made as to whether all risks identified are within the scope of the project's risk response planning process.

Implementation (phase). The third of four sequential phases in the project life cycle. Also known as execution or operation phase.

Improve. The fourth element of the DMAIC phase where solutions and ideas are creatively generated and decided upon. Once a problem has been fully identified, measured and analyzed, potential solutions can be determined to solve the problem in the problem statement and support the goal statement.

In-control process. A process in which the statistical measure being evaluated is in a state of statistical control; that is, the variations among the observed sampling results can be attributed to a constant system of chance/common causes. *See also* Out-of-control process.

Individuals chart with moving range. A control chart used when working with one sample per subgroup. The individual samples are plotted on the x chart rather than subgroup averages. The individuals chart is always accompanied by a moving range chart, usually using two subgroups (two individual readings) to calculate the moving range points.

Infant mortality. High failure rate that shows up early in product usage. Normally caused by poor design, manufacture, or other identifiable cause.

Input. Any product, service, or piece of information that comes into the process from a supplier.

Instability (of a process). A process is said to show instability if it exhibits variations larger than its control limits, or shows a systematic pattern of variation.

Institutionalization. Fundamental changes in daily behaviors, attitudes and practices that make changes permanent, cultural adaptation of changes implemented by process improvement, design or redesign including complex business systems such as HR, MIS, training, etc.

Interaction effect. A condition in which the impact of a factor on the system changes depending on the level of another factor. If this is the case, it is said that the two factors interact with each other. These are also known as two-way interactions or second order effects. There are higher order interaction effects, such as third order effects that involve three factors, but frequently, higher order interactions are insignificant.

Interdependence. Shared dependence between two or more items.

Interface activity. An activity connecting a node in one subnet with a node in another subnet, representing logical interdependence. The activity identifies points of interaction or commonality between the project activities and outside influences.

Internal audit. An audit conducted within an organization by members of the organization to measure its strengths or weaknesses against its own procedures and/or external standards—a first-party audit.

Internal capability analysis. A detailed view of the internal workings of organization (for example, determine how well the capabilities of the match to strategic needs).

Internal customer. The recipient, person, or department of another person's or department's output (product, service, or information) within an organization (*see also* External customer).

Internal failure costs. Costs associated with defects found before the product or service is delivered.

Ishikawa diagram. *See* Cause and effect diagram.

J

Judgment sampling. Approach that involves making educated guesses about which items or people are representative of a whole, generally to be avoided.

Juran's trilogy. *See* Quality trilogy.

Just-in-time manufacturing (JIT). An optimal material requirement planning system for a manufacturing process in which there is little or no manufacturing material inventory on hand at the manufacturing site and little or no incoming inspection. It is time depended. That means that, time manufacturing coordinates inventory and production to get away from the batch mode of production in order to improve quality.

K

K. For process capability studies: a measure of difference between the process mean and the specification mean (nominal). It is represented by $(\text{Mean} - \text{Midpoint})/(\text{Tolerance}/2)$.

Kaikaku (Japanese). A breakthrough improvement in eliminating waste.

Kano model. A representation of the three levels of customer satisfaction defined as dissatisfaction, neutrality and delight.

KJ method. *See* Affinity chart.

KPIV. Key process input variable—an independent material or element, with descriptive characteristics, which is either an object (going into) or a parameter of a process (step) and which has a significant (key) effect on the output of the process.

KPOV. Key process output variable—a dependent material or element, with descriptive characteristics, which is the result of a process (step) which either is, or significantly affects, the customer's CTQ characteristics.

Kurtosis. A measure of the shape of a distribution. If the distribution has longer tails than a normal distribution of the same standard deviation, then it is said to have positive kurtosis (platykurtosis); if it has shorter tails, then it has negative kurtosis (leptokurtosis). Kurtosis is measured by $E(X\mu)^4/\sigma^4$. The value of 3 is for normal; greater than 3 is for leptokurtic; and less than 3 is for platykurtic.

L

Lean approach/lean thinking. (Lean and agile may be used interchangeably.) The focus is on reducing cycle time and waste using a number of different techniques and tools for example, value stream mapping and identifying and eliminating monuments and non-value-added steps. You know when a lean culture is present when: a) you have less fire-fighting, b) you meet all your operating targets, and operations are stable, c) your entire organization shares the same vision, d) everyone is always looking for a way to improve, but the improvements come from a standardized foundation, e) you can walk out on your manufacturing floor on any day, at any time, and know the actual condition of your operation, f) you hear “we” and “us” more often than “you” and “they.”

Lean manufacturing. Applying the lean approach to improving manufacturing and non-manufacturing operations.

Learning organization. An organization that has as a policy to continue to learn and improve its products, services, processes and outcomes; an organization that is continually expanding its capacity to create its future.

Leptokurtosis. For frequency distributions: a distribution that shows a higher peak and shorter tails than a normal distribution with the same standard deviation.

Levels. The set of conditions to which factors are changed. Simply put, levels are what the factors are changed to.

Life cycle. A product life cycle is the total time frame from product concept to the end of its intended use; a project life cycle is typically divided into five stages: concept, planning, design, implementation, and evaluation and close-out.

Life cycle costing. The concept of including all costs within the total life of a project from concept, through implementation, startup to dismantling. It is used for making decisions between alternatives and is a term used principally by the government to express the total cost of an article or system. It is also used in the private sector by the real estate industry.

Linear regression. The mathematical application of the concept of a scatter diagram where the correlation is actually a cause and effect relationship.

Linear responsibility matrix. A matrix providing a three-dimensional view of project tasks, responsible person and level of relationship.

Linearity. The extent to which a measuring instrument’s response varies with the measured quantity.

Long-term goals. Refers to goals that an organization hopes to achieve in the future, usually in three to five years. They are commonly referred to as strategic goals.

Lot. A defined quantity of product accumulated under conditions that are considered uniform for sampling purposes.

Lot tolerance percent defective (LTPD). For acceptance sampling: expressed in percent defective units; the poorest quality in an individual lot that should be accepted. Commonly associated with a small consumer's risk.

Lower control limit (LCL). For control charts: the limit above which the process subgroup statistics (\bar{x} , R, sigma) remain when the process is in control.

Lower specification limit (LSL). The lowest value of a product dimension or measurement which is acceptable.

M

Macro processes. Broad, far-ranging processes that often cross functional boundaries.

Main effect. A measure of the influence of varying the factor levels on the system response (or quality characteristic).

Maintainability. The probability that a given maintenance action for an item under given usage conditions can be performed within a stated time interval when the maintenance is performed under stated conditions using stated procedures and resources. Maintainability has two categories: serviceability—the ease of conducting scheduled inspections and servicing, and repairability—the ease of restoring service after a failure.

Management training. Usually refers to training and/or education provided to any management or professional level person from front-line supervision up to, but not including executives.

Market-perceived quality. The customer's opinion of an organization's products or services as compared to those of the competitors.

Master black belt. This is the highest level of technical and organizational proficiency. Because master black belts train black belts, they must know everything the black belts know, as well as understand the mathematical theory on which the statistical methods are based. Masters must be able to assist black belts in applying the methods correctly in unusual situations. Whenever possible, statistical training should be conducted only by master black belts. If it's necessary for black belts and green belts to provide training, they should only do so under the guidance of master black belts. Because of the nature of the master's duties, communications and teaching skills should be judged as important as technical competence in selecting candidates.

Matrix. A two-dimensional structure in which the horizontal and vertical intersections form cells or boxes. In each cell may be identified a block of knowledge whose interface with other blocks is determined by its position in the structure.

Matrix chart/diagram. A management and planning tool that shows the relationships among various groups of data; it yields information about the relationships and the importance of task/method elements of the subjects.

Matrix–statistics. An array of data arranged in rows and columns.

Mean. A measure of central tendency. It is the arithmetic average of all measurements in a data set. Also known as the average. There are two means: 1) mean (of a population) (μ)—the true arithmetic average of all elements in a population. \bar{X} -bar approximates the true value of the population mean, and 2) mean (of a statistical sample) (\bar{X} – x-bar)—the arithmetic average value of some variable. The mean is given by the formula, where “ x ” is the value of each measurement in the sample. All x ’s are added together and divided by the number of elements (n) in the sample.

Mean time between failures (MTBF). The average time interval between failures for repairable product for a defined unit of measure (for example, operating hours, cycles, or miles).

Measure. The second element of the DMAIC model, where key measures are identified, and data are collected, compiled, and displayed. A quantified evaluation of specific characteristics and/or level of performance based on observable data.

Measurement. Refers to the reference standard or sample used for the comparison of properties.

Measurement accuracy. The extent to which the average result of a repeated measurement tends toward the true value of the measured quantity. The difference between the true value and the average measured value is called the instrument bias, and may be due to such things as improper zero-adjustment, nonlinear instrument response, or even improper use of the instrument.

Measurement error. The difference between the actual and measured value of a measured quantity.

Measurement precision. The extent to which a repeated measurement gives the same result. Variations may arise from the inherent capabilities of the instrument, from variations of the operator’s use of the instrument, from changes in operating conditions, etc.

Measurement system capability. The method and tools used to collect and measure the results of the experiment must be carefully verified to avoid introducing distortion or bias.

Median (of a statistical sample). The middle number or center value of a set of data when all the data are arranged in an increasing sequence. For a sample of a specific variable, the median is the point \bar{X} such that half the sample elements are below and the other half, are above of the median.

Median chart. For variables data: a control chart of the median of subgroups.

Method. The manner or way in which work is done. When formalized into a prescribed manner of performing specified work, a method becomes a procedure.

Micro managing. Managing every little detail (for example, approving requisition for post-it notes).

Micro processes. Narrow processes made up of detailed steps and activities that could be accomplished by a single person.

Milestone. A significant event in the project (key item or key event). A point in time when a critical event is to occur; a symbol placed on a milestone chart to locate the point when a critical event is to occur.

Milestone chart. Another name for a Gantt chart.

Mission statement. An explanation of purpose or reasons for existing as an organization; it provides the focus for the organization and defines its scope of business.

Mode (of a statistical sample). The value of the sample variable that occurs most frequently.

Modified control limits. Control limits calculated from information other than the process's statistical variation, such as tolerances. Must be used cautiously, because the process could be working within its normal variation, but show up on the control chart as out of control if limits do not account for that variation.

Monitoring. The capture, analysis and reporting of actual performance compared to planned performance.

Monte carlo simulation. A computer modeling technique to predict the behavior of a system from the known random behaviors and interactions of the system's component parts. A mathematical model of the system is constructed in the computer program, and the response of the model to various operating parameters, conditions, etc. can then be investigated. The technique is useful for handling systems whose complexity prevents analytical calculation.

Moving average moving range charts. A control chart which combines rational subgroups of data and the combined subgroup averages and ranges are plotted. Often used in continuous process industries, such as chemical processing, where single samples are analyzed.

Multi-attribute evaluation. Simpler than QFD, this process rank orders and weights customer requirements relative to the competition. In addition it estimates the cost of each requirement in order to prioritize improvement actions.

Multidisciplinary team. A team of people is brought together to work on the experiment. Each member has expertise or knowledge that is directly applicable to the achievement of the experiment's objective.

Multi-voting. A decision-making tool that enables a group to sort and narrow through a long list of ideas to identify priorities. Faced with a list of ideas, problems, causes, etc., each member of a group is given a set number of votes. Those items receiving the most votes get further attention/consideration.

Multivariate control chart. A control chart for evaluating the stability of a process in terms of the levels of two or more variables or characteristics.

N

N. Population sample size.

n. Sample size (the number of units in a sample).

Natural team. A work group having responsibility for a particular process.

Next operation as customer. Concept that the organization is comprised of service/product providers and service/product receivers or internal customers.

Nominal chart. A control chart that plots the deviation from the nominal value. Often used when individual samples are taken in short-run, low-volume processes. Allows multiple part numbers manufactured by similar processes to be plotted on the same control charts.

Nominal group technique. A technique similar to brainstorming, used by teams to generate ideas on a particular subject. Team members are asked to silently come up with as many ideas as possible, writing them down. Each member is then asked to share one idea, which is recorded. After all the ideas are recorded, they are discussed and prioritized by the group.

Non-conformance. A deficiency in characteristics, documentation or procedure that renders the quality of material/service unacceptable or indeterminate.

Nonconforming unit. A sample (part) which has one or more nonconformities, making the sample unacceptable for its intended use. *See also* Defective unit.

Nonconformity. A departure of a quality characteristic from its intended level or state. The non-fulfillment of a specified requirement. A nonconformity may also be called a blemish, defect, or imperfection).

Nondestructive testing and evaluation (NDT&E). Testing and evaluation methods that do not damage or destroy the product being tested.

Nonlinearity (of a measuring instrument). The deviation of the instrument's response from linearity.

Non-value-added. Refers to tasks or activities that can be eliminated with no deterioration in product or service functionality, performance, or quality in the eyes of the customer.

Normal distribution. A probability distribution in the shape of a bell. It is because of this shape that sometimes it is referred as the bell shape distribution. The normal distribution is a good approximation for a large class of situations. It is a distribution for continuous data and where most of the data are concentrated around the average, and it is equally likely that an observation will occur above or below the average. One example is the distribution resulting from the random additions of a large number of small variations. The central limit theorem expresses this for the distribution of means of samples; the distribution of means results from the random additions of a large number of individual measurements, each of which contributes a small variation of its own. The normal distribution (or Gaussian distribution) is exhibited by many naturally occurring variables and its pre-

dictive properties are used extensively in statistical analysis. It is significant to know that in this kind of distribution the average, the middle and the mode are the same.

Normal plots. These are a useful graphical tool for (among other uses) helping to identify which factor effects are likely to be real (or active). Normal plots are used to determine the normality of a set of data. Factor effects that do not follow the expected normal distribution are assumed to have resulted from changing factor levels (as opposed to random fluctuations).

Normal score. These are expected ordered values for the standard normal distribution (that is, having a mean of 0 and a standard deviation of 1). They form the x axis locations of a normal plot. The scores can be obtained from existing tables.

Norms. Behavioral expectations, mutually agreed-upon rules of conduct, protocols to be followed, social practice.

np-chart. For attributes data: a control chart of the number of defective units in a subgroup. Assumes a constant subgroup size.

Number of affected units chart (np chart). A control chart for evaluating the stability of a process in terms of the total number of units in a sample in which frequency of an event of a given classification occurs.

O

Objective. A quantitative statement of future expectations and an indication of when the expectations should be achieved; it flows from goals and clarifies what people must accomplish.

Objective (in an experiment). The primary reason for attempting the experiment, that is, a description of the outcome the experiment is designed to achieve. This may be the elimination of an existing problem or the achievement of a desirable goal.

Objective evidence. Verifiable qualitative or quantitative observations, information, records, or statements of fact pertaining to the quality of an item or service or to the existence and implementation of a quality system element.

Operating characteristic curve (OC). For acceptance sampling: a curve showing the probability of accepting a lot versus the percentage of defective units in the lot.

Operational definition. A clear, precise description of the factor being measured or the term being used; ensures a clear understanding of terminology and the ability to operate a process or collect data consistently.

Opportunity. Any event that generates an output (product, service or information).

Optimization. Refers to achieving planned process results that meet the needs of the customer and supplier alike and minimize their combined costs. Also, it is the third element of the DCOV model.

Orthogonal array. A matrix of levels arranged in rows and columns. Each row represents the combination of factor level settings in a given experimental run. Each column represents a specific factor that can be changed from experiment to experiment. When a factor has not been allocated to a column, the column can be used to estimate an interaction effect. The array is called orthogonal because the effect of each factor on the experimental results can be separated.

Out-of-control process. A process in which the statistical measure being evaluated is not in a state of statistical control (i.e., the variations among the observed sampling results cannot all be attributed to a constant system of chance causes; special or assignable causes exist. *See also* In-control process.

P

p chart. Fraction defective chart (percent defective). (Also called a proportion chart.) For attributes data: a control chart of the percentage of defective units (or fraction defective) in a subgroup.

Parameter design (Taguchi). The use of design of experiments for identifying the major contributors to variation.

Pareto analysis. An analysis of the frequency of occurrence of various possible concerns. This is a useful way to decide quality control priorities when more than one concern is present. The underlying Pareto principle states that a very small number of concerns is usually responsible for most quality problems.

Pareto chart. Quality tool based on Pareto principle; uses attribute data with columns arranged in descending order, with highest occurrences (highest bar) shown first; uses a cumulative line to track percentages of each category/bar, which distinguishes the 20 percent of items causing 80 percent of the problem. It is considered to be one of the seven basic tools of quality. Sometimes it is also referred to as Pareto diagram.

Payback period. The number of years it will take the results of a project or capital investment to recover the investment from net cash flows.

Percent defective. For acceptance sampling: the percentage of units in a lot that are defective (i.e., of unacceptable quality).

Pilot. Trial implementation of a solution, on a limited scale, to ensure its effectiveness and test its impact; an experiment verifying a root cause hypothesis.

Plan. An intended future course of action.

Plan-do-check-act cycle (PDCA). A four-step process for quality improvement. In the first step (plan), a plan to effect improvement is developed. In the second step (do), the plan is carried out, preferably on a small scale. In the third step (check), the effects of the plan are observed. In the last step (act), the results are studied to determine what was learned and what can be predicted. The plan-do-check-act cycle is sometimes referred to as the Shewhart cycle because Walter A. Shewhart discussed the concept in his book

Statistical Method from the Viewpoint of Quality Control and as the Deming cycle because W. Edwards Deming introduced the concept in Japan. The Japanese subsequently called it the Deming cycle.

Plan-do-study-act (PDSA). The same basic model as the PDCA except instead of “check,” it was replaced in the early 1980s by Deming with “study” to denote action rather than complacency.

Plan matrix. In a designed experiment, the combination of factors and levels are assigned to a matrix which specifies the setting of factors for particular experimental runs. This matrix is known as the plan matrix. Alternative names given to this matrix are the experimental design and experimental layout.

Platykurtosis. For frequency distributions: a distribution which has longer tails than a normal distribution with the same standard deviation.

Point estimate (statistics). A single-value estimate of a population parameter. Point estimates are commonly referred to as the points at which the interval estimates are centered; these estimates give information about how much uncertainty is associated with the estimate.

Poisson distribution. A probability distribution for the number of occurrences of an event; n = number of trials; p = probability that the event occurs for a single trial; r = the number of trials for which the event occurred. The Poisson distribution is a good approximation of the binomial distribution for a case where p is small. A simpler way to say this is: A distribution used for discrete data, applicable when there are many opportunities for occurrence of an event but a low probability (less than 0.10) on each trial.

Poka-yoke. A term that means to mistake-proof a process by building safeguards into the system that avoid or immediately find errors. It comes from *poka*, which means error, and *yokeru*, which means to avoid. Also known as mistake-proofing and error-proofing.

Policy. Directives issued by management for guidance and direction where uniformity of action is essential. Directives pertain to the approach, techniques, authorities and responsibilities for carrying out the management function.

Population (statistical). The set of all possible outcomes of a statistical determination. The population is usually considered as an essentially infinite set from which a subset called a sample is selected to determine the characteristics of the population, that is, if a process were to run for an infinite length of time, it would produce an infinite number of units. The outcome of measuring the length of each unit would represent a statistical universe, or population. Any subset of the units produced (say, a hundred of them collected in sequence) would represent a sample of the population. Also known as universe.

P_{pk} . Potential process capability used in the validation stage of a new product launch (uses the same formula as C_{pk} , but a higher value is expected due to the smaller time span of the samples).

PPM. Parts per million.

Precision (of measurement). The extent to which repeated measurement of a standard with a given instrument yields the same result. A characteristic of measurement that

addresses the consistency or repeatability of a measurement system when the identical item is measured a number of times.

Pre-control. A method of controlling a process based on the specification limits. It is used to prevent the manufacture of defective units, but does not work toward minimizing variation of the process. The area between the specifications are split into zones (green, yellow and red) and adjustments made when a specified number of points fall in the yellow or red zones. A control process, with simple rules, based on tolerances. It is effective for any process where a worker can measure a quality characteristic (dimension, color, strength, etc.) and can adjust the process to change that characteristic, and where there is either continuous output or discrete output totaling three or more pieces.

Prediction equation. An equation which can predict an estimate of a response with factors set at predetermined levels.

Prevention costs. Costs incurred to keep internal and external failure costs and appraisal costs to a minimum.

Prevention versus detection. A term used to contrast two types of quality activities. Prevention refers to those activities designed to prevent non-conformances in products and services. Detection refers to those activities designed to detect non conformances already in products and services. Another term used to describe this distinction is designing in quality versus inspecting in quality.

Preventive action. Action taken to eliminate the causes of a potential nonconformity; defect, or other undesirable situation in order to prevent occurrence.

Price of nonconformance (PONC). The cost of not doing things right the first time.

Priorities matrix. A tool used to choose between several options that have many useful benefits, but where not all of them are of equal value.

Probability distribution. A relationship giving the probability of observing each possible outcome of a random event. The relationship may be given by a mathematical expression, or it may be given empirically by drawing a frequency distribution for a large enough sample. In essence, it is a mathematical formula that relates the values of characteristics to their probability of occurrence in a population.

Problem/need statement/goal. Documentation to define the problem; to document the need to find a solution; and to document the overall aim of the sponsor.

Problem/opportunity statement. Description of the symptoms or the “pain” in the process; usually written in noun-verb structure: usually included in a team charter and supported with numbers and more detail once data have been obtained.

Problem resolution. The interaction between the black belt (project manager) and an individual team member with the goal of finding a solution to a technical or personal problem that affects project accomplishment.

Problem-solving. A rational process for identifying, describing, analyzing, and resolving situations in which something has gone wrong without explanation.

Procedure. A document that answers the questions: what has to be done; where is it to be done; when it is to be done; who is to do it; and why do it.

Process. An activity or group of activities that takes an input, adds value to it, and provides an output to an internal or external customer; a planned and repetitive sequence of steps by which a defined product or service is delivered. A process where the energy transformation (or value-added) takes place. In manufacturing the elements are: machine, method, material, measurement, mother nature, manpower. In non-manufacturing the elements are: manpower, place, policy, procedures, measurement, environment.

Process analysis diagram. A cause-and-effect diagram for a process. Each step of the process and the factors contributing to it are shown, indicating all cause and effect relationships. This allows systematic tracing of any problems that may arise, to identify the source of the problem.

Process capability. Determination of whether a process, with normal variation, is capable of meeting customer requirements; measure of the degree a process is or is not meeting customer requirements, compared to the distribution of the process. *See also* Control, Control charts. The level of uniformity of product that a process is capable of yielding. Process capability may be expressed by the percent of defective products, the range or standard deviation of some product dimension, etc. Process capability is usually determined by performing measurements on some (or all) of the product units produced by the process. A statistical measure of the inherent process variability for a given characteristic. *See* C_p , C_{pk} , and P_{pk} .

Process capability index. The value of the tolerance specified for the characteristic divided by the process capability. There are several types of process capability indexes, including the widely used C_p and C_{pk} .

Process characterization. Is concerned with the identification and benchmarking of key product characteristics. This is done by way of gap analysis.

Process control. Maintaining the performance of a process at its capability level. Process control involves a range of activities such as sampling the process product, charting its performance, determining causes of any excessive variation and taking corrective actions.

Process decision program chart (PDPC). A management and planning tool that identifies all events that can go wrong and the appropriate countermeasures for these events. It graphically represents all sequences that lead to a desirable effect.

Process design. Creation of an innovative process needed for newly introduced activities, systems, products, or services

Process improvement. Refers to the act of changing a process to reduce variability and cycle time and make the process more effective, efficient, and productive. Specifically, it is focused on incremental changes/solutions to eliminate or reduce defects, costs or cycle time; leaves basic design and assumptions of a process intact. *See also* Process redesign.

Process map, or flowchart. Graphic display of the process flow that shows all activities, decision points, rework loops, delays, inspection and handoffs.

Process measures. Measures related to individual steps as well as to the total process; predictors of output measures.

Process optimization. Is aimed at the identification and containment of those process variables which exert undue influence over the key product characteristics.

Process owner. The manager or leader who is responsible for ensuring that the total process is effective and efficient.

Process redesign. Method of restructuring process flow elements eliminating handoffs, rework loops, inspection points, and other non-value-adding activities; typically means “clean slate” design of a business segment and accommodates major changes or yields exponential improvements (similar to reengineering). *See also* Process improvement.

Producer’s risk. The maximum probability of saying a process or lot is unacceptable when, in fact, it is acceptable. For a sampling plan, refers to the probability of not accepting a lot, the quality of which has a designated numerical value representing a *level* that is generally desirable. Usually the designated value will be the acceptable quality *level* (also called alpha risk and type I error).

Productivity. The measurement of labor efficiency when compared to an established base. It is also used to measure equipment effectiveness, drawing productivity, etc.

Profitability. A measure of the total income of a project compared to the total monies expended at any period of time. the techniques that are utilized are payout time, return on original investment (ROI), net present value (NPV), discounted cash flow (DCF), sensitivity and risk analysis.

Program evaluation and review technique (PERT). An event-oriented project management planning and measurement technique that utilizes an arrow diagram or road map to identify all major project events and demonstrates the amount of time (critical path) needed to complete a project. It provides three time estimates: optimistic, most likely, and pessimistic.

Progress trend. An indication of whether the progress rate of an activity or of a project is increasing, decreasing, or remaining the same (steady) over a period of time.

Project. Any undertaking with a defined starting point and defined objectives by which completion is identified. In practice, most projects depend on finite or limited resources by which the objectives are to be accomplished.

Project life cycle. The four sequential phases in time through which any project passes, namely: concept; development; execution (implementation or operation); and finishing (termination or close out). Note that these phases may be further broken down into stages depending on the area of project application. Sometimes these phases are known as: concept, planning, design, implementation, and evaluation.

Project manager. The individual appointed with responsibility for project management of the project. (In the six sigma methodology, that person has been designated to be the black belt).

Project objectives. Project scope expressed in terms of outputs, required resources and timing.

Project pre-selection meetings. Meetings held to supplement and/or verify qualifications, data and specifications.

Project rationale (“business case”). Broad statement defining area of concern or opportunity, including impact/benefit of potential improvements, or risk of not improving a process; links to business strategies, the customer, and/or company values. Provided by business leaders to an improvement team and used to develop problem statement and project charter.

Project reporting. A planning activity involved with the development and issuance of (internal) time management analysis reports and (external) progress reports.

Project risk analysis. Analysis of the consequences and probabilities that certain undesirable events will occur and their impact on attaining the contract/procurement objectives.

Project team (framework). The central management group of the project. The group of people, considered as a group, that shares responsibility for the accomplishment of project goals and who report either part-time or full-time to the project manager.

Proportion defective. Fraction of units with non-conformances (defects); number of defective units divided by the total number of units; translate the decimal figure to a percentage. *See also* Defect; Defective.

Q

Quality adviser. The person (facilitator) who helps team members work together in quality processes and is a consultant to the team. The adviser is concerned about the process and how decisions are made rather than about which decisions are made. In the six sigma initiative this person is also called champion.

Quality assurance (general). The function of assuring that a product or service will satisfy given needs. The function includes necessary verification, audits, and evaluations of quality factors affecting the intended usage and customer satisfaction. This function is normally the responsibility of one or more upper management individuals overseeing the quality assurance program; primary tools are statistical analysis, inspection and SPC. It is also a discipline (or department) that is charged with maintaining product or service conformance to customer specifications.

Quality audit. A systematic, independent examination and review to determine whether quality activities and related results comply with planned arrangements and whether these arrangements are implemented effectively and are suitable to achieve the objectives.

Quality characteristic. A particular aspect of a product which relates to its ability to perform its intended function, or the aspect-of a system to be measured in an experiment. It is a measure of the desired response of the system as opposed to error states or failure modes. This is used to determine the success of the experiment’s objective. It is also the unique characteristics of products and of services by which customers evaluate their perception of quality.

Quality control. The process of maintaining an acceptable level of product quality.

Quality control (technical). The planned process of identifying established system requirements and exercising influence through the collection of specific (usually highly technical and itself standardized) data. The basis for decision on any necessary corrective action is provided by analyzing the data and reporting it comparatively to system standards.

Quality cost reports. A system of collecting quality costs that uses a spreadsheet to list the elements of quality costs against a spread of the departments, areas, or projects in which the costs occur and summarizes the data to enable trend analysis and decision making. The reports help organizations review prevention costs, appraisal costs, and internal and external failure costs.

Quality costs. *See* Cost of quality.

Quality council (sometimes called “quality steering committee). Is the group driving the quality improvement effort and usually having oversight responsibility for the implementation and maintenance of the quality management system; operates in parallel with the normal operation of the business. (This leadership guides the implementation of quality or six sigma within an organization; establishes, reviews, and supports the progress of quality improvement teams.)

Quality engineering. The analysis of a manufacturing system at all stages to maximize the quality of the process itself and the products it produces.

Quality evaluation methods. The technical process of gathering measured variables or counted data for decision making in quality process review. Normally these evaluation methods should operate in a holistic context involving proven statistical analysis, referred to previously as statistical process control. A few example methods are: graphs and charts; Pareto diagrams; and exception reporting.

Quality function deployment (QFD). A structured method in which customer requirements are translated into appropriate technical requirements for each stage of product development and production. The QFD process is often referred to as listening to the voice of the customer. *See also* House of quality.

Quality improvement. Actions taken throughout the organization to increase the effectiveness and efficiency of activities and processes in order to provide added benefits to both the organization and its customers.

Quality loss function. A parabolic approximation (Taylor’s series) of the quality loss that occurs when a quality characteristic deviates from its target value. The quality loss function is expressed in monetary units. The cost of deviating from the target increases as a quadratic function the farther the quality characteristic moves from the target. The formula used to compute the quality loss function depends on the type of quality characteristic being used. The quality loss function was first introduced in this form by Genichi Taguchi.

Quality policy. Top management’s formally stated intentions and direction for the organization pertaining to quality.

Quality principles. Rules or concepts that an organization believes in collectively. The principles are formulated by senior management with input from others and are communicated and understood at every level of the organization.

Quality score chart (Q chart). A control chart for evaluating the stability of a process in terms of a quality score. The quality score is the weighted sum of the count of events of various classifications in which each classification is assigned a weight.

Quality system. The organizational structure, procedures, processes, and resources needed to implement quality management.

Quality system audit. A documented activity performed to verify, by examination and valuation of objective evidence, that applicable elements of the quality system are suitable and have been developed, documented, and effectively implemented in accordance with specified requirements.

Quality trilogy. A three-pronged approach to managing for quality. The three legs are quality planning (developing the products and processes required to meet customer needs), quality control (meeting product and process goals), and quality improvement (achieving unprecedented levels of performance). Attributed to Joseph M. Juran.

Quantitative measurement. A numerical measure which is independent of the observer, and is objective.

Questionnaires. *See* Survey.

R

Radar chart. A visual method to show in graphic form the size of gaps among a number of both current organization performance areas and ideal performance areas; resulting chart resembles a radar screen.

Random. Varying with no discernable pattern.

Random number generator. Used to select a stated quantity of random numbers from a table of random numbers, the resulting selection is then used to pull specific items or records corresponding to the selected numbers to comprise a “random sample.”

Randomization. The executing of experimental runs in a random order. If the quality characteristic, or response, is likely to vary due to testing conditions changes, one precaution is to randomize the run order.

Random sample. The process of selecting a sample of size n where each part in the lot or batch has an equal probability of being selected.

Range. Measure of dispersion — the difference between the highest and lowest of a group of values.

Range chart (R chart). A control chart in which the subgroup range, R , is used to evaluate the stability of the variability within a process. A control chart of the range of variation among the individual elements of a sample, i.e., the difference between the largest and smallest elements — as a function of time, or lot number, or similar chronological variable.

Ratio analysis. The process of relating isolated business numbers, such as sales, margins, expenses, debt, and profits, to make them meaningful.

Rational subgroup. A subgroup which is expected to be as free as possible from assignable causes (usually consecutive items). For control charting: a subgroup of units selected to minimize the differences due to assignable causes. Usually samples taken consecutively from a process operating under the same conditions will meet this requirement.

R-bar. Average range value displayed on a range control chart. Value is set at the time control limit(s) are calculated.

Regression analysis. A study used to understand the relationship between two or more variables, or another way of saying it, a technique for determining the mathematical relation between a measured quantity and the variables it depends on. The relationship can be determined and expressed as a mathematical equation. For example, the method might be used to determine the mathematical form of the probability distribution from which a sample was drawn, by determining which form best “fits” the frequency distribution of the sample. The frequency distribution is the “measured quantity” and the probability distribution is a “mathematical relation.” Regression analysis makes it possible not only to explain relationships but also to predict one variable from knowledge about another.

Reliability. The probability that a product will function properly for some specified period of time, under specified conditions. In measurement system analysis, refers to the

ability of an instrument to produce the same results over repeated administration-to measure consistently. In reliability engineering it is the probability of a product performing its intended function under stated conditions for a given period of time (*see also* Mean time between failures).

Repair. Action taken on a nonconforming product so that it will fulfill the intended usage requirements although it may not conform to the originally specified requirements.

Repeatability (of a measurement). The extent to which repeated measurements of a particular object with a particular instrument produces the same value. In other words, it is a measurement stability concept in which a single person gets the same results each time he/she measures and collects data; necessary to ensure data consistency and stability. *See also* Reproducibility.

Repeatability and reproducibility (R & R). A measurement validation process to determine how much variation exists in the measurement system (including the variation in product, the gage used to measure, and the individuals using the gage).

Repetition. Repetition means taking multiple measurements for each row of an experiment before proceeding to the next row. This precaution will combat the lack of repeatability.

Replication. Taking one measurement for each row, then repeating the entire experiment multiple times.

Reproducibility. The variation between individual people taking the same measurement and using the same gauging. In other words, it is a measurement stability concept in which different people get the same results when they measure and collect data using the same methods; necessary to ensure data consistency and stability. *See also* Repeatability.

Residual analysis. A means of comparing actual and predicted results of the experiment so as to verify that no bias has been introduced into the experimental procedure.

Resolution (of a measurement). The smallest unit of measure which an instrument is capable of indicating.

Resolution III. An experimental plan where some of the main effects are confounded with two-way interactions.

Resolution IV. An experimental plan where all the main effects are not confounded with two-way interactions, but the two-way interactions are confounded with each other.

Resolution V. An experimental plan where all the main effects and two-way interactions are not confounded with each other.

Response plot. The results of each run of the designed experiment as a measure of the identified quality characteristic.

Response surface methodology (RSM). A method of determining the optimum operating conditions and parameters of a process, by varying the process parameters and observing the results on the product. This is the same methodology used in evolutionary operations (EVOP), but is used in process development rather than actual production, so that strict adherence to product tolerances need not be maintained. An important aspect of RSM is to

consider the relationships among the parameters, and the possibility of simultaneously varying two or more parameters to optimize the process.

Responsibility. Charged personally with the duties, assignments, and accountability for results associated with a designated position in the organization. Responsibility can be delegated but cannot be shared.

Return on investment (ROI). An umbrella term for a variety of ratios measuring an organization's business performance and calculated by dividing some measure of return by a measure of investment and then multiplying by 100 to provide a percentage. In its most basic form, ROI indicates what remains from all money taken in after all expenses are paid.

Review. To examine critically to determine suitability or accuracy.

Revision plans. A mechanism (process) for updating processes, procedures, and documentation.

Rework. Action taken on a nonconforming product so that it will fulfill the specified requirements (may also pertain to a service).

Risk assessment. The process of determining what risks are present in a situation (for example, project plan) and what actions might be taken to eliminate or mediate them.

Robustness. The condition of a product or process design that remains relatively stable with a minimum of variation even though factors that influence operations or usage, such as environment and wear, are constantly changing.

Role-playing. A training technique whereby participants spontaneously perform in an assigned scenario taking specific roles.

Rolled through-put-yield. The cumulative calculation of defects through multiple steps in a process; total input units, less the number of errors in the first process step number of items "rolled through" that step; to get a percentage, take the number of items coming through the process correctly divided by the number of total units going into the process; repeat this for each step of the process to get an overall rolled-throughput percentage. *See also Yield.*

Root cause analysis. A quality tool used to distinguish the source of defects or problems. It is a structured approach that focuses on the decisive or original cause of a problem or condition.

Run. A set of consecutive units, i.e., sequential in time. In SPC a signal condition of seven consecutive points above or below the center line.

Run chart. A line graph showing data collected during a run or an uninterrupted sequence of events. A trend is indicated when the series of collected data points head up or down crossing the center line. When the run chart is referred to as time plot it is meant to be a measurement display tool showing variation in a factor over time; indicates trends, patterns, and instances of special causes of variation. *See Control chart, Special cause, Variation.*

S

s. Symbol used to represent standard deviation of a sample.

S curves. Graphical display of the accumulated costs, labor hours or quantities, plotted against time for both budgeted and actual amounts.

Sample (statistics). A representative group selected from a population. The sample is used to determine the properties of the population. (A finite number of items of a similar type taken from a population for the purpose of examination to determine whether all members of the population would conform to quality requirements or specifications.)

Sample size. The number of elements, or units, in a sample, chosen from the population.

Sample standard deviation chart (s chart). A control chart in which the subgroup standard deviation, s , is used to evaluate the stability of the variability within a process.

Sampling. The process of selecting a sample of a population and determining the properties of the sample with the intent of projecting those conclusions to the population. The sample is chosen in such a way that its properties (even though small) are representative of the population. Sampling is the foundation of statistics; it can save time, money, and effort; allows for more meaningful data; can improve accuracy of measurement system.

Sampling bias. When data can be prejudiced in one way or another and do not represent the whole.

Sampling variation. The variation of a sample's properties from the properties of the population from which it was drawn.

Scatter diagram. A graphical technique to analyze the relationship between two variables. Two sets of data are plotted on a graph, with the y-axis being used for the variable to be predicted and the x-axis being used for the variable to make the prediction. The graph will show possible relationships (although two variables might appear to be related, they might not be; those who know most about the variables must make that evaluation). Sometimes this is referred to as the scatter plot. The scatter diagram is one of the seven tools of quality. *See also* Correlation coefficient.

Scope. Defines the boundaries of the process or the process improvement project; clarifies specifically where opportunities for improvement reside (start- and end-points); defines where and what to measure and analyze; needs to be within the sphere of influence and control of the team working on the project—the broader the scope, the more complex and time-consuming the process improvement efforts will be. In other words, it is the work content and products of a project or component of a project. scope is fully described by naming all activities performed, the resources consumed and the end products which result, including quality standards. a statement of scope should be introduced by a brief background to the project, or component, and the general objective(s).

Screening. Techniques used for reviewing, analyzing, ranking and selecting the best alternative for the proposed action.

Shewhart control chart. A graphic continuous test of hypothesis. Commonly known as x-bar and R charts. *See also* Control chart.

Shewhart cycle. *See* Plan-do-check-act cycle.

Shewhart, Walter A. Walter A. Shewhart was a statistician at the forefront of applying statistical methods to quality management, in the late 1920s. Among other things, he helped to formalize the PDCA cycle.

Short-run SPC. A set of techniques used for SPC in low volume, short duration manufacturing.

Short-term plan. A short duration schedule, usually four to eight weeks, used to show in detail the activities and responsibilities for a particular period. a management technique often used “as needed” or in a critical area of the project.

Should-be process mapping. Process-mapping approach showing the design of a process the way it should be (e.g., without non-value- adding activities; with streamlined workflow and new solutions incorporated). Contrasts with the “As-Is” form of process mapping. *See also* Process redesign, Value-adding activities; Non-value added.

Sigma (σ). The standard deviation of a statistical population. It is also a statistical unit of measure which reflects process capability. This capability may be measured from either short- or long-term perspective. The conversions is as follows:

	Short term	Long term
Short term	No action (z value)	Add 1.5σ
Long term	Subtract 1.5σ	No action

Sigma hat ($\hat{\sigma}$). Symbol used to represent the estimate standard deviation given by the formula $Rbar/d2$. The estimated standard deviation may only be used if the data is normally distributed and the process is in control.

Sigma limits. For histograms: lines marked on the histogram showing the points n standard deviations above and below the mean.

Signal-to-noise ratio (S/N ratio). A mathematical equation that indicates the magnitude of an experimental effect above the effect of experimental error due to chance fluctuations.

Simulation (modeling). Using a mathematical model of a system or process to predict the performance of the real system. The model consists of a set of equations or logic rules which operate on numerical values representing the operating parameters of the system. The result of the equations is a prediction of the system’s output.

SIPOC. Acronym for suppliers, inputs, process, outputs, and customer; enables an “at-a-glance,” high-level view of a process.

Six sigma. Level of process performance equivalent to producing only 3.4 defects for every one million opportunities or operations. The term is used to describe process improvement initiatives using sigma-based process measures and/or striving for six sigma level performance. The sigma value indicates how often defects are likely to occur. The

higher the sigma value, the less likely a process will produce defects. As sigma increases, costs go down, cycle time goes down, and customer satisfaction goes up.

Six-sigma approach. A quality philosophy; a collection of techniques and tools for use in reducing variation; a program of improvement methodology.

Six-sigma quality. A term used generally to indicate that a process is well controlled, that is, process limits ± 3 sigma from the centerline in a control chart, and requirements/ tolerance limits ± 6 sigma from the centerline. The term was initiated by Motorola.

Skewness. A measure of a distribution's symmetry. A skewed distribution shows a longer than normal tail on the right or left side of a distribution.

Spaghetti chart. A before improvement chart of existing steps in a process and the many back and forth interrelationships (can resemble a bowl of spaghetti); used to *see* the redundancies and other wasted movements of people and material.

Special cause. Instance or event that impacts processes only under "special" circumstances, that is, not part of the normal, daily operation of the process.

Specification. The engineering requirement, used for judging the acceptability of a particular product/service based on product characteristics, such as appearance, performance, and size. In statistical analysis, specifications refer to the document that prescribes the requirements with which the product or service has to perform.

Sponsor (or champion). Person who represents team issues to senior management; gives final approval on team recommendations and supports those efforts with the quality council; facilitates obtaining of team resources as needed; helps black belt and team overcome obstacles; acts as a mentor for the black belt.

Sporadic problem. A sudden adverse change in the status quo that can be remedied by restoring the status quo. For example, actions such as changing a worn part or proper handling of an irate customer's complaint can restore the status quo.

Stability (of a process). A process is said to be stable if it shows no recognizable pattern of change. *See also* Control.

Stabilization. The period of time between continuous operation and normal operation. This period encompasses those activities necessary to establish reliable operation at design conditions of capacity, product quality, and efficiency.

Stages of experimental design. The typical stages in conducting a typical experimental design experiment are: 1) set objective, 2) select team, 3) define characteristic, 4) define characteristic of interest, 5) determine capability, 6) select factors, 7) select levels, 8) plan the experiment, 9) select the appropriate and applicable experimental plan, 10) conduct the analysis, 11) take action.

Stages of team growth. Refers to the four development stages through which groups typically progress: forming, storming, norming, and performing. Knowledge of the stages help team members accept the normal problems that occur on the path from forming a group to becoming a team.

Stakeholders. People, departments, and organizations that have an investment or interest in the success or actions taken by the organization.

Standard. A basis for the uniformity of measuring performance. Also, a document that prescribes a specific consensus solution to a repetitive design, operating, or maintenance problem. In other words, a statement, specification, or quantity of material against which measured outputs from a process may be judged as acceptable or unacceptable

Standard deviation. A measure of the variation among the members of a statistical sample. A calculated measure of variability that shows how much the data are spread around the mean. It is shown as the lower case of sigma of the Greek alphabet as σ for the population and s for samples.

Statistic. An estimate of a population parameter using a value calculated from a random sample.

Statistical confidence (statistical significance). The level of accuracy expected of an analysis of data. Most frequently it is expressed as either a “95% level of significance,” or “5% confidence level.”

Statistical control (of a process). A process is said to be in a state of statistical control when it exhibits only random variations.

Statistical inference. The process of drawing conclusions on the basis of statistics.

Statistical process control (SPC). Use of data gathering and analysis to monitor processes, identify performance issues, and determine variability/capability. Statistical methods for analyzing and controlling the variation of a process. *See also* Run chart; Control chart.

Statistical quality control (SQC). The application of statistical methods for measuring, controlling and improving the quality of a processes. SPC is one method included in SQC. Often, however, the term statistical process control is used interchangeably with statistical quality control although statistical quality control includes acceptance sampling as well as statistical process control.

Statistical thinking. A philosophy of learning and action based on three fundamental principles: 1) all work occurs in a system of interconnected processes, 2) variation exists in all processes, and 3) understanding and reducing variation are vital to improvement.

Statistics. The mathematical methods used to determine the best range of probable values for a project and to assess the degree of accuracy or allowance for unpredictable future events such as accidents, technological innovations, strikes, etc. that can occur during the project life. The techniques that can be used are risk analysis with Monte Carlo simulation, confidence levels, range analysis, etc.

Storyboard. A pictorial display of all the components in the DMAIC process, used by the team to arrive at a solution; used in presentations to sponsor, senior management, and others.

Storyboarding. A technique that visually displays thoughts and ideas and groups them into categories, making all aspects of a process visible at once. Often used to communicate to others the activities performed by a team as they improved a process.

Strategic planning. A process to set an organization's long-range goals and identify the actions needed to reach the goals.

Strategy. A framework guiding those choices that determine the nature and direction to attain the objective.

Stratification (of a sample). If a sample is formed by combining units from several lots having different properties, the sample distribution will show a concentration or clumping about the mean value for each lot: this is called stratification. In control charting, if there are changes between subgroups due to stratification, the R-chart points will all tend to be near the centerline. In other words, stratification is a way of looking at data in multiple layers of information such as what (types, complaints, etc.), when (month, day, year, etc.), where (region, city, state, etc.), and who (department, individual).

Stratified (random) sampling. A technique to segment (stratify) a population prior to drawing a random sample from each strata, the purpose being to increase precision when members of different strata would, if not stratified, cause an unrealistic distortion.

Subgroup. For control charts: a sample of units from a given process, all taken at or near the same time.

Suboptimization. The need for each business function to consider overall organizational objectives, resulting in higher efficiency and effectiveness of the entire system, although performance of a function may be suboptimal.

Summative quality evaluation. The process of determining what lessons have been learned after the project is completed. The objective is to document which behaviors helped determine, maintain or increase quality standards and which did not (for use in future projects).

Supplier. Any person or organization that feeds inputs (products, services or information) into the process; in a service organization, many times the customer is also the supplier. In other words, any provider whose goods and services may be used at any stage in the production, design, delivery, and use of another company's products and services. Suppliers include businesses, such as distributors, dealers, warranty repair services, transportation contractors and franchises, and service suppliers, such as healthcare, training and education. Internal suppliers provide materials or services to internal customers.

Supplier quality assurance. Confidence that a supplier's product or service will fulfill its customers' needs. This confidence is achieved by creating a relationship between the customer and supplier that ensures the product will be fit for use with minimal corrective action and inspection. According to J. M. Juran, there are nine primary activities needed: 1) define product and program quality requirements, 2) evaluate alternative suppliers, 3) select suppliers, 4) conduct joint quality planning, 5) cooperate with the supplier during the execution of the contract, 6) obtain proof of conformance to requirements, 7) certify qualified suppliers, 8) conduct quality improvement programs as required, and 9) create and use supplier quality ratings.

Survey. An examination for some specific purpose; to inspect or consider carefully; to review in detail (survey implies the inclusion of matters not covered by agreed upon criteria.). Also, a structured series of questions designed to elicit a predetermined range of

responses covering a pre selected area of interest. May be administered orally by a survey-taker, by paper and pencil, or by computer. Responses are tabulated and analyzed to surface significant areas for change.

SWOT analysis. An assessment of an organization's key strengths, weaknesses, opportunities, and threats. It considers factors such as the organization's industry, the competitive position, functional areas, and management.

Symptom. An indication of a problem or opportunity.

System. A system can be defined as a combination of elements that have an influence on each other and are organized to fulfill a purpose; a system can be the product itself or a process used for manufacturing or assembling that product; a methodical assembly of actions or things forming a logical and connected scheme or unit; a network of connecting processes that work together to accomplish the aim of the whole.

Systematic sampling. Sampling method in which elements are selected from the population at a uniform interval (e.g., every half-hour, every twentieth item); this is recommended for many six sigma measurement activities.

Systematic variation (of a process). Variations that exhibit a predictable pattern. The pattern may be cyclic (i.e., a recurring pattern) or may progress linearly (trend).

Systems approach to management. A management theory that views the organization as a unified, purposeful combination of interrelated parts; managers must look at the organization as a whole and understand that activity in one part of the organization affects all parts of the organization (also known as systems thinking).

T

Tacit knowledge. Unarticulated heuristics and assumptions used by any individual or organization.

Tactical plans. Short-term plans, usually of one- to two-year duration, that describe actions the organization will take to meet its strategic business plan.

Tactics. The strategies and processes that help an organization meet its objectives.

Taguchi, Genichi. Genichi Taguchi is a leading Japanese engineering specialist whose name is often taken to be synonymous with quality and the design of experiments as applied to engineering. His major contributions have been the integration of engineering practice and statistical methods to achieve robust designs. He developed the quality loss function and signal to noise ratio concepts.

Taguchi loss function. Pertains to where product characteristics deviate from the normal aim and losses increase according to a parabolic function; by merely attempting to produce a product within specifications doesn't prevent loss (loss is that inflicted on society after shipment of a product).

Takt (tact) time. The available production time divided by the rate of customer demand. Operating to takt time sets the production pace to customer demand. Sometimes spelled as "Tact" (total actual cycle time).

Tally sheet. Another name for "Checksheet."

t-Distribution. For a sample with size n , drawn from a normally distributed population, with mean \bar{x} and standard deviation s . The true population parameters are unknown. The t-distribution is expressed as a table for a given number of degrees of freedom and a risk. As the degrees of freedom get very large, it approaches a z-distribution.

Team. A set of two or more people who are equally accountable for the accomplishment of a purpose and specific performance goals; it is also defined as a small number of people with complimentary skills who are committed to a common purpose.

Team members. The individuals (green belts) reporting either part-time or full-time to the black belt (project manager) who are responsible for some aspect of the project's activities.

Team motivation. The process by which the black belt (project manager) influences his project team to initiate effort on the project tasks, expend increasing amounts of effort on those tasks, and to persist in expending effort on these tasks over the period of time necessary for project goal accomplishment.

Team performance evaluation, rewards, and recognition. Special metrics are needed to evaluate the work of a team (to avoid focus on any individual on the team) and as a basis for rewards and recognition for team achievements.

Team-based structure. Describes an organizational structure in which team members are organized around performing a specific function of the business, such as handling customer complaints or assembling an engine.

Termination (phase). The fourth and final phase in the generic project life cycle. Also known as Final or Close-out phase.

Theory of constraints (TOC). Goldratt's theory deals with techniques and tools for identifying and eliminating the constraints (bottlenecks) in a process.

Theory of knowledge. A belief that management is about prediction, and people learn not only from experience but also from theory. When people study a process and develop a theory, they can compare their predictions with their observations; profound learning results.

Throughput time. The total time required (processing + queue) from concept to launch or from order received to delivery, or raw materials received to delivery to customer.

Tolerance. The permissible range of variation in a particular dimension of a product. Tolerances are often set by engineering requirements to ensure that components will function together properly. In other words, the variability of a parameter permitted and tolerated above or below a nominal value.

Tolerance design (Taguchi). Provides a rational grade limit for components of a system; determines which parts and processes need to be modified and to what degree it is necessary to increase their control capacity; a method for rationally determining tolerances.

Top-management commitment. Participation of the highest-level officials in their organization's quality improvement efforts. Their participation includes establishing and serving on a quality committee, establishing quality policies and goals, deploying those goals to lower levels of the organization, providing the resources and training that the lower levels need to achieve the goals, participating in quality improvement teams, reviewing progress organization-wide, recognizing those who have performed well, and revising the current reward system to reflect the importance of achieving the quality goals. Commitment is top management's visible, personal involvement as seen by others in the organization.

Total productive maintenance (TPM). Aimed at reducing and eventually eliminating equipment failure, setup and adjustment, minor stops, reduced speed, product rework and scrap.

Total quality control (TQC). A management philosophy of integrated controls, including engineering, purchasing, financial administration, marketing and manufacturing, to ensure customer quality satisfaction and economical costs of quality.

Total quality management (TQM). A term initially coined by the Naval Air Systems Command to describe its management approach to quality improvement. Total quality management (TQM) has taken on many meanings. Simply put, TQM is a management approach to long-term success through customer satisfaction. TQM is based on the participation of all members of an organization in improving processes, products, services, and the culture they work in. TQM benefits all organization members and society. The methods for implementing this approach are found in the teachings of such quality leaders as Philip B. Crosby, W. Edwards Deming, Armand V. Feigenbaum, Kaoru Ishikawa, J. M. Juran, and others. The concept of TQM is based on a) planning, and b) communication. To support this concept there are six principles: 1) TQM starts on top, 2) TQM requires

total involvement, 3) TQM focuses on the customer, 4) TQM uses teams, 5) TQM requires training for everybody, and 6) TQM uses tools to measure and follow progress. In total, these principles will transform any organization if applied appropriately and with management commitment. The fundamental steps of implementing TQM are: 1) create a steering committee to oversee the implementation, 2) develop measures of quality and quality costs before the improvement program begins, 3) provide support to the teams, and 4) reward success

Traceability. The ability to trace the history, application, or location of an item or activity and like items or activities by means of recorded identification.

Training. Refers to the skills that employees need to learn in order to perform or improve the performances of their current job or tasks, or the process of providing those skills.

Transactional leadership. A style of leading whereby the leader articulates the vision and values necessary for the organization to succeed. The leader sees the work as being done through clear definitions of tasks and responsibilities and the provision of resources as needed.

Tree diagram. A management and planning tool that shows the complete range of sub-tasks required to achieve an objective. A problem-solving method can be identified from this analysis.

Trend analyses. Mathematical methods for establishing trends based on past project history allowing for adjustment, refinement or revision to predict cost. Regression analysis techniques can be used for predicting cost/schedule trends using data from historical projects

True x-bar causes. For x-bar control charts: changes in the x-bar control chart which are due to actual changes in the mean produced by the process. True x-bar changes are usually accompanied by a stable pattern in the R-chart.

t-test. A test of the statistical hypothesis that two population means are equal. The population standard deviations are unknown, but thought to be the same. The hypothesis is rejected if the t value is outside the acceptable range listed in the t-table for a given a risk and degrees of freedom. Another way of describing it is a method for testing hypotheses about the population mean; the t statistic measures the deviation between the sample and population means, in terms of the number of standard errors.

Type I error (alpha error). An incorrect decision to reject something (such as a statistical hypothesis or a lot of products) when it is acceptable. Also known as producer's risk and alpha risk. (In control chart analysis: concluding that a process is unstable when in fact it is stable.)

Type II error (beta error). An incorrect decision to accept something when it is unacceptable. Also known as consumer's risk and beta risk. (In control chart analysis: concluding that a process is stable when in fact it is unstable.)

U

u-chart. For attributes data: a control chart of the average number of defects per part in a subgroup. Count per unit chart.

Uniform distribution. This distribution means that all outcomes are equally likely.

Unit. A discrete item (lamp, invoice, etc.) which possesses one or more CTQ characteristics. (Note: units must be considered with regard for the specific CTQ characteristics of concern by a customer and/or for a specific process.)

Unit of measure. The smallest increment a measurement system can indicate. *See also* Resolution.

Unit price (UP) contract. A fixed price contract where the supplier agrees to furnish goods/services at unit rates and the final price is dependent on the quantities needed to carry out the work.

Universe. *See* Population.

Upper control limit (UCL). For control charts: the upper limit below which a process remains if it is in control. The UCL just like the LCL are process driven.

USL (upper specification limit). The highest value of a product dimension or measurement which is acceptable. Customer driven.

V

Validation. Confirmation by examination of objective evidence that specific requirements and/or a specified intended use are met.

Validity. Refers to the ability of a feedback instrument to measure what it was intended to measure.

Value-added. Refers to tasks or activities that convert resources into products or services consistent with customer requirements, The customer can be internal or external to the organization.

Value-adding activities. Steps/tasks in a process that meet all three criteria defining value as perceived by the external customer: 1) the customer cares, 2) the thing moving through the process changes, and 3) the step is done right the first time.

Value analysis, value engineering, and value research (VA, VE, VR). Value analysis assumes that a process, procedure, product, or service is of no value unless proven otherwise. In other words, it is an activity devoted to optimizing cost performance. It is the systematic use of techniques which identify the required functions of an item, establish values for those functions and provide the functions at the lowest overall cost without loss of performance (optimum overall cost). Value analysis assumes that a process, procedure, product, or service is of no value unless proven otherwise.

Value stream. The primary actions required to bring a product from concept to placing the product in the hands of the end-user.

Value-enabling activities. Steps/tasks in a process enabling work to move forward and add value to the customer but not meeting all three of the value-adding criteria; should still be scrutinized for time and best practices — can it be done better?

Value stream mapping. The technique of mapping the value stream.

Variability. The property of exhibiting variation, that is, changes or differences, in particular in the product of a process.

Variable data. Data resulting from the measurement of a parameter or a variable as opposed to attributes data. A dimensional value can be recorded and is only limited in value by the resolution of the measurement system. Control charts based on variables data include average (x-bar) chart, individuals (X) chart, range (R) chart, sample standard deviation (s) chart, and CUSUM chart.

Variables. Quantities which are subject to change or variability.

Variable sampling plan. A plan in which a sample is taken and a measurement of a specified quality characteristic is made on each unit. The measurements are summarized into a simple statistic, and the observed value is compared with an allowable value defined in the plan.

Variance. Any actual or potential deviation from an intended or budgeted figure or plan. A variance can be a difference between intended and actual time. Any difference between the projected duration for an activity and the actual duration of the activity. Also, in relation to a project, the difference between projected start and finish dates and actual or revised start and finish dates.

Variance (in statistics). The square of the standard deviation.

Variation. A change in data, a characteristic or a function that is caused by one of four factors: special causes, common causes, tampering, or structural variation. Change or fluctuation of a specific characteristic which determines how stable or predictable the process may be; affected by environment, people, machinery/equipment, methods/procedures, measurements, and materials; any process improvement should reduce or eliminate variation. *See also* Common cause; Special cause.

Verification. The act of reviewing, inspecting, testing, checking, auditing, or otherwise may establishing and documenting whether items, processes, services, or documents conform to specified requirements. In other words, the confirmation of data, application of judgment and comparison with other sources and previous monitor results.

Vision. A statement that explains what the company wants to become and what it hopes to achieve.

Visual control. A technique of positioning all tools, parts, production activities, and performance indicators so that the status of a process can be understood at a glance by everyone; provide visual clues: to aid the performer in correctly processing a step or series of steps, to reduce cycle time, to cut costs, to smooth flow of work, to improve quality.

Vital few, useful many. *See* Pareto analysis and Pareto chart

Voice of the customer (VOC). An organization's efforts to understand the customers' needs and expectations (voice) and to provide products and services that truly meet such needs and expectations. That understanding may be facilitated through data (complaints, surveys, comments, market research, etc.) representing the views/needs of a company's customers; should be translated into measurable requirements for the process. Generally, the VOC is identified as a functionality that the customer is seeking.

W

Waste. Activities that consume resources but add no value; visible waste (e.g., scrap, rework, downtime) and invisible waste (for example, inefficient setups, wait times of people and machines, inventory). It is customary to view waste as any variation from target.

WBS. *See* Work breakdown structure.

Weibull distribution. A distribution of continuous data that can take on many different shapes and is used to describe a variety of patterns; used to define when the "infant mortality rate" has ended and a steady state has been reached (decreasing failure rate); relates to the "bathtub" curve.

Work analysis. The analysis, classification and study of the way work is done. Work may be categorized as value-added work (necessary work), non-value-added (rework, unnecessary work, idle). Collected data may be summarized on a Pareto chart, showing how people within the studied population work. The need for and value of all work is then questioned and opportunities for improvement identified. A time use analysis may also be included in the study.

Work breakdown structure (WBS). A project management technique by which a project is divided into tasks, sub-tasks, and units of work to be performed. In other words, It is a task-oriented "family tree" of activities which organizes, defines and graphically displays the total work to be accomplished in order to achieve the final objectives of a project. each descending level represents an increasingly detailed definition of the project objective. it is a system for subdividing a project into manageable work packages, components or elements to provide a common framework for scope/cost/schedule communications, allocation of responsibility, monitoring and management.

Work instruction. A document which answers the question: How is the work to be done? (*see* Procedure).

X

X. Variable used to signify factors or measures in the input or process segments of a business process or system. It appears as part of the $Y = f(X)$. It is the independent factor that can control and or predict the $f(Y)$. The X must be directly correlated with the customer's needs, wants or expectations. Also known as: cause, control, and problem. It is the basis for identifying the projects for the black belts.

X-bar chart. Average chart.

X-bar and R charts. For variables data: control charts for the average and range of subgroups of data. *See also* Control chart.

X-bar and sigma charts. For variables data: control charts for the average and standard deviation (sigma) of subgroups of data. This chart is much more effective than the x-bar and R chart. *See also* Control chart.

Y

Y. Variable used to signify factors or measures at the Output of a business process or system. Equivalent to results. A key principle of six sigma is that Y is a function of upstream factors; or $Y = f(x)$. It is the depended variable that the predictors of $F(x)$ trying to define. It is also known as output, effect, symptom and monitor.

Yield. Total number of units handled correctly through the process steps. Mathematically it may be shown as the ratio between saleable goods produced and the quantity of raw materials and/or components put in at the beginning of the process.

Z

z-distribution. For a sample size of n drawn from a normal distribution with mean μ and standard deviation σ . Used to determine the area under the normal curve.

Zero defects. A performance standard popularized by Philip B. Crosby to address a dual attitude in the workplace. People are willing to accept imperfection in some areas, while, in other areas they expect the number of defects to be zero. This dual attitude had developed because of the conditioning that people are human and humans make mistakes. However, the zero defects methodology states that if people commit themselves to watching details and avoiding errors, they can move closer to the goal of zero.

$Z_{\max}/3$. The greater result of the formula when calculating C_{pk} . Shows the distance from the tail of the distribution to the specification which shows the greatest capability. *See* C_{pk} .

$Z_{\min}/3$. The smaller result of the formula when calculating C_{pk} . Shows the distance from the tail of the distribution to the specification which is the smallest capability. *See* C_{pk} .

z-test. A test of a statistical hypothesis that the population mean \bar{x} is equal to the sample mean \bar{m} when the population standard deviation is known.