Everything You Wanted to Know about Six Sigma
But Were Afraid to Ask

A supplement to IIE's Six Sigma Green Belt Course

Introduction

Six sigma was developed at Motorola in the 1980's as a way to help that organization improve its quality. Michael Harry and Bill Smith are generally considered to be the originators of the concept. It quickly spread to other organizations, most notably GE.

Six sigma is first and primarily a customer focused strategy for process improvement. Although it is supported by many tools and techniques, the main reason that an organization should use six sigma is to better serve its customers. Six sigma for process improvement is implemented using a structured approach to complete projects. Each project has two major objectives:

1. The first objective is to reduce variation.
2. The second objective is to come closer and closer to the meeting the voice of the customer.

While we stress that we use six sigma for the benefit of the customer, we recognize that developing and maintaining the customer focus is not easy. First, everyone in the organization has many customers. Some of these are internal and some are external. Second, many of these customers have different requirements, some of which are diametrically opposed to each other. Third, many of the customer requirements are not quantified, but rather qualitative in nature. Fourth, the customer requirements are, even when they are quantified, a moving target. What is acceptable today may and probably will not be acceptable tomorrow due to competitive factors in the market place. A good way to think about the six sigma process is as one that **continually works to come close and closer to giving the customer exactly what they want every time.** When we do that we will keep our customers and in most cases, attract new customers.

There are many ways to approach the six sigma improvement strategy. The way we have adopted at IIE includes the following major provisions:

1. Six sigma involves the use of statistical methods. However, we believe that statistics are the tools that help us understand what the process is telling us regarding the variation inherent in the process characteristics that are measured. When we fully understand the variation we can manage the processes instead of letting the process manage us.

2. Six sigma, to cite a cliché, requires a cultural change in the organization. The specific culture element that successful six sigma organizations change is part of the economic culture. It involves the law of diminishing returns. When this law is applied to improvement efforts, the application is something like, "we will continue to invest in the

improvement efforts so long as those efforts show a reasonable return on investment (or meet a payback criteria or have an appropriate cost benefit analysis.) However, eventually we will hit that point where it does not make sense financially to make further investments." Once that point of diminishing returns is reached these organizations no longer are willing to invest in making the indicated improvements. Those organizations that have fully embraced the six sigma methodology believe that they must continue to invest in making improvements, with the proviso of course that they have the ability to make those investments. They "know" that if they don't, their competitors will, and by so doing will grow their business at our expense. It is generally acknowledged that it costs much more to add a new customer than it does to retain an existing one.

3. For six sigma to work long term it must literally be driven from the top levels of the organization. And that pressure must be continually applied. As soon as the pressure disappears then the efforts will diminish. This is, of course, not unique with six sigma. For any management initiative to succeed it must be led by senior management.

4. Six sigma must always question existing processes and methods. The all important "why" question must be asked and asked. If the only answer that can be determined from that question is "because we always have" then we will have identified opportunities for improvement. With those opportunities, though, will typically be some defensive behavior on the part of the individuals performing the work.

5. Another cliché that has been overused but that is nonetheless true is that the journey is more important than the destination. Too many organizations think that once they reach the six sigma quality level of so many defects per million opportunities they have completed their task. In reality, we believe that the journey, the process of improvement, is what is important. Once we have reached the so called six sigma level we then should strive for the next step, the seven sigma, the eight sigma, and ever higher sigma levels. Once again the belief is that if we don't do it someone else will. And in the process steal our customers.

Although Six Sigma is a powerful methodology there are several conditions that must be in place for six sigma to be effective. First of all, an organization must have processes in place. This sounds elementary, but there are many business operations that take place without a defined process. This results in some tasks being done differently depending on whom is doing the task. Without the documentation it is also quite possible for the same individual to perform the same task different ways each time the task must be performed. We can define a process as a set of conditions or set of causes which work together to produce a given result. It typically includes suppliers, inputs, processes that add value, outputs, and customers. A process is any work that meets the following four criteria:

- It is recurrent
- It affects some aspect of organizational capability
- It can be accomplished differently so as to make contribution to the customer and/or profit
- It involves co-ordination

Once a defined process is in place then the process must be brought into a state of statistical control. In general terms, when we say that a process is in control we are implying that it is predictable. Being predictable is good in that we know what will happen next. Being predictable does not mean the process is doing what it should be doing; rather it means it is always doing the same thing. Sometimes a process can be predictably "bad." Being predictable lets us manage our process.

Once an organization has defined processes and once these processes are in a state of statistical control, then, and only then, should we begin efforts to improve the processes. We may have to make changes to processes to bring them into control. But interventions designed to improve processes should wait until the processes are predictable or stable as we sometimes say. Then, when a change is made, the impact of that change on process performance can be evaluated. Hopefully we see a change in the process when we make a change. If we are not in control, it means we are not predictable and we cannot say with any degree of certainty that the change we made caused the change in the processes' performance.

Six Sigma Structured Approach

The six sigma improvement methodology uses a structured approach that uses an acronym that either appears as DMAIC or DMAIIC. In the first instance this stands for define, measure, analyze, improve, and control. We have modified this at IIE to define, measure, analyze, improve, implement, and control. It is our belief, based upon years of experience, that by including the implement step we will make sure that the six sigma belt understands that it is his or her responsibility to actually implement the recommended improvement and not hand it off.

Define is the first step. It is usually the hardest. The define step requires us to define all of the following:

- The process
- The problem
- The desired solution
- The business case
- The customers and their requirements
- The suppliers and their inputs
- The items to measure
- The ways to measure

All too often the first pass on define results in defining or describing symptoms of the problem. Many tools are typically available to be used at this step of the DMAIIC process. They include check sheets[1], SIPOC analysis, Pareto charts, long term process capability measures, and measurement systems analysis including gage R&R and operational definitions. Control charts are often used at this step as part of the process analysis to help direct the investigation to the root cause(s) of the problem. Team skills come into play since six sigma improvement projects are typically completed using the team approach.

After define has been completed then the measuring process commences. Data is collected. Sometimes this requires that the method for collecting the data be developed. Many of the same tools are used in measure as in define, including check sheets, Pareto analysis, process capability evaluation, cost of quality, and once again measurement systems analysis.

When the data has been collected the process moves from measure to analyze. Analyze attempts to make sense out of the measures collected. Primary tools at the analyze step involve the use of descriptive statistics to describe the current state as well as predict what might happen.

At the improve step possible process improvements are developed and evaluated in a logical and systematic fashion. A key aspect of six sigma is the development of the cost justification at this step of the DMAIIC process. Although six sigma and the culture change mentioned earlier dictate that organizations should always strive to improve, no organization has unlimited resources to invest in the improvement activities. The recommended improvements are submitted to the senior management steering committee that is leading the six sigma effort and this team uses the cost justifications to help prioritize. Tools used during the improve step include both idea generation techniques such as brain storming as well as modeling techniques like regression and correlation, simulation, and design of experiments. Obviously financial analysis tools are used at this step.

The next step in the IIE DMAIIC process is implement. This involves developing a project plan for making sure that the approved project is incorporated into operations. Without the implement step as a formalized part of the process projects are often handed off and the recipients perform the implementation when they get around to it. Typical project management tools are used at this step of the six sigma structured approach.

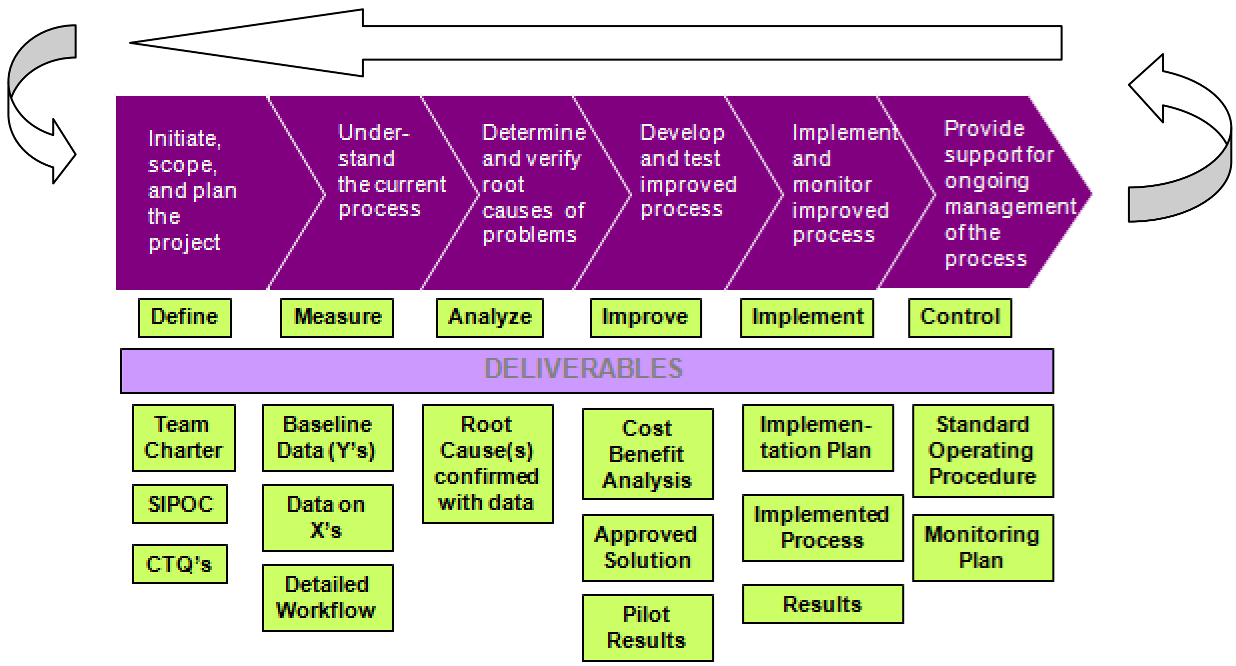
The last step in the DMAIIC process is control. When we use control in this context we have two sub meanings: standardize and validate. We standardize by making sure that the new method or new process is used as it should be and that all stakeholders who are supposed to use the new improved method actually use it. Validate involves verifying that the benefits ascribed to the improvement project, including the financial benefit are real. Many six sigma projects work like this: the improved process reduces the number of errors made; which means less time and resources are required to fix those errors; which frees up more resources to produce more

[1] Many of these tools will all be described later in this document.

error free product. An assumption is often made that all of the additional production can be "sold." This is not always the case. The control step must find evidence that either sales are up or some other resources have been reduced to accommodate the better quality processes now in place. Auditing skills as well as process capability and statistical process control tools are often used at this step of the process.

Although we have gone through DMAIIC we are not done yet. Six sigma is a continuous process so once we get to and through control, we do it all again.

The diagram below shows the DMAIIC process and typical deliverables.



Six Sigma Implementation

Six sigma to be successful must be implemented from the top down. Of course we can say that for any initiative in any organization. This implementation involves management not only supporting the six sigma effort but also participating. Nothing sends a signal like what managers do as opposed to what they say. Everybody looks to management and reads those signals. Once management is committed and involved it must share with everyone in the organization the direction that is being taken. Then it is essential that appropriate projects be selected. It is a tremendous waste to spend time and effort improving processes that provide products and services that will no longer be provided by the organization. Senior management should know the strategic direction of the organization and is in the position to keep this from happening.

It should go without saying that resources must be provided. Naturally decisions should be made based upon data, not "feel."

Six Sigma Structure

As six sigma has evolved a fairly loose structure revolving around some martial arts titles have evolved. The direction and overall responsibility for six sigma resides with what is usually called the *steering committee.* These are senior managers who are knowledgeable of six sigma. The responsibility of the steering committee includes the aforementioned project identification. The steering committee in effect guides the entire effort and makes sure that resources are available.

A key job of the steering committee is to establish implementation strategy and policies. *Champions* are logically members of the steering committee. The champion is in effect the project sponsor and serves as the liaison between the improvement team and the steering committee. The champion works with the team but is not an official member of the team. Often the champion has to motivate the team, open doors, prevent scope creep, and keep the projects on schedule.

The *white belt* or *yellow belt* is the introductory level. It is often referred to as the executive overview. This belt has a very basic understanding of variation and the six sigma process.

Green belt is the first true level of practitioner. Green belts understand problem solving, data collection and analysis, data interpretation, process improvement concepts, and cost analysis. In an ideal six sigma implementation all members of an organization would be at least green belts.

The *black belt* has been trained in all of the key concepts and tools of six sigma. It is a comprehensive training program. This permits the black belt to teach, coach, transfer knowledge, identify opportunities, and influence the use of six sigma methods. Black belt training is somewhat unique in that it requires a project to be completed. The project must demonstrate the correct application of appropriate tools while at the same time achieving a tangible benefit for either the host organization or one of its customers. Many black belt training programs last three weeks, with each week of training being about one month apart. A typical curriculum for six sigma black is shown on the next page.

To earn a black belt the participant must satisfactorily complete the project as well as pass a 5 hour examination given at the conclusion of the training.

Week 1	**Week 2**	**Week 3**
Project Chartering	Progress Report	Progress Report
Descriptive Statistics	Sampling	Goodness of Fit Testing
Probability	Statistical Process Control	Project Management
Inferential Statistics	Short Run SPC	Team Processes
Reliability	Design of Experiments	FMEA
Regression and Correlation	Simulation	Cost of Quality
Computer Applications		Exam

Near the top of the hierarchy is the *master black belt.* The Six Sigma master black belt title is the highest level of Six Sigma designation that you can attain. To earn this designation at IIE participants will be evaluated on their performance as it relates to knowledge and proficiency in Six Sigma, teaching Six Sigma, and coaching green and black belts. In order to be recognized as a master black belt, the candidate must demonstrate the following core competencies:

Advanced statistics – The candidate will be required to take an exam to evaluate your proficiency in statistical applications.

Coaching – The candidate must demonstrate an ability to encourage black belt and green belt candidates and practitioners. Coaching and mentoring of ongoing projects is essential to this competency. An IIE-approved representative will attend at least two coaching sessions to observe your skills with Six Sigma project teams.

MBB projects - Candidates are required to have at least three approved projects demonstrating proficiency in applying the strategy, methods, and tools generally associated with Six Sigma.

Six Sigma philosophy – Again, the candidate must have a firm understanding of Six Sigma prior to enrollment and must have completed a recognized green belt and black belt training program. Course certificates must be submitted to validate this competency.

Training – Candidates must demonstrate the ability to teach Six Sigma topics. An IIE-approved representative will observe your training skills for at least one full day.

Each candidate is evaluated individually based on his or her qualifications as subjectively judged by an accepted judging panel. Candidates will be given an examination as part of their evaluation for Six Sigma master black belt. There are no guarantees that a candidate, simply by enrolling, will earn the master black belt designation.

The last designation is the *master black belt trainer.* About all that can be said about this position is that the master black belt trainer trains master black belts, black belts, green belts, and white belts.

Projects

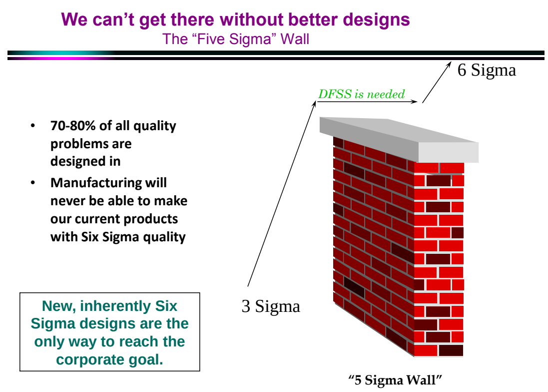
By now it should be obvious that six sigma, as a continuous improvement strategy, uses projects extensively to accomplish its improvement goals. Successful projects have many characteristics, including the following:

- Connected to business priorities. All six sigma projects must develop a business case prior to the initiation of the project and must demonstrate that the project has met its financial goals.
- Linked to strategic operating plans. If the projects don't align with business strategy the obvious question is, "why do the project?"
- The typical six sigma project should be completed in three to six months. This is short enough to show a return on the investment and short enough for the project to be completed before other work starts to interfere.
- Successful six sigma projects have quantitative measures of success. Objectives are set very specifically, for example, to reduce the cost of poor quality by a given percent, reduce the reject rate by a specified amount, or meet a financial metric such as payback. If there is no quantitative measure it is virtually impossible to determine if the project has been successful.

Projects are typically led by black belts and include all stakeholders. All projects must have a champion. The projects are chartered and begin with a problem statement which includes the statement of quantifiable objectives. Naturally the projects must address a customer need in some fashion.

Design for Six Sigma

A systematic methodology, with tools, training and measurements which enable us to design products/processes/services that meet customer expectations and can be produced at the 6σ (or higher) level.

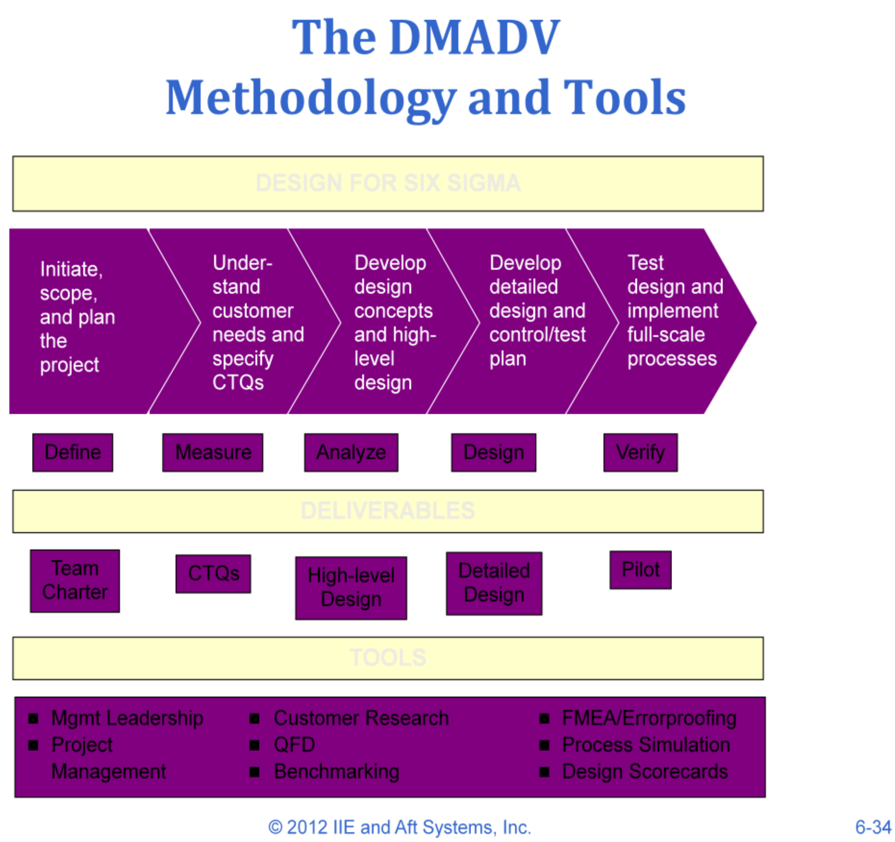


Design for Six Sigma (**DFSS**) is a separate and emerging business-process management methodology related to traditional process six sigma. While the tools and order used in Six Sigma require a process to be in place and functioning, DFSS has the objective of determining the needs of customers and the business, and driving those needs into the product solution so created. DFSS is relevant to the complex system/product synthesis phase, especially in the context of unprecedented system development. It is process *generation* in contrast with process *improvement*.

DFSS uses a different acronym. **DMADV**, **D**efine – **M**easure – **A**nalyze – **D**esign – **V**erify, is sometimes synonymously referred to as DFSS. The traditional DMAIC (**D**efine – **M**easure – **A**nalyze – **I**mprove – **C**ontrol) Six Sigma process, as it is usually practiced, which is focused on evolutionary and continuous improvement manufacturing or service process development, usually occurs after initial system or product design and development have been largely completed. DMAIC Six Sigma as practiced is usually consumed with solving existing manufacturing or service process problems and removal of the defects and variation associated with defects. On the other hand, DFSS (or DMADV) strives to generate a new process where none existed, or where an existing process is deemed to be inadequate and in need of replacement. DFSS aims to create a process with the end in mind of optimally building the efficiencies of Six Sigma methodology into the process *before* implementation; traditional Six Sigma seeks for continuous improvement *after* a process already exists.

DFSS seeks to avoid manufacturing/service process problems by using advanced Voice of the Customer techniques and proper systems engineering techniques to avoid process problems at the outset (i.e., fire prevention). When combined, these methods obtain the proper needs of the customer, and derive engineering system parameter requirements that increase product and service effectiveness in the eyes of the customer. This yields products and services that provide greater customer satisfaction and increased market share.

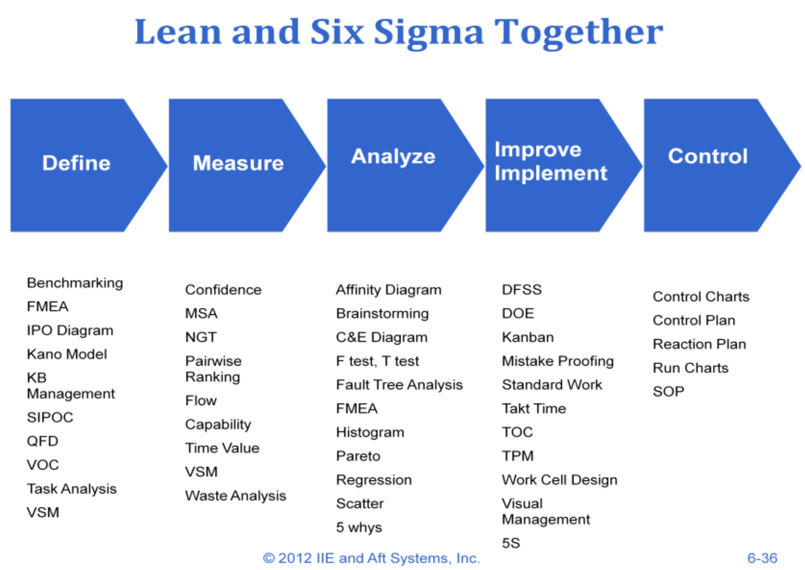
Some of the tools associated with DFSS and the DMADV methodology are shown in the figure below. The key is of course the customer focus.



Lean

Another widely used improvement strategy is lean. It is based upon the Toyota Production System. Simply described lean identifies the value stream within the organization and works to reduce the waste within the value stream. Lean has developed a set of tools including value stream mapping, 5S, standard work, pull systems, and single minute exchange of dies. Lean stresses minimizing inventory and reducing cycle time.

A few years ago Michael George thought it would be worthwhile to take the best of both lean and six sigma and developed what is known as lean six sigma. This is put into the DMAIIC framework and uses a wide array of tools. The next diagram shows lean and six sigma together.



Summary

To summarize the basics of six sigma there are really just three key points to remember:

1. Always remember that what is done in six sigma is done for the benefit of the customer.
2. Decisions should be made based on what the data shows.
3. The DMAIIC process is the framework for guiding the improvement process.

Root Cause Analysis

All of the disciplines within our organizations routinely seek to solve their problems, to resolve the day-to-day obstacles to their goals, as well as the bigger, general problems that develop to threaten the success of their operations. All of us who are a part of an organization are problem solvers . . . and root cause analysts, although many of us may prefer to think of our problem solving process as something less fancy than "root cause analysis". But, as we come to our problems in an effort to control and prevent interruptions, obstacles, errors, and counter-quality occurrences, we none-the-less are all looking for the same things: root causes of problems that when removed prevent the problem. So, whether our work is Quality, Engineering, Safety, Production, Maintenance, or just about any other function in the organization, we should become comfortable with the concept of root cause analysis, or whatever we want to call the task of finding the root causes and best prevention solutions to our operations problems.

First let's clarify what it is we are talking about when we say "prevention solutions", or rather what we are not talking about. Fixing things, cleaning up, removing, reworking, redesigning, modifying, and fortifying, are not prevention and control steps. They instead are correction steps. These actions may or may not be a result of prevention actions, but they in themselves are not prevention steps. Prevention has to do with WHY the design was inadequate, WHY the machine needs repair, WHY cleanup is necessary. This is not to say that these correction-step responses are not important to the operation. Certainly we want to discover immediately when things need early repair. Root cause analysis should uncover such opportunities to remedy, but clearly, as our primary goal for analysis, we want to design out of our operation the need for avoidable repair, rework, clean up, and expensive redesign. We are trying to find something that someone can do to keep the problem from ever happening again. Obviously the act of cleaning up the mess every time the problem occurs is not prevention. We must instead design *prevention* and *control* into how we do things. That is what meaningful root cause analysis is all about.

Before we can prevent anything within our organization, we must have four things:

1. *We must have a way to identify, record, and compare the causes producing the problem that we seek to correct and prevent.*

> Most of us, if we have experience at our jobs, will be able to spot something immediately that we can do that we think might solve the problem. However, in most operations we will find that if the problem solving is done only through the eyes of experience, the resulting solutions tend to be one-dimensional. That is, a maintenance man sees something he can fix to get the machine up and running again. The Engineer sees as a solution to the same problem a way to change the machine design to avoid the problem. The Production supervisor sees a way to change the procedure to avoid the problem. The Operations Manager may see an opportunity to farm the job out to a vendor as the best solution to that same problem. While all of these responses may be valid, the goal of meaningful root cause analysis is to accurately identify *all* of the causes, and to record them in a way that provides decision support for the organization. For this reason the root cause analysis methodology must not allow the analyst's personal preference, agendas, and bias to control the investigation. We want our decision-makers to have visibility of all of the available options, as well as a means to validate, compare and evaluate them before allocating resources of the organization. This is an important difference from other root cause analysis systems that makes the REASON concept so successful in producing tangible improvements in operations. REASON does not allow personal bias or agendas to color, distort, or misguide.

2. *We must have a clear understanding of the nature of the systems formed by those identified causes.*

We will want to know if the problem is a final result of many actions and inactions, decisions and omissions that are a part of how we are doing things; or is the problem the first result of someone coming in contact with an existing condition that waits quietly to cause problems. Our root cause analysis method should show us the type of system with which we are dealing. Clearly, if our analysis method drives the analysis process to identify only one root cause, or requires the analyst to select personally from a prepared list of causes only one part of the causal system as being the most significant, we at that point loose visibility of the whole system. At that same time, the analysis becomes highly prone to error. It is for this reason that meaningful root cause analysis must first focus upon the whole causal system. Appropriate prevention response cannot be designed reliably without that visibility. The REASON method provides a clear understanding of the nature of the internal system that produced the problem.

3. *We must know and understand the principles to which those causal systems adhere*.

Once we know and understand the principles behind organizational phenomena, the mystery surrounding causes is replaced with fundamental, practical systems knowledge. That is, principles can be applied in order to design and assure continuing control of operations. The first premise of engineering is that when principles are properly applied the result *is predictable* success; and when principles are not properly applied, the result is *predictable* system failure. With the essential visibility of the whole causal system, and the understanding of functioning principles, root cause analysis provides practical capabilities to design quality into our operations. This allows us to isolate and remove the sources of counter-quality. The REASON method teaches and keys to these principles of control.

4. *And . . . within our organization, we must have internal control of some part of the system.*

Part of the root cause analysis process is identifying the points in the causal process where internal control exists. Again, the analysis methodology must identify the complete causal system and all points of control, if the organization is to have true administrative control. If our root cause method allows the analyst to use personal bias *to* identify only what he considers to be the one, most significant root cause, he in effect is being allowed to make the administrator's decision . . . based upon assumptions.

> Root cause analysis should therefore provide a means to depict and logically validate the cause and effect relationships in the entire causal system, so that the person with the responsibility for making the decision has a means of validating the data upon which his decision is to be based. The administrator's broad knowledge of the organization's budget, planning, goals and limitations, coupled with the capability to personally validate causal data for himself, better assures sound decision making and improved operations control results. Because we control what happens in our organizations with policies, procedures, and practices, a successful root cause analysis must pinpoint prevention opportunities for policy/procedure/practices improvement, as well as identify those necessary fixes and clean-ups that are more obvious and immediate. The REASON method orders and depicts the data in a format that provides a means to check for accuracy and completeness at each step.

In summary, root cause analysis should be the systematic process of gathering and ordering all relevant data about counter-quality within an organization; then identifying the internal causes that have generated or allowed the problem; then analyzing for decision-makers the comparative benefits and cost-effectiveness of all available prevention options. To accomplish this, the analysis methodology must provide visibility of all causes, an understanding of the nature of the causal systems they form, a way to measure and compare the causal systems, an understanding of the principles that govern those causal systems, and a visibility of all internal opportunities for the organization to control the systems.

The story is told that before an important battle a king sent his horse with a groomsman to the blacksmith for shoeing. But the blacksmith had used all the nails shoeing the knight's horses for battle and was one short. The groomsman tells the blacksmith to do as good a job as he can. But the blacksmith warns him that the missing nail may allow the shoe to come off. The king rides into battle not knowing of the missing horseshoe nail. In the midst of the battle he rides toward the enemy. As he approaches them the horseshoe comes off the horse's hoof causing it to stumble and the king falls to the ground. The enemy is quickly onto him and kills him. The king's troops see the death, give up the fight and retreat. The enemy surges onto the city and captures the kingdom. The kingdom is lost because of a missing horseshoe nail.

The cause tree explains step-by-step how the events leading to the king's death unfolded. Notice that two separate event 'branches' had to occur together for the sequence to continue to the fateful end. If any of the causes could have been prevented then the kingdom would have been safe.

The five rules of causation are designed to improve the RCA process by creating minimum standards for where an investigation and the results should be documented. The rules are created in response to the very real biases we all bring to the investigation process.

- **Rule 1 - Causal Statements must clearly show the "cause and effect" relationship.**

  This is the simplest of the rules. When describing why an event has occurred, you should show the link between your root cause and the bad outcome, and each link should be clear to the RCA Team and others. Focus on showing the link from your root cause to the undesirable patient outcome you are investigating. Even a statement like **"resident was fatigued"** is deficient without your description of **how and why this led to a slip or mistake**. The bottom line: the reader needs to understand your logic in linking your causes to the outcome.

- **Rule 2 - Negative descriptors (e.g., poorly, inadequate) are not used in causal statements.**

  As humans, we try to make each job we have as easy as possible. Unfortunately, this human tendency works it way into the documentation process. We may shorten our findings by saying **"maintenance manual was poorly written"** when we really have a much more detailed explanation in our mind. **To force clear cause and effect descriptions (and avoid inflammatory statements), we recommend against the use of any negative descriptor that is merely the placeholder for a more accurate, clear description**. Even words like "carelessness" and "complacency" are bad choices because they are broad, negative judgments that do little to describe the actual conditions or behaviors that led to the mishap.

- **Rule 3 - Each human error must have a preceding cause.**

  Most of our mishaps involve at least one human error. Unfortunately, the discovery that a human has erred does little to aid the prevention process. You must investigate to determine WHY the human error occurred. It can be a system-induced error (e.g., step not included in medical procedure) or an at-risk behavior (doing task by memory, instead of a checklist). **For every human error in your causal chain, you must have a corresponding cause.** It is the cause of the error, not the error itself, which leads us to productive prevention strategies.

- **Rule 4 - Each procedural deviation must have a preceding cause.**

  Procedural violations are like errors in that they are not directly manageable. Instead, it is the cause of the procedural violation that we can manage. If a clinician is violating a procedure because it is the local norm, we will have to address the incentives that created the norm. If a technician is missing steps in a procedure because he is not aware of the formal checklist, work on education.

- **Rule 5 - Failure to act is only causal when there was a pre-existing duty to act.**

  We can all find ways in which our investigated mishap would not have occurred - but this is not the purpose of causal investigation. Instead, we need to find out why this mishap occurred in our system as it is designed today. A doctor's failure to prescribe a medication can only be causal if he was required to prescribe the medication in the first place. The duty to perform may arise from standards and guidelines for practice; or other duties to provide patient care.

Root Cause Analysis Tools

Flow Charts

Flow charts are easy-to-understand diagrams showing how steps in a process fit together. This makes them useful tools for communicating how processes work, and for clearly documenting how a particular job is done. Furthermore, the act of mapping a process out in flow chart format helps you clarify your understanding of the process, and helps you think about where the process can be improved.

A flow chart can therefore be used to:

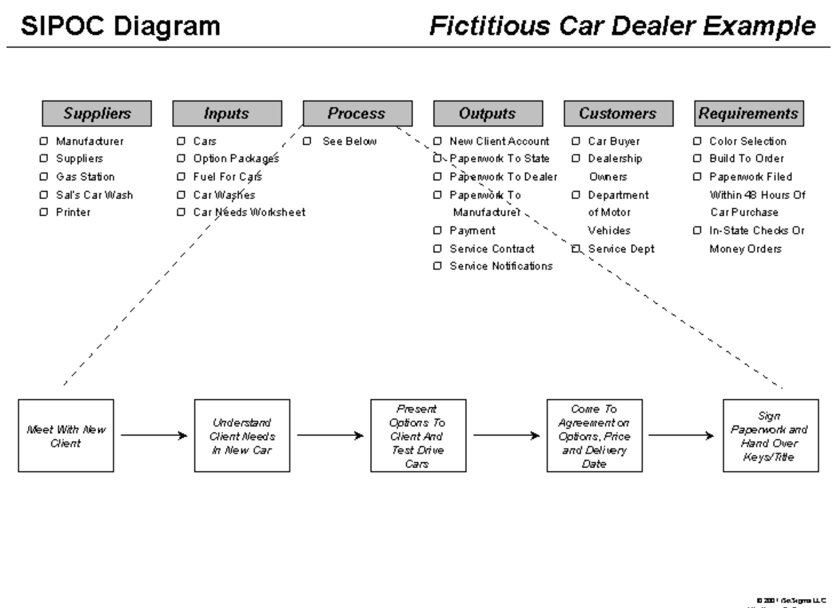
- Define and analyze processes.
- Build a step-by-step picture of the process for analysis, discussion, or communication.
- Define, standardize or find areas for improvement in a process

Also, by conveying the information or processes in a step-by-step flow, you can then concentrate more intently on each individual step, without feeling overwhelmed by the bigger picture.

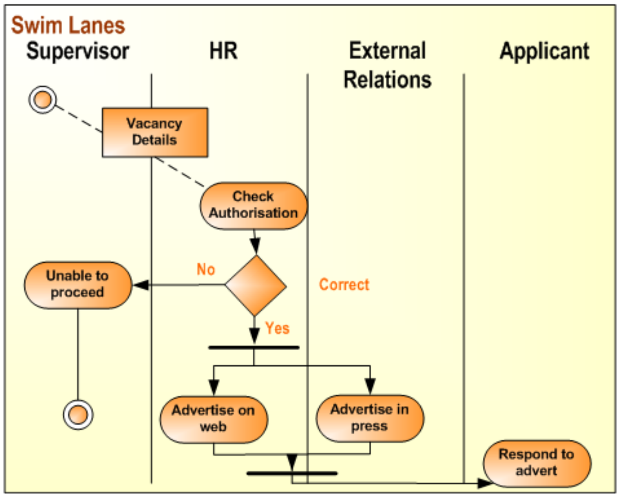
Besides the standard flow chart that most individuals are familiar with there are some specialized ones that are useful in six sigma root cause analysis.

Before beginning a process improvement project, you must first identify all the relevant elements. You use a *SIPOC Diagram* to help define these. It is typically used at the Measure phase of the Six Sigma DMAIIC (Define, Measure, Analyze, Improve, Implement and Control) process. A SIPOC diagram helps to identify the process outputs and the customers of those outputs so that the voice of the customer can be captured. The SIPOC diagram includes a high-level map of the process that "maps out" its basic steps. Through the process, the suppliers (S) provide input (I) to the process. The process (P) your team is improving adds value, resulting in output (O) that meets or exceeds the customer (C) expectations. These can be better defined as:

- Suppliers: Significant internal/external suppliers to the process.
- Inputs: Significant inputs to the process. This would include things such as materials, forms, information, staff, etc.
- Process: One block representing the entire process.
- Outputs: Significant outputs to internal/external customers. This would be anything the business unit distributes. Frequency/timing is listed along with the output. Examples of outputs would be reports, ratings, products, documents, etc.
- Customers: Significant internal/external customers to the process. This would include anyone who receives outputs. It is important to note that the customer must get the output directly from the business unit and does not necessarily have to be a user of the output. If the output is received from a third party, they are not customer s. Examples of customers could be managers, CEOs, boards of directors or other departments.



A *Swim Lane Diagram* is a type of Flowchart, and it can be used to display the same type of information. What makes a Swim Lane Diagram unique is that the Flowchart objects are kept in lanes (that is, columns or rows), grouping them together. These lanes help visualize stages, employees, departments, or any other set of separated categories. A basic flow diagram can be enhanced by the use of 'Swim Lanes' to indicate who has responsibility for carrying out a particular action. The diagram below shows the start of a process map for recruiting staff within an institution. At the simplest level a flow diagram can give you a feel for how complex a process is merely by the number of steps involved. The swim lanes add an extra dimension as they indicate where data is flowing backwards and forwards between departments.



This diagram shows only the first few steps in a process but it is evident even from this that there are a lot of steps and a lot of movement back and forth.

Check Sheet

A *check sheet* is a structured, prepared form for collecting and analyzing data. This is a generic tool that can be adapted for a wide variety of purposes.

When to Use a Check Sheet

- When data can be observed and collected repeatedly by the same person or at the same location.
- When collecting data on the frequency or patterns of events, problems, defects, defect location, defect causes, etc.
- When collecting data from a production process.

Check Sheet Procedure

1. Decide what event or problem will be observed. Develop operational definitions.
2. Decide when data will be collected and for how long.
3. Design the form. Set it up so that data can be recorded simply by making check marks or Xs or similar symbols and so that data do not have to be recopied for analysis.
4. Label all spaces on the form.
5. Test the check sheet for a short trial period to be sure it collects the appropriate data and is easy to use.
6. Each time the targeted event or problem occurs, record data on the check sheet.

Check Sheet Example

The figure below shows a check sheet used to collect data on telephone interruptions. The tick marks were added as data was collected over several weeks.

Telephone Interruptions

Reason	Day					
	Mon	Tues	Wed	Thurs	Fri	Total
Wrong number	卌	||	|	卌	卌||	20
Info request	||	||	||	||	||	10
Boss	卌	||	卌||	|	||||	19
Total	12	6	10	8	13	49

Excerpted from Nancy R. Tague's The Quality Toolbox, Second Edition, ASQ Quality Press, 2004, pages 141–142.

<u>Pareto Chart</u>

A Pareto chart is a bar graph. The lengths of the bars represent frequency or cost (time or money), and are arranged with longest bars on the left and the shortest to the right. In this way the chart visually depicts which situations are more significant.

When to Use a Pareto Chart

- When analyzing data about the frequency of problems or causes in a process.
- When there are many problems or causes and you want to focus on the most significant.
- When analyzing broad causes by looking at their specific components.
- When communicating with others about your data.

Pareto Chart Procedure

1. Decide what categories you will use to group items.
2. Decide what measurement is appropriate. Common measurements are frequency, quantity, cost and time.
3. Decide what period of time the Pareto chart will cover: One work cycle? One full day? A week?
4. Collect the data, recording the category each time. (Or assemble data that already exist.)
5. Subtotal the measurements for each category.
6. Determine the appropriate scale for the measurements you have collected. The maximum value will be the largest subtotal from step 5. (If you will do optional steps 8 and 9 below, the maximum value will be the sum of all subtotals from step 5.) Mark the scale on the left side of the chart.
7. Construct and label bars for each category. Place the tallest at the far left, then the next tallest to its right and so on. If there are many categories with small measurements, they can be grouped as "other."
8. Steps 8 and 9 are optional but are useful for analysis and communication.
9. Calculate the percentage for each category: the subtotal for that category divided by the total for all categories. Draw a right vertical axis and label it with percentages. Be sure

the two scales match: For example, the left measurement that corresponds to one-half should be exactly opposite 50% on the right scale.

10. Calculate and draw cumulative sums: Add the subtotals for the first and second categories, and place a dot above the second bar indicating that sum. To that sum add the subtotal for the third category, and place a dot above the third bar for that new sum. Continue the process for all the bars. Connect the dots, starting at the top of the first bar. The last dot should reach 100 percent on the right scale.

Pareto Chart Example

This example shows how many customer complaints were received in each of five categories.

Excerpted from Nancy R. Tague's *The Quality Toolbox*, Second Edition, ASQ Quality Press, 2004, pages 376-378.

Cause Effect Diagram

Also known as Cause and Effect Diagrams, Fishbone Diagrams, Ishikawa Diagrams, Herringbone Diagrams, and Fishikawa Diagrams.)

When you have a serious problem, it's important to explore all of the things that could cause it, before you start to think about a solution. That way you can solve the problem completely, first time round, rather than just addressing part of it and having the problem run on and on. Cause and Effect Analysis gives you a useful way of doing this. This diagram-based technique, which combines Brainstorming with a type of Mind Map, pushes you to consider all possible causes of a problem, rather than just the ones that are most obvious. It is sometimes referred to as organized brainstorming.

Cause and Effect Analysis was devised by Professor Kaoru Ishikawa, a pioneer of quality management, in the 1960s. The technique was then published in his 1990 book, "Introduction to Quality Control." The diagrams that you create with Cause and Effect Analysis are known as Ishikawa Diagrams or Fishbone Diagrams (because a completed diagram can look like the skeleton of a fish).

Cause and Effect Analysis was originally developed as a quality control tool, but you can use the technique just as well in other ways. For instance, you can use it to:

- Discover the root cause of a problem.
- Uncover bottlenecks in your processes.
- Identify where and why a process isn't working.
- Identify items to measure.

Causes in the diagram are often categorized, such as to the 8 M's, described below. Cause-and-effect diagrams can reveal key relationships among various variables, and the possible causes provide additional insight into process behavior. Causes can be derived from brainstorming sessions. These groups can then be labeled as categories of the fishbone. They will typically be one of the traditional categories mentioned above but may be something unique to the application in a specific case. Causes can be traced back to root causes with the 5 Whys technique.

Typical categories are:

The 6 Ms (used in manufacturing)

- Machine (technology)
- Method (process)
- Material (Includes Raw Material, Consumables and Information.)
- Man Power (physical work)/Mind Power (brain work): Kaizens, Suggestions
- Measurement (Inspection)
- Milieu/Mother Nature (Environment)

The original 6Ms used by the Toyota Production System have been expanded by some to included the following and are referred to as the 8Ms. However, this is not Globally recognized. It has been suggested to return to the roots of the tools and to keep the teaching simple while recognizing the original intent, most programs do not address the 8Ms.

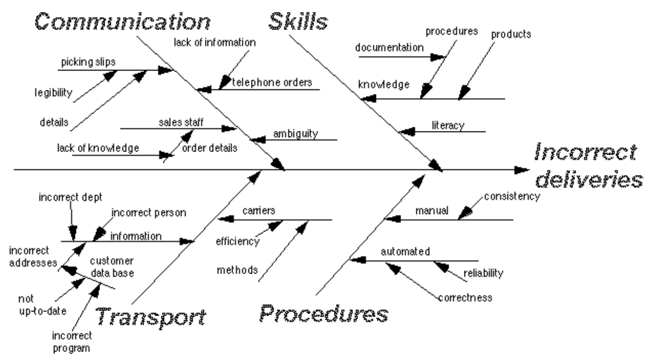
- Management/Money Power
- Maintenance

The 8 Ps (used in service industry)

- Product=Service
- Price
- Place
- Promotion/Entertainment
- People(key person)
- Process
- Physical Evidence
- Productivity & Quality

The 5 Ss (used in service industry)

- Surroundings
- Suppliers
- Systems
- Skills
- Safety



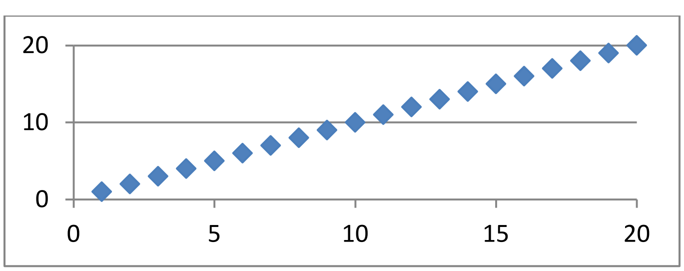
Scatter Diagrams

The scatter diagram is one of the tools of quality. A scatter diagram is a graphical technique used to analyze the relationship between two variables. It shows whether or not there is correlation between two variables. Correlation refers to the measure of the relationship between two sets of numbers or variables. Two sets of data are plotted on a graph, with the y-axis being used for the variable to be predicted and the x-axis being used for the variable to make the prediction. The graph will show possible relationships (although two variables might appear to be related, they might not be: Those who know most about the variables must make that evaluation). **However, correlation does not necessarily mean a direct cause and effect relationship**. If it appears that values for one of the variables can be predicted based on the value of the other variable, then there is correlation.

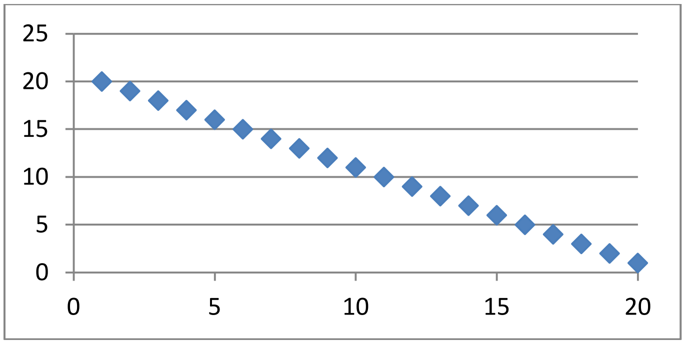
Interpreting a scatter diagram:

Scatter diagrams can show different types of correlation. Correlations are measures of the strength of a relationship. A +1 means a perfect positive relationship, a 0 means no relationship, and a -1 means a perfect negative relationship. The scatter plots are shown below.

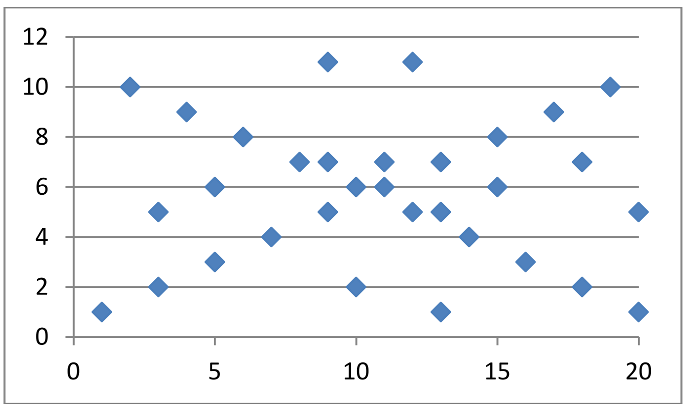
r=1



r=-1



r=0



If there is a cause effect relationship and a significant correlation then the mathematical relationship can be determined and a predictive model built.