Glossary

Lean Six Sigma Green & Black Belt

100% Effective Training

CONTENTS

STATISTICS & STATISTICAL TESTS	2
MEASUREMENT SYSTEM ANALYSIS (MSA)	10
CONTROL CHARTS	11
PROCESS CAPABILITY	15
DESIGN OF EXPERIMENTS (DOE)	17
LEAN CONCEPTS	22
PROCESS IMPROVEMENT TECHNIQUES	23
DEFECT PREVENTION	27
PROCESS MEASURES	29
PROCESS FLOW AND PLANNING	33
ABBREVIATIONS & ACRONYMS	38

STATISTICS & STATISTICAL TESTS

Alpha Risk: See *Type I error*.

Alternative Hypothesis: The hypothesis accepted if the null hypothesis is rejected. Denoted by H_a.

Analysis Of Variance (ANOVA): A hypothesis test for analysing continuous data which determines whether the means of three or more datasets are statistically different from each other.

Attribute (or Discrete) Data: Data which cannot be treated as continuous. Usually subdivided into ordinal (e.g. counts), nominal and binary (e.g. go/no-go information) data.

Average: Of a sample (x-bar) is the sum of all the responses divided by the sample size.

Beta Risk: See *Type II error*.

Bimodal Distribution: A frequency distribution with two peaks. Usually an indication of samples from two processes incorrectly analysed as a single process.

Binomial Distribution: A trial only has two possible outcomes (yes/no, pass/fail, heads/tails), one outcome has probability p and the other probability q = 1-p, the probability that the outcomes represented by p occurs x times in n trials is given by binomial distribution.

Central Limit Theorem: If samples of size n are drawn from a population and the values of x are calculated for each sample, the shape of the distribution is found to approach a normal distribution for sufficiently large n. Allows one to use the assumption of a normal distribution when dealing with x. The definition of *sufficiently large* depends on the population's distribution and what range of 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, sample size should be increased. One of the most important concepts at the heart of inferential statistics.

Chi-Square: The test statistic used when testing the null hypothesis of independence in a contingency table or when testing the null hypothesis of a set of data following a prescribed distribution. (**Chi-Square Distribution:** The distribution of chi-square statistics.)

Coefficient of Determination (R^2): The square of the sample correlation coefficient, a measure of the part of variable that can be explained by its linear relationship with a variable; it represents the strength of a model. (1 – R^2) *100% is the percentage of noise in the data not accounted for by the model.

Coefficient Of Variation (CV): Defined as the standard deviation divided by the mean (s/X-bar). It is the relative measure of the variability of a random variable. E.g. a standard deviation of 10 microns would be extremely small in the production of bolts with a nominal length of 2 inches, but extremely high for the variation in line widths on a chip whose mean width is 5 microns.

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

Confidence Limits: End points of the interval about the sample statistic that is believed, with a specified confidence coefficient, to include the population parameter.

Continuous Data: Data which can be subdivided into ever-smaller increments.

Correlation Coefficient (r): A number between -1 and 1 that indicates the degree of linear relationship between two sets of numbers.

Degrees of Freedom: A parameter in the t, F, and x^2 distributions. A measure of the amount of information available for estimating population variance; s^2. It is the number of independent observations minus the number of parameters estimated.

Discrete Data: See *Attribute Data*.

Exponential Distribution: A probability distribution mathematically described by an exponential function. One application is to describe the probability that a product survives a length of time in service under the assumption that the probability of a product failing in any small time interval is independent of time.

F Statistic: A test statistic used to compare the variance from two normal populations. (**F Distribution:** Distribution of F-statistics.)

Frequency Distribution: A set of all the various values that individual observations may have and the frequency of their occurrence in the sample or population.

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 less quantitative, but equally valid, way to determine goodness-of-fit.

Hypothesis Tests, Alternative: The hypothesis accepted if the null hypothesis is disproved. The choice of alternative hypothesis will determine whether one- or two-tail tests are appropriate.

Hypothesis Tests, Null: The hypothesis tested in tests of significance is that there is no difference (null) between the population of the sample and specified population (or between the populations associated with each sample). The null hypothesis can never be proved true. However, it can be shown, with specified risks of error, to be untrue; that is, a difference can be shown to exist between the populations. If not disproved, one may surmise that it is true. (It may be that there is insufficient power to prove the existence of a difference rather than no difference at all; that is, the sample size may be too small. By specifying the minimum difference that one wants to detect and P, the risk of failing to detect a difference of this size, the actual sample size required, however, can be determined.)

Hypothesis Tests: A procedure whereby one of two mutually exclusive and exhaustive statements about a population parameter is concluded. Information from a sample is used to infer something about a population from which the sample was drawn.

Kurtosis: A measure of the shape of a distribution. A positive value indicates that the distribution has longer tails than the normal distribution (platykurtosis); while a negative value indicates that the distribution has shorter tails (leptokurtosis). For the normal distribution, the kurtosis is 0.

Mean: The average of a set of values. We usually use x to denote a sample mean, whereby we use the Greek letter μ to denote a population mean.

Median: The number that is in the middle when all observations are ranked in magnitude.

Mode: The number in a set that occurs the most frequently.

Normal Distribution: Symmetric distribution characterised by a smooth, bell-shaped curve.

p-Value: The probability of making a Type I error; the probability of H_0 being true. This value comes from the data itself. Also provides the exact level of significance of a hypothesis test.

Poisson Distribution: A probability distribution for the number of occurrences per unit interval (time or space), where l = average number of occurrences per interval is the only parameter. The Poisson distribution is a good

approximation of the binomial distribution for the case where n is large and p is small. l = (np).

Population: A set or collection of objects or individuals. It can also be the corresponding set of values, which measure a certain characteristic of a set of objects or individuals.

Probability Distribution: The assignment of probabilities to all of the possible outcomes from an experiment. Usually portrayed by way of a table, graph, or a formula.

Probability: Measure of the likelihood of a given event occurring. It takes on values between 0 and 1 inclusive with 1 being the certain event and 0 meaning that there is relatively no chance at all of the event occurring. How probabilities are assigned is another matter. The relative frequency approach to assigning probabilities is one of the most common.

Random Sampling: A commonly used sampling technique in which sample units are selected in such a manner that 0 combinations of n units under consideration have an equal chance of being selected as the sample.

R: Pearson product movement coefficient of correlation.

Residual: The difference between an observed value and a predicted value.

Regression: A statistical technique for determining the best mathematical expression describing the functional relationship between one response and one or more independent variables.

Sample Size: The number of elements or units in a sample.

Sample: A group of units, portion of material, or observations taken from a larger collection of units, quantity of material, or observations that serves to provide information that may be used as a basis for making a decision concerning the larger quantity.

Skewness: A measure of the symmetry of a distribution. A positive value indicates that the distribution has a greater tendency to tail to the right (positively skewed or skewed to the right), and a negative value indicates a greater tendency of the distribution to tail to the left (negatively skewed or skewed to the left). Skewness is 0 for a normal distribution.

Standard Deviation (s, σ): A mathematical quantity that describes the variability of a response. It equals the square root of variance. The standard deviation of a sample (s) is used to estimate the standard deviation of a population (σ).

Standardised Normal Distribution: A normal distribution or a random variable having a mean and standard deviation of 0 and 1 respectively. It is denoted by the symbol Z and is also called the Z distribution.

Statistical Sampling: Statistical process for determining the characteristics of a population from the characteristics of a sample.

T Distribution: A symmetric, bell-shaped distribution that resembles the standardised normal (or Z) distribution, but it typically has more area in its tails than does the Z distribution. That is, it has greater variability than the Z distribution.

T Test: A hypothesis test of population means when small samples are involved.

Test Statistic: A single value, which combines the evidence obtained from sample data. The p-value in a hypothesis test is directly related to this value.

Type I Error: An incorrect decision to reject something (such as a statistical hypothesis or a lot of products) when it is acceptable.

Type II Error: An incorrect decision to accept something when it is unacceptable.

Variance: A measure of variability in a data set or population. It is the square of the standard deviation.

Z Distribution: See *Standardised Normal Distribution*.

Z Value: A standardised value formed by subtracting the mean from each measurement and then dividing this difference by the standard deviation.

MEASUREMENT SYSTEM ANALYSIS (MSA)

Bias: Systematic 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.

Calibration: The comparison of a measurement instrument or system of unverified accuracy to a measurement instrument or system of a known accuracy to detect any variation from the required performance specification.

Gauge: Any device used to obtain measurements. The term is frequently used to refer specifically to shop floor devices, including go/no-go devices.

Repeatability: The extent to which repeated measurements of a particular object with a particular instrument produce the same value.

Reproducibility: The variation in measured values between different people taking the same measurement and using the same test equipment (gauge).

CONTROL CHARTS

C Chart: Count chart where the subgroup size is constant.

Common Causes: Causes of variation that are inherent in a process over time. They affect every outcome of the process and everyone working in it. (See also *Special Causes*.)

Control Chart: A chart with upper and lower control limits on which values of some statistical-measure for a series of samples or subgroups are plotted. The chart frequently shows a central line to help detect special causes.

Control Limits: Upper and lower bounds in a control chart that are determined by the process itself. They can be used to detect special causes of variation. They are usually set at +/-3 standard deviations from the centreline.

Control: A process is said to be in a state of statistical control if the process exhibits only random variation (as opposed to systematic variation and/or variation with known sources). When monitoring control with control charts, a state of control is exhibited when all points remain between set control limits without any abnormal (non-random) patterns.

Count Chart: A control chart for attribute data which evaluates the stability of a process in terms of the count of events of a given classification occurring in a sample. Assumes the Poisson distribution.

Cumulative Sum Control Chart (CuSum): A control chart, which plots the cumulative deviation of each subgroup's average from the nominal value. 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 average.

In-Control Process: A process in which the statistical measure being evaluated is in a state of statistical control (i.e. the variations among the observed sampling results can be attributed to a constant system of chance causes). (See also *Out-Of-Control Process*.)

LCL: Lower control limit. For control charts, the limit above which the process subgroup statistics must remain when the process is in control. LCL is typically three standard deviations below the centreline.

Multivariate Control Chart: A control chart for evaluating the stability of a process by looking at the levels of two or more variables or characteristics at the same time.

NP Chart: A control chart for attribute data of the proportion of defective units (or fraction defective) in a subgroup. Assumes a constant subgroup size. Based on the binomial distribution.

Out-Of-Control Process: A process is said to be out-of-control if it exhibits variations larger than its control limits or shows a systematic (non-random) pattern of variation.

P Chart: A control chart for attribute data of the proportion of defective units (or fraction defective) in a subgroup. The total number of units in each subgroup can be different. Based on the binomial distribution.

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.

Run Chart: A basic graphical tool that charts a process over time, recording either individual readings or averages over time.

S Chart: A control chart in which the subgroup standard deviation, S, is used to evaluate the stability of the variability within a process.

Special Causes: Causes of variation that arise because of special circumstances. They are not an inherent part of a process. Special causes are also referred to as assignable causes. (See also *Common Causes*.)

Statistical Process Control (SPC): The application of statistical techniques in the control of processes. SPC is often considered a subset of SQC, where the emphasis in SPC is on the tools associated with the process but not product acceptance techniques. Often the term *statistical quality control* is used interchangeably with *statistical process control*.

Tampering: Action taken to compensate for variation within the control limits of a stable system. Tampering increases rather than decreases variation, evidenced in the funnel experiment.

Trend Control Chart: A control chart in which the deviation of the subgroup average, X-bar, from an expected trend in the process level is used to evaluate the stability of a process.

U Chart (Count-Per-Unit Chart): A control chart for count data which evaluates the stability of a process using the average count of events of a given classification (e.g. defects) per unit occurring in a sample. Each subgroup can be of a different size.

UCL: Upper control limit. For control charts, the upper limit below which a process statistic must remain to be in control. Typically, UCL is three standard deviations above the centreline.

X-bar and R Charts: Applies to variable data and is used to create control charts for the average and range of subgroups of data.

X-bar and S Charts: For variable data; control charts for the average and standard deviation (sigma) of subgroups of data.

PROCESS CAPABILITY

Capability: A measure of quality for a process usually expressed as sigma capability, C_{pk}, Z-score or defects per million opportunities (DPMO). It is obtained by comparing the actual process with the specification limits.

C_p: During process capability studies, Cp is a capability index which shows the process capability potential but does not consider how centred the process is, so does not describe the actual situation. Cp may range from 0 to infinity with a large value indicating greater potential capability. A value of 1.33 or greater is usually desired.

C_{pk}: During process capability studies, Cpk is an index used to compare the actual variation of a process within the specification limits. Cpk has a value equal to Cp if the process is centred on the nominal; if Cpk is negative, the process mean is outside of the specification limits; if Cpk is between 0 and 1 then the some of the natural variations of the process falls outside the spec limits. If Cpk is larger than 1, the natural variation falls completely within the spec limits. A value of 1.33 or greater is usually desired.

DPO: Defects per Opportunity. Equals the number of defects observed (D), divided by the product of the number of things processed (N) and the number of opportunities for each thing to be defective (O). DPO = D/(N x O).

DPMO: Defects Per Million Opportunities. Equal to **DPO** x 1,000,000.

DPU: Defects Per Unit. Equals the number of observed Defects (D), divided by the total number of things observed (N).

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 $\mathbf{C_{pk}}$ and $\mathbf{C_p}$.

Sigma Quality Level: A commonly used measure of process capability that represents the number of standard deviations between the centre of a process and the closest specification limit. The actual number of standard deviations is the long-term sigma level. See also *Sigma Shift*.

Sigma Shift: The difference between long and short-term process sigma, commonly quoted as 1.5 standard deviations. Arose from the observation that short-term process capability must be better than the calculated process capability (e.g. $\mathbf{C_{pk}}$) in order to ensure the process continues to meet the target level when long-term drifts and variations are allowed for. Lookup tables for Sigma Level quote the short-term Sigma, which explains why 3.4 DPMO is referred to as *six sigma quality* even though 3.4 DPMO is actually 4.5 standard deviations from the mean.

Specification Limits: The bounds of acceptable values for a given product or process. They should be established by the customers' needs.

Specification: A document that states requirements to which a product or service must conform.

Tolerance: The permissible range of variation in a particular dimension of a product. Often set by engineering requirements to ensure components will function together properly.

DESIGN OF EXPERIMENTS (DOE)

Aliasing: When two factors or interaction terms are set at identical levels throughout the entire experiment (i.e. the two columns are 100% correlated).

Balanced Design: A design is balanced if each factor is run the same number of times at each setting.

Blocking: A technique to deal with known and controllable nuisance variables. Separate blocks are created, in each of which the nuisance factor is held constant while the factors of interest are varied. The effect of the nuisance variable cannot be calculated.

Conjoint Analysis (Stated Preference Technique): A marketing DOE. You cannot measure the response of interest (purchases), so measure a surrogate instead (preference/intention). Often uses forced ranking to increase discrimination.

Effect: The change in the response variable that occurs as a factor is changed from one level to another.

EVOP (Evolutionary Operations): Making a series of small DOEs to gradually evolve towards the optimum settings of each factor. Used when the full range of factor settings cannot be explored in a single

experiment. (Examples: safety concern; all output must be within customer spec.)

Experimental Design: 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.

Factor: An assignable cause which may affect the responses (test results) and of which different versions (levels) are included in the experiment. A controlled or uncontrolled input variable.

Fold-overs: A way to reduce confounding in a fractional factorial design.

Fractional Factorial Experiments: Looks at only a fraction of all the possible combinations contained in a full factorial. If many factors are being investigated information can be obtained with smaller investment. The general notation for a fractional factorial design is: 2_R^{K-P} = # Runs

Full Factorial: All possible combinations of the factors and levels. Given k factors, all with two levels, there will be 2^k runs. If all factors have 3 levels, there will be 3^k runs.

Full Factorial Experiments: Designed experiments in which all possible treatment combinations formed from two or more factors, each being studied at two or more versions (levels), are examined so that interactions (differential effects) as well as main effects can be estimated. Full factorials examine every possible combination of factors at the levels tested and allow

most questions to be answered completely. The general notation for a full factorial design is: 2^k = # Runs

Hard-to-Change: A factor which cannot be changed as easily as the others, limiting randomisation from the ideal. Examples include machine temperature and office layout. Failure to correctly allow for hard-to-change factors leads to incorrect identification of which effects are significant.

Inner Array: A Taguchi term used to identify the combinations of controllable factors to be studied in a designed experiment. Also called *design array* or *design matrix*.

Interaction: The effect of one factor on the response depends on the setting of another factor.

Interaction Plot: A graphical display showing how two factors (input variables) interact if one factor's effect on the response is dependent upon the level of the other factor.

Level: A specific value or setting of a factor.

Main Effects Plot: A graphic display showing the influence a single factor has on the response when it is changed from one level to another. Often used to represent the linear effect associated with a factor.

Mixture Designs: A Designed Experiment where the factors cannot be varied independently, for example when they must add up to a fixed total volume or amount of money.

Noise: Unexplained variability in the response. Typically, due to uncontrolled variables.

One-Factor-At-a-Time Approach: A popular, but inefficient way to conduct a designed experiment.

Randomisation: A technique used to spread the effect of uncontrollable nuisance variables across the entire experimental region.

Replication: Repetition of the set of all treatment combinations to be compared in an experiment. Each repetition is called a replicate. Replication includes resetting the experimental conditions thus includes all sources of experimental error. A repeat measures repetitions without resetting the conditions between runs therefore only captures some errors such as those due to the measurement system.

Resolution: The resolution of a design is a value such as III, IV, V, etc., that represents the type of confounding for that design.

Response Surface Design: A Designed Experiment intended to explore non-linear relationships between factors and responses, used to optimise and tolerance a process.

Response Variable: An output which is measured or observed.

Run (Treatment Combination, Trial): A single set-up in a DOE from which data is gathered. For example, a 3-factor full factorial DOE with **replicates** has 8 runs.

Screening Design: A Designed Experiment of low **resolution** intended to quickly identify the few critical Xs from a large number of possible factors.

Split-Plot Design: A technique used to ensure correct randomisation is maintained when one or more of the factors are **hard-to-change**.

Taguchi designs: Used for robust parameter design. The primary goal is to find factor settings that minimise response variation, while adjusting (or keeping) the process on target.

Tolerance: In DOE, tolerance is a measure (from 0 to 1) of the independence among independent variables.

LEAN CONCEPTS

Customer Value Add: Any activity that changes the form, fit, or function of a product to meet the needs of the customer, which the customer is willing to pay for (or would complain if it was not performed), and which is correct the first time.

DOWNTIME: Acronym used to remember the eight wastes (Defects, Overproduction, Waiting, Non-Value Added (additional operations; also called Overprocessing), Transportation, Inventory, Motion, and Employee Talent).

Essential Non-Value Add: Any activity that is required to create/process a product but the customer should not pay for. Also called *Business Non-Value Add* and *Business Value Add.*

Non-Value Add: Any activity that is not Customer Value Add. Non-value Add activities can be subdivided into true Waste (TIM WOOD or DOWNTIME) and Essential Non-Value Add.

Rework: Non-value add work performed to correct a defect that has occurred.

TIM WOOD: Acronym used to remember the seven wastes (Transportation, Inventory, Movement, Waiting, Over-processing, Overproduction, Defects). A variant is TIM P WOOD where P is untapped People.

Toyota Production System: A manufacturing system or philosophy founded by Kiichiro Toyoda that focuses on the link between cycle time, WIP and batch size. Provides for the elimination of waste in ways that companies employ human resources, equipment and material.

PROCESS IMPROVEMENT TECHNIQUES

5S: A process and method for creating and maintaining an organised, clean and high performance workplace. The 5Ss are Sort, Set in Order, Shine, Standardise, and Sustain. (6S is 5S + Safety).

6 Ms: Man, Machine, Materials, Measurement, Methods, Mother Nature. The six influences used in the classic Cause-and-Effect (fishbone, Ishikawa) diagram.

Adaptive Control: A defect prevention method that detects errors or possible errors during processes before they can become defects.

Benchmarking: An improvement process in which a company measures its performance against that of best-in-class companies, determines how those companies achieved their performance levels, and uses the information to improve its own performance. The subjects that can be benchmarked include strategies, operations, processes, and procedures.

Cause-And-Effect Diagram: A tool for analysing process dispersion. 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. The diagram illustrates the main causes and sub causes leading to an effect (symptom).

Check Sheet: A simple data-recording device. The check sheet is custom-designed by the user, which flows him or her to readily interpret the results. The check sheet is one of the seven tools of quality. Check sheets are often confused with data sheets and checklists (see *Individual Entries*).

Checklist: A tool used to ensure that all important steps or actions in an operation have been taken. Checklists contain items that are important or relevant to an issue or situation. Checklists are often confused with check sheets and data sheets (see *Individual Entries*).

Decision Matrix: A matrix used by teams to evaluate problems or possible solutions. After a matrix is drawn to evaluate possible solutions, for example, 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. Third, each possible solution is rated on a scale of 1 to 5 for each criterion and the rating recorded in the corresponding grid. Finally, the costings of all the criteria for each possible solution are added to determine its total score. The total score is then added to help decide which solution deserves the most attention.

Failure Mode Effect Analysis (FMEA): A system used to understand and predict the result of a failure in a process/machine and therefore to plan appropriate countermeasures**.**

Flowcharting: 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 analysing the forces that will aid or hinder an organisation in reaching an objective. An arrow pointing to an objective is drawn down the middle of a piece of paper. The factors that will aid the objective's achievement (called the driving forces) are listed on the left side of the arrow; the factors that will hinder its achievement (called the restraining forces) are listed on the right side of the arrow.

Histogram: 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.

Kaizen: A Japanese term that means gradual unending improvement by doing little things better and setting and achieving increasingly higher standards.

Nominal Group Technique (NGT): 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 prioritised by the group.

Pareto Chart: A graphical technique used to quantify problems so that effort can be expended in fixing the *vital few* causes, as opposed to the *trivial many*. The Pareto principle suggests that most effects come from relatively few causes; that is, 80% of the effects come from 20% of the causes.

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.

Scatter Diagram: A graphical technique to analyse 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 or dependent variable (i.e. the value may *depend* on the value of something else) and the x-axis used for the input or independent variable.

Single Minute Exchange of Dies (SMED, Rapid Setup): Reduction of Setup Time to less than 10 minutes by analysis of change-over processes in order to reduce the actual time spent when the equipment is non-productive.

Takt Boards: Visual tool used to communicate required production rates, and track progress to that requirement.

Total Preventive Maintenance (TPM): A proactive approach to equipment maintenance involving maintenance personnel and operators focusing on maintaining reliable equipment, eliminating breakdowns, and eliminating equipment related defects. Has 5 pillars: maintenance prevention; autonomous maintenance; planned maintenance; skills development, education and training; continuous improvement.

DEFECT PREVENTION

Acceptance Sampling: Inspection of a sample from a lot to decide whether to accept or not accept that lot. 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.

Adaptive Control: A defect prevention method that detects errors or possible errors during processes before they can become defects.

Cost of Poor Quality: Costs associated with providing poor-quality products/services. There are four categories of costs: internal failure (costs associated with defects found before the customer receives the product/service), external failure (costs associated with defects found after the customer receives the product/service), appraisal (costs incurred to determine the degree of conformance to quality requirements), and prevention (costs incurred to keep failure and appraisal costs to a minimum).

Defect Prevention: Any attempt at eliminating the root cause of defects prior to their occurrence. See *Mistake-Proof*.

Defect: A nonconformity or departure of a quality characteristic from its intended level or state.

Inspection: Measuring, examining, testing, or gauging one or more characteristics of a product or service and comparing the results with specified requirements to determine whether conformity is achieved for each characteristic.

Lot Sampling: Inspection process by which a sample of parts is inspected and based on the outcome the entire lot may be accepted or rejects.

Mistake Proof: Process to ensure that defects cannot be created (e.g. square pegs and round holes).

Poke-Yoke: Japanese term for mistake proofing. An engineered method which makes it very difficult or impossible to produce a defective part. Does not require human assistance.

Self-Checks: Inspection process that is done by the same person that performed the work.

PROCESS MEASURES

Capacity: see *Completion Rate*

Completion Rate (CR): Amount of product or service that completes a process in a given period of time; the amount of production over a given time period. Also called Exit Rate (ER), Throughput, Capacity.

Cycle Time: The time taken by a single process step or operation to process a single unit. Also called Task Time. Can be divided into Value-Added, Essential Non-Value Added and Non-Value Added time.

Cycle Time Interval: The elapsed time from when a product is run on a given workstation until it is run again. Describes how often a work order will be released to the floor. It is a function of the batch size and is calculated by multiplying the batch size by the yield and dividing by the demand.

Economic Value Add: A measure of the value created by a business in a single period of time. It is the return a business makes above its cost of capital. Economic Value Add = Earnings – (Cost of Capital x Capital Invested).

Efficiency: The ratio of the actual product produced to a standard. Calculated by dividing the standard parts per hour by the actual parts per hour.

Exit Rate: See *Completion Rate*.

First Pass Yield (FPY): The proportion of units that pass through a process step correctly on the first attempt.

Lead Time (LT): The time for a single output to complete the process from the beginning to the end; the time it will take for the next unit placed into the process to exit from it. Also called Process Lead Time (PLT).

Little's Law: The relationship between WIP, Average Lead Time, and Average Completion Rate. It is defined as LT = WIP/CR.

Loss Function: A technique for quantifying loss due to production deviations from target values.

Manufacturing Cycle Time: See *Process Cycle Time*.

On Time In Full (OTIF): A key indicator based on the percentage of deliveries to customers which are both 100% complete and on time.

Order Frequency: Similar to Cycle Time Interval but is a term used to represent purchased items.

Overall Equipment Effectiveness: Term used in total productive maintenance to describe the percentage of time a piece of equipment is producing quality product at the desired rate. World-class OEE is quoted as >85%, although this varies between industries. Calculated by multiplying the % availability level, % operating level and % quality level.

Process Cycle Efficiency (PCE): A measurement of the percentage of value add time through a process. Calculated by dividing the total value add time for all process steps by the Lead Time.

Process Lead Time (PLT): See *Lead Time (LT).*

Processing Time: The total of the Cycle Times for all the steps in a process on a single part.

Productivity: Measurement used to represent the percentage of time an operation is performing to a standard. Calculated by dividing the standard hours earned by the actual operating time. Can also be calculated by multiplying the utilisation by the efficiency.

Queue Time: Time delay associated with waiting on an activity or task to be performed (typically refers to a buffer of parts/product).

Rolled Throughput Yield (RTY): The product of the First-Pass Yields for successive operations in a process; the cumulative probability of getting the process right first time on each of the steps sequentially.

Setup Time: The length of time from the last good product of a production run to the first good product(s) of the next production run.

Task Time: See *Cycle Time*.

Takt Rate: the inverse of Takt Time: the customer required output divided by the net available time.

Takt Time: The time allowed for every task in a process to complete one output, calculated from the customer required volume translated into available production time. A calculated figure used as a reference for Just In Time (JIT) one-piece flow analysis where production is run flexibly in direct relation to customer demand rather than plant capacity or maximum speed.

Throughput: The output of a process (see also *Completion Rate*).

Uptime: Net operating time less downtime, setup time, etc.

Utilisation: The ratio of the actual operating time to the total available operating time. Calculated by dividing the actual operating time by the total available time.

Work-In-Process (WIP): Work that has been released into production for processing but have not been completed as finished goods or outputs.

Yield: The amount of material that is processed by an operation less the scrap.

PROCESS FLOW AND PLANNING

ABC Analysis: Used to rank order purchased parts and material according to the annual dollar value spent on each. More emphasis should be placed on the few parts that account for most of the cost.

Batch: A run of identical products/parts through a process; the number of product/parts run between product changeovers.

Bill of Material (BOM): The listing of all components used to make up an assembly. The relationship between the end item assembly (e.g. bike) and all lower level items or assemblies (wheel, seat, etc.).

BOM Explosion: MRP function that uses the start times, the lot sizes, and the BOM to generate gross requirements of any required components at the next level(s).

Bottleneck: The slowest activity within a process. Every process has a bottleneck.

Buffer: Typically used to describe the amount of inventory or queue in front of an operation.

Constraint: A process step or activity that cannot meet customer demand; one where the Cycle Time is greater than the Takt Time.

Cycle Stock: Represents the amount of inventory associated with the cycle time interval.

Dependant Demand: Demand for components that make up independent demand products. E.g. if the independent demand for a bicycle is 4, then the dependant demand for pedals is 8.

Downtime: Non–productive time generally due to equipment stoppage, lack of materials, or lack of operator – generally refers to machine breakdown.

External Setup: Setup that can be done while a machine or process is in operation. Does not delay production.

First-In First-Out (FIFO): Often refers to a stock control system that makes sure that the first products made are the first dispatched to the customer.

Generic Pull: The establishment of a WIP cap or limit on the amount of inventory within a predefined physical work area. Tool used to control and predict cycle time.

Independent Demand: Any demand that comes from outside the system. This includes all demand for final products as well as some demand for components (e.g. when they are sold as replacement parts).

Inventory Turns: Represents an efficiency measure of inventory, and can be measured as gross annual sales divided by average on-hand inventory.

Just-In-Time (JIT): A manufacturing practice pioneered by the Toyota Motor Company where each workstation acquires the required materials from upstream workstations precisely as needed. JIT requires

a systems approach to transforming the manufacturing environment and is focused on continuous improvement.

Kanban: Japanese word for signal. It is used in a pull system to signal when production is to start, and can take a number of forms (e.g., cards, boards, lights, bins).

Lean Production: A manufacturing strategy that uses less of everything vs. traditional manufacturing. Focus is on eliminating waste/non-value add activities from processes.

Lot Sizing: MRP function that divides the netted demand into appropriate lot sizes to form jobs. Lot sizes group all demand requirements over a given period defined in MRP.

Manufacturing (or Material) Resources Planning (MRP II): Builds on MRP by including demand management, forecasting, capacity planning, master production scheduling, rough-cut capacity planning, capacity requirements planning, dispatching, and input/output control.

Master Production Schedule: MPS is the source of demand for the MRP system. It gives the quantity and due dates for all parts that have independent demand. The MPS contains gross requirements, on-hand inventory balance, and scheduled receipts.

Material Requirements Planning (MRP): Is a *Push* system as work is scheduled to start based on demand vs a *Pull* system that authorises production as inventory is consumed. The basic function of MRP: Uses the Bill of

Material, On-Hand inventory balance, and Scheduled Receipts then performs Netting, Lot Sizing, Time Phasing, and BOM Explosion on each level in the Bill of Material, to create Planned Order Releases, Change Notices, and Exception Notices.

One-Piece Flow: A part of Just In Time (JIT) philosophy in which production is possible with minimal levels of work in process, batch size, lead time, space, inventory, conveyance.

Pull System: Process that authorises production as inventory is consumed. A pull system directly responds to plant changes, but must be forced to accommodate customer due dates. The Toyota Production System is an example of a classic pull system.

Push System: Process that schedules production based on demand. A push system directly accommodates customer due dates, but must be forced to respond to plant changes. MRP is an example of a classic push system.

Queue Management: The process for controlling wait time; waiting to be processed, waiting to move, waiting for parts and material, etc.

Replenishment Pull System: A pull system whereby the supplying process is de-coupled from the consuming process via buffer inventory. Part replenishment is based on consumption from the buffer inventory.

Safety Stock: The amount of inventory needed to compensate for variation (i.e. demand, quality, and supplier delivery).

Safety Time: The additional time added to the lead time or setback time of a product within an MRP system. Used to compensate for variation in cycle time and vendor lead time.

Sales & Operations Planning (S&OP): The process that takes as input sales and marketing forecasts, customer orders, and plant capacity to produce a master schedule that generates all material requirements necessary to fulfil these requirements.

Setup: The process of changing from producing one product type to a different type. Contains both internal and external elements.

Synchronous Pull: Process by which products or subassemblies are triggered once an item reaches a certain level of completeness. Often referred to as a trigger pull system.

ABBREVIATIONS & ACRONYMS

BB	Black Belt
CTC	Critical to Customer
CTQ	Critical to Quality
DFLSS	Design For Lean Six Sigma
DFM (DFA)	Design for Manufacture (Assembly)
DFMEA	Design Failure Mode Effect Analysis
DMADV	Define, Measure, Analyse, Design, Verify
DMAIC	Define, Measure, Analyse, Improve, Control
DOE	Design of Experiments
DPMO	Defects per Million Opportunities
FIFIO	First In First Out
FMEA	Failure Mode & Effect Analysis
FPY	First Pass Yield
GB	Green Belt
KPIV	Key Process Input Variables
KPOV	Key Process Output Variables
LCL	Lower Control Limit
MBB	Master Black Belt
MSA	Measurement System Analysis
OEE	Overall Equipment Effectiveness
OTIF	On Time In Full
PDCA	Plan Do Check Act
PFMEA	Process Failure Mode Effect Analysis
QFD	Quality Function Deployment
RPN	Risk Priority Number
RTY	Rolled Throughput Yield
SIPOC	Supplier, Input, Process, Output, Customer

SMED	Single Minute Exchange of Dies
SOP	Standard Operating Procedure
SPC	Statistical Process Control
TPM	Total Preventative Maintenance
UCL	Upper Control Limit
VOB	Voice of Business
VOC	Voice of Customer
WIP	Work In Progress
WIP	Work in Process
X	Input
Y	Outputs