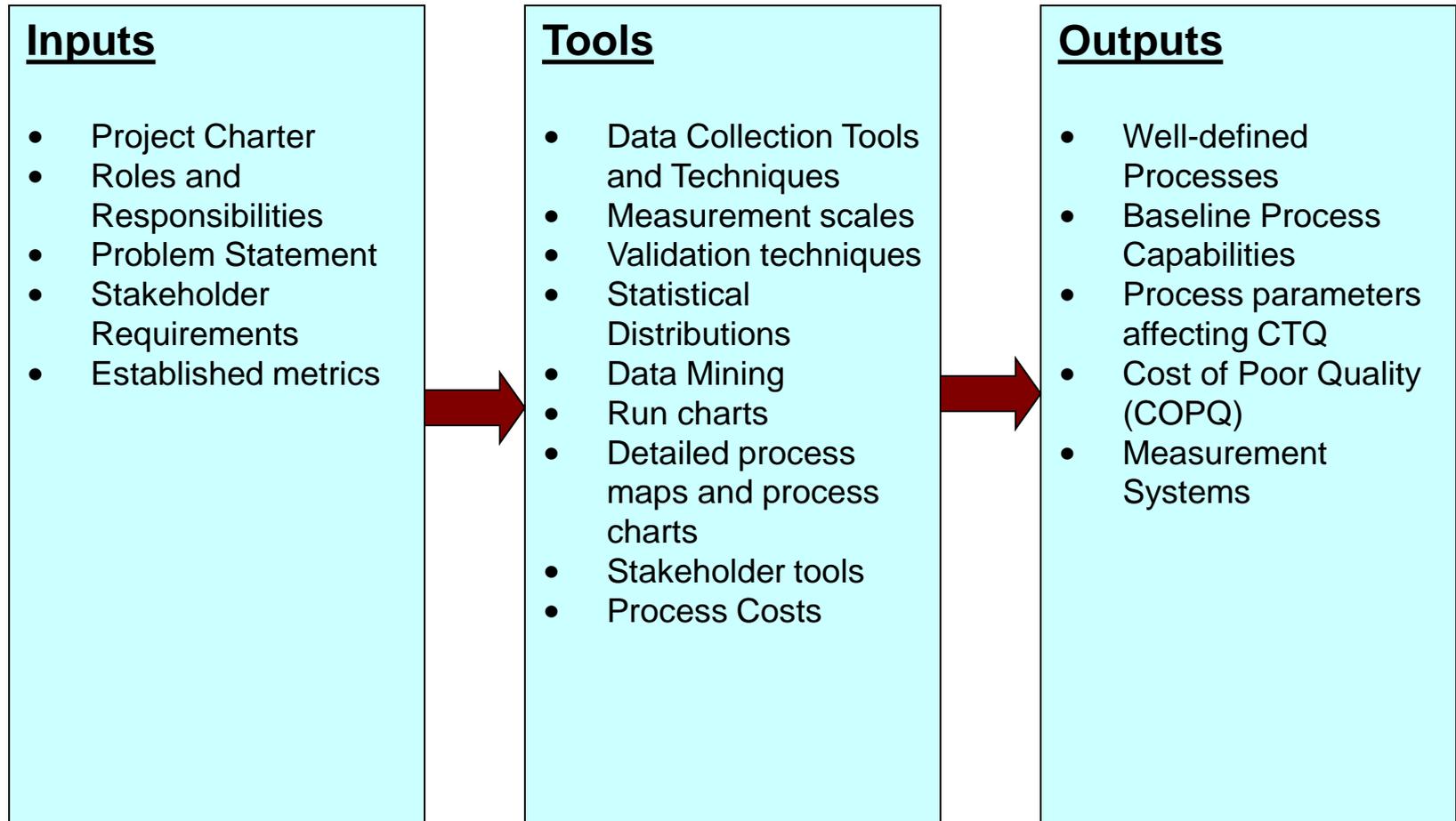


Six Sigma Green Belt - Study Guides



Index – Six Sigma Methodology (Measure)



Objective of Measure phase

- In Measure phase, our objectives are:
 - Data collection to understand present system better
 - Validation and reliability of measurement system and key metrics
 - Determining the process capability for present system
 - Determining how progress and project success would be measured

Inputs

- Inputs for Six Sigma Measure are covered in Outputs for Six Sigma Define. (for details, please refer to Chapter 4: Six Sigma Methodology – Define)

Tools – Data collection tools and techniques

	Continuous data (Variables)	Discrete data (Attributes)
Definition	<ul style="list-style-type: none"> ● This is information that can be measured on a continuum or scale e.g. ● Weight of packages sent ● Customer wait time for every customer service call ● Average speed of cars traveling in a highway 	<p>This is a whole number (or count) of attributes like :</p> <ul style="list-style-type: none"> ● Number of people buying a product ● Number of defects per 1000 events ● Number of satisfied customers
Identification	<p>To identify continuous data, ask the question whether the data can be expressed to any desired level of precision or decimal point e.g. What is the distance covered by the car? This can be answered as 1 mile, 1.1 miles, 1.1.1 miles etc. Any data that can be measured to any desired level of precision is called continuous data.</p>	<p>To identify discrete data, ask the question whether the data can be expressed by 1 level of precision e.g. Is your age equal to or greater than 35 years? This can be answered as Yes or No. There is no further level of precision possible. So, the data type is discrete</p>
Tools used	<p>Data collection: Demographic questions (e.g. age etc.), fill-in-the-blank questions (e.g. distance covered, temperature, humidity etc.)</p> <p>Data analysis tools : ANOVA etc.</p>	<p>Data collection: Ranking, Rating, Yes/No questions etc. – covered in chapter 2: Stakeholders, Customers and financial measures</p> <p>Data Analysis tools: Chi-square, regression etc.</p>

Conversion of data types

- Why is data conversion required?
 - Data conversion helps in using appropriate tools to analyze data for example, if discrete data is plotted in control charts intended for continuous data, the results will be erroneous; similarly tools like chi-square can only be used for discrete data
- Converting Discrete data to Continuous data:
 - Discrete data are often caused by rounding off the data to too few levels or precision or decimal points. To convert discrete data to continuous data, try to find out if the data can be expressed in greater level of precision – this can usually be achieved by asking for greater accuracy in data collection.
- Converting Continuous data to Discrete data:
 - Continuous data can easily be converted to discrete data by changing the data collection scale. Consider a case study where we are trying to determine whether average heights of people in different countries are different. We conduct a survey of 100 people in 50 countries, where we ask every person their heights (the height measurements using this approach is a continuous scale).

Conversion of data types (continued)

To convert the data to discrete type, we can categorize each person's height as follows:

- Less than 4 Feet : Very Short
 - 4 feet to 5 feet : Short
 - 5 feet to 5.5 feet: Average
 - 5.5 feet to 6.2 feet: Tall
 - Greater than 6.2 feet: Very tall
-
- Please note that using a different measurement scale has helped us convert the continuous data type to discrete data type.

Collecting data using Check Sheet

- Check sheets are very important tools for data collection. Inputs gathered from check sheets can be used for creation of pareto diagrams, cause and effect diagrams etc.
- Creating check sheet – steps involved
 1. Determine the measurement objectives. Ask questions such as "*What is the problem?*", "*Why should data be collected?*", "*Who will use the information being collected?*", "*Who will collect the data?*"
 2. Create a form for collecting data. Determine the specific things that will be measured and write this down the left side of the check sheet.
 3. Collect the frequency of data for the items being measured. Record each occurrence directly on the Check Sheet as it happens.
 4. Tally the data by totaling the number of occurrences for each category being measured.

Sample check sheet case study

- As the project manager of a six sigma effort to determine the lost bags in ABC Airlines company, you decide to do create a check sheet of the opportunities (i.e. lost bags)
- You start by talking to the baggage division of the airlines, who provide you the information about the major categories into which you can divide the problem they have.
- You can use the sample check sheet below to collect information required for analysis (e.g. creating a Pareto diagram as mentioned in Chapter 4: Six Sigma Methodology – Define)

Category (Problem)	Frequency of bags lost
Human Error	-
Bags stuck in machinery	-
Wrong tagging	- - - - - -
Wrong bags taken by customer	- - -
Other Reasons	-

- You should provide the check sheet to each of the operators who track lost bags. They would be asked to tick off the problem category when each occurrence occurs
- Information from check sheets of all the operators could be collected and aggregated to do a Pareto Analysis of major reasons of losing bags in the airlines.

Other data collection techniques

- Coding data
 - Data coding is used to get variable data required for control charts (control charts will be covered later on in the chapter)
 - The data is standardized by subtracting nominal or other target values from actual measurements.
 - Coding data is often standardized so that measurement units are converted to whole numbers (e.g. 0.022 miles will be recorded as 22)
 - Coding data enables the user to plot several parts from a given process into the same control chart.
- Gauging
 - This will be covered in detail later in the chapter

Measurement scales

- From a six sigma perspective, measurement scales help in categorizing data into different types so that they can be collected and analyzed separately. Major measurement scales include Nominal, Ordinal, Interval and Ratio Measurement scales
- Nominal
 - Here, items are assigned to groups or categories. There is no ordering of data (i.e data collected does not show that something is better than the other). Nominal scales are therefore qualitative rather than quantitative. Variables measured on a nominal scale are often referred to as categorical or qualitative variables
 - Examples: country or origin, sex (Male/Female), and religion

Measurement scales (continued)

- Ordinal
 - When items are classified according to whether they have more or less of a characteristic, the scale used is referred to as an ordinal scale. Categories have a logical or ordered relationship to each other. These types of scale permit the measurement of degrees of difference, but not the specific amount of difference i.e. although there are differences between the different items, the differences cannot be quantified.. Any questions that ask the respondent to rate something use ordinal scales.
 - Example: How would you rate the quality of our food?
 - Very Good – 5; Good – 4; Average – 3; Poor – 2; Very Poor – 1;

Measurement scales (continued)

- Interval
 - In Interval scales, the distance between adjacent points on the scale are equal. These types of scale permit the measurement of degrees of difference, and the specific amount of difference. These scales do not have a natural zero. This is a widely used scale because important tools like measuring of averages, mode, median, mean etc. can be used for such scales. Please note that although for an interval scale, differences make sense, ratios do not e.g. difference in dates makes sense but there is no meaning in ratio of the dates.
 - Example: Dates, Temperature etc.
 - Very hot: $80^{\circ} - 90^{\circ}$
 - Hot: $70^{\circ} - 80^{\circ}$
 - Average: $60^{\circ} - 70^{\circ}$
 - Cold: $50^{\circ} - 60^{\circ}$
 - Very cold: $40^{\circ} - 50^{\circ}$

Measurement scales (continued)

- Ratio Measurement
 - In ratio scale, the scale consists not only of equidistant points but also has a meaningful zero point. If we ask respondents their ages, the difference between any two years would always be the same, and 'zero' signifies the absence of age or birth. Hence, a 100-year old person is indeed twice as old as a 50-year old one.
 - Example: Sales, Profit, market share, age etc. are all expressed on a ratio scale.

Validation techniques

- Validation techniques are very important since they
 - Ensure that whatever data we received from the system is acceptable
 - Quantify the reliability of measurement system and key metrics
 - Help in determining process capability
- For any system, the total variation that we observe in a system could be because of 2 important reasons:
 - Process variation:
 - Expected variation: this is the variation which is inherent in the system. So, there may be slight difference in measurements taken (e.g. although the same ice-cream vending machine is used to vend ice-creams to customers, there may be slight variation in the size of ice-creams produced. This is an expected variation which is created due to the way in which the ice-cream vending machine works)
 - Variation due to change in process: Process changes may result in a lot of variation in the data we are getting from the system (example, after doing a six sigma exercise which resulted in process improvements, the data collected may show decrease the number of defects)

Validation techniques

- Measurement system:
 - There is no such thing as a perfect measurement. Each measurement has some degree of variation due to limits of the instrument and people using them. Major causes of variation are:
 - Different employees taking measurements separately
 - Changes in specifications or procedures for data collection
 - Variation inherent in measurement system

Validation technique (continued)

- Total variation = Process Variation + Measurement Variation
- In six sigma, we will be making a transition to a data driven culture and will be making important decisions based on the data we have collected. Hence, it is very important that we ensure that our measurement systems are accurate, and the data we are getting are reliable.
- Without a proper measurement system, we would be collecting data which is neither accurate, nor reliable. The total variation (which is the sum of process variation and measurement variation) would be very high because of the high variation in the measurement system. Basing our six sigma project decisions on unreliable data and measurement systems will provide us inaccurate and wrong results.

Validation techniques (tools)

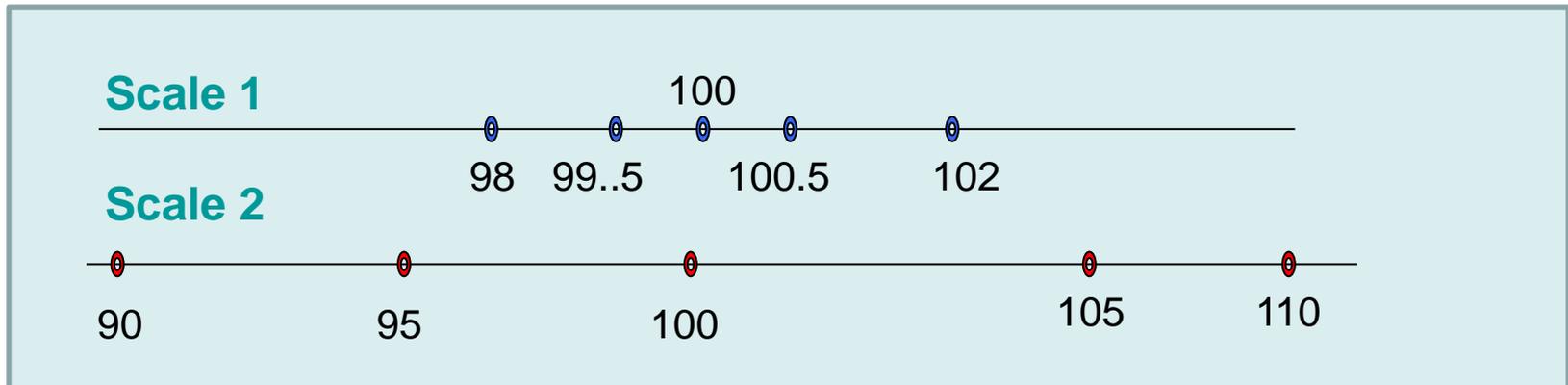
- There are several tools used for validation of data and the measurement system. Important tools are
 - Gauge R&R study
 - Statistical system analysis – ANOVA and other statistical quality control tools (these are beyond the scope of a six sigma green belt course and will be covered in a six sigma black belt course)

Important characteristics of measurement systems

- Accuracy:
 - This is an average value of several measurements taken
- Precision:
 - This shows how the measurements are clustered around the center i.e. spread of the measurements
- Linearity
 - How well the measurement system performs over a range of events
- Stability
 - How well does the measurement system performs over time

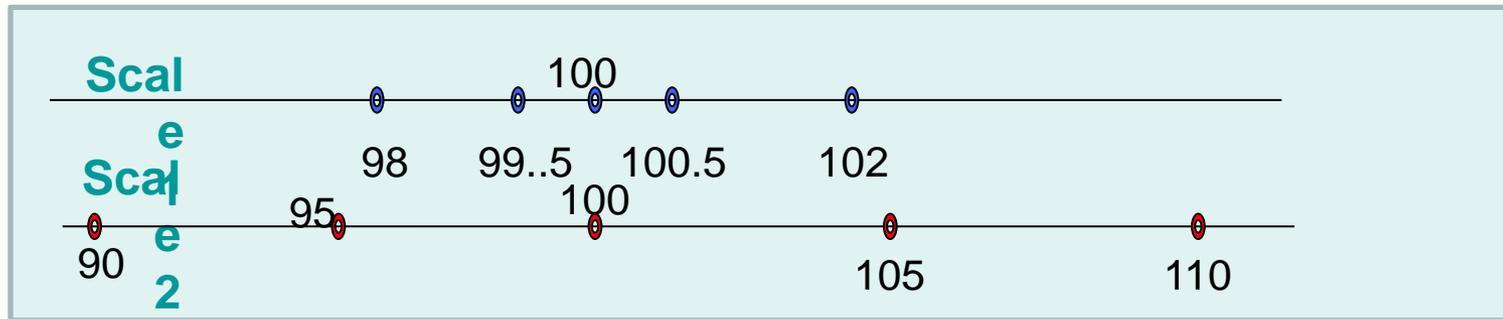
Example: Accuracy and Precision

- You are given a 100 KG weight. 2 weighing scales are used.
 - Measurements got from 1st weighing scale: 100.5 KGs, 99.5 kgs, 98 kgs, 102 kgs
 - Measurements got from 2nd weighing scale: 95 KGs, 105 kgs, 90 kgs, 110 kgs



- Please answer the questions below:
 - Which weighing scale is more accurate?
 - Which weighing scale is more precise?

Example: Accuracy and Precision



- Please answer the questions below:

- Which weighing scale is more accurate?

Answer: Accuracy is the average value of measurements taken.

Average value of measurements taken using scale 1 = 100.0

Average value of measurements taken using scale 2 = 100.0

So, both scales are equally accurate.

- Which weighing scale is more precise?

Answer: Precision shows how the measurements are clustered around the center i.e. spread of the measurements

As is clearly evident from the diagrams above, in Scale 1, the measurements are closer to the center than in scale 2. So, scale 1 provides better precision than scale 2.

Example: Accuracy and Precision

- Points to Note
 - Measurements having same accuracy may have different precision
 - Measurements having same precision may have different accuracy

Gauge R&R study

- Gauge R&R study is a powerful tool to determine the ability of a measurement system.
- The 2 R's of Gauge R&R study:
 - Repeatability: How consistently does the measurement system measure an event over time?
 - Reproducibility: How consistently can several operators measure an event i.e. if different operators were asked to measure the same event, would they get similar results?

Case Study – Gauge R&R study

- A baseball pitching machine for practice by pros is being evaluated. The baseball machine throws balls every six seconds – some pitches are “valid” while others which are out of reach of the bat are considered “invalid”.
- We have three observers and the baseball pitching machine pitches the ball 25 times. This is recorded in a video and all the three observers watch the video. Each time the ball is pitched, each observer is asked to rate whether they thought that the pitch was “valid” or “invalid” This is done twice for each observer (i.e. two trials for each observer) – data collected is shown in next page
- Master Attribute: This attribute shows the actual or true value of the event

Case Study – Gauge R&R study (continued)

Information Collected:

ID	Master Attribute	1st Observer		2nd Oobserver		3rd Observer	
		Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2
1	Valid	Valid	Valid	Valid	Valid	Valid	Valid
2	Invalid	Valid	Invalid	Invalid	Valid	Valid	Valid
3	Valid	Invalid	Invalid	Valid	Valid	Invalid	Valid
4	Valid	Valid	Valid	Invalid	Invalid	Valid	Invalid
5	Invalid	Invalid	Valid	Valid	Invalid	Invalid	Invalid
6	Invalid	Valid	Invalid	Invalid	Invalid	Invalid	Invalid
7	Valid	Valid	Valid	Valid	Valid	Valid	Valid
8	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
9	Valid	Valid	Valid	Valid	Valid	Invalid	Invalid
10	Valid	Invalid	Invalid	Invalid	Invalid	Invalid	Valid
11	Invalid	Invalid	Invalid	Invalid	Invalid	Valid	Valid
12	Invalid	Valid	Valid	Invalid	Invalid	Invalid	Invalid
13	Valid	Valid	Valid	Valid	Valid	Valid	Valid
14	Invalid	Invalid	Invalid	Invalid	Valid	Invalid	Invalid
15	Valid	Valid	Valid	Valid	Valid	Valid	Valid
16	Valid	Valid	Valid	Valid	Valid	Valid	Valid
17	Invalid	Invalid	Invalid	Valid	Invalid	Invalid	Invalid
18	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
19	Invalid	Invalid	Invalid	Valid	Valid	Valid	Valid
20	Valid	Valid	Valid	Valid	Valid	Valid	Valid
21	Invalid	Valid	Valid	Invalid	Invalid	Invalid	Invalid
22	Invalid	Invalid	Invalid	Valid	Invalid	Invalid	Invalid
23	Valid	Invalid	Invalid	Valid	Valid	Valid	Valid
24	Valid	Invalid	Invalid	Valid	Invalid	Valid	Invalid
25	Valid	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid

Case Study – Gauge R&R study (continued)

- Please calculate the following parameters for the Gauge R&R study: (answer in next page)
 - Observer accuracy score : % of time both the trials of each observer equal those of the master attribute
 - Observer Repeatability score: % of time both trials of observer are the same

Case Study – Gauge R&R study (continued)

ID	Master Attribute	1st Observer		Accuracy	Reliability
		Trial 1	Trial 2		
1	Valid	Valid	Valid	1	1
2	Invalid	Valid	Invalid	0	0
3	Valid	Invalid	Invalid	0	1
4	Valid	Valid	Valid	1	1
5	Invalid	Invalid	Valid	0	0
6	Invalid	Valid	Invalid	0	0
7	Valid	Valid	Valid	1	1
8	Invalid	Invalid	Invalid	1	1
9	Valid	Valid	Valid	1	1
10	Valid	Invalid	Invalid	0	1
11	Invalid	Invalid	Invalid	1	1
12	Invalid	Valid	Valid	0	1
13	Valid	Valid	Valid	1	1
14	Invalid	Invalid	Invalid	1	1
15	Valid	Valid	Valid	1	1
16	Valid	Valid	Valid	1	1
17	Invalid	Invalid	Invalid	1	1
18	Invalid	Invalid	Invalid	1	1
19	Invalid	Invalid	Invalid	1	1
20	Valid	Valid	Valid	1	1
21	Invalid	Valid	Valid	0	1
22	Invalid	Invalid	Invalid	1	1
23	Valid	Invalid	Invalid	0	1
24	Valid	Invalid	Invalid	0	1
25	Valid	Invalid	Invalid	0	1
Total				15	22
% scores				60%	88%

Here are the accuracy and reliability scores for Observer 1.

Compute the scores for Observer 2 and Observer 3 ? (answer in next page)

Case Study – Gauge R&R study (continued)

ID	Master Attribute	2nd Oobserver		Accuracy	Reliability	3rd Observer		Accuracy	Reliability
		Trial 1	Trial 2			Trial 1	Trial 2		
1	Valid	Valid	Valid	1	1	Valid	Valid	1	1
2	Invalid	Invalid	Valid	0	0	Valid	Valid	0	1
3	Valid	Valid	Valid	1	1	Invalid	Valid	0	0
4	Valid	Invalid	Invalid	0	1	Valid	Invalid	0	0
5	Invalid	Valid	Invalid	0	0	Invalid	Invalid	1	1
6	Invalid	Invalid	Invalid	1	1	Invalid	Invalid	1	1
7	Valid	Valid	Valid	1	1	Valid	Valid	1	1
8	Invalid	Invalid	Invalid	1	1	Invalid	Invalid	1	1
9	Valid	Valid	Valid	1	1	Invalid	Invalid	0	1
10	Valid	Invalid	Invalid	0	1	Invalid	Valid	0	0
11	Invalid	Invalid	Invalid	1	1	Valid	Valid	0	1
12	Invalid	Invalid	Invalid	1	1	Invalid	Invalid	1	1
13	Valid	Valid	Valid	1	1	Valid	Valid	1	1
14	Invalid	Invalid	Valid	0	0	Invalid	Invalid	1	1
15	Valid	Valid	Valid	1	1	Valid	Valid	1	1
16	Valid	Valid	Valid	1	1	Valid	Valid	1	1
17	Invalid	Valid	Invalid	0	0	Invalid	Invalid	1	1
18	Invalid	Invalid	Invalid	1	1	Invalid	Invalid	1	1
19	Invalid	Valid	Valid	0	1	Valid	Valid	0	1
20	Valid	Valid	Valid	1	1	Valid	Valid	1	1
21	Invalid	Invalid	Invalid	1	1	Invalid	Invalid	1	1
22	Invalid	Valid	Invalid	0	0	Invalid	Invalid	1	1
23	Valid	Valid	Valid	1	1	Valid	Valid	1	1
24	Valid	Valid	Invalid	0	0	Valid	Invalid	0	0
25	Valid	Invalid	Invalid	0	1	Invalid	Invalid	0	1
Total				15	19			16	21
% scores				60%	76%			64%	84%

Case Study – Gauge R&R study (continued)

ID	Master Attribute	1st Observer		2nd Oobserver		3rd Observer		Overall accuracy
		Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2	
1	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Y
2	Invalid	Valid	Invalid	Invalid	Valid	Valid	Valid	N
3	Valid	Invalid	Invalid	Valid	Valid	Invalid	Valid	N
4	Valid	Valid	Valid	Invalid	Invalid	Valid	Invalid	N
5	Invalid	Invalid	Valid	Valid	Invalid	Invalid	Invalid	N
6	Invalid	Valid	Invalid	Invalid	Invalid	Invalid	Invalid	N
7	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Y
8	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid	Y
9	Valid	Valid	Valid	Valid	Valid	Invalid	Invalid	N
10	Valid	Invalid	Invalid	Invalid	Invalid	Invalid	Valid	N
11	Invalid	Invalid	Invalid	Invalid	Invalid	Valid	Valid	N
12	Invalid	Valid	Valid	Invalid	Invalid	Invalid	Invalid	N
13	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Y
14	Invalid	Invalid	Invalid	Invalid	Valid	Invalid	Invalid	N
15	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Y
16	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Y
17	Invalid	Invalid	Invalid	Valid	Invalid	Invalid	Invalid	N
18	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid	Y
19	Invalid	Invalid	Invalid	Valid	Valid	Valid	Valid	N
20	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Y
21	Invalid	Valid	Valid	Invalid	Invalid	Invalid	Invalid	N
22	Invalid	Invalid	Invalid	Valid	Invalid	Invalid	Invalid	N
23	Valid	Invalid	Invalid	Valid	Valid	Valid	Valid	N
24	Valid	Invalid	Invalid	Valid	Invalid	Valid	Invalid	N
25	Valid	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid	N
Total								8
% scores								32%

Case Study – Gauge R&R study (continued)

- Inferences from the case study:
 - The overall accuracy is very low i.e. 32%.
 - The reliability of the operators is close to 80% i.e. for the same event, observers reach different conclusions.
 - The accuracy of individual operators is also low (close to 60%)
- All the above measures make us believe that this measurement system is not accurate. Some suggestions:
 - Another measurement system needs to be defined to measure the observations.
 - Alternately, the measurement system needs to be enhanced (example – instead of watching a video of the pitching machine, we could consider providing observers a slow motion for the video).
 - Please note that for all the observers, reliability is higher than accuracy. Whenever the observers are more consistent (reliable), but wrong in their ratings (accuracy), then they may be applying the wrong rules or they are not very aware of the measurement process. There is an opportunity for training the observers about the measurement process.

Probability Distributions

- Detailed study of probability distributions is done in a Black Belt course.
- Important distributions used include:
 - Binomial
 - Poisson
 - Normal
 - Chi-square
 - Student's t
 - F distribution
- Usually it is impossible to measure the whole population, and samples are used for calculation. (e.g. if we want to conduct a poll about the height of different people in a country, talking with all the individuals in a country would be very difficult. So, a sample of individuals is taken and the results got is extrapolated to the entire population).

Data mining

- In measure phase of six sigma, a lot of data is collected and analyzed. A rich source of data could be databases in the company.
- Data mining defined (TwoCrows): An information extraction activity whose goal is to discover hidden facts contained in databases. Using a combination of machine learning, statistical analysis, modeling techniques and database technology, data mining finds patterns and subtle relationships in data and infers rules that allow the prediction of future results.
- Typical applications include market segmentation, customer profiling, fraud detection, evaluation of retail promotions, and credit risk analysis.
- There are several software available which can be used for data mining. (leading vendors for data mining include Oracle, IBM, SAS, Microstrategy, CA, DMreview etc.)

Run chart

- These are plots of data arranged in a time or order sequence.
- Used for preliminary analysis of data measured on a continuous scale. (e.g. performance of a machine or person over time)
- Helps identify whether the system is under control – as defined by Shewhart (1931, 1980) *“A phenomenon will be said to be controlled when, through the use of past experience, we can predict, at least within limits, how the phenomenon may be expected to vary in the future. Here it is understood that prediction within limits means that we can state, at least approximately, the probability that the observed phenomenon will fall within the given limits.”*
- Helps identify common causes and special causes of variation
 - Common cause: These are inherent in the process and can be predicted within reasonable limits
 - Special cause: These variations may be caused because of extraneous or unexpected reasons. Special cause of variations cannot be predicted.

Case study – preparing a run chart

1. You are the manager of ABC Airlines. You would like to analyze how long it would take for a customer service rep to service a customer.
2. You observe a customer service rep doing her work and get the measurements for the time it takes her to service each customer. (see chart)

Customer #	Time taken to service a customer (minutes)
1	11
2	12
3	13
4	10
5	9
6	8
7	20
8	10
9	13
10	9
11	11
12	13
13	10
14	9
15	10

Case study – preparing a run chart (continued)

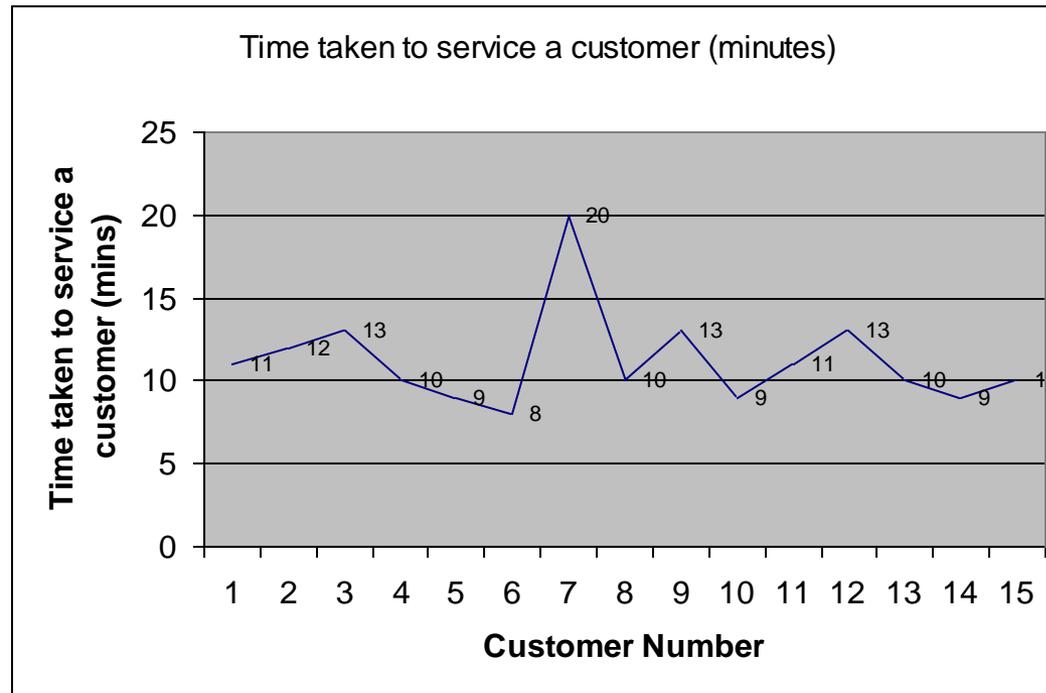
3. Next, you find out the median of the time required by the customer service rep to service each customer. Median is defined as “the middle number in a set of data when it is ranked from lowest to highest, it is an indicator of central location in a data set”

- To calculate median,
 - Rank all the data points from lowest to highest (shown in chart here)
 - - Determine the central location (i.e. corresponding to data point # 8 i.e. value 10)
 - So, Median for the data is 10

Data point #	Customer #	Time taken to service a customer (minutes)
1	6	8
2	5	9
3	10	9
4	14	9
5	4	10
6	8	10
7	13	10
8	15	10
9	1	11
10	11	11
11	2	12
12	3	13
13	9	13
14	12	13
15	7	20

Case study – preparing a run chart (continued)

4. Plot a line chart which shows distribution of data around the median.



Case study – preparing a run chart (continued)

How is a run chart useful?

- It helps determine the **special causes of variation**. To find out special causes of variation, do the following
 - Determine if there are some values which are very much above or below the median (e.g. in this case, customer # 7 who takes 20 minutes to service is a special cause of variation) – we can analyze to find out what resulted in the special cause of variation e.g. did the customer not have all his documents, speak a different language etc?
 - Determine Trends i.e. unusually long series of consecutive data points above or below the median. In the diagram, we do not have any trends. However, if we find a trend e.g. 7 data points where the customer service rep takes more than 10 minutes (median) to service a customer, this is a special cause of variation. We can try to figure out whether the customer service rep was tired, or the computer systems were not functioning properly etc.

Case study – preparing a run chart (continued)

- Helps determine the **median value**, and possibility of process improvements (e.g. if we could decrease the median time for servicing customers from 10 minutes to 8 minutes through improved processes or automation, it will mean savings for everybody).
- Helps determine the **common cause of variation**. (e.g. in this example, most customers are serviced between 10 ± 3 minutes i.e. between 7 minutes and 13 minutes). Reduction of common cause of variation helps in further process improvement

Detailed process maps and Pareto charts

- In Measure phase, we review the process maps and Pareto charts created in Define phase
- Additional details are added to the charts to make them more comprehensive and complete
- Details about creation of process maps and Pareto charts : please refer to chapter 4: Six sigma methodology - Define

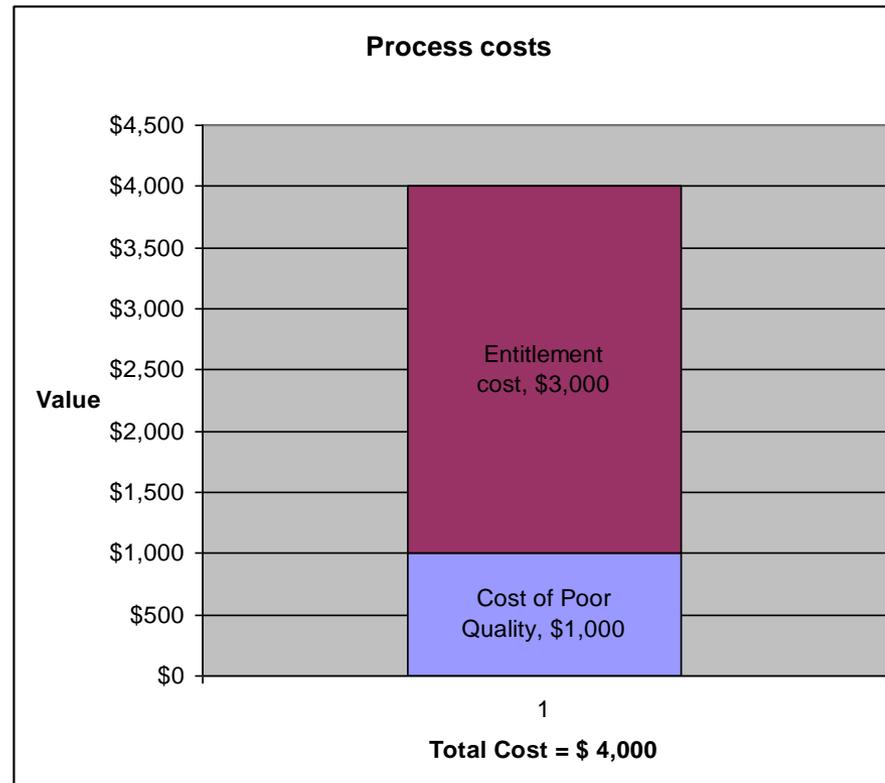
Stakeholder tools

- For tools used by stakeholders - please refer to - Chapter 2: Stakeholders, Customers and Financial Measures
- Some important tools used to determine stakeholder requirements:
 - Balanced scorecard (tool used to measure different stakeholders goals quantitatively and translate these goals into metrics)
 - Kano Model (Kano Model is very effective in differentiating between the different attributes of a product from a customer perspective. Inputs from the Kano Model are very valuable for a design team to understand customer requirements and aspirations)
 - Quality function deployment – QFD (After getting inputs from the customer, QFD can be used to map the voice of the customer to internal company processes and also provide competitive evaluation. QFD analysis includes inputs from all groups inside the organization, and forms the basis for determining the requirements for the project)

Process costs

- From a process perspective, process costs are divided into 2 high level categories:
 - Entitlement costs: These are costs associated with producing goods correctly the first time.
 - Cost of Poor Quality (COPQ): These are costs associated with not performing work correctly the first time and with producing low quality goods
- Total process cost = Entitlement cost + COPQ

Sample process cost calculation



Please note:

- To increase profits, it is very important to reduce total costs
- Since Cost of Poor Quality (COPQ) is an important component of the cost calculation, it is important to reduce COPQ to improve profits (details of COPQ will be covered later in the chapter)

Outputs – Well defined processes

- At the end of measure phase, we should have
 - Better definition of the processes because of detailed process maps and Pareto charts
 - Detailed Data related to different processes which could be used to develop metrics and help in data analysis in the six sigma Analysis phases

Measurement Systems

- We will have detailed understanding of the measurement systems at the end of measure phase.
- Use of validation techniques e.g. Gauge R&R study and data mining to determine the capability of existing measurement systems – this will help us evaluate the measurement system and ensure that we have a devised a measurement system which has high accuracy and precision.

Outputs – Baseline Process Capability

- Baseline process capability
 - Through use of run charts and statistical distributions, we will get better understanding of the process capability
 - In a six sigma Black Belt course, Process capability would be measured using indices like (C_p and C_{pk}). Process performance would be measured using indices like P_p , P_{pk} and C_{pm} : this is beyond the scope of a six sigma Green Belt course.
- Better understanding of process costs also helps us define the baseline process capability. Once the baseline process capability is defined, we can target to improve the process during Analyze and later phases of the Six sigma project.

Process capabilities impacting CTQ

- CTQ (Critical to Quality): These are the important characteristics of a product or process whose performance standards or specification limits must be met in order to satisfy the customer. They align improvement or design efforts with customer requirements.
- Better understanding of the process and understanding of requirements through use of stakeholder tools helps us determine the important process parameters which will impact CTQ. This will become a critical input in the Analysis phase of the six sigma initiative.

Cost of Poor Quality (COPQ)

- These are costs associated with not performing work correctly the first time and with producing low quality goods
- COPQ is divided into 4 categories:
 - Appraisal costs (monitoring and measuring quality parameters e.g. costs associated with quality audits, managing outside vendors, dealing with supplier quality problems etc.)
 - Internal Failure costs (internal costs associated with correcting a low quality product e.g. costs associated for rework, longer cycle time, higher inventory etc.)
 - Prevention costs (preventing a low quality product from reaching final customer e.g. audit personnel, recall of produced goods etc.)
 - External failure costs (impact of poor quality product on final customer e.g. loss of goodwill, write-offs, service problems etc.)

Savings associated with reducing COPQ

- Hard savings (can be directly measured)
 - Decrease in costs
 - Less rework
 - Lower cycle time
- Soft savings (intangible and may not be directly measured)
 - Loss of goodwill
 - Loss of competitive advantage
- Cost avoidance savings
 - Savings from costs that might have occurred in the future if process had not improved.