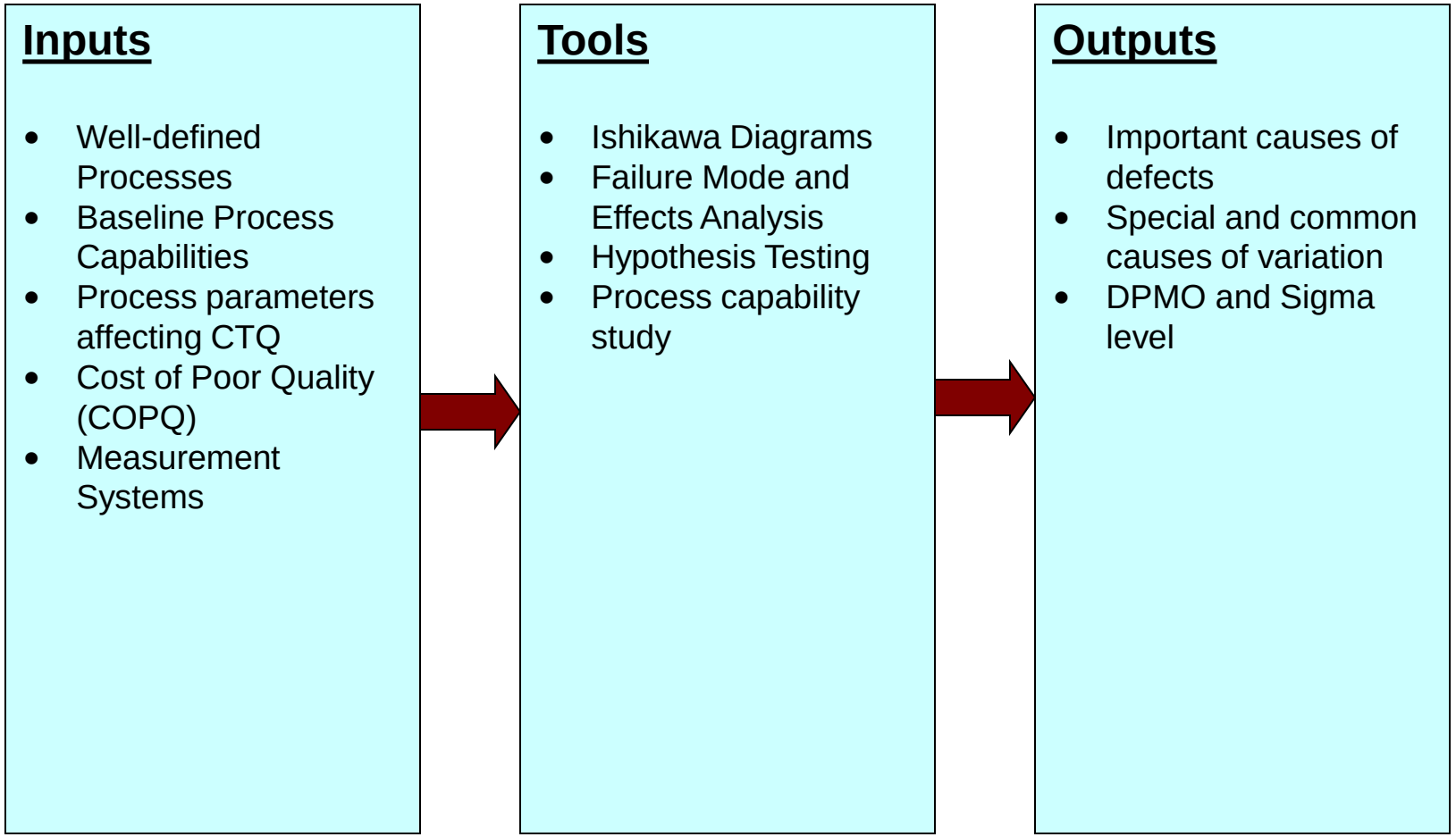
Lean Six Sigma Green Belt Study Guides

Index – Six Sigma Methodology (Analyze)



Objective of Analyze phase

- In Analyze phase, our objectives are:
  - Doing analysis of present system
  - Analyzing whether the present system can be further improved
  - Determining the failure points for the proposed changes
  - Determining major milestones and risks in successfully completing the project
  - Analyzing how the process capability would improve if suggested changes are made.

Inputs

- Inputs for Six Sigma Analyze are covered in Outputs for Six Sigma Measure. (for details, please refer to Chapter 5: Six Sigma Methodology – Measure)

Tools – Ishikawa Diagrams (cause and effect or Fishbone diagram)

- Ishikawa diagrams are also referred to as cause-and-effect or Fishbone diagram.
- Developed by Kaoru Ishikawa in 1960's, this is a graphic representation of possible causes for any particular problem under study.
- Benefits of Ishikawa diagram
  - Usually created by a group of people who have knowledge of the process and understand the problems in the present system.
  - Is a very powerful tool to organize and graphically display all the knowledge the team has about a particular problem
  - Clarifies the understanding the team has regarding the process. If an Ishikawa diagram does not show appropriate level of detail, it indicates that the team has a superficial knowledge of the problem. Hence, additional study of the system or involvement of Subject Matter Experts is required.
  - Is a starting point to determine the Vital X's that impact the customer's critical to quality variable : Y. (Details about Y and Vital X's as defined in the chapter 2: Stakeholders, customers and financial measures)

Ishikawa diagram – Steps involved

- Steps involved in creation of Ishikawa diagram:
    1. Create a process map of the existing system (Process Maps discussed in Chapter 4: Six sigma methodology – Define)

    2. Define the problem to be solved. This could be a critical requirement or Y variable. (Discussed in chapter 2: Stakeholders, customers and financial measures)

    3. Put a team together who have good knowledge of the process and understand the problems involved with the process

    4. Conduct a brainstorming or Nominal Group Technique session (Discussed in chapter 3: Setting up and managing a six sigma project). In the session, determine all the causes of the problem.

    5. Categorize the causes identified into groups and subgroups. A popular way to do this is through using Affinity diagrams (Discussed in chapter 3: Setting up and managing a six sigma project).

Ishikawa diagram – Steps involved

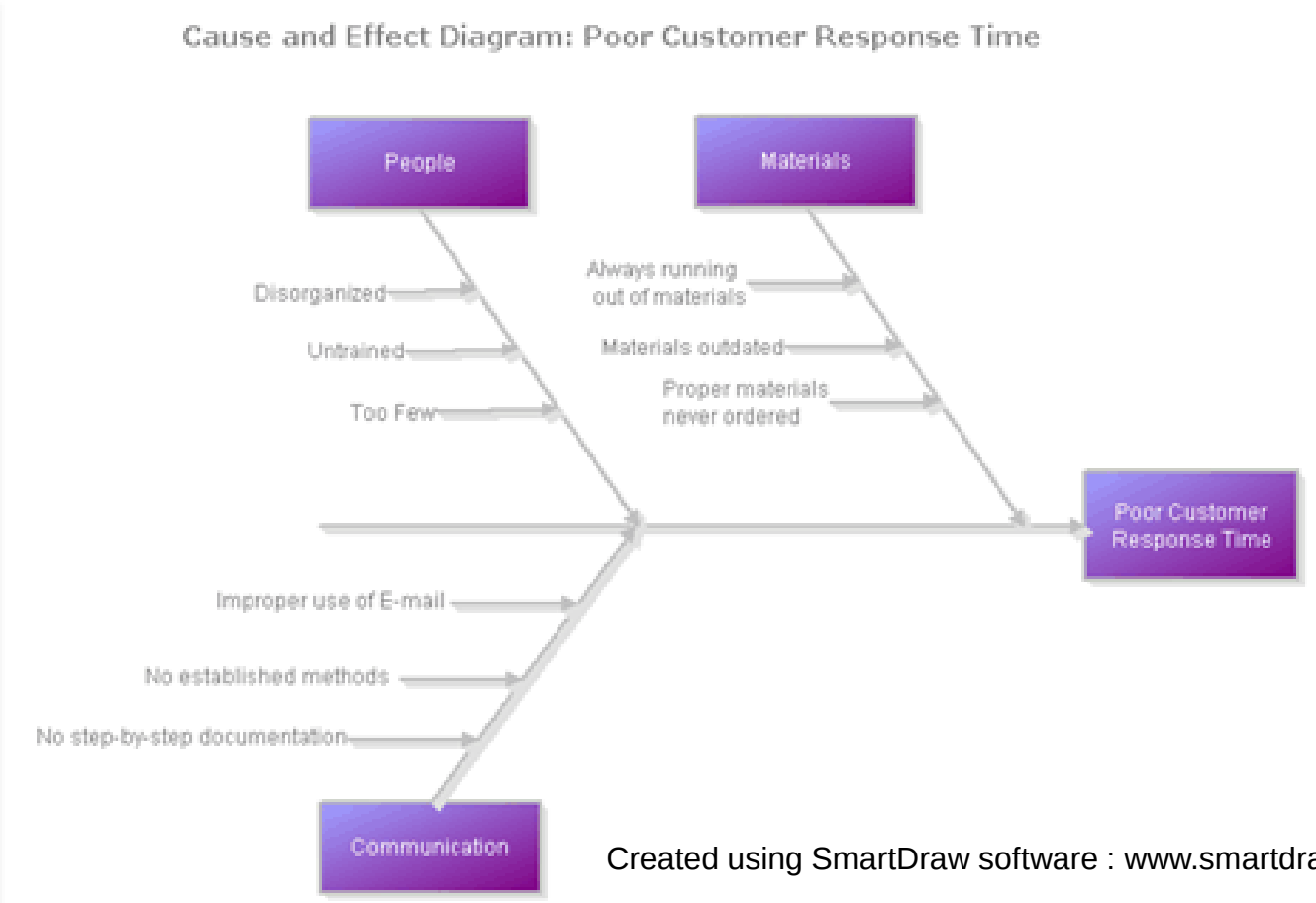
6. Once groups and subgroups are available, create an Ishikawa diagram using 3 steps: (sample in next page)

   a. Draw a box on the far right side where the problem under consideration is written down.

   b. Draw a horizontal arrow which points to the box on the right

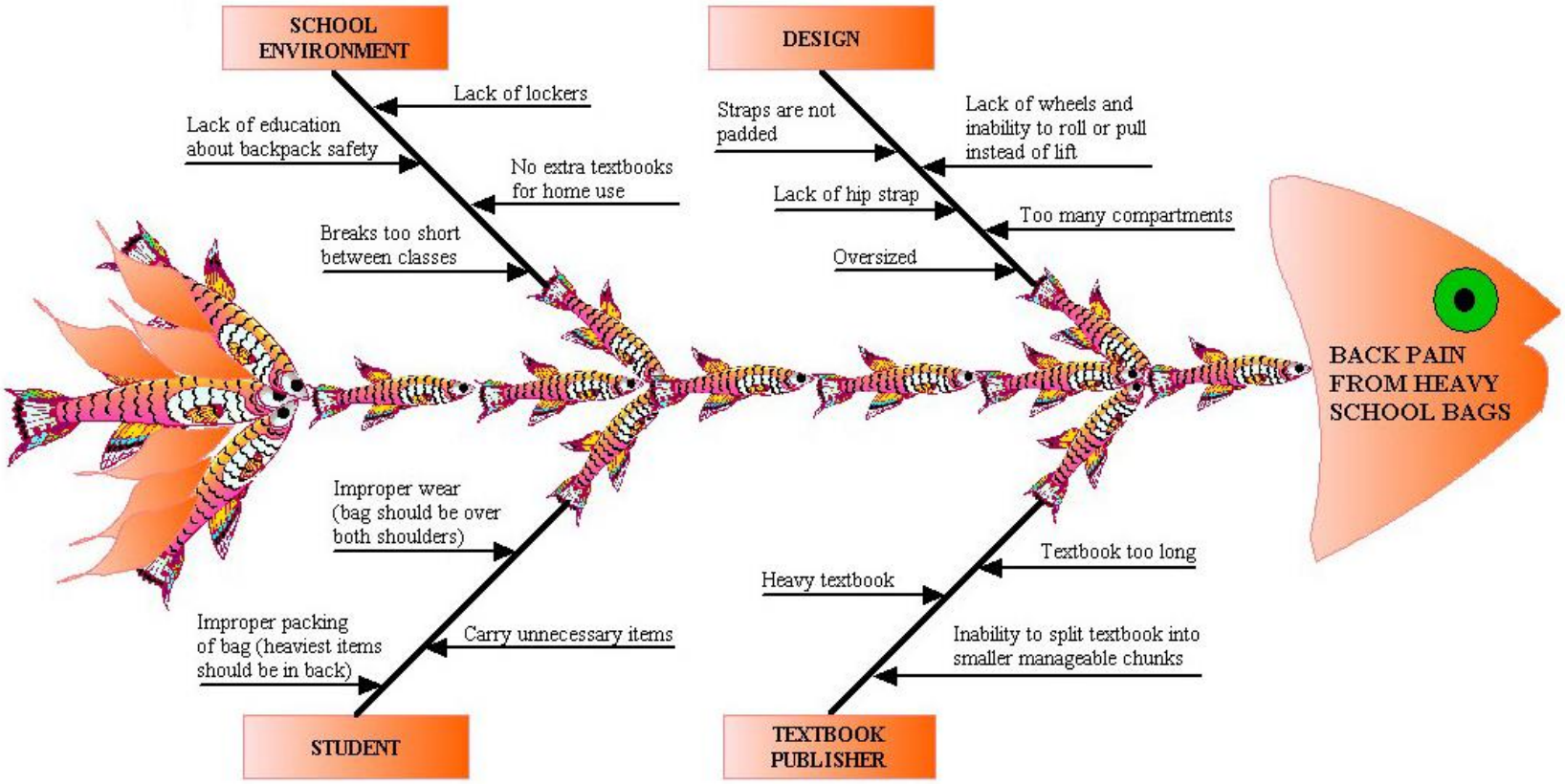
   c. Write the names of categories above and below the horizontal line. Start with high level groups and expand each group (upto 3 or 4 levels). Write down the detailed cause data for each category.

Sample Ishikawa Diagram - 1



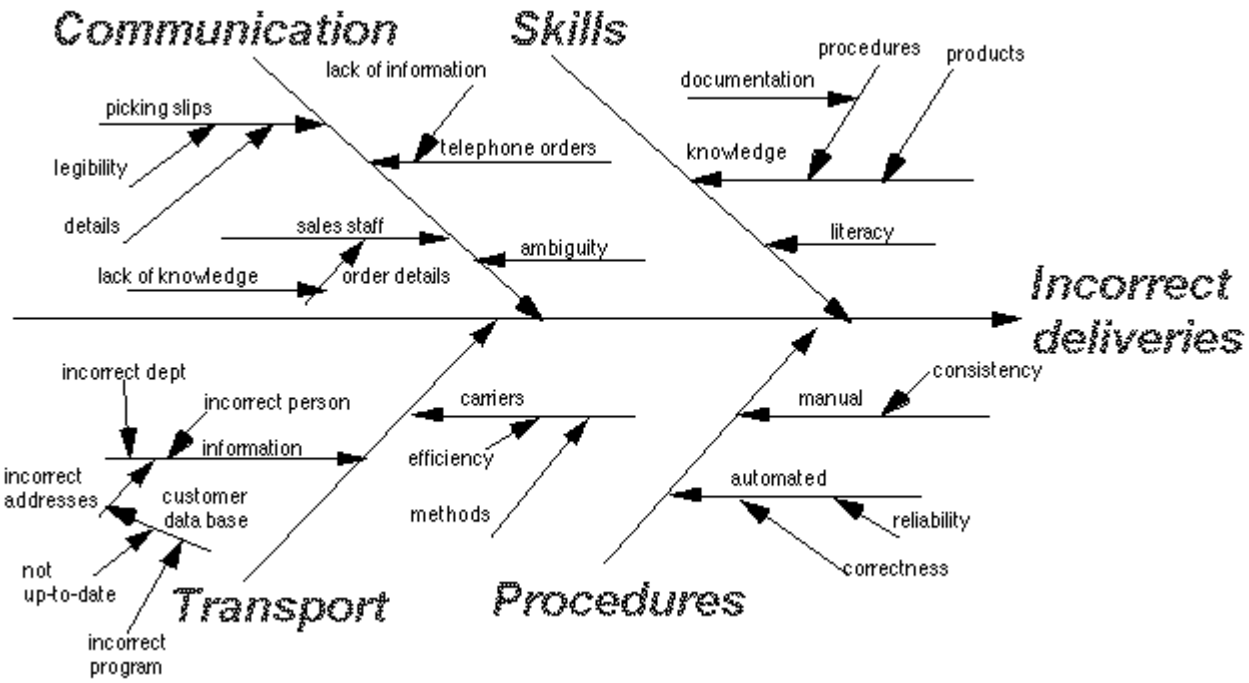
Created using SmartDraw software : www.smartdraw.com

Sample Ishikawa Diagram - 2



Created using SmartDraw software : www.smartdraw.com

Sample Ishikawa Diagram - 3



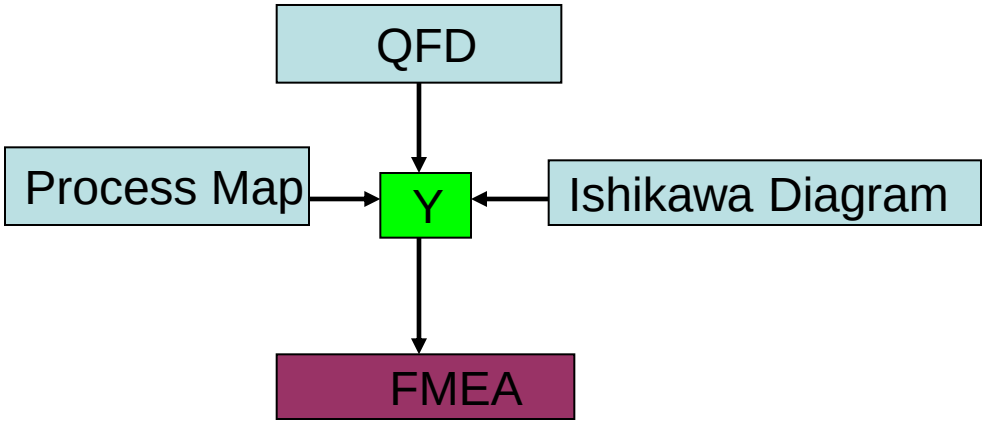
From hci.com

Failure Mode and Effects Analysis (FMEA)

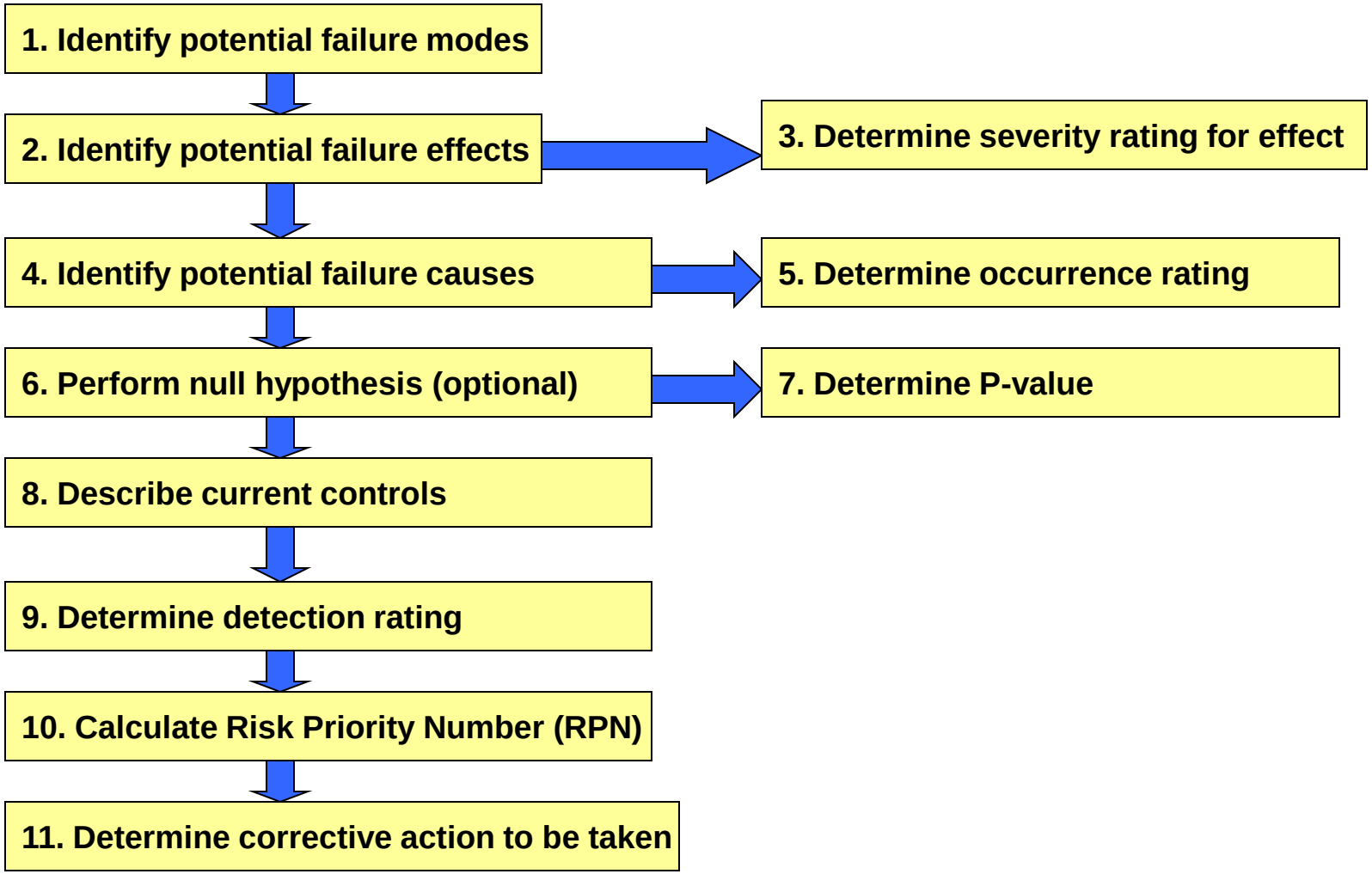
- Failure Mode and Effects Analysis (FMEA) was formally used in the Airlines industry in 1960's. This is now a very common technique used across several industries

- FMEA is a tool to:
  - Identify effects or consequences of a potential product or process failure
  - Identify methods to eliminate or reduce the chance of a failure occurring

- Information from Process Map, Ishikawa Diagram and QFD are used in creation of FMEA



Steps in FMEA Analysis



Steps in FMEA Analysis (Continued)

1. Identify Potential failure modes: Failure modes are physical description of a failure. (e.g. let us consider a case study where the manufacturing department in our company has manufactured an ear thermometer which is used to register body temperature via the ear canal. So, one potential failure mode is “Thermometer not working properly.”)

2. Identify Potential failure effects: Failure effects are the impact of failure on the customer i.e. the “Y” variable (e.g. However, the thermometer registers wrong temperature than the actual temperature of the patient. So, the potential failure effect here is “Wrong Temperature registered.”) Please note that there could be more than one potential failure effect or Y variable.

3. Determine the severity rating for the effect: Severity is a rating corresponding to the seriousness of an effect. This is done in a scale from 1 to 10: 1: failure has least impact, 10: failure has maximum impact. (e.g. the team decides that measuring of wrong temperature is a very critical issue and hence assigns a severity rating of 9)

Steps in FMEA Analysis (Continued)

4. Identify potential causes: These are the low level bones of the Ishikawa diagram. They correspond to the Vital X's or root causes for the problem identified. (e.g. it was determined that a failure cause for the problem is that thermometer was not calibrated properly). Please note that for each effect, there could be more than one potential failure cause. Similarly there could be multiple effects for each failure cause.

5. Determine the occurrence rating: Occurrence is a rating scale of the possibility that a failure effect and its corresponding failure cause will occur in the current system. This is done in a scale from 1 to 10: 1: failure very unlikely, 10: failure certain. (e.g. the team decides that measurement of wrong temperature due to wrong calibration of thermometer has a low occurrence and assign it a value of 4)

Steps in FMEA Analysis (Continued)

6. Perform Null hypothesis (optional): This will be covered in detail in a black belt course. A null hypothesis is used to determine if there was any difference between the failure modes (e.g. in this case, the null hypothesis would be “There is no difference between calibration scales of thermometers”)

7. Determine P-value (optional): This will be covered in detail in a black belt course. This represents the probability of making an incorrect decision by rejecting a true null value. (e.g. in this example, the p-value was determined to be 0.04)

7. Describe Current Controls: The team determines and describes the controls which are in place to ensure that the failure mode does not occur before the product goes out to the customer (e.g. in this case, random trials on thermometers on small samples is done to find out if some thermometers do not register temperature accurately)

Steps in FMEA Analysis (Continued)

8. Determine the Detection Rating: The detection rating corresponds to the probability that current controls would be able to detect potential failure modes before the product is released to the customer. This is done in a scale from 1 to 10: 1: will detect failure, 10: almost certain that will not detect failure. (e.g. in this case, the team decides that there is a very low probability that current controls will detect error – hence they provide a low detection rating of 8)

9. Calculate Risk Priority Number (RPN): RPN is a quantitative measure of the areas of greatest concern. It is calculated as:

RPN = Severity Rating * Occurrence Rating * Detection Rating

(e.g. in this example, RPN = 9 * 4 * 8 = 288)

Steps in FMEA Analysis (Continued)

10. Determine corrective action to be taken. Please note that corrective action has to be taken in the following cases:

- Severity Rating is very high (e.g. 8, 9 or 10). So, failure has very high impact on the customer e.g. in this case, severity rating is 9 and we know that corrective action must be taken to handle the potential failure effects

- RPN is very high : RPN identifies areas of greatest concern. So, it is a good indication of which effect needs to be corrected and also identifies the important causes that need to be fixed in order to take care of the effect.

FMEA Worksheet

Process or Operation	Potential Failure Mode	Potential Failure Effects	SEV	Potential causes	OCC	Null Hypothesis	P-Value	Current Controls	DET	RPN	Recommended Actions

Sample FMEA worksheet completed

- Let us consider the case study we discussed earlier where the manufacturing department in our company has manufactured an ear thermometer which is used to register body temperature via the ear canal. FMEA Worksheet for the case-study is provided below:

Process or Operation	Potential Failure Mode	Potential Failure Effects	SEV	Potential causes	OCC	Null Hypothesis	P-Value	Current Controls	DET	RPN	Recommended Actions
Temperature measured using ear-canal thermometer	Thermometer not working properly	Wrong temperature recorded	9	Thermometer not calibrated properly	4	No difference in calibration scales of thermometers	0.04	Random tests on sample	8	288	Because of high Severity level, corrective action necessary

Hypothesis testing

- Details of hypothesis testing will be covered in a six sigma black belt course.
- This course would provide a high level overview of hypothesis testing, its use and benefits.
- When is hypothesis testing required?
  - Hypothesis testing is required when decisions are made about a population using sample data.
- What is the benefit of hypothesis testing?
  - Uses statistics to help quantify the risks associated assigned to making specific decisions. It helps us determine the confidence level that the decision we are making about a small sample would apply to the whole population. (for example, opinion polls about who would win a particular election are done from a small sample of people. However, the information got from the sample is then extrapolated to the whole population of voters to give an indication of which candidate would win the election: hypothesis testing would provide us with a confidence level that our opinion poll is accurate. It will also help us determine the margin of accuracy for the poll).

Hypothesis testing (continued)

- How is a hypothesis test conducted?
  - Determine the null hypothesis (H_o) – this is something we assume to be true unless proved otherwise. We then decide whether to reject the null hypothesis in favor of the alternate hypothesis (H_a). The alternate hypothesis (H_a)is opposite to the null hypothesis (H_o) e.g. in the case study we discussed earlier,
    - H_o: There is no difference in calibration scales for thermometers
    - H_f: There is a difference in calibration scales
  - Since the decision is based on sample available, there is always a potential that we may make one of the 2 types of errors:
    - Type I error: Error of rejecting the null hypothesis when it is true. Probability of getting a Type I error is denoted by α.
    - Type II error: Error of accepting the null hypothesis when it is false. Probability of getting a Type II error is determined by β.

Hypothesis testing (continued)

- Use the appropriate statistical test for hypothesis testing. Some important tests used are t-tests, chi-square tests and two proportion tests.
- If the hypothesis testing determines that null hypothesis H_o was true, the team will know that their analysis was statistically valid. They can go ahead with
- If the hypothesis testing determines that results were not significant, then the team would have to do further analysis to determine root cause of problem.

Process capability study

- Process capability is the extent to which any stable process is able to meet specifications.
- Run charts (Discussed in Chapter 5: Six sigma methodology – Measure) are used to create control charts. These charts are used to find out whether a process is stable over time and over several events. Special causes of variation are determined and steps taken to ensure that the variation is minimized.
- The process data (in form of a histogram) is created. This usually takes a bell shape (also referred to as normal curve). The normal curve is used for determining process capability.
- Voice of the customer is used to determine the USL (Upper Specification Limit) and LSL (Lower Specification Limit). This is compared with the process level for the existing process.

Process Capability study – Case study

- ABC Industries manufactures spherical ball bearings which are supplied to different automobile manufacturers and are used in the manufacturing process of cars. Approximately 1 million ball bearings of a particular type are produced daily.

- Of late, there have been several complaints from customers (automobile manufacturers) that the spherical ball bearings were not conforming to requirements, and many of them had to be rejected.

- A critical criteria used for evaluating spherical ball bearings is the size of the ball bearing (this is a measure of the diameter of the ball bearing in centimeters – cm). ABC industries decided to conduct a process capability study to study this criteria i.e. size of the ball bearing. A six sigma expert was assigned the responsibility for conducting the study.

Process Capability study – Case study (continued)

- Sample vs. Population:
  - The six sigma expert understood that it was very expensive and time-consuming to study the whole population of spherical ball bearings produced by the company.
  - So, he decided to take a subset of the population. Based on discussions with subject matter experts, a representative sample was determined as ball bearings produced in one run (8 hours). Information from sample was extrapolated to the whole population.
  - Some commonly used terms in describing the sample and population characteristics:
    - Center: the central point in the data (represented by X in the sample and u in the population)
    - Spread: dispersion of data around the center (represented by S in the sample and in the population)

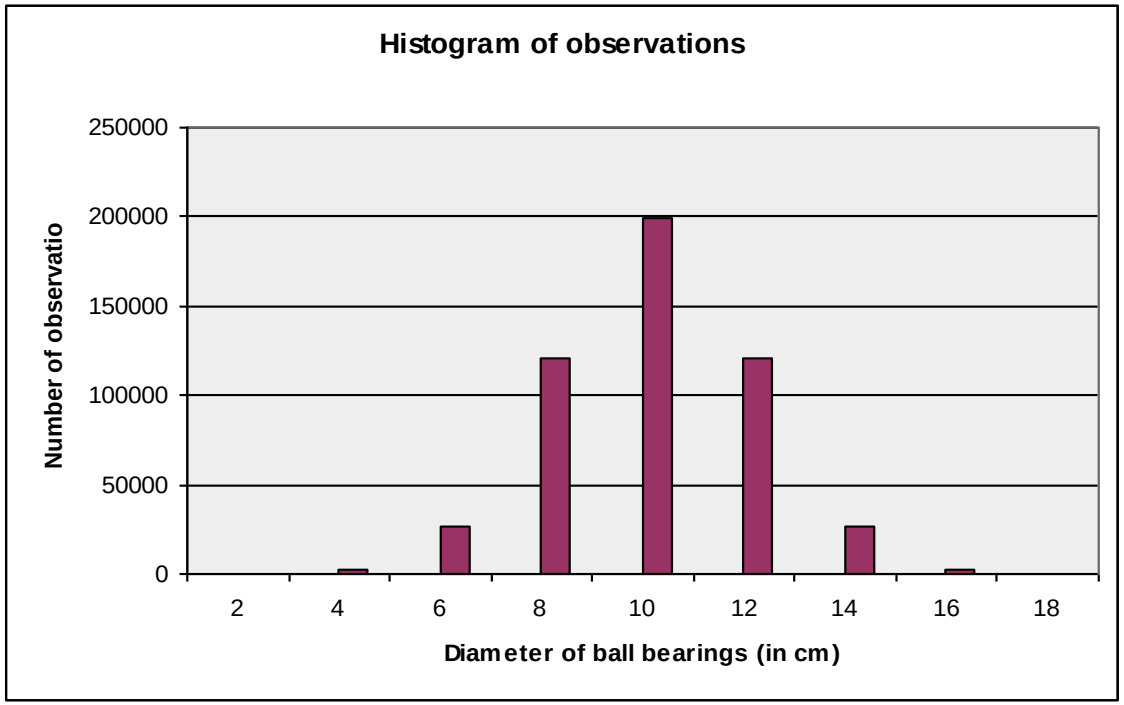
Process Capability study – Case study (continued)

- Since size (diameter) of the ball bearings is a critical parameter that customers consider, the six sigma expert measured the diameter of all the ball bearings produced in one run.
- To simplify calculations, the six sigma expert divided all the data collected into 9 ranges as shown below:

Range of ball bearing sizes (diameter)	Mean of range	Number of observations
1 - 3 cm	2	64
3 - 5 cm	4	2200
5 - 7 cm	6	26995
7 - 9 cm	8	121000
9 - 11 cm	10	199471
11 - 13 cm	12	120985
13 - 15 cm	14	26000
15 - 17 cm	16	2250
17 - 19 cm	18	67

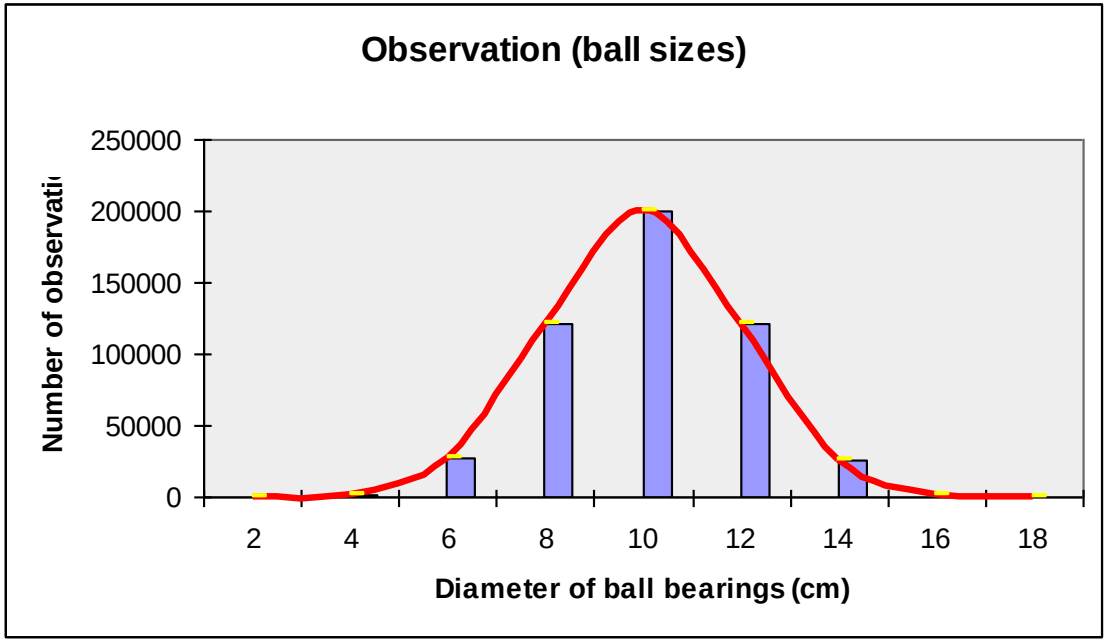
Process Capability study – Case study (continued)

- Data got was plotted as a histogram as shown below:



Process Capability study – Case study (continued)

- The six sigma expert saw that the information followed a bell curve (similar to normal distribution)



For the purpose of calculations, the six sigma expert concluded that a normal curve could be used.

Process Capability study – Case study (continued)

Determining the DPMO (i.e. Defects per million opportunities):

Once we know the USL and LSL, we can find out how many measurements fall outside of these limits and calculate the DPMO (i.e. Defects per Million Opportunities).

Range of ball bearing sizes (diameter)	Mean of range	Number of observations	Calculation
1 - 3 cm	2	64	
3 - 5 cm	4	2200	
5 - 7 cm	6	26995	
7 - 9 cm	8	121000	
9 - 11 cm	10	199471	
11 - 13 cm	12	120985	
13 - 15 cm	14	26000	
15 - 17 cm	16	2250	
17 - 19 cm	18	67	
Total observations (opportunities)		**499033**	**Sum of all the observations**
Defects (i.e. observations outside of specification limits)		**4581**	**64+2200+2250+67**
Defects per Million opportunities		**9180**	**4581 / 499033 * 1,000,000**

Process Capability study – Case study (continued)

Determining the sigma level:

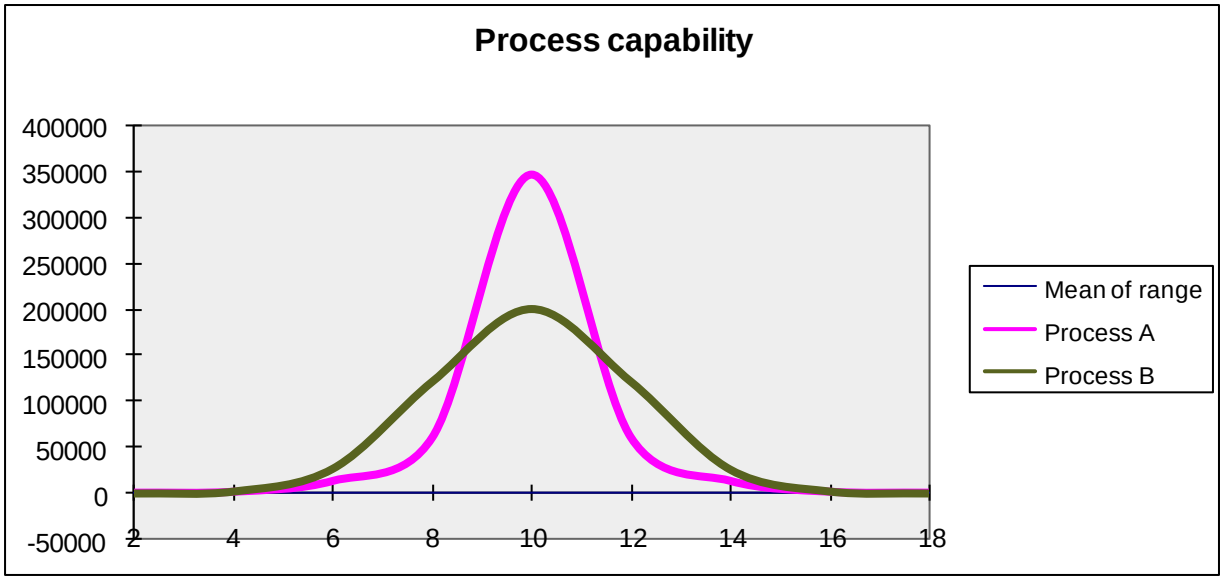
Once we know the DPMO level, we can use the six sigma chart provided below to determine the sigma level of the process

Sigma Quality Level	Defects per Million Opportunities (DPMO)
1	697700
2	308700
3	66810
4	6210
5	233
6	3.4

Since the process has a DPMO of 9180, we know that the sigma level for the process is more than 4 sigma (i.e. 4)

Improving process capability

Improvement in process capability is possible by decreasing the variation (or spread) around the center. If there is less spread, more measurements are closer to target and fewer are out of specification



Please compare the two processes above : although both processes have the same specification limits and are centered on target, process A is more capable. This is because the process has less spread and measurements are closer to the center. This indicates a higher sigma level and lower DPMO

Outputs: Important causes of defects

- By use of FMEA and cause-and-effect diagrams discussed earlier in the chapter, we get to know the important causes for defects.

- The information is quantified through use of Severity rating, Occurrence Rating, Detection Rating and RPN : this then forms an input in the Improve phase of six sigma.

Outputs : Special and Common causes of variation

- Through use of run charts, control charts and study of process capability, we will identify special and common 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.
- In a six sigma project, we should target to eliminate Special cause of variation and minimize common cause of variation.

DPMO and Sigma Level

- As discussed earlier in the chapter, use of process capability study will help us in calculating the DPMO (Defective Parts per Million) and the sigma level of the process.

- This helps us in benchmarking our processes and quality levels with similar processes used by competitors and to identify potential for improvements.