PROJECT ON SIX SIGMA

BALA VENKATA VAMSIDHAR[1]

[1]Department of Mechanical Engineering, M.Tech, student, GITAM UNIVERSITY

ABSRACT: Six sigma is a measure of quality that strives for perfection. The six sigma process uses data and rigorous statically analysis to identify "defects" in a process or product, reduce variability, and achieve as close to zero defects as possible.

Using a universal measurement scale, six sigma defines and estimates the opportunities for error and calculates defects in the same way every time, thus offering a mean for measuring improvements. It is a Greek word "sigma" which is used in statics to indicate standard deviation.

INTRODUCTION

Six Sigma (**6σ**) is a set of techniques and tools for process improvement. It was introduced by engineer Bill Smith while working at Motorola in 1986. Jack Welch made it central to his business strategy at General Electric in 1995. It seeks to improve the quality of the output of a process by identifying and removing the causes of defects and minimizing variability in manufacturing and business processes. It uses a set of quality management methods, mainly empirical, statistical methods, and creates a special infrastructure of people within the organization who are experts in these methods. Each Six Sigma project carried out within an organization follows a defined sequence of steps and has specific value targets, for example: reduce process cycle time, reduce pollution, reduce costs, increase customer satisfaction, and increase profits.

History of Six Sigma

The roots of Six Sigma as a measurement standard can be traced back to Carl Friedrich Gauss (1777-1855) who introduced the concept of the normal curve. Six Sigma as a measurement standard in product variation can be traced back to the 1920's when Walter She what showed that three sigma from the mean is the point where a process requires correction.

Many measurement standards (Cpk, Zero Defects, etc.) later came on the scene but credit for coining the term "Six Sigma" goes to a Motorola engineer named Bill Smith. (Incidentally, "Six Sigma" is a federally registered trademark of Motorola).

DMAIC

The **DMAIC** project methodology has five phases:

- ***D****efine* the system, the voice of the customer and their requirements, and the project goals, specifically.
- ***M****easure* key aspects of the current process and collect relevant data; calculate the 'as-is' Process Capability.
- ***A****nalyze* the data to investigate and verify cause-and-effect relationships. Determine what the relationships are, and attempt to ensure that all factors have been considered. Seek out root cause of the defect under investigation.
- ***I****mprove* or optimize the current process based upon data analysis using techniques such as design of experiments, poka yoke or mistake proofing, and standard work to create a new, future state process. Set up pilot runs to establish process capability.
- ***C****ontrol* the future state process to ensure that any deviations from the target are corrected before they result in defects. Implement control systems such as statistical process control, production boards, visual workplaces, and continuously monitor the process. This process is repeated until the desired quality level is obtained.

Implementation roles

One key innovation of Six Sigma involves the absolute "professionalizing" of quality management functions. Prior to Six Sigma, quality management in practice was largely relegated to the production floor and to statisticians in a separate quality department. Formal Six Sigma programs adopt a kind of elite ranking terminology (similar to some martial arts systems, like judo) to define a hierarchy (and special career path) that includes all business functions and levels.

Six Sigma identifies several key roles for its successful implementation.

- Executive Leadership includes the CEO and other members of top management. They are responsible for setting up a vision for Six Sigma implementation. They also empower the other role holders with the freedom and resources to explore new ideas for breakthrough improvements by transcending departmental barriers and overcoming inherent resistance to change.

- Champions take responsibility for Six Sigma implementation across the organization in an integrated manner. The Executive Leadership draws them from upper management. Champions also act as mentors to Black Belts.

- Master Black Belts, identified by Champions, act as in-house coaches on Six Sigma. They devote 100% of their time to Six Sigma. They assist Champions and guide Black Belts and Green Belts. Apart from statistical tasks, they spend their time on ensuring consistent application of Six Sigma across various functions and departments.

- Black Belts operate under Master Black Belts to apply Six Sigma methodology to specific projects. They devote 100% of their valued time to Six Sigma. They primarily focus on Six Sigma project execution and special leadership with special tasks, whereas Champions and Master Black Belts focus on identifying projects/functions for Six Sigma.

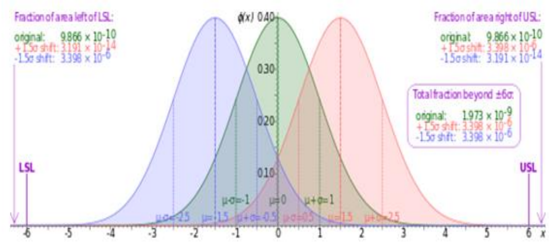
- Green Belts are the employees who take up Six Sigma implementation along with their other job responsibilities, operating under the guidance of Black Belts.

Etymology of "six sigma process"

The term "six sigma process" comes from the notion that if one has six standard deviations between the process mean and the nearest specification limit, as shown in the graph, practically no items will fail to meet specifications. This is based on the calculation method employed in process capability studies.

Capability studies measure the number of standard deviations between the process mean and the nearest specification limit in sigma units, represented by the Greek letter σ (sigma). As process standard deviation goes up, or the mean of the process moves away from the center of the tolerance, fewer standard deviations will fit between the mean and the nearest specification limit, decreasing the sigma number and increasing the likelihood of items outside specification. One should also note that calculation of Sigma levels for a process data is independent of the data being normally distributed. In one of the criticisms to Six Sigma, practitioners using this approach spend a lot of time transforming data from non-normal to normal using transformation techniques. It must be said that Sigma levels can be determined for process data that has evidence of non-normality.

NORMAL DISTRIBUTION CURVE



Graph of the normal distribution, which underlies the statistical assumptions of the Six Sigma model. In the centre at 0, the Greek letter μ (mu) marks the mean, with the horizontal axis showing distance from the mean, marked in standard deviations and given the letter σ (sigma). The greater the standard deviation, the greater is the spread of values encountered. For the green curve shown above, $\mu = 0$ and $\sigma = 1$. The upper and lower specification limits (marked USL and LSL) are at a distance of 6σ from the mean. Because of the properties of the normal distribution, values lying that far away from the mean are extremely unlikely: approximately 1 in a billion too low, and the same too high. Even if the mean were to move right or left by 1.5σ at some point in the future (1.5 sigma shift, coloured red and blue), there is still a good safety cushion. This is why Six Sigma aims to have processes where the mean is at least 6σ away from the nearest specification limit.

APPLICATIONS OF SIX SIGMA:

Six Sigma mostly finds application in large organizations. An important factor in the spread of Six Sigma was GE's 1998 announcement of $350 million in savings thanks to Six Sigma, a figure that later grew to more than $1 billion. According to industry consultants like Thomas Pyzdek and John Kullmann, companies with fewer than 500 employees are less suited to Six Sigma implementation or need to adapt the standard approach to make it work for them. Six Sigma however contains a large number of tools and techniques that work well in small to mid-size organizations. The fact that an organization is not big enough to be able to afford Black Belts does not diminish its abilities to make improvements using this set of tools and techniques. The infrastructure described as necessary to support Six Sigma is a result of the size of the organization rather than a requirement of Six Sigma itself.

Although the scope of Six Sigma differs depending on where it is implemented, it can successfully deliver its benefits to different applications.

Manufacturing:

After its first application at Motorola in the late 1980s, other internationally recognized firms currently recorded high number of savings after applying Six Sigma. Examples of these are Johnson and Johnson, with $600 million of reported savings, Texas Instruments, which saved over $500 million as well as Telefonica de Espana, which reported $30 million euros of revenue in the first 10 months. On top of this, other organizations like Sony and Boeing achieved large percentages in waste reduction.

Engineering and construction:

Although companies have considered common quality control and process improvement strategies, there's still a need for more reasonable and effective methods as all the desired standards and client satisfaction have not always been reached. There is still a need for an essential analysis that can control the factors affecting concrete cracks and slippage between concrete and steel. After conducting a case study on Tinjin Xianyi Construction Technology Co, Ltd., it was found that construction time and construction waste were reduced by 26.2% and 67% accordingly after adopting Six Sigma. Similarly, Six Sigma implementation was studied at one of the largest engineering and construction companies in the world: Bechtel Corporation, where after an initial investment of $30 million in a Six Sigma program that included identifying and preventing rework and defects, over $200 million were saved.

Finance:

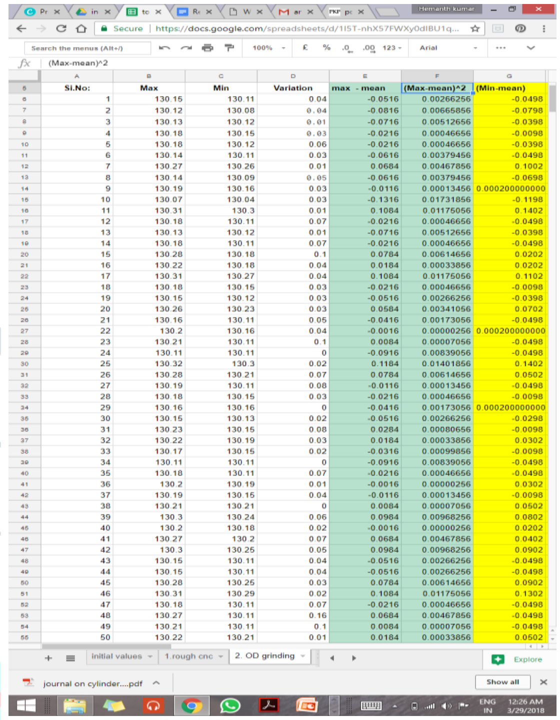
Six Sigma has played an important role by improving accuracy of allocation of cash to reduce bank charges, automatic payments, improving accuracy of reporting, reducing documentary credits defects, reducing check collection defects, and reducing variation in collector performance. Two of the financial institutions that have reported considerable improvements in their operations are Bank of America and American Express. By 2004 Bank of America increased customer satisfaction by 10.4% and decreased customer issues by 24% by applying Six Sigma tools in their streamline operations. Similarly, American Express successfully eliminated non-received renewal credit cards and improved their overall processes by applying Six Sigma principles. This strategy is also currently being applied by other financial institutions like GE Capital Corp., JP Morgan Chase, and Sun Trust Banks, with customer satisfaction being their main objective.

Supply chain:

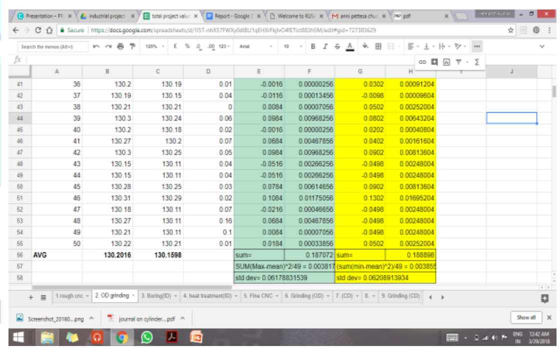
In this field, it is important to ensure that products are delivered to clients at the right time while preserving high-quality standards from the beginning to the end of the supply chain. By changing the schematic diagram for the supply chain, Six Sigma can ensure quality control on products (defect free) and guarantee delivery deadlines, which are the two major issues involved in the supply chain.

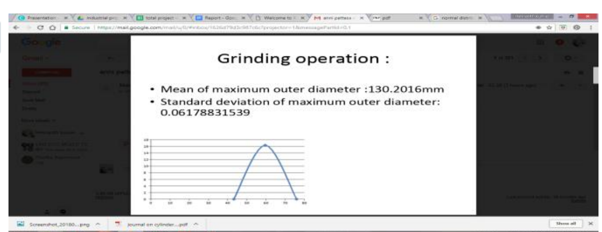
Healthcare:

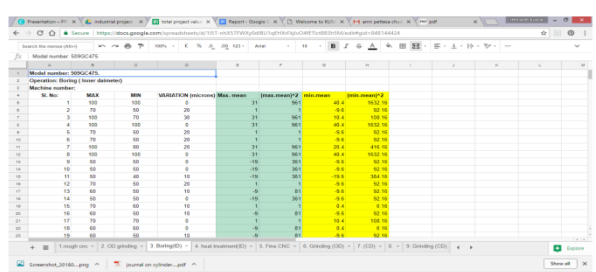
This is a sector that has been highly matched with this doctrine for many years because of the nature of zero tolerance for mistakes and potential for reducing medical errors involved in healthcare. The goal of Six Sigma in healthcare is broad and includes reducing the inventory of equipment that brings extra costs, altering the process of healthcare delivery in order to make more efficient and refining reimbursements. A study at the University of Texas MD Anderson Cancer Center, which recorded an increase in examinations with no additional machines of 45% and reduction in patience preparation time of 40 minutes; from 45 minutes to 5 minutes in multiple cases.

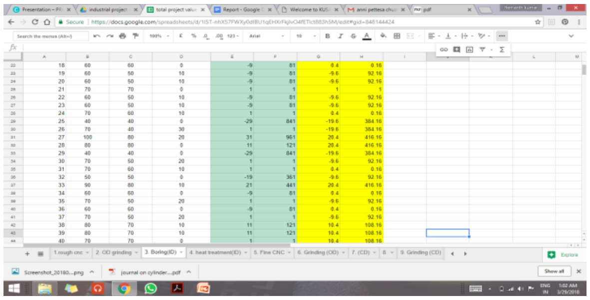


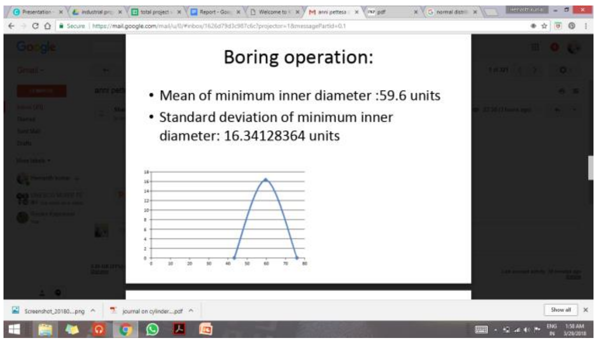
Si.No:	Max	Min	Variation	max - mean	(Max-mean)^2	(Min-mean)
1	130.15	130.11	0.04	-0.0516	0.00266256	-0.0498
2	130.12	130.08	0.04	-0.0816	0.00665856	-0.0798
3	130.13	130.12	0.01	-0.0716	0.00512656	-0.0398
4	130.18	130.15	0.03	-0.0216	0.00046656	-0.0098
5	130.18	130.12	0.06	-0.0216	0.00046656	-0.0398
6	130.14	130.11	0.03	-0.0616	0.00379456	-0.0498
7	130.27	130.26	0.01	0.0684	0.00467856	0.1002
8	130.14	130.09	0.05	-0.0616	0.00379456	-0.0698
9	130.19	130.16	0.03	-0.0116	0.00013456	0.000200000000
10	130.07	130.04	0.03	-0.1316	0.01731856	-0.1198
11	130.31	130.3	0.01	0.1084	0.01175056	0.1402
12	130.18	130.11	0.07	-0.0216	0.00046656	-0.0498
13	130.13	130.12	0.01	-0.0716	0.00512656	-0.0398
14	130.18	130.11	0.07	-0.0216	0.00046656	-0.0498
15	130.28	130.18	0.1	0.0784	0.00614656	0.0202
16	130.22	130.18	0.04	0.0184	0.00033856	0.0202
17	130.31	130.27	0.04	0.1084	0.01175056	0.1102
18	130.18	130.15	0.03	-0.0216	0.00046656	-0.0098
19	130.15	130.12	0.03	-0.0516	0.00266256	-0.0398
20	130.26	130.23	0.03	0.0584	0.00341056	0.0702
21	130.16	130.11	0.05	-0.0416	0.00173056	-0.0498
22	130.2	130.16	0.04	-0.0016	0.00000256	0.000200000000
23	130.21	130.11	0.1	0.0084	0.00007056	-0.0498
24	130.11	130.11	0	-0.0916	0.00839056	-0.0498
25	130.32	130.3	0.02	0.1184	0.01401856	0.1402
26	130.28	130.21	0.07	0.0784	0.00614656	0.0502
27	130.19	130.11	0.08	-0.0116	0.00013456	-0.0498
28	130.18	130.15	0.03	-0.0216	0.00046656	-0.0098
29	130.16	130.16	0	-0.0416	0.00173056	0.000200000000
30	130.15	130.13	0.02	-0.0516	0.00266256	-0.0298
31	130.23	130.15	0.08	0.0284	0.00080656	-0.0098
32	130.22	130.19	0.03	0.0184	0.00033856	0.0302
33	130.17	130.15	0.02	-0.0316	0.00099856	-0.0098
34	130.11	130.11	0	-0.0916	0.00839056	-0.0498
35	130.18	130.11	0.07	-0.0216	0.00046656	-0.0498
36	130.2	130.19	0.01	-0.0016	0.00000256	0.0302
37	130.19	130.15	0.04	-0.0116	0.00013456	-0.0098
38	130.21	130.21	0	0.0084	0.00007056	0.0502
39	130.3	130.24	0.06	0.0984	0.00968256	0.0802
40	130.2	130.18	0.02	-0.0016	0.00000256	0.0202
41	130.27	130.2	0.07	0.0684	0.00467856	0.0402
42	130.3	130.25	0.05	0.0984	0.00968256	0.0902
43	130.15	130.11	0.04	-0.0516	0.00266256	-0.0498
44	130.15	130.11	0.04	-0.0516	0.00266256	-0.0498
45	130.28	130.25	0.03	0.0784	0.00614656	0.0902
46	130.31	130.29	0.02	0.1084	0.01175056	0.1302
47	130.18	130.11	0.07	-0.0216	0.00046656	-0.0498
48	130.27	130.11	0.16	0.0684	0.00467856	-0.0498
49	130.21	130.11	0.1	0.0084	0.00007056	-0.0498
50	130.22	130.21	0.01	0.0184	0.00033856	0.0502

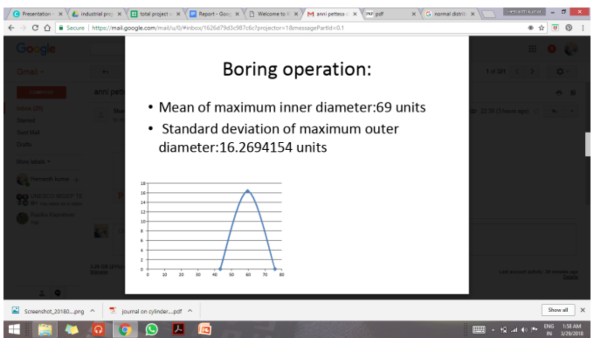












FISH BONE DIAGRAM:

We are going to discuss the fishbone diagram, which is one of the seven basic quality control tools.

The fishbone diagram is also known as the Ishikawa diagram, cause and effect diagram, fishikawa diagram, and herringbone diagram.

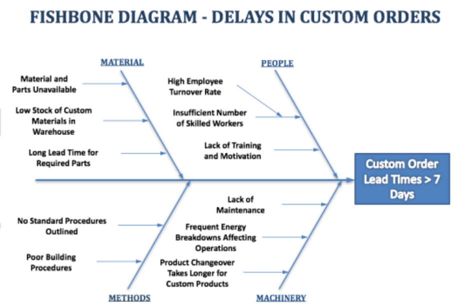
It got the name fishikawa because it was developed by Japanese professor Kaoru Ishikawa in 1960, a highly regard expert in quality management, and it looks like fish skeleton. For the same reason it is also called as fishbone diagram.

This tool helps you explore the causes that might be producing the problem. It is very important for you to know the real cause of the problem before you start thinking about any possible solution.

The fishbone diagram gives you a comprehensive list of possible causes to identify the root cause of the problem. The first advantage of this tool is that it provides you with a better understanding of the problem, and you can eliminate the root cause of the problem in one shot rather than solving a part of problem the first time, then again solve another part, and so on…

The fishbone diagram uses a brainstorming technique to collect the causes and come up with a kind of mind map which shows you all identified causes graphically. Sometimes it happens that the most obvious cause turns out to be minor and the cause thought to be a minor one was causing the issue. This diagram gives you an opportunity to think more thoroughly about the root cause of the problem, which leads to a robust resolution.

The fishbone diagram forces you to consider all possible causes of a problem instead of focusing on the most obvious one. Here causes are grouped into several categories to easily identify the correct source of the variation.



Categorization of Causes in a Fishbone Diagram

category of causes based on your requirements. For every industry there is a different A fishbone diagram can be used in any industry. You only need to customize the categorization of causes. Some generic categorizations for popular industries are given below.

In the manufacturing industry, you can categorize the factors (causes) by 6Ms:

- Machine
- Method
- Material
- Manpower
- Measurement (Inspection)
- Milieu (Mother Nature – Environment)
- Management
- Maintenance

The first six were populated by Toyota, and later on two more "Ms" were added to the list.

If you're in the marketing industry, you can categorize these factors by 7Ps:

- Product
- Price
- Place
- Promotion
- People
- Positioning
- Packaging

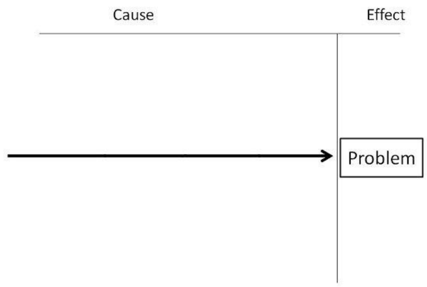
And if you're in the service industry, you can categorize these factors by 5Ss:

- Surroundings
- Suppliers
- Systems
- Skills
- Safety

A search on the internet can show you many more classifications; however, the above given classifications are more popular than the rest.

How to Draw a Fishbone Diagram

The following are the steps to draw a fishbone, or cause and effect, diagram.



Identify the Effect (Problem)

First of all write down the problem. Many times it happens that the identification of the main problem is not straightforward. In such cases, a short brainstorming session is helpful to point it out.

Draw a rectangle on the right side of a drawing sheet. Write the problem inside this box and draw a straight arrow towards the left side of the box wall from the left side of the paper. This drawing should look like the spine and head of a fish.

Identify and Categorize Causes

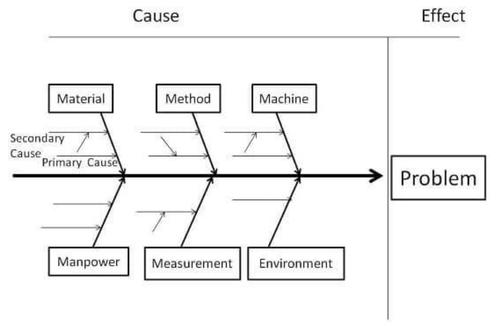
In this step you will identify all the main factors of the problem and categorize them; for example, Category-I, Category-II, etc. If you are having problem with categorization, use any of the generic headings given above.

Brainstorm Possible Causes

Now for each category, brainstorm the possible causes of the problem. You can also sub-categorize them if needed. While brainstorming, ask yourself questions like "Why does this happen?" Note the answer. Then again ask "Why does this happen?"

Your fishbone or Ishikawa diagram is complete, and you can see all possible causes of the problem

Now you can sit with your team members and investigate further to identify the root cause of the problem and discuss the solution. And once you decide on the solution to implement it and eliminate the problem from your project.



Important Points to be Noted While Developing a Fishbone Diagram:

There are some points you should keep in mind while developing a fishbone diagram, such as:

- There should be clarity on the problem for which you are going to draw the diagram.
- Team members should be experienced and involved with the problem.
- Discussion should be focused and moderated by the project manager.
- For each factor, think of all possible causes and add them to the bone.
- If any bone is becoming too bulky, try to split it into two or three branches.

Benefits of a Fishbone Diagram

There are many benefits of fishbone diagrams. Some of them are as follows:

- It is a visual tool which is very easy to understand and analyze.
- It helps you identify the root cause of the problem.
- It helps you finding bottlenecks in the process.
- It helps you identify ways to improve the process.
- It helps you when team members are fighting and blaming each other for any problem.
- It involves in-depth discussion of the problem which educates the whole team.
- It prioritizes further analysis and helps you take corrective action.

Limitations of a Fishbone Diagram:

The following are a few limitations and/or drawbacks of a fishbone diagram:

- A fishbone diagram does not single out the root cause of the problem. Graphically speaking, all causes look equally important.
- Sometimes effort is wasted in identifying causes which have little effect on the problem.
- A fishbone diagram is based on opinion rather than evidence. This process involves a democratic way of

selecting the cause, i.e. voting down the causes, which may not be an effective way of identifying causes.

- If the discussion is not controlled properly it may deviate from its objective.

The worthiness of a fishbone diagram is dependent on how you develop the diagram. If the participant are less experienced, less involved and not more knowledgeable, your diagram will be very neat and clean and you might not be able to identify the root cause of the problem.

Therefore to develop a sound fishbone or Ishikawa diagram, involve experienced and knowledgeable experts and ask as many "whys" as you can (up to five "whys" is more than enough).

PROCESS CAPABILITY CHART

In process improvement efforts, the **process capability index** or **process capability ratio** is a statistical measure of process capability: the ability of a process to produce output within specification limits.The concept of process capability only holds meaning for processes that are in a state of statistical control. Process capability indices measure how much "natural variation" a process experiences relative to its specification limits and allows different processes to be compared with respect to how well an organization controls them.

If the upper and lower specification limits of the process are USL and LSL, the target process mean is T, the estimated mean of the process is and the estimated variability of the process (expressed as a standard deviation).

Process capability indices are constructed to express more desirable capability with increasingly higher values. Values near or below zero indicate processes operating off target (far from T) or with high variation.

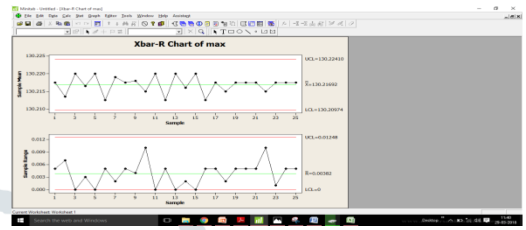
Fixing values for minimum "acceptable" process capability targets is a matter of personal opinion, and what consensus exists varies by industry, facility, and the process under consideration. For example, in the automotive industry, the Automotive Industry Action Group sets forth guidelines in the Production Part Approval Process, 4th edition for recommended C_{pk} minimum values for critical-to-quality process characteristics. However, these criteria are debatable and several processes may not be evaluated for capability just because they have not properly been assessed.

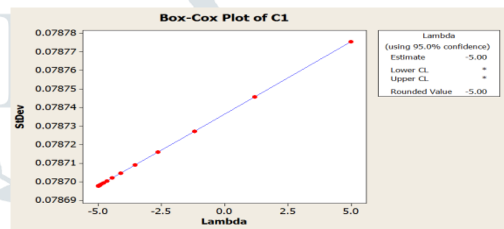
Since the process capability is a function of the specification, the Process Capability Index is only as good as the specification. For instance, if the specification came from an engineering guideline without considering the function and criticality of the part, a discussion around process capability is useless, and would have more benefits if focused on what are the real risks of having a part borderline out of specification

PROCESS CAPABILITY=USL-LSL/6σ

- *Where USL=upper specific limit*
- *LSL=lower specific limit*
- *σ=standard deviation.*

- *For OD, Process capability=130.31-130.07/6*0.06178831539=0.647371*
- *For ID, Process capability=100-40/6*16.2694154=0.614650.*
- *For process capability < 1 = more defects.*
- *For process capability = 1 = null defects*
- *For process capability > 1 = less defects*





CONCLUSION

- Using fishbone diagram we have concluded the process capability of outer diameter and inner diameter of the cylindrical liners.
- By using fishbone diagram the process analysis of six sigma has been increased.
- We conclude that by X and R charts there is more variations in R chart so there are more defects.

REFERENCES

BALA VENKATA VAMSIDHAR[1]

Arumugam, V., Antony, J. and Kumar, M. (2013) 'Linking learning and knowledge creation to project success in Six Sigma projects: an empirical investigation', International Journal of Production Economics, Vol. 141, No. 1, pp.388–402.

Black, K. and Revere, L. (2006) 'Six Sigma arises from the ashes of TQM with a twist',International Journal of Health Care Quality Assurance, Vol. 19, Nos. 2–3, pp.259–266.

Breja, S.K., Banwet, D.K. and Iyer, K.C. (2011) 'Quality strategy for transformation: a case study', The TQM Journal, Vol. 23, No. 1, pp.5–20.

Celano, G., Costa, A., Fichera, S. and Tringali, G. (2012) 'Linking Six Sigma to simulation: a new roadmap to improve the quality of patient care', International Journal of Health Care Quality Assurance, Vol. 25, No. 4, pp.254–273.

Chakraborty, A. and Tan, K.C. (2012) 'Case study analysis of Six Sigma implementation in service organisations', Business Process Management Journal, Vol. 18, No. 6, pp.992–1019.

Chakravorty, S.S. (2009) 'Six Sigma programs: an implementation model', International Journal of Production Economics, Vol. 119, No. 1, pp.1–16.

Desai, D.A., Antony, J. and Patel, M.B. (2012) 'An assessment of the critical success factors for Six Sigma implementation in Indian industries', International Journal of Productivity and Performance Management, Vol. 61, No. 4, pp.426–444.

Easton, G.S. and Rosenzweig, E.D. (2012) 'The role of experience in Six Sigma project success: An empirical analysis of improvement projects', Journal of Operations Management, Vol. 30, Nos. 7–8, pp.481–493.

Goh, T.N. and Xie, M. (2003) 'Statistical control of a Six Sigma process', Quality Engineering, Vol. 15, No. 4, pp.587–592.

Heavey, C. and Murphy, E. (2012) 'Integrating the balanced scorecard with Six Sigma', The TQM Journal, Vol. 24, No. 2, pp.108–122.