# Capacity Maturity Model Integration, Quality Techniques, and Agile Manufacturing in Management

*Monireh Safaie*

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IN THE NAME OF GOD

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# INTRODUCTION

One of the main objectives of any organization is to achieve “productivity” (especially continuous and sustainable improvement). Researchers have developed a variety of methods to achieve this objective, including Six Sigma and QFD among others. An organization will choose one of these methods according to the situation, the time required to react, and to obtain a desired result. As a result, it will achieve short or long-term productivity and increased profits.

After examining a number of organizations, several researchers concluded that there are some gaps in the results of current methods used in quality management and developed a model to fill these gaps. To this end, they tested the Capability Maturity *Model* Integration (CMMI) process improvement and training program (used in software companies) in industry, especially in the manufacturing sector, and achieved significant results. The result gaps found with other methods have been greatly reduced and efficiency has been increased. Consequently, Capability Maturity *Model* Integration (CMMI) has become commonly used in industry, especially in the production sector. Capability Maturity *Model* Integration (CMMI) is a comprehensive guide for the planning and execution of processes and can guide an organization to high levels of maturity, increasing productivity by identifying process areas and maturity levels in proportion to their integration.

On the other hand, the Six Sigma technique approach is one of the most well-known techniques used in organizations. Significant results (obtained in the short and long term), have led to this model being further promoted in many organizations. In the Six Sigma approach, attention is paid to reducing errors in the processes and controlling unintended events and occurrences. The main focus of the Six Sigma approach is to create a product according to customer needs, with the least possible number of errors in the production processes, and seeking to improve the quality of products, services, and processes.

With rapid growth in technology, rapid changes in customer needs and demands, and increased information exchange with other organizations and industrial centers across the world, the agile manufacturing (AM) approach has received a lot of attention from organizations. Using this approach, it is possible to adapt to the speed of technological growth and changes in customer needs to produce a product with the required changes at the lowest cost.

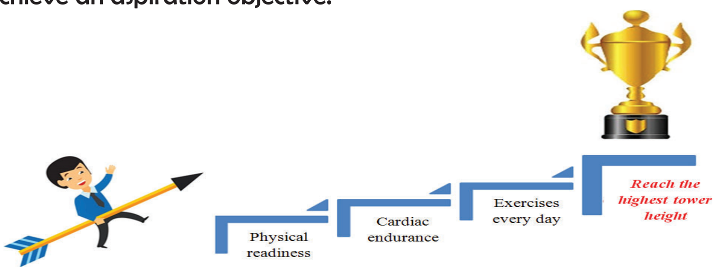
- The aim of this book is to provide useful solutions for organizations to become more competitive domestically and globally, and thus achieve a competitive advantage.
- This book presents the concepts of the relevant models with the formulas removed to better clarify the concepts.
- The book also provides a quick overview of the models and their important points.
- This book also describes the work series of a number of other researchers to introduce a comprehensive and sustainable method by combining them.

# CHAPTER ONE

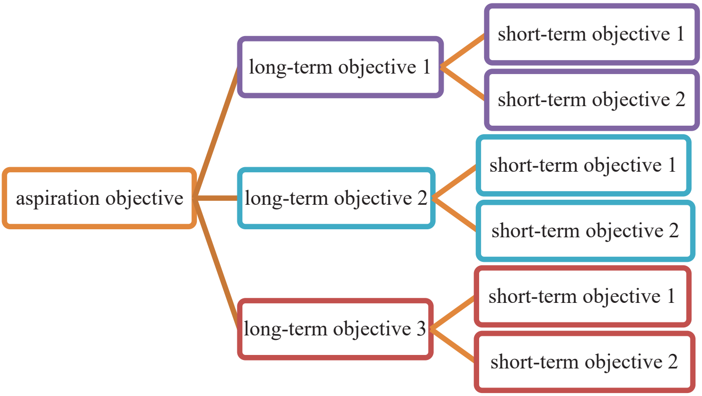
# WONDERFUL MANAGEMENT

## Introduction

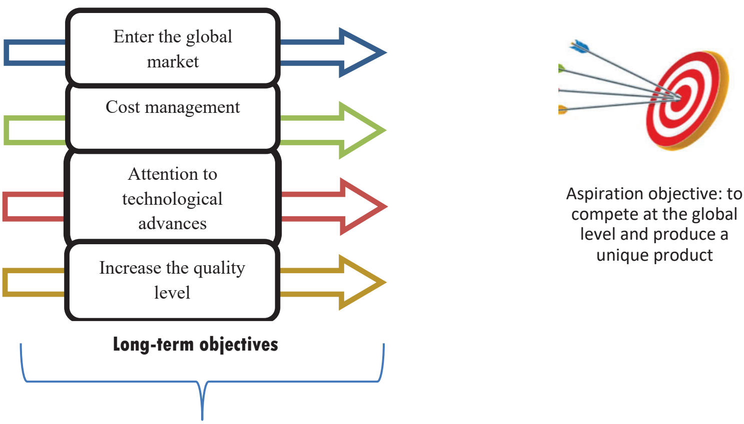
"Management" is an activity that everyone deals with during the course of his or her life. All life-matters involve some form of management, such as time management, cost management, objective management, and so on. Everyone has aspirations and objectives for his or her life. To achieve these objectives, we all need **appropriate planning** and **proper management**. For example, a 15-year-old person may wish, at the age of 20, to stand on the highest point of the tallest tower in the world—this is an aspiration objective and achieving it may or may not be possible. This is the moment when a person decides to plan for the future and, therefore, it is necessary to turn this **aspiration objective** into a set of **simple objectives**. Such simple objectives could include: walking every day; climbing stairs; increasing endurance; and taking physical exercise. Consequently, the achievement of simple objectives must be managed to achieve the aspiration objective. As a result, **a successful person is someone who plans to achieve an aspiration objective.**



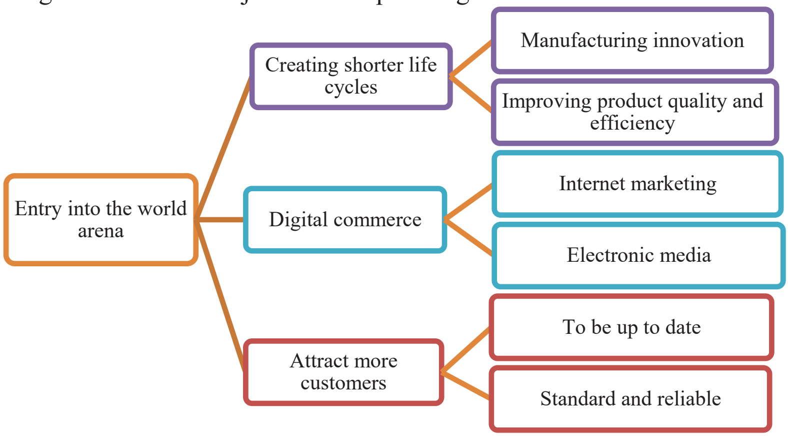
**Note:**
*To better achieve the objectives, each **short-term objective** can be considered a **long-term objective** and to achieve it, **simpler objectives** are defined.*



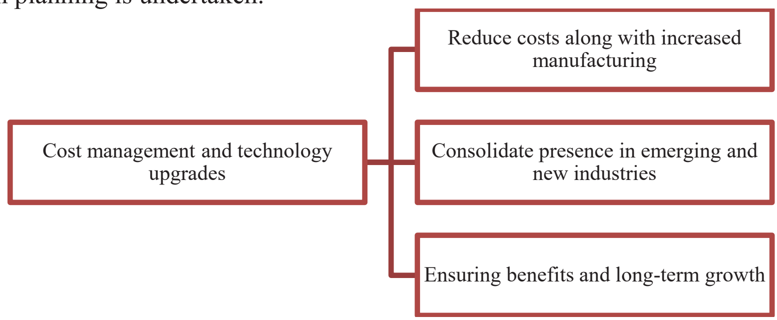

For example, in an organization or company, the ***aspiration objective*** is ***global competition and the manufacture of unique products.*** To achieve this objective, it is necessary to define the long-term objectives, such as: ***entering the global market; increasing the level of quality; creating conditions for employee creativity and innovation; paying attention to customer needs; paying attention to technological advances; and cost management***. For each of these long-term objectives, short-term objectives are considered and planned so that they can achieve the aspiration objective.



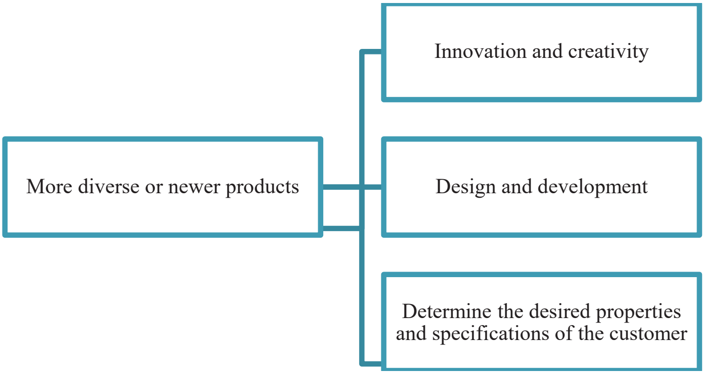
Now, suppose that the **first long-term objective** for the organization is to enter the global market; achievement of this objective will be done by defining the short-term objectives and planning how to achieve them.



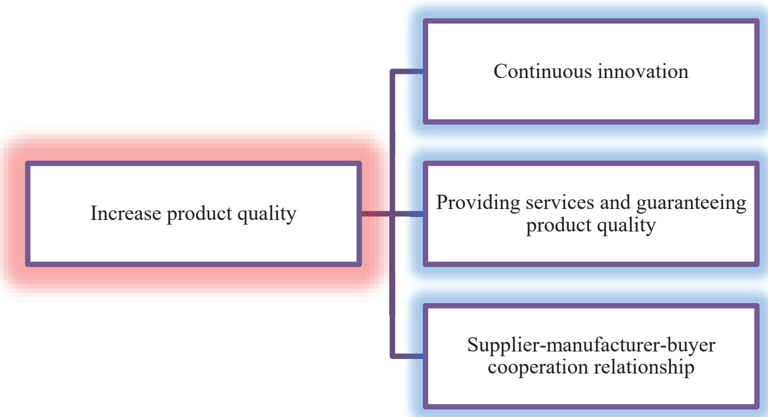

However, after entering the global market, we will come to understand that we need cost management and technology upgrades. Thus, the **second long-term objective** is identified—we define the short-term objectives, then planning is undertaken.




Following this, we may find that the organization needs a more diverse or newer product range as the market for the current product is saturated. As a consequence, we have defined our **third long-term objective**. Again, we define the short-term objectives and then undertake the appropriate planning.




This trend continues because consumer populations develop dynamically. Over the course of this period of time, it is important to note that for each long-term objective, we use a specific method to achieve it. In the above example, in relation to three long-term objectives, three specific methods were also specified. Now, the organization or business is faced with three different methods that can give three different results. How do we coordinate and adapt these methods while achieving the fourth long-term objective of increasing product quality?



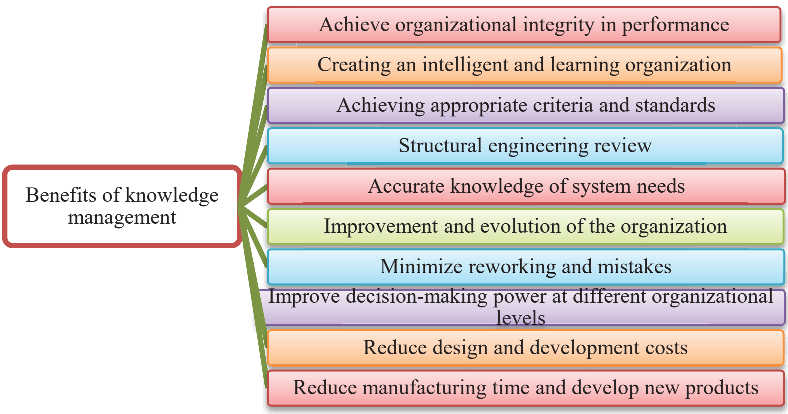

It is clear that **there is a need to integrate methods!**

On the other hand, the researcher might suggest that we must **do work with zero errors.** This means ***doing everything "right and great" the first time****; in particular,* ***doing "the right work" correctly first time.***[1]

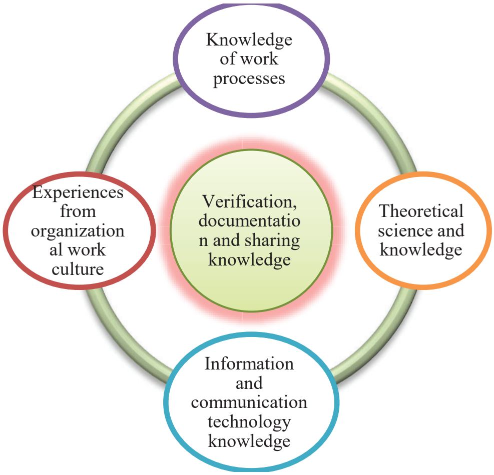
[1] That is, firstly, we must select the correct job and then do the job correctly the first time.

How then do we complete the job without error in an organization with many tasks and complexities? A task may be performed that is related to another task, but the operator is entirely unaware of this; or, with staffing and administrative tasks (such as design and planning), all the steps may be done carefully, but in the last step, we realize that a mistake was made at the first step. How can we repeat all the steps from the beginning while the mind is tired and there is still some doubt about the mistake? What happens if we repeat all the steps from the beginning and realize that the initial solution was, in fact, correct? All of these items indicate that **the administrative steps or industrial and manufacturing steps in the organization require integration and event recording.**

Now, let us assume that we have met all the necessary standards, we have weighed up all the aspects, and all the technology and equipment are ready to produce the product; but the final product is not produced to an acceptable standard? What is the reason? If everything has been done carefully, why has a quality product not been produced? In these cases, **experience and the knowledge of experienced people** are considered *organizational assets* because they are effective in **saving product manufacturing time** and **ensuring acceptable product manufacturing standards**. The following figure presents the benefits of knowledge management.




However, such people are not always available to us. ***Documenting people's knowledge*** *and* ***integrating it*** *is an important way of ensuring future manufacturing capability*.




If we assume that we have complied with all of the above and delivered an acceptable product to the customer, is this enough? Does time stand still while we rejoice in our success? Will competing companies not take action? Will the customer use only this product for hundreds of years to come? Where is *our foresight, attention to customer needs, technological advancement, which can be summed up in the phrase "take advantage of opportunities and threats against the organization"* in our planning? As such, there is a need to devise a method with **appropriate flexibility in the face of change**.

**Note:**

Flexibility is a requirement for every organization.

Given all of the above and the manufacturing of diverse products, what happens if we wish to improve a previous product? How do we know if improvement is needed? If improvement or development is needed, how do we implement this improvement or development with the least amount of reworking? Here, *all the* ***steps*** *and the* ***interactions of these steps*** *in product manufacturing must be considered.*

On the other hand, in improving or developing a product, we must look at four items. These are: (1) *understanding where we have been before*; (2) *knowing where we are now*; (3) *deciding where we want to go*; *and* (4) *prioritizing the* ***reinforcement of strengths*** *and the* ***avoidance of obstacles****.*

As such, we need to pay full attention to the inside of the organization and the outside of the organization to determine the appropriate response.

**Road map:**

The **need for integration** can be met by the **Capacity Maturity Model Integration (CMMI)** process. The **need for flexibility** can also be met using ***agile manufacturing***. However, it should be noted that product manufacturing requires ***appropriate product quality*** and product quality should never be forgotten. Also, ***systems engineering*** will lead to comprehensive attention being paid to all issues, making it easier to ***decide to improve or develop***.

**Note:**

Integration→ **CMMI**
Flexibility → **Agile Manufacturing**
Quality → **Six Sigma or Other Methods for Quality Improvement**
Improvement and/or Development→ **Systems Engineering**

## Book structure:

In the second chapter of this book, the **Capacity Maturity Model Integration (CMMI)** process (including capacity levels and maturity levels) is introduced. If you have created an organization, it is possible to use this model to *optimize that organization*; if you are just starting out, you should *use all available resources* properly. **Agile manufacturing** is also introduced to address *on-time delivery, technology upgrades, and customer needs*. Chapter 4 on **systems engineering** describes how to achieve *systemic improvement or development*, while in the fifth chapter, the **Six Sigma**[2] quality technique is discussed. To implement this, specific quality improvement methods are needed, each of which is explained in a separate chapter. At the end of each chapter, a schematic roadmap is presented.

To achieve better management, several points need to be considered:

**A) Do everything in due time and with patience and care.**

Sometimes, we wish to undertake some work. To get the work done faster, we try to connect "the top and the bottom" of the job. For example, we may want to design a product according to a particular standard, but say "we have a lot of work today, we do not have time. But we have time tomorrow and we will do better to make it according to what we have learned and according to our opinion." As a result, we end up doing the work for today with low accuracy and at high speed, while tomorrow, we

[2] The Six Sigma technique is one of the best techniques; it can be applied to achieve product quality and productivity. This technique is a comprehensive method with several steps. To perform each step requires several quality methods, which are expressed in each step.

will have more work and will not have the opportunity to return to previous work to correct it. As such, correction and improvement may lag for an extended period of time without us making any changes. When we finally make the effort to undertake the correction and improvement of this work, we will encounter several problems:

1) Correction takes a long time—it would have taken less time when we first did the job; but now, we feel that spending a long time on its resolution is no longer worth it.

2) The next piece of work has already been done; if we modify the previous work, we must do all of this subsequent piece from the beginning, i.e. do a "rework."

3) We have so many important issues in front of us that we end up saying "this issue is not important and we will not do it."

Ultimately, in this scenario, there will be no correction and improvement *because it will require a lot of time and energy*.

Therefore, we must always keep in mind that it is better to do the job properly the first time and according to the precision and circumstances that we want. This is a "to-do" principle. The first step may take longer than before,[3] but we have gained in valuable areas:

- We did the job better.
- We do not have the stress of failing to complete the previous job.
- Our minds are not focusing on past issues and we think more deeply about the future.
- There is no need to return to this prior step and if there is a need for improvement, less time will be needed.

**B) Prioritize tasks in planning.**

Often when we think about our daily tasks, we somehow worry about when and how to do all this. As such, we *prioritize the hardest work in planning*. When you start and try to finish this hard job of planning, you will feel that you have lifted a heavy burden from your shoulders. As a result, you will feel more relaxed, you will have more self-confidence, your daily worries will be reduced, and everything else will be done more quickly and accurately.

Always remember that the priority is "*do the hard work*", i.e., do **tasks that require difficult decisions and a strong will**. Doing this hard work requires **a lot of patience, perseverance, and motivation**. If you take a step every day to advance your objectives, you will find that those objectives are not so distant.

[3] We connected "the top and bottom of the job" last time, but now we want to do "the job" carefully.

**Note:**
Make hard work the highest priority and do it with joy and motivation.

**Warning:**
"Hard work" concerns "work plans" and jobs that require a lot of effort, experience, and training. Hard work does not mean choosing something/work you do not know about, as by doing it, you will become tired and be distracted from the main task.

**C) Create motivation for yourself.**

- If you feel you have no interest in doing something or in undertaking a particular piece of work, give yourself a chance to rest. For example, if you complete a particular section or finish some reports, you can go out and have fun.
- Set ***big and special objectives*** for yourself. Bigger objectives motivate a person more than smaller objectives. A big objective has a greater effect and can be a strong source of motivation.
- Act like a "motivated person." If you are bored and do not have the motivation to work, *imagine that* you are full of motivation. The good thing about this is that as soon as you start, you slowly feel that passion has come alive in you.
- Plan to do and then complete a ***small task***. For example, clean your desk, pay a bill or receipt, or visit your employees—you just need to start doing something. Once you have done this, you will feel ready to do the next piece of work. So, if you do not have the patience to do anything, start a small task so that its completion will enthuse you.

**D) Start your work slowly.**

Instead of trying to get started at speed, ***take the first steps slowly***. When you start work calmly and with relaxation, your brain does not receive the command that it must be completed as quickly as possible. But what happens if the human brain feels the need to finish its work schedule quickly? Often, the person may not start the job at all. ***Starting a business without haste is better than not starting it at all.***

**E) Do not compare yourself to others.**

Comparing yourself to others in terms of the results of your efforts and where you stand deprives you of human motivation and creativity. There will always be countless people who are more capable than you and there are few who surpass everyone, both materially and spiritually. *As such, just focus on **yourself**, **the plan you have in mind**, and, of course, **the results you achieve**. Do this to find out how you can improve and implement "mental planning*."

It is also important to reexamine your results, because you can find past mistakes and avoid repeating them or making similar mistakes. Another benefit is that it creates "double motivation." Understanding what have been the results of your efforts and where you stand helps increase your energy and enthusiasm; you will often be amazed at your success.

**F) Always remember your successes.**

***Always and all the time, remember your successes,*** *instead of thinking about your failures and mistakes.* It is better to write them down, particularly the details, because it is very easy to forget about successes and occasionally referring to your written notes can bring back good memories in you and of course, keep alive the motivation for work and effort in you.

**G) Act like a hero.**

Read the life stories of your heroes, follow their behaviors and deeds, and listen to their words. Discover what was so special about their work that made them so successful? However, always remember that these people are like us and other people, and therefore, let them inspire you, instead of placing them on a pedestal and praising them unconditionally.

**H) Try to make your work environment more bearable with a little fun.**

Remember to make space for some fun and jokes (in the workspace you create or in the plans you have in mind). As a result, you will increase your motivation to do the job and complete it.

**I) Do not just look for comfort and do not be afraid of failure.**

Say goodbye to laxity, which is a form of laziness, and fight problems to motivate yourself. Instead of fearing failure, accept it as useful and important information and a natural part of success. Experience failure and ask yourself, what does this failure teach me?

**J) Read about what you want to do.**

When you start a job, do some research on the work process. You will be better aware of the value of the work ahead and the problems you may encounter. Sometimes unwarranted expectations and waiting unnecessarily reduces a person's motivation and wastes their initial enthusiasm and seriousness. By managing your desires, you can avoid wasting the energy that results from your passion. As such, maintain your motivation to the very end. *It is useful and instructive to know about those who were in a similar situation to you, what happened, what path they chose, and what steps they took.* **You can choose the right method and start your activity by combining their chosen method and what you have in mind.** This situation can reduce your anxiety and you can better control the work situation. Both emotionally and practically, this awareness gives encouragement and assurance, because you know at least to some extent that others who have gone that way have encountered similar events.

**K) Determine why you want to do this work.**

If you do not know why you want to do this work, or you do not have enough reason to do it, it will be very difficult for you to get the job done. Choose something that you have a strong reason to do. If you are unable to complete the activity, stop doing it and start something else (for which the reasons are stronger and clearer).

**L) Write down your objectives.**

Write down your purpose for doing the activity, then stick it on the wall, your computer, or a mirror. During your day, review your work steps and this awareness makes it easier for you to continue.

**M) Act with a positive outlook to get the job done (strive for positive thinking).**

Learn to think positively and to get negative thoughts out of your head before they get in your way. We may not all always be able to think positively; we believe that we can strengthen this feeling in ourselves and help us to work harder.

**N) Divide your work schedule up into several smaller plans.**

If you have a large project in hand, divide it up into several smaller sections. Start by focusing on the first section of the work and when this section is done, start on the next one. The small successes you achieve in doing these initial parts will increase your motivation and prevent discouragement. If you follow this method, you will be amazed at the result.

**O) Review the available information.**

Having the necessary information at the beginning of any piece of work is essential, but sometimes the media conveys information that is negative. To evaluate your mental archives, eliminate negative points and use useful and positive information to achieve your objective according to your insight.

**P) Use your creativity.**

Take a piece of paper and write the objective you would like to achieve on it. Now write 20 ways, ideas, or views about this objective. Try adding 10 more ideas to your list; of course, not all of these ideas will be useful or good. Use your creativity and find ideas that will help you reach your objective. You will not only use your creativity, but also come to realize how creative you are. In doing this, you will increase your motivation to do the work and provide yourself with suitable spiritual conditions.

**Q) Listen to wise sayings.**

Set up a small library for yourself. Write or record sentences that lead to personal growth and motivation. Listen to them while riding the bus or subway, driving, cycling, running, or walking, and read your notes.

**R) Think beyond your living environment and ability.**

Do not think that your future is only focused on your current abilities and what you have now; the world is not limited and your abilities are far greater than you think. Plan for a future where there are fewer constraints, using the experience you have gained so far and where you are now, i.e. broaden your horizons.

**S) Consider time.**

Life is short, so focus on today and do what you want. Tomorrow there will be other work to do.

## References

The author's experiences and research.

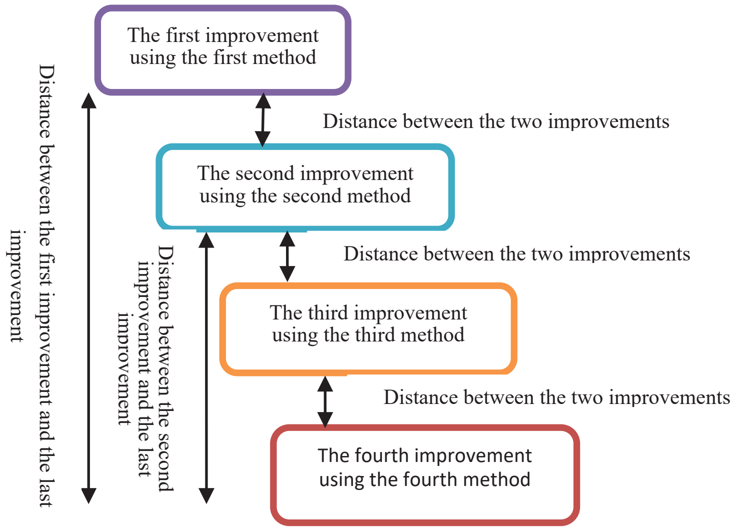
# CHAPTER TWO

# CAPACITY MATURITY MODEL INTEGRATION (CMMI)

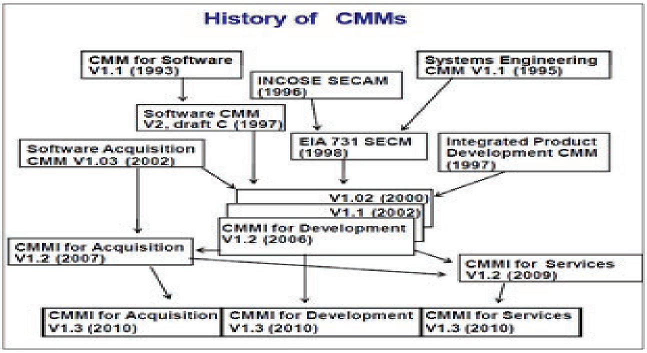
Now more than ever, organizations need to deliver better, faster, and cheaper products and services. On the other hand, with advances in technology, almost all organizations are increasingly realizing that manufacturing and producing products and services is very complex because complex product and service components cannot be produced and developed within a single organization. As such, it is common to make several components within an organization to provide several suppliers; finally, all the varied components have to be assembled and integrated into the final product.

Organizations must be able to manage and control this supply chain complexity. They need a **comprehensive and integrated approach** to develop their products and services and achieve their business objectives.

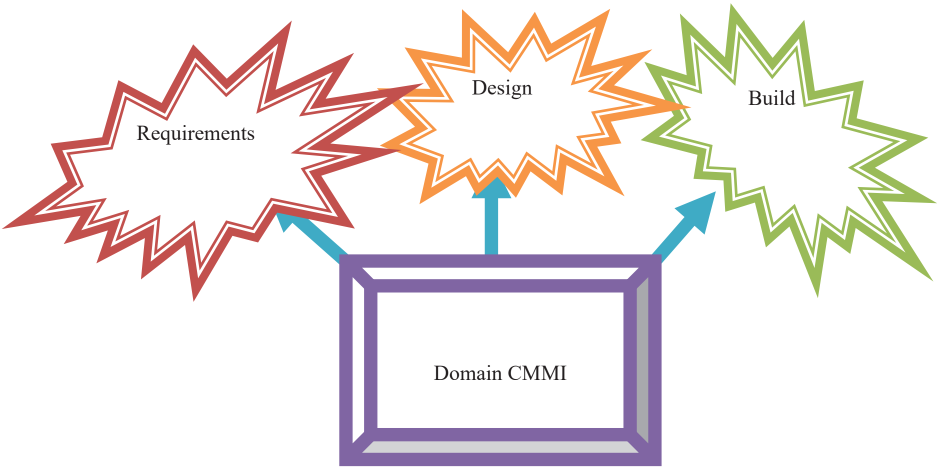
In today's understanding, there are a number of ways (including models, standards, and guidelines) to help an organization's progress. However, many of these improvement methods focus on a specific part of the business. They do not provide a systematic approach to the problems that organizations face and, therefore, the intractable obstacles that exist in the organization continue.




In this regard, maturity models have been proposed to help reduce and remove obstacles (intervals) to organizational improvement. These models eventually led to the development of Capacity Maturity Model Integration (CMMI).




As mentioned, the Capacity Maturity Model Integration for Development (CMMI-Dev) provides an opportunity to prevent or eliminate obstacles/barriers. This model includes a number of *best practices* and recommended *measures/actions to develop* products and services. These methods cover all steps of the product life cycle—from receipt to storage. The emphasis in this model is on what is necessary to build and maintain the product.




The CMMI model is a combination of two structures. The first structure is made up of **capacity levels and maturity levels**. The second structure is made up of **process areas.**[4] In the following, explaining and

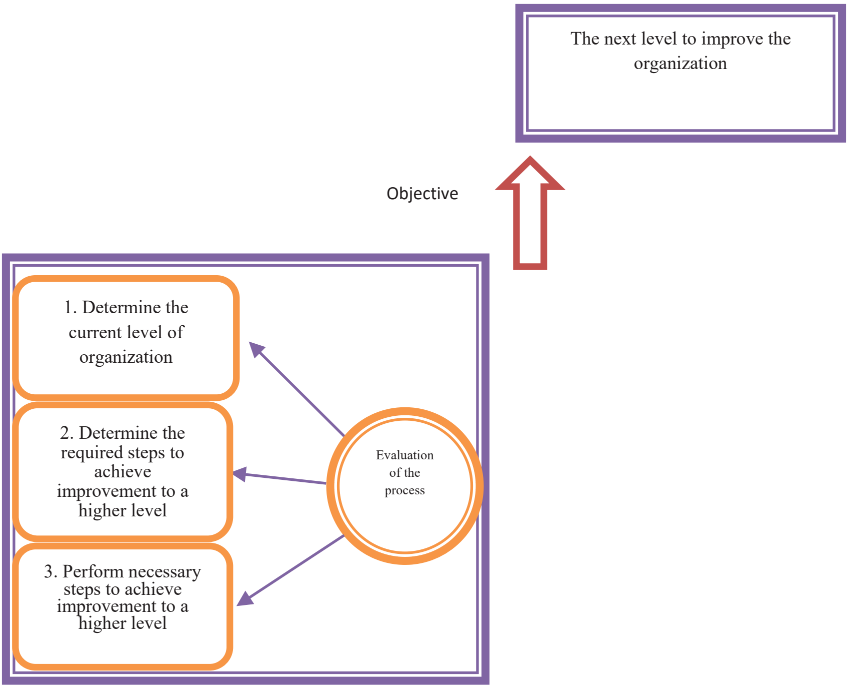
[4] Achieving any level of maturity/capability requires the implementation of process areas.

combining these two structures is discussed. It is worth noting that the CMMI approach and the quality approach, in general, constitute a ***process approach***, because the mutual interaction of processes (process balance) is considered.

**Capacity levels and maturity levels**

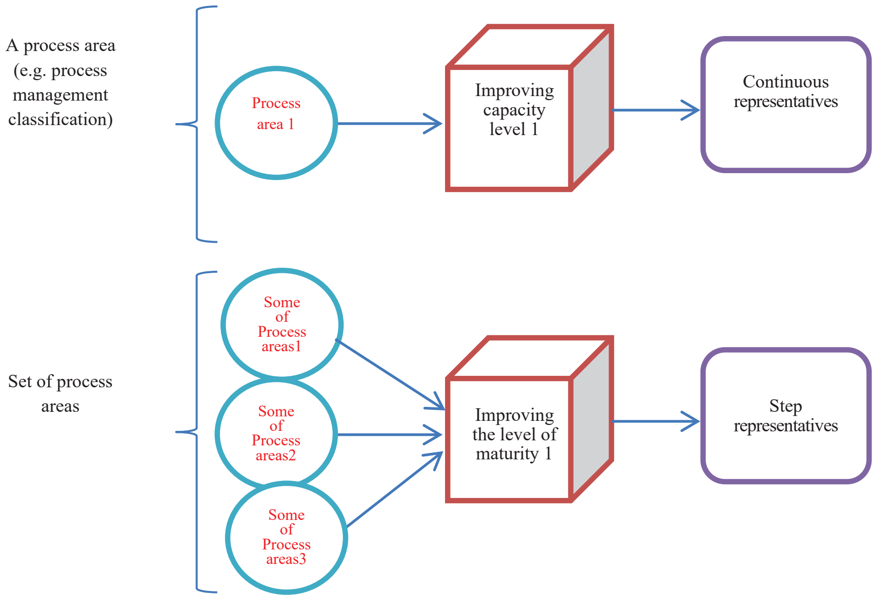
The CMMI model introduces levels of process maturity/capability to define an "improvement path" using an incremental (step-by-step) and continuous process and with a large number of small steps. These steps are based on the concepts and philosophies of Schwartz, Deming, Juran, and Crosby. These levels make it possible for the organization to assess the current levels of these processes. These levels help to prioritize the actions needed for progress (to achieve higher levels and further improvement).

**Note:**
Levels provide a recommendation (guidance) of the organization's evolutionary path to improve its processes and develop products or services.



Therefore, in the CMMI-Dev model, levels are introduced to ***determine the current situation of the organization*** and ***move towards improvement***. As such, the organization can move from its current situation to continuous optimization. Alternatively, the organization can start from a zero-level and move towards improvement.

The capacity maturity model integration (CMMI) supports two pathways of improvement. One path empowers the organization to increase process improvements associated with a ***specific process area*** (or group of selected processes) (***capacity levels***).[5] The other path enables the organization to improve a set of processes, including success in ***a set of process areas*** (***maturity levels***).[6]




[5] In the following, four classifications will be introduced (having 22 process areas). These four classifications are continuous representatives (i.e. capacity levels).

[6] As mentioned, four classifications are used for capacity levels (continuous representatives). But for maturity levels, a combination of 22 process areas can be used (step representatives), regardless of the four classifications.

To achieve a particular level, the organization must meet all the objectives of a process area (capacity level) or set of process areas (maturity level) to improve, regardless of whether it is a capacity level or a maturity level. ***Both provide ways to improve processes to achieve business objectives.***

**Note:**
**Process:** a set of activities that have one or more inputs; by processing the inputs, one or more outputs are obtained that create value for the process customer.
**Process area:** implement a set of related actions in an area to meet important

**Capacity level**

**- Level zero**

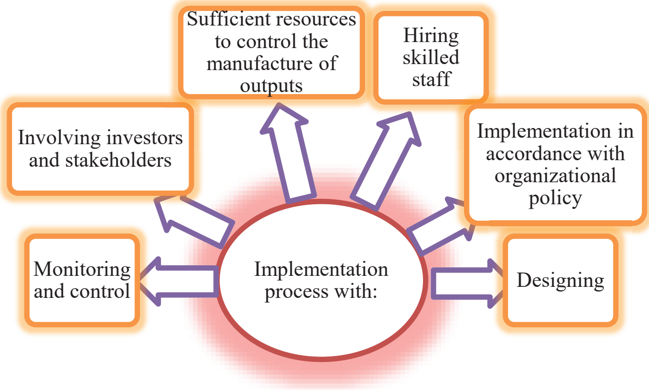
An *incomplete process* is a process that has not been done, or has been done only partially. One or more specific objectives from the process area are unsatisfactory and *there are* ***no general objectives*** *for this level* because there is no reason to create and execute the process partially.

**- Capacity level 1: implemented (ongoing)**

The indexing process at this level is the *implementation process*. The implementation process is the process that enables and supports work requirements to produce work products. At this level, process area-specific objectives are satisfactory. The result of capacity level 1 is significant improvements; however, if these improvements are not maintained, then they can be lost at any time.

**- Capacity level 2: Managed**

A capacity level 2 process is a *management process*. A management process is an implementation process that has *the basic infrastructure to support the process*. In fact, capacity level 2 (management process) is a combination of capacity level 1 (implementation process) and the following elements: *design; implementation under organizational policy; hiring skilled employees; sufficient resources to control the manufacture of outputs; involving relevant investors; and monitoring and control.*




**- Capacity level 3: defined**

Capacity level 3 is determined by the *definition process*. The definition process is a management process that is based on a set of *standard organizational processes* under the appropriate guidelines for the organization.

*A special score between levels 2 and 3 concerns the standards, process descriptions, and methods*. This is because, at capacity level 2, the standards, process descriptions, and methods can be quite different for each specific instance of the process (such as a particular project). However, at capacity level 3, standards, process descriptions, and methods are based on a set of organizational standard processes that are appropriate for a particular project or organizational unit and are therefore more robust (except for the differences permitted by the appropriate guidelines).

Another critical advantage of capacity level 3 processes is that they give a *more accurate description* than those at capacity level 2. A clearly defined process describes the following: *purpose; inputs; input measures; actions; roles; measurements; validation steps; outputs; and output measures.*

**The distinction between level 3 capacity and level 2 capacity:**

A) Defining and describing *standards, processes, and methods.*

B) Determining and describing *purpose, inputs, input criteria, actions, roles, measurements, verification steps, outputs, and output criteria.*

**- Capacity level 4: Quantitatively managed**

Capacity level 4 is described as the *quantitative management process*. The quantitative management process is based on a defined process that controls the use of quantitative and statistical techniques. Quantitative objectives should be set for the implementation of a process and its quality, and used as criteria for process management.

Achieving capacity level 4 indicates that this area of the process is a *key driver of the business* and the organization wishes to achieve control through quantitative and statistical techniques. This analysis gives more insight into the implementation of selected sub-processes that ensure a competitive advantage in the market.

**- Capacity level 5: optimization**

Capacity level 5 is described as the *optimization process*. An optimization process is a quantitative management process based on the common concept of intrinsic causes of change and instability in the process. The focus of the optimization process is continuous improvement, enhancing improvement and innovation.

Reaching capacity level 5, selected sub-processes can be implemented consistently and continuously, and common causes of change and instability can be reduced.

**Note:**
*Remember that "change" is an inherent cause in every process, and, while it is possible to improve all processes, this may not be affordable.* **It is better to focus on those processes that help us achieve our business objectives.**

**Comparison between capacity levels and maturity levels**

| Level of capability | Description | Indicator process | Level of maturity |
|---|---|---|---|
| **Level Zero: Incomplete** | The process is not done or only superficially done | Incomplete process | **Level one: initial** |
| **Level one: performed** | Processes performed as usual | Performed process | |
| **Level two: managed** | At this level, the implementation of the CMMI model begins; planning, organizing, directing and monitoring related resources and investors (including customers, stakeholders, suppliers, etc.) to achieve the objectives of the organization | Managed process | **Level two: managed** |
| **Level three: defined** | Process definition is performed under set standards | Defined process | **Level three: defined** |
| **Level four: Quantitative managed** | Use of quantitative and statistical techniques to perform and control the process | Quantitatively managed process | **Level four: quantitatively managed** |
| **Level Five: Optimized** | Determining the intrinsic causes of change and instability in the process for correction and improvement | Optimized process | **Level Five: optimized** |

### 3.2 Maturity levels

Maturity levels offer a good evolutionary path to achieving organizational processes and moving to the next maturity level. Excepting level 1, each level of maturity consists of a large number of key processes that an organization must have to achieve a specific level of maturity. There are 5 levels of maturity (with a combination of 22 processes) and each process includes 3 to 5 objectives and several activities. A maturity level also includes a number of general and specific methods for defining the set of processes needed to achieve improvement.

#### Maturity Level 1: Initial

At maturity level 1, processes are usually specific and irregular. The organization usually does not offer a robust environment to support these processes. *Success in these organizations depends on the competencies and heroes of people in the organization and does not depend on the use of common processes.* Despite disorder, organizations can produce the products they need, but often exceeding the budget and schedule set out in the plan.

An organization at maturity level 1 is characterized by a *desire to succeed, abandoning its processes in times of crisis, and a failure to repeat success*.


#### Maturity Level 2: Managed

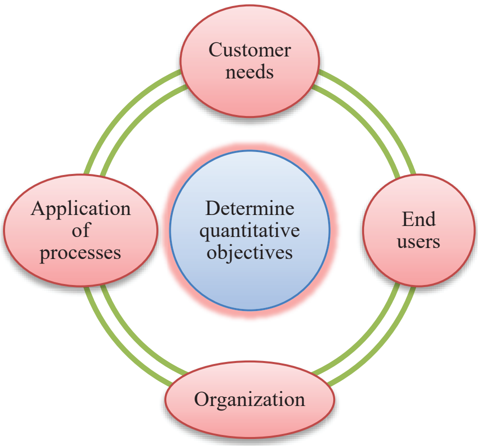
At maturity level 2, project processes are designed and implemented according to organizational policy. Skilled employees are provided with sufficient resources for the *generation of controlled outputs, involving relevant investors, as well as monitoring, controlling, visiting, and evaluating*. This level helps to ensure that *existing methods are maintained during times of stress and crisis and projects are carried out and managed according to documented plans*.

**Maturity level 3: Defined according to the standard**

At maturity level 3, processes are identified, understood, and described according to set standards, tools, and methods. At this level, a set of standard organizational processes can be created and improved on at any time. These standard processes are used to ensure stability across the entire organization. Projects create defined processes according to the set of standard organizational processes and guidelines.

**Maturity Level 4: Quantitatively managed**

At maturity level 4, organizations and projects set *quantitative objectives* as scales of project management for quality process implementation. The quantitative objectives are set according to **customer needs, end-user and organizational requirements, and application processes.**




In the selected sub-processes, a special measure of process implementation is collected and statistically analyzed. Measuring the quality of process implementation requires evaluation of the relationships between different sub-processes and their impact on achieving the objectives. This is also helpful in monitoring statistics and other quantitative techniques for the sub-processes and to identify and use sub-processes that have the greatest general value for business. A ***baseline for process implementation and models*** can be used to help achieve quality and process implementation objectives and, consequently, business objectives.

A score between maturity levels 3 and 4 gives the ***predictability of process implementation***. At maturity level 4, selected projects and sub-processes are controlled using statistical tools and other quantitative techniques; predictions are based on statistical analysis of the process data.

**Maturity Level 5: Optimized**

At maturity level 5, the organization continually improves its processes based on a ***quantitative understanding of business objectives and implementation requirements***. The organization uses quantitative methods to *understand* ***significant change in processes*** *and the* *cause of success (or failure) of processes.*

Process improvement is measured using statistical techniques and other quantitative techniques. The results are then compared to quality objectives and process implementation objectives.

A critical score between maturity levels 4 and 5 focuses attention on ***management of and improvement in organizational performance*** (at maturity level 5). Data analysis helps identify deficiencies or gaps in performance. These intervals are used to drive organizational process improvement to achieve significant performance improvement.

**Process areas**

The development of Capacity Maturity Model Integration provides a pathway for organizations to move from their current processes to engineering and management excellence. In the original model, there are 22 process areas. These are divided into four classifications (process areas),[7] while three further classifications cover integrated product and process development,[8] and another classification covers supplier source because group structure plays an important role in successful product development. Many organizations adapt to a particular group structure and create a specific group dynamic for the organization. Most projects and organizations with complex products use specified suppliers *and subcontractors to supply product components*. As a result, throughout the project, an organization's ***relationships with its suppliers*** need to be managed to avoid errors and correctly identify affiliated teams.

**Development of the CMMI model and the relationship between process areas**

Process areas are divided into two parts—basic process areas and advanced process areas. In this model, basic process areas prepare the organization to achieve in advanced process areas.

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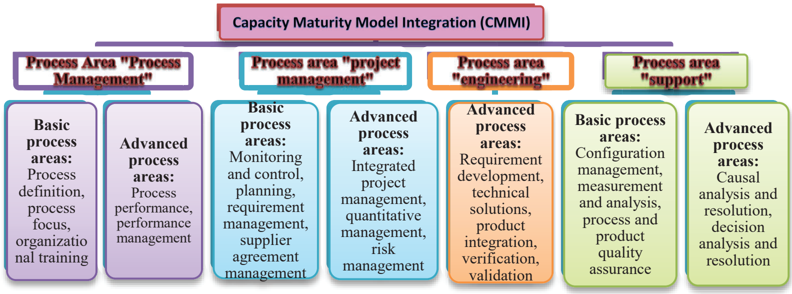
[7] To clarify, the 4 process areas, including 22 process areas, become four classifications that include 22 process areas.

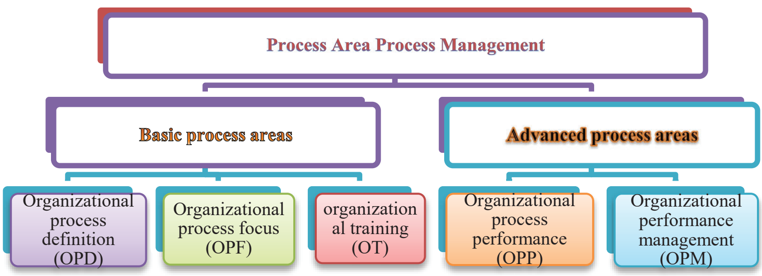
[8] Integrated Product and Process Development (IPPD). IPPD is an approach that creates a timely set of relevant stakeholders to achieve better customer satisfaction through meeting needs, expectations and wants throughout the manufacturing cycle.




Regardless of grouping, classification, or level, process areas mutually interact and affect each other. For example, the *Decision and Solution Process Analysis Area* (Support Process Area at maturity level 3) includes special methods, such as the *Formal Evaluation of the Process* and the *Technical Solution Process Area* (Engineering Process Area). A *technical solution is selected from alternative solutions*. The ultimate objective of these two process areas is to choose the best alternative solution and make the correct decision, which determines the interaction between the two areas. Awareness of key connections between process areas leads to the productive use of CMMI-Dev.

### 1- Process management

The Process Management process area, prepares a framework for the consistent creation and implementation of processes in the organization. The five process areas for this classification are shown in the CMMI-Dev model in the following figure.




### Basic Process areas: Process Management

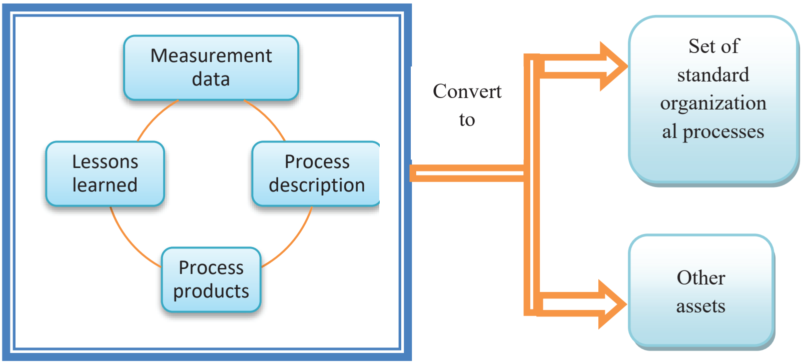
Basic process areas in process management prepare the organization with the appropriate capacity to divide and document the best practices, most valuable organizational processes, and the organizational knowledge throughout the organization.

**Process area: Organizational Processes Definition (OPD)**

**Purpose:** creates and maintains a set of standard processes, work-environment standard, and other assets based on the process requirements and objectives of the organization. Projects, therefore, create a process definition[9] based on a set of standard organizational processes. Other assets also support the implementation of the process definition.

**Note:**
Other assets include: a description of the process details; life cycle models; appropriate process guidance; and documentation of the process and data reports.

Methods and products of work are the result of the implementation of process definitions, including: data measurement; process description; process products; and lessons learned. These methods and products of work are integrated and united and allocated to a set of standard organizational processes and other assets.



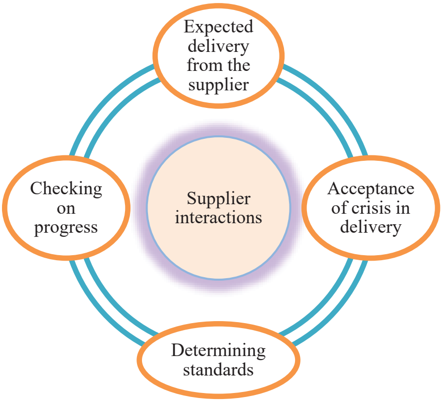

Methods and products of work resulting from the implementation of the process definition

**Further description:** projects are required to implement process definitions based on a set of standard organizational processes. Other organizational process assets are used to properly support and apply the process

[9] The defined process is a set of interconnected sub-processes that constitute an integrated and coherent process for the project.

definition. Work-environment standards are used to guide the creation of proper project work environments. Rules and guidelines are used to assist groups in their structure, shape, and action.

The set of standard processes of the organization is used to describe the interaction of supplier standards. Supplier interactions are identified by tracking: the delivery expectation for the supplier; the acceptance of crisis in delivery; determining standards (such as technology standards and phased standards); and checking on progress.




**Process area: Organizational Process Focus (OPF)**

**Purpose:** this area is for the planning, deploying, and developing **organizational process improvements**, which are based on the general concept of **strong and weak organizational processes** and **most valuable processes.**[10]

**Further description: selected improvements for organizational processes include**:

- Proposals for process improvement.
- Measuring processes.
- Lessons learned[11] in process implementation.
- Outcomes of process evaluation activities and product evaluation activities.
- Results of customer satisfaction assessment.
- Market results and signs vs. organizational processes.
- Other recommendations for preliminary improvements to the organization.

[10] Determining the strengths and weaknesses of organizational processes is done using Pareto charts. The Pareto chart is also a good chart for achieving organizational process focus in terms of process activity amount and process-critical points.

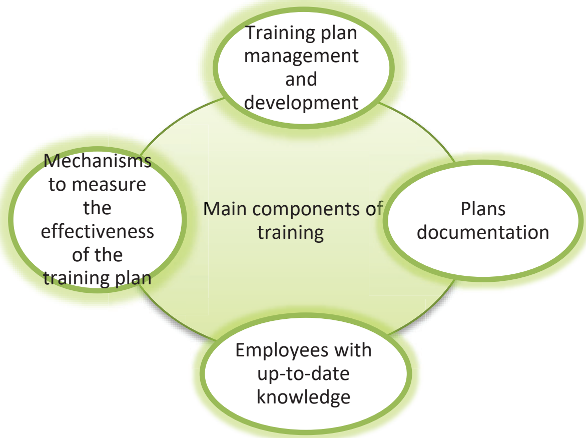
[11] Organizational knowledge.

Organizational process improvement planning includes: planning evaluation; planning implementation; planning testing; and planning development.


Also, in the **evaluation of plans**, **evaluation of the timeline**, and **scheduling**, items such as **the evaluation objective, the resources needed to perform an evaluation, and the evaluation arguments** should be considered.

**Process Area: Organizational Training (OT)**

**Purpose:** in this process area, training needs are identified to implement the organization's strategy. In practice, training is provided for skills development and guides the organization's employees to perform a set of standard organizational processes. The main components of the training include: training plan management and development; plan documentation; employees with up-to-date knowledge; and mechanisms to measure the effectiveness of the training plan.




**Further description:** an organizational training plan includes the following activities:

- Identify training required by the organization.
- Provide training to meet these needs.
- Create and maintain training capabilities.
- Create and maintain educational records.
- Evaluate the effectiveness of the training.

Identifying the training needs for the process is based on the skills required to perform the standard set of processes in the organization. *Skills and knowledge can be technical, organizational, or contextual.* ***Technical skills*** concern the ability to use the equipment, tools, materials, data, and processes required by a project or process. ***Organizational skills*** are related to behaviors relevant to the organizational structure, roles and responsibilities, and the principles and operating methods of employees. ***Contextual skills*** include self-management, communication, and interpersonal skills for the successful performance of work in the organizational and social context on projects and support groups.

**Note:**

Organizational training is provided to:

1- Support the strategic business objectives of the organization.
2- Meeting educational needs (in projects and support groups).

### Advanced Process Areas: Process Management

Advanced process areas of process management improve an organization's capacity to achieve quantitative (numerical) objectives of quality and process implementation objectives.[12]

Each of the advanced process areas of process management depends on the **organization's ability** to develop organizational processes and support assets. The **basic process areas of process management** prepare the ground this.

### Process Area: Organizational Process Performance (OPP)

**Purpose:** quantitative (numerical) objectives are defined according to the business objectives of the organization to achieve the quality objectives and process performance objectives. The organization prepares projects and support groups using the most common measurements, a process baseline, and process implementation models.

**Further Description:** this process area includes a number of activities:

- Establish organizational quantitative quality objectives and process performance objectives based on the business objectives.
- Select processes or sub-processes to analyze process performance.
- Create definitions for the actions used in process performance analysis.
- Create process performance basics and process performance models.
- Data collection and analysis and the creation of process performance baselines and process performance models can be undertaken at different levels of the organization according to the needs of projects and the organization.

The expected process performance can be used to determine project quality objectives and process performance objectives. They can be used to set a baseline against which actual project performance can be compared. This information is used for quantitative project management.

The actual performance results become part of the organizational process assets (available to all projects). Process performance models are used to show past and present process performance and predict future process outcomes.

For example, hidden defects in delivered products can be predicted by measuring work product features (such as complexity) and process features (such as preparation time for peer review).

As such, the organization can do the following:

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[12] Taken from the business objectives of the organization.

- Determine whether processes behave consistently or show a consistent trend (are they predictable?).
- Identify processes in which performance is within normal limits.
- Identify processes that exhibit unusual behavior (e.g. scattered, unpredictable).
- Identify aspects of processes that can be improved in the organization's standard processes set.
- Identify the process that shows the best performance in implementation.

Established and maintained assets in this process area (e.g. actions used to describe sub-process behavior, basics of process performance, and process performance models) are inputs for the process areas of quantitative project management, causal analysis and resolution, and organizational performance management.

**Process Area: Organizational Performance Management (OPM)**

**Purpose:** to proactively manage performance and achieve the business objectives of the organization. This also includes the analysis of the process performance baseline, the organization's ability to achieve its business objectives and quality outcomes, and the process performance objectives.

According to this concept, the performance of an organization is improved by the active choices of the organization and increasing development and improvement in innovation, so that they can be measured.

This process area enables the organization to manage the organization's performance by:

1- Duplicate analysis of the collected data of the project.
2- Identifying performance gaps against business objectives.
3- Selecting and deploying progressive action to remove this gap.

**Further Description:** this process area supports the process area of organizational process definition to guarantee the quality objectives of the project and process implementation and support quantitative (numerical) management.

The organization analyzes data collected from process definition performance to develop a quantitative (numerical) concept of product quality, service quality, and process performance. In this area of the process, the term **improvement** includes all **technological innovations and**

**improvements.** These improvements are made for the project work environment.

**Note:**
**Improvement** refers to all ideas that will change the ***processes, technologies, and performance of the organization*** so as to better achieve the ***business objectives of the organization*** and ***related quality objectives.***

The business objectives for this process area are:

- Improving manufacturing quality.
- Increasing productivity.
- Reducing the time cycle.
- Increasing process efficiency and effectiveness.
- Increasing stability while fulfilling the budget and schedule.
- Increasing satisfaction for customers and end-users.
- Reducing development or manufacturing times to adjust performance, add new features, or adapt to new technologies.
- Improving supplier cycle performance and increasing suppliers.
- Improving resource utilization throughout the organization.

The organization can proactively identify and require **enhancements and improvements in innovation** through use of the following:

- ✓ **The internal resources of the organization**, including employees, other similar units of the organization, dissimilar units of the organization, customer feedback and complaints, and after-sales service and warranties.
- ✓ **External resources**, including university faculty members, competitors, and being in conscious competition with them, as well as the implementation of successful improvements taken from other organizations.

Understanding improvements and their impact on quality objectives and process performance objectives depends on the organization's ability to effectively **identify, evaluate, implement, and develop process improvements.** Long-term planning is needed to understand the effects of improvements and benefits, as well as how to deploy labor and identify, evaluate, and maintain improvements, including the identification of innovations.

**Note:**
**Long-term planning** is necessary for:
- ✓ *Understanding the effects of improvements and benefits.*

**Employing skilled personnel** is necessary to:
- ✓ *Identify and evaluate possible improvements.*
- ✓ *Maintain improvements.*
- ✓ *Identify innovations.*

Proposals for improvement are purposed, evaluated, and validated according to their ***impact on the environment***. Based on this evaluation, improvements are prioritized and selected for new development, as well as project continuation. According to the development plan, performance-related data is collected, and the effects of improvement on quality objectives and process performance objectives are analyzed using statistical and other quantitative techniques.

The improvement cycle seeks to continuously optimize organizational processes based on quality objectives and process performance objectives. Business objectives are revisited periodically to ensure their proper performance and, if necessary, the objectives are updated according to the appropriate schedule.

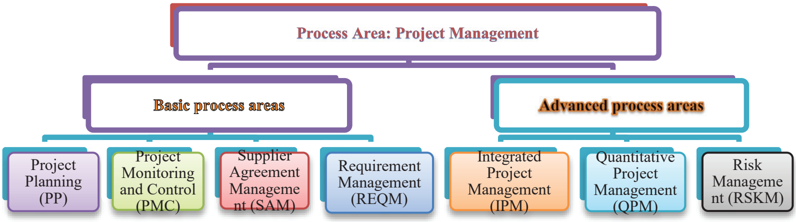
Note that, in this area of the process, the selection of improvements for development is based on a quantitative (numerical) concept of the potential benefits and estimated costs of the improvement options. The organization can also adjust its business quality objectives and process performance objectives as appropriate.

It is worth noting that this process area extends the measures of organizational process by focusing on process improvements based on a quantitative understanding of a standard set of processes and technologies, their expected quality, and the expected performance of processes in the organization.

**2- Project Management**

Organization are involved in several projects or plans that deliver products. Project management process areas cover reports about project management activities in project planning, monitoring, and control.

The seven process areas of project management in the CMMI-Dev model are shown in the following figure.




### Basic process areas of project management

These areas of the process include the activities of project planning; creating and maintaining commitments and obligations; monitoring progress in comparison to the plan and program; taking corrective actions; and managing agreements with suppliers.

### Process Area: Project Planning (PP)

**Purpose:** to establish and maintain plans that define project activities, such as project progress planning, involving relevant investors, obtaining commitments to provide planning requirements; and adhering to the plan.

**Further Description:** Planning begins with the product and project requirements and needs (in other words, what is to be built). The impact of other related investor plans on the project is investigated and investor commitments and obligations to cooperate with the project are reviewed. For example, such plans cover items such as configuration management, investigation, and measurement and analysis.

> **Note:**
> The project planning includes all key elements, including project definition, resource allocation, staff, budget, and schedule.

The project planning process area includes the following activities:

- Development of the project plan.
- Proper interaction with relevant stakeholders.
- Commitment to the plan.
- Maintaining adherence to the plan.

Planning includes estimating the features of work products and tasks, determining the required resources, negotiating the commitments, producing the schedule, and identifying and analyzing the project risks.

The project plan is usually modified as the project progresses to address changes in requirements and ***commitments***,[13] dealing with incorrect ***estimates***,[14] taking corrective actions, and following trend changes. Teams usually do not anticipate beyond what is known about a project or repetition of past conditions, except for risks, major events, and far-reaching implications and limitations.

**Process Area: Project Monitoring and Control (PMC)**

**Purpose:** to consider methods for controlling and monitoring activities and performing the correct activities.[15] It is also important to monitor the progress of the project plan, determine the frequency of progress checkpoints, and measure and determine deviations.

**Further Description:** progress is primarily determined by comparing the actual job and task specifications, efforts made, the cost, and the schedule to the plan. Proper visibility allows timely corrective action to be taken if performance has significantly deviated from the plan. Deviation is important if it is not resolved in that it prevents the project from achieving its objectives. These actions may require periodic re-planning, including revision of the original plan, creating new agreements, or additional mitigation actions in the current plan.

**Process area: Supplier Agreement Management (SAM)**

**Purpose:** the management of products obtained/purchased from a supplier.

**Further description:** this area of the process involves determining project needs. This determines the components produced by the supplier. Manufacturing resources are proactively identified (due to their importance for further satisfaction of project needs); the supplier is selected; and agreement with the supplier is established.

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[13] Commitment to the schedule is indicated when:

1- Tasks are assigned and accepted during iterative scheduling.
2- User stories are described or estimated.
3- Iterations are maintained.

[14] Estimates: representing repetition and team-specific factors that affect time, effort, resources, and risks for performing repetition.

[15] Efficiency is measured by the number of resources used to perform a particular activity and increasing efficiency means reducing the wastage of resources in performing an activity. Effectiveness is measured by the degree to which activities are aligned with the determining objectives. Thus, increasing effectiveness means that project activities become more aligned with the objectives.

Supplier performance improvement is pursued particularly in agreement with the supplier and the agreement is amended accordingly. Checks and acceptance tests on supplier-manufacturer product components are also carried out under these amendments.

The manufacturer must agree with the supplier on the schedule, the budget, critical steps to be taken, meetings on status, quality reviews, and the acceptance of criteria. This area of the process can also be used to benefit the project (such as purchasing materials).

The business objectives of this process area should include:

- Determining the type of product required for manufacture.
- The selection of suppliers.
- Establishing and maintaining agreements with suppliers.
- Implementation of the agreement with the supplier.
- Accepting and receiving the manufactured products.
- Ensuring the successful transfer of manufactured products.

Suppliers can meet most business-related needs, including in-house suppliers (such as suppliers who are in the same organization and are not outside the project), suppliers making parts outside the organization, suppliers with reputable books and references, and commercial suppliers.

An agreement with a supplier is created to manage the relationship between the organization and the supplier. The agreement is written between the organization (project provider) and the supplier. This agreement can be a contract (commitment), license, agreement of service level, or an agreement note. The product obtained from the supplier for the project will be delivered under the supplier agreement.

**Process Area: Requirement Management (REQM)**

**Purpose:** taking appropriate steps to ensure management of the set needs to support the planning and implement of project needs. As such, it describes the steps needed to control required changes and ensure the promotion and maintenance of other related plans and data. It also ensures the existence of *requirement management* in project products and discipline between requirements and project planning and work products. These requirements can be *traced to the customer's needs* in defining the product and product components.

**Further Description:** This area of the process ensures that changes in requirements are reflected in the project planning, activities, and products. This cycle of change can affect the engineering process and, therefore, requirement management is a dynamic process area and will often take the form of a continuous sequence of events. This process area is essential for control and discipline in the engineering process area. Existing processes in this process area manage all the general or received requirements of the project, including both technical and non-technical requirements.[16]

Engaging in appropriate activities, the project team ensures that a set of requirement verifications are managed to support project planning and implementation needs. The requirements provider and requirements receiver are identified in the project parts and sections. The project team manages any necessary changes to the requirements and can infer and identify any instabilities.[17]

Once a project's needs are defined, they are reviewed with the needs provider to resolve any issues and prevent misunderstandings before being included in the project plans. Once the supplier and needs recipient have agreed on terms, the project participants have a commitment on requirements.

As the project evolves, necessary changes are managed and inconsistencies between plans, work products, and needs are identified.

Part of the management requirements is the documentation of changes in requirements and their logic; two-way traceability between source requirements, product needs, product components, and other work products is maintained.

Changes occur according to changes in existing requirements, designs, or implementation.

Measures that maintain requirements are based on changes in creating, designing, or implementing requirements. In projects that require increased manufacturing capacity, changes can be due to: the inference of customer needs; technological maturity; technological obsolescence; and standard inference. Changes in requirements can also result from changes in customer or end-user needs and new requirements in process development.

### Advanced Process Areas of Project Management

Activities that should be done in these areas of the process are: the creation of a process definition based on a set of standard organizational processes; the creation of a project work environment based on the organization's work-environment standards; integration and cooperation with relevant investors; forming and maintaining groups to lead projects; quantitative (numerical) management of projects; and risk management.

Each advanced process area of project management depends on the organization's ability to plan, monitor, and control the project. Basic project management process areas provide this ability.

### Process Area: Integrated Project Management (IPM)

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[16] Non-technical requirements such as the creation of project tax requirements by the organization.

[17] These instabilities may occur in schedules, work products, and requirements.

**Purpose:** using the process definition in the management of the project. The process definition of a project is created and maintained based on a set of organizational standard processes.

Relevant stakeholders should also:

(1) Perform their duties in a coordinated and timely manner.
(2) Address project needs, plans, objectives, problems, and risks.
(3) Fulfill commitments.
(4) Identify, track, and resolve coordination issues.

**Further Description:** the project uses organizational process assets to create and maintain organizational work-environment standards; groups are also created using the rules and guidelines of the organization. Project-related investors are integrated through identifying, negotiating, and tracking critical dependencies, as well finding solutions to mitigate these dependencies. *Involving stakeholders in the project is a key element for effective management*. In a successful project, all relevant stakeholders are involved in the management, planning, and reporting of the project.

This process area also refers to the coordination of all project-related activities, including the following:

- **Development activities** (e.g. needs development, design, and verification).
- **Service activities** (e.g. delivery, help desk, operations, and customer contact).
- **Acquisition activities** (e.g. requests, monitoring of the agreement, and transferals to operations).
- **Support activities** (e.g. configuration management, documentation, marketing, and training).

### Process area: Quantitative Project Management (QPM)

**Purpose:** achieving quality objectives and process performance objectives based on organization and customer objectives, and using project quantitative analysis. An appropriate definition of the process can help achieve these objectives and manage projects quantitatively.

**Further Description:** techniques in this process area help us gain some understanding of the expected performance of processes or sub-processes. This understanding is used as the basis for establishing a defined process by evaluating alternative processes or sub-processes for the project and selecting items that best meet the performance quality and process objectives.

The project definition concerns a set of interrelated sub-processes forming an integrated and related process. A process definition is created to achieve project quality and process performance objectives. The process definition involves the use of a combination of statistical techniques and other quantitative (numerical) techniques for better process management and increased manufacturing quality. Measurement data[18] must be collected from all critical processes and management activities. These measurements can provide valuable insight into project performance and using them, an analyst can predict whether the project will achieve its quality and process performance objectives.

Based on forecasts, the project's process definition can be adjusted or changes can be made towards achieving the quality and process performance objectives. As the project progresses, the implementation of selected sub-processes[19] must be closely and carefully monitored to determine if the project is on track to achieve its objectives.

The quantitative management methods of the project, unlike the integrated project management methods, help to develop processes or sub-processes with the quantitative concept of expected performance. These methods include:

- ➢ Selection of sub-processes and critical signs for performance monitoring and achieving quality and process performance objectives for the project process.
- ➢ Selection of measurement and analysis techniques for use in quantitative project management.
- ➢ Monitoring the performance of selected sub-processes using statistical and other quantitative techniques, and determining whether the quality and process performance objectives are satisfactory.
- ➢ Analysis of the causes of incomplete performance in selected processes and sub-processes.

Establishing effective communication with the supplier is also important for the successful implementation of this area of the process. Effective communication can involve the specification of quality and process performance objectives for the supplier. Effective communication can also use measurements and analysis techniques to gain insight into supplier performance and progress. It is easier to monitor supplier progress to achieve the quality and process performance objectives of the project.

[18] Data collection for quality objectives and process performance objectives.
[19] The selected sub-process is obtained by evaluating alternative processes or sub-processes and selecting the most appropriate one.

***An essential element of quality management is trust in forecasts*** (with the ability to forecast accurately and extensively so that the project can meet its quality and process performance objectives). Sub-processes are managed using statistical techniques and other analysis techniques are selected and used based on the process performance forecasting requirements.

***Another essential element of quantitative management is the broad concept of diverse expectations in process performance and the identification of the most appropriate one. Quantitative management, therefore, requires statistically correct thinking and the correct use of a variety of statistical techniques.***[20]

Process Area: Risk Management (RSKM)

**Purpose:** to identify potential problems before they occur so that activities for risk reduction can be designed and implemented throughout the life of the product or project. As a result, contradictions and pressures on achieving the objectives are reduced.

**Further description:** risk management is a continuous process that looks to the future[21] and this is an important part of project management. Risk management includes items that can delay the achievement of objectives in times of crisis and that might put the project at risk. Risk management activities are used for the identification of risk parameters, risk detection, and risk assessment.

Risk management considers both "inside" and "outside" the project, including: technical and non-technical concepts; cost sources; schedule; performance; and other risks. A quick and thorough inspection of the risk is also important because reducing and eliminating risk is typically easier and less expensive than dealing with it later, and the sooner changes to the steps of the project are made, the more likely everything will work correctly. The risk management method is as follows:

- Define a risk management strategy.
- Identify and analyze the risks.
- Investigate risk identification and use risk reduction plans as needed.[22]

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[20] Statistical techniques are used in two parts of the project: measuring the actual performance of the project and determining the extent of deviation from the plan and predicting project expectations for the achievement of quality and process performance objectives.

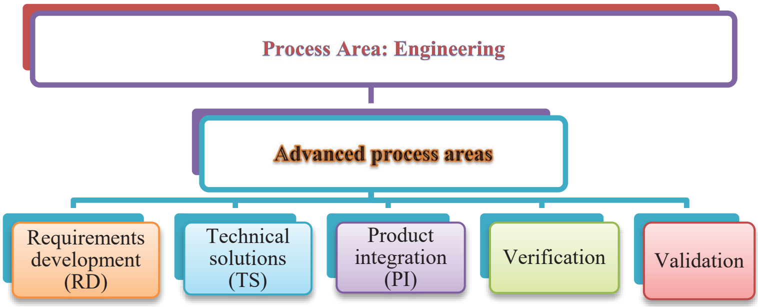
[21] Continuously and progressively.

[22] Consider reasonable risks in any work and reduce existing risks to a reasonable level. A reasonable level of risk can be defined as $\frac{1}{3}$ of potential profit.

### 3- Engineering process areas

Engineering process areas integrate the following: processes related to the various disciplines of engineering in the development process of a single product[23]; support for products that tend to have a process improvement strategy; and a strategy that focuses on the essential objectives of business versus specific technical disciplines. As such, it prevents effective processes from tending towards an "iron spirit in the organization."

The five engineering process areas in the CMMI-Dev model are shown in the following figure.




### Process Area: Requirements Development (RD)

**Purpose:** to identify customer needs and translate these needs into product requirements. In other words, to deduce, analyze, and create customer needs, product requirements, and product component requirements.

**Further Description:** analyze a set of customer needs to produce a high-level concept solution in determining product requirements. This set of requirements is compiled to create the first set of product component requirements. Other requirements that help define the product are deduced and collected for the product components. This set of product requirements and product components describes the following: product performance; properties and qualities; design features; and verification requirements.

This area of the process describes three types of requirement: customer needs, product requirements, and product component requirements.

[23] Products that need to be assembled (with several components forming a unit).

These requirements also include the requirements of investors, such as those related to different steps of the product life cycle (e.g. accepting a crisis test); signs of manufacture (such as reactions, safety, validity, and maintainability); and requirements related to constraints created by the choice of design solutions (such as the integration of commercial products or the use of a particular architectural pattern).

All projects have development requirements, but design requirements provide the basis. The business objectives that this process area should include are:

- Inference, analysis, validation, and correlation of customer needs, expectations, and constraints to fulfill customer preferences.
- Collection and integration of investor needs.
- Development of product life cycle requirements.
- Development of expected product performance requirements for the customer and quality indicators.
- Creation of first product requirements and product component requirements related to customer needs.

A needs and requirements analysis for each step of the product life cycle reflects *customer expectations* and includes: the needs of investors; the operating environment; end-user satisfaction; health and safety; and affordability.

This area of the process includes all customer needs related to product level requirements because the customer can also have special design requirements.

In the future, it is necessary to define customer needs for product requirements and product component requirements. Customer needs also determine the design solutions selected to fulfil the product requirements and product component requirements.

Requirements are identified and redefined at all steps of the product life cycle. The following are also analyzed to determine the various pressures on requirements: design decisions; appropriate actions for sub-process; and feedback during each step of the life cycle.

This process area includes the specific purpose of customer needs development. This specific purpose defines a set of customer needs for use in product requirements development. The specific purpose of product requirements development defines a set of requirements for the product or product components for use in the product design. Furthermore, the specific purpose of requirements analysis and validation is to analyze customer needs, product requirements, and product component requirements to define, infer, and understand the needs and requirements. Processes related to the requirements development process area and processes related to the technical solution process area interact with each other.

Requirements together with quality indicators in product performance describe what products to produce. This definition can include the description, decomposition, and separation of product functions.

The requirements definition also specifies considerations or constraints on how the requirements will be practically understood in the project. Quality indicators also include the following: product availability; maintenance; modifiability; shortened timeframes; responsiveness; and security.

Such analyses continuously occur and are mostly available in more detailed sections. Successful analysis of the process product architecture offers detail on design, product manufacture, and product testing, and includes the following considerations:

- Limitations on diversity.
- Imitable technologies.
- Resulting costs.
- Resulting time constraints and scheduling.
- Dangers and risks.
- Considerations of customers or end-users.
- Introduction of factors through business considerations of the developer unit, rules, and regulations.

For manufacturing lines, engineering processes (including requirements development) may be applied to at least two levels of the organization: at the product line level and the project level. At *the level of the organization's product line*, an analysis of employee opinions and product credibility is performed to help infer, analyze, and generate the primary assets for the project's manufacturing line. At *the project level*, these assets are used and then the product line is planned as part of the project's engineering activities.

The term "requirements" is used in the technical solution process area. Requirements are reflected in the product architecture, product design, and product components (e.g. by coding and construction). Requirements also provide the product integration process area because the components of the product are combined and the relationship between them must be confirmed. As a result, it is necessary to ensure that they have met the interface requirements (as determined by the development of requirements).

**Process area: Technical solution (TS)**

**Purpose:** to select, design, and implement solutions to achieve the requirements of the product, product components, and throughout the product life cycle.

**Further description:** datasets of design details for the product components are produced and developed (to be used in the product integration process area). Once the product component requirements have been identified, defined, and assigned, engineers need to answer the following questions: how will the product components be produced? Does the organization need to undergo development to produce them? Is it necessary to adopt a subcontract along with the contractor? Alternatively, should a subcontractor be brought in from outside the organization?

Choosing appropriate solutions requires additional information on the specifications of potential design solutions (using quality features,[24] simulations, and prototypes[25]). In this area of the process, it is necessary to select from alternative solutions (in choosing the optimal design) for "crisis" situations. It is worth noting that such a crisis can vary significantly for each product, depending on the product type, the operating environment, the implementation requirements, the support requirements, and cost, schedule, and delivery.

**Note:**
It can be said that the technical solution process area focuses on the following:

- Evaluation and selection of solutions that can meet the appropriate performance and quality requirements.
- Careful development of designs along with details for the selected solutions.
- Implementation of designs for the product or product components.

**Process area: Product integration (PI)**

**Purpose:** 1) to assemble the product using the product components; 2) to ensure that the assembled product behaves properly and seamlessly (i.e. it has the necessary quality features and performances); and 3) to deliver the product to the customer.

**Further description:** product integration goes beyond assembling product components at the end of the design stage and manufacturing just once. Product integration can be done gradually, using an iterative process of

[24] Quality methods for creating quality features will be reviewed in later chapters.
[25] Prototypes can be used to gain sufficient knowledge to prepare a technical dataset or complete a set of requirements.

assembling product components, evaluating them, and then assembling more product components.[26] Product integration can also be done continuously using highly automated devices; however, the final product must be tested to ensure device performance and correct manufacture. This testing process can begin with analysis and simulation (e.g. use of rapid prototypes, virtual prototypes, and physical prototypes)[27] and continue on to achieve the final product. For some products, the final step of integration occurs when they are deployed on site.

Interface management should be considered during the project. Indeed, an important aspect of product integration is the management of internal and external interfaces of products and product components to ensure compatibility. This compatibility is not limited to user and customer interfaces, but also to interfaces between product components, internal and external data sources, middleware, and other components that may not be under the control of the organization although the product relies on them.

**Process area: Verification**

**Purpose:** to ensure that the products meet the specified requirements.

**Further Introduction:** this process area concerns the verification of work products and methods to examine the compliance of products with the specified requirements (including those for the customer, product, and product components). For manufacturing lines, core assets and related product line change mechanisms must also be verified. In general, verification is an incremental process, beginning with the verification of product components and usually ending with the verification of the fully assembled product.

Verification also includes making "repeated visits" to the work location.

**Note:**
The making of "similar visits" is a proven way to eliminate defects early on and provide valuable insight into work products and product components being developed and maintained.

[26] That is, each product may be made of several parts (and these parts are made of other sub-parts).
[27] The choice of prototyping depends on the performance of the design tools, product complexity, and associated risks.

Verification methods and criteria must comply with the requirements, methods, and environmental specifications of the work products. Verification is done according to existing methods and criteria.

**Validation indicates that the product meets its intended use, while verification indicates whether the product properly reflects the specified needs.** In other words, *verification ensures that you made the product correctly, whereas validation ensures that you have made the correct product.* The important result is to create a better understanding of the work products and processes to avoid defects and identify opportunities for process improvement.

**Process area: Validation**

**Purpose:** to validate products according to customer needs, thus, the product or component of the product (if placed in the desired environment) is checked as to whether it fulfills its intended use.

**Further description:** validation can be done in the operating environment or an environment similar to the operating environment. Coordinating with the customer on the verification of requirements is an important element of this process area.

The scope of the validation process area covers the validation of products, product components, selected intermediate products, and processes. These valid elements often need to be re-verified and re-validated. Issues discovered during validation are usually resolved in the process area of requirements development or technical solutions.

Validation activities can be applied to all aspects of the product, including operations, training, manufacturing, and maintenance and support services. Validation activities use similar verification approaches (e.g. testing, analysis, inspection, demonstration, or simulation).

**Return to and repetition of engineering processes**

Most process standards agree that there are two ways in which processes can be used. These are called return and repetition.

**Return**

A process uses the successful experiences of system elements within the system structure. Performance successes are used as inputs for the next step in the system structure. For example, the verification process is designed to use and inspect the assembled product, the main product components, and even the sub-components. In other words, how much of the verification process is used in the product depends entirely on the size and complexity of the finished product.

It is worth noting that the project management process area can also be a return.

**Repetition**

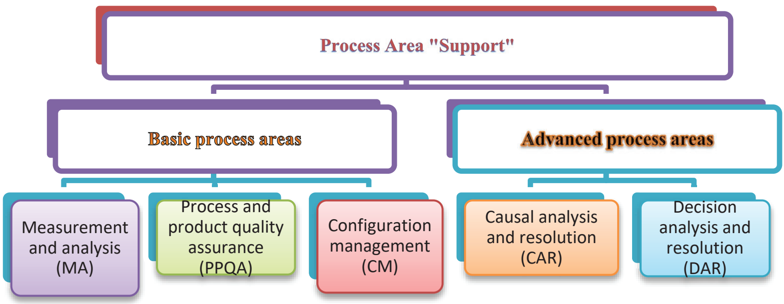
This is when processes are repeated at the same level of the system. New information is generated using feedback in the process report. Typically, this new information raises questions that need to be resolved before completing the process.

For example, repetition is likely to occur between requirements development and technical solutions. Reusing processes can resolve the questions raised. Initially, repetition can ensure the quality needed to execute the next process. The engineering processes (e.g. requirements development and verification) are repeatedly applied to a product to ensure that they have been performed consistently before delivery to the customer. As such, engineering processes use product details. For example, several questions (concerning processes related to the verification and validation process areas) can be resolved in the process areas related to requirements development and/or product integration. The return and repetition of these processes can ensure that the project meets quality requirements for all product components before it is delivered to the customer.

**4- Supporting Process Areas**

Supporting process areas cover activities that support product development and maintenance. Supporting process areas see the use of core process to perform other processes. In general, supporting process areas include processes that are focused on achieving the project objectives, as well as processes that are mostly internal to the organization.

For example, product and process quality assurance can be applied to all areas of the process. The five areas of the support process in the CMMI-Dev model are shown in the following figure.



### Basic process areas of "support"

The basic process areas of "support" include basic support performances that are used by all process areas.

### Process area: Measurement and Analysis (MA)

**Purpose:** to guide projects and organizations with measurement methods in coordination with measurement requirements and objectives and to support information management needs. The results can be used to understand appropriate decisions and corrective actions that are necessary, as well as to develop and sustain measurement capabilities (which are used to support management information needs).

**Further description:** the analysis and measurement process area includes the following actions:

- Determine the objectives of measurement and analysis to identify the information needed to adjust the objectives of the project, organization, or business.
- Identify techniques and mechanisms of measurement and analysis for data collection, storage, reporting, and feedback.
- Prepare the results of the objectives to be used in making informed decisions and taking suitable (appropriate) actions.

The integration of measurement and analysis supports the project processes through:

- Planning and estimating objectives.
- The pursuit of real accomplishment and progress versus anticipated plans and objectives.
- Identifying and resolving incomplete processes.
- Preparing a basis for the unified measurement of additional future processes.

Measuring and analyzing product components provided by suppliers is essential for the effective management of quality and of project costs. With careful management of supplier agreements, we can provide insightful supporting data on supplier performance analysis. Measurement objectives for information needs are derived from project, organizational, and business objectives.

### Process area: Process and Product Quality Assurance (PPQA)

**Purpose:** to provide an objective view of employees and management about related work processes and products.

It also supports all process areas with the preparation of special methods for assessing the reality of performed processes, work products, and services versus the description of processes, standards, and methods.

**Further description:** the delivery of high-quality products is supported by:

- Evaluation of processes and work products versus applicable descriptions, standards, and procedures.
- Identification and documentation of inconsistencies.
- Provide feedback to employees and project managers on the results of quality assurance activities.
- Product quality assurance at all levels.
- Feedback on related work products and processes over the life of the project.

To support quality assurance activities, checklists for process descriptions, standards, and procedures are available. Non-compliant items are recorded through peer review and followed up if necessary. Related work products and processes are identified and evaluated throughout the project.

Determination of these elements can be based on sampling or criteria consistent with organizational policies and process and project needs. Once inconsistencies are identified, they are addressed within the project and resolved where possible.

Process Area: Configuration Management (CM)

**Purpose:** to establish and maintain product integration in configuration identification, configuration control, configuration status calculation, and configuration investigation. Configuration management ensures that the delivered product is reproducible, traceable, testable, and verifiable before release.

**Further description:** The configuration management process area has the following actions:

- Identify the configuration of selected work products that form the baseline at a spatial and temporal point.
- Control change for configuration items.
- Recognize the manufacture or purchase of work products in the configuration management system.
- Integrate maintenance of the baseline.
- Prepare common data auditing and configuration for developers, end-users, and customers.

Work products under configuration management include: a) products delivered to the customer; b) the interior design of work products; c) obtained products; and d) tools and other components used in creating and describing these work products.

In (c), it is necessary for both the supplier and the project to come under configuration management. Conditions (rules) for conducting configuration management must be established in agreement with the supplier. Methods must be established and maintained to ensure complete and consistent data.

Part (d) concerns: planning; process descriptions; requirements; data design; drawings and maps; product specifications; coding; components (compilers); product data files; and product technical publications.

Product configuration management may be implemented on several levels. Thus, the baseline offers a strong basis for further evaluation of configuration items. Extended baselines are also added to the configuration management system. Changes in the baseline and releases of work products are reviewed in configuration management. Configuration management is systematically controlled and monitored by configuration control, change management, and configuration inspection.

**Note:**
Work products that are subject to configuration management include: products that are delivered to the customer; designated internal work products; purchased products; tools; and other items used to create and describe these work products.

**- Advanced process supporting areas**

Advanced process supporting areas are used to prepare projects and the organization by improving capacity for support. Each of these process areas relies on specific inputs or methods from other process areas.

**Process area: Causal Analysis and Resolution (CAR)**

**Purpose:** to identify the causes of "selected victories" and take action to improve the implementation of the process.

**Further description:** this area of the process identifies quality and productivity by preventing defects or problems and improving the success of the process properly and seamlessly. In this area of the process, the following steps are performed:

- **Identification and analysis of the causes of selected victories.** Selected victories can provide solutions that may prevent future defects and problems, or may be successful in the projects or organizations in which they are employed.
- **Steps for completing this area of the process include:**
  - Eliminate defects and prevent the recurrence of defects and problems in the future.
  - Data is actively collected and analyzed to identify potential problems and take corrective action.

- ❖ Integrating process success will help improve process performance in the future.

Project members identify the causes of selected successes and prevent negative outcomes or reinforce positive outcomes in the future. The initial definition of the project processes is proposed and the roots and causes of defects are analyzed along with activity planning to identify effective process changes for improvement. Thus, a set of organizational standard processes is created.

Performing a causal analysis for all victories is impractical and the objects are selected according to the estimation of assets and business objectives of the organization; they can be estimated in terms of quality, productivity, and time cycle.

**Process Area: Decision Analysis and Resolution (DAR)**

**Purpose:** to analyze possible decisions in the formal evaluation of the process to identify alternatives in the event of a crisis.

**Further description:** decisions must be made at all stages of the manufacturing and product life cycle. These decisions, as with risks, must be properly managed to ensure standardized solutions. This process area supports all process areas and the reasonableness of the issues must be determined in the formal evaluation of the process.

Formal evaluation of the process involves the following actions:

- ➢ Evaluate alternatives in times of crisis.
- ➢ Identify alternative solutions.
- ➢ Select appropriate methods to evaluate the alternatives.
- ➢ Use properly evaluated alternative solutions in times of crisis.
- ➢ Assess the crisis and select properly evaluated alternative solutions.

The formal evaluation of a process can include the following: make the decision to buy or build; develop manufacturing processes; select suppliers; select distribution locations; and other decisions. Guidelines are used for decision-making when formal evaluation of processes involves unplanned issues. Guidelines often suggest the use of formal process evaluations, especially with issues related to risks or moderate to severe pressures; or when they affect the ability to achieve project objectives.[28]

The final solution may involve the repetitive activities of identification and evaluation, such as how the various parts of the identified options can be combined; how emerging technologies can change the options

[28] Do not forget that documenting formal evaluation processes will also help the organization in the future.

available; and how the supplier's business status can change during the evaluation period.

**General Methods and Special Methods**

In each area of the process, clear guidance is needed on implementation and improvement. To this end, objectives and methods to determine the best pathways in the process areas are described. Each of objective and method can be divided into general and specific parts. It is worth noting that general objectives are synonymous with maturity levels and general objectives consist of general methods. It can be said that the general methods provide guidelines for achieving general objectives and subsequently achieving maturity levels in the CMMI-Dev model.

**1- Specific Objectives**

Specific objectives describe the unique features that must be achieved to satisfy the process area.

An example of a specific objective in the configuration management process area is the *integration and maintenance of the created baseline.*

The following presents specific objectives for the process areas of CMMI.

| OPF | |
|---|---|
| SO1 | Determine Process Improvement Opportunities |
| SO2 | Plan and Implement Process Actions |
| SO3 | Deploy Organizational Process Assets and Incorporate Experiences |
| **OPD** | |
| SO1 | Establish Organizational Process Assets |
| **OPM** | |
| SO1 | Manage Business Performance |
| SO2 | Select Improvements |
| SO3 | Deploy Improvements |

| OT | |
|---|---|
| SO1 | Establish Organizational Training Capability |
| SO2 | Provide Training |
| **OPP** | |
| SO1 | Establish Performance Baselines and Models |

| REQM | |
|---|---|
| SO1 | Understand Requirements |
| SO2 | Obtain Commitment to Requirements |
| SO3 | Manage Requirements Changes |
| SO4 | Maintain Bidirectional Traceability of Requirements |
| SO5 | Ensure Alignment Between Project Work and Requirements |
| **PMC** | |
| SO1 | Monitor the Project According to the Plan |
| SO2 | Manage Corrective Action to Ensure Closure |

| PP | |
|---|---|
| SO1 | Establish Estimates |
| SO2 | Develop a Project Plan |
| SO3 | Obtain Commitment to the Plan |
| **SAM** | |
| SO1 | Establish Supplier Agreements |
| SO2 | Satisfy Supplier Agreements |

| IPM | |
|---|---|
| SO1 | Use the Project's Defined Process |
| SO2 | Coordinate and Collaborate with Relevant Stakeholders |
| RSKM | |
| SO1 | Prepare for Risk Management |
| SO2 | Identify and Analyze Risks |
| SO3 | Mitigate Risks |

| QPM | |
|---|---|
| SO1 | Prepare for Quantitative Management |
| SO2 | Quantitatively Manage the Project |

| RD | |
|---|---|
| SO1 | Develop Customer Requirements |
| SO2 | Develop Product Requirements |
| SO3 | Analyze and Validate Requirements |
| PI | |
| SO1 | Prepare for Product Integration |
| SO2 | Ensure Interface Compatibility |
| SO3 | Assemble Product Components and Deliver the Product |
| VAL | |
| SO1 | Prepare for Validation |
| SO2 | Validate Product or Product Components |

| TS | |
|---|---|
| OS1 | Select Product Component Solutions |
| SO2 | Develop the Design |
| OS2 | Implement the Product Design |
| VER | |
| SO1 | Prepare for Verification |
| SO2 | Perform Peer Reviews |
| SO3 | Verify Selected Work Products |

| CM | |
|---|---|
| SO1 | Establish Baselines |
| SO2 | Track and Control Changes |
| SO3 | Establish Integrity |
| MA | |
| SO1 | Align Measurement and Analysis Activities |
| SO2 | Provide Measurement Results |
| DAR | |
| SO1 | Evaluate Alternatives |

| PPQA | |
|---|---|
| SO1 | Objectively Evaluate Processes and Work Products |
| SO2 | Provide Objective Insight |
| CAR | |
| SO1 | Determine Causes of Defects |
| SO2 | Address Causes of Selected Outcomes |

## 2- General Objectives

General objectives are those that are used in *several* process areas.

**Note:**
The CMMI development model has five general objectives, which are synonymous with maturity; each general objective may be applied to multiple process areas.
As mentioned earlier, to achieve a specified maturity level, it is necessary to create and maintain multiple process areas.

### 3- Special methods

Specific methods describe expected actions to achieve specific objectives in a process area.

**Example:** a special method in the project control and monitoring process area is given for *monitoring requirements to identify defects and deviations in project planning.*

### Focus: Work products

Work products specify similar outputs of a special method.

**Example:** the work product for the special method of project supervision planning parameters in the project monitoring and control process area is the *recording of significant (important) deviations.*

### Focus: Sub-methods

The sub-method is the description of details that facilitate the definition and implementation of the general or specific method.

**Example:** a sub-method for the special method of taking the correct action in the project control and monitoring process area is to *determine appropriate actions for the identified issues, then implement and document them.*

### 4- General methods

The reason for naming them general methods is that they involve the **use of one method in several process areas**. **General methods** describe actions that are considered important for achieving a **general objective**. It can be said that a general method is one that involves **the expected content of the model**.

For example, a general method for the general objective of creating a process as a management process is *to provide sufficient resources to carry out the process, develop work products, and prepare process equipment.*

> **Note:**
> To achieve any general method requires the use of special methods.

Four general methods are given below in detail.

### A) Creating a process

Creation is an important concept in process improvement. Formalization of the process indicates that the process is ongoing. As such, there is commitment and consistency to the performance of the process (e.g. in implementation).

The formalization process is similar to process maintenance during times of crisis and stress.[29]

**B) Performing the process**

Process performance concerns a process that utilizes the effort necessary to satisfy specific objectives in each process area.

**C) Managing the Process**

Process management concerns the implementation of the process according to organizational policy. The organization uses the skills of its employees (including relevant investors, monitoring, controlling, and visiting) to ensure sufficient resources for the generation of controlled outputs.

Process management is related to the following: formalization of the process; achieving process-specific objectives; costs; schedule; quality objectives; and control.

> **Note:**
> Control helps ensure that the created process is maintained at critical times.

**D) Defining the process**

The definition of the process involves process management by using the set of standard processes of the organization, according to the appropriate guidelines of the organization. The definition of the process also suggests that the process is maintained. Process definition shares process experiences and methods as organizational process assets.[30]

> **Note:**
> **Organizational process assets** use "artificial products" to describe, execute, and improve processes. These artificial products are valuable assets because they are developed or achieved to meet the business objectives of the organization.

The set of standard organizational processes (which are the basis of the process definition) are created and improved. Standard processes define the basic elements (foundations) of the process that are expected in its

[29] Process recognition does not mean that the process is fixed over time and does not change; rather, by changing the objectives and requirements of the process, the implementation of the process changes accordingly.
[30] Documentation of organizational process assets.

definition. Standard processes also describe the relationships between process elements.

Each process definition provides a basis for the planning, performance, and improvement of project tasks and actions. A project may have more than one process definition (for example, one for product development and another for product testing). The process definition clearly explains the following: objectives; inputs; crisis entry; actions; roles; measurements; verification; outputs; and crisis exit.

**Communication between process areas**

As mentioned, there are connections between process areas. In particular, advanced process areas are created on the basis of basic process areas. Each process area uses the findings of the previous process area to achieve the creation, maintenance, and improvement of the objectives.

There are also connections between general methods and each general method uses the *results of the previous general method*. For example, a process definition is *based on process management* and process management is *based on process implementation.*

**Description of general objectives and general methods**

**General Objectives 1: Achieving Specific Objectives**

Specific objectives are achieved from each process area and therefore the process should support the conversion of *input* work products to *output* work products.

**- General method 1.1: Performing Special Methods**

**Purpose:** to perform the expected process using special methods for the production of work products and delivery of services. These special methods can be informally documented and planned. The accuracy of these special procedures depends on the people who manage and do the work; this varies considerably.

**General Objective 2: Establish Process Management**

Create and manage a process.

**General Method 2.1: Create an Organizational Policy**

**Purpose:** create and maintain the organizational policy for the planning and implementation of the process.

Define the organizational expectations for the process. These expectations must be accessible and visible to members of the organization. In general, senior management is responsible for creating and directing the requirements, guidelines, and expectations of the organization. Organizational policies for several process areas are given in the following.

- **Details of configuration management**
  **Policy:** develop organizational expectations for creating and maintaining a baseline and track and control changes for work products (under configuration management).
- **Details of decision analysis and resolution**
  **Policy:** create organizational expectations for the selection and analysis of possible decisions in the formal evaluation of the process to evaluate the identification of alternatives in times of crisis. This will also guide what decisions are needed in the formal evaluation of process. The analysis systematically includes the causes of the chosen victories.
- **Details of Project Management Integration**
  **Policy:** organizational expectations are created and maintained to define the project process from the start to the end of the project life cycle. The project process definition is used in project management and collaboration with investors.
- **Details of Measurement and Analysis**
  **Policy:** create organizational expectations for setting measurement objectives/measures and preparing measurement results by identifying the information needs and objectives of the project, organization, or business.
- **Details of the Definition of Organizational Processes**
  **Policy:** create organizational expectations for the creation and maintenance of a standard set of processes in evaluating organizational process assets throughout the organization and create appropriate rules and guidelines.
- **Details of Focus on Process Concentration**
  **Policy:** create organizational expectations to determine process improvement opportunities in planning, implementing, and developing process improvements throughout the organization.
- **Details of Organizational Performance Management**
  **Policy:** create organizational expectations for the analysis of business performance using statistical and other quantitative techniques. Cooperation is necessary to achieve the quality and performance objectives of the process. Organizational expectations are also used to determine performance deficiencies, identify and develop processes, and improve technology.
- **Details of Organizational Process Performance**
  **Policy:** create organizational expectations for creating and maintaining a process performance baseline and creating and maintaining process performance models based on the set of standard processes of the organization.

- **Details of Organizational Training**

  **Policy:** organizational expectations are prepared and identified to identify the organizational training strategy with subsequent training.

**General Method 2.2: Process Planning**

**Creating and maintaining a plan to perform the process**

**Purpose:** to determine what is needed to perform the process. The objectives of creation in the preparation of the plan are obtained from documenting the process performance plan, preparing the process description, and agreeing the plan with relevant investors. This general approach may reinforce the set of expectations of other parts or lead to a new set of expectations.

After creating the plan, documentation of the plan is completed as follows: maintain the plan; update it to reflect corrective actions; and change the requirements or objectives.

**Sub-methods**

1- Planning for process performance should be defined and documented.

2- The process description should be defined and documented.

3- The process description includes the standards and procedures.

4- The plan review involves a review of satisfactory processes to determine the impact of the policies used and then review the planned actions, requirements/needs, and standards to ensure the plan for relevant investors.

5- If necessary, revise the plan.

**General method 2.3: Preparation of Resources**

Provide sufficient resources for performing the process, developing work products, and providing process equipment.

**Objective:** to ensure that the necessary resources are available to perform the process when needed, as defined in the plan. Resources include an adequate budget, appropriate physical facilities, skilled staff, and appropriate tools and equipment.

**General Method 2.4: Definition of Responsibility**

Responsibility and power are defined in terms of performing processes, developing work products, and preparing process services.

**Purpose:** to ensure responsiveness in the performance of the process and achieve specific results throughout the life of the product. Also, to ensure that employees have the appropriate powers to meet their designated responsibilities.

One’s responsibility may determine and document the use of work details. The planning of process performance is used to determine and document work details.

**Sub-methods**

1- General responsibility and power should be determined for the performance of the process.
2- Responsibility and power should be determined for the performance of special tasks in the process.
3- Confirm that designated employees understand and have the appropriate levels of responsibility and power.

**General Method 2.5: Training Employees**

Train employees to perform processes or support processes as needed.

**Purpose:** to ensure that employees are trained in the necessary skills, have suitable experience, are able to exchange ideas with colleagues, and help each other progress. Employees should be trained in the skills and knowledge required for the performance of the process.

**General method 2.6: Configuration Management (control of work products)**

Put selected work products of process under the appropriate level of control.

**Purpose:** integrated creation and maintenance of selected work products of the process (or their description) throughout their useful life.

Occasionally, it may be necessary for work products to be subject to formal configuration management or set to the configuration management baseline. This type of control includes defining and creating baselines at predetermined points. These baselines are formally reviewed and approved, and serve as the basis for developing the features of the work products.

**General Method 2.7: Identify and Engage Investors**

Identify and engage with suitable investors for the process.

**Purpose:** to create and maintain the involvement of investors during the implementation process. The involvement of investors covers planning, decisions, commitments, communication, integration, review, evaluation, definition of requirements, and problem-solving.

The purpose of planning for the involvement of investors[31] is to ensure that they interact in the process. This is essential as it does not allow a large number of effective individuals and groups to prevent the implementation of the process.

[31] Stakeholders in the organization.

**Sub-methods**

1. Identifying and engaging investors relevant to this process. Investors are identified between input suppliers, the performance of process actions, and users of outputs. Investors are identified and the appropriate level of involvement in the process is set out.

2. These identifications should be separated out into project plans or other plans.

3. Relevant investors should be engage as appropriate.

**General Method 2.8: Process Monitoring and Control**

Monitoring and control of process performance by comparing it to the process performance plan and taking appropriate corrective action.

**Purpose:** to lead and direct process performance under daily supervision and control. Maintain the ability to properly review the process and take appropriate corrective action if needed. Process monitoring and control may be accompanied by appropriate measurement of specific processes or the manufacture of work products in the process.

**Sub-methods**

1. Evaluate the actual progress of process actions compared to the plan.

2. Process, products, and services should be evaluated.

3. Revisit the actions taken and process outcomes and compare them to the process performance plan.

4. Work together with officials and managers to identify process defects and issues, and revisit actions, situations, and process results.

**Purpose of visits:** random and periodic visits alongside senior management ensure surface-level management and the ability to properly review the process through on day-to-day monitoring and control, examining the reality on the ground.

5. Identify and evaluate the impact of deviating from the plan in performing the process.

6. Identify problems in planning for performance and implementation of the process.

7. Take corrective action if the requirements and objectives are unsatisfactory, if deficiencies have been identified, or if progress is significantly different to the plan.

**General Method 2.9: Assessment of Objective Compliance**

The evaluation of compliance with process objectives and work-products is compared to the process description, standards, and methods, and their degree of fulfillment.

**Purpose:** to ensure that selected work-processes and products are used as designed and align with the descriptions of the process, standards, and methods. Especially in times of crisis, compliance here must be ensured.

**General Method 2.10: Revisit the Situation with Upper Management (Senior management)**

Revisit process actions, situations, and outcomes with senior management and resolve any issues.

**Purpose:** to prepare the upper levels of management and properly review the process.

Senior management includes those levels of management in an organization that have the highest level of responsibility for the process. In particular, upper management levels include senior management personnel. These reviews are also of benefit to managers who are involved in preparing general policy and guidance for the process. However, this is not for managers who are involved in direct day-to-day monitoring and control of the process because different managers have different requirements for the process. These examinations help to ensure that informed decisions are made about the planning and performance of the process and can take the form of periodic or occasional visits.

**General Objective 3: Formalize the Process Definition**

Create a process using the process definition.

**General Method 3.1: Creating a Defined Process**

**Purpose:** to create and maintain a process description based on the standard set of organizational processes, including process creation requirements. Using a proper process definition, diversity in how processes are performed is reduced throughout the organization, and process assets, data, and training can be used more effectively in process implementation.

The process definition provides the basis for planning, performing, and managing actions related to the process, products, and services.

**Sub-methods**

1. From the set of standard processes of the organization, select the processes that cover the process area and that are most useful to achieve the requirements or requisite performance of the organization.
2. Create a process definition using processes selected according to the organization's guidelines.
3. Ensure that attention is paid to organizational process objectives in the process definition.
4. Document the process definition and record it appropriately.
5. If necessary, revise the description of the process definition.

**General Method 3.2: Collect Information for Improvement (Collect experiences of each process)**

Use the result of process planning and implementation to support the future and improve the processes and assets of the organization.

Examples of process experience include: work products; measurements; lessons learned; and suggestions for process improvement. Organizational process assets include both information and products and are intended to make planning and performance align or similar processes more valuable and successful. The information and products obtained are stored in the organizational measurement repository and organizational assets.

**Sub-methods**

1. Process and product measurements should be kept in the organization's measurement repository.
2. Process and product measurements should first be defined in the set of common measurements for the standard organization process set.
3. Documentation should be established in the repository of the organization's process assets.
4. Lessons learned from the process should be documented in the repository of the organization's process assets.
5. Improvements should be suggested for organizational process assets.

**General Objective 4: Create Quantitative Process Management**

The creation of quantitative process objectives relies on the process definition.

**General Method 4.1 Creating Quantitative Objectives for the Process**

Quantitative objectives for the process must be established and maintained. These quantitative objectives indicate process quality and performance according to customer needs and business objectives.

**Purpose:** to determine quantitatively specific objectives for the process and obtain the consent of investors. These quantitative objectives can describe: work products; service quality; and process performance.

Quantitative objectives can be for a specific process or have a broader scope for a set of processes. These quantitative objectives provide criteria for judging whether products, services, and process performance are satisfactory for customers, end-users, management, and process users.

**Sub-methods**

1. Create quantitative objectives related to the process.
2. Assign quantitative objectives to a process or sub-process.

**General Method 4.2: Sub-process Performance Stability**

The performance stability of one or more sub-processes determines the capability of the process to achieve the quantitative and process performance objectives.

**Purpose:** to create performance stability in one or more sub-processes using statistical and other quantitative techniques. The stability of the selected sub-processes determines the creation of process performance and quantitative quality objectives.

A sustainable sub-process shows no significant indication of specific causes[32] of change and instability in the process. Sustainable sub-processes are predictable within the natural limits of the sub-process.[33]

The selected process and products are measured in the organizational measurement repository to support process performance analysis and future-defining decision making.

**Sub-methods**

1. The performance of one or more important sub-processes in the general performance of the process is managed statistically.
2. The process's ability to achieve the quantitative objectives should be statistically predicted according to the performance of the sub-processes.
3. Performance measurements of selected processes should be combined into the organizational process performance.

**General Objective 5: Institutionalizing the Optimal Process**

**General Method 5.1: Ensuring continuous improvement of the process**

Ensure continuous improvement of the process to achieve the business objectives.

**Purpose:** to select and systematically deploy process and technological improvements that can help to achieve quality and process performance objectives.

Agile and innovative process optimization depends on workforce participation and alignment with business values and organizational objectives. The organization's ability to respond quickly to changes and opportunities is increased by looking for ways to accelerate learning and sharing. Process improvement is an inherent part of the all-process implementation plan. As a result, it leads to a cycle of **continuous improvement**.

**Sub-methods**

1. Create and maintain quantitative objectives of process improvement that support the business objectives of the organization.
2. Process improvements should be identified from measured improvements in process performance.
3. Define strategies and manage the deployment of selected process improvements based on the quantitatively expected benefits, estimated effects and costs, and measurement of changes in process performance.

**General Method 5.2: Correcting the Root Causes of Problems**

Identify and correct the root causes of defects and other problems in the organization.

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[32] General causes are negligible.

[33] Control limits.

**Purpose:** to analyze defects and other problems using quantitative process management (such as the root correction of causes of all kinds of defects, prevention of these defects, and prevention of problems that may occur in the future).

The fundamental analysis of a cause can be beneficially applied to processes that are not managed quantitatively. However, the focus of this general method is the quantitative management of processes, even if the ultimate root causes lie outside the process.

**Special Methods and Objectives**

We briefly describe specific methods and objectives and general methods and objectives.

**Examples of Special objectives:**

**Specific Objective 1: Determining the cause of "selected victories"**

Specific Objective 1.1: Determine the selected victories for analysis

Specific Objective 1.2: Analysis of causes

**Specific Objective 2: Include reasons for the chosen victory**

Specific Objective 2.1: Implement the proposed actions

Specific Objective 2.2: Evaluate the impact of these actions

Specific Objective 2.3: Record data from the cause analysis

**- General methods and objectives:**

**General Objective 1: Achieve specific objectives**

General Method 1.1: Perform special methods

**General Objective 2: Create a managed process**

General Method 2.1: Creating an organizational culture

General Method 2.2: Process design

General Method 2.3: Prepare resources

General Method 2.4: Determining responsibilities

General Method 2.5: Training employees

General Method 2.6: Control of work products

General Method 2.7: Identify and involve investors

General Method 2.8: Process monitoring and control

General Method 2.9: Agreement with the evaluation of objectives

General Method 2.10: Visit/examine situations with the highest level of management

**General Objective 3: Institutionalize a defined process**

General Method 3.1: Create a defined process

General Method 3.2: Collect reports from process experiments (collecting improvement information).

**General Objective 4: Establish process quality management based on quantitative objectives**

General Method 4.1: Create quality objectives

General Method 4.2: Performance stability of sub-processes

**General Objective 5: Create continuous optimization**

General Method 5.1: Ensure continuous improvement of the process

General Method 5.2: Correct the common causes of problems

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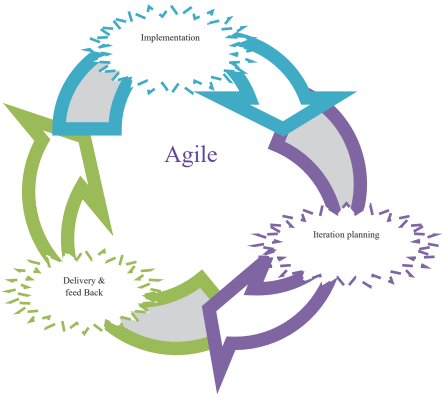
# CHAPTER THREE

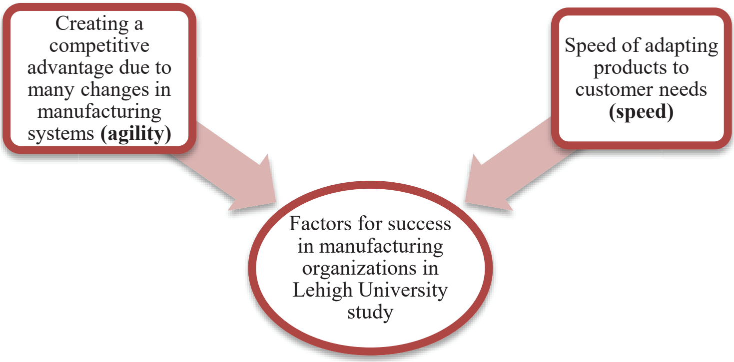
# AGILE MANUFACTURING

In the dictionary, the word "agile" means "quick movement" and the "ability to think quickly and intelligently." In the 1990s, the concept of agile manufacturing was introduced as a responsive strategy to business challenges that companies could use to improve their manufacturing performance. Since then, many studies have been conducted on agile manufacturing and attempts have been made to provide practical ways to achieve it.




In 1991, Lehigh University researched thirteen major manufacturing organizations, including General Motors, General Electric, and IBM, to find out the characteristics of successful organizations. The results of this research included the following points:

- New competitive environments require many changes in manufacturing systems and organizations (**agility**).
- Organizations (having competitive advantages in these new environments) must be able to quickly manufacture products that meet customer needs (**speed**).



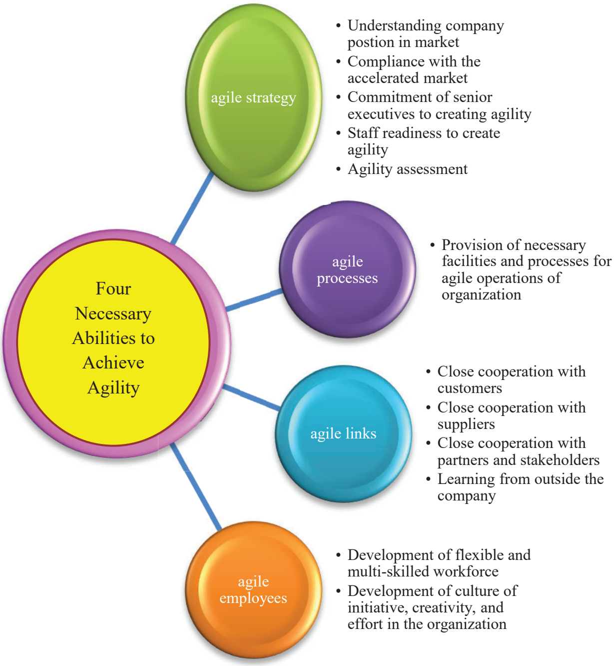

Agility and speed require the following features:

- A flexible manufacturing system;
- A knowledgeable workforce;
- A management structure that encourages team innovations both inside and outside the organization.


**Creating Agile Thinking**

An organization needs to develop agile thinking for agile manufacturing.

The agile manufacturing reference model investigates the development of companies of small and medium size. The four competencies needed to achieve agility are **agile strategy, agile processes, agile links, and agile employees**.




**1) Agile strategy:** as shown in the figure, this includes processes for understanding the company's position in its field of activity and compliance with the accelerated market, the commitment of senior managers to achieving agility, and preparing all employees in this direction and evaluating it.

To implement an agile model, various strategies have been proposed:

***A) Supply chain management***

In this context, research has focused on types of supply chain vulnerabilities, chain agility and management, and inventory costs throughout the supply chain.

***B) Simultaneous engineering***

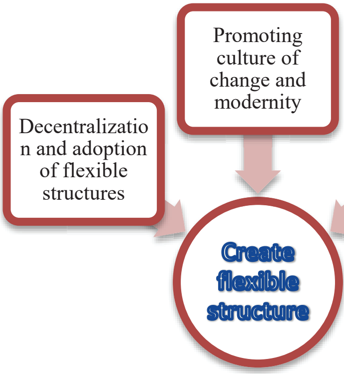
In the implementation of this method, frequent changes in design are reduced; as a result, a systematic method is created for the simultaneous design of the product and its manufacturing processes.

***C) Flexible structure***

The structure of the organization needs to be flexible. To increase the scope of the organization, the following actions can be taken:

- Forming partnerships with other organizations.
- Promoting a culture of change and modernity.

- Improving flexibility by decentralizing and adopting flexible structures.




An agile organization should offer "solutions" to its customers, rather than just sell them a product (i.e. identify the customer's needs and offer a solution, rather than pressure selling the product to the customer). The ultimate objective of agile manufacturing is ***the realization of the concept of customization and meeting the special and diverse needs of each customer***. The following actions may be effective:

- Creating a culture of thinking and innovation in the organization.
- Investing in new ideas and appreciating them.
- Creating close relationships with customers and constantly collecting their opinions.
- Creating the necessary hardware platform to support customization.


**2) Agile processes (technologies):** provide the necessary facilities and processes for the agile performance of the organization because an agile manufacturing system requires appropriate hardware and software. As result, it becomes possible to quickly change the arrangement of the manufacturing system from the manufacture of one product to another.

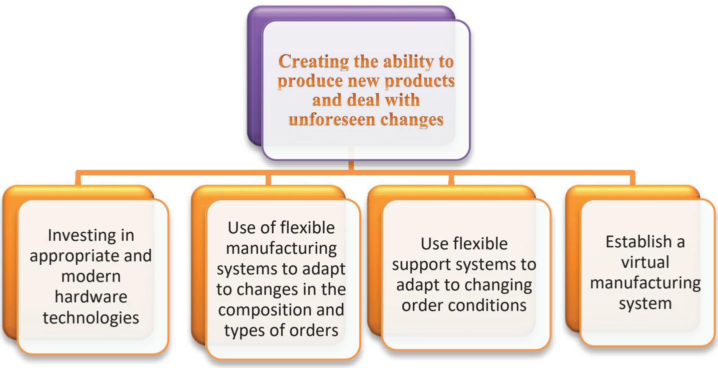
One of the differences between agile systems and other systems is the high content of information used. The volume of information exchanged between partner companies is high and the need to protect the key information of each organization is significant.


Agile organizations, therefore, need **advanced and flexible information and communication systems** that ensure both a smooth and secure flow of information and responses to problems and the ability to adapt to changing conditions. In this regard, the following actions are recommended:

- Use appropriate standards and protocols in inter-organizational information exchange.
- Integrate the distributed components of the organization into the organization's virtual environment (including customers, suppliers, and partners).

**3) Agile links (through systems):** develop close cooperation with customers and suppliers and partners and engaging with learning from outside the company. The agile manufacturing system must be able to quickly evaluate the product design process in terms of necessary manufacturing processes, manufacturing times, and related costs, while minimizing design changes and activities that do not add value. An agile manufacturing system can deal with unforeseen changes. These changes can be in the product model and therefore, the agile manufacturing system must be capable of manufacturing new products. The following actions are important in this regard:

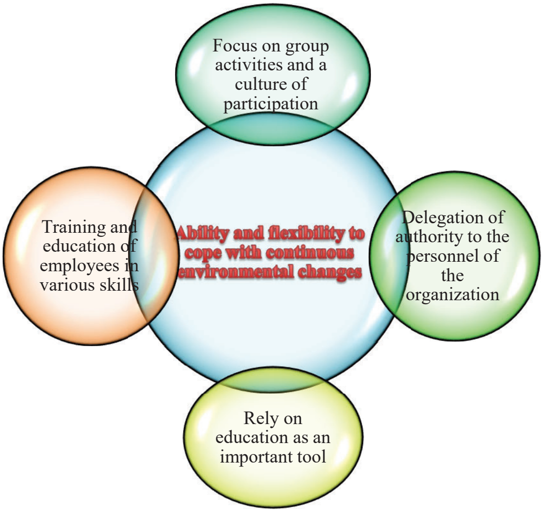
- Invest in appropriate and modern hardware technologies.
- Use flexible manufacturing systems to adapt to changes in the composition and types of orders.
- Use flexible support systems to adapt to changing order conditions.
- Establish a virtual manufacturing system.




**4) Agile employees:** enabling the development of a flexible and multi-skilled workforce and the creation of a culture focused on creativity and taking the initiative, and supporting such efforts throughout the organization. One of the issues in moving towards an agile organization is how to manage and motivate the workforce. The most difficult part in achieving the objective of agile management is not changing the corporate structure, but changing the culture and management practices.

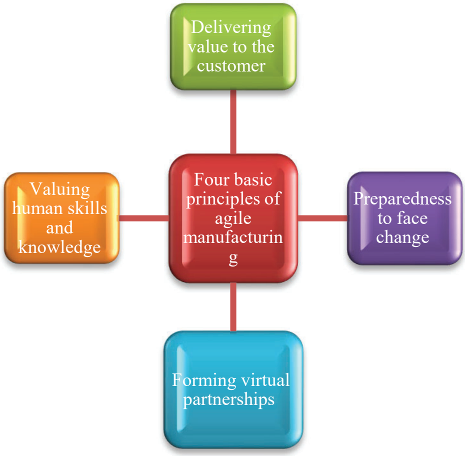
In an agile organization (facing continuous environmental change), ability and flexibility play an important role. In this regard, the following measures are effective:

- Focus on group activities and building a culture of participation.
- Delegate authority to personnel in the organization.
- Education is an important tool.
- Train and educate employees in various skills.



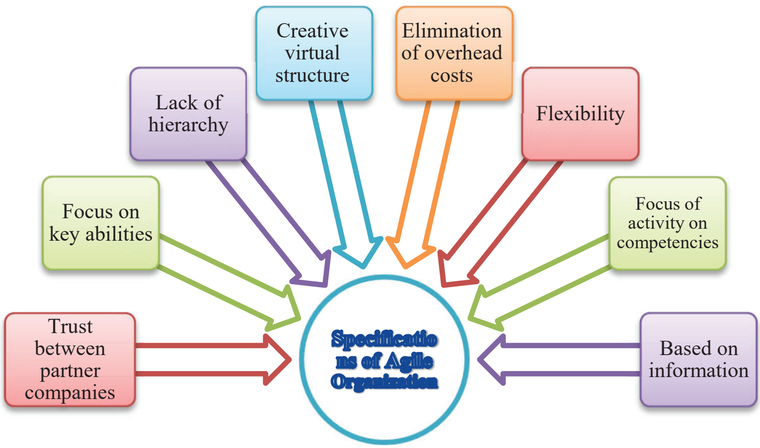

The organization will be agile once it can achieve better coordination by leveraging knowledge and cooperation (both internally and with other organizations). Also, the organization has to be able to create, produce, deliver, and support all the required resources quickly and efficiently. Creating agile thinking requires four basic principles:

1) Delivering value to the customer;
2) Preparedness to face change;
3) Valuing human skills and knowledge;
4) Forming virtual partnerships (intra-organizational and extra-organizational cooperation).




The following specifications are observed in an "agile organization"

| | | | |
|---|---|---|---|
| 1) | **Based on information** | 2) | **Focus of activity on competencies** |
| 3) | **Flexibility** | 4) | **Elimination of overhead costs** |
| 5) | **Creative virtual structure** | 6) | **Lack of hierarchy** |
| 7) | **Focus on key abilities** | 8) | **Trust between partner companies** |



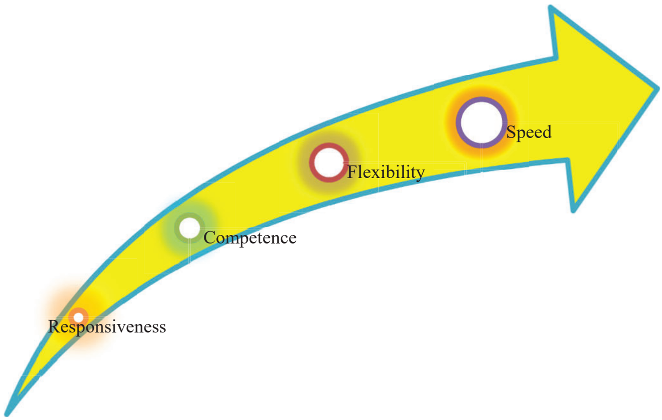

## Three Ways an Agile Organization can Overcome Competitors

There are always competitors in every business activity and, although their actions cannot be controlled, their impact on the market and business activity can be limited. Here are three simple ways to increase sales and the share of the market:

- Use non-contractual, non-stereotyped, and non-conventional marketing methods.
- "Pure," untouched and uncovered markets should be captured.
- Try always to be a professional.

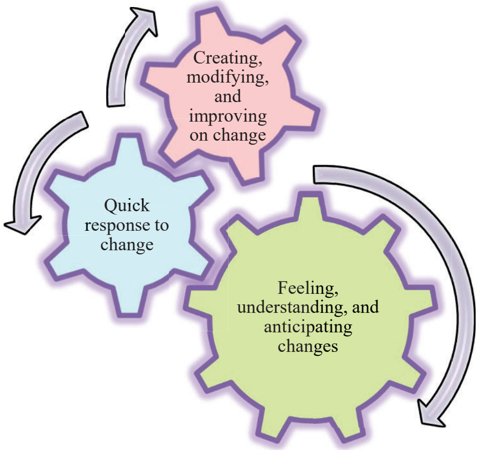
**Agile abilities**

Agile abilities are focused on creating and developing the ability to respond appropriately to change.



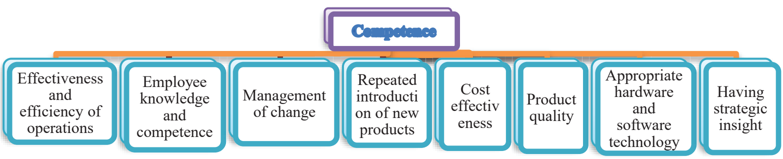

**1) Responsiveness** involves recognizing change and responding quickly to it:

- Feeling, understanding, and anticipating change;
- Quickly responding to change;
- Creating, modifying, and improving on change.




**2) Competence** concerns a wide range of abilities to ensure productivity and achieve the objectives of the organization. These abilities include:

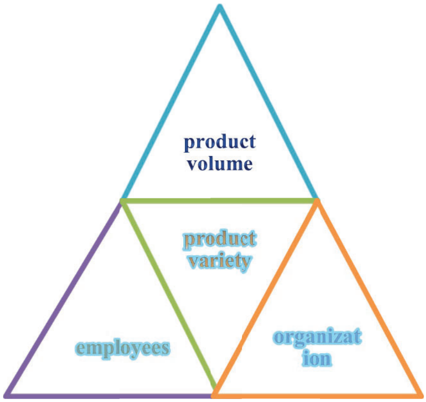
- Having strategic insight;
- Appropriate hardware and software technology;
- Product quality;
- Cost-effectiveness;
- Repeated introductions of new product lines;
- Management of change;
- Able employees in terms of knowledge and competence;
- Effectiveness and efficiency of operations.




**3) Flexibility** relates to the ability to produce and deliver different products and achieve different objectives with the same resources and equipment. Flexibility is considered in the following four areas:

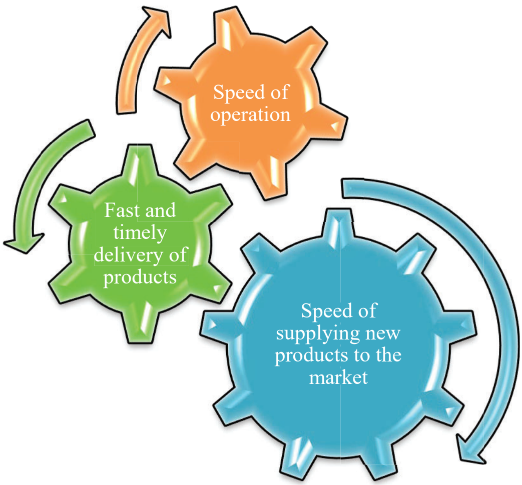
- Flexibility in product volume;
- Flexibility in product variety;

- Flexibility of the organization;
- Flexibility of employees.




**4) Speed** refers to the ability to perform operations in the shortest possible time, including:

- The speed of supplying new products to the market;
- Fast and timely delivery of products;
- Speed of operations.



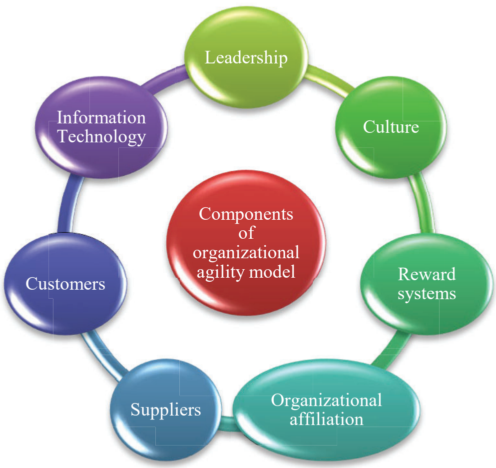
Finally, organization, manpower, technology, and innovation can all be considered factors that help create agility in the organization.

***Reasons why organizations need to become agile:***

- Short-term market opportunities;
- Rapid introduction of new products to market;
- The unpredictability of continuous change at the market level;
- Integrate the capabilities of independent companies to take advantage of immediate opportunities.


**3-9 Organizational Agility Model**

Successful implementation of the agile model in an organization concerns factors such as leadership, culture, reward systems, organizational memberships, suppliers, customers, and information technology.



The factors in this model are described below.

- ✓ **Leadership:** leadership is necessary to support employees in building relationships with customers and suppliers to help organizational agility. This can include the ability to continuously control change as well as monitor opportunities and threats.


- ✓ **Culture:** an organizational culture originates from the history of decisions, actions, symbols, and philosophy of the organization. Culture refers to organizational learning over time. A strategic leader is someone who can shape the organizational culture to create competitive advantages.
- ✓ **Reward systems:** to accept the culture of innovation in an organization, individuals must believe that creating an organizational reward and support system will help ensure continuous improvement. One of the responsibilities of leadership is to define an ethical climate for the organization and expectations about the integrity of its members.
- ✓ **Organizational memberships:** to oversee change in an organization, coordination between the customers, suppliers, employees, and officials of the organization is necessary. Organizational membership is one of the most important parts of organizational agility. An approach based on teamwork reduces the boundaries between managers and employees in their areas of specialization. In other words, organizational affiliation leads employees to make greater efforts to achieve individual and

organizational objectives. As a result, they strive to give the organization a competitive advantage in meeting customer needs.

- ✓ **Suppliers:** the focus of discussion in this part of the model is the relationship between the suppliers and members of the organization. This section concerns the organization's marketing approach and strategy. Distributors have to constantly add new customers, while suppliers provide organizational information and place scheduled orders for the products of the organization, which seeks to optimally meet the needs and wants of customers.
- ✓ **Customers:** this section is about how to deal with the customer. In addition to recognizing customers and creating a long-term base, we must pay attention to the interpersonal dimensions of customer-organization relationships.
- ✓ **Information technology:** is an essential component of the effective participation of members of the organization in creating networks of customers and suppliers.

### Scrum and Sprint

**Scrum** is one of the agile project management frameworks and helps small teams to gradually develop **complex products**[34] (using close communication and mutual support). Scrum focuses on how employees do work, instead of what employees do. In a scrum, teams develop the product during **sprints**[35] and share a portion of the product they have worked on every two weeks. In this way, customers can get new features as soon as they are created, before identifying and removing any flaws they might have.

**Before the sprint starts:** in scrum, the **product owner**[36] first receives a list of their customer's wants and needs. This list is in a special format called a **user story**.[37] The product owner then creates tasks for each user

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[34] A complex product is a product about which our knowledge is incomplete and will emerge over time.

[35] A sprint occurs every two weeks to prepare codes and check performance for delivery to the customer.

[36] The product owner illustrates the future product; if a member of the team has a question about the performance of the product features desired by the customer, they will ask him or her. The main task of the product owner is to:

- o Collect and take notes of user stories provided by customers;
- o Refine the backlog and prioritize what needs to be done;
- o Manage customers and demonstrate new product features.

[37] The user story should include the "role," "possibility or feature," and the "result". For example, as a manager, I want a native scheduling report so that I can calculate the exact amount of my employees' salaries.

story and places them in the **backlog**,[38] estimating the required time to perform each task as a group. Finally, the product owner decides which parts should be worked on during the sprint. If some parts cannot be done in a single sprint, these parts are termed **epic**. In this case, there are three options:

1. Do it in several sprints;
2. Postpone it to another time;
3. To complete this, we must define a new project and form a separate team to work on it.

During the sprint, the **scrum master**[39] provides visual tracking of project progress to control bottlenecks and delays in the process. Furthermore, completed tasks must be tested.

- After the sprint is over, team members give feedback on what they have done. There are two types of sprint feedback.
- Sprint Review: in a two-hour session, team members talk about what they did during the sprint and what they were scheduled to do but were unable to for whatever reason.
- Sprint Retrospective (take a look at what happened): in a session lasting 1 hour, people talk about their work processes and ask which ones were done well and which ones can be improved on in the next sprint.

After these feedback sessions, the team evaluates the new user stories and decides what should be done during the next sprint.

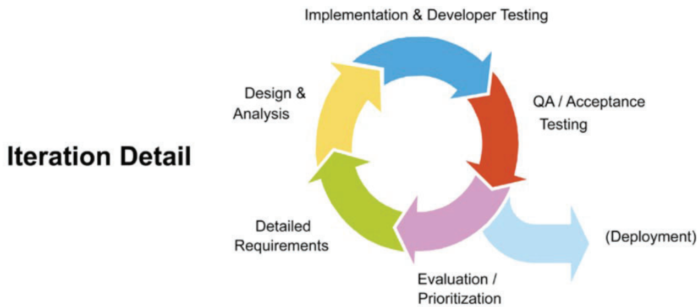
**Daily performance of scrum and sprint**

Scrum development team members spend 15 minutes each day, at the same time and in the same place, monitoring progress towards the *sprint objective* and creating a schedule for the day. Team members share **what they did yesterday**, **what they are doing today**, **and what obstacles they face** to help them achieve the objective.

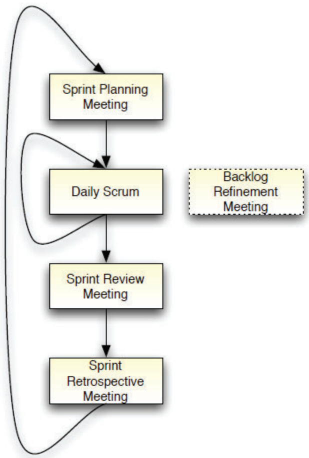
[38] All the features (that the customer wants the product to have), as well as product defects (which need to be removed), are included in this backlog.

[39] The scrum master is similar to a project manager who emphasizes facilitating teamwork in the scrum framework. The main task of the scrum master is to:

- Remove organizational and other barriers that prevent employees from doing their jobs;
- Facilitate team events;
- Track the progress of sprints;
- Improve processes.




**Standing** during the daily scrum helps keep it short. Topics that need more attention are reported by each member of the team. It is also common during sprints to discover additional tasks that are required to achieve the sprint objectives.




Organizational barriers include barriers that arise from issues beyond the team's control. The daily scrum is intended to disrupt old work habits. Members must remain vigilant about signs of the old approach, for example, looking only at the scrum leader when speaking is a sign that the team has not received the necessary training to be a self-organized entity.

**What should be raised in each sprint meeting?**

The best way is to use the Deming cycle. The Deming improvement cycle (PDCA) includes the following elements: *planning, do, check, and action (corrective)*. In the ***Planning*** phase, there is a need to determine the objective for improvement. In the ***Do*** phase, regular activities are carried out to realize the development plan. In the ***Check*** phase, the new situation is compared to the anticipated conditions and the effectiveness of the plan is ensured. In ***the corrective Action*** phase, new standards and effective processes are used to prevent the recurrence of primary problems. As a result, these new standards pave the way for further progress.

**Note:**
Work processes are usually unstable at the beginning. Therefore, before the **PDCA** cycle is started, all current processes must be implemented according to the **SDCA** cycle (i.e. standardization, do, check, and act). The *SDCA cycle* ensures **the stability of current processes** while the *PDCA cycle* seeks **process improvement**.

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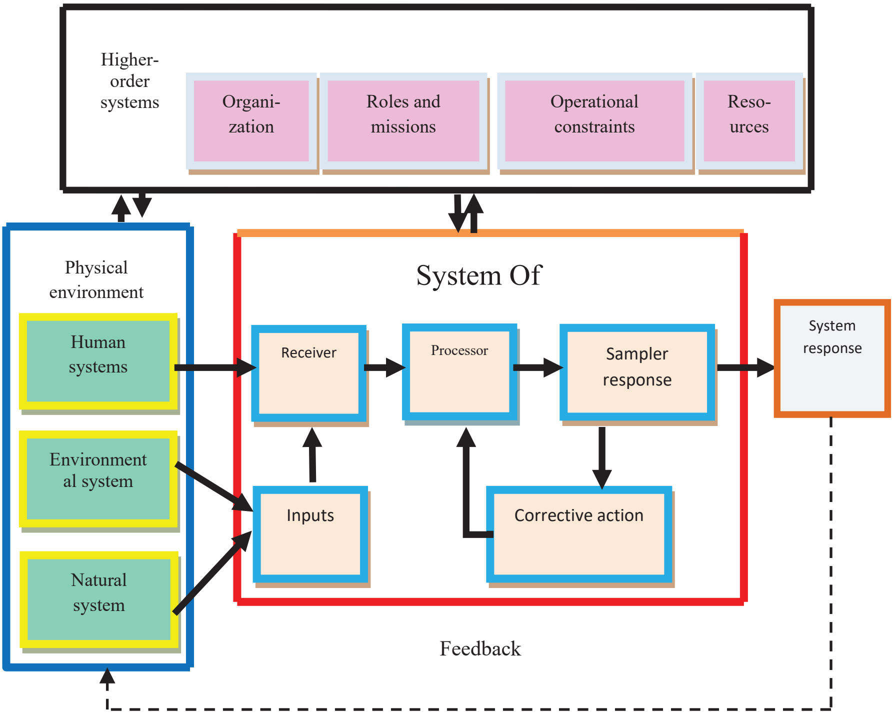
# CHAPTER FOUR

# SYSTEMS ENGINEERING

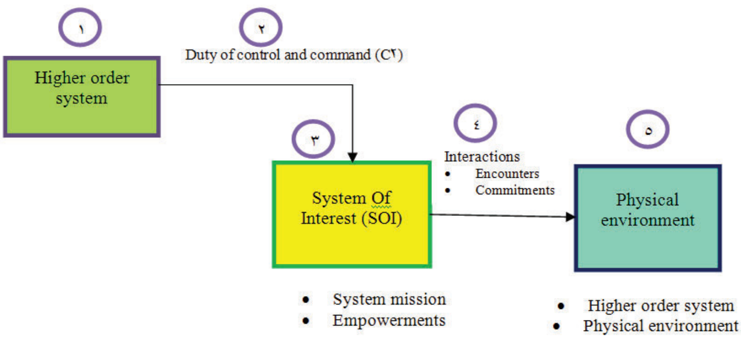
Naturally, in every system and system environment, there is a fundamental pattern of stimulus-response behavior. For example, systems may respond positively to good news. Conversely, a system may respond negatively to threats and use defensive, monopolistic, or retaliatory tactics. Thus, a well-designed and learning system responds to different types of inputs (including stimuli and information) under different operating conditions and constraints.



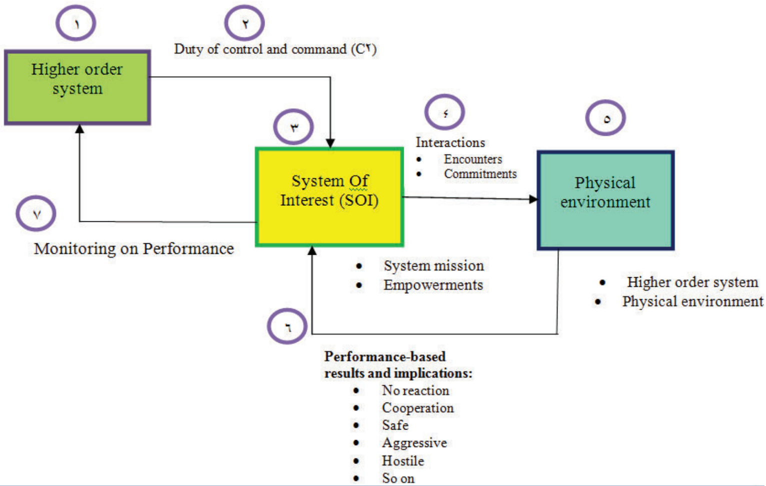
Each system includes a physical environment and a system of interest (SOI), both of which are controlled by *higher-order systems.* The **higher-order system** sees the organization prepare, assign roles and missions, impose operational constraints, and provide resources for the SOI. The **elements of the physical environment** provide the input stimulus for the SOI and also affect the capacities and performance of the operation.

To apply the concepts of systems engineering in an organization, it is necessary to investigate the types of interaction structures used in various situations.

An **open-loop interaction structure** is a simple system in which a higher-order system imposes a stimulus on the SOI to perform a task and respond to its operating environment. ***Note that there is no feedback on completion of the task.***

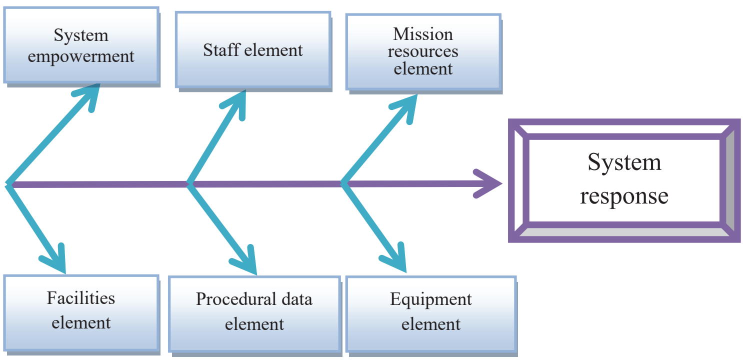



The **closed-loop C2 interaction structure** corrects the feedback defect of the open-loop interaction structure. In this case, the SOI imposes on the higher-order systems to provide continuous performance monitoring of task progress, completion, and success.



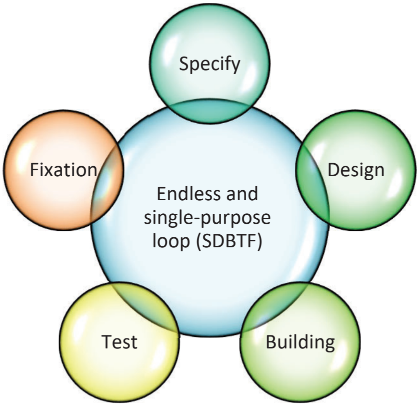

**Combined system interactions**

As can be seen in the above cases, system interactions with the environment have been investigated. However, as a systems engineer (SE), it is necessary to investigate the combination of interactions between system elements and the whole system.

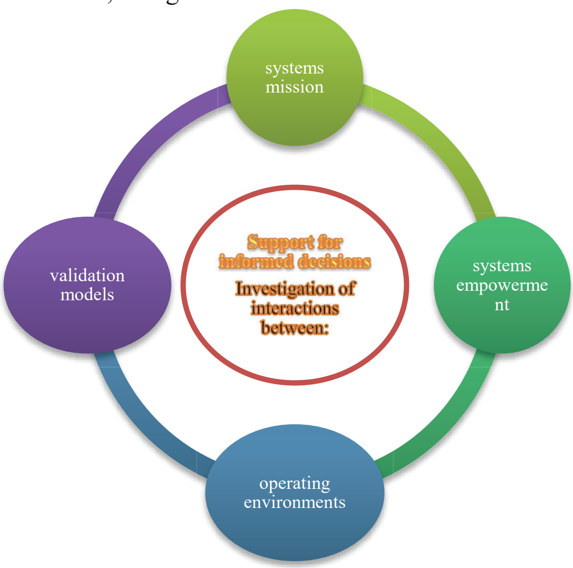



Sometimes, unknowingly, system buyers or developers impose irrational and impractical schedules and budgets that lead to non-compliance and defects, and so on. Priority should be given to **informed and practical decisions** and better methods should be used for manufacturing systems ***without*** non-conformities, additional costs, and failed schedules.

The endless and single-purpose loop of **Specify-Design-Building-Test-Fixation (SDBTF)** prevents the occurrence of non-compliance with specification requirements, hidden defects, design gaps, errors, and deficiencies, etc.

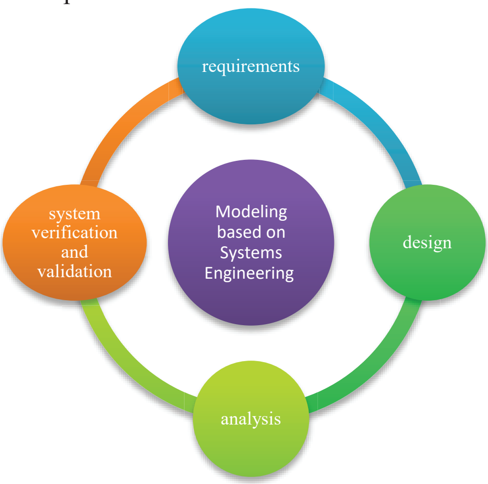



As a result, a *key principle of systems engineering and development* (D&SE) is making conscious reality-based decisions. The mechanism for *supporting conscious decision-making* is the behavioral interaction modeling of SOI systems mission, systems empowerment, and their operating environments, along with various validation models.



**Note:**
If you ask an engineer to determine *system capacity*, he or she will answer **"I write the requirements."** Although this answer has a degree of accuracy, *the requirements are merely mechanisms for documenting and communicating so as to determine the user's needs in terms of acceptance on delivery*. The answer you should hear from a systems engineer (SE) is: **"I determine the capabilities and performance levels of the system to achieve the specific outcomes desired by the user."**

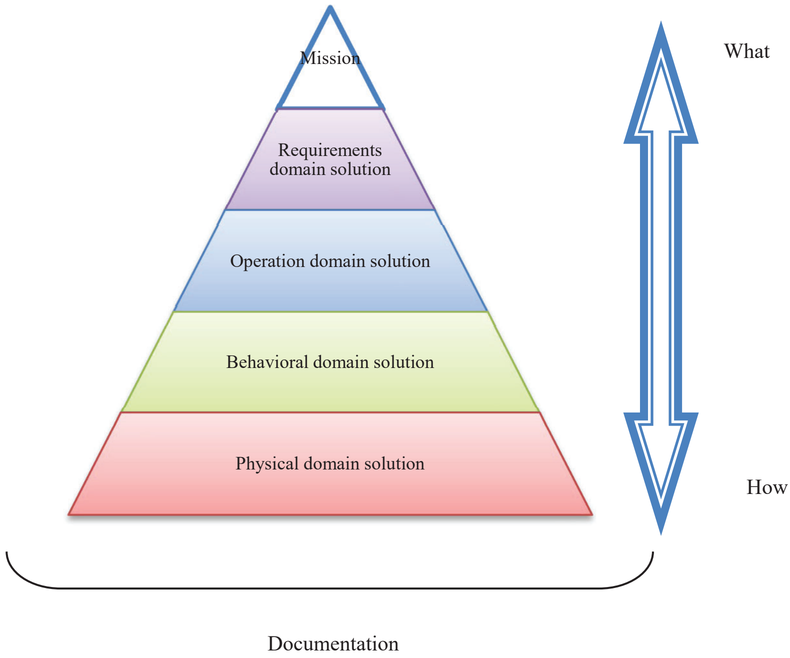
The formal application of modeling **to support requirements, design, analysis, and system verification and validation,** begins at the conceptual design step and continues through all steps of development, even the later life cycle steps.




If a defect is found in the system, the following steps are performed according to the SDBTF-DPM engineering model:

- Step 1 - Understand the user's needs, problem, or the operational problem space.
- Step 2 - Limit and specify user problem spaces and solutions.
- Step 3 - Understand how the user intends to use the system.
- Step 4- Model the behavioral actions and interactions of the system with its operational environment.
- Step 5 – Determine the effective cost, acceptable risk, and physical implementation.

Steps (2) to (5) identify the **four domain solutions** in an organization, each of which is defined in accordance with the following figure:




The four domain solutions method is made up of sets of dependent, sequential, and logical decisions (requirements-operations-behaviors-physical) in each solution, forming a system or entity design and minimizing redesign and rework. The analysis for each step of the operation includes the following solutions:

**A) Problem definition (mission):** here, we define the basis for the user to **formulate, limit, and specify a *requirements domain solution***. That is, there is a balance between the *requirements, technology, cost, development schedule, and risk.*

**B) Requirements domain solution:** this solution provides the basis for the **conceptualization, development, and maturation of *operational domain solutions***. This solution is developed with user involvement through collecting, defining, and reviewing user reports, use cases (UCs), and scenarios (reports). The results are used to extract the system capacities and, subsequently, specification requirements.

**Further Description:** defines the objectives, outcomes, and results based on performance (at each step or sub-step of the operation). Requirements at all levels of abstraction must be *traceable to the user's mission*.

**C) Operation domain solution:** this forms the basis for the **concept, development, and maturity of the *behavioral domain solution***. This solution defines *how to deal with* ***using and interacting with other systems in the operating environment***.

**Further description:** the user performs operational tasks (OT) based on the use case (UC) required to complete the mission. Each OT requires the user to monitor, command, and control (MC2) the system, product, or service operations. Operations and OTs must *be traceable and compatible with the requirements domain solution*.

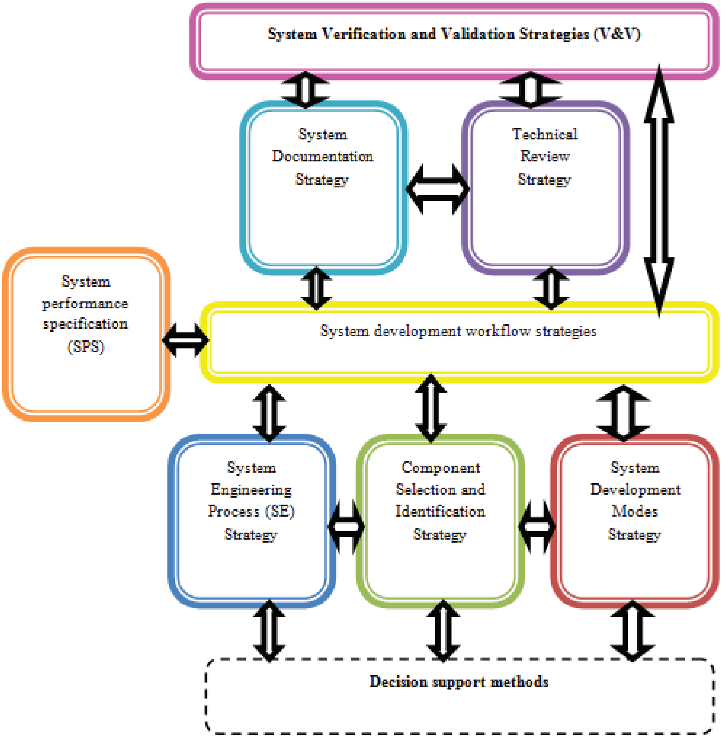
**D) Behavioral domain solution:** this solution forms the basis for the **development and maturity of *the physical domain solution*** based on the physical components, with readily available technology and applied knowledge.

**Further description:** describes stimulus-response behavior, which is required to achieve the specific performance implications of UC and specific scenarios. This requires configuration of sets of logical capabilities of the system, product, or service to enable UCs and scenarios through the C2 user and system. Reasonable capacities and performance-based outcomes must be traceable to the operational domain solution and comply with the requirements domain solution.

**E) Physical domain solution:** this solution consists of physical components to implement the behavioral domain solution. The components must be traceable to the behavioral domain solution and compatible with the requirements domain solution.

**Systems Engineering and Development Strategies and Principles**

The organization must prove that it can adequately deliver the proposed system on time, within budget, and according to the terms of the contract and the perceived risk for the buyer. The system development phase may require the development or implementation of the system operations, processes, and procedures to support the user's mission and providing services for the operation, maintenance, and strengthening (OM&S) of the system phase.




This raises the issue of how we can create a strong system development workflow strategy to improve our chances of success. (This strategy should also consider the consequences of user constraints—technical, cost, scheduling, and risk.) The answer is embedded in a number of support strategies, which are discussed in the following:

**1) System Verification and Validation Strategies (V&V).** These verify and validate **component compliance with specifications, designs, and test procedures**. *These components and the final system* meet the **operational needs of the user.**

**2) Systems Engineering Process (SE) Strategy.** An SE process model leads to the development of institutions at every level, acts as a problem-solving method, and sees the development of multilevel solutions. Efficiency and effectiveness in problem-solving are demonstrated in the SDBTF-DPM engineering model.

**3) System Development Modes Strategy.** This strategy indicates different strategies of system development models to determine how the project can achieve the design and development of systems, subsystems, assemblies, subassemblies, etc.

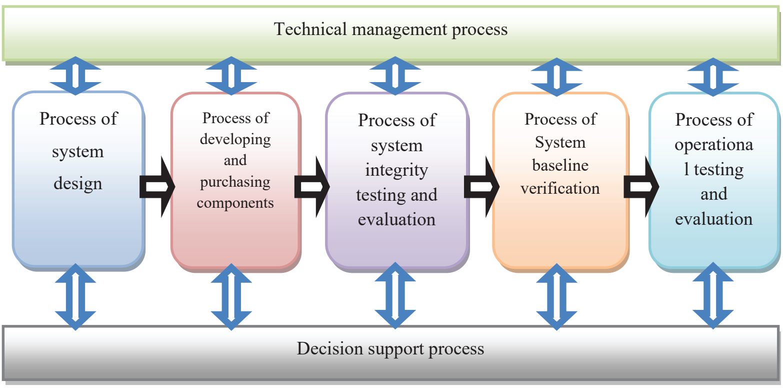
**4) Component Selection and Identification Strategy.** A strategy of system configuration, identification, and component selection is defined for the physical implementation of the system in each of the entity system design solutions.

**5) System Documentation Strategy.** Documentation strategies point to key artifacts of technical decision-making (specifications, plans, and drawings, etc.) that facilitate the development of a system design solution.

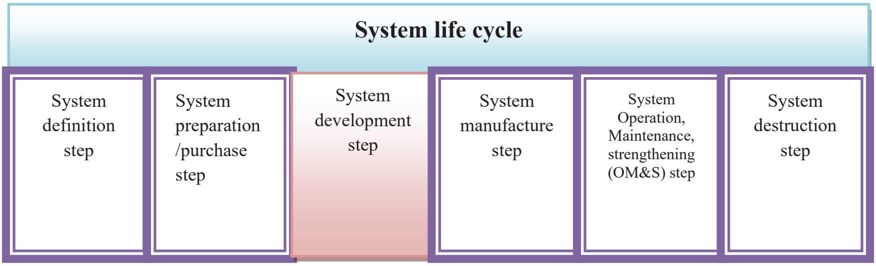
**6) Technical Review Strategy.** This strategy reviews and evaluates the status, progress, maturity, and risk of the evolving system design solution and each of its multilevel components. Review and evaluation take place at different decision-making steps or control points during system development.

**7) System development workflow strategies.** These are supported by two active processes—technical management and decision support:

- The **main purpose of the technical management process** is the planning, organization (staff and resources), coordination, and control of the product development team (PDTs), which is responsible for delivering the assigned entities (products, subsystems, and assemblies, etc.) within technical, technological, cost, scheduling, and risk constraints.
- The **main purpose of the decision support process** is to prepare meaningful data to support technically informed decision-making in each of the workflow processes through the development and use of analytics and business studies (such as analysis of alternatives (AoAs), prototypes, models, simulations, tests, and proof of concept, demonstrations, or technological methods).



Once the system development phase is complete, the workflow progresses to the system manufacturing phase or system OM&S phase, whichever is feasible.




**Principle Developmental Test & Evaluation (DT&E)**

**DT&E Technical Risk Reduction Strategy.** This strategy ensures that the system design solution evolves and matures and its components comply with the lower-level SPS and EDS[40] requirements. The DT&E objectives are:

1. Identification of potential technical and operational capacities and constraints that can be traced from alternative concepts and design options.
2. Support for the identification of efficiency-cost exchanges through the provision of alternative capacities and constraints analysis.
3. Support for identification and description of design technical risks.
4. Assess progress in achieving critical operational issues (COI), reducing buyer technical risk, meeting manufacture process requirements, and system maturity.
5. Assess the validity of the hypotheses and conclusions of the AoA.
6. Provide data and data analysis in support of the decision to confirm system readiness for operational test and evaluation (OT&E).
7. In automated information systems (AIS), ensure support information systems security certification (before sensitive data is processed) and standards compliance certification.

**Completion principle of system design solution**

Conventionally, a system design solution is not considered complete unless it has been formally approved by complying with the system performance specifications (SPS) according to the system buyer or user acceptance.

[40] Establishment of development specification (EDS).

Technically, the system design solution is not complete until all hidden defects (including gaps, errors, and design flaws) have been resolved and approved through the critical design review (CDR).

*One of the main challenges of system development is to eliminate hidden defects before user acceptance and use in practice*. The SITE[41] process is the last line of defense before user acceptance. The more time you spend testing the system/product, the more hidden defects can be identified and corrected. However, this leads to a challenging question: how much testing is both necessary and sufficient? **It is impossible to eliminate all defects**, especially in large and complex systems; however, critical defects must be eliminated as much as possible.

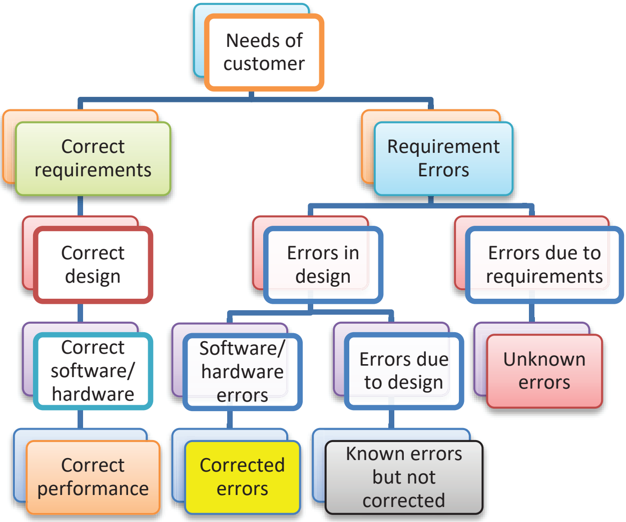
In the employer-user system view, there are three key technical implications that determine system success: (1) compliance with specification requirements; (2) meeting the user's operational needs concerning operating profit, suitability, usability, availability, effectiveness, and efficiency; and (3) a system that has no hidden defects, no work skills, and no component integration issues.

Errors are propagated through system development steps, especially in the following two main points:

**1. Errors arise from the following.** Incorrectly written and poorly written specifications; hidden defects due to the misinterpretation of specification requirements, design errors, design defects, and flaws; inadequate, low (borderline), or weak materials or components; poor manufacturing processes and poor work skills; and, finally, poor testing methods and inadequate testing.

**2. Failure to correct errors when they occur leads to an increase in the number of errors downstream.** Downstream error remanufacturing leads to unnecessary costs and planning errors that affect delivery, profitability, and customer satisfaction.

[41] System integrity, test, and evaluation.




**The principle of solving defects**

The number of hidden defects in a field system, product, or service depends on: (1) the willingness and commitment or provision of sufficient resources to avoid and eliminate them; (2) staff competence in terms of experience, knowledge, and training; (3) the use of appropriate tools, processes, and methods; (4) the time available to do the job; and (5) periodic evaluation of the quality and integrity of the development and maturation of the multilevel system design solution. This involves:

a) Technical compliance with the requirements;
b) Tracing the source or origin of user requirements;
c) Solution validation to solve the user problem space;
d) Compatibility and completion of decision artifacts that guide SE&D.[42]

During the system development phase, the evolution and maturation of the system design solution is prototyped, modeled, simulated, and tested to validate design decisions (concerning risk reduction and the collection of performance data). These actions are referred to as DT&E development configurations, which endorse the system design solution:

- Technically complies with specification and design requirements;
- Can be traced to user or source requirements;
- Has an acceptable risk.

[42] Systems engineering and development.

After completing the system verification process, the system, product, or service may undergo system validation assessments by the user. System validation may be required by the contract, through market testing of consumer products, or user field experiences of contract-based systems.

### 3 Principles of System Verification

In developing a system verification strategy, two types of verification are used to answer specific questions:

- **Design verification** answers the question of whether the system, product, or service components are ideal; and whether the architectural adjustment and interconnection of components (representing design configurations) produce behavioral responses and performance according to the desired outcomes.
- **Product verification** answers the question of whether the system or product design configuration can be verified as producing the desired responses and behavioral outcomes; and whether the work skills, material composition, and integrity of a particular instance of reliability and system predictability produce the same results.

### The Principle of System Validation

System validation assesses stakeholder satisfaction with implications based on product performance for the documented operational needs and expectations. The purposes of validation are:

- To evaluate a multilevel system design solution or one of the entities during system development and then determine whether it meets the user's operational needs. Remember that the user can be an external user or SE system developer, engineer, designer, or tester.
- To perform field exercises with trained real users to operate a deliverable system, product, or service to complete missions.

### System Validation: User Content

The final proof of system validation is deployed with its users. This is typically done across both businesses and users. For example business product developers test marketing ideas and new products during development and combine their feedback. After the product is released to the public, surveys, sales, interviews, and other methods are used to collect customer satisfaction data.

Buyers and users of military and government systems use independent testing agency (ITA) services. ITA services are used to validate the system based on user personnel trained by the system developer. During validation, the system or product depends on the conditions and scenarios of the actual field operation environment. This is referred to as OT&E.

**SITE Process: V&V Strategy**

The first objectives of the SITE V&V strategy confirm that the components and levels of integrated entities—products, subassemblies, assemblies, and subsystems—are:

1) Can be tested using the test configuration (documented and controlled by CM);
2) Consistent and interactive;
3) Performance under the specification requirements;
4) Ready for integration at higher levels, as appropriate.

The SITE V&V strategy provides a basis for validating each entity at multiple levels of integration (for example, component levels, subassembly, assembly, subsystem, product, and system):

- To produce results under capacity requirements based on the specified performance, before, during, and after, depends on the effective conditions of the specified operating environment.
- It is compatible and interacts with internal entities and external system entities in the system architecture if required.

To implement the SITE process, verification methods and requirements specified in SPS are used to develop system verification procedures. Verification methods, such as inspection, analysis, demonstration, testing, and similarity (conditional), are identified as verification requirements for each SPS requirement. Each system test procedure describes the configuration of the test environment, the operating environment (primary and dynamic), the data inputs, and the expected test results. This system test procedure is required to generate compliant data to support validation of requirement in the SPS or lower-level specification.

During SITE, the system developer formally verifies the system using proven quality assurance (QA) test methods, software quality assurance (SQA), system buyer representatives, and the user and the system developer acting as witnesses. Multilevel verification measures compare actual test data and results to system verification methods. SITE culminates in a formal system verification test (SVT) to determine general system compliance with SPS requirements. If differences between the required SPS performance and the actual performance results are identified, deficiency reports (DR) are recorded and failures sent for corrective action.

Best engineering practice says: (1) to create designs that meet the requirements of the specification; (2) pre-sample technical risk areas; (3) document design decision artifacts through meeting notes, maps, and parts lists for review and verification; (4) fabrication, assembly, integrity and testing (FAIT) of components under maps; and (5) testing and verification the levels of component integration.

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# CHAPTER FIVE

# SIX SIGMA TECHNIQUES

**History of Six Sigma**

The name and initial idea of Six Sigma are both attributed to Bill Smith, who was Motorola's senior quality and reliability engineer in the 1970s and 1980s. Bill Smith observed that there was an increase in the error rate with an increase in product complexity and the number of parts. He recognized the inefficiency of the Three Sigma quality level and combined the concept of reliability and quality engineering techniques before presenting the idea of Six Sigma to Bob Galvin, CEO.

**The concept of six sigma**

The Six Sigma level[43] is an aspirational goal and no company using this method has been able to reach the Six Sigma level yet. However, increasing the sigma level leads to significant improvements in quality and reduced organizational costs, with the reliable establishment of a process of continuous improvement.

**Sigma** stands as a benchmark for measuring the dispersion of a statistical population and the **Six Sigma philosophy** is based on the *reduction of fluctuation and change*. **Six Sigma** expresses a range of values of random variables with a normal distribution. In this case, 99.73 % of all values are expected to lie in the Three Sigma range (at both sides of the average value of the statistical population).

Qualitative defects are expressed through a root cause (called oscillation[44]). To improve quality, oscillations need to be measured, reduced, and prevented. All steps of the implementation of Six Sigma projects are explained according to this objective.

**Six Sigma** is a **data-driven** method that aims to achieve **superior quality**. Six Sigma is different from other quality methods because it

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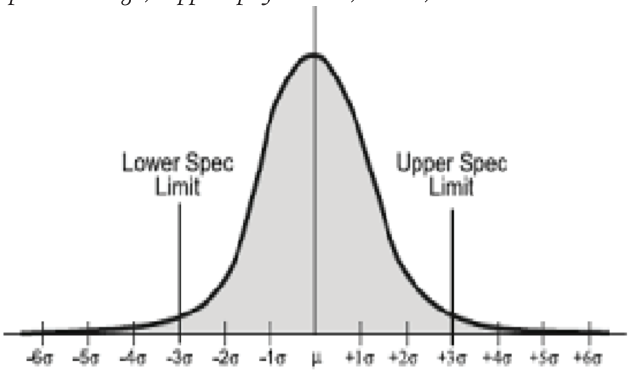
[43] Six Sigma means 6δ (δ is the sign for standard deviation). To create process performance capability, ideal limits are considered. The objective limits of 6δ are the goal to be achieved through research and study

[44] Oscillations cause deviations in the manufacturing path. There are two types of oscillation: general oscillations and random (specific) oscillations. The objective is to eliminate random oscillations.

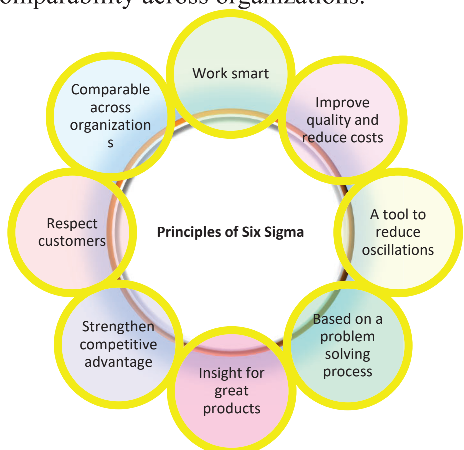
stresses the importance of **preventing mistakes before they happen**. In particular, it can be said that:

*Six Sigma is an approach that closely measures an organization's repetitive processes in product design, supplier performance, service, and so on.*




The internal logic of the Six Sigma concept can be summarized by the following principles:

- Work smart, not just work hard.
- Improve quality and reduce costs.
- It is a tool to reduce oscillations (changes).
- It is a method based on problem-solving.
- Generate insight for better products.
- The objective is to strengthen the competitive advantage of the organization.
- Respecting customers.
- Universal comparability across organizations.



As is clear, **Six Sigma** involves **innovative and systematic activity** that **estimates the causes of each defect** and **statistically measures the errors that occur in each management department, analyzes the causes, and, finally, removes them**.

The definition of a **defect** in Six Sigma includes all factors that hinder the process of service delivery or manufacturing. The **Six Sigma methodology** *focuses on minimizing and resolving defects* in industrial or service environments.

In Six Sigma plans, anything that conflicts with customer satisfaction and the desired utility is called **waste**. The **Six Sigma strategy** involves the use of statistical tools in a structured method. As a result, with the acquisition of the required knowledge in today's competitive world, the manufacturing of products and provision of services can be done better, faster, and at lower cost.

**Six Sigma methodologies**

**The Six Sigma methodology** has been established as a **process-oriented**[45] method with emphasis on **results and effectiveness**, seeking to **improve the quality of products, services, and processes**. The Six Sigma methodology is a business insight philosophy that guides the achievement of the highest level of customer satisfaction (in companies that operate at the level of global quality and seek continuous improvement). In this methodology, criteria are defined for aligning strategic organizational objectives and values with customer needs and expectations. Six Sigma has two methodologies that vary depending on the type of project involved.

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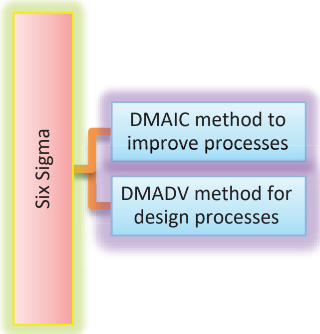
[45] A process-oriented approach not only establishes a connection and sequence between activities, but also defines the ultimate objective and customer. Process orientation means understanding the fact that every activity is valuable only when it helps to complete a process and that process also meets a need in a larger process network and creates new value. Therefore, the process approach concerns the systematic use of processes within an organization, along with identification of processes and interaction between these processes and their management.




A) For projects related to process improvement use DMAIC.[46]


The DMAIC methodology is a closed-loop process consisting of the following phases:

1) **Defining.** Identifying customer needs and expectations and defining the project scope and processes.

2) **Measuring.** Measuring process performance, developing a data collection plan, comparing recorded information, and defining the results.

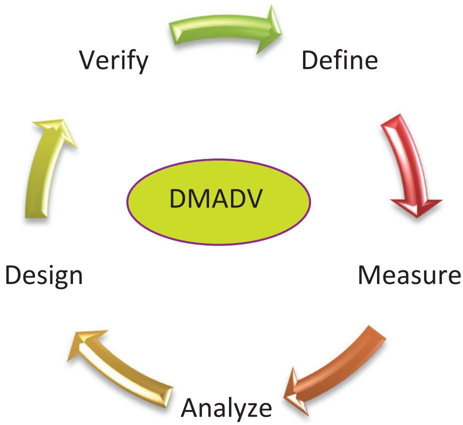
3) **Analyzing.** Analyzing the causes of defects and sources of deviations, and prioritizing opportunities for improvement.

4) **Improving.** Improving the process and developing the executive plan.

5) **Controlling.** Controlling process deviations, developing strategies to control and monitor processes, and implementing system and structural improvement.

[46] Define, measure, analyze, improve, and control.

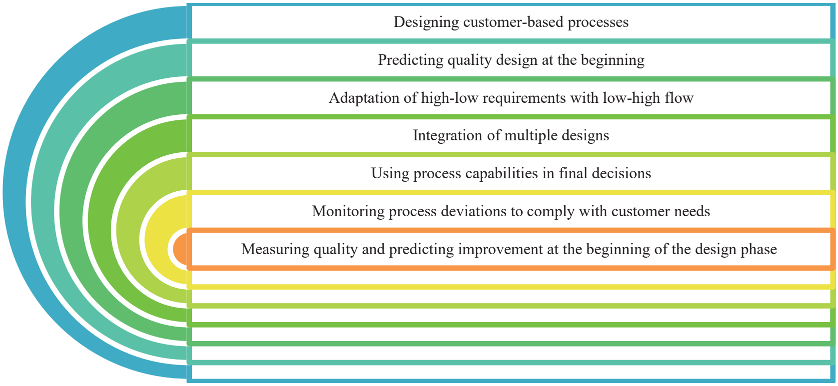
**B) For projects related to new process design or previous process redesign use DMADV.[47] This is also called DFSS or design for Six Sigma.**




Design for Six Sigma is a systematic method that uses a toolset, training, and measurement to design products with new processes. The design objective for Six Sigma is to *reduce* the defect rate, *increase* the sigma level, and *increase* the positive interactions that occur during product manufacture. Components of this methodology include:

- Designing customer-based processes.
- Predicting quality design at the very beginning.
- Adaptation of high-low requirements with low-high flow.
- Integration of multiple designs.
- Using process capabilities in final decisions.
- Monitoring process deviations to comply with customer needs.
- Measuring quality and predicting improvement at the beginning of the design phase.

[47] Define, measure, analyze, design, and verify.



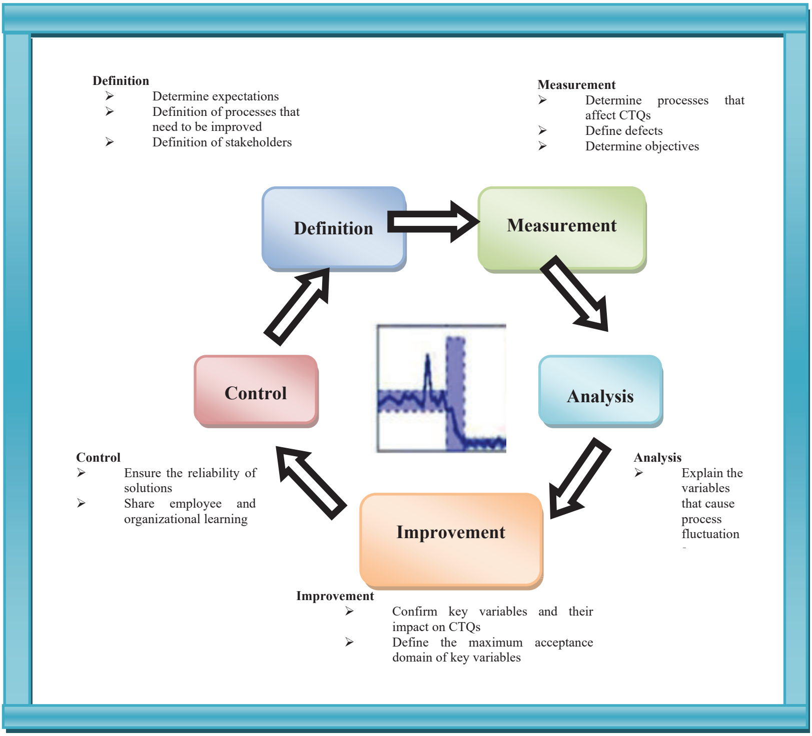

As such, the DMAIC methodology is used for improvement and the purpose is to improve process management to achieve superior management. As such, the DMAIC methodology, which is also more common, is studied here.

**What is the DMAIC Model?**

The DMAIC model is a set of tools that are used to diagnose and improve industrial and business processes.

The following four phases must be implemented logically and on time for each project:

**Definition phase: What is important?**
**Measurement phase: How do we do it?**
**Analysis phase: What is the problem?**
**Improvement phase: What should we do?**
**Control phase: How do we guarantee stable performance?**




Each step is briefly described in the figure above. To give greater familiarity with the DMAIC model, these steps are described below.

**1. Definition phase**

**Purpose:** customer needs are stated and processes and products that need to be improved are identified. In this phase, project objectives and boundaries are determined based on the organization's business objectives, customer needs, and processes that need to be improved.


**A) Preparation of the project charter**

A project charter is a contract between the leader of an organization and the project team that is created at the beginning of the project.

**Purpose:** to determine what is expected of the team; to focus the team; to unite the team with different people in the organization; and to transfer ownership of the project from the project manager to the team members.

A project charter often includes the following fields:

A) Definition of the problem;

B) Definition of the objectives;

C) Project scope;

D) The individual roles of team members;

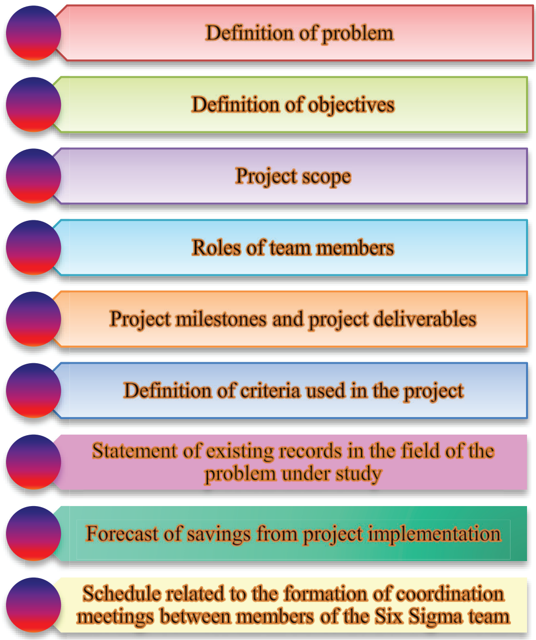
E) Project milestones and project deliverables;

F) Definition of criteria used in the project;

G) Statement of existing records in the field of the problem under study;

H) Forecast of savings from project implementation;

I) Schedule related to the formation of coordination meetings between members of the Six Sigma team.




**Note 1: Seventh Field, Section F.** The criteria outlined in the **f Field** indicate current process performance and tracking to determine project improvement. For example, one of the most common criteria in Six Sigma projects is the failure rate for one million failure opportunities and the process sigma level. It is necessary to state the current values of the criteria in the project charter and determine the project objectives based on improvements in these criteria.

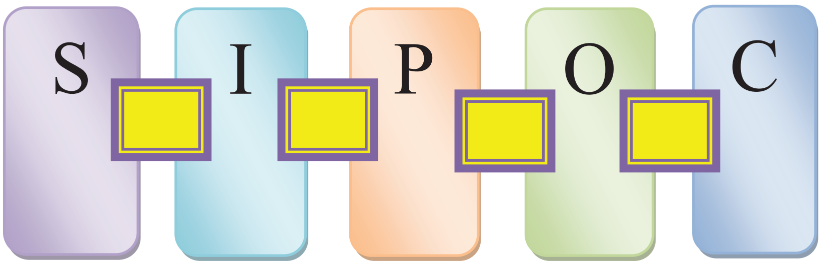
**Note 2: Ninth field, paragraph r.** This field of the project charter is designated to encourage management to support the project and is therefore of particular importance. Due to limited resources, teams have to focus on projects the financial impact of which offer good justification. Approximate estimates can be used to determine the financial impact of projects.

**B) Preparation of SIPOC chart**

SIPOC is a general process map and includes **suppliers, inputs, processes, outputs, and customers**. The SIPOC chart is a highly effective communication tool to ensure that all members of the project team understand the process. SIPOC also shows team leaders and what each team member has to work on. With this tool, the **process scope** is specified and general **process levels** are drawn up, then **suppliers, inputs, outputs, and customers** are identified.

**How to create a SIPOC chart:**

- Specify the process.
- Specify the start and endpoints of the process (process limits).
- List key outputs and customers.
- Identify, name, and arrange the main steps of the process.




**Suppliers**
Person/organization providing input to the process

**Inputs**
Resources (e.g. materials, data, and information) added to the process by the supplier

**Process**
Series of steps where input is converted to output, as well as creating value for customer and stakeholders

**Outputs**
Products or services that result from the process

**Customers**
Person/organization that receives the products or services

### C) Review of "Voice of the Customer"

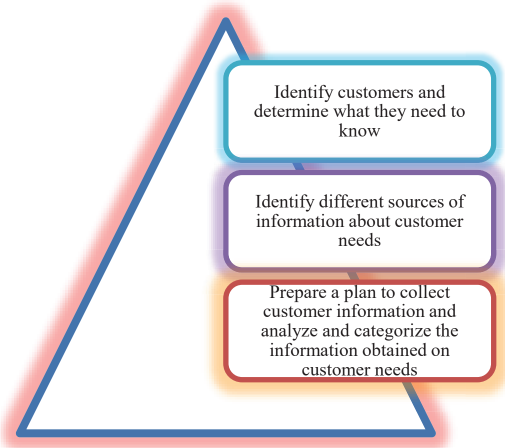
The Voice of the Customer (VOC) is used to describe the customer's needs and perceptions of the product or service.

**Purpose:**

- To decide which products or services should be offered.
- To identify critical specifications for those services or products.
- To decide where improvement efforts should be focused.
- To determine the effectiveness of these improvements (as a criterion for measuring customer satisfaction).
- To identify key factors affecting customer satisfaction.

**How to check the "customer's voice":**

There are three steps, as explained below.




**A) Identify customers and determine what they need to know.**

Identify key customers (both internal and external) who use the product or service, and list potential parts that may be relevant to the project.

**B) Identify different sources of information about customer needs.**

Customer information is usually obtained from both "reactive" and "proactive" sources.

**Reactive sources** include items such as customer complaints, calls to receive services, and warranty claims. *Usually, in these cases, the customer provides the information to the organization without the organization contacting the customer.*

**Proactive resources** include items such as interviews and surveys. Usually, to get the desired information, *the organization must go to the customer and ask him or her.*

**C) Prepare a plan to collect customer information and analyze and categorize the information obtained on customer needs.**

After completing these three steps, a list of customers, customer-related sections, and appropriate proactive and reactive sources for data collection can be drawn up and numerical or verbal data expressing customer needs can be specified. To identify customer needs, tools such as the Kano model and dependency charts can also be used.

**D) Determining what is Critical to Quality (CTQ)**

**The CTQ tree** is a tool that converts the "customer's voice" into product/service quality requirements. As such, the CTQ tree is used to convert customer-wide needs to quality-specific requirements. This tree diagram helps the team move on to detailed product specifications. It also ensures that all aspects of customer needs have been identified.

We use the CTQ tree when the customer needs are not exactly clear or they are extensive and complex. The steps for preparing this chart are as follows:

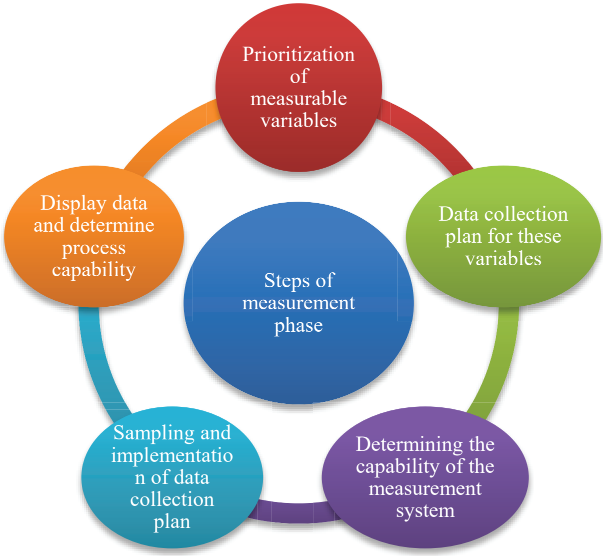
A) Provide a list of customer needs. This list is usually obtained after investigating the customer's voice (third step of the definition phase).

B) If the customer needs are general and difficult to measure, then they should be converted into product and process requirements and specifications that are clear and easily measurable. (The analysis and decomposition of customer needs are usually continued until the process specifications or input specifications (necessary to achieve quality) are achieved.)

**Note:**
To ensure that the various steps of the definition phase are performed correctly, examine the checklist of this phase at the end.

### 2. Measurement phase

**Purpose:** to create a real understanding of problems and conditions in the process, as well as the locations and sources of these problems. Such knowledge helps to reduce the domain of potential causes (which should be the focus in the analysis phase. In general, in the measurement phase, the diagnosis of the expected performance of the process, the current state of the process, the definition of process input/output variables, and the evaluation of the measurement systems are performed.




Here, we describe the steps of this phase:

**A) Evaluation, review, and prioritization of measurable variables**

**Purpose:** to ensure that the collected data aligns with the stated needs. The first step in data collection is to identify key specifications and adjust the objectives accordingly.

Because data collection takes a lot of time, it is very important to focus on the size of the key specifications. In general, the following steps need to be taken to evaluate, review, and prioritize the measurable variables.

**1) Identification of measurable variables.** The CTQ tree chart and SIPOC general map constitute the starting point for identifying possible values for measurement.

**2) Prioritization of measurable variables.** Tools such as failure mode and effects analysis (FMEA) and a prioritization matrix can be used.

**B) Planning and preparing a data collection plan for these variables**

**Purpose:** to ensure that all individuals (who collect data) measure the desired specifications in the same way.

A data collection plan usually includes the following:

- The type of data that needs to be measured.
- Operational definitions of the data being measured.
- How to measure data.
- How to record data.

- Factors that need to be considered in sampling (for example, where it is necessary to collect data from shift-workers, operators, various devices, and other factors that affect sampling).

#### C) Determining the capability of the measurement system (conducting an R&R gauge study)

Changes observed in the process consist of two parts—one is real variability and the other is variability as a result of measurement. Therefore, to be sure of the numbers obtained on process variability, it is necessary to ensure that this variability is not due to the measurement system.

Measurement system analysis uses a set of tests to determine the reliability of the system used to measure the variables.

#### Measurement System Analysis (MSA)

There are two types of measurement system analysis (for both qualitative and quantitative data). The analysis used depends on the type of data. The measurement system includes: the units to be measured; tools; operators; and measurement methods. When performing a measurement system analysis, it is necessary to assess the degrees of bias, linearity, stability, discrimination, and variability (or precision) of the measurement system.

**Bias** is the difference between the observed value from the measurement and a known standard or reference value. If there is a bias in the average of the measured values, the measurement system may need calibration.

**Linear communication** determines whether the measuring instrument works uniformly across its measurable range or not.

**Stability** indicates the capability of a measurement system over time.

**Tool discrimination power** or **tool sharpness** indicates the ability to detect very small changes in the measured specifications.

**Variability or precision** consists of **repeatability** and **reproducibility**.

**Repeatability:** when an operator measures an item multiple times, it indicates the capability of the measurement system to return a value for different measurements of this item.

**Reproducibility:** if several operators measure the specification of an item, it shows the degree of agreement of these operators with an expressed value.

#### D) Sampling and implementation of the data collection plan

Measuring the specifications associated with all products or components in a process is usually time-consuming and costly. In some cases, comprehensive tests (regardless of cost or time) to examine all pieces are not possible. In these cases, sampling is used rather than having to examine all the items of the statistical population. Sampling is a method that can estimate the parameters of the statistical population (by examining a smaller number of pieces in the statistical population). The accuracy of sampling depends on the number of samples (taken from the population) and can be calculated using statistical formulas.

First, the required number of samples is calculated based on the number of failures using a statistical formula. This number is then moderated by taking into account cost and time constraints. After moderating the sample size, preparing a data collection plan, and ensuring the capability of the measurement system and its improvement, it is necessary to allocate sufficient time for sampling. In this time allocation, all the instructions and steps in the data collection plan are to be performed. The data should be properly recorded according to the existing instructions for data recording so that the data is available for analysis.

E) Display data and measure process capability

Process capability refers to the ability of a process to continuously produce a product that meets the customer-defined specifications (tolerance). Capability indicators are used to predict the performance of a process. In these indicators, the length of process change is compared to the length of specific tolerance for the product. These indicators are widely used in many industries and determine whether the process under study is statistically stable in terms of control or not.

When determining the criteria and measuring the process capability, it should be noted that the main emphasis in the measurement phase is on the process outputs. As such, it should be noted that the values of the defined criteria are obtained from the available data and information. These criteria may be $C_p$ and $C_{pk}$, or criteria such as the sigma level and number of failures out of a million potential failure opportunities.[48] To be used, the obtained information and data should be presented in an easily understandable manner. All data display charts (including Pareto charts) can be used for this purpose.

**3. Analysis phase**

The measurement phase indicates the basic performance of the process. Having categorized the data on the basic performance of the process, it becomes possible to identify locations/causes of problems and gain a true understanding of existing process problems and conditions. This helps maintain focus on the issue. In the analysis phase, theories about the root causes are created and measured using data, and finally the root causes of problems are identified. The identified causes provide a basis for the development of solutions in the next phase.

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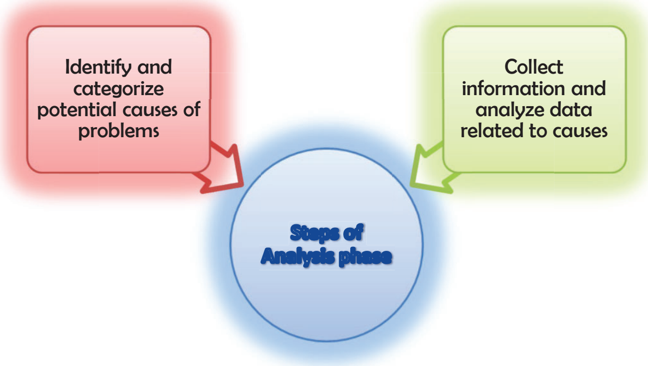
**Steps:** the main task in the analysis phase is to identify and prove the potential causes of problems, which are:

A) Identify and categorize potential causes of problems.

B) Collect information and analyze data related to these causes.



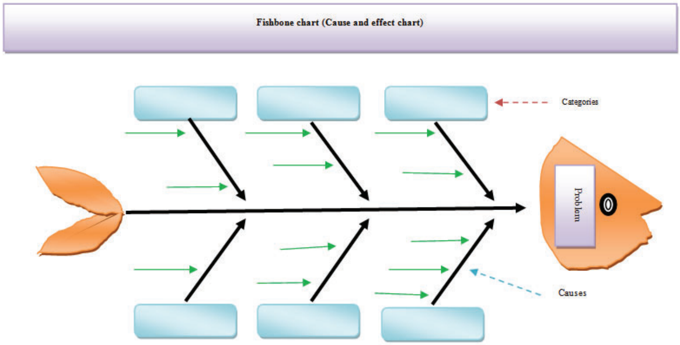

We examine these steps further below.

**A) Identify and categorize potential causes for problems**

**Introduction:** many improvements to the end product/process output are costly and, in some cases, impossible. As such, before a problem occurs in the process, it is better to identify the causes of these problems and solve them radically so that there are no extra costs. On the other hand, process specialists may cite many causes for a problem, which makes the examination and sampling of these causes difficult and costly. It is therefore necessary to categorize these causes so that they are easily analyzable and the need for several samplings using a preliminary investigation is eliminated.

When a problem is considered, the team identifies a system of potential causes and then organizes those causes to observe the cause-and-effect relationships. Effective causes on the process output are divided into two categories: general causes and specific causes. Specific causes are not part of the routine process and are the result of unusual process events. For example, manpower errors and unplanned events are specific causes. On the other hand, factors such as design, the selection of machinery, and preventive maintenance, etc., which are not accidental and are an integral part of the process, are known as general causes and inherent changes in the process are the result of these causes. The point to note is that *Six Sigma examines general causes within the process.*

Here, we identify and organize a large number of potential causes and make decisions about them. Use **brainstorming** in the **analysis phase** to quickly generate ideas on **identifying potential causes**. Brainstorming meetings are creative—they motivate everyone to think and generate excitement and energy. The results of brainstorming meetings are usually categorized and summarized in the form of a cause and effect chart.




Charts help to structure the causes of a problem so that you can find a connection that identifies its different aspects. Most people have experienced solving a problem *many times* because the activities they performed were not focused on the root causes of the problem. As such, the use of cause and effect charts and tree charts helps provide effective and efficient solutions in the first instance and ensures that you have considered all the root causes of a problem.

The cause and effect chart presents the potential causes of the problem in a visual way. The chart shape determines how the potential causes relate to each other. It is often the case that people who work on improvement activities without studying the causes, reach conclusion too quickly. They either focus on one possible cause, ignoring other possibilities, or they focus their activities on eliminating the superficial signs of the problem. Cause and effect charts create a structure that simplifies our understanding of the relationship between a large number of potential causes of a problem. These charts provide a framework for planning (what data to collect). A lot of intellectual power is spent on creating a cause-and-effect chart, but ***these charts identify only potential causes*** and thus data needs to be collected to determine ***which of these causes is involved in causing the problem.*** **They usually focus on causes for which it is easy to collect data.** However, it can be difficult to observe or measure some important causes.

As such, it is necessary to develop creative methods for collecting data on these causes. Often, a simple test—for example, changing the factor under study and observing its effect—can be helpful. Identifying potential causes also helps to focus one's efforts. To ensure that all potential causes are considered, it is suggested that ***the process be investigated from both a data view and a process view.***

**Process view:** drawing a map of the process details, performing added value analysis and analyzing the time cycle are activities used in the process view and help improve our understanding of the process. This view also helps us to track time cycle problems and identify opportunities to reduce process costs.

**Data view:** data classification, distribution charts, and multivariate charts are tools used in the data view that help us identify causes of process changes, waste, and quality problems. This view identifies the root causes of differences between outputs.

B) Investigating causes, collecting information, and analyzing data related to causes

**Purpose:** if we want to examine the major difference between the inputs and outputs, we can say that the inputs are better under our control, while the outputs are monitored. If we want to **improve the process**, this improvement should be done on the **inputs**.

***How to check:***

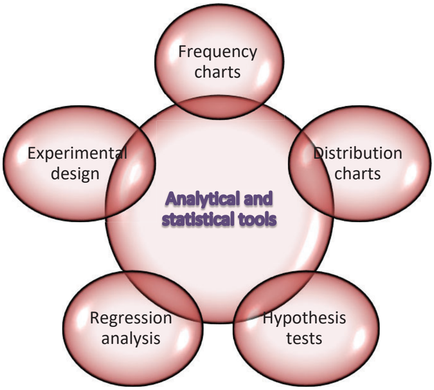
This step of the analysis phase is similar to the steps taken in the measurement phase. However, our emphasis in the **measurement phase** was more on the **outputs**, while in the **analysis phase**, we focus more on the **inputs** (causes of problems) and try to find the relationship between the **inputs and outputs.**

In this phase of the methodology, the main task is to prove *what causes have an effect on the output of the work.*

Existing data can be analyzed, or new data can be collected, but it is often necessary to collect data and information about inputs and outputs simultaneously.

Once the data and information about the causes has been collected, it is necessary to analyze them. The analysis of these causes depends on the type of data (collected). Below are some analytical and statistical tools used to investigate causes:

- Frequency charts;
- Distribution charts;
- Hypothesis tests;
- Regression analysis;
- Experimental design.




**4. Improvement phase**

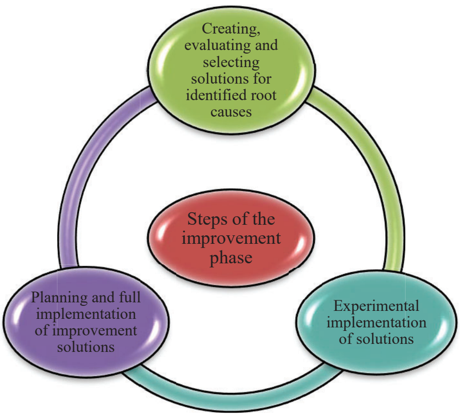
In the improvement phase, it is necessary to be prepared to provide solutions to causes that have been investigated, implement solutions, and evaluate the results. The purpose is to demonstrate that solutions have been provided to problems and improvement using the data.

**Steps:** in the improvement phase, identification, followed by the evaluation and implementation of solutions, and finally the evaluation of the results, are discussed. As such, it is necessary to undertake the following steps:

A) Creating, evaluating, and selecting solutions for identified root causes of problems.

B) Experimental implementation of solutions.

C) Planning and full implementation of improvement solutions.



We will now explain each of these steps.

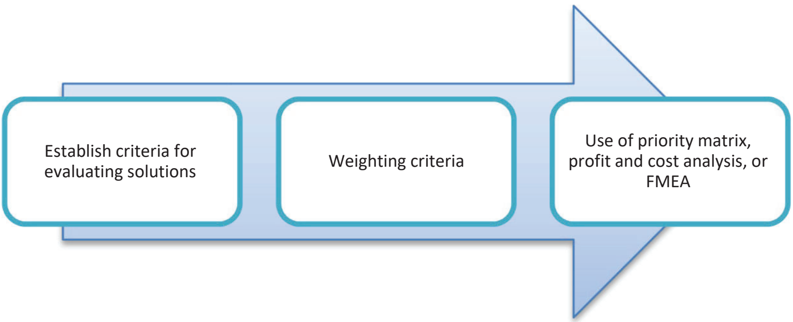
**A) Creating, evaluating, and selecting solutions for identified root causes**

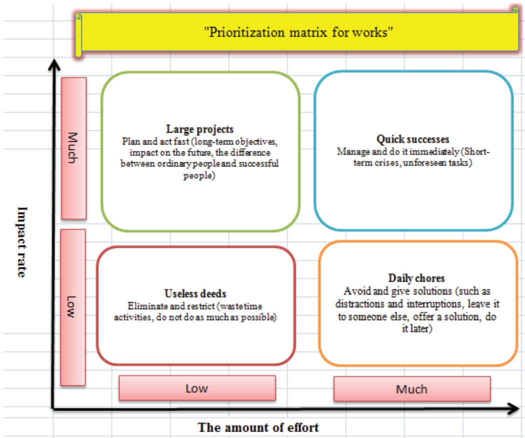
**Purpose:** to specify how to choose solutions, "how to" leadership solutions, determine the value of risk associated with solutions, and select appropriate solutions.

**To create and present improvement solutions**, we follow these steps:

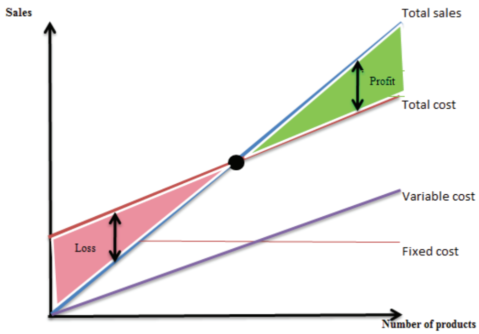
- Investigate what is available in terms of process and verified causes.
- Organize brainstorming meetings to provide solutions and use creative techniques.
- Link presented ideas to problem-solving.

**Evaluate and select solutions:** to find better solutions, it is necessary to evaluate them. Criteria have to be created to evaluate solutions; these criteria should be weighed; and finally, existing solutions should be evaluated with the help of these criteria. A prioritization matrix, FMEA, or cost-benefit analysis are usually used to evaluate solutions.





A prioritization matrix



Cost-benefit analysis

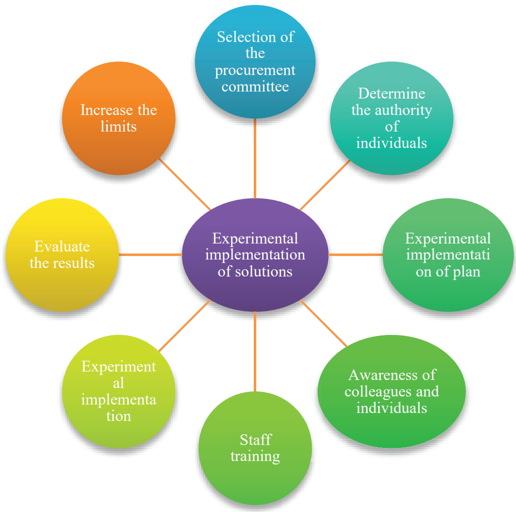
Formal profit/cost analysis can help explain the concept of solutions in financial language and motivate team members to provide appropriate solutions.

**B) Experimental implementation of solutions**

**Purpose:** to investigate the expected results of a solution, its applicability needs to be confirmed and the risks associated with failure need to be reduced.

After the evaluation phase, if one solution is found to be better than the others, work begins with that solution. If there is no specific choice, we apply a "decision-making" approach. This decision-making is done using methods such as consensus, majority vote, minority vote, and the opinion of the team leader. To run the experimental solutions, we follow these steps:

- Selection of the procurement committee.
- Determine the limits of the authority of the participants.
- Plan the experimental implementation of the solution.
- Inform colleagues and participants.
- Train employees.
- Experimental implementation.
- Evaluate the results.
- Increase the limits.




**C) Planning and full implementation of solutions**

Planning for the full implementation of solutions leads to implementation activities being performed at the right time and with the appropriate budget/cost. This planning provides a path to successful implementation of solutions.

You can use planning tools such as planning networks and Gantt charts to plan the implementation of improvement solutions. To complete solution implementation planning, it is necessary to prepare a resource and budget plan and a project stakeholder plan in addition to the solution implementation schedule. Once the necessary planning has been done, these plans should be completed on time. It also important to make sure that everything goes according to plan.

**5. Control phase**

**Purpose:** during the improvement phase, the solution is implemented experimentally and the necessary planning for the implementation of the solution is completed. Providing a solution to a problem may only temporarily solve the problem. *The control phase ensures that the problem is solved and new methods are improved on over time.*

**Steps:** to ensure that the improvement solutions are fully implemented and become part of the normal operation of the process, the following steps are required:

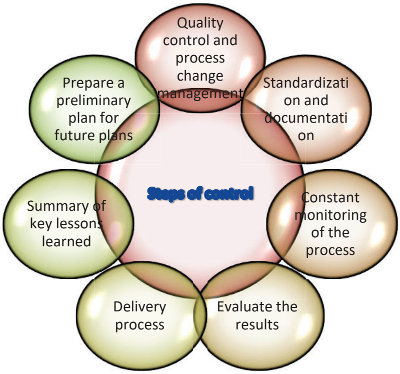
A) Quality control and process change management.

B) Standardization and documentation of effective methods.

C) Constant monitoring of the process.

D) Evaluation of the results.

E) Delivery of the process, summarizing key learning and preparing a preliminary plan.




**A) Quality control and change management of the process**

With process control, it is necessary to make sure that each person uses standardized and well-tested methods when working with a new process. Standard methods are methods that achieve the desired results with more confidence.

Different processes may be sensitive to different factors and so different processes need different controls. These controls also depend on certain factors (and which processes are sensitive to these factors). For process quality control methods, such as SPC and pre-warning systems, inspection and audit, inspection of 100 % output, sampling plans, control plans, and other quality systems, can be used. To ensure process quality control, the PDCA[49] cycle can be used. In this chart, emphasis is placed on the parts that are inspected in the process and it is specified what corrective actions should be taken if these events happen.

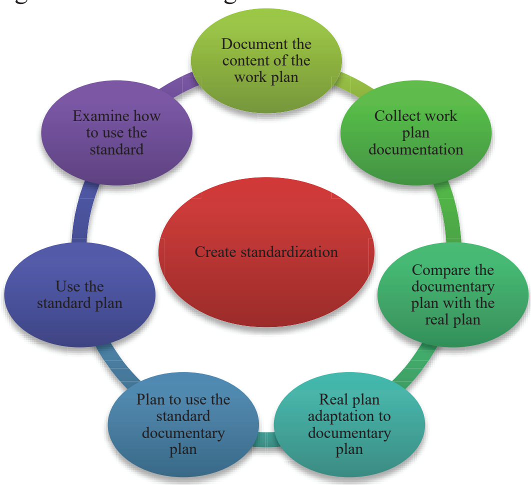
[49] Plan-do-check-act.

### B) Standardization and documentation of effective methods

Standardization ensures that the core components of a process are always running in the best possible way. A standard implementation method shows the working method with all the details and all its variables. In fact, with standardization, process and technology information is recorded in writing. In this way, it becomes easier for others to do the work.

Standards should be written in such a way that even people who are not fully trained can easily use them, explain enough about the details of the job, specify how oscillations can be prevented, and provide clear instructions to users. The following steps are usually taken to create standard methods and plans, and to ensure that these methods are used:

1) Documenting the content of the work plan;
2) Collecting documents to show the work plan;
3) Comparing the documentary plan with the real plan;
4) Matching the real plan with the documentary plan;
5) Planning to use the standard documented plan;
6) Applying the standard plan;
7) Evaluating the results of using the standard.




### C) Controlling the process

A common way to control the process is to use control charts. Control charts differentiate between unwanted process fluctuations and unwanted product fluctuations, determine the process capability, and play a key role in deciding on product status and process fluctuations.

**D) Evaluate the results**

**Purpose:** in this step, it is necessary to evaluate the results after the implementation of process improvements. This ensures that the process is stable and that implemented changes and improvements are part of the process.

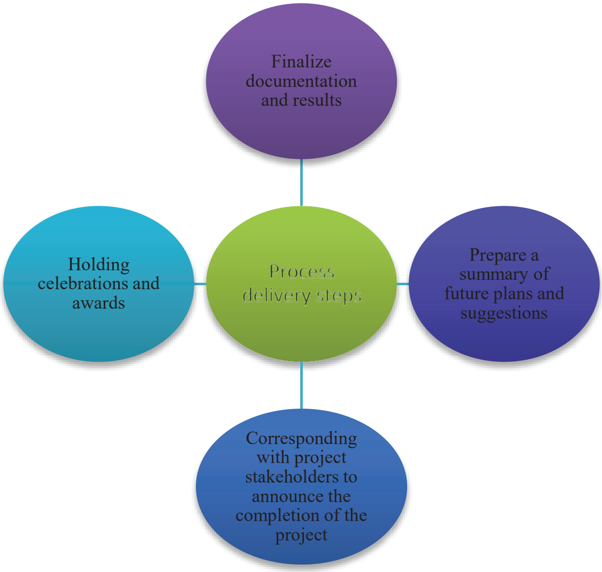
The results obtained from the process inspection and control are reviewed and, if necessary, improvements are made. Samples are taken from the process under control and process sigma level or indicators that were considered in the definition phase to evaluate process improvements are calculated. In the next step, these indicators are delivered to the process owner.

**E) Delivering the process, summarizing the key lessons learned, and preparing a preliminary plan**

**Purpose:** if the results of the process are well documented, they can be used as a resource for other individuals in the future.

The completion and termination of the project and summarizing and documenting the lessons learned from the project are done. The resultant documentation usually includes the results of the project, the work steps taken, the project costs incurred, and the project resources, etc.

1. Finalizing the correction documents and providing results from the work to relevant individuals.
2. Preparing a summary of the plan and giving suggestions.
3. Corresponding with the individuals involved in the project to announce the completion of the project.
4. Holding celebrations and awarding prizes to individuals involved in the project.




### Reasons for the success of Six Sigma

Successful implementation of Six Sigma depends on the connection of the following concepts.

- **A clear commitment of management with a top-down attitude.** Employees should witness active leadership and guidance during project implementation by the organization's senior management.
- **A measurement system for tracking and following progress.** This creates a tangible picture of the organization's efforts.
- **Internal and external modeling of the organization's products services and processes.** This information can lead to very significant change when the organization begins to discuss and understand the true state of the sales market. This experience leads to the reformation of the organization with a philosophy of problem-solving.
- **Training at all levels of the organization.** Without the necessary training, people cannot fully understand the attitude and philosophy of improvement.

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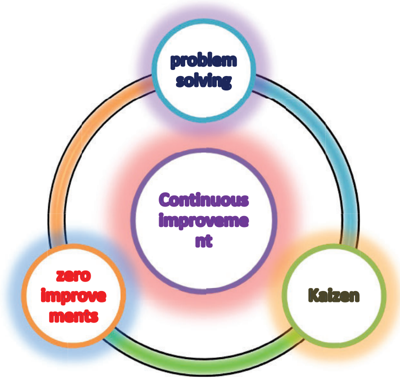
# CHAPTER SIX

# CONTINUOUS IMPROVEMENT

Continuous improvement is an effective process to increase the productivity of an organization, with the aim of steady, consistent growth and quality improvement in all steps of the manufacturing process. The objective of improvement is to achieve higher levels of performance and efficiency than those that exist. There are three methods for continuous improvement. These are: *problem solving; Kaizen; and zero improvements.*



### The problem-solving method

The problem-solving method is used to improve a process; the quality department of the organization has responsibility for monitoring this process.

If process improvement is done within the framework of the problem-solving method, great results can be achieved. Usually, in the early steps of the plan, significant results are achieved quickly because the solutions are clear or the people responsible have great ideas. However, in the long-term, a systematic approach is necessary.

The problem-solving method, also known as the scientific method, has different modes depending on the type of application, although they are all similar. This method consists of seven integrated steps and each step depends on the previous step. The continuous improvement of the process is the main objective and these steps form the framework to achieve that objective.

#### Step 1: Identify opportunities

The purpose of this step is to identify and prioritize improvement opportunities. It includes two parts: identifying the problem and forming a group. The problem is, in fact, an answer to the question, ***what is the problem?*** Some problem identification methods include:

- Pareto analysis related to frequent symptoms of external dangers, such as complaints and relapses, etc.
- Pareto analysis of frequent symptoms of internal dangers, such as rework and wastes, etc.
- Suggestions provided by key members, such as managers, unit heads, specialists, and logistics staff, etc.
- Study consumer needs.
- Information on product performance is compared to that of competitors through laboratory applications and results.
- Collection of statements by key persons outside the organization, such as customers, suppliers, journalists, critics, and so on.
- Findings and statements of government monitors and affiliated laboratories.
- Customer comments.
- Employee comments.
- Brainstorming in workgroups.

In this approach, it is not said that problems are good or bad, but rather that they provide opportunities for improvement. There are 3 criteria for diagnosing the problem:

1. Performance outside the specified standard.
2. Deviation from observations and facts.

3. Unknown cause (if the cause is known, there will be no more problems).

Finding problems is not a difficult task because there are always more problems than can be analyzed. However, their priority should be determined by a "quality council" or working group using the following criteria:

1. Is the problem important and far-reaching? Why?
2. Is problem solving effective in achieving the objectives?
3. Can the problem be clearly defined numerically?

The second part of step 1 involves the forming of a group. If the group is a normal working group, this section is complete. If the problem is related to different specialties, the team must be selected by the quality department to improve a specific process. Then, the designated group leader takes over the job as the main owner of the process and appropriate objectives and deadlines are also specified.

**Step 2: Determine the scope of action**

The reason for the failure of problem-solving is often the lack of useful information. We should note that a problem that is a result of defective design contains half of the solution.

Good and complete design criteria for problems have the following specifications:

1. They make the problem wholly describable and understandable.
2. The results should be specified (what is wrong and when and where this error occurs; not why there is a problem and who is responsible for it).
3. Focus on the facts without making personal judgments.

At this step, in addition to the statement of the problem, the group needs a general charter. This charter specifies the following:

1- **Responsible:** who is responsible for the group?
2- **Purpose and scope:** which desirable outcomes and specific fields need improvement?
3- **Composition:** who are the members of the group and the main managers of the process and sub-processes?
4- **Leading and control:** what are the solutions for the internal performance of the group?
5- **General issues:** What methods and resources should be used?

**Step 3: Analyze the current process**

The purpose of this step is to understand the process and how to implement it. Key activities (such as data collection, determining and defining process limits, external factors, customers, internal factors, suppliers, process procedure, identifying root causes, and determining the level of customer satisfaction) are performed to determine the required measurements in the process analysis.

The first step is to prepare a workflow chart. The workflow chart fully describes complex tasks with easily understandable explanations. This is often a useful experience for the group because it is rarely the case that all team members immediately understand the process. Performance criteria are then defined. The taking of appropriate measurements is a key issue in improving the process. If something is not measurable, it cannot be improved, in other words; *what can be measured can be improved.* The team determines whether the measurements needed to understand and improve the process are used or not. If new measurements are required, the group should do the following:

- Create performance scales according to customer needs.
- Specify the data needed to control the process.
- Establish regular feedback from customers and suppliers.
- Determine scales for quality, price, time, and input and output factors.

Once performance scales have been created, the group can gather all the available data. If there is not enough data, the group must get new information.

### Collecting data

1- Helps to ensure the existence of problems.
2- Enables the group to work with facts.
3- Makes it possible to create measurement criteria for the main parts of the process.
4- Enables the team to measure the effectiveness of the implemented solutions.

It is important that the group collects only the required data and uses this data to solve the problem. The group should develop a plan that includes information from internal and external clients to answer the following questions:

1- What problem or operation do we want to investigate?
2- For what purpose will the data be used?
3- How much data is needed?
4- What results can we get from calculating the data?
5- According to the results, what action should be taken?

- Data can be collected instantly through control sheets, computers, and software. The team should identify customers and their expectations and systematically review ongoing procedures.
- Some of the data and information that can be of use include:

- Design information: such as specifications, plans, bill of material (BOM), cost reviews, and “repairability” rate, etc.
- Process information: determining the method, equipment, users, raw materials, and constituent departments, etc.
- Statistical information: mean, median, range, standard deviation, skewness, elongation, and frequency distribution, etc.
- Qualitative information: Pareto charts, cause-and-effect charts, control sheets, dispersion charts, control charts, histograms, process capability, sampling for acceptance, durability tests, equipment, and user matrix analysis, etc.

A cause-and-effect chart has a particular importance at this step. Determining all causes requires experience, creativity (through brainstorming), and a broad understanding of the process; as such, a cause-and-effect chart is a great starting point for the team and the project manager. The objective is to find the causes, not the solutions, and all possible causes, no matter how insignificant, are noted.

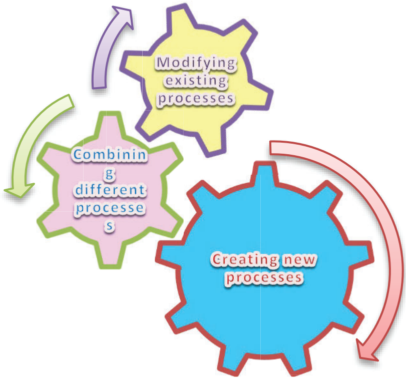
Identifying the root cause is very important; this can be done using a survey. Investigating the most likely causes is a good idea because a mistake at this step can waste both time and assets. Here are some investigation methods:

1- Investigate the most probable cause for the problem.
2- Review all data related to the main cause.
3- Examine process control when operating satisfactorily and when performance is not satisfactory.
4- Use experimental design, Taguchi quality engineering, and other advanced techniques to identify vital factors and determine their level.

### Step 4: Planning for Future Processes

The purpose of this step is to provide solutions to problems and determine the best ones for improving the process. Once all the information has been provided, the project team begins its search for possible solutions. Often, more than one solution is needed to improve the situation. Most of the time, solutions are obtained simply by a brief and superficial analysis of the data.

There are three types of “creativity” in this process improvement: **1) creating new processes; 2) combining different processes; and 3) modifying existing processes.**




The first type of creativity, *creating new processes*, is situated at the highest level; an example of this is the invention of the transistor. The second type, *combining two or more processes*, is where a combined activity creates a better process, i.e. there is a unique combination of things that are currently available. This kind of creativity strongly depends on modeling. Ultimately, *modification*s (meaning changes in process data) make it more efficient. Changes are successful when managers use the experience, learning, and energy of powerful workgroups or project teams. These three things are interdependent.

In this step, creativity plays a big role and brainstorming is its main technique. Brainstorming is the free exchange of ideas in a group to find a solution to a problem. All monitoring is recorded on a blackboard or similar device. Even minor and insignificant ideas are encouraged, as they may lead to useful ideas. The purpose of these meetings is to increase the number of comments. Group members are asked to combine ideas and no one is allowed to criticize others as this limits creativity. Brainstorming is mainly done with the members of the project team, but other individuals can also attend meetings.

Once possible solutions have been identified, evaluation or testing begins. More than one solution may help solve the problem. Evaluation or testing determines which of the possible solutions is most likely to succeed, while also identifying their advantages and disadvantages. Criteria (used to judge possible solutions) include cost, feasibility, impact, resistance versus change, results, and training. Solutions may be classified into limited domain or wide domain categories. One of the specifications of control charts is their ability to evaluate possible solutions.

**Step 5: Make changes**

Once the best solution has been selected, it can be implemented. The purpose of this step is to prepare executive plans, get verification, and implement process improvement plans. Although the project team has the authority to organize corrective actions, it often requires more than the consent of the quality committee or other responsible authority. In this case, a written or oral report will also be provided to the group.

The contents of the executive plan report should include the following:

- Why should this be done?
- When to do it?
- How to do it?
- Who will do it?
- Where to do it?

The answers to these questions determine the actions taken, assign responsibilities, and establish the executive headings. The quality and quantity of the report depend on the complexity of the changes. Small changes may only require an oral report, while larger changes may require a comprehensive written report.

Alongside verification by the quality council, it is best to obtain the verification of the departments, groups, and affected individuals. The benefit of this that it increases support for those involved in the process and gives an opportunity to hear proposed reforms.

### Step 6: Guide and approve changes

The purpose of this step is to control and evaluate changes by investigating the effectiveness of improvement plans through collecting data and measuring progress. Institutionalizing changes and ensuring progress in assessment is essential for improvement. Changes are often made on a small scale. If successful, they are the applied in all departments.

The last component of the executive plan is to control the activities that answer the following questions:

- What information should be controlled and what resources are needed?
- Who will be responsible for the assessment?
- How should the assessment be done?
- When does the assessment start?

Measurement tools (such as control charts, Pareto charts, histograms, control sheets, and questionnaires) are used to monitor and evaluate process changes. The team should periodically evaluate the results during this step to see whether problems have been solved or other measures are needed.

They also investigate whether an unforeseen problem has arisen as a result of the changes or not.

If the group is ***not satisfied*** with the work, some steps must be repeated.

If the group ***is satisfied*** with the result of the changes (or *is satisfied* in terms of the positive and useful control of the process, process verification, and user verification), then change is institutionalized. Effective control ensures that important variables are always monitored.

Marginal issues of quality, system, environment, and monitoring should be approved. Finally, employees must be able to recognize what to do and how to do a particular process. They should also be well trained in other tasks so as to be better aware of future customer needs. Verification of user capabilities is a process that must be performed regularly.

#### Step 7: Continuous improvement

Achieving improved levels of process efficiency is the objective of this step. No matter how successful initial efforts for improvement are, the improvement process continues.

Everyone in the organization has to make a systematic effort to develop customer-oriented and flexible processes, while also striving for continuous quality improvement. A key activity is the regular monitoring of progress by the quality department or working groups. Management must create a system that identifies areas for improvement.

We must always strive for the highest levels of performance by reducing complexity, instability, and out-of-control processes. Although the problem-solving method does not guarantee success, experience has shown that through its use, there is the highest probability that success can be achieved.

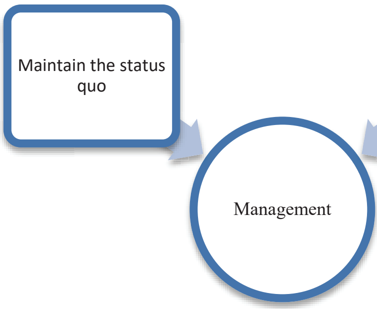
### Kaizen and Innovation

In Japanese, *Kaizen* means continuous improvement. This improvement is something that everyone, including managers and employees, should pay attention to it; furthermore, Kaizen is a very inexpensive approach. The Kaizen philosophy is based on the fact that our lives (whether working, social, or family) are focused on striving for continuous improvement. Although improvements under Kaizen may seem small, the process has dramatic and exciting results in the long term. *The Kaizen process is based on "right mind thinking." The Kaizen process makes tremendous progress through the performance of low-cost activities. In Kaizen, success is associated with reduced risk. As a result, managers do not incur exorbitant costs through Kaizen.*

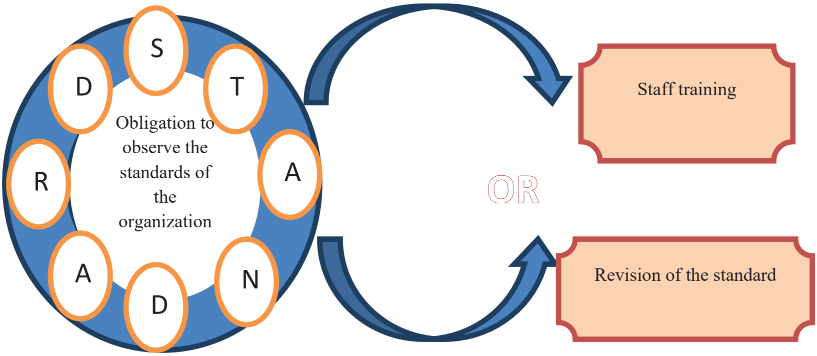
The mindset of managers (with a focus on **large-scale change and technological innovation** in Western countries) is based on the principle of securing **the latest management concepts and manufacturing methods in the shortest possible time**. The impact of innovation on technological change is dramatic, *while, in the short term, Kaizen* *activities are often unemotional and quiet.* The fact is that innovation sees quick moves to change technology, but the results are often problematic. The message of the Kaizen strategy is summed up in this sentence: **not even a day should be spent without making any improvement in one of the parts of the organization or company.**

**Kaizen and Management**

Management has two important tasks: maintaining the current situation and improving processes. Maintaining the current situation includes activities to maintain current levels of technology and management, along with executive standards and their establishment through training. Management (through maintaining the status quo) ensures conditions in which anyone can follow the **standard operating procedures.** However, improvement also concerns activities that are done to improve current standards. As such, the Japanese concept of management is a combination of the two views of maintenance and improvement.

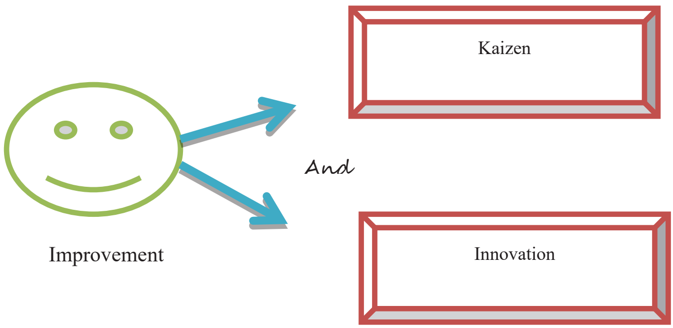



Management must first prepare working items for all individuals (in relation to the company's major activities, regulations, policies, instructions, and job descriptions). Then, management monitors observance of the standardized working method by all employees. If individuals are not able to comply with the standard, management will have two options—one is to train employees and the other is to revise standards so that employees can perform their tasks accordingly.




Even unskilled workers should think about improving their work (by gaining more skills). These workers (as individuals or teams) try to take steps to improve the work assigned to them. Improving standards means determining higher standards. After determining higher standards, the task of management is to monitor observance of the new standards. Continuous improvement is possible only through the observance of higher standards by employees. Thus, maintenance and improvement have become "two integral parts" for most Japanese managers.

It can be said that improvement means **Kaizen and innovation**. **Kaizen** involves making minor improvements to the current situation through relentless effort, while **innovation** refers to general reform of the current situation through massive investment in new technology or equipment.




*Kaizen* represents small improvements resulting from leadership efforts, but *innovation* includes dramatic and extraordinary improvements as a result of large investments. Kaizen emphasizes individual effort, beliefs, communication, training, teamwork, the use of "thinking power," the workforce, individual discipline and "right mind," and low-cost improvements.


Some companies start doing business successfully and grow rapidly before disappearing at the same speed, due to a decline after initial success or a declining market. The worst companies are those that only seek to maintain their position (i.e. no improvement). In such a company, there is no incentive to do Kaizen or innovation and change is imposed only through market conditions and competition. In such a company, management does not pursue specific objectives.

**Twenty Principles of Management in Kaizen**

These principles form the basis of Kaizen thinking:

1. Do not ask why a particular piece of work has not been done, but think about how you can do it.
2. Do not worry about a problem, but take action to solve it now.
3. Do not be satisfied with the current situation, but believe that there is always a better way.
4. If you make a mistake, try to solve it right away.
5. Do not look for perfection in achieving an objective. If you are 60 % sure of achieving the objective, then get to work.
6. To get to the root of a problem "ask why?" 5 times
7. *Gemba* (the place where value is created) is the actual location of the error event. **Do not try to solve location-specific problems from your office.**
8. Always use up-to-date data and information to solve a problem.

9. Do not immediately seek to spend money to solve a problem. Instead, use your intellect. If your intellect does not find a way, ask your colleagues and use collective wisdom.

10. Never ignore the small details of an issue. The root of many big problems is in these small points.

11. Senior management support is not limited to words. Management must have a visible and tangible presence.

12. Do not hesitate to delegate authority to subordinates to resolve issues wherever possible.

13. Never look for the culprit and never judge hastily.

14. Visual management and information transfer are the best tools for problem-solving in teams.

15. One-way top-down communication complicates an organization's problems. Senior management must have a two-way relationship with the lower levels of the organization.

16. Humans have many abilities; use multi-skill patterns and job enrichment to make them flourish.

17. Only do activities that add value to your organization.

18. Don't forget that the "five Ss" are the foundation of creating quality products.

19. Solve your working environment problems based on teamwork patterns.

20. Removing *muda* (waste) is an endless process. Never get tired of this task.

### Kaizen and the Deming cycle

The first steps taken in establishing the Deming improvement cycle (PDCA) are "planning, do, check, and (corrective) action." This cycle is a reliable tool for Kaizen continuity and the implementation of strategic policies to improve standards.

Planning means determining objectives for improvement. In the action phase, regular activities are carried out to realize the plan. In the check phase, the new situation is compared with the anticipated conditions, and the effectiveness of the plans is ensured. In the corrective action phase, new standards and effective processes are used to prevent the reoccurrence of primary problems and pave the way for further progress.

Work processes are usually unstable at the beginning; therefore, before the PDCA cycle, all current processes must be standardized according to the SDCA cycle, i.e. "standardization, do, check, and action." The SDCA cycle ensures **the stability of current processes**, while the PDCA cycle pursues **process improvement**.

### Three basic steps in the practical implementation of Kaizen

According to Kaizen, to achieve gradual and continuous improvement in organizations, the following three basic steps must be taken:

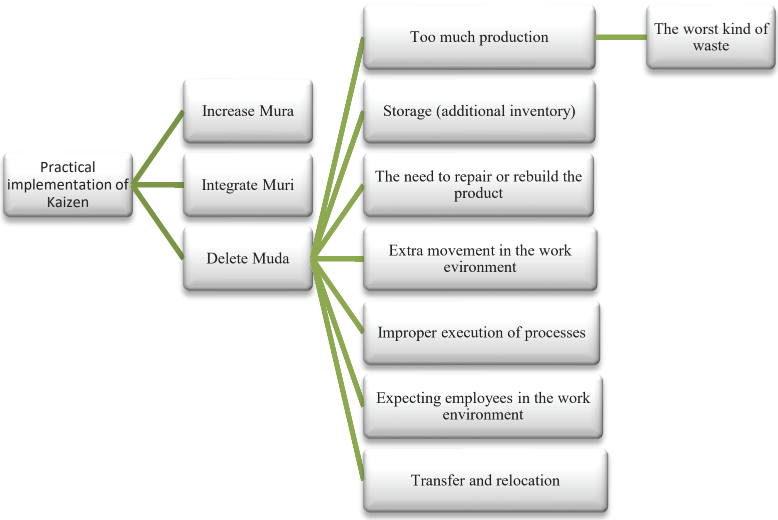
1. All activities that are costly but do not produce value (muda) should be eliminated.

2. Activities that are done in parallel in another place (mura) should be combined.

3. Some activities are necessary to complete and improve the quality of services (muri), therefore it is better to add to the activities of the organization. This is the basis of gemba Kaizen (Practical Kaizen) workshop.

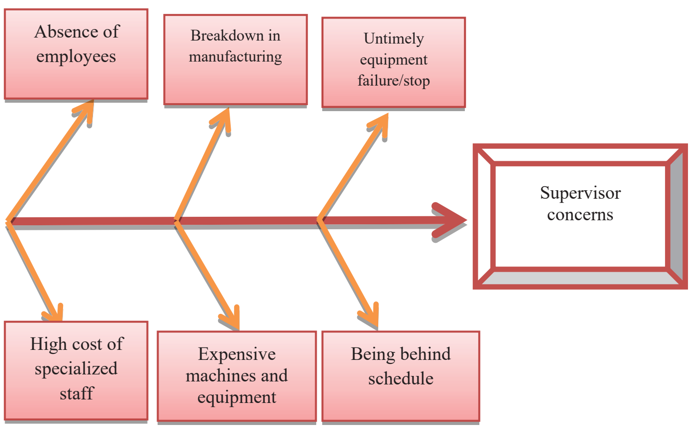
*Muda* refers to those activities that attract and consume resources and reserves, but do not create any value. There are many types of *muda* that an organization should identify and try to eliminate in its activities and knowledge of its resources. Seven types of *muda* have been identified by Taichi Ono (Vice-President of Manufacturing, Toyota Motor Company), which are listed below:

1. Losses due to overproduction;
2. Losses due to storage (additional inventories);
3. Losses caused by the need to repair or rebuild a product;
4. Losses caused by extra movement in the work-environment;
5. Losses caused by improper process implementation;
6. Losses caused by employee expectations in the work-environment;
7. Losses caused by the transfer and movement of tools, equipment, and semi-finished products.

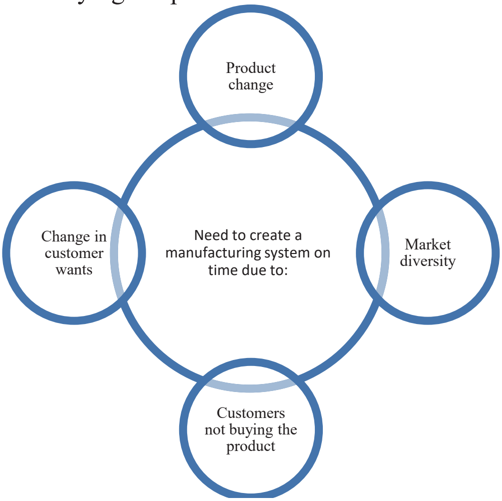



**Losses due to overproduction**

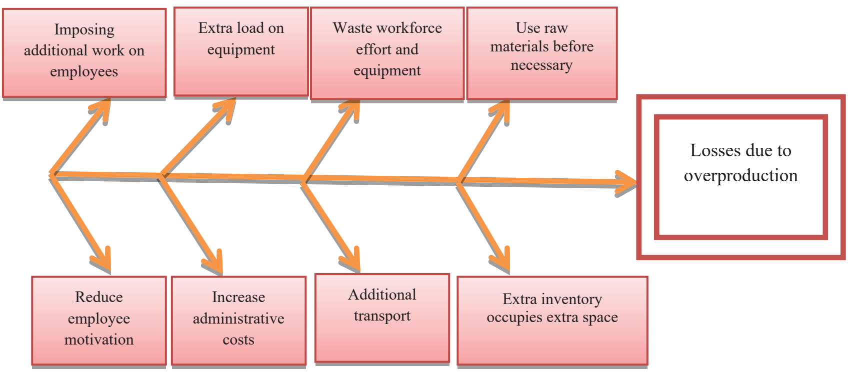
This loss is due to the concerns of the "supervisor mind" because he or she is worried about problems such as equipment failure, the inadequacy of some products, and the absence of employees. The supervisor produces as much as possible increasing their confidence and thus gets ahead of schedule. When expensive machines and equipment are being used, taking full advantage of the equipment and increased manufacturing is attempted.



In a timely manufacturing system, being ahead of the manufacturing schedule is even worse than being behind it because, due to the *diverse demands of the market and changes to the product*, overproduction can lead to no one buying the product.



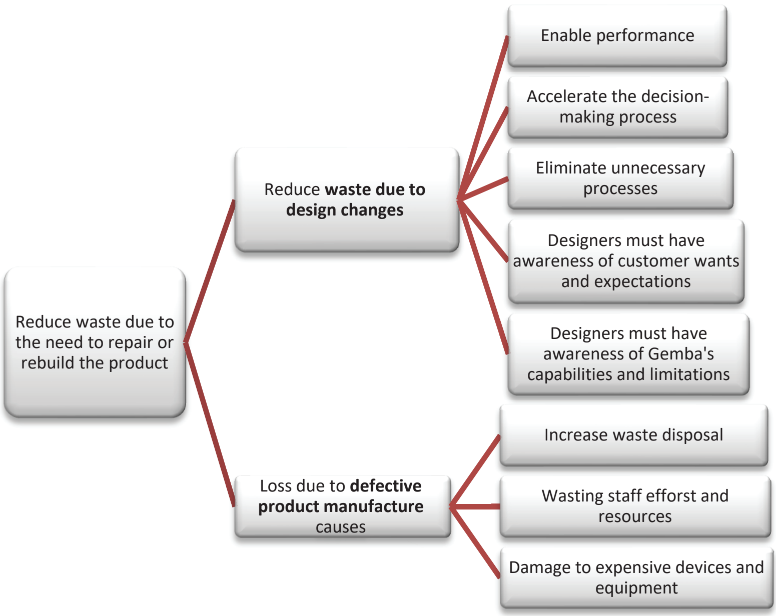

Too much manufacturing leads to multiple losses, including: the use of raw materials before necessary; wasting workforce effort and equipment; placing an additional load on equipment; imposing extra work on employees and thus reducing their motivation; using extra space to accumulate inventory; additional transportation requirements; and surplus product with added administrative costs.



If the inventory level in the warehouse is high, no one is seriously aware of the occurrence of quality deficiencies, equipment and device failures, and employee absences. A low inventory level can help identify potential problems and solve them accurately. This is the behavior followed in a timely manufacturing system. If the inventory level on the manufacturing line (i.e. semi-manufactured products) goes down to zero, then, in each workstation, only one product goes through the manufacturing path, making Kaizen activities inevitable.

**Losses due to a requirement to repair or reconstruct products**

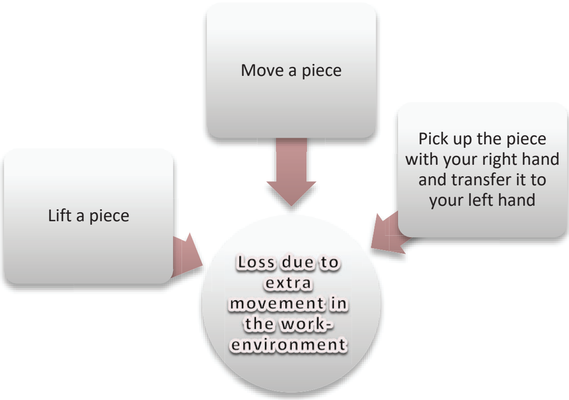
Waste and recycling interfere in the manufacturing process in terms of reworking and the use of costly agents. Sometimes, waste products have to be thrown away, resulting in the waste of staff efforts and resources. Today, mass manufacturing lines are equipped with automated machines that work at high speed. As a result, a defect can lead to the manufacture of large numbers of defective products. Defective products can sometimes damage expensive devices and equipment and an operator of a machine that produces at high speed must be a careful person who will stop the device in case of failure.



It should be noted that changes in the design and manufacture of defective product are both forms of waste. Waste in the form of frequent design changes can be reduced by efficient performance, the elimination of unnecessary processes, or speeding up the decision-making process, if designers do their jobs well in the first step. Designers should also be well aware of customer wants and expectations; they should also be aware of the capabilities and limitations of the gemba. By doing this, losses caused by changes to the design are minimized. It should be noted that Kaizen activities are effective in engineering projects as well as for gemba issues.

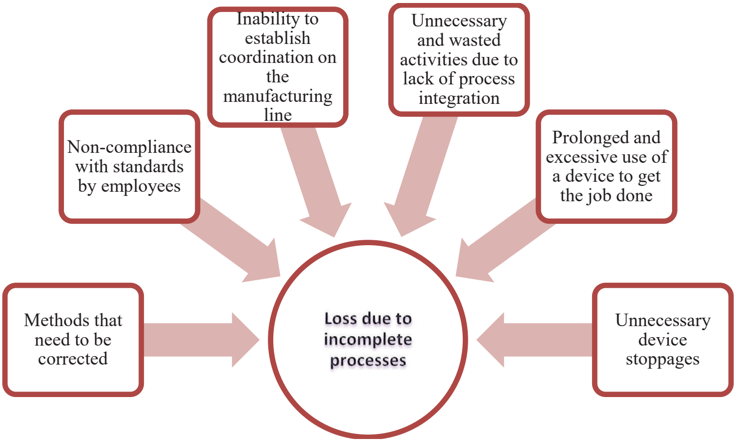
**Losses caused by extra movement in the work-environment**

Any physical movement (that is not directly related to the manufacture of added value) is non-productive. **Even lifting something or moving an item unnecessarily, and sometimes even lifting the piece with the right hand and transferring it to the left hand** can be considered wastes. To identify motion losses, how people use their hands and feet should be noted. Then, the appropriate location of pieces and tools should be selected so that such losses are reduced.



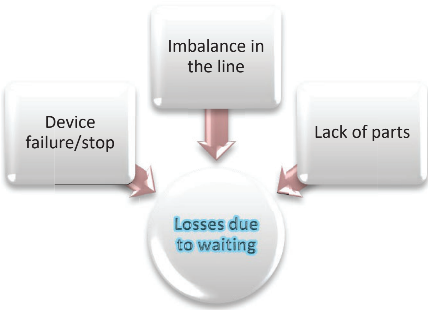

**Losses due to incomplete processes**

Sometimes incomplete technology or design processes cause waste. Prolonged and excessive use of a machine to get work done, unnecessary downtime of machines, or methods that need to be corrected are examples of "process wastes" that must be identified and prevented. At each step (where work is done on a piece of the product), added value must be created. Waste elimination is mainly based on having the "right mind" and low-cost methods. Some unnecessary and wasted activities can be eliminated by integration with other operations. Process losses can result from an inability to coordinate the manufacturing line. Sometimes users try to summarize complete process standards and do what they deem necessary. This is one of the causes of process losses.




**Losses due to waiting**

If the user's hands are empty, losses due to waiting occur. If manufacturing stops due to an imbalance in the line, a shortage of pieces, or a malfunction of the machine, a loss due to waiting occurs. Even if the user is simply standing by the device and looking at it, there is a loss. Such losses are easily identifiable.




**Losses due to transfer**

At the company or workshop, you can see all kinds of vehicles such as trucks, lifts, and transport conveyors. Displacement is one of the main factors in operations, but none of these displacements add value to the product; sometimes, during displacement, losses are inflicted on the product. During relocation, various processes must be designed to minimize relocation. To eliminate losses caused by displacement, manufacturing lines that are located on their own or are distant from each other must be brought together and merged. As manufacturing increases, losses due to transfers intensify because redundant transfers increase significantly. **If you see a conveyor belt in a company, you should immediately ask the question, "can we remove this machine?"**

Losses can be seen in engineering work. Engineers are aware of the latest technologies and even if there are simpler solutions to achieve the objective, they prefer to use more sophisticated strategies, which give them the opportunity use their scientific and professional information. Such thinking leads to a failure in the needs of the gemba and the customer.

**Losses due to time**

Another type of waste is wasting time. Although this type of waste is not in Mr. Tai Chi Ono's seven categories, the improper use of time causes stagnation. In other words, whenever materials, products, information, and documents are left unused, they do not create any added value. In the manufacturing hall, for example, waste occurs due to storage, while in the administrative department, there is a loss when information left on the desk or inside the computer is waiting for a decision or signature. Thus, the seven categories of waste, without exception, lead wasted time.

This type of waste is more common in the service sector. At bottlenecks and different service stations, by eliminating times that do not bring added value, capabilities can be developed and, as a result, customer satisfaction can be improved. Eliminating waste is free of charge and thus this is one of the easiest ways to improve one's operations. The only work we have to do is going to the gemba and carefully consider what is going on there. After recording the losses there, we must take positive steps to eliminate them.

**Kaizen implementation steps**

To train individuals in productivity improvement workshops with a practical Kaizen approach, the following steps are necessary:

1. Select the sample area.
2. Create and organize an improvement team (Kaizen team).
3. Collect the required statistical data for the sample area with the help of team members.
4. Familiarize workshop participants with the concepts and tools of improvement.
5. Start the "5S" system.
6. Identify losses (*muda*) and make a list of them.
7. Analyze the causes of each "loss event" in the sample area and find solutions using teamwork.

8. Choose more practical solutions.
9. Make any physical changes to the arrangement of the sample area without wasting time.
10. Consider "improvement done" as a standard.
11. Inform your colleagues of success.
12. Evaluate the results for use in the next steps.
13. Move on to the next problem.

### The gemba (the real place of work)

In Japanese, the gemba is the actual location of the organization's main operations. In business, the gemba is a place of value-added activity. The main activity of companies (with the goal of profit) can be divided into three main parts: development, manufacturing, and sales. No company can survive without these activities and the gemba is the real place of these activities.

In service environments, the gemba refers to the place where customers are in direct contact with the provided services. For example, in a hotel, places such as the waiting room, dining room, guest room, reception desk, hotel entrance, and security guard post at the entrance are all gemba locations.

The manager of the organization should be in close contact with the facts of the gemba to identify and solve problems. The inattention of the manager of an organization to the gemba often leads to the plans and needs of the organization being incomplete and far from the real needs of the gemba. The importance of maintaining focus on the gemba at the top of the management structure requires committed staff. Employees must be eager to play their role; they should also be happy to participate in the management of the company and the "working society." The senior manager of the organization must create a sense of commitment and pride in employees. Finally, it can be said that the gemba is a source of "right mind" and low-cost improvements. Gemba-oriented management involves:

- Identifying gemba needs;
- Investigating problems and thinking about solutions;
- Low resistance versus change;
- Continuous compliance;
- The reality of proposed simple solutions;
- Implementation of solutions with an emphasis on "right mind" and low cost;
- Employee enjoyment of work and employee satisfaction in Kaizen;
- The flourishing of work;
- Thinking about Kaizen and improving the process along with doing daily activities;

- No need for senior management verification to make changes.

**Gemba golden rules**

Close communication with the gemba and understanding its (real and unmediated) events is the first effective step in its management. Five golden rules have been defined for the management of the gemba:

*Rule 1. Go to the gemba and find the cause of the problem;*
*Rule 2. Review equipment, tools, materials, and all items related to the gemba;*
*Rule 3. Make a temporary decision to troubleshoot the problem in the gemba;*
*Rule 4. Find the root cause and effect;*
*Rule 5. Design new standards to prevent the reoccurrence of problems.*

**Rule 1: Go to the gemba and find the cause of the problem**

A manager is responsible for performing activities, such as hiring and training employees, establishing operational standards, and overseeing the manufacturing process. Management determines the conditions for the gemba and what happens in the gemba is directly reflected in management. Thus, the first step in managing the gemba is to be present there. In gemba management, managers and supervisors usually go to the scene of production and investigate what is happening. Managers and supervisors (after acquiring the habit of going to the gemba) develop the self-confidence to solve specific problems.

**Rule 2: Review equipment, tools, materials, and all other items related to the gemba**

Defective devices, returned products, broken tools, and even dissatisfied customers should all be identified. By observing the facts of the gemba, managers can become aware of the causes of the problem and root them out by using working methods and being in the "right mind." For example, as soon as a machine breaks down, some managers, before even looking at it, gather the team in the meeting room to discuss the issue and try to clear the obstacle. Kaizen recognizes that the solution to a problem begins by recognizing the problem.

With a thorough understanding of the problem, half the solution has been completed. One of the important tasks of a supervisor is to consistently pay attention to the gemba. He or she can then anticipate potential problems and prevent their reoccurrence.

**Rule 3: Make a temporary decision to remove a problem in the gemba**

For example, if a device fails, it must rapidly be returned to a working state. Temporary measures can only eliminate obvious defects and complications, but do not lead to an investigation of the root causes of problems. This is a reason to visit the gemba as examining the tangible, known, and physical factors there (and asking why the problem occurred), allows us to discover the root cause of the problem.

### Rule 4: Find the root cause of the problem

Many problems (according to gemba laws and related considerations) can be solved by using the "right mind." In many cases, by looking at the roots of a problem, its causes can be identified. Solving some problems requires preparation and planning, including design problems, or the application of technology and new manufacturing systems. In such cases, managers need to gather the necessary information from all dimensions. Advanced tools may even be needed to solve the problem. For example, if a device stops (due to metal fragments falling on the belt), the stoppage can be temporarily solved before a permanent solution can be found. It may take hours or even days to do this. This way of thinking is clear to Kaizen managers. **Kaizen executives focus on getting work done on time and believe that tomorrow is too late to get it done.**

### Rule 5: Design new standards to prevent the reocurrence of problems

One of the main management tasks of the gemba is the realization of three actions for customer satisfaction. These three actions (mentioned in previous sections) are: good quality, reasonable price, and timely delivery of orders. Managers face all kinds of problems and issues daily—product returns, device malfunctions, and delays or absences of employees at work are some common issues and problems. After a problem has occurred, management must resolve it and ensure that the problem never happens again. After reviewing operational standards, he/she replaces the old methods with new methods. As a result, the cycle of "standardization, do, check, and (corrective) action" is constantly evolving. The final rule in gemba management is standardization. With accurate implementation of this cycle, the application of Kaizen is complete and the management (by carefully and comprehensively reviewing the current processes), eliminates defects in the process, paving the way for future success.

The standard is to do the job well. If the employees in the gemba follow such a standard, the customer will be satisfied; however, the customer's wants and expectations are constantly changing and, as a result, the standards of the gemba are constantly improving and changing.

### Standardization in Kaizen

The day-to-day operations of organizations are usually based on formulas that have been agreed with employees. If these formulas have been written according to a clear and understandable framework, they are described as "standard." An enthusiastic manager who is trying to improve the quality of his or her company's performance should upgrade the work-environment standards. The manager has two main tasks: maintenance and continuous improvement. Managers must not only ensure that standards of current technology, management, and operations are properly met, but, by upgrading these standards, they must continue with other tasks to ensure continuous improvement.

### Maintain and improve standards

The manager should identify any errors in the gemba, such as wastes or dissatisfied customers, and review the relevant procedures to prevent reoccurrence and elimination of apparent failures. If current standards are properly identified and carefully observed, the system does not produce abnormal products and the processes are under control. In this case, the next step is that the current situation should be promoted to a more favorable situation, as described in the SDCA cycle.

The use of superior models and comparison of the current situation with more successful processes should be considered. As such, it is better to have higher systemic standards. In reviewing these standards, priorities, such as quality, operating costs, delivery, safety, and severity of customer dissatisfaction, should be considered. During day-to-day working (maintenance of the status quo where employees comply with the prevailing standards), two situations may occur: no abnormal products or results are observed; or failures occur despite the observance of standards (the occurrence of these failures is the starting point for reviewing current standards and determining new standards). The first expectation from management is to create current standards in the system and be sure of their establishment. If these standards are established and no abnormal event is observed in the system, the system is described as being under control. Establishing this situation in the system, we should try to improve on current standards.

When a process of improvement is implemented in the organization, new standards prevail and higher standards are introduced. The recent level of governing standards provides the basis for establishing new and higher standards.

### Management and operational standards

**Management standards** are used to manage the affairs of employees and include directives, rules and regulations, management policies, job descriptions, financial laws, and so on. **Operating standards** include procedures that employees use to achieve three objectives: *optimal quality, reducing manufacturing costs, and delivering customer orders on time. Management standards deal with the internal regulations of the company and workforce management, while operational standards deal with customer expectations and wants.* In achieving the above three objectives we pay attention to customer satisfaction.

**Note:**
In Japanese, the term "standard" means a process that is "a guarantor of safety and comfort for employees," "cost-effective and productive for an organization," and "a guarantor of quality" for customers.

If employees comply with the company standards and do their jobs well, customer satisfaction and the provision of quality products or services is the result. Also, the company becomes well-known and grows by doing these activities. Finally, the employees have job security.

### Features of standards

Each standard is expected to have the following key features:

1. Standards represent the best, easiest, and safest way to perform operations. Standards are the result of years of effort and thinking and teach employees how to succeed in their tasks. The best methods (for doing an activity) must be maintained and taught to others. Safer, more cost-effective, and easier methods should always replace the old methods.

2. Standards show the best way to maintain technical knowledge and build skills. If individuals in the work environment have experienced a better way of doing something, but do not share their knowledge with others, improvement is limited. Higher standards can only be achieved through continuous improvement and the implementation of operational standards. In such cases, if there has been a relocation of employees, the necessary technical knowledge (which adds to the quality of the work) remains.

3. Standards are a mechanism for measuring and evaluating performance. By adjusting standards, appropriate and measurable methods can be implemented to evaluate performance in the work environment.

4. Standards define the relationship between cause and effect. A lack of appropriate standards leads to ignorance of variables. Deficiencies caused by a lack of standards are not identifiable and preventable.

5. Standards provide a basis for maintenance and improvement. Full and strict observance of standards leads to system maintenance and upgrade, as well as improvements in work. Without specific standards, there is no way to detect if improvements have been made.

6. Standards provide a basis for training. Once a standard has been developed, the next step is to train employees. The reasons for compliance must be clear to all employees so that they can do their jobs well.

7. Standards provide a good basis for auditing and diagnosis. In the gemba, standards are set in the right place and the main points of the job

become clear to employees. This helps supervisors and managers ensure that the work progresses properly.

8. The standards also result in error prevention data and data on process variable reduction. We can be sure of non-repetition of failures only when we have achieved the use of Kaizen in the development and establishment of new standards.

### Improving product quality by preventing defects (poka-yoke)

An **error** happens when an action or state is different to what was expected. An error commonly refers to any deviation from the expected or desired state. Mistakes are *indeed normal, but the rate of repetition of mistakes is not normal.* When an error occurs, its source should be identified and it should be prevented from reoccurring by correcting and controlling its source.

Many errors can also be detected before they are encountered or experienced, usually using precautionary measures and tools such as failure mode and effect analysis (FMEA).

Defects are usually caused by errors. When the result of a process or activity is not the expected one, that result is described as defective. Errors have an effect on the output of a process or activity.

There are three main techniques for **quality control inspection**:

**1. Judicial inspection.** After the completion of operations, the defective product is separated from the "healthy product." In this type of inspection, delivery of the defective product to the customer is prevented, *but the failure rate across the company is not reduced.*

**2. Information inspection.** *The causes of the defect are investigated* and the obtained information provides feedback on related processes. Based on this feedback, steps can be taken to reduce the failure rate. Thus, in this inspection method, the review-feedback activity cycle begins when a defect has already occurred.

**3. Inspection of origin.** Defects are seen as the result or effect of a simple mistake. Attempts are made to correct the source of the error through a total inspection *before it results in a fault.*

In a complex work environment, some tasks may go wrong and it is possible that these mistakes will lead to the manufacture of a defective product. Defects are considered waste and if not identified, defective products are produced. To become a global competitor, a company must not only follow the philosophy of zero-defect manufacturing (non-defective manufacture), but apply it practically.

A Japanese manufacturing engineer named Shigeo Shingo developed this theory as a powerful tool to achieve zero defects and eventually eliminate the need for quality control inspections. *Yoke* means avoidance and *poka* means an unintentional mistake. In English, poka-yoke is often translated as infallible or safe from failure. Poka-yoke is based on respect for the intelligence of workers. By eliminating repetitive tasks and activities that depend on memory and caution, poka-yoke frees up workers so that they can devote their time to worthwhile activities.

It can be said that poka-yoke means zero quality control (ZQC). In a ZQC system, a 100 % inspection can be performed through poka-yoke, which is both inexpensive and requires little effort. Zero quality control (ZQC) has three components that can help prevent malfunctions:

**1. Origin inspection.** In this method of inspection, the *factors* that cause the defect (*not the resulting defect*) are controlled.

**2. One hundred percent inspection.** In this inspection, low-cost infallible tools are used for the automatic inspection of errors and defective working conditions.

**3. Immediate action.** In the immediate action method, as soon as an error occurs, the manufacturing operation stops immediately. Manufacturing is stopped until the problem is resolved.

All of the above are key elements of zero quality control and, if used properly, can guide the system to achieve the objective of zero defects.

Zero quality control (ZQC) is a quality control method to achieve ***zero failure***. The word "zero" refers here to the purpose of this method, which is to create products with zero waste. ZQC is based on the principle that waste generation can be prevented through process implementation control, even when a machine or process fails. ZQC is a method that does not rely on individuals because machines and individuals sometimes make mistakes. As such, we must look for ways to prevent these errors from leading to damages/failures and waste.

The reason for paying attention to ZQC is that the existence of failure in the products of an organization will lead to higher costs. Flawless manufacture maintains customer satisfaction and loyalty and, in some cases, a failure in a company's products can cause a significant financial loss. A failure always leads to increased costs—a failure in a company's products will increase the company's costs and, consequently, the cost of its products.

ZQC assures the manufacturer that defective products will not be produced from the beginning. It also allows companies to produce exactly what the customer has ordered.[50] Finally, ZQC is a key parameter in the

[50] Organizations utilizing "timely" manufacture (JIT manufacturing).

competition to adopt agile manufacturing methods with reduced product storage.

The ZQC system does not talk about process invincibility, but rather ***process infallibility***. ZQC recognizes that it is normal for people to make mistakes in their work, and if a mistake is made and a machine does not work properly, this does not mean that the operator has failed.

The personnel of different manufacturing lines have a significant role in achieving the ZQC objective of manufacturing products with zero failures. Many of the process's infallibility techniques are performed by teams, consisting of workshop employees, engineers, and maintenance personnel, as well as quality control personnel. The help and cooperation of people in this field are very important.


Most failures occur in one of the following cases:

**1. Error in process design.** If appropriate standards and procedures are not followed in process design, failures will result. For example, if the correct temperature is not selected in the heat treatment of metals, all products will be damaged.

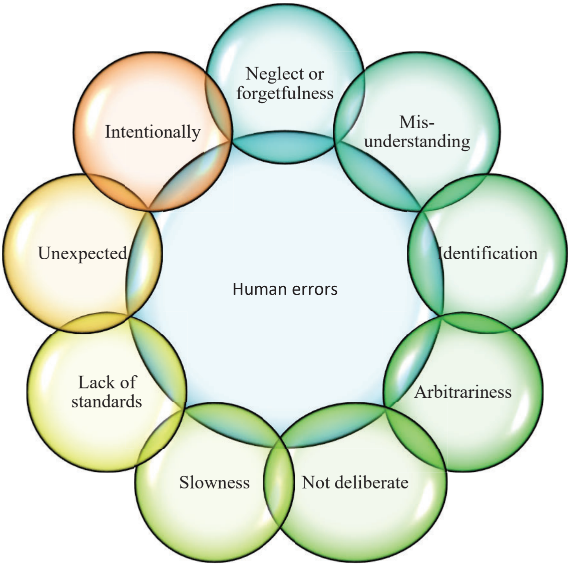
**2. Variability in processes.** Variability is an integral part of processes that will lead to deviations in process output. However, set values of deviations in the process are, to some extent, acceptable; deviations beyond those values are identified as failures. For example, a device may have high variability due to wobble in its clamping tool, causing deviations in products. Proper maintenance and principle measurement system analysis can prevent such problems.

**3. Use of inappropriate materials.** Sometimes, inappropriate materials are used. In such cases, errors can be prevented by using pre-arrival material inspection and quality management systems.

**4. Equipment erosion and unsuitability.** Inadequate equipment and the erosion of equipment also lead to malfunctions. These failures can be prevented by using proper maintenance systems and tool and equipment management.

**5.** Even if the above four cases are implemented correctly, simple human errors can sometimes lead to malfunctions.

The first four cases are all predictable. As a result, solutions to prevent them from occurring are workable. In the following, we will analyze Case 5 further as ***most defects are caused by human error.***




Human error can be divided into 10 main types:

**1. Inattention or forgetfulness.** If people are not focused, they can forget to do certain tasks, or do them out of order, leading to mistakes. The way to prevent such errors is to *use checklists or remind employees before and during the process.*

**2. Errors caused by misunderstanding.** This error usually occurs when people are not already familiar with the specifications and conditions of the environment. *Training and standardization of work procedures* can help prevent such mistakes.

**3. Identification error.** Sometimes we misjudge a situation because we only look at it very quickly, or the situation is so distant that we cannot recognize it. For example, if we see a 10,000 rial banknote and believe it to be for 20,000 rial, we make such an error. Ways to prevent such mistakes include *training in accuracy and caution.*

**4. Errors caused by inexperience.** Sometimes an error occurs due to a lack of experience. For example, a novice worker cannot do their job well because they have not yet gained the necessary experience. Ways to prevent such mistakes include *skilling of the workforce and the standardization of working practices.*

**5. Errors caused by arbitrariness.** Sometimes individuals ignore the rules. For example, where a traffic light is red, but you cross the street because there is no other car at that moment. Ways to prevent such mistakes include *basic training and increasing experience.*

**6. Unintentional errors.** Sometimes people make mistakes because they are distracted and unaware. For example, where a person is engrossed in their thoughts, regardless of whether the light is red or they cross the street. We can prevent such errors through *increasing accuracy, discipline, and standardization of work.*

**7. Errors caused by slowness.** Sometimes people do tasks slowly because of delays in analyzing and reacting. For example, a person who sees an obstacle too late and thus brakes late. To prevent such mistakes, we can *take preventative measures, acquire skills, and standardize the work.*

**8. Errors due to a lack of standards.** Some errors occur due to a lack of work standards and proper instructions. For example, the taking of measurements has to follow standard procedures; in the absence of these standards, errors are likely. Ways to prevent such errors include *standardizing work and creating appropriate work instructions.*

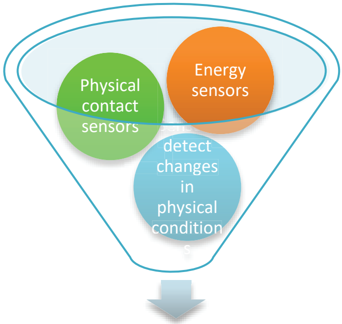
**9. Unexpected errors.** Sometimes errors occur when equipment does not work as expected. For example, emergency equipment failures can be occur. Ways to prevent such errors include *comprehensive maintenance (TPM) and standardization of work.*

**10. Intentional errors.** Some people make deliberate mistakes—crimes and sabotage are examples of such errors. Ways to prevent such mistakes include *basic training, improved discipline, and analysis of work-life relationships.*

**Use of Exploration Tools in Poka-yoke**

Many errors occur due to operators having low accuracy during the process. Exploration tools and sensors prevent operators from making diagnostic errors. Sensors used in poka-yoke systems can be divided into three main groups:

- Physical contact sensors;
- Energy sensors;
- Sensors that can detect changes in physical conditions.




Exploration Tools in Poka-yoke

**A) Physical contact sensors**

These sensors work through physical contact with a product or a part of the device. Most of the time, especially in automated processes, these sensors send an electrical signal when contact is made. This signal can stop, turn on a device, or give it another specific command.

**Microswitches and limit switches** are the most widely used poka-yoke tools. They can detect the presence of items such as work-pieces, mold, and cutting tools; they are very flexible. For example, limit switches can be used to ensure that the manufacturing process does not begin before the correct placement of the work-piece or stops the process if the shape of the work-piece is incorrect.

**B) Energy sensors**

These sensors use energy instead of physical contact to find faults. A photoelectric sensor can detect opaque, semi-opaque, and transparent objects (depending on the needs of the process). Optical and radiation instruments are of two types: transient and reflective. In the transit type, two devices are used, one to send a beam of light (like a lamp) and the other to receive it. Transmission systems are normally either “on” or “off.” When a transmission system is on, it means that there is no obstacle blocking the light beam; when it is off, it means that there is an obstacle in the way and no light passes through. The reflective type of photoelectric sensor is sensitive to a beam reflected from an object and the presence of that object can be detected. A proximity sensor is sensitive to changes in the distance from the object, as well as changes in magnetic force.

**C) Sensors that detect changes in physical conditions**

The third type of poka-yoke sensor is a tool that is sensitive to changes in circumstances. These devices detect any change in conditions in three categories: pressure, temperature, and electrical flow.

Pressure changes can be detected through pressure-sensitive gauges and switches. For example, this tool can help identify the interruption of lubrication power circuits or a drop in oil pressure, etc. Temperature changes can also be detected using temperature-sensitive instruments such as thermometers and thermostats, etc.

### Achieve error-free manufacture through poka-yoke

The eight principles of fundamental improvement through poka-yoke and zero defects are:

**1. Integrate quality with the process.** When an error occurs, this makes it impossible to manufacture a defective product. To achieve this objective, 100 & inspection and poka-yoke prevention tools are used.

**2. All harmful errors and defects can be eliminated.** It must be assumed that mistakes are not inevitable. Where the will is strong enough, there will be a way to eliminate all errors and mistakes.

**3. Stop doing the wrong task and start doing the right task.** "Buts" should be removed from our sentences in general, such as "this is not right, but it must be done now"; rather we might say *stop doing the wrong work right away.*

**4. Instead of "not thinking about it," think about "how to do it right."** Instead of thinking of excuses, think about how the work can be done correctly.

**5. To succeed, a 60 % chance is good enough, so implement your idea now.** You need to analyze the causes of a problem and then think of a solution. If the chance of success is more than 50 %, run it. You can modify your path according to the results later on.

**6. When everyone works together to eliminate mistakes and flaws, they will be reduced to zero.** Zero mistakes and flaws cannot be achieved by one person alone. Everyone in the company must work together to eliminate mistakes and defects.

**7. Ten thoughts are better than one.** Brainstorming is important, but the wisdom and creativity that comes from the efforts of ten people are valuable. Teamwork is the key to developing effective ideas for improvement.

**8. Use "five Ws" and "one H" to search for the real cause.** If the product is defective, the number of inspections should not be increased. Instead, you should analyze the root of the problem to make sure your solution is a real solution. The question should be asked "why is the product damaged?" Do not be satisfied with reasons that come to mind easily, but ask "why" again. Ask "why" at least 5 times to discover the root of the problem. Then you have to ask "how can we solve the problem?" Once we have the solution, we have to implement it.

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# CHAPTER SEVEN

# PRIORITIZING CUSTOMER NEEDS

## TYPES OF NEEDS

There are five types of needs that managers need to be aware of to identify customer needs:

1. **Stated Needs.** Needs that are expressed in relation to a feeling. For example, when wishing to buy a car, one says, “I need a car.” Here the customer has expressed a “need.”
2. **Real Needs.** In this case, the customer expresses a need, **but what they want is not clear in what they said!** For example, they may express a need for a car, but fail to clarify that they want a low-cost car.
3. **Unstated Needs.** Unspecified or unexpressed needs are those that the customer expects from the seller. For example, when buying a car, the customer will expect good after-sales service.
4. **Secret Needs.** These are needs that the customer is not willing to accept, but that are an important part of their wishes. To understand these needs better, let us go back to the example of the car. In this need, one wants to have a quality car, but the status and the amount of money that they can pay to meet their needs are important.
5. **Unreal Needs.** The customer is interested in having features such as a music system and GPS in buying their car, but do not make this clear.

The marketer should try to discover the *real needs* by asking questions of the customer and make it the main objective. Thus, we can build a better relationship with our customers. How do these needs become wants and how can they be changed?

### Wants: the second key to startup analysis

“Wants” come from a desire to satisfy needs. Human wants vary depending on a person’s perceptions, environment, culture, and society. For example, marketers can reinforce the idea *that insurance can meet a person’s need for safety. They do not create a human need for safety.* After identifying needs and wants, the most important issue for the marketer is to be aware of “demand.”

### Demand: The customer's willingness and ability to buy

**When a customer is willing and able to buy what they need or want,** these needs and wants become demands. The customer may want to buy something, but not be able to buy it and thus not be able to satisfy their desires. For example, many of us would like to have a car, but maybe only a few can afford it. If there is both the ability and the desire to buy a product, and there is supply, there is a demand for it.

Many factors affect the conversion of wants into demands. These factors can be distinguished as social and emotional factors.

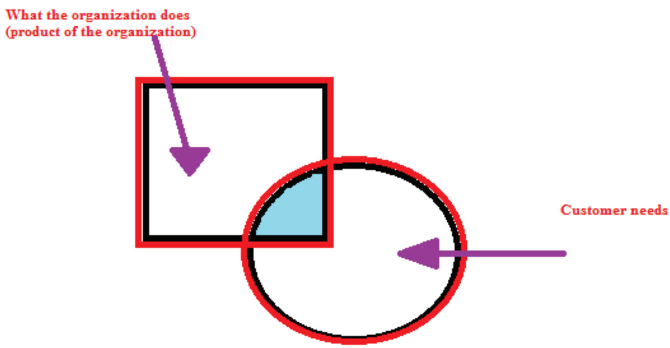
- **Social factors.** Social factors can affect behavior and thus demand for different products.
- **Emotional factors.** In terms of emotional factors, customers can act under the influence of an event or external factor to demand a product or service. For example, demand for insurance may increase after a major event occurs.

### Customer satisfaction

Nowadays, manufacturing or service organizations consider customer satisfaction to be an important criterion for measuring the quality of their work; this trend is increasing. The importance of the customer and customer satisfaction is related to "satisfaction at the global level." Discovering and recognizing the needs and expectations of customers is an important factor in job and business success, or, at least, maintaining the relative position of an organization among its competitors. A successful organization is one that: can meet the needs of customers; has regular and timely delivery and distribution; and can provide services at a standard above expectations (offering quality products or services to customers at a reasonable price). Achieving such a level of customer satisfaction is not possible without constant testing and review of the quality of the system to ensure an adequate response from the organization to the ever-changing needs and expectations of customers.

Quality is found in meeting customer expectations or even overcoming and solving problems, according to one definition. Deming considers quality to be concerned with predicting the future needs of customers. The primary objective of an organization should be to achieve the highest level of customer satisfaction, rather than greater profits, because this satisfaction will lead to an increase in the processes that lead to greater profits.

The amount of customer satisfaction can be explained with the help of the Tabul model.




In the figure above, customer needs are shown by the circle while the square represents the products or services that the organization offers. Satisfaction is achieved when the organization's products fully coincide with customer needs; in other words, when the circle is inside the square. Our objective is to be able to achieve this level of work better and faster than other competitors.

From the customer's point of view, only the part of the square that is inside the circle is satisfactory, while other parts of the square are considered unimportant and unnecessary items. To move in the correct direction to meet customer needs and wants, the organization must always listen to their opinions. The organization must also ensure that the marketing, design, manufacturing, and distribution processes best meet the needs and expectations of customers.

**Customer understandings of the concept of quality**

The American Society for Quality Control (ASQC) has researched and defined the most important factors influencing customers in the selection and purchase of products or services:

1- Product performance;
2- Product features;
3- Product-related services;
4- Product warranties;
5- The price of the product;
6- The reputation of the producer.

**Product performance**

The most important point in product performance is ease and convenience when using the product. This means that a product can be used as soon as it is purchased. Other points include:

**1- Availability of a product.** This means that the product can be accessed and used when necessary.

**2- Product reliability.** The product is free from operational errors on purchase.

**3- Product maintenance ability.** This means that the product can be kept in good condition relatively easily.

### Product features

Typically, the specifications and features of a product and service refer to its structure and technology, or related ethical and psychological issues. The specifications of a product are usually what comes after its original identity and performance. For example, the primary task of a car is to move and transport people; having a *stereo player is one of its features*.

### Product services

An emphasis on serving customers is one of the most important tools in improving the reputation of an organization in the opinion of a customer. Serving the customer is an intangible issue that cannot be resolved using a few parameters, but depends on a number of items, both large and small, that can affect customer perceptions. *Achieving a high level of customer satisfaction is different to achieving a high level of quality and is a very difficult task.* Organizations that focus on serving customers well will always look for new ways to best meet their needs.

### Product guarantee

A product warranty or guarantee expresses a general commitment by the organization to product quality and increases customer satisfaction.

Establishing a guarantee system forces an organization to place more emphasis on customer perceptions of quality products or services because if the concept of quality in the customer's opinion is different to the product's performance, the organization will be obliged to pay out under guarantee. Another advantage of the guarantee system is the receipt of feedback from customers. In this way, the organization can evaluate the error rate of its work and obtain useful information.

Guarantees in the sale of a product are one of the best marketing strategies for products or services. A guarantee encourages customers to buy products or services because it reduces risk when buying. In this way, the organization shows consistency and commitment and the number of customers will increase leading to greater sales volume.

### Product price

In today's world, customers prefer to pay a higher price to get a better quality product. Customers will compare the organization's products or services with those of its competitors and often select products on the basis of reliability and quality. However, given that customer criteria are variable, the price of the product should not be completely ignored and you should maintain contact with buyers and try to provide products or services that meet their valuations.

### The reputation of the producer

Almost all of us categorize organizations according to our experience and perception, not just on the product itself. Customer satisfaction is based on perception.

It is important to note that the cost of attracting a new customer is approximately five times the cost of retaining an old customer. For this reason, customer maintenance is one of the most important strategies to improve the economic situation of an organization. In this regard, paying attention to feedback from customers is one of the most important tools for customers and market maintenance.

### Feedback

An organization must constantly consult with its customers and review and analyze their feedback. This feedback helps the organization to:

- Uncover customer dissatisfaction.
- Discover potential areas of quality improvement.
- Compare the performance of the organization with its competitors.
- Recognize the needs of customers.
- Choose better opportunities and conditions for improvement.

Feedback is often in the form of information sheets, reviews, focus groups, toll-free numbers, customer visits, report sheets, and customer complaints and grievances.

# CHAPTER EIGHT

# STATEMENTS AND COUNCIL OF QUALITY

## QUALITY STATEMENTS

Items such as organizational insight, the organization's mission, and the organization's quality control policy are usually reviewed properly only once before being reviewed and updated occasionally. These values can vary in every organization with greater emphasis being placed on one value or another.

### Organization Insight Statement

Organizational insight concerns how an organization will be in 5 or 10 years. Realistic insight is based on what we want to achieve and what is practical and possible. The description of this is usually very short, consisting of only a few sentences. Some examples are given below:

- "A love of pristine and beautiful places involves participating in the struggle to save these places, and helping to stop the severe deterioration of environmental health around the globe."
- "Our vision is a world in which all basic human needs, such as housing, clean water, health, food, and reliable energy, are achieved in an environmentally friendly and sustainable way; also, creating a company that improves the quality of the environment and the communities in which we work and live."
- "To become the most successful and respected company in the field."
- "Becoming a global reference to help organizations focus on what matters most."

### Organization Mission Statement

Determining the mission of an organization involves answering the following questions:

Who are we? Who are our customers? What do we do? How do we do this?

These questions are usually answered with a single paragraph of text and describe the general performance of the organization. The text also states all the ideals and objectives for employees, customers, and suppliers quite clearly. For example:

- To produce the best product (not causing any unnecessary damage) and use business approaches to implement solutions to environmental crises.
- To provide the conditions for economic growth (through the development of energy and infrastructure) and create solutions to support communities and protect the planet.
- To attract and retain customers with extremely valuable products and experience the satisfaction of having a quality product.
- Empowering organizations with insightful solutions to lead businesses toward success.

### Organizational Quality Policy Statement

A quality policy acts as a guide for everyone in the organization by explaining all the methods that should be used to provide its products and services. These policies are determined by the chief executive manager using feedback from the workforce and the full verification of a national or international quality control council. Some examples of these policies can be seen below:

- Quality plays the most important role in the organization.
- Consider and pay attention to all the needs of internal and external customers.
- Equal or superior to others in terms of competition.
- Continuous improvement of quality.
- Considering the necessary items for manufacture of products and related professional issues.
- Effective use of the total workforce.

## Quality Council

To ensure that "quality" defines the "culture" of an organization, there needs to be an association providing appropriate leadership and guidance. Usually in an organization, this council consists of the executive and senior managers of the various parts of the organization (such as the design, marketing, finance, manufacture, and quality control departments), plus a coordinator or consultant. This coordinator can sometimes take on specific tasks that are beyond the ability or knowledge of others. The person who is selected for this position is usually an intelligent young person with a lot of potential for executive work. This person must report on performance to the chief executive officer (CEO).

The main responsibility of the coordinator is to create mutual trust between the two parties, i.e. between company officials and staff. Other tasks include conveying the needs of the groups to the quality council and informing the council of progress. At the same time, the coordinator must monitor the behavior and decisions of the groups to ensure that the council is fully aware of their ability to perform their tasks. Coordinators assist group leaders in carrying out their responsibilities and share experience with other groups. By holding coordination meetings, they invite the leaders of different groups to participate and put them in constant contact and communication with each other.

In smaller organizations (where executive chiefs are responsible for several departments), the number of quality council members decreases. In such organizations, the coordinators may be members and employees of the organization.

In general, the tasks of this council can be divided into the following:

1) Expanding the core values and objectives of the project, defining missions and tasks, and also adopting an efficient policy to increase quality improvement. Also, the necessary information and data for these decisions should be collected with the help of all employees.

2) Development of strategic and long-term plans (with predetermined objectives and decisions to improve quality every year).

3) Planning educational and training plans to make more people aware of the whole project.

4) Searching for, discovering, and observing the weaknesses of the organization in terms of quality.

5) Making decisions about the criteria for evaluating the amount of work in the organization and establishing these criteria.

6) Identifying projects that can play an important role in improving the process (especially those that have an impact on the satisfaction of internal and external customers).

7) Defining and creating multi-tasking and segregated projects in the form of collective workgroups and monitoring their progress.

8) Establishing a system for discovering diligent employees and rewarding them.

In large organizations and manufacturing centers, a quality council can be formed for each department. Although the principles and methods of all of them are similar, their scope and context will be defined by their area of work. The first tasks of such councils may be very difficult, but gradually the workload will be reduced. The purpose of these groups, in principle, is to maintain and then upgrade the quality improvement of company processes.

Once the group has been properly established, relevant items are put on the meeting agenda, including:

- Reports of group progress.
- Reports on customer satisfaction.
- Reports on progress in achieving objectives.

- Reports on defining new groups for new projects.
- Reports on celebrations (held to recognize and encourage hardworking personnel).
- Reports on modeling at the organization level.

After three to five years, the quality council will have become part of the organizational culture and will have a full presence in all its executive meetings. At this time, there will no longer be a need for a special section focused on quality, as it will now be at the forefront of the agenda.

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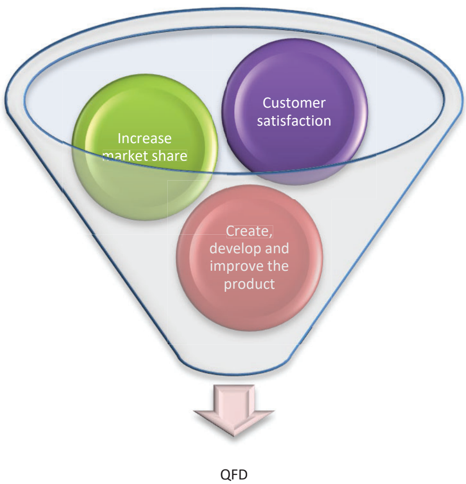
# CHAPTER NINE

# QUALITY FUNCTION DEPLOYMENT (QFD)

Quality function deployment (QFD) is a planning tool used to allocate resources and meet customer expectations and is a commonly used and accurate method for product design, engineering, manufacture, and evaluation. QFD is an advanced quality tool that aims to increase market share by satisfying customers. This tool has a lot of maneuverability for identifying and determining those customer needs that enable an organization to outperform its competitors. After identifying and determining the needs of customers, these are included in the design requirements; during this process, the wants of the customers are translated into engineering language. If the organization implements QFD properly, it can increase quality productivity and engineering knowledge, as well as reduce costs, product development time, and engineering changes.



The results of QFD are measured based on the number of design and engineering changes, market entry time, cost, and quality. They are used to devise a complete plan for simultaneous engineering.

QFD seeks to create added value for a product from the formation of the product concept in the minds of designers by focusing on developing a correct and clear understanding of customer wants and then extending these wants to all steps of the product creation/development process. QFD focuses on customer expectations and needs. Hence, it is commonly referred to as the "customer's call." It is used to convert specific customer expectations and needs into engineering features through the following stages:

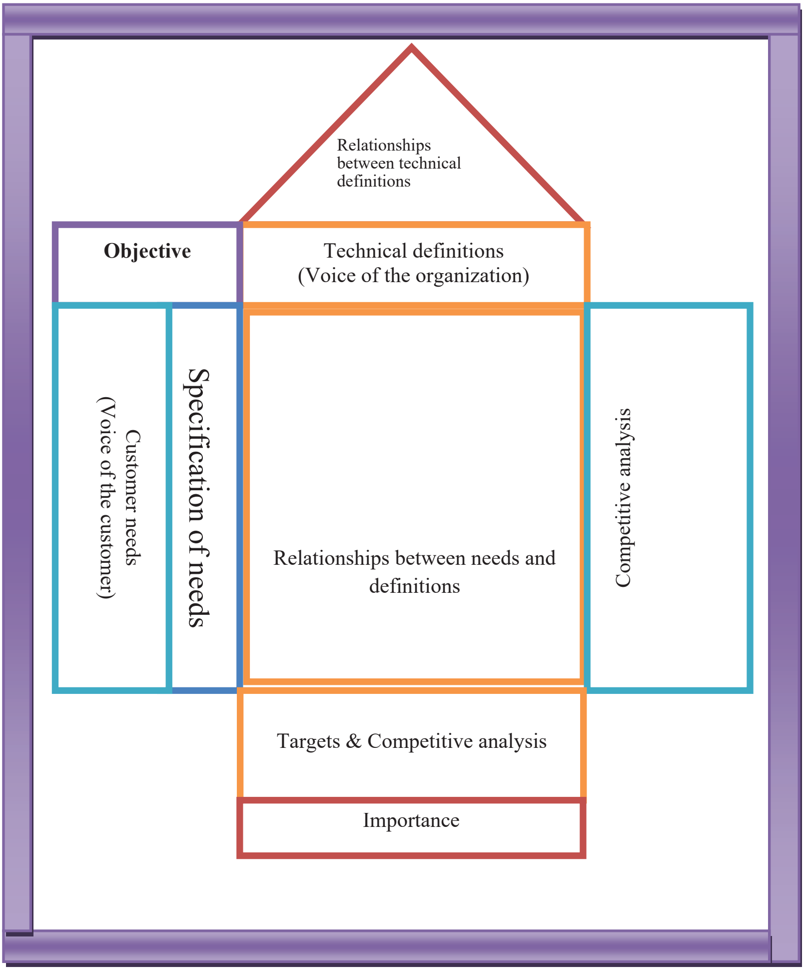
- Planning
- Piece development
- Process planning
- Manufacture planning.

In the QFD process, the conflict between customer needs and expectations is recognized and solutions are provided before manufacturing begins. It should be noted that some customer needs can have a negative impact on other needs of the same customer; in such cases, customers often fail to rank their needs according to importance. Misperceptions and misconceptions are other problems that arise when a product moves from marketing to design, design to engineering, and engineering to manufacture. This problem occurs when the customer's voice is forgotten and, instead, only the organization's comments are expressed in the product design phase, i.e. rather than focusing on customer expectations, focus is put on items that the customer is not interested in. By implementing QFD, the organization becomes committed to implementing the relevant customer opinion in the final product.

Resources used to determine customer needs include focus groups, polls, complaints, consultations, standards, and government regulations. In most cases, customer expectations may appear vague or seem obvious, and it is the job of the QFD team to translate these expectations into precise and explicit requirements. It is important to note that these requirements must be accurate and realistic, and not just what the managers of the organization want.

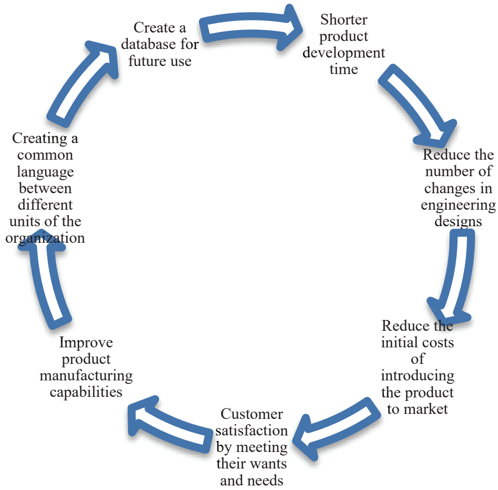
**Note:**
It is worth noting that QFD is used to produce both *new products* and to improve *existing products.*

The process involves identifying and determining the best values for pieces, components, materials, and specifications of the product manufacturing process.



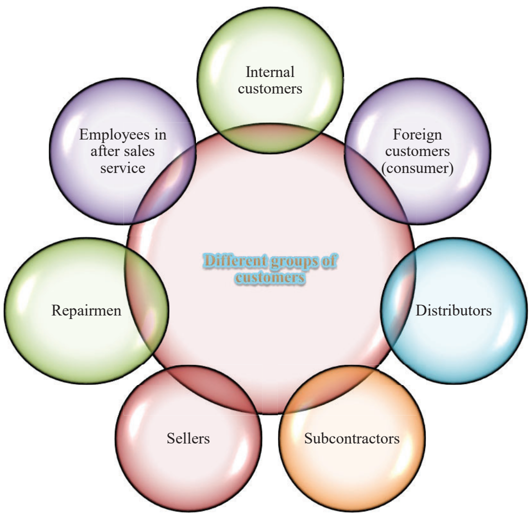

**QFD capabilities and benefits**

The most important expected benefits (if used properly at the organizational level) are described below:




**Step 1: Understand customers and their wants**

Identifying and understanding the wants, expectations, and needs of customers is one of the most important steps in completing a QFD project. The first concept in a QFD project is to identify the customers of the product (service) under consideration. What are the relevant wants in terms of the product features for the internal units of the organization and external customers?



QFD starts with a marketing approach to determine what the customer expects about a product. During data collection, questions such as the following should be asked and answered by the QFD team.

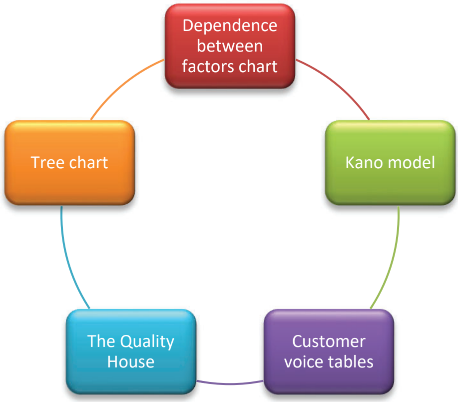
- What does the customer want?
- What are his expectations?
- What is the priority?
- Have customer expectations been used to advance the design process?
- What can the QFD team do to achieve customer satisfaction?

**Step 2: The next step in analyzing a QFD project is to determine the tools and methods to listen to the customer's voice.**

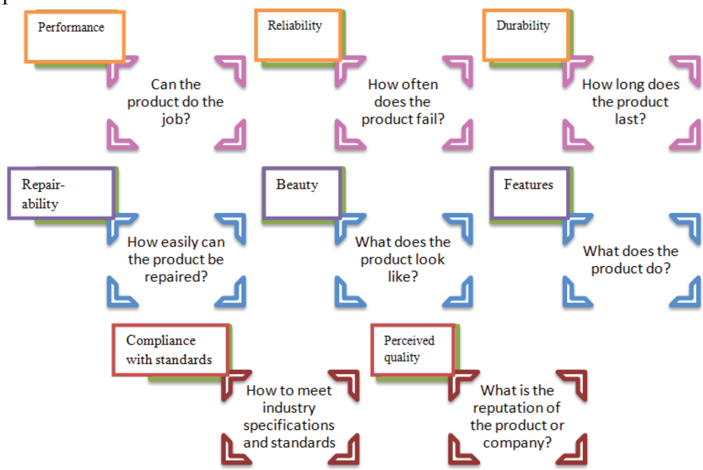
There may be components of the customer's comments that are not in the form of questions for him/her and this issue will lead to new definitions of the product. A "customer voice table" can be a useful tool for recording and developing a deep understanding of customer wants and expectations concerning the product.


**The third phase of the QFD project begins after receiving the customer's requests and ends with its evaluation and analysis.**

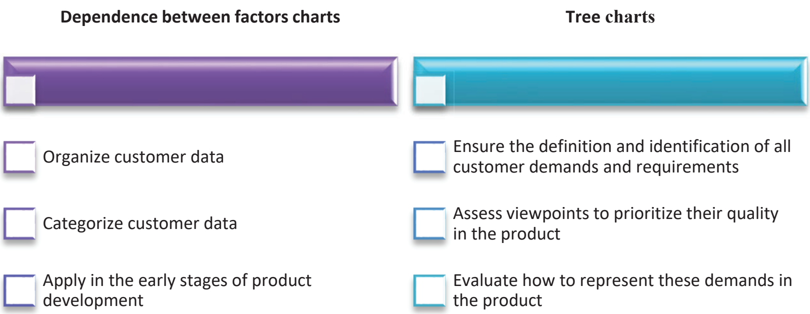
There are various tools for categorizing, prioritizing, and analyzing the raw wants of the customer. Among the most important ones, we can mention items such as dependence between factors charts, tree charts, the Kano model, QFD, and customer voice tables, etc.



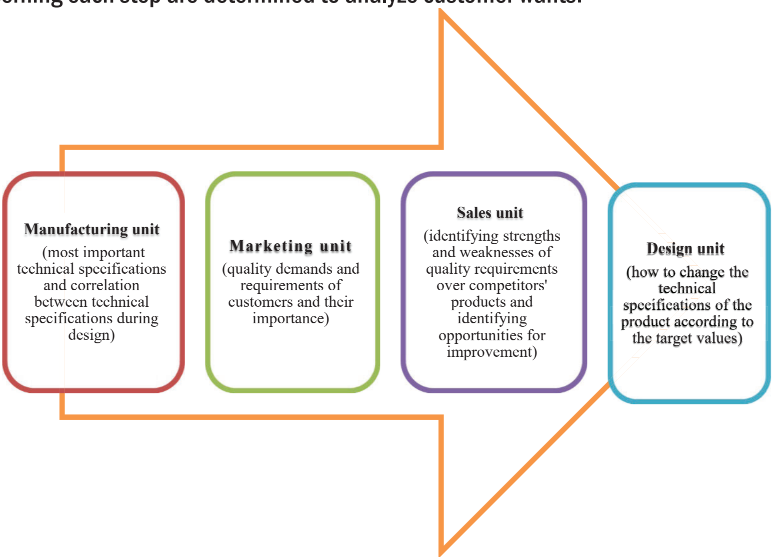

The information obtained from the customer voice table shows a wide range of customer requests that can be distinguished, reviewed, and compared as follows.




After reviewing and analyzing the customer's wants, they should be classified and organized by the QFD team. Dependence between factors and tree charts can be used to perform this step. In the early steps of development and evolution of a product or service, dependence between factors charts can be used. As a result, it is possible to organize customer data and categorize it into groups (each with a specific need). In parallel with the use of dependence between factors charts, tree charts are used to ensure that all customer wants and needs have been identified and defined. In some cases, a tree chart is used to obtain a customer's point of view so as to prioritize the desired qualities of the product and to evaluate how these are represented in the product compared to competitor products. While expanding understanding of the general wants of the customer, the effective and efficient use of these two charts allows the QFD team to explain them and add any demands that have been missed for some reason.




In the fourth step of the QFD project, the responsibilities of different units concerning each step are determined to analyze customer wants.



**House of Quality**

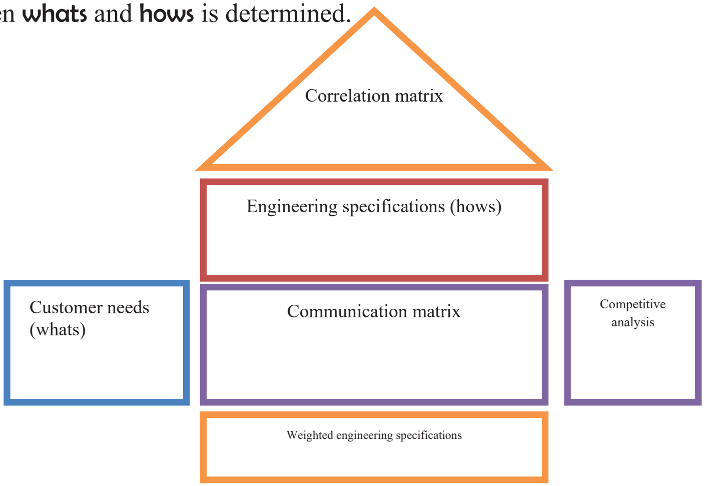
The primary planning tool used in QFD is the House of Quality. The House of Quality translates the customer's voice into design requirements that correctly estimate the size of the objective specifications and arranges them so that the organization can meet those requirements. Many managers and engineers believe that a House of Quality is an essential tool for quality planning. The reason for the name of this tool is its appearance, which is similar to the framework of a house.

A House of Quality is a powerful tool for translating the customer's voice and desired product qualities into quantitative requirements, significantly increasing the traceability and consideration of a product by the organization. The House of Quality, in a very simple and tangible way, can be considered a matrix of **whats** and **hows** that explain the following concepts.

- **Whats** (*or customer's voice*) include the wants and tendencies of customers in relation to products or services (*customer needs*).

- **Hows** (*or the voice of the organization*) indicate how to represent customer wants in the product (*product technical requirements*).

The House of Quality is a matrix through which the relationship between **whats** and **hows** is determined.




*On the right hand side*, the items drawn from the customer's voice are listed, i.e. *what the customer expects from the product. On the left hand side,* customer needs are prioritized, and this is also called the *planning matrix*. The information in the planning matrix is based on items such as customer modeling, customer importance rate, purposive size, magnification factors, and sales points.

The upper floor of a House of Quality includes technical descriptions. In this section, the stability of a product is determined according to the engineering specifications, limitations, and design parameters. The interior walls of the house reveal the connection between customer wants and the technical description. In this section, customer expectations are translated into engineering features that can be understood by the organization's engineers.

The roof of the house describes the relationship between the technical descriptions. Relationships are determined between similar or opposing technical descriptions. The substructure (base) of the house is also a technical description that is prioritized according to items such as technical modeling, degree of technical difficulty, and purposive size.

### The structure of a House of Quality

#### Step 1: Prepare a list of customer needs (what)

Quality function deployment (QFD) begins with a list of objectives. The reference for this list is usually "what" the customer expects from a particular product. It should be noted that this initial list of customer needs is often vague and general. Additional definitions are completed by adding a new list of "secondary customer needs" (used to support primary needs). In other words, the primary needs of the customer may be followed by a large number of secondary needs. Although the items listed as secondary customer needs are more accurately expressed than for primary needs, they are usually not fully implemented because they require additional and more complete definitions. Thus, the customer needs list is ultimately divided into three levels of needs: the first level (primary), the second-level (secondary), and the third-level (tertiary). For example, product "trustability" can be called a primary need, while reliability, longevity, and maintenance capability can all be described as secondary needs.

#### Step 2: Prepare a list of technical definitions (how)

The purpose of a House of Quality is to design a product or change a product design to meet/exceed customer expectations. When customer expectations are expressed in terms of their needs, the QFD team (to meet one or more of these needs) should specify the engineering specifications and required technical definitions. These technical definitions make up the roof of the House of Quality.

Each engineering feature must directly affect one of the customer's needs and express it in a measurable format.

Implementing customer needs, as long as these needs are not translated into corresponding engineering features, is very difficult. These corresponding specifications represent the expression of the customer's voice in technical language. Each customer need is broken down into smaller components and the corresponding technical definitions are listed (third level requirements).[51] The technical definitions are completed by a secondary list, which is more accurate than that of the primary technical definitions. This process is similar to converting system-level engineering features to component-related features (component level). Secondary technical definitions can include parts specifications and manufacturing parameters that are of interest to engineers. Usually, these technical (secondary) definitions are not directly applicable and traceable, and more complete definitions are needed to implement them.

This refining process continues until all applicable items are obtained. Finally, the list of technical definitions is divided into three categories: first level, second-level, and third-level technical definitions.

**Note:**
Remember that, for successful QFD implementation, the technical requirements and definitions must be as detailed as possible and their details must be given sufficient attention.

Some technical definitions may affect more than one customer need or inversely affect another technical definition. For technical definitions, it is better to use brainstorming meetings with members of the engineering department.

### Step 3: Develop a communication matrix between "what" and "how"

The next step in building a House of Quality is to compare customer needs and technical definitions to determine the relative relationships between them. Finding the connections between customer needs and technical definitions is often very complicated because each of the technical definitions may affect a large number of customer needs and vice versa.

### Create an L-shaped chart

One way to reduce the complexity of determining the relationship between customer needs and technical definitions is to use an L-shaped matrix. Figure L (which shows the two-dimensional communication and the interactions between the two subjects) is completed with a list of customer needs vertically arranged and a list of technical definitions

[51] This process is similar to refining marketing features and converting them into engineering features.

horizontally arranged. One of the advantages of the L-shaped matrix is that it makes complex communication easy to understand, as well as not requiring much experience to use.

### Communication matrix

The internal part of a House of Quality is called the communication matrix and is filled in by the QFD team. The communication matrix is used to give visual expression to the degree of influence that technical definitions and customer needs have on each other. This step is very time-consuming because the number of evaluations is equal to the number of product technical definitions multiplied by the number of customer needs. In the first step of the product development process, the development time and the need for further changes are reduced.

It is necessary to use a set of symbols to express the degree of communication between technical definitions and customer needs. For example:

- Two concentric circles to express strong communication.
- A circle to express the middle relationship.
- A triangle to express poor communication.
- Blanks to indicate a lack of communication.

Each degree of the relationship between technical definitions and customer needs is determined by placing the relevant sign at the intersection of a particular technical definition and a particular customer need. This method allows very complex forms of communication to be described and interpreted with minimal experience.

These symbols, which are used to define communication, are then replaced by numbers. These weights are used in later steps to balance contrasting properties and determine the exact weight at the bottom of the matrix.

Once the communication matrix is complete, it is time to look at the status of the empty rows and columns. An empty row indicates that the customer's needs are not related to any of the technical definitions; as a result, a technical definition must be used to meet the customer's needs. An empty column indicates that a specific technical definition does not affect any of the customer's requirements and, after careful consideration, may be removed from the House of Quality.

### Step 4: Develop a matrix of interactions between the "hows"

The *gable roof of a House of Quality*, called a *correlation matrix*, is used to identify the interrelationships between each of the technical definitions. The correlation matrix is a triangular table that is added to the technical definitions and uses symbols to express the intensity and type of interaction.

Signs reflect the direction of correlation. For example, a very positive interaction indicates a completely positive correlation and a very negative interaction indicates a completely negative correlation. This table enables the user to understand which technical definition supports another technical definition and which technical definition contradicts another definition. The contradiction of technical definitions is very important and indicates the existence of conflicting requirements, identifying points at which a balance must be achieved. **Balances that are not identified and addressed often lead to unmet needs, large engineering changes, increased costs, and poor quality.** Some of these balances require top-level management decisions; however, rapid resolution of these balancing issues is essential to reducing product development time.

### Step 5: Competitive Evaluation

The competitive evaluation section consists of two weighted tables (or charts) of competitive products with the current products of the organization. These tables are divided into two categories: customer evaluation and technical evaluation.

#### Competitive evaluation of the customer

The competitive customer evaluation creates a column (related to each customer need) on the right hand side of the communication matrix. The numbers 1 to 5 in the competitive evaluation column describe the competition situation with number 1 meaning that it is very bad while number 5 meaning that it is very good. In this category, signs, and symbols can be used instead of numbers.

Competitive evaluation of customers is a surefire way to determine whether a customer's needs have been met, as well as whether we should focus on specific issues to meet them or not. This assessment also allows the organization to determine its position in relation to its main competitors in terms of customer needs. It should be noted that both of these assessments are very important for the organization because they enable the organization to understand and improve the position of its product in the market.

#### Technical competitive evaluation

A competitive technical evaluation creates a row (associated with each of the technical definitions) in the House of Quality and at the bottom of the communication matrix. For this purpose, products are evaluated according to the technical definitions. As in the competitive evaluation of the customer, the information in the row of technical competitive evaluation is entered using a number between 1 and 5, with number 1 indicating the worst case and number 5 indicating the best case. This classification can be done by drawing signs below each of the technical definitions.

The competitive technical evaluation often leads to gaps and shortcomings in technical and engineering judgments. Those customer needs and technical definitions that are highly interrelated should also show a strong correlation in terms of their competitive evaluation. For example, if the evaluation of a technical definition of an organization shows that the product is better than those of its competitors, the relevant customer competitive evaluation should be better than that of its competitors; if this connection is not seen between them, it means that a mistake has been made in the technical and engineering judgments, which must be corrected.

### Step 6: Develop the Customer's Priority Needs

Customer priority needs consist of several columns covering each customer need. These columns are located on the right hand side of the customer competitive evaluation section of the House of Quality and include factors such as importance to the customer, objective value, growth factor, point of sale, and definite weight.

#### The degree of importance

The QFD team (or preferably the focus group) prioritizes each customer need by assigning a score (degree) to it. That is, according to the customer's opinion, a number between 1 and 10 is written in the importance column, with 1 indicating least importance and 10 indicating most importance. In other words, the highest number is assigned to the most important from the customer's point of view. The degree of the importance factor shows the ratio of the importance of each customer's needs in terms of other needs.

It is often difficult to assign such ratios because each member of the QFD team may believe that different customer needs are deserving of a higher number leading to differences of opinion. However, the degree of importance is very useful for prioritizing activities and choosing the best decision.

#### Objective value

The objective value column is similar to the customer competitive evaluation columns in terms of the scale used (1 for the worst and 5 for the best). This column is used when the QFD team decides whether a product should remain unchanged, be improved, or is ready to succeed against its competitors.

#### Increase factor

The factor of increase is the ratio of the objective value to the current value of the product in the competitive evaluation of the customer. The larger this ratio, the greater the activity and effort needed. Issues that need to be considered include the current product situation, the objective value, and the reason for the difference between the two.

Sometimes, achieving a value for the adjusted objective is difficult or even impossible. As a result, the objective value must be reduced to an acceptable level.

#### Point of sale

The point of sale tells the QFD team how customer needs can increase sales. The objective of this section is to promote the best customer needs and maintain the needs that lead to the highest product sales. For example, the selling point of a customer with a high sales capability could be 1.5.

#### Definite weight and percentage

Finally, the definitive weight of each requirement is obtained by multiplying the degree of importance to the customer by the increase factor in the selling point.

Weights and percentages can be used as a guide for the product development planning step.

### Step 7: Develop Priority Technical Definitions

Priority technical definitions make up a section consisting of several rows (related to each technical definition) at the bottom of the competitive technical evaluation in the House of Quality. These priority technical definitions include rows for the degree of technical complexity, objective value, and definite and dependent weights.

The QFD team identifies the most important technical definitions to meet the customer’s needs. This identification allows the determining of specific objectives (guiding us in future designs), evaluation of the progress of objectives, and a reduction in the application of individual opinions.

#### Degree of complexity

Many House of Quality users add a row for the degree of technical complexity to implement each of the technical definitions, which is the first row in the technical priority definitions section. Adding this row allows us to evaluate the ability to implement an adjusted improvement in quality.

#### Objective value

The objective value is a row added to each of the technical definitions at the bottom of the degree of complexity. Objective value is an objective measurement scale that shows the value needed to achieve a technical definition. Evaluating all the information entered into the House of Quality and selecting the objective value answers the question of how much effort is needed meet and exceed customer expectations.

### Definite and dependent weight and percentage

The next two rows deal with the priority technical definitions, the definite weight, and the dependent weight. An easy and common way to determine weights is to assign numerical values to the symbols of the communication matrix. The difference between these two weights (definite and dependent) is that in the dependent weight, information about the increase factor and the selling point can also be found.

These two weights show the impact of technical definitions on customer needs. Of course, we can also use the Pareto chart to show which technical features have the highest priority in meeting customer needs. Also, given the degree of technical complexity, we can make better decisions about what resources should be allocated and where to improve quality. The important point is that the House of Quality should not necessarily be defined according to this proposed model and each QFD team can use a bespoke model to meet their specific needs.

### The four-step QFD approach

The four-step QFD approach consists of four matrices that are related to each other and each matrix is completed according to the information contained in the previous matrix. Relationships between the matrices include key information fields and only this information is passed on to the next matrix. If necessary, new matrices can be created and more than four matrices can be used. The four main phases of this approach are described below:

### Product planning

QFD begins by collecting customer feedback and requests and inputting them into the House of Quality matrix (after categorizing and performing the necessary analyses). This phase is dedicated to completing the House of Quality matrix.

### Product design

The general objective at this step is to translate the key technical descriptors of the House of Quality, identified in the first phase, into the specific features of the product components. The components are the sub-subsets of the product (such as systems, parts, and input materials, etc.) and their combination will create the product.

The inputs of this phase are:

- Technical specifications with high priorities.
- The size of the objective and the weighted importance of each of the specifications.

- Product tasks.
- Necessary pieces and mechanisms.

The outputs of this step are:

- Determine the key features of the piece.
- Choose concepts from a better or even newer design.

The operation of this step of the QFD, like the first phase, takes place within a matrix. This matrix is called the product design matrix. The QFD team may increase or decrease the information recorded on this matrix (as needed and according to the diagnosis). The columns on the right hand side of the matrix, which contain information such as key technical specifications, objective size, and weighted importance, are filled according to the results of the first step (from the House of Quality). To fill the top row of the matrix, you need to list all the relevant product parts (even the smallest ones). For convenience, they can be sorted and categorized using dependency or tree charts. This should be done with the help of experts. If these experts are not members of the QFD team (especially for designs that require a lot of changes), we start from the lowest level, i.e. the list of pieces. The results obtained from these charts, i.e. the product components, are entered in the upper row of the matrix.

Then, as with the House of Quality, the relationship between each component part and technical specification is determined. The symbols of the first step with the same weights are used to show the intensity or weakness of communication. After calculating the relative and absolute weights using the symbols, the most important features are determined. These features provide the input for the next step and should be considered there. By studying the manufacturing process or assembling the product, areas that cause problems can be identified and eliminated.

### Process planning

The general purpose of this phase is to determine how to achieve the critical features of the defined components in the previous step. At the beginning of this step, the process used should be studied and identified. Seeking new solutions to the process may help us determine the use of a new process. In this step, the information inside the matrix (the process planning) is collected and analyzed. In this matrix, the critical properties of the process must be identified so that they can be investigated in subsequent steps. Following on, measures should be taken to eliminate the various problems caused.

To fill the matrix, you must first specify the process that will be used. If this process is about creating a new product, it may require the study of a new area. For this purpose, a flow process chart (FPC) can be drawn. Such a chart identifies the following:

- Necessary equipment.
- Flow input material.
- Location of the addition of input materials.
- Responsible operators.

The control specifications of the process in each step must then be determined. These specifications may affect the key features of the components. These specifications and other factors that the QFD team identify require the assistance of certified and masterful process engineers. After preparing the relevant information, it can be entered into the new matrix. In this phase, as previously, the initial columns of the matrix (which are related to the critical specifications of the pieces, the objective size, and their weighted importance), are completed using the results of the previous matrix, i.e. product planning.

In the next step, the specifications of the process are transferred to the top row of the matrix and then the relationship between them and the critical properties is determined using the symbols from the previous phases. Similarly, their weighted importance for the calculated process specifications is determined according. Finally, the purposive size for each important specification of the process is determined and recorded in the matrix. The adjusted size of the purposes should be compared with the existing capacity of the company to determine the status of each specification.

### Manufacture planning

The general objective in the last step is the continuous maintenance of the key features of the process identified in the previous step. Here, the choice of key control features of is not considered, but the value, degree, and method of control of each of them needs to be known. For this reason, most of the critical features of the third step are transferred to this phase.

The inputs of this phase are:

- Process feature sizes from the process planning matrix.
- High priority items using the FMEA method.
- Key features sizes.

The desired results expected from this phase can include details of key features of planning and control to:

- Minimize the value of differences in the final product.
- Assist in predicting and preventing potential problems.

At this step, the method and degree of control of each specification must be determined. As such, we can specify the following actions for each feature:

- Investigate the need for training to prevent problems.
- Determine important specifications for control.

- ➢ Methods of control.
- ➢ Standard of inspection and frequency of sampling.
- ➢ Tools of testing and measurement.
- ➢ Inspectors.

In this phase, operations are performed inside a matrix. Due to the variety of processes and control methods, it is necessary for the QFD team to design a matrix according to the needs of each particular project.

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# CHAPTER TEN

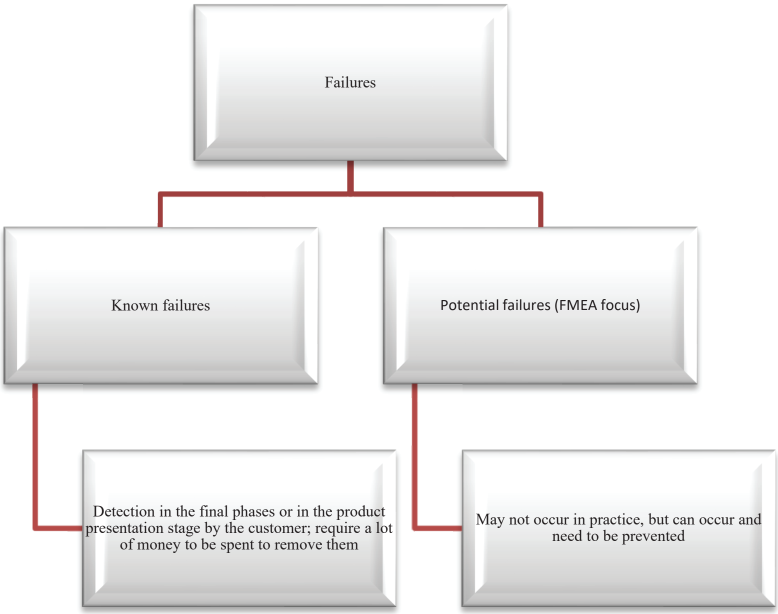
# FAILURE MODE AND EFFECTS ANALYSIS (FMEA)

Today, increasing competition, increasing customer expectations, and rapid technological change have resulted in a rapid increase in manufacturer commitments and any shortage or deviation in product performance can lead to loss of market share. For this reason, organizations seek to identify and solve problems early so as to ensure their competitiveness.

There are two types of failures:

- **Known failures;**
- **Potential failures.**

**Known failures** are usually identified by the customer in the final steps or the product delivery phase. As a result, a lot of money must be spent to eliminate them. However, **potential failures** (which are the focus of FMEA) are usually related to situations that have not happened yet in practice, but *could occur*. As such, we aim to prevent their occurrence.




There are many definitions of FMEA, but the following is the most common:

*FMEA is a systematic method to prevent errors. This method is used for the following reasons:*

- **To identify and prioritize potential failure modes in a system, product, process, or service;**
- **To define and implement actions to eliminate or reduce the occurrence of potential failure modes;**
- **To record the results of the performed analyses to provide a complete reference for solving problems in the future.**

FMEA seeks to identify defects that may occur in the final product, system, service, or machinery. After identifying defects, the FMEA approach looks for ways to diagnose and eliminate these defects. These solutions are documented so that they can be referred to it in the future if needed. FMEA is a low-risk tool that is used to predict problems and defects in the design or development of processes and services in an organization.

The sooner defects are identified and eliminated, the lower the costs imposed on the organization. The importance of using methods that prevent defects is clear.

The FMEA technique has the following specifications:

- FMEA is an analytical and reliance technique based on the law of prevention, rather than cure and is used to identify potential causes of failure. The focus of this technique is on increasing the security factor and, ultimately, customer satisfaction by preventing failure.
- FMEA is an action (not a reaction). The FMEA technique focuses on acting before the event, rather than acting after the emergence of a problem. Unlike other qualitative techniques that are reactive, this technique is active. In many cases, when we encounter a problem, corrective actions may be defined and implemented to eliminate it; these actions are a reaction to what has happened. In such a case, the permanent elimination of a problem requires a lot of money and resources because moving from an existing situation to an optimal situation involves overcoming a lot of inertia (resistance to change). However, with FMEA, by predicting potential problems and calculating their risk level, measures can be defined to eliminate or reduce the incidence of such problems. This precautionary approach relies on actionable measures and corrective action (in the early steps of product or service design), which will certainly lead to reduced costs and time.
- FMEA is a dynamic tool in the cycle of continuous improvement. The FMEA technique, if performed correctly and on time, results in a lively and permanent process. In other words, in making fundamental changes to the design, the FMEA procedure must also be updated and applied continuously.

One of the factors driving the success of FMEA is *its implementation time.* This technique is designed for action before the event and not after problems are revealed. In other words, one of the fundamental differences between FMEA and other qualitative techniques is that FMEA is active, not a reactive. In addition, any changes to the product or process design at this step are easily made, thus eliminating or reducing the possibility of the need for critical changes in the future. FMEA is a "living" and permanent process if implemented properly and on time. That is, whenever fundamental changes are to be made to the product design or manufacturing (or assembly) process, it must be updated; thus, it is a dynamic tool used in a cycle of continuous improvement. The purpose of implementing FMEA is to look for any and all items that can cause failure of a product or process (before the product reaches the manufacturing step or the process is ready for manufacture). FMEA does not solve problems on its own, but should be used in conjunction with other problem-solving techniques. FMEA preparation offers significant opportunities for an organization (but if these are only in documentary form, identified problems will never be solved).

### Fields of application and types of FMEA

The FMEA technique can be used in the following areas:

- Designing a new system, product, or process.
- Changing existing designs or manufacturing and assembly processes.
- When the manufacturing or assembly processes of a product takes place in a new environment or under new working conditions.
- Adjusting continuous improvement plans.

In general, FMEA can be used in any of the design or development phases of a product, system, service, or process. FMEA can also be used effectively when conditions change or new conditions prevail (e.g. changes in standards).

There are several types of FMEA, the most common of which are:

- System FMEA for designing systems and subsystems from the earliest step.
- Design FMEA to design new pieces or make changes to current designs.
- Process FMEA for the design or development of manufacturing and assembly processes.
- Service FMEA for design or development activities and services.
- Machinery FMEA for machine design.

### DFMEA

DFMEA is a systematic method used to identify and prioritize product/piece design defects and, ultimately, to eliminate them. The objective of FMEA is to ensure that during product design, the design team is fully aware of all customer wants and product quality requirements, and are aware of how to fulfill these wants and requirements in the final design.

Any mode (that means the expected performance of a piece or product cannot be estimated) can lead to a potential failure in DFMEA (e.g. discoloration or a short circuit, etc.) Design failures are due to shortcomings in product design (for example, the defined engineering specifications do not match the ability of the process or protection against environmental factors is weak, etc.).

DFMEA strengthens the design process by reducing the risk of failure in the following ways:

- Assists in objectively evaluating design requirements and their alternatives.
- Assists with the initial design to increase the capacity to build and assemble.
- Increases the likelihood of paying attention to possible failure modes and their effects on the system and operations (when designing/adjusting processes).
- Prepares a list of potential failure modes, which are prioritized according to their impact on the customer, working on improving the design and adjusting testing strategies according to priorities.

Through implementation of DFMEA, design problems are identified and solved where possible. As a result, the design process involves less risk and is strengthened. FMEA ensures firstly that the designed product will be properly manufactured and serviced. Secondly, it ensures that defects are not ignored and all potential failures and design problems have been considered.

The advantages of using DFMEA are:

- It reduces the failure rate of the product in its useful life.
- By identifying and preventing the occurrence of potential modes during the useful life of the product, less damage occurs.
- It reduces the time required to introduce a new product.
- Prolongation of the time taken to introduce a product time market is usually caused by the emergence of problems and issues in the final steps of design or the early stages of manufacture. Implementing DFMEA prevents such problems from occurring steps by identifying them early. Therefore, with an increase in the quality level, the product will achieve market success in a shorter time.
- Helps avoid spending extra money.
- DFMEA is an active process—we act before problems occur. As such, it prevents additional costs because the cost of solving a problem in the final stages of design or early steps of manufacturing are very high.
- DFMEA implementation provides useful information for project auditing.

- We can identify product features that require special controls. For example, where the pitch of a screw must be precisely controlled, but this control may not be necessary for the head screw.
- Prioritizes actions and activities needed to improve design.
- Increases motivation for teamwork.

### PFMEA

The following activities are performed for PFMEA:

- Identify potential process failure modes related to the product.
- Evaluate the potential effects of these failures on the customer.
- Identify potential causes of failure in the manufacturing or assembly process, as well as process variables (which must be controlled to reduce occurrence or identify failure conditions).
- Draw up a list (sorted by importance) of potential process failure modes and thus provides a prioritization system for corrective actions.

The preparation of a PFMEA approach begins with a flowchart of the general process steps (or initial control plan). This flowchart should specify the process specifications for each operation.

In a manufacturing unit, the full realization of the FMEA method requires the preparation of DFMEA and PFMEA for all new pieces, modified pieces, and new conditions for using these pieces. During the FMEA process, the responsible engineer (directly and actively) is expected to cooperate with all representatives of the relevant departments. These departments include (but are not limited to) assembly, manufacturing, materials, quality, and after-sales service. The FMEA acts as a catalyst (to accelerate the exchange of ideas between departments affected by design/process outcomes) and thereby promotes a team approach.

### FMEA standard form

Usually, a specific form or structure is used for FMEA analysis. In this form or structure, fields are provided for the information needed for FMEA analysis. Each organization may make changes to the form according to its needs (to make the form more efficient and specialized). The various fields of this form are described below.

**1. Piece Name or Process Description:** in this section, the name of the piece or of the components of the piece or processes to be analyzed is given.

**2. Name of Process/Part Responsible:** the name of the organization, department, unit, or individual (responsible for process design).

**3. Names of the members of the FMEA team:** in this section, information about the manager and members of the FMEA group is given.

**4. Date of publication:** date of preparation and completion of the form

**5. Last revised date.**

**6. Process/Performance:** in this column, the desired performance for the component or piece (at the time of completion of the DFMEA) and the components of the process (at the time of completion of the PFMEA cycle) are listed. The performance of the component must be derived from the functional needs of the piece or the customer's wants, or derived from the safety requirements and government regulations (determined from within or outside the organization). These needs or wants are usually determined using QFD. If we use the form for PFMEA in this column, details of the process steps are completed.

**7. Potential failure modes:** any defect, problem, or opportunity for performance/process improvement can be a failure mode. Typically, a potential failure also leads to reduced component/process performance.

In PFMEA, potential failure modes lead to the expected objectives in the process/design not being met. In other words, this section gives a description of non-compliance in a particular operation. The potential failure mode can be the cause of a potential failure state in a subsequent operation or the result of a potential failure in a previous operation, but in the preparation of PFMEA, the input materials or components are assumed to be intact. We list any potential failure modes for a particular operation based on component, subsystem, system, or process specification. It is assumed that failure is likely to occur; not that it will necessarily happen.

**8. Effects of potential failure on performance:** the effect of potential failure is a result of the mode of failure and we describe the failure effects in terms of what the customer may notice or analyze. The impact of failures on all customers must be considered. Note that the customer may be internal, external, next in the sequence of operations, or an end consumer.

If problems of performance can affect safety or non-compliance, this must be stated. If the customer is next in the operational sequence, the effects can be expressed in terms of product/process performance, such as "not assembled," "damage to the machine," "does not connect," "does not mount," and "does not pair," etc.

**9. Severity:** a rating is given to indicate the degree of the effect of the potential failure mode. In PFMEA, the intensity is an estimate of the severity of the effect of the potential failure mode on the customer. Estimating severity may require expertise and knowledge beyond that of the team/responsible engineer in the manufacturing process. In these cases, we should consult with the design engineer, whoever is responsible for DFMEA, and the on-call engineer.

**10. Potential causes of failure:** here we note that there is a defect in the piece/process design resulting in the occurrence of a failure mode. In other words, the root causes of the failure must be identified, not the signs of failure. To achieve this objective, brainstorming and cause and effect analysis (i.e. a fishbone chart) can be used.

As much as we can, we should list all the causes that come to mind for each failure. Any potential cause of failure in PFMEA describes how failure occurs and, therefore, it must be properly expressed to be modifiable or controllable. If the identified cause has a direct impact on the failure mode, in other words, it is the root cause, this part of the FMEA form is complete. Sometimes, several overlapping causes need to be identified through the design of experiments (DOE) statistical approach. The causes must be well explained so that targeted corrective efforts can be made.

**11. Occurrence:** ranking values are based on the probability of failure due to an expected cause that occurs during the life of the process/piece. If the probability value cannot be estimated, records from similar systems are used. In PFMEA, we consider only the probabilities of occurrence that cause failure modes. The failure probability rate is estimated based on the number of failures that are likely to occur during process implementation. If statistical data for similar processes are available, they should be used to determine the occurrence rank. In other cases, a non-quantitative estimate can be used through previous column description and records of information related to similar processes.

**12. Current controls (detection methods):** these are methods or tests that can be performed to diagnose potential failure modes and can vary in complexity. In general, the objective is to detect the defect as early as possible using the brainstorming method. Current controls present a description of controls that prevent or detect the occurrence of a failure mode as much as possible. Three types of process control/design should be considered:

- Controls that prevent the occurrence of a failure mode or reduce its rate.
- Controls that identify the cause/causes of a failure and provide the basis for corrective action.
- Controls that detect the state of failure.

In PFMEA, these controls can be process controls (such as error-free fixture or statistical process control (SPC)). Evaluation can be done as part of the same operation or subsequent operations.

**13. Detection:** this refers to the chance or probability of identifying and discovering a failure or cause of failure through location control (before product design for mass production has been approved). Records analysis and brainstorming can be used for this purpose.

**14. RPN:** this number is obtained by multiplying severity by occurrence by detection. RPN indicates failure prioritization and has no meaning or value on its own, but is used to rank potential defects of process/design.

RPN = severity × occurrence × detection

RPN can have digits between 1 and 1,000. For a high RPN, the team must take appropriate corrective action to reduce it.

**Note:** in general, regardless of the outcome of the RPN, special attention should be paid to situations with a high severity rating.

**15. Proposed measures:** measures are proposed in FMEA to reduce severity, occurrence, and detection. To facilitate this, the failure mode can be prioritized as follows.

**16. Responsibility:** the final date of implementation and the person responsible for the proposed actions are recorded in this section.

**17. Actions Taken:** this section tracks whether a proposed action was taken on the due date or not.

**18. RPN revision:** after implementing the proposed actions, the FMEA team re-estimates the severity, occurrence, and detection ratings, and calculates a new RPN.

**Failure Mode & Effects Analysis (FMEA)**

"Piece Name" or "Process Description":
Name of "Process / Part Responsible": Date of publication:
Name of FMEA Team Members: Last revised date:

| Process / Performance | Potential failure mode | Effects of "potential failure" | Severity | Potential causes of failure | Occurrence | Current controls | Detection | RPN | Proposed measures | Responsibility | Taken Actions | RPN revision |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | |
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# Chapter Eleven

# Effects: Measurement System Analysis (MSA)

## Measurement System

Today, the results of measurement processes are more important than ever. Quality systems in any organization are based on the statistics obtained for processes and products. For example, recognizing whether a manufacturing process is properly controlled is done by using statistics collected about the process. The numbers obtained for the process are compared to statistically calculated control limits; if these numbers fall outside the control limits, the process will need to be adjusted. Otherwise, the process will continue to work without making the necessary corrections.

The utilization rate of analyses based on the measurement and collection of data informs the process quality or the measurement system. The measurement system consists of measurement operations, implementation methods, measurement tools, software, and operators for assigning a value to the measured specification. If the quality of the measurement system and consequently the resulting numbers is low, the use of analytical methods will also be low. However, if the quality of the numbers of the measurements is high, the results of the performed analyses are much more useful.

The number (recorded as the value of an attribute) does not necessarily correspond to the actual value of that attribute, but may deviate. The actual specification of the diameter of a piece, for example, is evaluated using a measuring system that is defined by the individuals involved, the equipment used, the environment, and the instructions for the process; as such, a number is assigned to it. This number is a function of two values, namely, the actual specification of the piece and the degree of deviation in the measurement system. If the numbers developed from the measurement system are close to the actual numerical specifications, the quality of the measurement system is high. Each component of the measurement system can result in some deviation in the measurements. For example, changes in ambient temperature can cause the expansion and contraction of pieces and devices and result in changes in measurements. Furthermore, the angle of the measuring instrument against the piece being measured will result in a different inner diameter specification of the piece.

Measurement system analysis (MSA) is a tool for analyzing the quality of the measurement system. Its main purpose is to improve the quality of the measurement system and reduce deviations. The statistical criteria commonly used to assess the degree of quality of a measurement system are (as with other processes), **standard deviation** and **bias**. The criterion referred to as **bias**, indicates the centrality of the numerals obtained from the measurement in comparison to a standard or its nominal value. The criterion of **standard deviation** also specifies fluctuations in the numbers obtained through measurement.

**Accuracy** is a similar criterion to **bias**. If the average numerical point is close to the actual point, the accuracy is higher and the bias is reduced. The degree of **precision** is the criterion of **standard deviation**. Therefore, if we measure a specification several times, we will see changes in the obtained results due to variability (which is an inherent specification of natural processes). A good measurement system has high accuracy and precision; in other words, it has less bias and standard deviation.

### The oscillation of pieces and the measurement system

All pieces and products have a level of variation according to the principle of variability. Therefore, when investigating the specification of a piece, we do not expect the specification of that piece to be equal to a constant. In other words, if we want to accept a piece, we do not expect the actual specification to be exactly equal to the predetermined value. In such cases, an "acceptance domain" is usually introduced for the attribute. This acceptance domain is usually introduced through the concepts of a high technical specification limit (USL) and a low technical specification limit (LSL).

It can be concluded that, to reduce errors in the measurement system, we must use one whose fluctuation rate is very small compared to the fluctuations and domains of the piece specification. If the measurement system fluctuations are less than the acceptance domain and the fluctuations in the specification (that we intend to measure), the measurement system error rate will decrease, and vice versa.

### Measurement system evaluation

The ideal measurement system will provide only perfectly accurate measurements and each of the measures obtained from the process will fully comply with the measured criteria. The measurement system (which has these favorable conditions) has a standard deviation and degree of bias of zero, and there is no possibility of a recorded deviation in size due to the measurement system relative to the actual size of the piece.

Due to the principle that variability is an integral and inherent part of all processes, the measurement system will not exist with ideal conditions and in most measurement systems, some deviation is observed. The purpose of measurement system analysis is to **reduce deviations and the variability of the measurement system**.

Although each measurement system can have different statistical features, in general, the following features can be expected:

1. The measurement system must be under statistical control. In other words, the causes of fluctuations in *the measurement process should be based only on general causes and not on specific causes. In such a situation, it can be said that the process is statistically stable.*

2. Compared to the fluctuations in the manufacturing process, the value of fluctuations in the measurement process should be far smaller.

3. Compared to the acceptable limits for the technical specifications of a piece (LSL, USL), the value of fluctuations in the measurement process should also be very small.

4. The measurability of the measurement system (instrument) must be at least one-tenth greater than the expected accuracy of the specification. For example, if we wish to measure a specified size of up to one-tenth of a millimeter, we must use a tool that can measure those dimensions up to one-hundredth of a millimeter.

### Types of fluctuations in the measurement system

One objective in measurement system analysis is to obtain information about the value and type of fluctuations in the measurement process (caused by the reaction of the measurement system to environmental factors). This type of information is very valuable and its analysis helps relevant officials and process experts in the following ways:

- In creating a criterion for accepting measuring instruments.
- In creating a basis for comparing one measuring instrument with another.
- To adjust instructions for evaluating a measuring instrument (which is thought to be inefficient).
- To provide a basis for comparing a measurement device, before and after repair.
- To establish an appropriate method to ensure the value of fluctuations in the manufacturing process and the acceptable degree of competence of the processes.

- To provide the information necessary to know the performance curve of an instrument, indicating the possibility of accepting the size of a piece in relation to its true value.

Deviations can be divided into five groups based on the existence of fluctuations in the measurement process. These categories include stability, bias, linear communication, repeatability, and reproducibility.

**Bias:** bias is the difference between the average of a large sample of results obtained for a specification and the actual value of the specification. The values for bias are used to inform a numerical index for measuring accuracy.

**Stability:** shows the compatibility and durability of a measurement system over time. Control charts are a good tool for assessing the stability of measuring instruments. To do this, the dimensions obtained by a measuring device from a constant piece over time are plotted on a control chart.

**Linear communication:** linear communication is the value of difference that occurs in the bias value in the operating range of the instrument. The operating range of the instrument is the range in which the instrument can be used to measure the specifications.

**Repeatability:** repeatability concerns the observed changes in size (when an operator repeatedly measures a specification of the same piece in the same location with the same instrument). Repeatability is the inherent deviation of a measuring instrument and is equal to the standard deviation of the instrument.

**Reproducibility:** reproducibility is the value of deviation in the average of size values due to factors other than the inherent deviation of the tool.

These factors include people, humidity, temperature, and maintenance techniques. For example, the reproducibility of a tool can be defined as the difference between the average sizes obtained by different operators. Reproducibility is the value of deviation in measuring the same specification with a tool under different conditions.

### Measurement systems evaluation process

There are a number of methods for evaluating measurement systems that can be used in different environments. These methods are often referred to as instrument repeatability and reproducibility because they are used to evaluate the instrumentation in terms of repeatability and reproducibility.

The exact performance of the measurement system evaluation process leads to better estimation and evaluation of the competence of a device (instrument) and the operator that uses the device. Finally, it leads to improvement of the measurement system.

**Step 1: Prepare for evaluation**

The purpose of this step is to determine the process that should be used. There may be several measurement processes used in manufacturing, service, and laboratory systems, etc. We may have a list of measurement processes in our organization that need to be evaluated. We then choose one of them as the first process for evaluation, or we arrange the list based on decision-making and prioritization methods. Thus, the arrangement of the evaluation of the various measurement processes of the organization is made clear. Some organizations phase out the evaluation of their measurement processes and evaluate their categorized processes in each phase.

The instructions in this section are used to evaluate measurement systems that perform dimensional measurements and we also use a regular procedure to perform such measurements. After selecting the measurement process, it is time to prepare the evaluation actions. At this step, the following activities should be done:

1. Determine the measurement system to be studied along with the appropriate measuring instruments and methods.
2. Test procedure documentation.
3. Determine the number of operators, the number of sample pieces, and the number of iterations. Normally, 3 operators, 4 to 10 sample pieces, and 3 to 6 repetitions are considered. If the number of operators, sample pieces, and repetitions increase, we will have more confidence in the results, but they will also cost more.
4. Using an economic analysis, the value of each of the above parameters can be determined according to the required level of reliability and the budget available.
5. Determine the operators that should be used. Operators must be selected from among people who have received the necessary training in the measurement system and have the appropriate qualifications.
6. Determine the samples that should be selected and the location of their selection. Samples should be selected from current processes and cover the operating range of the measurement process. Appropriate methods should be used to generate a randomly selected sample from the statistical population of pieces (measured by the system). In practical terms, it is better to select samples on different days and from different work shifts.

### Step 2: Stability Assessment

This step is performed to evaluate the stability of the measurement process and whether it is statistically controlled over time or not. A measurement process is considered to be in a stable state if its deviations are only due to general causes, while specific causes do not cause reasonable deviations in that system. In other words, in this case, it is said that the process is under statistical control and its deviations are due to the nature of the process with no specific cause affecting the process and moving it out of its normal state. In this case, the behavior of the measurement process can be predicted with high confidence due to its stability.

Statistical process control (SPC) and Shewhart control charts are commonly used to assess stability. The steps of stability assessment are as follows:

- Select a sample piece based on one of the following two methods:
  - Select a standard sample piece. If a standard sample is not available, a manufacturer sample can be selected that is approximately equal to the middle of the operating range of the measurement system.
  - Select several standard sample pieces in the lower, middle, and upper ranges of the measurement operating range. For example, if the measurement system aims to measure sizes between 10 and 50 mm, in this method, samples of about 10 mm (low), about 30 mm (average) and about 50 mm (high) are selected. If standard sample pieces are not available, manufacturer samples can be used. If several samples are used, the control chart and data analysis should be done separately for each sample piece.
- Measure the standard piece over time. In this case, it is measured at regular time intervals, such as hourly, daily, or weekly, etc. In each measurement (3 to 5 times in a small time interval), the standard sample piece is measured and the numbers are recorded. The obtained values for each measurement form a group. This process continues until at least 25 data groups are collected.
- Draw control charts. In this step, appropriate control charts are considered and (after performing calculations and setting the control limits) the data are drawn on them. (Each group forms a point in the control chart and the control limits of the control charts are calculated based on the principles of statistical process control.)
- Evaluate the control charts to analyze the stability of the measurement system. The measurement system is stable if both charts show controlled status. If one of them indicates an out-of-

control situation, the root cause must be identified and removed (corrected). After modifying the measurement system, several other data groups should be collected and analyzed. This continues until the stability of the measurement system has been proven.

After ensuring that the measurement system is suitably controlled, it is important to maintain its controlled position. A measurement system that is under control may once again get out of control due to the influence of certain factors. If the measurement system gets out of control, the results of the data will no longer be valid. For this reason, both during the measurement system evaluation process and after verification and use of the instrument, it must be ensured that the instrument remains under control. In addition to the assessment procedure of stability, we may use similar methods to control the instrument at other times.

### Step 3: Assess the Power of Detection (Resolution)

Detection power assessment is performed to evaluate the detectability and cleanliness of small changes in the specification measured in the measurement system. This step can be done simultaneously with the previous step (stability assessment). The assessment of diagnostic power is done according to the following steps:

- Select a standard sample.
- Measure the standard sample 3 to 5 times in each iteration to form a group.
- Measure and form groups according to a regular schedule to form at least 25 groups.
- Design a suitable control chart and draw the points on it.
- Analysis: If one of the following conditions exists, the power of detection is insufficient:
  - There is only one, two, or three possible values in the whole range;
  - There are only four possible values in the whole range if the number of subgroups (number of points in a group) is at least 3.

### Step 4: Determine the Accuracy

The purpose of this step is to determine the proximity of the average of the results obtained for a specification by the measurement system to the actual value of that specification. In other words, the purpose of this step is to determine the degree of bias of the measurement system. Determining the accuracy is done through the following steps.

Select a sample piece based on one of the following two methods:

- o Select a standard sample piece with a size approximately in the middle of the operating range of the measurement;
- o Select several standard sample pieces in the lower, middle, and upper ranges of the measurement operating range.

If standard sample pieces are not available, manufacturer samples can be used. In this case, the selected manufacturer pieces must first be measured 15 times under standard conditions with standard equipment (preferably using calibration laboratories) and their average calculated. The obtained average is considered the reference value for each sample.

- ➢ Measure standard samples (15 to 25 times in a small time range) with a similar operator, equipment, and conditions.
- ➢ Calculate the average of the observations for the sample.
- ➢ Calculate the bias value of the measurement system based on the following equation.
- ➢ Perform hypothesis testing based on the following steps:
  - o Determine the type of hypothesis test;
  - o Determine the type of statistics;
  - o Determine the reception area;
  - o Statistical calculation: placement of obtained values;
  - o Decision making: if the statistical value is within the acceptable range, the bias value can be ignored. Otherwise, the bias value is negligible. Furthermore, the instrument must be sent to a calibration laboratory for correction.

### Step 5: Calibration

The purpose of this step is to reduce the bias of a measuring instrument based on the calibration process. Calibration activity is usually reviewed under defined conditions by trained individuals using equipment and standard and exact examples of tools, and is performed according to defined standards. For this reason, companies often use the services of calibration laboratories or create suitable conditions for simpler tools to perform calibration activities.

Calibration laboratories have standard and appropriate equipment and samples, specialized and trained individuals, suitable environmental conditions, and other suitable hardware and software for calibration, which are also evaluated and approved by the competent authorities.

### Step 6: Assess Linearity

The purpose of this step is to evaluate the degree of difference that arises in the value of the bias over the operating range of the instrument. The process of evaluation in linear communication is done according to the following steps:

- Select 3 to 5 standard samples that roughly cover the operating range of the measurement.
- Measure standard samples (15 to 25 times) with a small-time range and a similar operator, equipment, and conditions.
- Calculate the average of observations for the intended sample.
- Calculate the bias of the measurement system.
- Draw the obtained bias for the samples on the chart. The vertical axis of this chart shows the bias value and the horizontal axis shows the size of the reference value of the samples.
- Draw a line of best fit for the points on the chart. The linear equation is calculated using linear regression techniques.
- Calculate the value of the linear regression line slope.
- Calculate the value of linear communication and the percentage of linear communication.
- Calculate the correlation coefficient.

The slope of the regression line indicates the extent to which the size of the reference value or part size affects the measurement system bias.

The ideal mode is one in which the slope of the line is zero and, in general, it is better if the absolute value of the line slope is less. The value of the correlation coefficient is determined by the degree of correlation between the size to be measured and the degree of bias of the measuring instrument. The above information can be used to assess the linearity of the measuring device. Using hypothesis testing techniques, the hypothesis of no linear relationship for a device can be accepted or rejected.

### Step 7: Determine the Repeatability and Reproducibility (R&R)

The purpose of this step is to evaluate the variability of the measurement system. Variability indicates the degree of the standard deviation of the measurement system. Variability is divided into two components: repeatability and reproducibility. The process of assessing repeatability and reproducibility based on ANalysis Of VAriance (ANOVA) is performed according to the following steps:

- Create a random schedule for measurements. At this step, an appropriate randomization plan is determined to randomly determine the arrangement of the experiments.

- Repeat and create a randomization plan if there is a need for repetition in the evaluation plan.
- Perform tests according to the plan. When performing a test, it must be performed exactly as planned and an expert should oversee the plan and record the results. The results should be recorded anonymously and the operators should not be aware of the measurements taken by other operators.
- Perform the analysis of variance on the data as follows: in two-way analysis of variance tables, sources of change are usually displayed as the first factor, the second factor, the interaction, and the error. The error effect indicates the value of variability in the device, which is also indicative of repeatability. The second source of change concerns changes caused by the measurement operators and their interaction, representing reproducibility. The variance related to repeatability is calculated based on the analysis of variance table.
- Calculate the percentage share of each component in the total standard deviation. At this point, the standard deviation of each component is calculated. Then, by dividing them by the total standard deviation, we calculate the percentage share of that component in total standard deviation.
- Evaluate the contribution of the standard deviation of repeatability. If the share of the standard deviation of repeatability is small, it indicates reduced variability of the tool and more confidence in its size. Therefore, in this case, we must introduce a threshold for the acceptability of the share of the repeatability standard deviation. This threshold is usually considered to be 5 %. If the share of the standard deviation of repeatability is less than 5 %, the repeatability value is acceptable, otherwise, the repeatability is not acceptable and the tool needs to be corrected.
- Calculate the share of the R&R standard deviation in the total standard deviation.
- Evaluate the share of the R&R standard deviation. The share of the standard deviation of R&R (like the share of the standard deviation of repeatability), is better if it is less, indicating lower variability in the measurement system. In this case, too, a threshold must be introduced for the share of the R&R standard deviation to be acceptable. Usually, the acceptable limit for the share of the R&R standard deviation is 30 %. If this standard deviation is less than 30 %, the R&R value is acceptable, otherwise the R&R value is unacceptable. As such, before continuing to analyze or use the

measurement system, it must be improved and its variability reduced.

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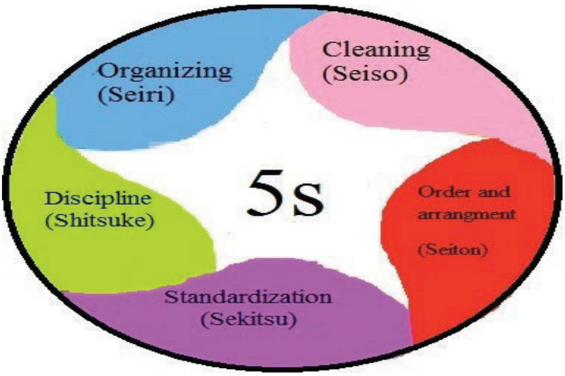
# CHAPTER TWELVE

# 5S

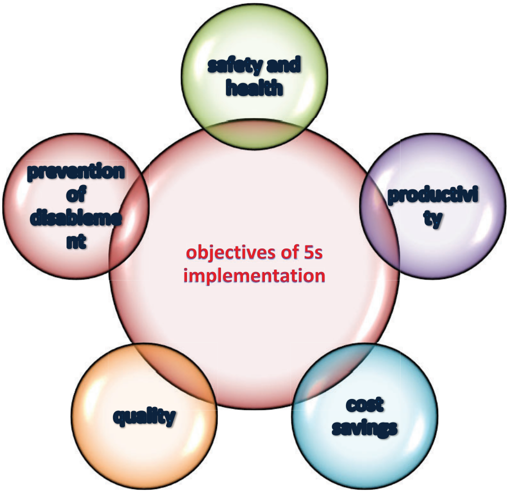
## WHAT IS THE 5S GROOMING SYSTEM?

This system was first designed and implemented in Japan. The 5S approach was first developed by modeling American and European industries; the model was then developed and systematized. The phrase "5S" is based on the initials of the five Japanese words:

- Tidiness: Seiri;
- Orderliness: Seiton;
- Cleanliness: Seiso;
- Standardization: Seiketsu;
- Discipline: Shitsuke.




The implementation of 5S has several objectives. Some of the most important objectives are: safety and health; productivity; cost savings; quality control; and prevention of disablement.




The 5S or "visual control" system is focused on accident prevention and increased productivity. 5S is a prerequisite for the successful implementation of a number of other systems and models and a big advantage is that it can be implemented anywhere. Perhaps it would be better to say that the ultimate objective of the 5S is waste prevention. As a result, in environments that are managed by implementing a visual control system:

There are no unnecessary and inessential objects.
Existing items are arranged in a special order (clean and hygienic).

It encourages frugality and a safe environment.

**Note:**
The most important factor in realizing a visually controlled environment is trying to **create the right habits in employees**.

**Organizing ("organizing, segregation, and repair" or Seiri)**

In 5S, the activity of "organizing" sees the regularization of all the components of an organization to achieve objectives. In the 5s point of view, organizing means distinguishing the necessary from the unnecessary, acting decisively, and applying priority management to remove unnecessary elements. The purpose of organizing is to create a desirable and appropriate order. To be successful in organizing, you have to prioritize. Examples of implementation of this S can be listed as follows:

- Separation of necessary items from unnecessary items (identify the administrative requirements that exist around you and classify them in terms of their priority of use; distinguish between obsolete forms (useless) and circulating forms (in use)).
- Throw away objects that are not used (throw away waste).

**Note:**
For this purpose, we must identify all necessary tools, items, and forms and determine the performance of each of them.

### Order and arrangement (Seiton)

In 5S, "order and arrangement" involves putting objects in appropriate and ordered locations so that they can be used in the best possible way. Order and arrangement is a way to find and use needed objects, without having to search in vain for them. Thus, everything is in the right location (according to the performance, quality, and safety of the work). The workplace should always be orderly and arranged so that everything can be reached quickly and easily. Examples of implementation of this S can be listed as follows:

- Put the objects we use most often in the workplace (e.g. equipping people's desks with office supplies).
- Put the objects that we rarely use in an "out of reach" location (e.g. use a proper archiving system so that work records from previous years are located further away from the current workspace; use a library or shelves for storage of reference books, pamphlets, and instructions).
- Label and identify all zones, files, and shelves (e.g. label the files to reflect their contents).
- Establish the specific location of everything (e.g. put files and office supplies in a defined location; establish and classify forms on special shelves; use an appropriate system and equipment to classify letters, or work in hand for the current run).
- Take and return everything in the shortest timeframe possible (e.g. return records to the archive location; arrange the items and tools that we use with daily; put one's chair behind the desk when leaving the workplace).

- Mark the "boundaries" and "locations" of objects and ensure the identification of where people work (e.g. signs indicating the names of people or use identification tags; determine the location of the company's vehicles and the location of people's desks).
- Display the order and arrangement on the bulletin board for advertising or informing employees (e.g. install advertising or information placards in appropriate locations).
- Design "announcements" so that they are easy to read (with a focus on proper placement and visibility, aesthetic design, and legibility).

**Note:**
The goal is to put objects in the best location in the best possible way and ensure the ability to access them at maximum speed (less than 30 seconds).

### Cleaning (Seiso)

In 5S, "cleaning" is the disposal of waste and the cleaning of objects from contaminants and foreign materials. In other words, cleaning involves a kind of inspection. Inspection and cleanliness of the work environment are emphasized to eliminate pollution. Some appliances, equipment, and locations must be kept clean and free of contamination, and need to be identified accurately. Cleaning is not just about scouring the workplace and its equipment, but also involves inspections and reviews. Examples of implementation of this S can be listed as follows:

- Define the responsibilities of all individuals for the cleanliness of the workplace (maintaining cleanliness in the workspaces of all employees and the cleanliness of employee clothing).
- Perform continuous inspection and cleaning by the service provider.
- Identify and repair damage caused by leaks, erosion, and cracks, etc.
- Identify sources of pollution and try to eliminate or control them.
- Clean the workplace (e.g. regular washing with disinfectant; cleaning of the warehouse; collecting used equipment; and cleaning things as soon as they get dirty).
- Eliminate dust (e.g. proper ventilation in warehouses and halls; use of air filters; use of covers; and putting items and objects in closed containers).
- Clean places that are out of sight (e.g. under tables, corners of rooms, under office supplies and technical equipment, and behind windows, files, drawers, etc.).

**Note:**
Prevent dirt and keep the environment, property, and people clean; eliminate or control pollution.

*Remind yourself to keep your workplace as clean as your house.*

**Standardization (Seikitsu)**

In 5S, "standardization" is the permanent control and correction of organizing, order and arrangement, and cleaning. Examples of implementation of this S can be listed as follows:

- Periodic reviews (including the formation of an inspection committee; inspection and review of those elements covered; and the holding of internal audits).
- Use of signs and symbols (signs indicating direction and guidance).
- Marking of "hazardous areas" or areas requiring "special care" (e.g. chemical storage and high-pressure equipment).
- Signage for firefighting equipment (e.g. signs for alarms and safety devices, fire extinguishing system guidance, and "no smoking").
- Prepare to prevent errors and mistakes (e.g. training personnel about dangers and developing instructions for the use of special equipment).
- Labels to indicate the accuracy of tools (e.g. recording and marking of the degree of accuracy of equipment and the date of validity and control for them).
- Codify system implementation instructions.
- Organize steering committee meetings to review the results of periodic inspections and make the necessary decisions to advance the 5S objectives.
- Necessary activities along with competitions for organizing, ordering, arranging, and cleaning as best as possible (considering evaluation criteria, determining the sample unit, and assigning personnel to oversee the monthly evaluation parameters of cleanliness in the workplace).

**Note:**
The main emphasis in standardization is on management, which (by using appropriate checklists and standardizing regulations through innovation and creativity) standardizes and controls the work environment in such a way that all factors are engaged with the necessary speed and accuracy.

### Discipline (Shitsuke)

In 5S, *discipline involves the training of habits and abilities to perform a particular task*. Here, the key point is to create the right habits rather than the wrong ones. This starts with *teaching* "the right way to do the job" to personnel and them *practicing* it. These practices are realized through adjusting the rules and following them seriously. Examples of implementation of this S can be listed as follows:

- Practice discipline (training, continuous monitoring, evaluation, and rewarding personnel for their discipline).
- Exercise punctuality (training in the optimal use of time, especially in the repairs department and in holding meetings).
- Paying attention to the work aesthetic and observing appearances (e.g. wearing the appropriate clothes in the office or organization).

> **Note:**
> Discipline is the process of repeating and practicing "doing a job." For example, individuals must follow appropriate safety rules until they become a habit.

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# CHAPTER THIRTEEN

# DESIGN OF EXPERIMENT

Experimental design is a scientific approach that allows the researcher to gain knowledge and better understand a process, as well as determine how the inputs affect the outputs:

- Which inputs have the greatest impact on the output?
- How much of each input gets the best output?
- What are the factors affecting changes in output?
- How can they be minimized?
- How can the impact of uncontrollable inputs be minimized?

We have expectations about the processes that exist in an organization and the satisfaction of these expectations is a matter of process performance. Quality is also part of process performance and, in relation to quality, we can ask the following questions. Are there factors that affect the quality of the process? How do these factors affect quality? If these factors change, how does the quality change? How do we change these factors to achieve the best quality performance? And what controllable factors are available to minimize the effect of uncontrollable factors on quality? These questions can all be answered by doing experiments and so there is a need for testing in industry.

The "design of experiments" approach is one of the most powerful techniques for improving quality and increasing productivity. In this approach, through experiments, changes in the process/system are consciously applied to investigate their impact on the performance specifications or response of the process or system. The statistical approach is the most effective way of optimizing these changes, for example, in the case of SPC.

Any experiment that has the flexibility to change the process input variables so as to observe the output response comes under the design of the experiments. The design of the experiment involves the systematic manipulation of the number of variables in which the effect of these manipulations is evaluated. Conclusions are then made and finally the obtained results are analyzed and interpreted.

The objectives of such designed experiments are:

- Determine the variables and the size of their impact on the output response.
- Determine the levels of these variables.
- Determine how to manipulate these variables to control the output response.

SPC is thus a passive statistical method, while designing experiments is an active statistical method for obtaining information. In this way, the user information to improve the process is obtained through *tests performed on the process*, *changes made at the input*, and *observation of the output*. Therefore, the design of the experiment should be done before SPC, unless the customer determines the product specifications.

An experiment always involves cost and time. Therefore, the performance of effective experiments that obtain the most information with the least cost and time is the objective of every engineer or researcher. The cost and time increase as the number of factors increases. As such, there is a need for a method in which the most information about the process can be obtained with the least cost and time; logical conclusions can be presented; and documentary evidence about the process can be obtained. This method is called design of experiments (DOE) and fulfills the mentioned objectives in the best way.

The use of design of experiments also helps engineers to develop and evolve manufacturing and create processes that are resistant to environmental factors and other sources of change. Timely and successful application of design of experiments in the development of the manufacturing process can substantially reduce manufacturing times and costs, leading to processes and products that have inherently better performance and are more reliable than those obtained by using other methods.

By applying and understanding the concept of design of experiments, managers and engineers can discover how to bring uncompetitive products, for example, back into international competition with higher quality. Today managers and engineers need to have sufficient knowledge of design of experiments methods before deciding on how to improve and develop a product and process.

In most industries, the correct and effective application of a design of statistical experiments approach is key to increasing efficiency, reducing variability, reducing design delay times, and developing better products, resulting in improved customer satisfaction.

In each experiment, several variables are available to the analyst. The analyst may modify those variables according to the needs of the experiment. For this reason, these variables are also called controllable variables. Controllable variables are factors that change by increasing or decreasing the number of materials (or, for example, turning a valve, changing the direction of a key, and changing a piece). Uncontrollable variables lead to noise in the process and reduce the possibility of identifying controllable variables. Identifying these variables is also of particular importance and thus information about them must be collected. *One of the most important factors (causes of failure in the DOE) is the lack of identification and collection of information on such variables.* The most common uncontrollable variables are shift changes of operators, changes in the ambient temperature, and changes in raw materials from outside the company.

Using various techniques (e.g. SPC), a large number of input factors or variables may be identified. Using all of them (due to a large number of experiments as well as the measurement costs for each of them) is very difficult and perhaps even impossible; therefore, the number of variables is be reduced by selecting the most important ones.

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# CHAPTER FOURTEEN

# TAGUCHI QUALITY ENGINEERING

Dr. Genichi Taguchi introduced the concept of "loss performance." Loss performance combines the elements of cost, purpose, and diversity to obtain its measurement criterion and considers specification limits to be of secondary importance. In addition, he expanded the concept of "robustness."

**Robustness** means addressing "factors of disorder" to ensure the proper operation of the system. Factors of disorder are uncontrollable variables that can lead to large variability in a process or product.

**Loss function**

Taguchi defines *quality as a loss that is transmitted to society from the moment that a product is shipped*. Social losses include the failure to satisfy customer needs, the failure to achieve ideal performance, and dangerous side effects. Many experts also consider losses to include raw materials, energy, and the workforce, which produce unusable products and unwanted output in the manufacturing process.

Assuming that the objective value is correct, significant losses are caused by deviation of the critical functional specifications of the product from the objective value.

**Note:**
The scale usually used to measure being outside the specification limits is "quality loss." According to the specification limits scale, any product that is within these limits is "good" and any product that is outside those limits is "bad." From the customer's point of view, a product that is located within the specification limits is as good (or bad) as a product that only slightly exceeds these limits. (Customers consider quality in terms of achieving an objective, not just being within specified limits.) As such, it seems that we are using an incorrect measurement system. The loss function solves the above problem by combining cost, purpose, and variety, and providing an appropriate measurement criterion.

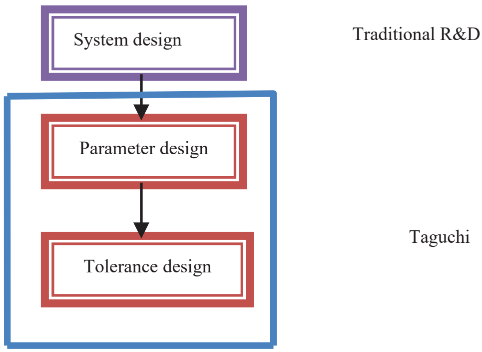
Of course, it should be noted that the feature of “quality” is not static. In the real world, it is impossible to achieve objective value, because it changes due to the presence of factors of disorder. Additionally, loss performance must show the diversity of a large number of elements, not just the diversity of one element. Factors of disorder can be divided into two categories: external and internal. Factors of internal disorder can be divided into two further categories: “unit to unit” and “malfunction.”

A refrigerator temperature control device is a good example for explaining the concept of disorder. Factors of external disorder depend on user performance (for example, the number of times the refrigerator door is opened and closed, the amount of food in the refrigerator, and the initial temperature, etc.). **Unit-to-unit internal disorder** refers to variability in manufacturing, such as how strong the insulation is, variation in the control sensor, and so on. While this type of disorder is inevitable, every effort should be made to keep it to a minimum. **A malfunction internal disorder** could be caused by coolant leakage, mechanical corrosion of compressor components, and so on. This type of disorder is primarily *the result of product design.* Factors of disorder result in deviation from the objective, which in turn causes harm to society.

### Parameter design

The product development process has three steps: product design, process design, and manufacture design. These three steps are given along with the three sources of diversity or disorder (i.e. environmental variables, product failure, and the existence of variation in the manufacturing process). *It is only in the product design step that we can think of sources of diversity.*

Taguchi’s philosophy is based on the design of strong and stable tolerance parameters. Appropriate design relies on components such as system design, parameter design, and tolerance design. Stable design includes the last two components and system design is the same as what has traditionally been known as R&D.




System design involves the development and evolution of a prototype. This component of the design process uses engineering and scientific knowledge to determine product and process parameters. Awareness of customer needs is critical in this step.

Parameter design involves the selection of optimal conditions (parameters), so that the product has the lowest sensitivity to irregular variables. To do this, we first start with lower quality and less expensive parts and raw materials. Certainly, nothing is more foolish than doing research using expensive parts and raw materials. By identifying the factors under control and the factors of disorder and addressing each of them separately, variability can be reduced and high quality and low-cost products can be achieved.

**Tolerance design**

Tolerance design is a process through which an appropriate statistical tolerance is determined around the objective value. During the parameter design process, we try to calculate approximate tolerances with low costs, but in situations where the parameter is sensitive, we use tolerance design. Thus, we use **ANOVA** *to determine the* ***effective factors in creating variability*** *and* ***loss performance*** *to determine the relationship between quality and cost.*

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# CHAPTER FIFTEEN

# COSTS OF QUALITY (COQ)

## WHAT ARE THE COSTS OF QUALITY (COQ)?

One definition of quality states that quality is measured by the cost of non-compliance, not by indicators. Therefore, the **costs of quality (COQ)** measurement system is essential for analyzing quality. The COQ technique has unique specifications. Some features of the costs of quality system are listed below:

- Estimation and analysis of the set of costs related to ensuring the appropriate quality of products and services.
- A criterion for measuring the organization's acceptance of quality and investigating its effects on profits and loss.
- Awareness among employees of costs due to low quality.
- Creating a context and culture focused on reducing business costs and increasing organizational competitiveness.

> **Note:**
> The main purpose of this system is to **identify, reduce, and eliminate costs** cause by a lack of quality in different steps of the manufacturing chain of a product.

Any activity, whether in the design phase or other steps, if not done correctly nor to the standard that it should be, will lead to problems and issues. Naturally, this failure will impose more costs on the organization than desired. A step at which the quality level is low produces different effects.

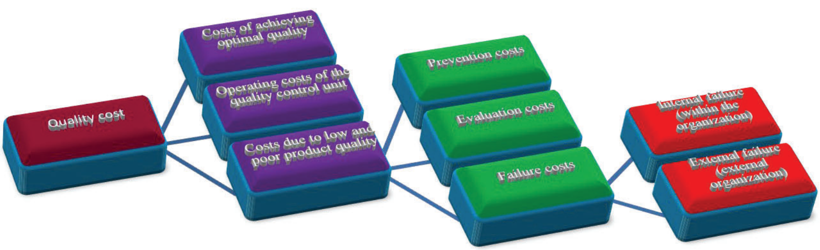
Consider the following table. The different steps of product manufacture are listed on the right of the table and the adverse effects of non-compliance in each step are listed on the left. Note that as we get closer to the final steps, the consequences and costs of mistakes, non-compliance, and lack of quality in performance increase.

| Different steps of product manufacture | Adverse effects of non-compliance |
|---|---|
| **Supply** | Refer the product to the supplier and replace it |
| **Construction** | Rework, waste |
| **Assembly** | Disassembly, rework, waste |
| **Distribution** | Product recall, part replacement |
| **Delivery** | Exchange, sell below price |
| **After-sales service** | Warranty, replacement, credit reduction |

### Costs of Quality

There are three main views on defining the costs of quality:

- Costs of achieving the desired quality through design and organization.
- Operating costs like the equipment quality control unit and salary, etc.
- Costs arising from low and undesirable quality of the product, such as increased wastes and reduced product prices, etc.




Costs due to poor quality are divided into three areas: prevention costs, evaluation costs, and failure costs. Failure costs are also divided into internal and external failure:

1. Prevention costs;
2. Evaluation costs;
3. Failure costs;
    - Internal failure;
    - External failure.

### Prevention costs

Prevention costs are costs incurred through the implementation of actions and plans to prevent non-compliance, i.e. preventing errors.

Prevention costs include all costs associated with identifying, preventing, or reducing the risk of non-compliance or defects. They also include the following:

- Costs related to preventive measures and activities within the framework of the quality assurance system.
- Costs related to planning, preparation, training, design, and development; as well as preventive maintenance, evaluation, and system audits, etc.

The prevention of problems is better and more economical than having to solve them. Some examples of the methods used include:

1) Plans for new product verifications that require a comprehensive review before mass manufacture.
2) Plans for reviewing new or changed designs that require the engagement of performance areas at the beginning of the design process.
3) Plans for supplier selection that focus on quality, not price.
4) Reliability testing to prevent high failure costs.
5) Training and testing of employees to do the work right for the first time and from then on.
6) Facilitating customer wants in the organization, for example, by quality function deployment (QFD).

By effectively managing prevention costs, the possibility of achieving quality improvement can be maximized.

#### Evaluation costs

These costs are spent on measures to achieve quality requirements, including certification and quality control in all steps, such as design, purchase, manufacture, transportation and distribution, and after-sales service.

Other evaluation costs include things such as calibration, experimentation, and the performance of tests, and product audits, etc.

#### Internal failure costs

**Internal failure costs** are those costs incurred before products are delivered to the customer. Additionally, these are costs incurred within the organization due to non-compliance and defective parts and products in each of the design, manufacturing, and delivery steps. Costs such as waste, reworking, re-testing, re-inspection, product improvement, equipment downtime, workforce overtime to solve problems, corrective actions, and redesign are also costs due to internal failure.

### External failure costs

Costs incurred after delivery of products and services to the customer due to non-compliance or defects are costs due to external failure.

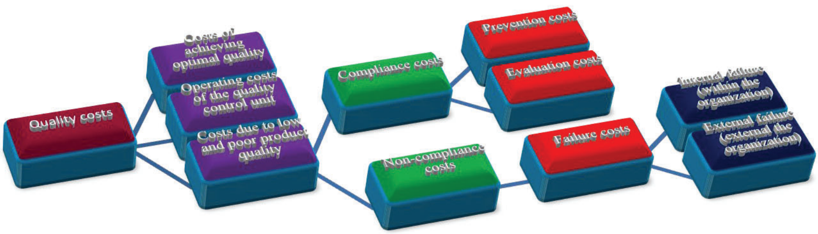
These costs include equipment failure or error costs, wasted time, warranty period costs, defect-related administrative costs, and a consequent reduction in customer goodwill and trust.

Such costs can be divided into two further categories: compliance costs and non-compliance costs.

Prevention costs and evaluation costs are both commonly referred to as compliance costs. **Compliance costs can be defined as the cost of "doing the work right the first time."**

Internal failure costs and external failure costs are known as non-compliance costs and are costs incurred as a result of **"doing the work wrong the first time."**

Unfortunately, for most companies, the bulk of quality costs is made up of the re-inspection of errors or mistakes, rework, repairs, losses, warranty period costs, and refunds to the customer, all within the range of non-compliance costs. Organizations should focus on reducing non-compliance costs and increase investment in compliance costs.




### Steps of setting up and establishing a costs of quality system

The implementation of the COQ technique, due to its systematic nature, should be done according to the process approach and has a number of different steps. This means that system inputs are specified, then processes and operations are performed on them, finally resulting in outputs.

1. Preparation.
2. Identify and determine the costs of non-compliance (CONC).
3. Collection of COQ system data.
4. Analysis of COQ data.
5. Improve quality and reduce costs.
6. Continuous improvement of COQ performance.

### Step 1: Preparation

The activities in this step, which must be carefully planned and systematically performed, are:

a) Establish a COQ committee;
b) Appoint a person responsible for COQ;
c) COQ training of employees;
d) Define the domain of the COQ system;
e) Commitment to providing the necessary resources by senior management or a manager who has the requisite authority and executive power.

#### a) The Costs of Quality Committee

The organization's senior management should play an active role in the establishment of the committee. This committee will include the managers of operational units. **If there is a monitoring committee for comprehensive quality management system or other items related to quality, this committee can also take over the tasks of the COQ committee.**

The COQ committee acts as a policy reference for costs of quality system management. The COQ committee is responsible for planning, implementing, targeting, and increasing employee awareness about the COQ system and other items related to the implementation and promotion of COQ activities in the organization.

#### b) Person responsible for the committee

The responsible person must be one of the managers of the organization and be appointed by the organization's senior management. They are responsible for ensuring the continued and effective operation of this system. The implementation of the COQ system does not depend solely on the performance of the quality assurance department. Only through the combined efforts of the quality assurance and finance sectors can quality measurements and indicators be converted into tangible financial indicators. Close cooperation between finance and accounting staff and managers/quality supervisors in manufacturing and engineering units is essential.

**Committee Member Responsibility:** The main role of financial/accounting employees includes determining costs according to COQ activities, collecting and processing COQ system data from all units, and preparing COQ reports for all levels of the organization, units, areas of work and processes.

The main role of the managers/supervisors in manufacturing and quality units in cooperation with finance/accounting staff is to identify costs of quality items that need to be monitored. They are also responsible for collecting COQ system data, analyzing costs of quality, and taking appropriate corrective actions to solve problems and pursue a policy of continuous improvement of costs of quality.

**c) COQ Training**

Another activity of the preparation phase is the training of COQ officials and members in the costs of quality system. The presence of managers and supervisors of all key units (being related in various ways to the COQ project) are required. The necessary assurances of the adequacy of appropriate awareness, skills, and knowledge (related to staff roles in the COQ system) must be gained. Also, we must overcome misconceptions about COQ.

**d) Definition of the system domain**

The domain of the system must be clearly defined. At the same time, it should be clarified whether COQ exists in the whole organization and all its activities or focuses only on some of the critical and key processes?

The definition of the system domain has a significant effect on the resources required to create the system, as well as the extent to which the system affects the organization. The COQ committee is responsible for determining the domain of the COQ system, given the fact that the system must first be able to identify the costs of major non-compliances cases.

**e) Commitment to provide necessary resources**

The commitment of management is a prerequisite for implementing the COQ system. The COQ manager must obtain the necessary human and financial resources to implement the COQ system. The amount of these resources depends on the domain of the system.

**Step 2: determine non-compliance costs cases**

This step should be aligned with the domain of the COQ system and includes the following activities:

a) Prepare a checklist for non-compliance costs;
b) Assess identified cases of non-compliance costs;
c) Identify data sources of non-compliance costs;
d) Match financial accounts with non-compliance costs.

### a) Determining non-compliance costs cases and preparing a non-compliance costs checklist

Make a list of the major causes of non-compliance costs. In addition to identifying non-compliance costs cases, this list can be useful in clarifying the definition of each of the non-compliance costs cases for COQ committee members.

This list generates a common understanding of non-compliance costs among COQ committee members. The brainstorming technique can be used to prepare the list and the designated items can be used to prepare a checklist of potential non-compliance costs.

| Non-compliance costs | Compliance costs |
|---|---|
| **External failure** | **Evaluation** |
| **Customer complaints** | Inspection of incoming items |
| **Damage during warranty** | In-process inspection |
| **Returned products** | Final inspection and test |
| **Decrease in sales** | Trial manufacture |
| **Compensation for products** | Consumable items in inspection and testing |
| **Warranty renewal** | Analysis of inspection results report |
| **Product recall** | Performance testing |
| **Internal failure** | **Prevention** |
| **Rework** | Planning and preparing work instructions |
| **Waste** | Ensuring the performance of suppliers |
| **Manufacturing line stoppage** | Process capability studies |
| **Replacements, accidents, engineering changes** | Training |
| **Inspection and retesting** | Quality improvement plans |
| **Error analysis** | Data collection and analysis |

### b) Evaluation of identified non-compliance costs cases

Establish criteria for evaluating each of the non-compliance costs cases with reference to the following two questions: how can the identified non-compliance costs cases be calculated? And can they be estimated based on available data?

At this step, the non-compliance costs cases are finalized, although they may be revised in the future.

### c) Determining data sources for non-compliance costs

Some sources of COQ system data are:

- Registered accounts, such as the cost of replacing products returned by customers due to defects.
- Basic accounting records, such as the number of man-hours worked by manufacturing unit employees who are assigned to repair defective products.

- o Estimates, such as judging wasted time of employees due to manufacturing line imbalances or late delivery of parts.
- o Cross-sectional records, such as records on time spent for rework and troubleshooting by employees.

#### d) Matching financial accounts with non-compliance costs

The location and references of costs of quality data in the organization must be specified by the COQ system. How this data is collected should also be specified.

The accounting ledger and the general ledger are good starting points for reviewing costs of quality data due to their detailed accounting procedures. In presenting numbers on quality costs, their correspondence with the budgets of different units can be used. The experience of previous years can be used to provide solutions for calculating and quantifying costs of quality.

### Step 3: Collect system data

This step includes the following activities:

a) Determine costs of quality cases;
b) Provide status reports.

#### a) Calculating costs of quality cases

The following methods can be used to calculate costs of quality:

##### i. General invoicing

In this method, existing data is extracted and collected from the organization's accounts, for example, using recorded rework costs if any.

Numbers for unit pricing and repeated defect problems if they occur can be used. The cost of defects can be calculated according to the price of the defect, multiplied by the number of times the defect occurs.

##### ii. Total personnel

This method can be used if personnel are hired to investigate and work on defects, and the salaries and benefits of these employees can be used in calculating quality costs.

##### iii. Losses to resources/workforce

This method involves calculating the actual costs of special activities (such as expenses related to the amount of spent time by an employee on performing a particular troubleshooting activity and payment for the elimination of a particular defect).

The above information can be obtained from scheduling sheets, documents, and invoices, or any other method provided to exactly determine these costs cases. In this regard, a list of rates of various costs should be made available.

#### b) Provide status reports

The results obtained on COQ should be reported to the committee and the management of the organization. Such reports show the relationship between prevention, evaluation, and failure costs relative to each other as well as relative to other accounts. The following guidelines can be used to collect and report costs of quality data.

- Use existing cost management systems as much as possible.
- Costs of quality should be included in the routine management of accounts.
- Decide on performance indicators that are tailored to business conditions and collect costs of quality data for them.
- The initial cost estimate does not need to be very accurate.
- The ability of employees in the early steps to identify costs of quality gradually increases; at the beginning, there is an expectation of high costs of quality.
- Costs are related to where they occur.
- Total costs of quality are monitored periodically.
- In departments selected for improvement, costs of quality should be collected more carefully and monitored more frequently.

The following indicators and ratios can be used to report costs of quality:

- Annual wastage costs to annual sales.
- Monthly rework cost to monthly manufacturing cost.
- The ratio of internal failure costs to total manufacturing/service costs.
- The ratio of internal failure costs to sales.
- The ratio of inspection costs of incoming items to total cost of incoming products.
- The ratio of total quality costs to total manufacturing/service costs.

### Step 4: Analyze costs of quality data

Analysis of COQ data highlights the importance of current problems and prioritizes them. In COQ system data analysis, costs of quality cases are prioritized and targeted for improvement.

#### a) Prioritize costs of quality cases for improvement

Three common ways of prioritizing costs cases for improvement are: costs of quality procedure analysis, deviation analysis, and Pareto analysis.

##### i. Analysis of costs of quality procedure

This method is useful when past and present data are available and can be compared to each other. The costs of quality procedure analysis highlights the important procedures in costs of quality cases that need to be considered; decreases or increases in non-compliance cost data due to seasonal fluctuations; and costs of quality that occur only once, such as a manufacturing stoppage due to unfamiliarity with how to use new machines.

#### ii. Deviation analysis

This method is highly effective when the goals and objectives for system performance are specified. This method is done by tabulating costs of quality data and comparing them with objectives. In this method, the deviation between the actual data and the intended objectives is analyzed.

#### iii. Pareto analysis

First, costs of quality are sorted based on the size of their share in the list of quality costs and then the cases that have the largest share in quality costs are reviewed and corrective action(s) taken.

#### b) Aim for improvement

This activity deals with prioritizing costs of quality cases and helps the organization to achieve its general objectives.

For example:

- Reduce total costs of quality relative to the volume of sales equations by up to 10 % for the current year.
- Reduction of reworks to 25 % in the current year.
- Reduce complaints during the warranty period by up to 20 % in the current year.

To achieve each of these objectives, appropriate corrective action and monitoring progress towards meeting the objectives are necessary. Objectives should be small and preferably measured in terms of currency. The domain of the COQ system should always be considered in light of the above objectives. Determining the objectives should be done with the cooperation of the employees (who are responsible for the implementation of the plans) so that employees feel a sense of ownership and participation in achieving the objectives.

### Step 5: Improve quality and reduce costs

To improve quality and reduce costs, the following activities should be performed:

- Assigning individuals to the position of process managers and appointing quality teams to monitor the priority cases from a costs of quality perspective.
- Discuss non-compliance costs.
- Improve and use systematic methods, such as PDCA.

- Recalculate the cost of non-compliances cases.

### Step 6: Continuous improvements in system performance

Non-compliance costs cases and related compliance costs cases should be reviewed periodically. Competitive conditions are constantly changing and organizations need to take a precautionary approach in ensuring they are ready to compete. Depending on the circumstances, the validity of previously calculated quality costs may be gradually reduced.

To implement continuous improvement in the performance of the COQ system, the establishment of a preventive system and the planning of a schedule for improvement activities should be considered.

Many costs of quality in an organization are hidden and not easily identifiable, such as the costs of change and correction. These costs are **hidden costs**.

Others are recognizable and can be easily measured, such as rework costs. These costs are known as **apparent costs**. Apparent costs (like the tip of an iceberg floating in the ocean) have a much smaller volume than hidden costs (the underwater part of the iceberg). Hidden costs can also be calculated by calculating apparent costs and multiplying them by the relevant factor.

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# Chapter Sixteen

# Simultaneous Engineering

Simultaneous engineering is a method in which conceptual thinking, product design, and manufacturing planning are performed simultaneously with a multidisciplinary team. Simultaneous engineering is also known as symmetric engineering or parallel engineering. A simultaneous engineering team is made up of experts in the fields of business, engineering, manufacturing, and marketing. At the right time, suppliers of equipment, items, and services also join the simultaneous engineering team. Recently, simultaneous engineering has driven changes in management structure, although some managers have also claimed that they were using it already before learning the field.

In the past, most of an organization's tasks involved simply completing a specific task and then passing the product on to the next unit, according to the organization's hierarchy. As a result, staff were often unaware of the problems that would arise for the organization's *internal customers.*[52] The term "sequential engineering" was used to describe this process; in contrast, in simultaneous engineering all major activities are performed simultaneously. This system gives immediate feedback for tasks and prevents problems and issues related to quality and productivity.

Simultaneous engineering relies on a team of specialists who simultaneously design and develop a product to ensure ease in manufacture and customer satisfaction. Engineering techniques (in terms of the industry, mechanics, electronics, structure, quality, and materials), manufacturing, and business (purchasing, marketing, and finance), along with ideas from suppliers and customers, are all used in the product development process (taking into account all operating aspects and costs).

When professionals are involved in determining product definitions and specifications, the price of the product decreases and efficiency increases. As a result, products of better quality and lower cost are produced and enter the market in a shorter timeframe. If individuals from every organizational unit join the team at the beginning of the work, the

[52] External customers are employees in the next process.

number of engineering changes (that will occur in the future) will be reduced, information will flow better, and employees will agree on how to build a better product.

In sequential engineering, once designs have been completed, they are passed on to the next unit. As a result, there is a lack of optimal use of different specialties in the team. This problem is solved in simultaneous engineering and, as a result, the time required for a new product (to be introduced to the market) is reduced.

Sequential engineering requires the steps of redesign, revalidation, and reprototyping. Each step of the process is completely independent of the others and the waiting time is very long because as soon as a problem is observed, the project is sent back to the beginning to restart the process. Of course, the existence of these circles seems obvious because, at each step, a high level of specialization is required. However, simultaneous engineering combines all these circles and steps and the product is designed for successful use as it passes through its life cycle. That is, rather than preparing the product for final testing and manufacture, it is designed to be perfectly accurate from the very first steps, taking into account the various specifications such as marketing, assembly, and serviceability.

### The reason for implementing simultaneous engineering

Late and untimely changes in design during product development increase the waiting time and cost of a product. Simultaneous engineering helps us control costs by transferring all of these designs to the beginning of the project, rather than designing during the course of product completion. This transfer increases the initial design time, but the profit value obtained is much greater than the value of lost time. The time spent on product and feature design in the simultaneous engineering model is significantly longer than sequential engineering, but this added time (which is the result of brainstorming meetings between experts) leads to a more complete definition of the final product.

Fewer changes in design and reduced waiting times in product manufacture result in responsiveness to customer needs. Also, simplifying the process of rejecting and discarding defective products can lead to a rapid increase in profits, which is another good reason to use simultaneous engineering.

Cash flow is very important for budgeting the activities of an organization. As increased sales lead to improved payment of costs, it is possible for the organization to produce and sell more; however, product returns by customers can waste a large amount of the organization's operating budget and make product scheduling difficult or impossible due to rework.

In simultaneous engineering the product is designed according to manufacturing capabilities and makes statistical process control efficient. The manufacture of a product, taking into account the capabilities of the process, leads to increased customer satisfaction and thus reduces customer returns and reduces the cost of rework. It is quite clear that this method increases profits because time and costs previously spent on rework (due to non-compliance in returned products) are now used in the manufacture of new products. However, if the product is not produced according to the desired capabilities, the organization takes a very large step backward in the need to continuously inspect products and waste earned profits.

*The benefits of simultaneous engineering*

*Since the desire of customers determines the direction of market movement, if it is possible to act 6 months ahead of one's competitors to satisfy customers, the organization will receive more and significant profits.* Also, although it is important to reduce the time required to bring a product to market, ***consumers often prefer to buy similar products of the same quality at a lower price.*** Therefore, if a product is designed without considering the price and cost, inefficiency will cause the company to easily lose profit (the profit gained due to the early delivery of the product to the market). Simultaneous engineering helps manufacturers improve and develop the process using necessary tools and communication and management techniques, as well as by considering scheduling and cost efficiency (from the beginning of the product's life).

The first benefit to a company from implementing simultaneous engineering is a significant reduction in marketing time or product entry time to the market. Other benefits include:

- The rapid development and progress of a product;
- Improved quality;
- Less work for progress and development:
- Fewer engineering changes;
- Increased productivity.

The benefits described above are all due to the rapid entry of a product to the market and are affected by it. This increase in quality and the reduced reworking significantly reduces direct workforce costs.

**Teams**

Simultaneous engineering uses special teams to achieve the company objectives, from the definition and design step to the sales step. This is done to make effective use of the previous experience of team members and with an emphasis on making quick and accurate decisions, as well as meeting customer needs and efficient management in risk and changes. These teams consist of specialists in marketing, research and development, design, manufacturing, testing, and logistics (alignment with the desired projects and in the form of management plans). Also, at the right time, suppliers and customers join the team and share their ideas to achieve common objectives.

To achieve simultaneous engineering, it is necessary to change the method of doing work. Obstacles to the rapid development of products must also be avoided, resulting in lower costs. Individuals cannot think only of their work, as they have to worry about other units and the work of colleagues. For this reason, information (from manufacturing, quality, and service units, as well as suppliers and customers) is very valuable for product design and development.

Implementing the philosophy of simultaneous engineering requires the commitment of the upper and lower levels of the organization. All team members should be committed to the project rather than competing on behalf of their work units. The best employees should be placed in managerial roles and the team should be well aware of the strengths and weaknesses of all its members.

Through the positive interaction between the members of the design team, more designs can be produced; studies show that approximately 90 to 95 % of the total cost[53] of a product is determined at the design step.

To avoid problems in teams, team members should be rewarded for extra work and tasks should be precisely specified. Each member must look at the other members as internal customers and also have trust in the suppliers.

Computer networking technology enables an organization to achieve the positive results of co-location teams while maintaining the advantages of task-oriented organizations.[54] By connecting team members to each other through the network, the project will move towards a set of managed resources and applications. There are three major benefits to using this technology:

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[53] These costs include the cost of purchasing/manufacturing product parts, assembling them, and testing products and services.

[54] In a task-oriented organization, organizational units are designed and created based on the tasks of the organization. For example, in a manufacturing and trading organization, units of product design, production, warehousing, marketing, sales, and so on are considered. This method is one of the oldest organizational methods and is still used in many organizations, especially for operational levels.

1. It eliminates co-location costs.
2. It maximizes communication between team members and external consultants.
3. It records project progress for managerial and financial applications.

### Tools

#### Organizational tools

- Total quality management[55]
- Computer networks
- ISO 9000
- Quality function deployment (QFD)

#### Product development tools

- Computer-aided design software
- 3D prototyping software (solid)
- Finite element analysis software
- Fast prototyping techniques
- Design techniques for construction and assembly

#### Manufacturing tools

- Computer-aided manufacturing
- Computer numerical control (CNC) Tools
- Continuous improvement of process
- Timely manufacture

#### Statistical tools

- Design of experiments (DOE)
- Statistical process control (SPC)

**Note:**
Computer-aided design and computer-aided manufacturing bridge the gap between design and rapid construction.

Important points:

- Simultaneous engineering does not mean simultaneous design and manufacture; rather, it has the opposite meaning. No manufacturing starts until everyone (involved in the design, manufacturing, marketing, and selling a product) has fully agreed on the design specifications.

[55] Total quality management (TQM), is an approach to continuous improvement in product quality through the participation of all levels and tasks of the company. The TQM approach seeks to bring about improvement through the participation of all departments, activities, and individuals.

- Simultaneous engineering is not a cross-cutting solution or a magical tool for success, but a special way of thinking. Individuals who participate in the simultaneous engineering plan must acquire the necessary expertise before joining the team because if these specialties are not available, implementation of simultaneous engineering will not benefit the organization.
- Simultaneous engineering requires multiple tests of the product to achieve the best design and, like design (which is done in only one step), testing has only one step.
- Like sequential engineering, in simultaneous engineering, team members must be assigned to different units of the organization; however, this action may disrupt the performance of the team. So, instead of eliminating sequential engineering processes, we try to improve communication in doing all designs in the team.
- Never provide unworkable timelines for implementing simultaneous engineering because the disadvantages of not implementing such timelines are much greater than the longer implementation time required for simultaneous engineering.
- To achieve a one-step design, do not use a very low standard of allowed errors and unattainable requirements.
- Avoid changing the main definitions and specifications of the product during the design phase, because when the main specifications of the product change during the development period, fundamental changes occur in the manufacturing system and its tools. As a result, costs increase exponentially.
- Do not buy pieces at the lowest price.
- If the process of developing your product is very simple, do not complicate it.

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# Chapter Seventeen

# Product Liability

Competition between manufacturers is an important motivating factor in the manufacture of new and improved products. In fact, advanced and untested technologies can result in hazards that are unpredictable before widespread use of the product. Also, the design of diverse products and products that are technically complex has greatly increased the severity and frequency of such events. Therefore, we need to work on reducing accidents and potential hazards and compensate damaged consumers for detrimental occurrences.

Consumers often sue for accidents, deaths, and financial losses from products that have been incorrectly designed or manufactured. Although large manufacturers can usually pay the costs of incurred damage to consumers, small manufacturers often go bankrupt due to their inability to pay. Therefore, while it is necessary to compensate losses of damaged consumers, the survival of the manufacturers must also be guaranteed.

Damage caused by products usually depends on three factors:

- Behavior with product consumer awareness.
- The environment in which the product is used.
- Whether the company has paid attention to quality control and product safety analysis during design and construction.

Because the usage environment, habits, and abilities of consumers are different, it can be very difficult to create a comprehensive safety plan to reduce injuries. Also, changing human behavior and environments, while not impossible, is more difficult than changing manufacturing plans and improving quality control. As such, using the imagination and initiative of manufacturers, the risk of injury can be greatly reduced. Furthermore, personal injury law (in relation to the use of defective products) has placed great responsibilities on manufacturers.

It is not unreasonable to expect manufacturers to increase product reliability to prevent injury (from use of their products). Product manufacturers know better than others about designs, materials, manufacturing methods, and how to use them safely. On the other hand, due to the complex design of many products, consumers often do not know enough about the dangers that can arise in their use. Manufacturers have accepted the risk of injury caused by the product and try to reduce it:

- In the entry of the product to the market.
- In the estimation of costs caused by injury.
- And in the product pricing (so that these costs are included).

Examples include the use of safety glass to prevent serious injury to consumers from shards of broken glass, or the use of safety guards around the blades of a cutting machine to prevent amputation. As a result, the continuous improvement of safety and quality of the product is undertaken.

### Consumer Product Safety Act (CPSA)

In 1971, the United States of America passed a consumer safety law called the Consumer Product Safety Act. Its rules focus on:

1) Protecting people from damage caused by faulty products.
2) Assisting consumers in determining the relative safety of a product.
3) Standardizing safety standards for products and rectifying incompatible local and state laws.
4) Conducting extensive research into identifying causes and preventing injury, disease, and death.

#### Product Liability Law

Product liability law deals with complaints about product-related accidents, which require the payment of compensation to injured persons. This area of law includes the law of damage due to negligence, pure liability, and the law of contract of sale or guarantee. Liability may result from design or manufacturing defects, inadequate service, non-compliance with warranties, and negligently misleading or deliberately false marketing.

In any claim or complaint about liability in relation to a product, the plaintiff must prove cause, that is, prove that the product was responsible for his injury with a probability of at least 51 %.

***Neglect*** is often considered to represent the classical theory of product liability; in short, the manufacturer is responsible to the customer for the careful design and manufacture of the product. To receive compensation for damage, a consumer must prove that the manufacturer has been negligent in performing its tasks and, as a result, has produced a defective product that has harmed the consumer.

***The theory of pure liability*** states that if someone sells a product that is defective and dangerous, he is liable for damage to the consumer or his assets. The focus of claims under pure liability is on product defects, not constructive negligence. According to this theory, injured people must prove that the product was defective and dangerous, that this defect existed at the time of manufacture, and that it caused damage. Additionally, almost all courts will ask the plaintiff (i.e injured people) to prove that they had a safer plan (which could have replaced the current plan) to build a product.

A product being considered defective is one of the main issues in a product liability complaint. A manufacturing defect in a product can be easily proven by comparing a defective product with a sound product from the same manufacturer. However, proving a design flaw is difficult. Some of the factors used to diagnose defects in product design in the courts are:

- Product utility.
- Study of feasibility and approximate cost of safety improvement.
- Public awareness of the danger caused by the product.
- Intensity and frequency of accidents caused by the product.
- Adequacy of instructions and warnings.
- The environment in which the product is used.
- Consumer care and accuracy in using the product.
- Conditions and duration of the product's life.

The contractual agreement between the parties for product quality and safety is generally in the form of a guarantee, which is controlled by trade codes or sales rules.

There are two types of warranty: explicit and implied. An explicit warranty is an arbitrary explanation that is published in brochures by the manufacturer or trader to introduce the product and encourage people to buy it. An incorrect description of the product here may cause harm to the consumer. In this case, he can engage in an explicit warranty lawsuit because the product did not have the specifications described by the manufacturer.

An **implied warranty** states that the product is perfectly suited for the intended purpose. The law determines who is responsible for preparing a suitable product. An implied warranty is therefore automatically a part of the day-to-day sales contract that is set by the trader (seller) and cannot be excluded in law by a contractual agreement.

**Prevention**

The manufacturer of a consumer product must eliminate the risk of any liability for the product, or reduce the risk to the extent that it is able to make a profit and continue to grow and develop. Achieving this objective requires a product liability prevention plan. Although this plan is different for different companies, there are common elements in the creation of an effective plan.

### Organization

An appropriate organizational structure must be established to prepare an effective prevention plan. This structure relates to the size of the organization and the skills of its employees. The structure must define their tasks and give them the necessary authority to succeed in performing these tasks. Organizational coordination policies should also include appropriate prevention concepts.

To ensure product safety, a formal committee should be formed with a safety engineer or an external consultant. The task of the safety committee is to review and regulate the organization's various safety activities.

Committee members must be from the areas of design, manufacture, marketing, and quality control. The safety engineer should also supervise them as the "boss." In addition, the safety engineer must:

1. Be in contact with insurance organizations and government legislators.
2. Participate in accident claims.
3. Arrange educational plans.
4. Lead audit plans.
5. Act as a consultant for different departments.
6. Have sufficient information about relevant events and methods in this area.

### Training

Appropriate training is essential for an effective plan. All employees should be aware of the importance of product safety and, therefore, arranging field trips with training meetings and brochures can be an effective step in teaching prevention plans to employees. New or transferred employees should also be trained in the same plans and information, including changes to national or state laws, the results of relevant lawsuits, and product audit feedback.

### Review of new products

Product liability complaints are often in relation to new products, rather than well-established products. As such, it is necessary to conduct in-depth study into a product before it enters the market. In the review process, the safety of the consumer is paramount; functionality, cost, and sales volume are all of secondary importance. In other words, product safety is a major design parameter and safe design techniques should be used in this regard. Some of these techniques include:

1- Analysis of defects, effects, and critical cases.
2- Defect (error) tree analysis.
3- Error safety concepts.
4- Weibull distribution (density) and other methods of data testing.
5- Safety signs for product safety specifications.
6- Encrypted identification for tracking.

The starting point of the review process is the product description written by the designer. This description includes the following elements: the purpose of the design; its estimated life; possible defects; design-limiting parameters; product presentation environment; development tests; and final acceptance criteria. The steps of product design and development are carefully recorded and a group (team) is formed to review the product. The review team assesses the product's compliance with current and future industry and government standards, as well as applicable laws and regulations. In addition, the group reviews all information related to product-related accidents. These reviews should be performed at the appropriate steps of the product life cycle.

From an economic point of view, designing an accident-free product is not possible and cost-effective. In this case, the unsafe components of a product should be kept safe or enclosed, so that users are not exposed harm. In some cases, the product can be designed so that the defect does not cause disability. If such a design is not possible, there should always be appropriate warnings in text, color, or images on the product and its packaging.

Customer-centric tests are performed to predict the results of misuse of the product. Designers test a product to find out whether the product will work well or not if it is used properly. A customer-centric test determines what will happen if a product is not used properly.

Because small changes in the design and raw materials of an existing product can cause serious damage, reviews should be done when changes are made to the product.

**Preliminary manufacture review**

The review of a new product is done with "handmade" samples. Therefore, it is necessary to conduct a continuous review of the primary manufacturing items to determine whether there is a defect that was not found in the review of samples. For inherently hazardous products, this step of manufacturing control is essential. The manufacture review evaluates the manufacturing plan to ensure that the following elements are appropriate:

- Work equipment and tools;
- Manufacturing machinery;
- Transportation of materials;
- Testing equipment;
- Safety warnings;
- Inspection system;
- Sampling plan;
- Packing and shipping outside the company;
- Instructions for use;
- Effective safety information for distributors and vendors.

All employees involved in the product review process can evaluate the product design in terms of safety. The greater the number of individuals assessing product safety, the more likely they are to identify risks before the product is sold on the market.

**Periodic manufacture audits**

Most manufacturers conduct periodic audits to investigate the effectiveness of the quality control system. These audits can also be used on a larger scale to assess safety parameters. Audits should be performed on products that have recently been produced, either in the distribution network, or those that have been used by customers for some time. The result of the audits will be sent to the product safety committee of the organization.

Control of warranties, advertisements, agreements, etc.

The product liability prevention plan should include ongoing reviews of warranties, advertisements, trade agreements, catalogs, and technical publications. This review should include the following:

1- Check whether the product can be sold on the market or not, i.e. does the product use appropriate raw materials and manufacturing methods? Phrases such as “safe” and “this product guarantee user safety” should not be used in product catalogs. If the product is considered safe and someone is harmed as a result of working with it, then this claim has been proven to be untrue and the product is defective.

2- Analysis of advertisements, sales brochures, technical reports, and introduction and supply of products by a legal advisor.

3- Checking purchase orders to determine the warranty period for each specific product.

4- Analyzing the distribution of products by the seller and exemption from compensation agreements to determine how to deal with defective items. These agreements can be used in court and are a legal confirmation that the organization produces defective products.

5. Determine where the terms non-compliance and non-compliant product are used.

### Complaints and claims

A complaint makes a connection between the market and the organization about how its product works. This information informs the manufacturer that the existing situation requires corrective action. A Pareto analysis of complaints can lead to changes in product design or manufacture and reduce the risk of injury. Complaints about bodily harm, financial loss, or product safety should be addressed immediately.

Complaints are usually made to sellers, distributors, or employees. This initial notice will be sent to the appropriate department for consideration. An expert, with the help of the organization's insurance company, will examine the situation and decide on the following issues:

- The reason for the complaint.
- The nature and severity of the damage, if any.
- Defects that caused the situation.
- How long there has been a defect in the product and whether or not it was defective when sold.
- Whether there has been negligence on the part of anyone.

A timely hearing can lead to a speedy agreement on reasonable claims and help prepare defenses against those complaints that lead to a lawsuit. Because of its potential seriousness and severity, the complaint handling process is done in appropriate and relevant sections.

#### Maintaining records

To defend a product liability lawsuit, we need to have access to design, manufacturing, and sales records. The specific types of records that should be kept are as follows:

- Product development and testing records.
- Results of inspections of systems, products, work processes, and audits.
- Records of oral and written communication with customers about requirements, product demand, non-standard materials, and complaints.
- Basic design information.
- Product life cycle information.
- Agreed items by government centers, customers, and independent organizations.
- Evidence of acceptance of raw materials.

These documents must be stored properly and a copy must be available.

The document maintenance time depends on many factors. Documents are usually kept for as long as the expected life of a product plus 18 years and a copy must be available. Other considerations include the inherent risk of the product, the need for critical evidence for the defense, and how to store this information.

### Plan for product return by the customer

Although the cost of return strongly depends on the type and number of products returned, it can add a significant cost and has led to the bankruptcy of many organizations. An effective plan for product return can help reduce recovery costs and the risk of product liability. When an organization receives a warning about a defective product, it must decide whether or not to recall all products suspected of being defective.

This decision is based on three factors:

1- The most likely scenario in terms of personal injury or financial losses. This probability is determined according to the specifications, defects, number, severity of hazards, and return cost.
2- The appropriate means of communication (radio, television, newspaper, telephone, or custom post, etc.) used to contact consumers.
3- Determining whether the product should be repaired, replaced, or the cost of damages should be paid to the customer or not.

If we need to recall a product, it is very important to identify the defective units and link this identification with the manufacturing documentation. This type of detection is called tracking. The traceability of a product can have a decisive impact on identifying the number of units that need to be recalled. For some products, the expiration date is also important.

### Representation

Part of the product liability prevention plan includes details of the raw materials, pieces, and suppliers. Therefore, the same assessment elements and safety criteria (used for the buyer (manufacturer)) apply to the supplier. For this purpose, the supplier company is visited and the product liability prevention plan is audited. The supplier is also obliged to visit the "buyer company" to evaluate any safety issues of raw materials and pieces. The results of this communications are eventually recorded in written (documented).

### Risk criteria

If an organization produces a wide variety of products, there is often a risk of product liability losses. Some products are inherently more risky than others and thus products are evaluated based on specific and unique measures of risk. The degree of control and prevention is determined by the degree of potential loss due to product liability. This method enables the organization to do its utmost to calculate and protect the number of critical products that are most at risk.

### Standards

All companies must have employees develop design and construction standards. Because manufacturers suffer the most from hard and unrealistic standards, employees must work in professional groups to improve the standards. Also, the legal staff of the organization (lawyers) should actively participate in the evaluation of product liability law.

### Audit

Periodic audits of the prevention plan are necessary to determine whether its performance is satisfactory. Periodic audits are used to measure the progress and improvement of the prevention plan. These audits are planned and carried out by internal employees of the organization in consultation with knowledgeable external experts. The results of these audits are published in the form of an internal memo.

### Customer service

Customer service can have a huge impact on the effectiveness of prevention plans. Customer service is front-facing and should report its observations on how the product is being used or misused. Also, if repairs are part of the work plan of this activity, they should be done according to the same requirements as the original product.

### Compensation

Usually, if compensation is involved, the customer will accept product errors and mistakes. The compensation plan should include the following:

- A guarantee policy that meets the customer’s needs.
- Availability of information about the steps for claiming compensation.
- Immediate handling of complaints and returned products, etc.
- Repair facilities offering rapid, skillful, and reasonably priced services.

Given that resources are limited, in many cases, a complete and flawless product is an unattainable objective. Although product safety is one of the main issues for insurance companies, few people consider it the most important feature of a product. As the saying goes “prevention is better than cure”, therefore, by implementing an effective prevention plan, the risk of significant litigation can be reduced.

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# CHAPTER EIGHTEEN

# CHARTS AND DOCUMENTATION[56]

## PARETO CHART

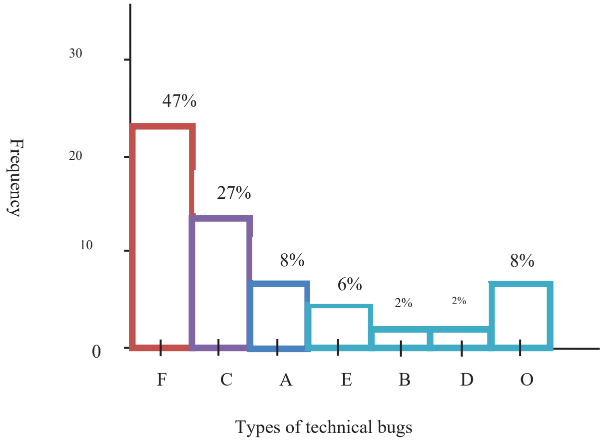
Alfredo Pareto conducted extensive study into the distribution of wealth in Europe. He found that a small group of people had a lot of wealth, while a large group of people had little wealth. Shortly after, this uneven distribution of wealth became conceptually inseparable from economic theory. Dr. Joseph Juran accepted this concept as a general law that could be generalized in many ways and coined the terms *the vital few* and *the useful many*.

A Pareto chart is a graph chart that arranges data categories in descending order from left to right. The vital few items are on the left and the useful many items are on the right. *Sometimes it is necessary to group some of the useful many items and display them under "others" as shown in the figure by an O.* The vertical axis of the chart is graded based on the currency or frequency unit and the percentage of each category is written in the corresponding column.

**Note:**
It is easy to distinguish a Pareto chart from a bar chart because the horizontal grading of the *Pareto chart* is based on *categories*, while the horizontal grading of the *bar chart* is *numerical*.

A Pareto chart is used to identify the most important problems. Usually, 80 % of the results are obtained from 20 % of items. This is visible in the following figure, where F and C account for approximately 80 % of the results.

[56] In this section, Six Sigma and QFD references are used.




Of course, the most important items can be identified by listing them in descending order, but a visual chart has the advantage of creating an immediate visual impact, as well as highlighting the "vital but few" items that need attention. In this way, resources can be directed towards corrective actions.

Examples of "vital but few" items include:

- A small number of suppliers is responsible for most of the returned products.
- A small number of problems has caused most of the process idle time.
- A small number of processes has caused most of the waste and rework costs.

The method for using a Pareto chart is very simple. Only five steps need to be taken:

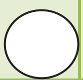
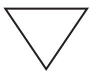
1. Specify the basis of data classification: problems, causes, and non-compliance cases, etc.
2. Specify the basis for grading the chart: currency or frequency unit (it is better to use a currency unit).
3. Collect data with an appropriate time interval.
4. Categorize the data, sorting the categories from highest to lowest.
5. Draw a chart and find the "vital but few" items.

The return on investment obtained from improving the quality in the "vital but few" is far greater than the return on investment from improving the quality of the "useful but many."

Experience has also shown that improvement is easier for "vital but few" items. Using a Pareto chart is an ongoing process—it offers a powerful tool for quality improvement and can be used to identify problems and evaluate progress.

### Flow Process Chart

Drawing a flow process chart can be useful for many products and services. This chart depicts the process of movement of a product or service (as it goes through all the various steps and operations). As a result, it is possible to observe the whole system, identify potential points of problem creation, and locate control activities. A chart concerning the question "who is the next customer?", gives the answer. Therefore, improvement can be achieved by reducing, combining, or eliminating some steps.

| Row | Symbol | Concept | Descriptions |
|---|---|---|---|
| 1 |  | Operation | Any conscious change in one or more specification of an object |
| 2 |  | Transportation | Moving products and raw materials or any of the manufactured parts to continue manufacture or storage |
| 3 |  | Inspection | All processes of product adaptation to predefined specifications |
| 4 |  | Storage | Any storage or warehousing of raw materials, finished products, and semi-finished products that have a storage basis |
| 5 |  | Delay | Part of the execution process that devotes time (inevitably or avoidably) to this in the manufacturing process |

## Cause and Effect Chart

A cause and effect chart is a figure that shows significant relationships between effects and causes. This chart was invented in 1943 by Dr. Caro Ishikawa and is therefore known as the Ishikawa chart. It is also called the *fishbone chart* because of its appearance.

A cause and effect chart is used to study "a bad effect," so as to correct its causes, and "a good effect," so as to identify its causes. There may be several causes for each effect. The effect is on the right side and the causes are on the left side. The effect can refer to a qualitative specification that needs to be improved. Causes are sometimes divided into root causes, such as working methods, materials, measurements, individuals, equipment, and environment.

Each major cause is divided into a large number of sub-causes. For example, factors such as education, knowledge, ability, and physical specifications, etc., can be included in the working methods subgroup. A cause-and-effect chart is a tool for showing these causes, both large and small.

The first step of the project team in drawing a cause-and-effect chart is to identify the "effect" and the "quality problem". The group leader writes the *effect* on the right side of a large paper and then the *main identified causes* are written on the chart.

Identifying all sub-causes requires brainstorming to be performed by the project team; this uses the creative thinking capacity of the group.

Once the chart is complete, it should be evaluated to find the most likely causes. This should be done in a separate meeting. In the work procedure, each person is asked to vote on the most likely sub-causes. Group members may vote for more than one reason. A circle is drawn around the causes that receive the most votes and four or five very probable causes are identified.

After determining the probable causes, solutions are developed to correct and improve the process. The judgment criteria for possible solutions include: cost, feasibility, resistance versus change, consequences, training, and so on. Once the group has agreed on solutions, the test and implementation step is reached.

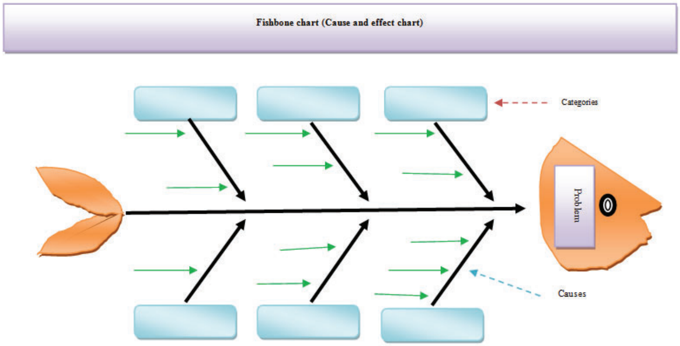
Finally, charts are posted in key locations of the company to encourage employees to refer to them when similar/new problems arise. Once the solutions are found and improvements are made, the graphs are reviewed.

Cause and effect charts have unlimited uses. In particular, one of their greatest benefits is the participation and assistance of all those who have contributed to the brainstorming process. In general, these charts are useful for the following:

- Condition analysis for improving the quality of a product or service, effective use of resources, and reducing costs.
- Elimination of conditions that result in non-compliance and customer complaints.
- Standardization of existing and proposed operations.
- Training and education of employees in decision-making and corrective action.

To achieve more accurate and usable results from brainstorming meetings, we should pay attention to several key principles:

1) If each person presents one idea at a time, the participation of all group members will become easier. If one person does not have an idea, he/she gives their turn to the next person. By following this method, one or two people do not dominate the brainstorming session.
2) Quantity is superior to quality. One person's idea may spark another's mind, like a chain reaction. Sometimes trivial ideas, or even foolish ones, finally lead to the best solutions.
3) Criticism or negative judgment of the ideas is not allowed as the exchange of ideas must take place in a carefree atmosphere to free the imagination. All ideas are written on the chart to be evaluated in the future.
4) Chart visibility is an important factor for participation in manufacturing. A large sheet of paper is recommended so that there is enough space to write all the sub-causes. This paper should be mounted on the wall so that everyone can see it easily.
5) A solution-oriented atmosphere should be created, rather than one filled with grievances and complaints. The focus should be on solving a problem, not on discussing where and how the problem started. To achieve this objective, the group leader must ask questions about why, how, what, where, when, and who.
6) Ideas should be allowed to develop in the minds of the group members over some time (at least one night) before holding another brainstorming meeting. After the first meeting, a copy of the ideas should be given to all members of the group. Once no more ideas are generated, the brainstorming process ends.




### The Voice of the Customer Table (VOCT)

The "voice of the customer table" (VOCT) is a tool that company experts use to translate the raw wants of customers into technical language. The content of the table (customer wants) is collected by going to the actual place of consumption of the product and gaining insight through interviews, questionnaires, and observation (of how the product is used by customers). The components of this table are as follows:

**1- Customer information:** in this section, the specifications of the people who use the product, such as gender, education, age, and specialization, are stated.

**2- Customer calls:** what the customer wants/expects from the product.

**3- What:** the purpose of purchase being the primary application and secondary application of the product according to the customer's wishes.

**4- When:** the time and frequency of product use by customers (in line with their expectations).

**5- Where:** geographical location, operating conditions, and environmental conditions of product use by customers.

**6- Why:** special specifications, safety concepts, and general requirements of the product and, in general, the reasons for the customer's expectations.

**7- How:** such as operating methods, industrial uses, and consumer uses of the product.

The main purpose of this table is to reduce the gap between customer expectations and the designer and manufacturer perceptions of the product. If the product is not welcomed by its target market, there is a gap between the thinking of the company's experts and the needs of customers, even if the product may have all the technical and quality specifications desired by the experts. To better organize and classify customer demands, dependence between factors and tree charts should be used.

**Table of customer's voice**

| row | who | VOC | what | when | where | why | How | Review of customer requests |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

## Factor Dependency Chart

This chart is a tool for gathering a lot of information. Once collected, the data is organized based on group interactions. A factor dependency chart should be used in the following cases:

- Opinions and ideas are so widespread and scattered that it is not possible to organize them.
- New methods and solutions are needed to overcome traditional methods of problem-solving.
- In support of a specific solution that is critical to the successful implementation of the system.

This method should not be used when the problem is very simple or requires a quick solution. The team that intends to perform QFD successfully must be composed of members with different specialties so as to investigate the issue from different dimensions. A team of 6 to 8 members is suitable for adapting different opinions and ideas. To prepare a factor dependency chart, the following four simple steps must be performed:

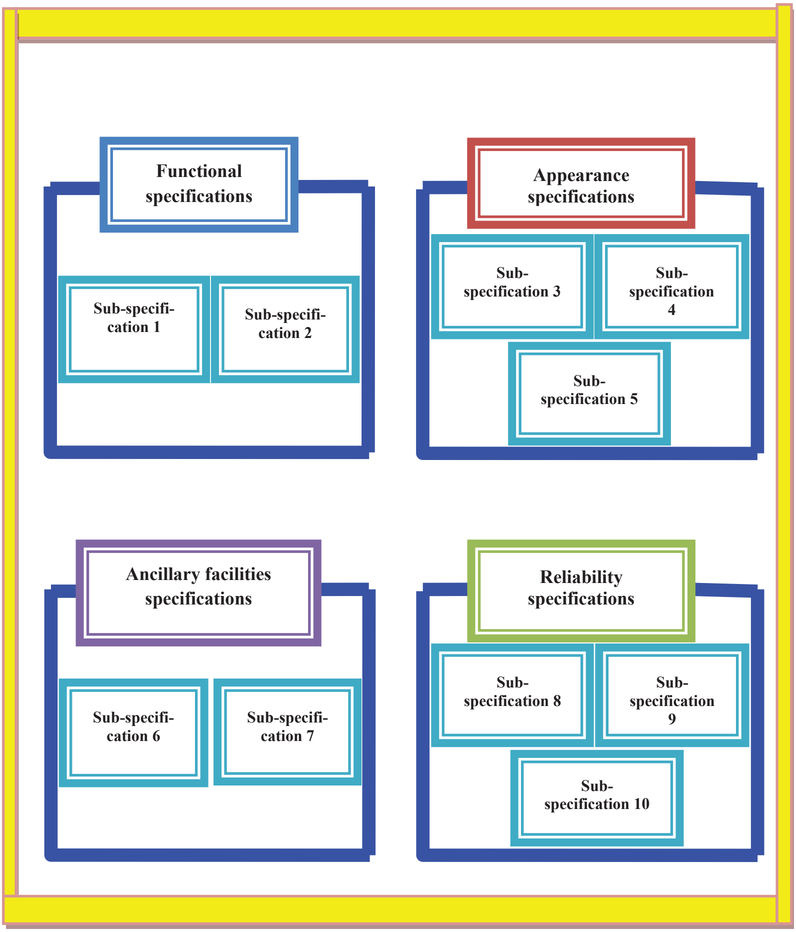
1. Definition and expression of purpose.
2. Recording of all answers and suggestions.
3. Grouping of all the answers.
4. Organizing groups into a factor dependency chart.

In the first step, the objective should be stated very briefly and as generally as possible.

In the second step, a brainstorming meeting should be arranged and all the answers presented in this meeting should be written on a piece of paper by those present and recorded in the meeting documentation. These should then be written on the backs of cards, the value of which will be determined after that end of the meeting and when the answers are needed.

Next, all the cards should be classified by placing similar and related cards into groups. Then, one of the cards or the word (that represents the group) is selected as the lead card of that group.

In the last step, lines are drawn around each of the groups and the related groups and categories (placed close to each other) are connected by lines.



### Tree chart

Tree charts help break large groups up into smaller parts and move from generalities to details. In a tree chart, the general and large components are shown to branch out and are divide into smaller components. These charts are used:

1- When an issue is identified in a large range and it is necessary to specify smaller details; by moving towards the details, the desired goal is achieved.

2- When improving actions to achieve a solution or practical plan.

3- When analyzing processes in detail.

4- When searching for the root of a problem.

5- When evaluating the executive cases for several potential solutions.

6- When a dependence between factors chart does not cover key issues.

7- As a communication tool to explain details to others.

What are the steps needed to implement this method?

A) Write a statement of purpose, issue, plan, or whatever is to be studied as a starting point.

B) Form sub-branches by posing and then answering questions that lead to the next level, such as "what needs to be done to achieve this objective?"; "why did this problem occur?"; "what is causing this problem?"; or "what are the components of this case?" According to the nature of the tree chart and its purpose, one of the questions asked must be answered.

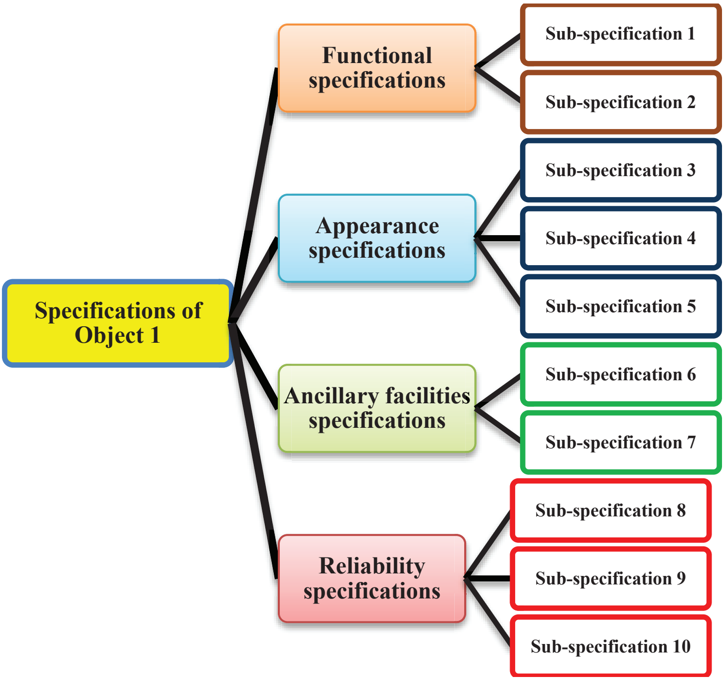
C) In this step, a necessary and sufficiently detailed review must be performed. Two questions need to be answered for this level of the chart:

1- Are all the issues in the sub-category necessary to go to a higher level?

2- Are the "highlights" sufficient to go to a higher level?

D) Perform steps "b" and "c" for the lower levels and continue to do so.

E) Continue the chart until the root of the problem is reached, the essential components are reached, the chart leads to the basic components, or the desired practical actions are reached.




## Kano Model

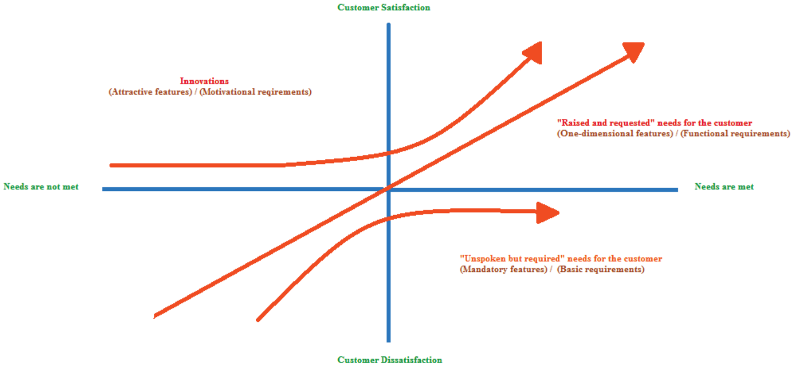
In the late 1970s, Professor Noriaki Kano and several Japanese colleagues developed the Kano model to define the quality of service in terms of client needs and to introduce "non-linear and two-dimensional quality." Adapting service quality and customer satisfaction parameters onto a two-dimensional axis makes the definition of quality more complex. Kano and his colleagues, therefore, identified three types of conditions for service that, when met, affect client satisfaction in different ways. These conditions include "mandatory features," "one-dimensional features," and "attractive features."

**Mandatory features** are features that are necessary, but on their own are not a sufficient condition for customer satisfaction. A mandatory requirement is one of the main and obvious features of the product; if the product or service does not have this feature, the client will be dissatisfied. The existence of this feature is **mandatory for a product from the customer's point of view, but its existence does not result in HAPPINESS.**

**One-dimensional features** result in customer satisfaction when they exist and, if not, they cause dissatisfaction. Therefore, we can say **if the quality of service is higher, client satisfaction will further increase; and vice versa**.

**Attractive features are traits that satisfy the client if they exist and if they do not exist, the client is not satisfied.** Attractive features have the greatest impact on the level of customer satisfaction.

Kano analysis is a measurement tool for prioritizing customer wants based on their impact on customer satisfaction and happiness. Kano analysis helps determine which requirements have the highest priority for the client. The Kano model promotes an understanding of product or service requirements. Furthermore, features that have a greater impact on client satisfaction can be identified. The Kano model provides useful guidance, especially when comparisons are needed. It can also help to differentiate a product or service by recognizing attractive features, which are key to succeeding in a competitive environment. Other advantages of the Kano model are that it requires minimal mathematical calculation and the relevant information is collected quickly.




The vertical axis shows the degree of satisfaction or happiness of the customer, while the horizontal axis shows the delivery rate of the desired quality requirements to the customer. The highest and lowest points of the vertical axis of the chart indicate the maximum and minimum customer dissatisfaction, respectively. The intersection of the horizontal and vertical axis indicates the place where customer wants are in equilibrium in terms of satisfaction and dissatisfaction. The right side of the horizontal axis indicates where the expected quality requirements have been fully delivered, while the left side of the horizontal axis shows the delivery point of a product or service that does not have the expected quality specifications and desired quality requirements.

Some notable points of the Kano model are:

- Customer satisfaction has the greatest relevance and dependence on this model.
- This model has the largest share in the market research budget.

- ➢ It increases and grows the wants and needs of the customer.
- ➢ A moderate level of competition between organizations.
- ➢ Success in this model depends on its correct implementation and the correct definition of indicators.

The advantages of the Kano model also include:

- ➢ Better communication with customers.
- ➢ Understanding customers and their needs.
- ➢ The final satisfaction of customers.

The limitations of the Kano model are as follows:

- ➢ Expressing needs without thinking.
- ➢ Troubleshooting and suspicion.
- ➢ Not considered important (not serious).

Two important points about the Kano model are:

- o The classification of features and specifications of products and services into three groups of needs is not permanent, as expectations and needs change over time. At first, a feature may be in the attractive quality group, but after a while this feature comes to be classified as a one-dimension quality and then, over time, becomes a mandatory quality and customers no longer ask for it. For example, in the past, having a radio in a car was an attractive quality. Radio broadcasting is currently in the one-dimension quality group and its absence in a car is a negative point. The important point here is that companies need to constantly innovate to create attractive qualities.
- o The forgotten issue in the Kano model is the relationship between these three types of qualities. What we learn from the Kano model is that qualities operate independently of each other. *However, this is not the case.* For example, if a product or service has an attractive quality, but lacks the one-dimension quality or mandatory quality, the effect of the attractive quality will not be in accordance with the model.

### Documentation

The documentation process descends from one level to another. If the system is properly combined, a change at one level rarely affects the levels above it; however, it may affect the lower levels.

### Policy

The first row of documentation concerns policy regulations and shows what should be done and why it should be done. The "why" can be determined only once as a qualitative policy statement. This statement should offer a simple and concise definition of the quality objectives of the organization. A quality policy regulations should be written in a way that is clear, concise, useful, practical, and easy to understand. For example:

> *Quality is the responsibility of every employee of the company. We are committed to continuously providing products and services that meet or exceed customer wants.*

The remainder of the policy regulation document indicates what work needs to be done to comply with the standard. The policy regulation can also be considered a basic provision of the system. Therefore, each standard element should be displayed separately on its own page.

#### Procedure

**Qualitative procedures** are found in the second row of the documentation. These procedures describe the methods used to implement and enforce the defined policies. The procedures clarify who should do each task, when these tasks should be performed, and where these tasks should be documented. These procedures must be such that they can be implemented in all parts of the organization. They can include strategies that are used to ensure the quality of the system. Procedures are much more detailed than policies, but should also be clearly and easily understood. Also, documentation of procedures is not required for all elements.

#### Work instructions

Work instructions are usually specific to a department, machine, task, or product, and explain how a task should be done. These instructions constitute the most detailed part of the documentation hierarchy. A work instruction may be in the form of a drawn plan, a prescription (instruction, on how to do a particular task), or simply a pattern for measuring compliance.[57] It is best to write a work instruction in consultation with the employee doing the job because this person will know the process and its problems well. Sometimes a documentation specialist may be needed to write instructions. It is also the case that including employees in writing the documentation gives them a sense of ownership and, as a result, it is likely that employees will take the initiative in suggesting future improvements.

#### Records

Records provide a documented path that has been followed for policies, procedures, and work instructions. Records may include a completed form, a seal of verification on a product, or a signature and date on some other documents. Records are used to track actions (performed on

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[57] For example, "turn the nut four turns clockwise."

a specific product or product category) and this data can be used to correct or replace a product if necessary.

# CHAPTER NINETEEN

# STRATEGY AND STRATEGIC MANAGEMENT

The vast majority of organizations believe that strategic quality planning is part of a company's work plans and cannot be separated from them in any way. Time horizons (for achieving anticipated strategic planning objectives) are usually between 3 and 10 years. Even short-term plans will need at least 1 year.

In both short and long-term plans, the first and most important step is to determine the aspirations and objectives that we plan to achieve.

## Aspirations and objectives

An aspiration concerns long-term decisions and objectives, along with short-term and cross-cutting decisions and objectives. Aspirations have their specifications and are very effective and efficient due to these specifications. The most important point in defining an aspiration is that it is "measurable." Aspirations must be based on statistical evidence; without statistical knowledge of the whole system, aspirations are merely reflections of our imagination, based on miraculous system changes in the form of fruitless slogans, encouragement, and hard work. Empty slogans are a product of imagination that is never realized. Aspirations must be perfectly definable, clear, and understandable. There must also be a specific time limit for completing the work and achieving the objective. Aspirations need to be defined in terms of the ways to achieve them. The necessary resources must also be precisely identified. If a proper cause-and-effect relationship is not found between the aspiration and the method chosen to achieve it, then, using this method, it will not be worth the investment.

Since the intention is progress and promotion, it is natural that aspirations require effort to be fulfilled; but they should not be so far from reality that achieving them is futile. All individuals, working groups, and departments of an organization that are somehow dealing with and influenced by the specified aspiration must be kept up to date and involved.

Objectives are the steps taken to achieve aspirations and all of the above are their specifications. Once these short-term objectives are met, long-term objectives will gradually be achieved.

### Seven steps in strategic planning

The whole process begins on the basis that quality and customer satisfaction is the focus in all planning and the future direction of the organization—something that guarantees the existence and survival of the whole organization.

### Step 1: Customer Needs

The first step is to discover the future needs and wants of customers. What will they be in the future? Will items that seem important to them now change? What will their future wants be? How has the organization responded to these wants and will the organization try to satisfy them?

### Step 2: The position and importance of customers in the organization's viewpoint

In the next step, the organization makes a decision about the importance of customers to the organization. In this way, we assess whether the position of customers in the organization's viewpoint will remain the same as in the past, be reduced or, conversely, become more important? Based on this decision, the organization will determine whether to improve or eliminate low-quality products.

### Step 3: Predict the future

In the next step, planners must anticipate the conditions that will emerge in the future and affect the organization's products. Statistical images, charts, economic forecasts, technical assessments, and other specialized planning techniques are all tools for better and more accurate prediction of the future. Many products of well-known organizations have become obsolete and useless because of this lack of attention to the future and changing technology. We should note that the rate of change increases day by day and new advances, technologies, and knowledge are constantly developing.

### Step 4: Analyze the gaps

In this step, the organization needs experts and planners who can discover the gaps and differences that exist between the current situation and the predicted situation in the future and determine the necessary operations to eliminate them. A quick look at all values will be a good way to discover the problems and differences between the present and the future.

### Step 5: Eliminate gaps

Here, the organization gets ready to implement its plans. Short-term objectives and responsibilities must be identified and all facilities used to achieve them.

### Step 6: Coordination

When implementing plans to align with predicted future change, the organization's management should not lose sight of its core values, the mission, and the operations required to achieve this insight. Otherwise, by moving in the wrong direction, we may forget the general process and the basic objectives of the organization and eventually move away from its primary destination, which is customer and employee satisfaction.

### Step 7: Implement

This step is usually the most difficult one. All available resources should be assigned to different groups. Daily information-gathering operations, design changes, and resistance to any changes in the organization should be assessed and resolved in the best possible way. The planning team should also be constantly informed about the progress of the work, providing necessary corrections and suggestions to the implementing groups.

Finally, it should be noted that strategic planning is important in any organization. If an appropriate plan is established, the organization becomes an entity that always does the right work at the most appropriate time, which is the ideal for any organization.

## Strategic thinking

Strategic thinking is not a choice, but a necessity to ensure the survival and success of a company. Global competition, continuous technological change, and rapid and varied evolutions in work culture are just a few of the factors that create a dynamic market.

Strategic management results in a plan to guide the company so that it can implement its insights, missions, objectives, and aspirations and not deviate from its wants. In other words, strategic management provides a plan to align *the strengths and weaknesses of the organization with the opportunities and threats of the environment*.

Every company needs strategic planning to develop a continuous, ongoing, and growing work plan. Therefore, strategic planning should not be considered a disposable tool that will be abandoned in the future. Successful strategic planning is under constant review. The strategy is a dynamic process and the plan must be designed and actively revised to respond to market pressures and shocks.

There is no substitute for planning and many empirical studies have shown that strategic planning is an influential factor in the survival of small businesses. Successful and small businesses provide evidence of the need for pre-designed planning with consideration of chain activity analysis; as such, a lack of systematic planning and decision making is one of the main reasons for the failure of many companies.

Developing strategic planning is critical to creating a competitive edge for a company. This **competitive edge**[58] is made up of a set of factors that differentiate a company from its competitors. The company must create a plan to generate a unique image of itself in the minds of potential customers. As such, before undertaking a new job, the entrepreneurial manager must ask questions that require strategic thinking. The planning process forces managers to assess the realities of our competitive world. Designing a strategic plan also prevents the company from falling into the trap of not distinguishing itself from its competitors, which is a very common mistake.

### Ten Steps to Success in Strategic planning

All successful entrepreneurs display one characteristic: they have an idea for a product or service that is useful to society and has the potential to be very profitable. Although good luck plays an important role in jobs, "small ideas" never come to fruition without strategic planning. As such, strategic planning is a pervasive process designed to help companies stay ahead and prepare for the future. Strategic management places particular emphasis on the customer. The strategic planning process consists of 10 steps:

#### The first step

Define a clear insight for your organization and express it in a meaningful phrase that reflects the company's mission statement. Big business leaders need to have a broad range of insights, but whatever the insight is, the goal is the same: to focus the attention of everyone in the organization on one objective. A company's insight communicates with everyone involved—inventors, employees, investors, customers, and society more generally. Here, "insight" refers to an idea or phrase that management is interested in, supports, and believes in. Very successful managers can communicate their insights and are open to the insights of those around them very well. The best way to do this is to write a statement that briefly defines the company's mission. The mission statement answers the initial question "what job am I in?" and should

[58] Competitive advantage.

determine the direction of the company more than anything else. Without a mission statement, the company will wander aimlessly around its target market, without knowing where to go or how to get there. This sentence is the starting point for job design, building a company structure, and competitive strategic design.

A good sentence should not be lengthy, but should still offer answers to some key questions:

- What are the main values and ideas of the organization?
- What are the main services and products of the company?
- Who are the company's customers and what are their characteristics?
- What are the needs and wants of customers when purchasing from us?
- How can we meet these needs and wants?
- What are the values of our customers and how can we better incorporate their desired values into our products?
- In which markets and in which segments of these markets will we compete?
- Will these markets evolve in the coming years? How?
- What are our core competencies and competitive advantages?
- What are our primary weaknesses?
- What foreign opportunities and threats do we face or will we face?
- Who are the shareholders and what impact do they have on the future of the company?
- What is our desired public perception?

### Step 2

Identify the driving force of the company and determine its market position. No employee can be good at everything and those who try often achieve less than they should. Successful new and established workers gain a special identity in the market (by identifying and developing a set of specific driving forces).

The driving force is defined by what the company does best and is the most important point of the company's strategy. New workers typically rely on one of the following driving forces:

**1- Knowledge:** some entrepreneurs base their work on the extensive knowledge they have gained (they have a specialist subject).

**2. Unique products and services:** some companies focus on the products and services they sell.

**3- Providing services to a particular market:** some companies keep their market position by meeting the needs of a certain segment of customers.

When these driving factors come together, the new worker can take his first step. Workers must be highly focused and ensure that they can create a competitive advantage by outperforming competitors in the market by meeting the specific needs of customers.

### Step 3

Evaluate the strengths and weaknesses of the company. After identifying the driving forces and the desired position of the company in the market, management should focus its efforts on assessing the strengths and weaknesses of the company. To create a successful strategy, the company needs to increase its strengths and cover or compensate for its weaknesses.

**Strengths** are positive internal factors that help achieve the objectives of the company. **Weaknesses** are negative internal factors that prevent the full realization of the company's objectives. Identifying strengths and weaknesses helps management identify the business as it currently is and how it will be in the future.

An effective way to achieve strategic insight is to prepare a balance sheet of the company's strengths and weaknesses. The positive side of the balance sheet should reflect the significant skills, resources, and knowledge that will help the company succeed. The negative part is used to record any restrictions that realistically reduce the company's competitiveness. This balance sheet should analyze all key areas of work. These areas include staff, assets, manufacturing, marketing, development, organization, and so on. The analysis should also provide a realistic picture of the company's management approach and structure so that it can be strengthened and obstacles to the company's further development can be removed.

### Step 4

Investigate the environment to discover opportunities and threats that the worker will face. When drawing up a list of the company's weaknesses, we must pay attention to the external environment of the company and identify opportunities and threats that may have significant impacts. **Opportunities** are positive external factors that can be used to achieve long-term objectives. When identifying relevant situations, great attention should be paid to potential markets and customer tastes. The number of potential opportunities is unlimited and, therefore, managers should analyze only those that are most important (i.e. two or three cases).

**Threats** are negative external factors that reduce a company's ability to achieve its objectives. Threats can take various forms, such as the entry of a new competitor into the market, government decrees to coordinate business activities, technological advances making the company's products obsolete, economic recession, rising interest rates, and so on. Managers must prepare appropriate plans to protect the company from such threats.

### Step 5

Identify the key factors for business success. Every business is characterized by a set of controllable variables that can determine the relative success of each company in the market. Managers can ensure a competitive advantage by identifying key success factors and applying them.

Success factors follow diverse patterns depending on the specified industry. Many of these competitive advantages, such as manufacture and distribution costs per unit, are cost-based. Other factors include product design, product quality, specific services provided by the company, the company's location, or its reputation for ethical and humanitarian work.

### Step 6

Analyze the competition. The primary objectives of this step are:

- Prevent confusion about competitors' actions and reduce reaction times in responding to competitors' strategies and tactics.
- Identify threats posed by competitors.
- Improve planning skills by anticipating competitors' actions.
- A better understanding of market performance and looking at the market from the competitor's angle.

Unfortunately, many companies refuse to gather information on their competition because they think it is too expensive. However, gathering information about one's competitors can be cheap, of course, if its principles are observed.

Assessments of competitiveness provide realistic views of the market and your company's position in it: who are your main competitors? What important areas have they developed? What is their cost structure compared to your company? Will new competitors enter the field? Can you identify the key strategies of your main competitors? What are the strengths and weaknesses of your competitors? How do customers evaluate companies in the market and what do they think? Finally, how do customers evaluate their products, services, workmanship, and additional services?

**Step 7**

Define the objectives and aspirations of the company. Managers must define the objectives and aspirations before determining the company's strategy.

Defining the objectives and aspirations is one of the most important parts of strategic management. Aspirations are big and broad objectives that the company seeks to achieve; it is better to be general and keep it brief. Aspirations should not be precisely defined, but rather, they should specify how to do work in general. For example, you could ask whether you wish to increase your market share? Does your liquidity balance need to be strengthened? Do you wish to enter a new market or are you looking to increase sales in the current market? And how much return on investment are you looking for? Defining these aspirations paves the way for the next step in which we identify the specific and realistic objectives.

Objectives are founded on specific executive desires. Common objectives include: profitability, manufacturing power, growth, efficiency, market share, financial resources, physical facilities, organizational structure, employee welfare, and social responsibility. Because some of these objectives may be in conflict with each other, the manager must also determine priorities—it must be decided which objectives are more important and which objectives are less important. Arranging objectives according to their priority helps managers resolve contradictions when they occur.

A good objective has the following specifications:

**Accurate and specific:** objectives must be precise and clear. For example, achieving good growth in sales is not a meaningful objective, while aiming for an increase in retail sales by 12 % and an increase in wholesale sales by 10 % over the next fiscal year is accurate and clearly represents what management is trying to achieve.

**Measurable:** managers must be able to plan the organization's progress towards the objectives. This requires a defined starting point from which to begin and a scale on which to measure progress.

**Available:** objectives must be "available" to motivate managers and employees, otherwise, they may consider the work they are doing to be useless and not try very hard. Of course, this does *not mean* that objectives should be *simply* available.

**Realistic and difficult:** under any circumstances, the manager's expectations should be high. In other words, if the objectives are reasonably difficult, while also still being realistic, the quality of work will be higher. As such, you should select objectives that challenge your work and your employees.

**Scheduled:** objectives should not only specify what should be achieved, but also when we should achieve it.

**Written:** the written objectives should not be over-complicated. The manager should consider a relatively small number of objectives, for example, between 5 and 15.

### Step 8:

List the strategic choices and choose the most appropriate one. By this point, managers need to have a clear picture of what they can do best, as well as their competitive advantages. In the same way, they should know the weaknesses and limitations of the *company*, as well as the weaknesses and limitations of its *competitors*. The next step is to evaluate strategic choices and then develop a work plan to achieve the objectives.

*The strategy is laid out in the company activity map. Managers draw this map to implement the company's missions, aspirations, and objectives. In other words, missions, aspirations, and objectives are the ultimate destination and the strategy shows us the means and tools to reach these destinations. The strategy is a basic plan that includes all the main parts of the organization and connects them as an integrated set.*

A successful and integrated strategy focuses on creating the key success factors that managers have achieved in the fifth step. For example, if the key success factor for a small manufacturer is maximizing the space and beauty of the showcase, the strategy should suggest ways to achieve this objective. For example, paying more profit to distributors and intermediaries (more than competitors) or designing better and more attractive packaging.

### Step 9:

Convert strategic plans into work plans. No strategic plan is complete until it is implemented in practice. Managers need to convert strategic plans into operational plans that lead the company's day-to-day operations and are the active and obvious part of the work. To implement the plan, company managers must divide the work up into projects, each of which has been carefully defined, and taking into account the following factors:

**Objective:** what is the purpose of the project design?

**Scope:** which parts of the company are involved in this project?

**Relationship:** what is the relationship between the specified project, other projects, and even the strategic plan itself?

**Resources:** how many workers and assets are needed for the successful implementation of the project?

**Scheduling:** what are the schedules and deadlines necessary to complete the project?

After determining the projects priorities, the implementation of the strategic plan can be started. It is necessary to use employees and delegate authority to them because their work will be affected by these projects and their willing participation contributes greatly to their success.

**Step 10:**

Performing precise control up to this step in the planning process identifies the company's objectives and the appropriate strategy to achieve them, but the actual performance of the company rarely corresponds to the planned objectives. Therefore, senior managers often feel a strong need to control the results that have deviated from the plan.

Uncontrolled planning has little operational value. As a result, the planning process also requires control steps. The plans created during these steps become standards for measuring the actual activity of the company. Everyone in the organization must understand and participate in the planning and control process.

Managers identify and track key performance indicators to control and execute projects on schedule. The source of these indicators is the operational information of the normal activity of the company. These indicators are the guiding points for detecting deviations from the specified standards. Accounting, manufacturing, sales, inventory, and other operating documents are the first sources of information that managers use to control activities. For example, in a project, key measures for after-sales service can include customer complaints, returned orders, on-time delivery, and so on.

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# CHAPTER TWENTY

# THE BALANCED SCORECARD METHOD (BSC)

## INTRODUCTION

Today, the senior managers of many companies and organizations expend significant time, energy, and resources on determining and adjusting the basic strategies of their organizations; however, many of them talk about the lack of proper implementation of their strategies. The vision that these managers have for their organizations often appears quite clear to them, but their employees' awareness and understanding of this insight is very low. As such, employee alignment and empathy for achieving the objectives of a strategic vision is very limited. Senior managers are always looking for solutions to ensure the proper implementation of their strategies. In the meantime, they often use performance evaluation methods as tools to control their implementation, but the characteristics of the modern knowledge and information economy have seriously challenged the effectiveness of traditional performance evaluation methods, which seemed appropriate for organizations in the industrial age.

In response to these circumstances, the balanced scorecard approach was introduced as a new method of performance evaluation.[59] This method was then developed as a tool to help strategic realization, as a system for managing strategy. This method has been highly complimented by management experts and managers of organizations.

### 2-1 History

In the late 1980s, several articles were published in European and American management journals about the inefficiency of company performance evaluation methods. In 1987, a survey by the National Association of Accountants (NAA) and the CAM-I[60] Institute found that

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[59] By Robert Kaplan (Harvard University Professor) and David Norton (outstanding Management Consultant in the United States).

[60] Consortium for Advanced Management International (CAM-I).

"60 percent of the 260 CFOs[61] and 64 CEOs[62] of American companies" were dissatisfied with "their companies' performance evaluation system." Traditional systems of performance evaluation relied mainly on financial measures, and the company's finance department was responsible for conducting these evaluations. In the age of industrial economics, financial *measures* were good *indicators*[63] of company success because the competitive advantages of that age were mainly based on cost reductions from the development of economies of scale[64] and mass manufacturing. As economic relations and business issues became more complex towards the beginning of the 21st century, company reliance on financial measures (to assess performance and demonstrate strengths and weaknesses) decreased and the inadequacy of simple financial measurements became more pronounced:

- In the age of the knowledge-based economy, the value-added activities of organizations do not rely solely on tangible assets. Today, organizational assets, such as employee knowledge and ability, customer and supplier relationships, product and service quality, information technology, and organizational culture, are far more valuable than physical assets. Also, the ability of organizations to use these intangible assets is the main factor in creating value. Comparisons based on financial measures cannot assess these intangible assets and do not reflect their impact on an organization's success.
- Financial measures in areas that can be assessed represent historical and past events—they provide a summary of the organization's activities in previous financial periods. Financial statements and the numbers contained within them show the past performance of the company. However, we know that good performance results (at monthly, six monthly, or even annual intervals) are not the reason for continued success in the future.
- Performance evaluations based on financial measures alone have given too much weight to the analysis of short-term profit and loss and thus emphasize factors affecting short-term profit and loss. In this regard, all measures related to reducing costs and increasing

[61] Chief financial officer.
[62] Chief executive officer.
[63] Indicators are used when there are several factors or functions for evaluation. They are ***indicators*** as long as they are not monitored and evaluated; if they are tested, they can be called ***measures***.
[64] This means that as the volume of manufacturing increases, the average cost of manufacturing per unit decreases.

revenues are evaluated positively. While many of these cost reductions, such as reducing employee training and stopping research and development activities, may increase short-term company profits, they may also reduce the company's competitive edge and jeopardize its long-term profits. However, increasing some revenue items may lead to a drop in customer loyalty in the long-term.

- Financial statements, in their nature, present a summary and aggregation of an organization's operations and activities. In many cases, the extent of aggregation is such that the information contained in these reports is unusable for decision-making at certain levels of managers and employees. Employees at all levels of the organization need performance information that is relevant to their day-to-day working activities.
- Traditional financial statements, even at their most advanced level, are only able to reflect the performance of the different units and divisions of an organization.

As such, the performance of the whole organization is obtained by aggregating the performances of different parts, but these financial statements are usually unable to reflect the effects of collaboration between various functional units. Today, most of the value-creating activities of an organization are the result of cross-functional collaboration and the provision of integrated solutions to customers and stakeholders. Traditional financial evaluation systems are not able to calculate the real value or cost of these collaborations and relationships.

Traditional methods of performance evaluation, mainly based on financial measures, are not only incapable of fully reflecting the reasons for a company's success or failure, but also do not establish logical, cause-and-effect relationships between the driving factors of success and the achievements obtained. Hence, they are unable to support management plans, especially strategic plans.

In the early 1990s, Robert Kaplan[65] and David Norton[66] began a research project to investigate the reasons for success of the top 12 American companies and study performance evaluation methods in these companies.

The study was published in the Harvard Business Review entitled "Measures that Drive Performance" (January, 1992). This article stated that successful companies do not rely only on financial measures to

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[65] Professor at Harvard Business School.

[66] At the time, he was the director of a research firm affiliated with the KPMG Consulting Institute.

evaluate their performance, but also evaluate their performance in three other perspectives: customers; internal processes; and learning and growth. Thus, Kaplan and Norton stated that to make a complete evaluation of the performance of an organization, this performance must be evaluated from four perspectives.

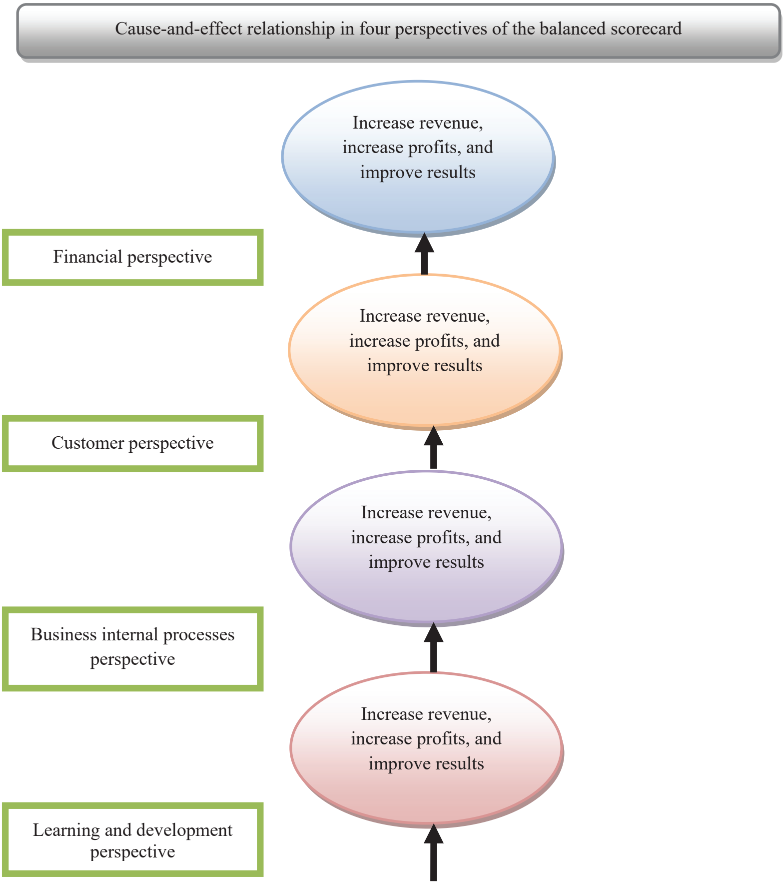
1- Financial Perspective;
2- Customer Perspective;
3- Internal Processes Perspective;
4- Learning & Growth Perspective.

Kaplan and Norton's findings confirmed the fact that successful companies determine their objectives with reference to each of these four perspectives. Measures are then selected to evaluate the success of these objectives in each perspective. Furthermore, the quantitative objectives associated with each of these measures are determined for the required assessment periods. Executive initiatives are then planned and implemented to achieve these objectives. Kaplan and Norton found a cause-and-effect relationship between the objectives and measures of these four perspectives connecting them to each other.

To succeed financially (the financial perspective), we must create value for our customers (the customer perspective) and this will not be practically achievable unless we excel in our operational processes and adapt them to the wants of our customers (internal process perspective). Achieving operational excellence and setting up value-creating processes is not possible unless we create the right work environment for employees and support innovation, creativity, learning, and growth in the organization (learning and growth perspective).

Kaplan and Norton called this performance evaluation method the balanced scorecard approach. Four years after the publication of the first article in this field, a number of organizations and companies had already implemented the balanced scorecard approach and had rapidly achieved results. These organizations not only used this method to evaluate performance, but also as a tool to control how their business strategies were implemented.

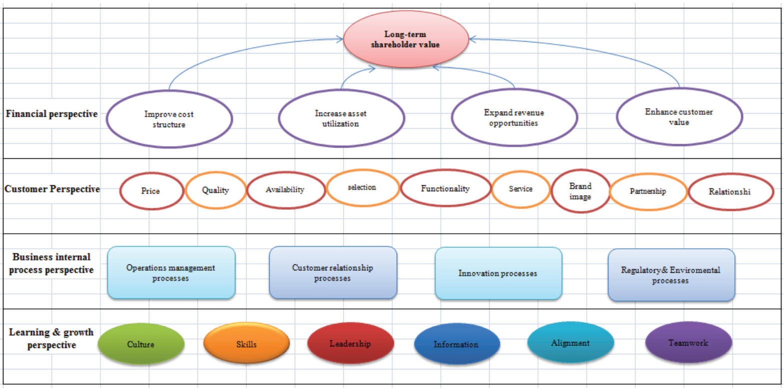
Kaplan and Norton found that these organizations used the measures of the balanced scorecard approach to communicate and transmit their strategies throughout the organization. They summarized their experiences in advising these organizations in a book entitled Balanced Scorecard, published in 1996 by the Business School of Harvard University. Thus, the balanced scorecard approach was devised not only as a powerful tool for performance evaluation, but also as a tool for strategy implementation.




### The Balanced Scorecard Approach as a Performance Evaluation System

Financial measures are good indicators for reflecting past events, but are inadequate for identifying the real value-creating factors and motivations in today's organizations (i.e. intangible assets such as the knowledge and ability of employees, communication networks, and customer relations). For this reason, financial measures are called "lag indicators" and show the results of past actions.

**The balanced scorecard approach**, while making use of these lag indicators, also takes into account indicators related to future performance motivations, i.e. "lead indicators." In the balanced scorecard approach, *lead and lag indicators* are determined based on the insight and strategy of the organization. Using this framework, the balanced scorecard approach converts the organization's insight and strategy into general objectives, related measures, quantitative objectives, and plans and initiatives to achieve them.




### Balanced Scorecard Approach Perspectives

In the model of Kaplan and Norton presented in 1996, four general perspectives for evaluating organizational performance are proposed: financial; customer; internal processes; and learning and growth. These four perspectives have so far remained consistent elements of the balanced scorecard approach, although it has been proven that the number of these perspectives can vary according to the themes and fields of attention of the organization concerning the realization of its strategy. Many organizations attach a lot of importance to *technology, manpower, environmental issues, and other stakeholders, such as raw material suppliers,* and these organizations also evaluate the realization of their strategy in terms of these factors.

### The Customer Perspective

To select objectives and measures for the customer perspective, organizations must answer two vital questions: first, who are our customers? And second, what are our suggested values for them? Many organizations believe that they know their customers and know what products and services they should offer them. In fact, they offer their products to all customers. Michael Porter believes that not focusing on a specific segment of customers and their desired values limits an organizations capacity to gain a competitive advantage. Organizations usually choose the desired theme of their customer perspective from the following strategic themes:

- **Operational excellence:** organizations that choose operational excellence focus on reducing the cost of upgrading product usage and the ease of use of their products and services.
- **Product Leadership:** organizations that choose a product leadership strategy emphasize continuous innovation and offering the best product or service to the market.
- **Intimacy with the customer:** in this strategy, satisfying the wants and needs of customers, providing solutions to their problems, and maintaining a long-term mutually beneficial relationship with them is one of the main objectives of the organization.

Additionally, measures that are widely used by companies in this perspective are *customer satisfaction, customer loyalty, market share, customer acquisition, and maintenance.*

### The Business Internal Processes Perspective

In the perspective of internal processes, organizations need to identify processes that can create value for customers and ultimately shareholders by excelling in them. Achieving each of the adjusted objectives in the customer perspective requires one or more operational processes to be performed efficiently and effectively. In the internal process perspective, a completely new set of operational processes may be needed to meet customer and shareholder expectations. The development of new products and services, manufacturing, after-sales service, and re-engineering of manufacturing processes are examples of such processes.

Some organizations rely heavily on suppliers of their materials and parts to provide their products and services to customers and carry out their manufacturing operations mainly through outsourcing. These organizations must, in the perspective of their internal processes, consider relationships with suppliers and develop appropriate measures to control these relationships.

### The Learning and Development Perspective

How ambitious objectives can be realized in the perspectives of internal processes, customers, and ultimately shareholders is hidden in the objectives and measures of this perspective. These objectives and measures enable the objectives in the other three perspectives and provide a foundation for establishing a balanced scorecard system. Once you have determined appropriate objectives and measures for the customer and internal process perspectives, you will immediately notice the gap between the required skills and competencies of employees and their current level. Also, the distance between the required information technology and the current level of the organization's information systems will be determined. The objectives for learning and growth should be defined to fill these gaps and close these distances, and appropriate measures should be developed to control their progress. As with the other perspectives of the balanced scorecard model, this perspective relies on a combination of lead and lag indicators. Measures such as employee satisfaction, appropriate work environment, access to necessary information systems, and employee training plans, are examples of subordinate measures in this regard for lead measures, along with employee skills and the presentation of new suggestions and designs.

### The Financial Perspective

Financial measures are an important component of the balanced scorecard system, especially in for-profit organizations. The measures in this perspective tell us what the outcome and financial achievement will be, ultimately leading to the successful implementation of objectives in the other three perspectives. We can try to improve customer satisfaction, while improving quality and reducing the delivery time of our products and services, but *if these measures do not lead to tangible results in our financial statements, they will not be of much value.* Classical performance indicators usually show up in the financial perspective. Examples of these measures include profitability measured by return on capital employed (ROCE); recently the economic value added (EVA) measure has been considered instead of or alongside it. In addition to profitability, revenue growth and increased productivity or utilization of assets are well-known measures in this regard.

### Ability to Execute Strategy

The results of a study of 275 managers showed that the ability to execute a strategy is far more important than the quality of the strategy itself.

These managers considered strategy implementation to be the most important factor in evaluating a company and its management. This finding seems surprising as, for the past two decades, management theorists, consultants, and business publishers have emphasized the formulation of strategy that leads to superior performance. It seems that formulating a strategy has never been important.

Other observers agree with the managers who participated in the study that the *ability to execute strategy may be more important than the strategy itself.* In the early 1980s, a study by some management consultants found that less than 10 % of effectively formulated strategies were successfully implemented.

In 1999, Fortune magazine published an article about the failures of well-known executives, concluding that an emphasis on insight and strategy creates the misconception that all we need to succeed is the right strategy. In most cases, which some people estimate to be up to 70 %, the *real issue* is not poor strategy, but *poor strategy implementation*. Thus, with a reported failure rate of between 70 and 90 %, we can understand why smart investors have realized that good performance is more important than good insight.

Why do organizations face such difficulty in implementing their well-formulated strategies? One problem is that strategies, as sustainable and unique ways to create value in organizations, are always changing, but strategy measuring tools are not. In the industrial age, companies created value using their tangible assets by converting raw materials into products.

In 1982, a study by the Brookings Institution found that the book value of tangible assets of industrial organizations equaled 62 % of their market value. Ten years later, that ratio had dropped to 38 %. Recent studies estimate that by the end of the 20th century, the book value of an organization's tangible assets was equivalent to 10 to 15 % of the organization's market value. Value-creating opportunities are shifting from the management of tangible assets to the management of knowledge-based strategies that aim to utilize an organization's intangible assets. Assets are such things as customer relationships, innovative services/products, high quality, responsive operating processes, information technology, databases, capability, skills, and employee motivation.

In an economy based on tangible assets, financial assessment and valuation techniques were sufficiently able to reflect investment in a company's inventory, property, machinery, and equipment on its balance sheet. Profit and loss statements could also record the costs associated with using these tangible assets, leading to revenue and profit. However, today's economy, in which intangible assets have become the main source of competitive advantage, needs tools to define and measure knowledge-based assets and the value-creating strategies that are made possible these assets. In the absence of such tools, companies have difficulty in managing what they are unable to define and measure.

Companies also struggle to implement knowledge-based strategies in organizations designed to compete in the industrial age. Many organizations operated under a central control system using large task organizational units until the late 1970s. Strategy was formulated at the highest level of the organization and was implemented through a culture of centralized command and control. Organizational evolution was very gradual and so managers could use management control system, such as the budget system. Such systems were designed for nineteenth and early twentieth-century industrial companies and are insufficient for today's rapidly evolving and dynamic environment.

Nowadays, most organizations do their operations through decentralized business units and teams. These units and teams are much closer to customers than to employees of large companies. These organizations have found that competitive advantage is created more through intangible assets, such as abilities and relationships created by employees, than investing in physical assets and gaining capital. The implementation of strategy requires the alignment and connection of all business units and support units with it. With drastic changes in technology, competition, and rules and regulations, strategy formulation and implementation is a continuous and participatory process. Today's organizations need *a language of communication to convey strategy, as well as systems and processes that help them to implement strategy and get feedback about their strategies.* **Success is achieved when the strategy has become everyone's daily work.**

The balanced scorecard approach maintains financial performance measures (lag indicators), but also introduces measures on future financial performance (lead indicators).

Relevant and appropriate measures for evaluating future performance are strategic measures. If financial measures cause mistakes in organizations, these strategic measures motivate them to undertake the appropriate work. Therefore, all objectives and measures of a balanced scorecard (financial and non-financial) must be derived from the organization's insight and strategy. Although the effect of the balanced scorecard was not well understood at the time it was introduced, it soon became a tool for strategy management—a tool for dealing with a 90 % failure rate.

Many companies became interested in implementing the balanced scorecard method because they had low performance, were losing money, and were following the common course of their industry. Each of these organizations brought in a new management team to change their performance. Each of these new management teams proposed new strategies and they made efforts to increase customer-orientation in their organizations. These strategies that do not just rely on cost reductions and downsizing, but also require changing the organization's position in a competitive market environment. More importantly, the new strategies require the acceptance of a set of cultural values and priorities. Under such circumstances, failing organizations needed employees to learn and understand the new strategy and change their behavior, which had been established over decades.

Despite the difficulties that most organizations experience in implementing strategy, four pioneering companies used the balanced scorecard approach to support their organizational and strategic evolution, and the long-term impacts soon became apparent. Companies benefited from their new strategy very quickly during implementation and the balanced scorecard approach was the difference. Each of these organizations implemented its strategies using similar material and human resources, and with similar products, equipment, employees, and customers. The reason for the difference was that a new management team used organizational resources to implement its strategy using the balanced scorecard approach. The balanced scorecard approach helped these successful organizations to establish a new system of management, designed to manage strategy. This new management system has three distinct dimensions:

**1. Strategy:** develop strategy as the center and focus of your organizational plan. The balanced scorecard approach, for the first time, made it possible for organizations to describe their strategies and transmit them throughout the organization so that employees could understand and act upon them.

**2. Focus:** strongly emphasize strategy, i.e. create a strategy-oriented organization. Using the balanced scorecard approach as a catalyst, all the resources and activities of the organization come to be aligned with strategy.

**3. Organization:** prepare all employees for a fundamentally different performance. The balanced scorecard approach created a new culture and structure for organizational communication between business units (queuing units), support units (staff units), and employees.

These organizations used the balanced scorecard approach to create a strategy-oriented organization. Ideally, the balanced scorecard approach should be used by organizations that want to adopt a bold growth strategy, so that they can direct movement, develop a management system for rapid growth, and align current employees and contracted staff with the strategy to attract, retain, and communicate deeply with objective customers.

### A New Approach to Organizational Management

The balanced scorecard approach has grown, matured, and developed as a new framework for measuring organizational performance. This method was originally proposed to overcome management constraints based on financial measures. Previously, financial measures were reported based on performance results (lag indicators) and did not pay attention to future performance factors, i.e. indicators that show how to create new value by investing in customers, suppliers, employees, technology, and innovation (lead indicators).

The balanced scorecard approach provided a framework for looking at the strategy adopted for value creation from four different perspectives:

1. **Finance.** Strategies focus on growth, profitability, and risk from a shareholder perspective.
2. **Customer.** Strategies focus on value creation and differentiation from a customer perspective.
3. **Business internal processes.** Strategies focus on prioritizing various business processes that lead to customer and shareholder satisfaction.
4. **Learning and growth.** Strategies focus on prioritizing the creation of an environment that supports organizational evolution, innovation, and growth.

Using the balanced scorecard approach, other managers could now assess how their business unit was creating value for current and future customers. The balanced scorecard approach, while maintaining interest in financial performance, demonstrates efficiency, value-creating factors, and competitive superiority in performance.

Performance measurement has consequences and outcomes beyond that which was recorded in the past. The measurement of performance focuses on the future because the measures selected by managers convey what is important to the organization; to make full use of this power, performance measurement must be integrated with the management system. A set of strategic evaluation criteria (rather than a budget) is at the center of the management process.

Organizations managed using the balanced scorecard approach realized other issues. The speed and spread of results (achieved by the pioneering organizations) highlighted the power of a balanced scorecard-based management system in focusing the entire organization around strategy. To achieve such intense focus, organizations institutionalized comprehensive evolution.

Organizations redefined their relationships with their customers, re-engineered the core processes of their business, taught new skills to their employees, and developed new technology infrastructure. Furthermore, a new work culture emerged that relied not on traditional task units, but on teamwork to support strategy.

The management system provided the mechanism for preparing and directing the evolution process, but the new culture that grew was more than just a management system.

Companies created a new type of organization based on the requirements of their strategy—a strategy-oriented organization. For the surveyed companies, creating a strategy-oriented organization was not a unified process (such as obtaining ISO 9000 certification or the Baldrige Award[67]) to meet a set of standard requirements. The strategies used were different and so the organizational evolution varied from company to company. The only common aspect was that each strategy-oriented organization placed strategy at the center of its transformation and management processes. By defining and explaining the strategy, transmitting it continuously, and linking it to evolving factors, a performance-based culture was formed that connected each individual and each organizational unit to specific aspects of the strategy.

Companies were leaving a performance management system exclusively attached to financial frameworks behind. In the first decades of the twentieth century, DuPont and General Motors introduced the measure of return on investment (ROI) as a tool for integrating the multiple organizational units of a company. In the mid-twentieth century, a company with multiple organizational units used its budget as the core of its management systems. In the 1990s, companies expanded their financial frameworks to find financial measures that correlated with shareholder values and criteria, such as economic value added (EVA) and value-based management. Even the best financial frameworks cannot cover all the dynamic aspects of performance in today's competitive knowledge-based environment.

Recognizing the limitations of management based on mere financial data, many companies in the 1980s and 1990s began to choose quality as their central organizational fulcrum. Over the years, companies have sought to win prestigious awards, such as the Malcolm Baldrige National Quality Award in the United States, the Deming Prize in Japan, and the EFQM Excellence Award in Europe, and to imitate companies such as Motorola and General Electric by using Six Sigma. However, quality alone was not enough (as with purely financial measures) and quality

[67] Malcolm Baldrige National Quality Award.

plans also needed to be replaced. Numerous companies that had received national quality awards soon found themselves in financial trouble.

Beyond financial and quality measures, some companies have emphasized and focused on customer orientation through implementing plans focus on the establishment of customer relationship management (CRM). Other companies have sought to acquire core capabilities and re-engineer their business processes, and others have emphasized strategic human resource management to show how motivated and skilled manpower can create economic value, or how information technology can develop and gain competitive advantages. Each of these aspects—financial, quality, customer, abilities, processes, employees, and systems—are important and play a role in value creation in organizations.

Each of these represents only one component of the network of management activities and processes, which must be implemented to achieve superior and sustainable performance. Focusing and managing just one of these aspects leads to partial optimization. Companies need to replace each of these clear and narrow focuses with a holistic view in which strategy is at the heart of the management system.

Strategy-oriented organizations use the balanced scorecard approach to place strategy at the center of their management processes. The balanced scorecard approach has made a unique contribution to management through a clear and unambiguous description of strategy. Before the introduction of the balanced scorecard approach, managers did not have a generally accepted framework for explaining strategy and they could not implement what they could not explain. The simple task of explaining the strategy is achieved by strategy plans and evaluation criteria, which is a tremendous improvement.

Evaluation criteria may be necessary, but are not enough to implement strategy successfully. The success of many world-class senior executives is found in their use of the balanced scorecard approach as a framework for a new performance management process. This process has resulted in significant performance improvements, quickly, reliably, and consistently. This approach, while based on strong historical foundations, can also meet the needs of the new economy.

### Principles of Strategy-oriented Organization

The managers of many organizations have *achieved successful results using alignment and focus.* The balanced scorecard approach enabled pioneer companies to focus and align their management team, business units, human resources, information technology, and financial resources with their organizational strategy.

Studies of companies that have successfully applied the balanced scorecard approach present a consistent pattern in achieving strategic focus and alignment. Although each of these organizations responded to this challenge differently, using a different sequence, five identical principles of a strategy-oriented organization have been found in practice.

### Principle 1 - Translate strategy into operational terms

The speed of achieving results from new strategies shows that the success of companies is not due to the introduction of a new product/service, a new investment, or even the development of new intangible/intellectual assets. Companies, of course, were always developing new products/services and investing in both tangible and intangible assets, but they could not make much profit from such investment over the years. To achieve results, companies had to invest in the abilities and assets (tangible and intangible) they already had. New strategies and the balanced scorecard approach were able to uncover and release abilities and assets that were hidden and frozen within the old organization. The balanced scorecard approach also provided guidelines for combining materials and elements to create long-term value.

The balanced scorecard approach provides a framework for continuously and consciously explaining and conveying strategy. Unlike the financial arena, where standard frameworks, such as general ledgers, balance sheets, and profit and loss statements, exist to document the company's financial plan, there is no generally accepted framework for describing strategy. Depending on the number of hypotheses and methodologies that are available for strategy formulation, there are a number of methods that can be used to explain strategy.

1992 saw the introduction of the balanced scorecard; more than 200 senior management teams were involved in its planning and design and they began the design work with the question: what is strategy? Using an empirical basis, they developed a general framework for the description and implementation of strategy, which they believed could be as useful as financial frameworks.[68] This new framework, called a strategy map, offers a logical and comprehensive structure for describing strategy and provides the basis for the design of the balanced scorecard, which is the cornerstone of the new strategic management system. Strategic plans and the balanced scorecard approach highlight the shortcomings of the tangible asset valuation systems of the industrial age. The cause-and-effect relationships

[68] Financial frameworks include things such as profit and loss statements, balance sheets, and cash flow statements (used by financial managers for financial planning and reporting).

reflected in the strategy map show how intangible assets are converted into tangible (financial) results, while the financial valuation system records and reflects the individual values of assets, such as cash, accounts receivable, inventory, land, buildings, and machinery. The value of such assets largely depends on who owns them.

In contrast, intangible assets usually have very little individual value; their value originates from their involvement in a series of interconnected strategies. The use of quantitative non-financial measures, such as manufacturing cycle time, market share, innovation, satisfaction, and ability, in the balanced scorecard approach allows value-added processes to be measured rather than inferred. Customer desires and values define a framework in which intangible assets, such as skills, motivated employees, and customer information systems, are converted into tangible results, such as customer maintenance, revenue from new products and services, and, ultimately, profit. The strategy map and balanced scorecard approach provide a tool to explain how value is created through the use of intangible assets from a stakeholder's viewpoint. Strategy maps and the balanced scorecard approach establish a method for the assessment and measurement of management in the knowledge-based economy.

By translating strategy into the logical structure of a strategy map and balanced scorecard, organizations create a common and understandable reference point for all their units and employees.

### Principle 2 - Align the organization with strategy

Synergy[69] is an overarching objective in organizational design. Organizations are made up of many departments, business units, and specialized departments, each with their own specific strategic goals. To improve organizational performance and make it greater than the sum of the performance of its various parts, these individual strategies must be interconnected and integrated. Each company defines the type of connection expected to create synergies and strives to ensure that these connections occur in practice—something that is easier said than done.

Organizations are traditionally designed around task specializations, such as finance, manufacturing, marketing, sales, engineering, and procurement. Each of these tasks has its own knowledge structure, language, and culture.

[69] Synergy is the construction of a whole in which the result of the whole is greater than the simple sum of the individual components because the result of the collective force is greater than the sum of the individual forces (that is, we can say using synergy, 2 + 2 = 5).

In this way, the structures of a task are constructed and stand as one of the main obstacles to the implementation of the strategy because most organizations have difficulty in communicating and coordinating between these tasks and specialized units.

Strategy-oriented organizations, however, break down these barriers. Managers in these organizations replace the formal reporting structure with an approach focused on strategic themes and priorities, which disseminate consistent outcomes and priorities across organizational units. A new organizational chart is not required as business units (operations) and support units are connected through the common strategic themes and objectives that inform their performance. Often, virtual and informal organizations are formed within the organization to emphasize the implementation of strategic themes. In all of these cases, successful companies use the balanced scorecard approach to create consistency across the organization and to ensure that the total performance is greater than the sum of its components would be.

#### Principle 3 - Make strategy everyone's responsibility every day

CEOs and their senior leadership teams cannot implement this new strategy on their own, but needed the active participation of their employees, i.e. we must move strategic responsibility from 10 (senior management team) to 10,000 (all employees in the company). The question is, how do you convert your strategy *from the board room* to the back room and from there *to the front lines of operations and customer service*?

A strategy-oriented organization needs all of its employees to understand the strategy, do their daily work, and contribute to success: this is not a top-down "command," but a top-down "interaction."

Senior managers use the balanced scorecard approach to assist in communicating and educating the new field of strategy within the organization. However, some observers may be skeptical about integrating strategic responsibility across an entire organization because they are afraid that valuable information will be leaked to competitors. Brian Baker, one of Mobil's executives, has responded to this assumption saying:

> Knowing our strategy will make them a little better unless they can implement it. On the other hand, we do not have a chance to carry out our strategy unless our employees are aware of it, and this is a chance we have to get.

Companies can train their employees about very complex business concepts. To understand the balanced scorecard approach, employees need to learn concepts such as customer segmentation, variable costing, and database marketing. Instead of assuming that employees are unable to understand these ideas, companies have to make a concerted effort to teach these key elements of strategy to their employees at all levels of the organization.

Companies thus implement evaluation objectives and criteria at all levels and business units (from top to bottom). In many cases, criteria are also used to assess the achievement of individual objectives. Strategy and criteria are combined and set generally at the organizational level and, instead of delivering objectives through the formal hierarchy as was previously done, the whole set of strategies is transferred from top to bottom. Individuals and units at lower levels could formulate their objectives in light of broader principles. Very positive results have been obtained from employees participating in identified tasks, beyond their tasks and responsibilities.

Finally, many successful organizations have linked their reward and service compensation system to the balanced scorecard method. Most senior executives prefer a teamwork-based performance reward system to an individual work-based system and used criteria for evaluating business units and different parts of the organization as a basis for rewards; this is an approach that emphasizes the importance of teamwork in implementing the strategy. The service compensation system can be based on a maximum of 25 strategic measures. Contrary to the confusion that many feared would result, the balanced scorecard service compensation system has been shown to enhance employee interest and motivation in all dimensions and elements of the strategy and increase employee desire to gain knowledge and information about the measures used in the balanced scorecard approach. Thus, strategy has become everyone's job every day because everyone understands it and is motivated to implement it.

### Principle 4 - Turn strategy into a continuous process

For most organizations, management processes form around budgetary and operational plans. The monthly management meeting is devoted to reviewing performance against the plan, analyzing past performance discrepancies and determining an action plan to resolve these discrepancies. This approach is inherently flawless and tactical management is essential anyway, but for most organizations there is no meeting in which managers specifically discuss strategy. Research shows that 85 % of management teams spend less than an hour a month discussing strategy. It is no wonder then that the implementation of strategy fails if the discussion of strategy does not even appear in the work plan and schedule of senior managers. Strategy-oriented organizations, however, take a different approach.

Companies that have successfully used the balanced scorecard approach have introduced a process for strategy management. *This process is referred to as a double-loop process; the process that combines the management of tactics (financial budgets and monthly review meetings) and the management of strategy to create an integrated and continuous process.* As there was previously no existing process for strategy management, each organization had to develop a new approach to this purpose. During these implementations, three important issues emerged.

First, organizations began to link strategy to the budgeting process. The balanced scorecard offers a criterion for evaluating investment items and executive plans that provide strategic meaning for screening (selecting) investment items. For example, more than 70 requests for financing were sent to a bank. The bank found that more than 50 % of these requests did not affect the adjusted criteria in the bank's balanced scorecard. These requests were rejected as non-strategic. The bank also found that almost 20 % of the adjusted measures in the balanced scorecard did not have a clear executive status and, therefore, it designed a process to manage strategic plans. Once this process was established within the bank's annual budget process, strategic plans and actions were handled differently. Companies have found that they need two types of budgets: a strategy budget and an operating budget[70] and this separation is necessary.

As the **balanced scorecard approach** seeks to support *long-term actions and plans against partial optimization (resulting from short-term actions), so the* **budgeting process** *must support long-term actions against the pressure to achieve short-term performance.*

The second and most important issue has been the invention of a simple management meeting to review strategy. Such meetings did not previously exist and thus special management meetings had to be scheduled on a monthly or tri-monthly basis to discuss the balanced scorecard, so that a wide range of managers could talk about strategy. As a result, a new force emerged. Many people have used terms, such as "exciting," to describe this event. Information feedback systems were designed to support this process. Originally, these systems were designed to meet the information needs of senior executives, but the number of organizations went a step further. They created an open reporting system so that the performance results were made available to everyone in the

[70] The strategy budget can be considered to be a long-term objective and the operating budget can be considered a short-term objective.

organization. By establishing the principle that every employee should receive the knowledge and awareness needed to do their job, empowering everyone. This created a culture that changed approaches and performance, and finally led to a process for strategy learning and adaptation.

Ideas and learning were constantly formed within the organization. Instead, of waiting until next year's budget cycle, the evaluation priorities and criteria were updated immediately. The senior management personnel of successful companies then used the generated ideas and knowledge by their organization to formulate and refine their strategies. As a result, strategy has become a continuous process, rather than an annual event.

### Principle 5 - Direct transformation through senior management leadership

The first four principles focus on the balanced scorecard, its framework, and the processes needed to support it. It has to be emphasized that you need something more than tools and processes to develop a strategy-oriented organization. Experience has repeatedly shown that the most important single condition for success is belonging to and active participation in the senior management team. The implementation of strategy requires fundamental change in every part of the organization and teamwork is necessary for the evolution of strategy. Strategy implementation requires continuous and focused attention to evolutionary plans and actions and organizational performance concerning planning outcomes. If people at the top of the organization are passive leaders in the process, then change will not occur, the strategy will not be implemented, and opportunities for successful performance will be lost.

A successful balanced scorecard plan begins with the recognition that it is not just an evaluation project, but an evolutionary project. The emphasis and focus are on mobilizing and creating momentum to start the process. Once the organization is mobilized, the emphasis and focus shifts to governance with an emphasis on fluid, teamwork-based approaches to deal with the unstructured nature of the transition to a new performance model. Gradually and over time a new management system is formed with a strategic management system that institutionalizes new cultural values and structures within the new management system.

Different steps can be taken over two or three years. In the first step, management with organizational mobilization must explain why evolution is necessary. Kotter[71] describes how transformational evolution begins at the top through three distinct leadership actions:

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[71] Kotter, John P. "Leading Change: Why Transformation Efforts Fail", Harvard Business Review 73, No. 2 (1995): 59-67.

1- Creating a feeling of serious necessity and need;
2- Creating guided alliances;
3- Developing insight and strategy.

The leaders of companies that have successfully used the balanced scorecard approach have all followed these steps. Many companies experienced difficult days, but the obvious threat of failure and job losses was the motivating factor for accepting change. The role of the balanced scorecard in driving successful evolution and performance should not be limited to declining companies. In many cases, the managers of well-established companies pursue extended objectives to ensure that their organization is not lazy and complacent. They use the balanced scorecard approach to convey insight into future performance, which the current status of evolution makes obvious to all. Once the evolutionary process has been launched, senior executives establish a governance process to guide the organization's transition to the desired status. This process defines, demonstrates, and reinforces new cultural values in the organization. It is very important to break the traditional power-based structures. The establishment of strategy teams, public meetings, and open communication are elements of this transitional governance.

As the evolution process progresses, managers modify the existing management system to establish and consolidate evolution. The model used in each of the studied organizations was different as each organization linked the balanced scorecard to its planning and budgeting process in the first possible period. Regardless of the sequence, however, each organization gradually created a new management system, which ended up being very similar to each other. By connecting traditional processes, such as the service compensation system and resource allocation, to the balanced scorecard approach describing the strategy, they created a strategic management system. The new management system linked each of the components of the organization to the determining criteria of the strategy.

For good managers, of course, there is no fixed status. By injecting a new strategy and culture into a management system, however, companies can create an obstacle to future growth. The competitive landscape is constantly changing and strategies must always be formed to reflect these changing opportunities and threats. The strategy must be a continuous process and the art of leadership is to create a delicate balance between stability and change.

### Obstacles related to the non-transfer of strategy.

In the industrial age, the efficient and effective use of a company's physical assets was the most important factor for success and profitability. Nowadays, the knowledge, skills and capabilities of employees are the greatest assets in achieving success.

If the employees of an organization, who are the largest factor in value creation, do not understand the organization's strategy correctly, how can they be expected to implement it? Using the right mechanisms to communicate and convey the strategy to all members of the organization is the key to success in implementing it.

### Resolving obstacles related to the transfer of strategy

The balanced scorecard approach is established through creating a common understanding and translating organizational strategy into general objectives, measures, quantitative objectives, and executive plans and initiatives in each of the four perspectives. For the translation of insight and strategy into operational terms, senior management is required to articulate its meaning of the insight statement that is easily understood by all members of the organization. Sentences, such as "best in class," "superior service," "competitive advantage," and "globalization," etc., remain on paper, but will not be implemented until they are translated into specific objectives and measures that are understandable to employees. In the process of developing the balanced scorecard, the organization's senior management team may specify that "superior service" means a 95 % rate for on-time delivery of customer service. In this scenario, all employees can understand the concept of superior service and recognize their role in achieving it.

### Obstacles related to the non-alignment of employees with the strategy

Formulating a strategy is one of the tasks and responsibilities of the organization's senior management, but its implementation is not possible without the help of middle managers and employees in the different units of the organization. All employees of the organization must find their material interests and work goals in the realization of the organization's strategy. If the implementation of the strategy only brings material reputation and achievement to the organization's senior management, other levels of management and employees will not follow it and there will certainly be limited motivation to support it. Designing and implementing service compensation systems, linked to suitable strategy evaluation criteria, can provide an appropriate mechanism to help align employees with strategy.

### Resolving obstacles related to the non-alignment of employees

By implementing the strategy at all levels of the organization, employees will have the opportunity to show how their daily activities contribute to the realization of the company's strategy. Balanced scorecard criteria are determined not only at the general level of the organization (the company), but also at the level of strategic business units (SBUs), shared service units, and even at the employee level. By connecting these evaluation criteria, a kind of alignment and empathy is created in achieving the objectives.

Instead of linking the reward and employee compensation systems to the realization of short-term financial objectives, managers will be able to use the balanced assessment method to link paid rewards directly to the realization of measures in terms of how business units, workgroups, or individuals can work effectively.

### Obstacles related to the non-commitment of senior management

As mentioned previously, strategy formulation is part of the responsibility of senior management, but its implementation is not possible without the full support and time and energy of the organization's senior managers.

Senior executives strengthen the strategy implementation process by showing their explicit support and creating concern in all organizational pyramids for strategy implementation. Holding strategy review meetings is an example of senior management actions to demonstrate its commitment to strategy implementation.

### Resolving the obstacle related to not allocating the necessary resources

Establishing a balanced scorecard method provides a great opportunity to link the strategic planning and budgeting processes. One of the most important components of a balanced scorecard in the four perspectives is the plans and initiatives needed to realize definitive objectives and measures. If quantitative long-term objectives are considered as measures, planning for the gradual realization of these objectives is also determined. Therefore, the required financial resources and manpower to achieve them definitively in the balanced scorecard should be the basis for developing the annual budgeting process. The other units of the company do not prepare their annual budget by adding a percentage to their numbers from the previous year, but, instead, the necessary expenses to achieve the objectives assigned to them according to the balanced scorecard system will be included in their budget. In this way, the senior management of the organization can prioritize and compromise between plans and strategic initiatives according to their limited resources and select the plans that will have the greatest impact on the realization of the organization's strategy, while consuming the least resources.

### Obstacles related to the non-allocation of necessary resources

*Most organizations have separate processes for strategic planning and budgeting. Some people in the organization are engaged in strategic planning and creating a picture of the organization's future, while others are busy predicting next year's activities and allocating financial and human resources to these activities. In many cases, there is very limited interaction between these two groups.*

As such, we may ask how one can expect the organization's strategy to be implemented without allocating the necessary resources. The answer lies in linking the budgeting process to the strategic planning process.

### Resolving obstacles related to the non-commitment of senior management

Many senior management meetings are devoted to comparing budget numbers with performance results and analyzing work unit budget deviations. Using the balanced scorecard approach, senior management can pay attention to effective elements in the realization of the organization's strategy. The balanced scorecard translates an organization's insight and strategy into a coherent set of measures across four balanced perspectives. Immediately, the senior management of the organization will have available information that gives greater insight than financial data alone. By studying the cause and effect relationships of the success factors in the organization, management will be informed about the progress of its strategy. This awareness and learning strengthens management interest in and commitment to supporting the strategic plan.

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# Chapter Twenty-One

# CMMI Six Sigma Agile System BSC (CSASB)

In presenting a new management model, it is necessary to select the content of each chapter. This does not mean that what has been left out is insignificant because there may be relevant points that can help solve a number of management issues.

A) The selection of the CMMI model.

As noted previously, there are two levels: maturity levels (discontinuous) and capacity levels (continuous). In terms of continuous capacity levels, four process areas (process management, project management, engineering, and support) have been discussed in detail.

**Process Management process areas:**
Organizational Process Definition (OPD)
Organizational Process Focus (OPF)
Organizational Process Performance (OPP)
Organizational Performance Management (OPM)
Organizational Training (OT)

**Project Management process areas:**
Integrated Project Management (IPM)
Project Monitoring and Control (PMC)
Project Planning (PP)
Quantitative Project Management (QPM)
Requirements Management (REQM)
Risk Management (RSKM)
Supplier Agreement Management (SAM)

**Engineering process areas:**
Product Integration (PI)
Requirements Development (RD)
Technical Solution (TS)
Validation (VAL)
Verification (VER)

**Support process areas:**
Causal Analysis and Resolution (CAR)
Configuration Management (CM)
Decision Analysis and Resolution (DAR)
Measurement and Analysis (MA)
Process and Product Quality Assurance (PPQA)

For the discontinuous maturity level, each of the 22 process areas can be used for each "required" level shown in the figure.

For better understanding, the inputs and outputs are displayed on the figure for each process area.

| **Level** | **title** | **Process areas** | |
|---|---|---|---|
| **1** | Initial | | Risk of rework |
| **2** | Management | ○ Requirements Management (REQM)<br>○ Supplier Agreement Management (SAM)<br>○ Measurement and Analysis (MA)<br>○ Process and Product Quality Assurance (PPQA)<br>○ Configuration Management (CM)<br>○ Project Planning (PP)<br>○ Project Monitoring and Control (PMC) | |
| **3** | Definition based on standard | Organizational Process Focus (OPF)<br>Organizational Process Definition (OPD)<br>Organizational Training (OT)<br>Risk Management (RSKM)<br>Decision Analysis and Resolution (DAR)<br>Integrated Project Management (IPM)<br>Requirements Development (RD)<br>Technical Solution (TS)<br>Validation(VAL)<br>Verification(VER)<br>Product Integration (PI) | |
| **4** | Quantitative Management | Organizational Process Performance (OPP)<br>Quantitative Project Management (QPM) | |
| **5** | Optimization | Organizational Performance Management (OPM)<br>Causal Analysis and Resolution (CAR) | High quality |

**process management**

| inputs | to: |
|---|---|
| objectives and needs in processes of the organization. | OPD |
| process requirements | |
| standards related with processes, work-environment, and other assets | |
| Rules and guidelines | |
| resterictions, resources and coordinations | |
| interactions between supplier standards | |
| strong and weak organizational processes | OPF |
| Performance and capability data | |
| Statistical management data | |
| most valuable processes | |
| proposals for process improvement | |
| Measuring processes | |
| business objectives in organization | |
| training needs | OT |
| objectives and needs in processes of the organization. | |
| standard processes and other assets | |
| quality and process objectives | OPP |
| common measurements | |
| Collected data from "process performance" and "organization capability" | |
| potential benefits and estimated costs of improvement options | OPM |
| "Quantitative objectives" to achieve "quality objectives" and "process performance objectives" | |
| standard processes and other assets | |
| planning, deploying, and developing "organizational process improvements" | |

| out puts | to: |
|---|---|
| standard processes and other assets | OT, OPM, IPM, PPQA |
| improvement information (e.g. lessons learned, data, and artifacts) | S, IPM |
| Methods and work products (data measurement, process description, process products, and learned lessons) | REQM, RD, TS, VER, VAL |
| planning, deploying, and developing "organizational process improvements" | OPM, PP, SAM, REQM, IPM |
| objectives and needs in processes of the organization. | OPD, OT, PP, RD, VAL, MA |
| management and development of "Training plan" to have "Employees with up-to-date knowledge" | CM, MA, PPQA |
| " plan documentation" and "mechanisms definition to measure training plan effectiveness" | |
| "Quantitative objectives" to achieve "quality objectives" and "process performance objectives" | OPM, IPM, QPM |
| prepares "projects and support groups" | MA, QPM, REQM, TS, VER, VAL |
| measurements, baselines, and implementation models of processes | QPM, CM |
| Analysis of "Process Performance Baseline" | PMC, QPM, MA, CM |
| identify and define" Process Performance Objectives" | OPF, OPP, OT, IPM, QPM, MA |
| Organization Ability to Achieve Business Objectives and Quality Outcomes | OPP, IPM, QPM |

**Basic project management**

| inputs | to: |
|---|---|
| product and its components requirements and needs | pp |
| involve "relevant investors" | |
| obtain commitments | |
| "other related investor plans" on the project | |
| review investors' commitments & obligations to cooperate with them | |
| What to build | |
| plans and replans | |
| what to monitor | PMC |
| status, issues, and results of process and product evaluations | |
| measures and analyses of processes and products | |
| status, issues, and results of reviews and monitoring in relevant investors | |
| performing the correct activities | SAM |
| plans | |
| agreement with supplier | |
| products and its components requirements | REQM |
| "requirements change" in "planning, activities and work products" | |
| Requirements Provider" and "Requirements Receiver | |

| out puts | to: |
|---|---|
| create and maintain "the plans" | SAM, IPM |
| provide "planning requirements" | OPD, REQM, RD, TS, VER, VAL |
| create "project progress planning" | IPM |
| what to do | RD |
| measurement needs | MA, PMC |
| what to monitor | PMC |
| product and its component requirements | REQM, RD, TS, MA, VER, VAL |
| re-planning | SAM, IPM |
| performing the correct activities | SAM, IPM, QPM, RD |
| controlling and monitoring activities | PMC |
| monitor the progress of the project plan | PMC, IPM |
| determine the frequency of progress visits | PMC, IPM |
| measure to determine deviations | CAR, MA |
| obtained / purchased Products from the supplier | TS, PI, VER |
| determining project needs | RD, VAL, REQM, MA, OPD, OT, PP |
| agreement with the supplier | IPM, OPD, QPM, REQM |
| "Visits" and "acceptance tests" on "supplier-manufacturer product components" | PMC |
| products and its components requirements | OPD, REQM, RD, TS, VER, VAL |
| control "required changes" and ensure "the promotion and maintenance of other related plans and data | PMC, IPM, OPM,PPQA |
| ensures "requirements management" and "discipline between requirements, planning and work products" | CM, PI. IPM,REQM, OPM, PPQA |
| traced to customer's needs to prepare "product and its components" Requirements | RD, REQM |

**Advanced project management**

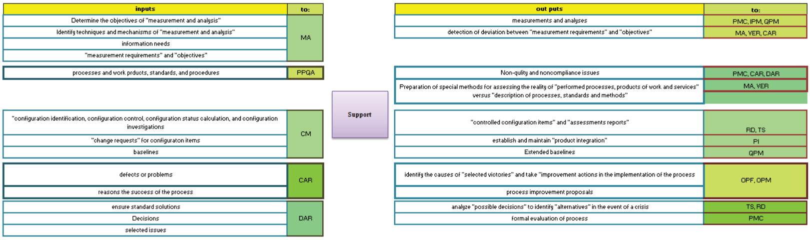
| inputs | to: |
|---|---|
| "process definition" based on "set of organizational standard processes". | IPM |
| organizational process assets | |
| standards related with processes, work-environment, and other assets | |
| rules and guidelines | |
| Project-related investors | |
| quantitative objectives for processes and sub-processes to statically manage | |
| Learned lessons, plannig, and performance data | |
| data of analyze supplier progress | |
| project quantitative analysis | QPM |
| appropriate definition of process | |
| statistical techniques | |
| effective communication with the supplier | |
| Process performance objectives, baselines, and models | |
| oppositions and pressures | RSKM |
| Potential risk due to instability in processes | |
| identified risks | |

| out puts | to: |
|---|---|
| identified risks | RSKM |
| project'scommon insight | SAM |
| rules and guidelines for staff, investors, customers and so on | OPD |
| project performance data | TS,OPP, OPF, IPM |
| Teaming for performing engineering and support of process | MA, QPM, REQM, TS, VER, VAL |
| coordination between" defined processes and work environment", "commitments", and "issues" | QPM |
| monitor supplier progress to achieve "quality objectives and process performance objectives | PMC |
| quality objectives, Process performance objectives, baselines, and models | OPM, IPM, QPM, CM |
| analyze supplier progress to achieve "quality objectives and process performance objectives | SAM, IPM |
| Potential risk due to instability in processes | RSKM |
| statistical management data | TS,OPP, OPF, IPM |
| quantitative objectives for processes and sub-processes to statically manage | OPM, IPM, QPM |
| data of Defined and constituent processes of the project | TS,OPP, OPF, IPM |
| identify "risk parameters, risk detection, and risk assessment." | DAR, IPM, QPM |
| activities for risk reduction | |
| risk categorizations, risk statuse, risk mitigation plans, and corrective actions | |

**Engineering**

| inputs | to: |
|---|---|
| customer needs | RD |
| quality indicators | |
| alternative solutions | |
| reports of requirements, product components, work products, verification and validation | |
| datasets of design details | TS |
| specifications of potential design solutions | |
| all of the reqirements | |
| reports of requirements, product components, work products, verification and validation | |
| product components | PI |
| Interface management | |
| requirements, product components, work products | VER |
| requirements, product components, work products | VAL |
| customer needs | |
| report of the expected performance of the product | |

| out puts | to: |
|---|---|
| product requirements | OPD, PP, REQM, VER, VAL |
| product component requirements | OPD, PP, REQM, VER, VAL |
| requirements of related investors | SAM, PP, PMC, IPM, |
| product requirements development | OPD, PP, REQM, VER, VAL |
| customer needs development | |
| requirements for "projects and products development" | |
| select, design and implement solutions to achieve the requirements | DAR, RD |
| alternative solutions | |
| product components | PI, VER, VAL |
| appropriate decisions for corrective actions | DAR, RD, SAM |
| Assemble the product using the product components | VER |
| ensure that the "assembled product" behaves properly and seamlessly | CM, VER, VAL |
| deliver the product to the customer | |
| ensure that the "products of the selected work" meet the "special requirements" | PI |
| ferequency of similar visits | PMC |
| Validates "products" against "customer needs" | RD, TS |




B) Creating agile thinking.

The organization needs to create agile thinking to achieve agile manufacturing.

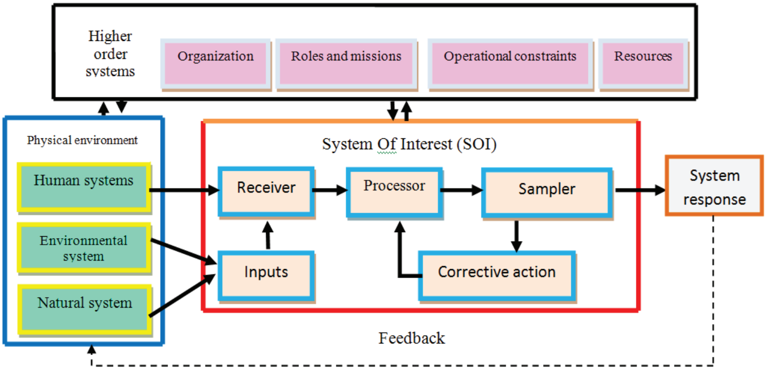

Note that the purpose of developing agile manufacturing is to achieve agile capabilities.[72] Therefore, team members should spend 15 minutes each day in the same time and place to review their progress in achieving organizational objectives and creating a daily plan. Team members share what they did yesterday, what they are doing today, and what obstacles

[72] Responsiveness, competence, flexibility, and speed.

they face. The best way to manage these meetings is to use the Deming cycle.[73]

D) Systems engineering.

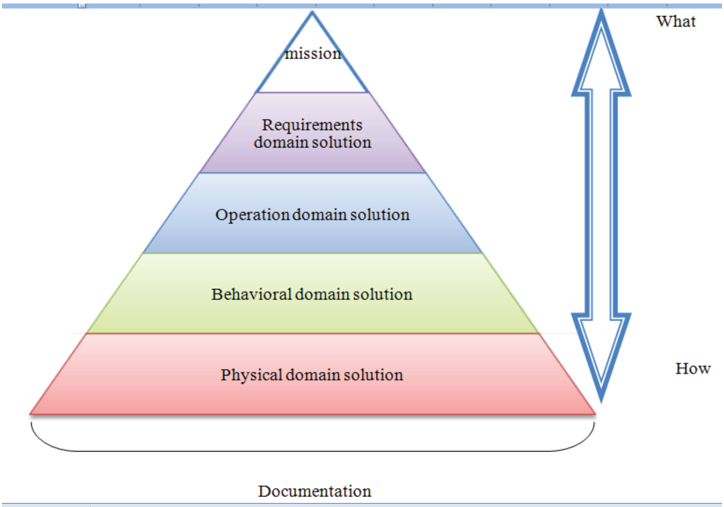
The first point is that we must have a systemic view: Higher-order system → System of interest (SOI) → Customer → In-system feedback & Out-of-system feedback.



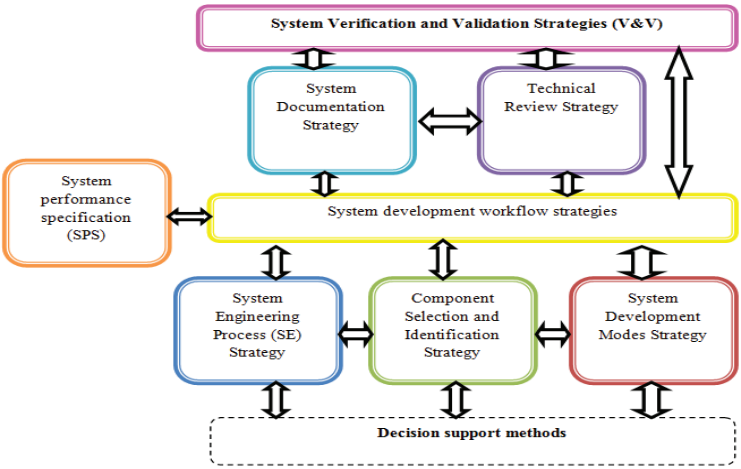

Second, if a defect is found in the system, the following steps are performed according to the SDBTF-DPM engineering sample:

- Step 1 - understand the user's needs, the problem, or the operational problem space.
- Step 2 - limit and specify user problem spaces and solutions.
- Step 3 - understand how the user intends to use the system.
- Step 4 - model the behavioral actions and interactions of the system with its operational environment.
- Step 5 - determine values for the effective cost, acceptable risk, and physical implementation.

[73] The SDCA cycle is used to stabilize current processes and the PDCA cycle is used to improve processes.

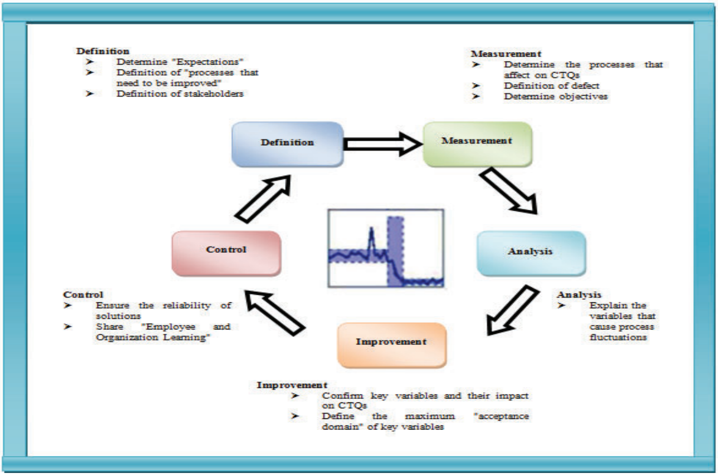



The third point is that if there is a need for development in the organization/product, we can use the following strategies to establish development, but do not forget the principles of systems engineering for development.



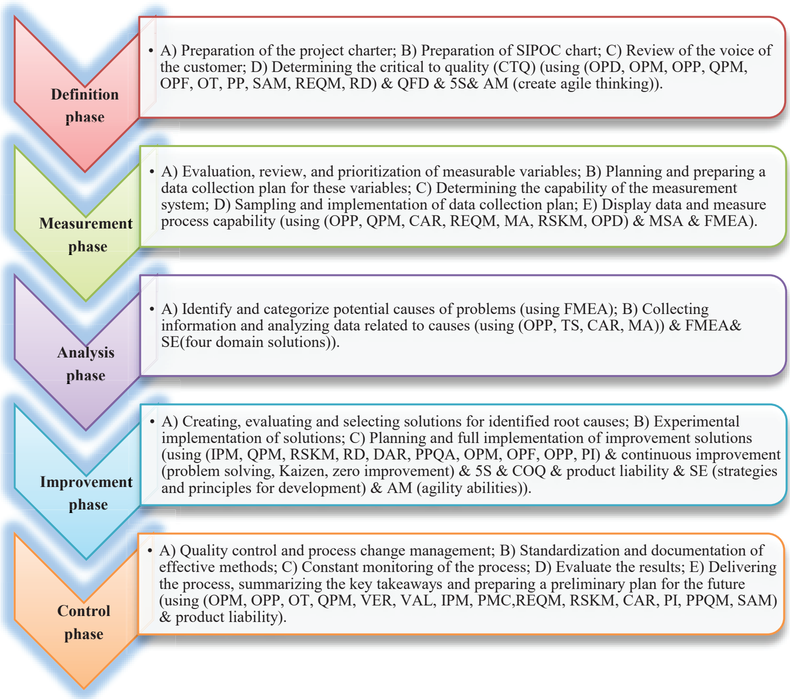
E) Six Sigma.

The most important part of this model is the use of quality techniques, especially Six Sigma, to ensure product quality. In this book (between DMAIC and AMADV), we are using the DMAIC method, as shown in the figure below.



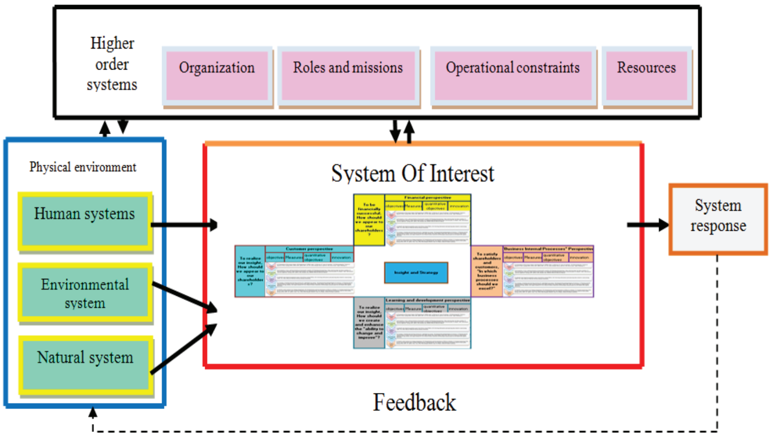

A strategy is needed to implement these techniques. The best strategy to implement is the BSC method, which has been successfully implemented in Six Sigma and pays attention to all aspects of the organization from four perspectives, ensuring the growth of the organization in all aspects.


The process areas in the CMMI model and the Six Sigma phases have been combined to create an integrated model. *Strengthening teamwork, flexibility, use of organizational knowledge, product diversity, customer feedback, and speed of reaction* are all inherent to the CMMI model, which is crucial for agile manufacturing. In addition, Six Sigma pays special attention to customer feedback and turning feedback into the quality features of the product, as with agile manufacturing. These two models—the CMMI model and the Six Sigma model—have inherent agile manufacturing characteristics.




Furthermore, to implement this model, it is better to use the BSC method so that all four perspectives in the organization grow in a balanced fashion.

Finally, we note that this model lies inside the system (according to systems engineering) and this system should be considered.




Using this model leads to quality implementation in an organization along with process standardization and improvement; as a result, we can also achieve continuous productivity. Therefore, all existing gaps between processes are eliminated and the whole organization strives, in an integrated manner, to produce a high-quality product and according to the organization's goals.

I hope that following this, I can take an effective step in the field of industry. Also, by presenting this model, I aim to assist in the survival of organizations in the manufacturing sector along with helping organizations develop a competitive advantage.

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