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TECHNISCHE UNIVERSITÄT WIEN

VIENNA UNIVERSITY OF TECHNOLOGY

MASTERARBEIT

Qualitätsfunktionen als Stützprozess des Produktionsprozesses – Vergleich mit Moderne Automobilproduktion „World Class Manufacturing“

ausgeführt zum Zweck der Erlangung des Akademischen Grades eines Diplom-Ingenieures unter der Leitung von

Univ.-Doz. Dipl.-Ing. Dr. Franz J. Brunner,

E 330

Institut für Managementwissenschaften

eingerichtet an der Technischen Universität Wien

Fakultät für Maschinenwesen und Betriebswissenschaften

von

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Ort, Datum eigenhändige Unterschrift

TECHNISCHE UNIVERSITÄT WIEN

VIENNA UNIVERSITY OF TECHNOLOGY

MASTER THESIS

Quality Functions as Supportive Process of the Production Process - Related with Modern Automobile Production "World Class Manufacturing"

ausgeführt zum Zweck der Erlangung des Akademischen Grades eines Diplom-Ingenieures unter der Leitung von

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LIST OF ABBREVATIONS

ASQ	American Society for Quality
CEDAC	Cause-and-Effect Diagram with the Addition of Cards
CI	Continual Improvement
COQ	Cost of Quality
CPI	Continuous Process Improvement
DMAIC	Define, Measure, Analyze, Improve, Control
DOE	Design of Experiments
ISO	International Organization for Standardization
JIS	Just in Sequence
JIT	Just in Time
LSL	Lower Specification Limit
OEE	Overall Equipment Efficiency
PDCA	Plan-do-check-action
QA	Quality Assurance
QC	Quality Circle
QC	Quality Control
QFD	Quality Function Deployment
SIS	Self-Inspection System
SQC	Statistical Quality Control
SQM	Strategic Quality Management
SuIS	Successive Inspection System
TIE	Total Industrial Engineering
TPM	Total Productive Maintenance
TQM	Total Quality Management
USL	Upper Specification Limit
WCM	World Class Manufacturing

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ABSTRACT

In the early 1980's, consumers became more powerful and started to demand high-quality goods and services at reasonable prices. The globalization of trade has made high-quality low-cost products available throughout the world. These factors increase the pressure on companies in order to achieve a specific quality. Today every business sector and especially automobile manufacturers are trying to lower the costs and accomplish certain quality level.

The goal of the thesis is to examine the quality functions which are very effectual and supportive in manufacturing processes, and then assign them in a production as supporting system. By doing this the main aim is to achieve the zero-defect quality. In the concluding part of the thesis a concept called "world class manufacturing" is investigated in one of the most successful automobile manufacturers in Turkey (Fiat), and an intense presentation is given about the topic.

KURZFASSUNG

In den frühen 1980'ern begannen Konsumenten durch ihre verstärkte Position am Markt, hochqualitative Produkte und Leistungen zu niedrigen Preisen zu verlangen. Die Globalisierung des Handels ermöglichte, dass hochqualitative Produkte zu niedrigen Kosten auf der ganzen Welt verfügbar wurden. Diese Faktoren erhöhen den Druck auf die Unternehmen eine spezifische Qualität zu erreichen. Heutzutage versuchen alle Geschäftsbereiche, insbesondere die Automobilhersteller, ihre Kosten zu senken und gleichzeitig bestimmte Qualitätsniveaus zu erreichen.

Das Ziel dieser Diplomarbeit ist die Funktionen der Qualität zu untersuchen und diese als unterstützendes System in der Produktion zu ordnen. Somit ist das Hauptziel dieser Arbeit, das Erreichen des Zero-Defect Quality. Der letzte Teil beschäftigt sich mit dem Konzept „world class manufacturing", welches bei einem der führenden Automobilhersteller (FIAT) in der Türkei erforscht und ausführlich vorgestellt wird.

1. INTRODUCTION

Quality management and business excellence have become major elements in the business strategy of many companies. Improvement in quality shows the way to increases in stakeholder satisfaction, profitability, market share and decreases in manufacturing costs, as well as promoting company competitiveness. Company strategy must focus on continuous process, product, organizational and people improvement, aimed at customer and stakeholder satisfaction, in order to remain competitive and ensure business survival. Such a strategy requires the application of quality and business excellence principles to all aspects of the business operation and processes.[1]

1.1 Research Objective

The objective of the Thesis is; to define, revise and to present some basic quality functions which are used in manufacturing such as; quality- planning, inspection, control, audits, circles, continuous process improvement and suppliers quality.

After sufficient explanations, the assignment of all these quality functions with production process will be done. Investigation and presentation of how these quality functions can make production process more efficient and reliable will be the aim of the assignment.

1.2 Research Questions

1. Which quality functions are related with the manufacturing processes?
2. What are missions and duties of the quality- planning, inspection, control, audits, circles, continuous process improvement and suppliers quality?
3. Which quality functions can be assigned direct with the production process and which not?
4. How quality functions can be supportive process for the production?

[1] M. N. A. Rahman & J D.T. Tannock, „TQM Best Practices" (2005)

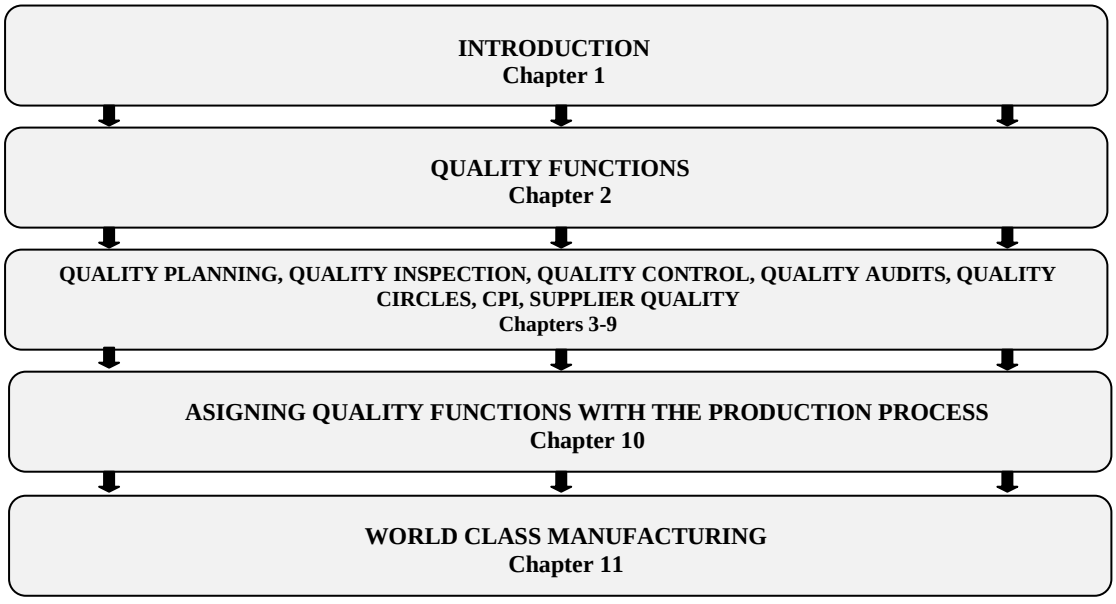
5. How can be achieved the zero-defect in production?
6. Investigation and presentation of World Class Manufacturing concept, related with one of the top car producers (TOFAS, Fiat) from Turkey.

1.3 Framework of the Thesis

After an introduction and identifying the quality functions, in the chapters between 3 and 9, all quality functions are defined and studied. Examples, methods, tools and explanations are specified.

In the chapter 10, the assignment of quality functions is illustrated. Which and how, can quality functions improve the manufacturing processes, is studied. A small scheme is presented of the montage\assembly process with the purpose of assignment functions. Several of functions are directly showed on the process; others are as the helping processes. Also an improvement part is studied where some additional ideas and topics are enclosed.

In the chapter 11 a brief explanation of the world class manufacturing concept is presented. After an investigation by the Fiat (Turkey), methods and tools are showed that are core elements of the WCM. Also Fiat production system and its specifics are presented in this chapter.

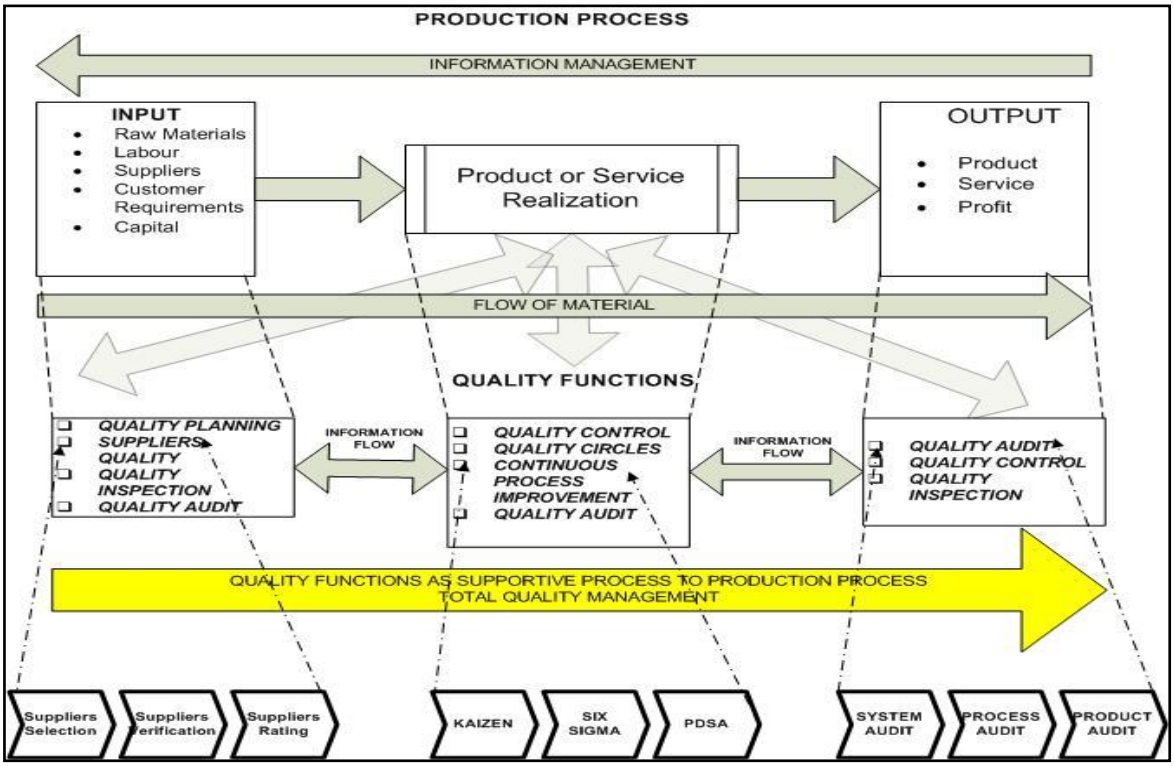


2. QUALITY FUNCTIONS

Manufacturing is very large and complex process which is consisted of many parameters and factors. In recent years automobile manufacturers are investing on achieving high-quality and improved processes.

In the following chapters, quality functions will be presented which improve and progress the manufacturing process. These are not production techniques, but supporting functions which take place in the manufacturing. These functions are:

- **Quality Planning**
- **Quality Inspection**
- **Quality Control**
- **Quality Audits**
- **Quality Circles**
- **Continuous Process Improvement**
- **Supplier Quality**



3. QUALITY PLANNING

Preparing for the future is crucial. In today's highly competitive and changing marketplace the margin for error is decreasing; hence planning for the future is necessary for survival and success. Planning and executing the plan are key activities in a company and are done by its managers. If done well, this process will give the desired results.

3.1 Definitions

Planning is the activity of establishing goals, and establishing the means required to meet these goals.[2] When this definition is applied to the "Quality", the result is:

Quality Planning is the activity of a establishing quality goals and developing the products and processes required to meet those goals.[2]

By using this definition, it should be noted that, quality planning is required for products, goods, services, and also for reports, invoices, purchase orders etc. So one more definition would be like

Quality Planning establishes the design of a product, service, or process that will meet customer, business, and operational needs to produce the product before it is produced.[3]

3.2 Quality Planning vs. Quality Control

This distinction is fairly obvious. Quality planning deals with setting goals and with establishing the means required to reach those goals. Quality control deals with execution of plans-conducting operations so as to meet the goals. Quality control includes also monitoring so as to detect differences between actual performance and goals.[2]

[2] J.M.Juran „Juran on Quality Design" (1992)

[3] Juran , "http://www.juran.com/HomeLeftNav/quality_planning.aspx"

3.3 Quality Planning vs. Quality Improvement

Quality improvement is directed at chronic problems, requiring diagnosis to discover the causes and providing remedies to get rid of the causes. Quality planning is directed at meeting customer-oriented goals, requiring application of the style of planning (Quality Road Map).[4]

3.4 The Quality Planning Road Map

The quality planning is done by a universal series of steps. If we expand these steps into a series of input-output diagrams, and also include the activity measurement, the result is Figure- 1.

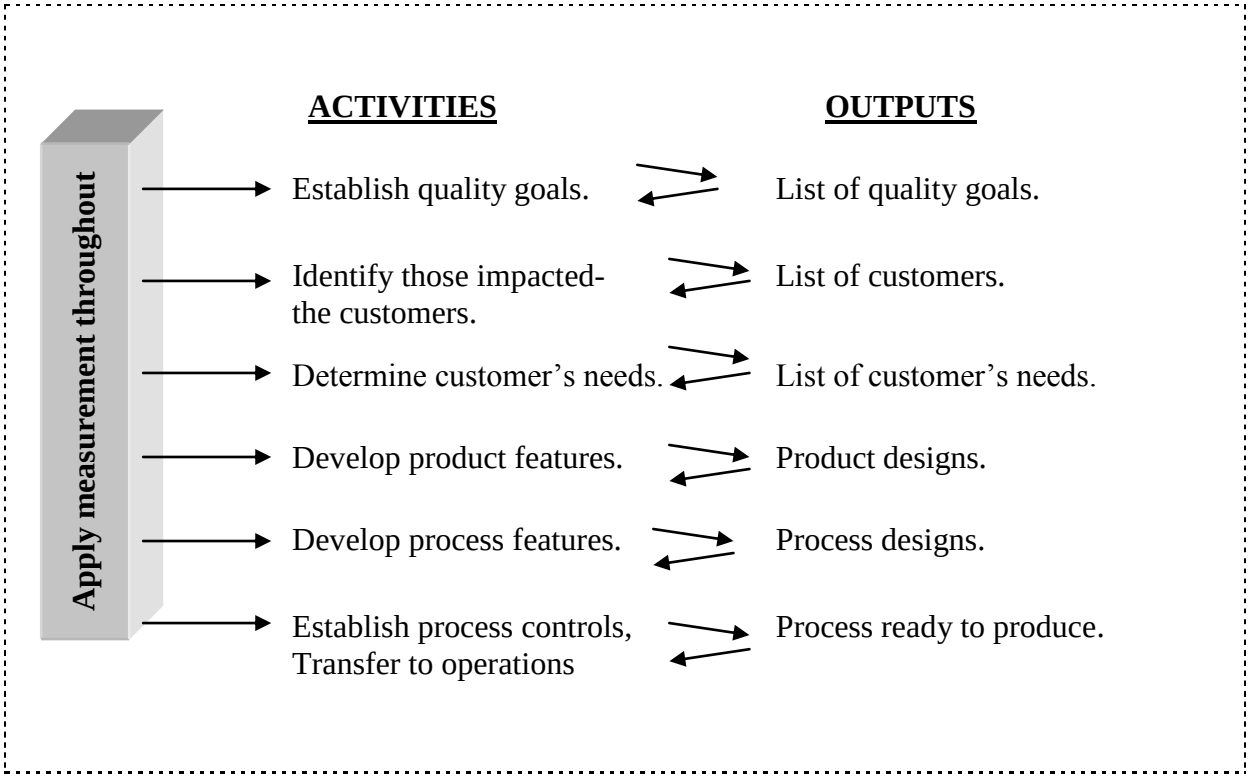


Figure 1.The Quality Planning Road Map[4]

[4] J.M.Juran „Juran on Quality Design" (1992)

In Figure-1 the steps are shown in their chronological sequence. The steps of the quality road map are stitched together by several commonalities:[5]

1. The interlocking input-output chain, in which the output for any step becomes the input for next step.
2. A series of spreadsheets (see Figure-2), which make the details of the interrelationship readily understandable and accessible.
3. A common, coherent system of measurement – units of measure and sensors-which applies to each step as well as to the entire sequence.
4. A triple role concept, under which every activity involves the triple role customer, processor, and supplier.

3.4.1 Quality Planning Spreadsheets

As quality planning gets on, it gathers a great deal of information. There are many customers, many needs, products and processes. The resulting combinations are so various, that it becomes needed to institute a structured means of organizing the information for ready interpretation and access.

There are many types of spreadsheets, but four types dominate the use of spreadsheets in quality planning. In figure (2-a) the horizontal rows list the various *customers*. The vertical columns show the *needs* of those customers. In figure (2-b) the customer needs have been moved to the horizontal rows. The vertical columns are then used to show the *product features* required to meet those customer needs. In figure (2-c) the product features have been moved to the horizontal rows. The vertical columns are than used to show the *process features* required to produce that product features.[5]

[5] J.M.Juran „Juran on Quality Design“ (1992)

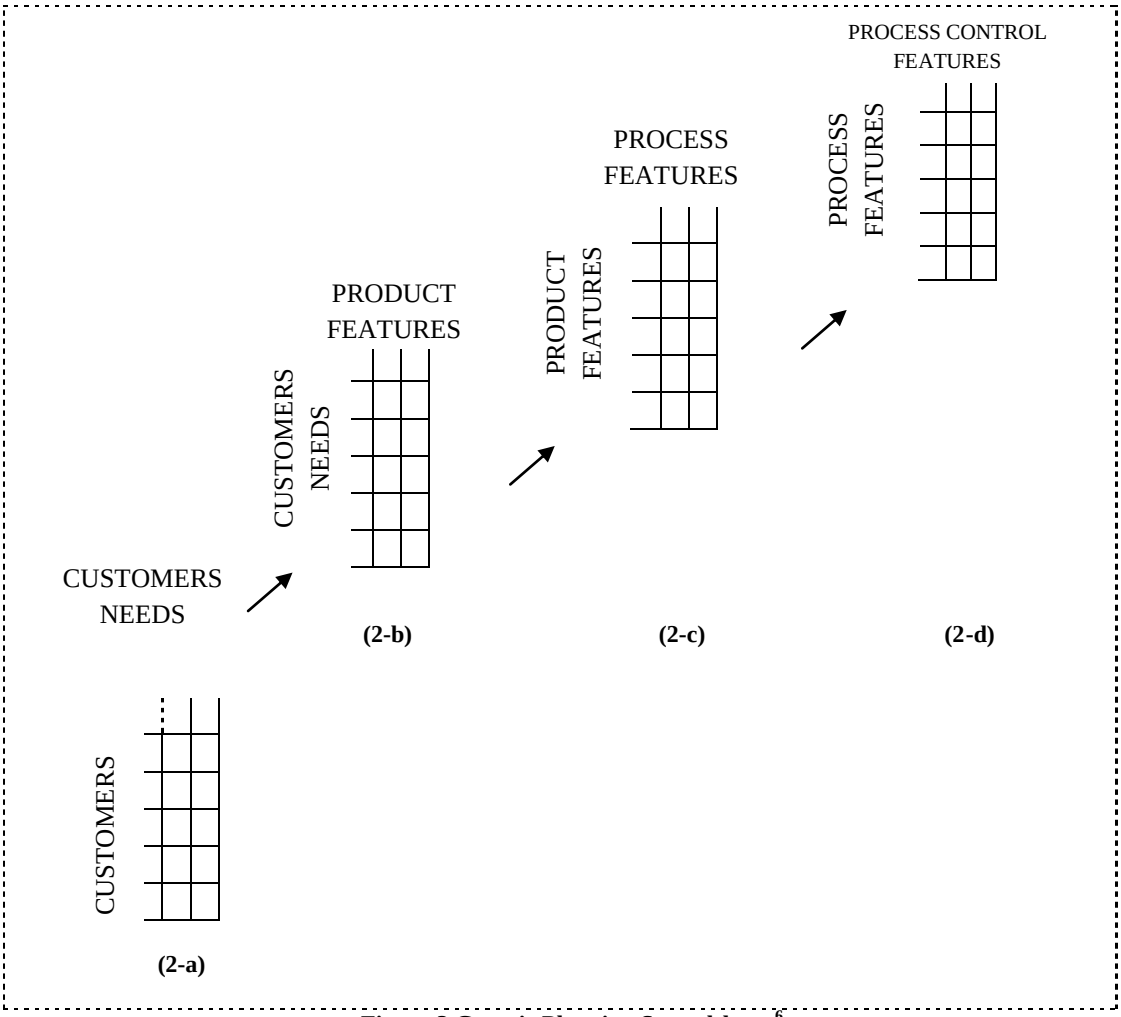


Figure-2 Generic Planning Spreadsheets[6]

Finally in figure (2-d) the process features have been moved to the horizontal rows. The vertical columns are then used to show the process control features required to keep the processes in a steady state.[6]

Quality planning, has been identified as an important means to develop a clear focus of the business in terms of customers served and value provided, along with identifying the areas in which the organization must excel in order to be successful.[7]

[6] J.M.Juran „Juran on Quality Design" (1992)

[7] S.S.K.Lam "Quality Planning Performance" (1997)

Many methodologies have been developed in the literature for quality planning, and organizations have also developed their own methodologies. Most of these planning methods are similar to the methodologies described in the literature which generally include setting up formal objectives, identifying appropriate quality strategies and searching for any innovative quality applications.[7]

3.5 Tools and Techniques for Quality Planning[8]

In this part, some tools and techniques, which are mostly derived from project planning and project management, will be examined.

3.5.1 Cost-Benefit Analysis

Quality planning must consider cost-benefits tradeoffs. The primary benefit of meeting quality requirements is less rework, which means higher productivity, lower costs, and increased stakeholder satisfaction.

3.5.2 Benchmarking

Benchmarking involves comparing actual or planned project practices to those of other projects to generate ideas for improvement and to provide a basis by which to measure performance.

3.5.3 Design of Experiments (DOE)

Statistical method that helps identify which factors may influence specific variables of a product or process under development or in production.

[8] P.Kumar „Quality Planning Tools“ (2007)

3.5.4 Cost of Quality (COQ)

Quality costs are the total costs incurred by investment in preventing nonconformance to requirements, appraising the product or service for conformance to requirements, and failing to meet requirements (rework). Failure costs are often categorized into internal and external. Failure costs are also called cost of poor quality.

3.5.5 Additional Quality Planning Tools[9]

Additional Quality Planning tools which help project and quality managers are as follows:

3.5.5.1 Affinity Diagramming

The affinity diagram helps to categorize brainstorming ideas.

3.5.5.2 Force Field Analysis

Force field analysis examines and evaluates all the forces for and against a decision. Project managers use this method to weigh the pros and cons of a decision.

3.5.5.3 Nominal Group Techniques

Nominal group techniques are structured procedures that identify and rank major problems or key issues that need to be addressed. Project managers may use this method to obtain multiple ideas from team members on a particular problem or issue.

3.5.5.4 Matrix Diagrams

Matrix diagrams are used to compare the efficiency and effectiveness of alternatives based on the relationship between two criteria. A project manager can use a matrix diagram to analyze the relationship between project cost and project performance.

[9] Elyse,PMP,CHIMPS, „Quality Planning“ (2006) – “http://www.anticlue.net/archives/000785.htm”

3.5.5.5 Flowcharts

Flowcharts are graphical representations of a process. A flowchart allows a project team to create a diagram of the events in a process. By examining flowcharts carefully, the project team can often identify gaps in workflow that could cause problems and errors.

3.6 Outputs of Quality Planning[10]

Management can increase chances of achieving quality in a product\process by understanding the Quality Planning outputs. The Quality Planning outputs are;

3.6.1 Quality Management Plan

Describes how the project management team will implement the performing organization's quality policy. It provides input to the overall project management plan and must address quality control (QC), quality assurance (QA), and continuous process improvement for the project.

3.6.2 Quality Metrics

A metric is an operational definition that describes in very specific terms, what something is and how the quality control process measures it.

3.6.3 Quality Checklists

A checklist is a structured tool, usually component-specific, used to verify that a set of required steps has been performed. Checklists may be simple or complex.

[10] S.S.K.Lam "Quality Planning Performance" (1997)

3.6.4 Quality Baseline

The quality baseline records the quality objectives of the project. The quality baseline is the basis for measuring and reporting quality performance as part of the performance measurement baseline.

3.6.5 Process Improvement Plan\Project Management Plan

Requested changes (additions, modifications, deletions) to the project management plan and its subsidiary plans are processed by review and disposition through the Integrated Change Control process.

Clarifying planning objectives before embarking on the planning process is an important first step in quality planning. In some organizations, quality planning has been conducted as a means of achieving top management involvement while some other organizations have conducted quality planning in order to identify potential quality improvement applications.[11]

Regardless of the sophistication of the process, the difficulty in quality planning lies in setting the right objectives and selecting one process approach over another. The ultimate objective of any quality planning exercise is to improve the overall performance of the organization through quality improvement of organizational efficiency and effectiveness.[11]

3.7 Quality Function Deployment (QFD)

Quality Function Deployment (QFD) is a potent multifunctional planning tool that integrates the voice of the customer into a product from design research right to the production process. QFD is used to encourage break-through thinking of new concepts and technologies. Its use facilitates the process of concurrent product engineering, encouraging teamwork, to work

[11] S.S.K.Lam “Quality Planning Performance” (1997)

toward a common goal of insuring customer satisfaction toward a common goal of insuring customer satisfaction.[12]

QFD has lots of processes and is a very wide topic, but relation with quality planning is that, the customer requirements, which are resulted from market research, warranty, and complaint summaries, can be very good and easily related with the product, process and production planning, which is again main issue of the quality planning.

3.8 Strategic Quality Planning

Strategic Quality Management (SQM) is the process of establishing long-range quality goals and defining the approach to meeting those goals. SQM is developed, implemented, and led by upper management. [13]

3.8.1 Seven Steps to Strategic Quality Planning[14]

1. *Customer Needs*: The first step is to discover the future needs of the customers. Who they will be? Will your customer base change? What will they want? How will organization meet and exceed expectations?
2. *Customer Positioning*: Next, the planners determine where the organization wants to be in relation to the customers. Do they want to retain, reduce, or expand the customer base? Products or services with poor quality performance should be targeted for break-through or eliminated.
3. *Predict the Future:* Next, the planners must look into their crystal balls to predict future conditions that will affect their product or service. Demographics, economic forecasts, and technical assessments of projections are tools that help predict the future. More than one organization's product or service has become obsolete because it failed to foresee the changing technology. Note that the rate of change is continually increasing.
4. *Gap Analysis:* This step requires the planners to identify the gaps between the current state and the future state of the organization.

[12] L.Hongen, Z.Xianwei "A Systematic Planning Approach To Implementing Total Quality Management Through Quality Function Deployment Technique" (1996)
[13] J.M.Juran, F.M.Gryna "Quality Planning and Analysis" (1993)
[14] D.H.Besterfield, C.B.Michna,G.H.Besterfield,M.B.Sacre, "TQM" (2003)

5. *Closing the Gap:* The plan can now be developed to close the gap by establishing goals and responsibilities. All stakeholders should be included in the development of the plan.

6. *Alignment:* As the plan is developed, it must be aligned with the mission, vision, and core values and concepts of the organization. Without this alignment, the plan will have little chance of success.

7. *Implementation:* This last step is frequently the most difficult. Resources must be allocated to collecting data, designing changes, and overcoming resistance to change. Also part of this step is the monitoring activity to ensure that progress is being made. The planning group should meet at least once a year to assess progress and take any corrective action.

Strategic planning can be performed by any organization. It can be highly effective, allowing organizations to do the right thing at the right time, every time.

3.9 Quality Planning Case Study

In this part, an example to the "quality planning road map" which is presented in earlier parts will be examined and presented. Example is based on the planning work done for the Ford Motor Company's Taurus model automobile.

In early 1980s, Ford began the initial planning for anew front-wheel-drive midsize car. The business environment included some ominous elements: strong foreign competition, decreasing market share, and projection of greatly increased fuel prices.[15]

Ford concluded that a new approach to designing the model was essential. Basic to the new approach was "customer satisfaction" with the objective being that the Taurus would be the best car in its class.[15]

Under Taurus, activities were organized as a team from beginning of the project. Thus, for example, manufacturing worked *simultaneously* with design and engineering before detailed specifications were finalized. This provided an opportunity to address producibility issues during the preparation of the specifications.[15]

[15] J.M.Juran, F.M.Gryna "Quality Planning and Analysis" (1993)

3.9.1 Steps and Applications[16]

i. ***Establish Quality Goals***: The quality goal was for Taurus to be "best in class."

ii. ***Identify those impacted-the customers:*** Some customers were obvious; others were not.

Company Function	*Customer*
Sales	Consumer
Legal	U.S Department of Transportation
Parts Manufacturing	Assembly plant

iii. ***Discover customers' need:***

Customer	*Need*
Consumer	Effective heater
DOT	Hi-mount brake light
Assembly plant	Ease of assembly

Need	*Translation*
Effective heater	Time to reach a required temp.
Ease of assembly	Reduction in the number of parts

These needs were detailed by conducting extensive marketing research and obtaining the input of technical experts.

iv. ***Develop Product Features***: This step made use of the marketing research to provide Product Development with detailed guidelines for 429 product features that were important to achieving high product salability. For example, the effort required to raise the hood was measured in pounds by a spring scale. Competitive data showed that the best competitor had a design requiring 9 pounds of effort. For Taurus, a goal of 8 pounds was set; the final design exceeded the goal by requiring only 7 pounds. Taurus achieved best in class for 80 percent of the product features.

[16] J.M.Juran, F.M.Gryna "Quality Planning and Analysis" (1993)

v. ***Develop Process Features***: The simultaneous approach to activities provided the Assembly Plant with the opportunity to identify specific manufacturing issues to be addressed during design and manufacturing planning.

vi. ***Establish Process Controls, Transfer to Operations***: As these plans were put into production, the coordination among all functions continued and resulted in final refinements to the product and process design.

4. QUALITY INSPECTION

The inspection of product and process has been a mainstay of quality programs since the inception of manufacturing processes. Often this inspection was performed by the craftsman or creator of the product. . The purpose of this inspection was to trigger and target corrective actions that would improve the delivered quality.

This approach worked well as long as production was law and nothing needed to be standardized, but, as industry evolved, problems with the simple system became apparent. Gradually, the inspection function was segregated from the manufacturing function. Skilled inspectors were created whose chief function was not to manufacture, but rather to inspect and judge. Entire departments were created to maintain this inspection function and keep it independent of production demands.[17]

In the past and even today, this inspection function can account for a large part of product's cost require a significant part of a company workforce. Inspection has an extensive track record that indicating that it can be an effective if sometimes expensive way in which to achieve higher quality product.[17]

4.1 Definitions

Inspection is the act of monitoring or observing, (usually involving sampling and related sampling plans), a process, procedure, or service to insure compliance with the operational definition and to insure that all customer requirements or internal prerequisites are meet.[18]

Inspection is a process of measuring, examining, testing . . . or any other comparison between unit [of product] and proper requirements.[19]

[17] William D. Mawby, "Integrating Inspection Management into your Quality Improvement System" (2006)

[18] „Quality Inspection" – "http://www.sixsigmaspc.com/dictionary/quality-inspection.html"

[19] Paulo Ghinato, „Quality control methods" (1998)

According to Garvin (1988), ***inspection*** has become an informal activity performed together with execution in order to ensure high-quality products. Mass production, interchangeability of parts and the increasing complexity of production cycles as well as products have set inspection apart from execution activities.[19]

Inspection, in turn, is the most important activity in the quality evaluation system of an industrial process. When correctly developed, the inspection makes possible to carry out a precise analysis of how the process operates and serves as a basis for a set of decisions that directly affect it, such as corrective and preventive actions which must be complied with in order to guarantee acceptable quality levels.[20]

4.2 Why inspecting earlier is generally better?[21]

As a preliminary, I want to emphasize an essential principle of quality management: "the sooner we eliminate errors, the better".

There are only six ways to deal with defects. They can be either prevented or corrected, and they fall into three broad categories: development, production, and delivery. Now let's look at a good illustration of this principle:

Stage	Prevent errors	Check & correct errors	1:10:100 ratio	Time consequences	Cost consequences
Development of style (samples)	Adapted design, capable factory		x1	Best option	Best option
		Early review of technical files	x1	Might cause slight delay	Very low cost
Mass production (workshop)	Good production & quality assurance		x10	Good option	More expensive
		Quality control after production	x10	Delays if repair is necessary	Expenses can balloon
Delivery to customer (shop/mail)	Exchange bad products		x100	-	Very high cost
		Customer keeps bad products	x100	-	Loss of future business

Table-1 "Quality Inspection" [21]

[20] E.P. Paladini, „An expert system approach to quality control" (2000)

[21] Reneaud Anjoran, "Quality Control" – "http://knol.google.com/k/renaud-anjoran/quality-control-the-three-types-of/28hirzfusi6bh/4#" (2009)

Many studies across all industries have demonstrated that there is a cost and time ratio for development: production: delivery of **1:10:100**. It means each error will cost **10** times more (in dollars and in time) to fix in production than it would to fix in development, and **100** times more if the error actually reaches the customer.

That's why checking quality only at the end of production is very risky. But you don't have to wait until everything is done.

4.3 General Requirements for Good Inspections[22]

Because inspections are so critical in the acquisition of the information that drives the basis of action on the process, it is important that the inspections be taken seriously. *Firstly*, they must be trough. One must make a list of all the important characteristics that are to be measured and must make this list known to the inspectors and facilitators of the inspection system. The definitions of the characteristics must be well-documented and well distributed throughout the organization.

Second, inspections must be consistent. That is, the application of the measurement must be coordinated between different inspectors, different instruments, and under different environmental conditions. Large differences between inspection methods can lead quickly to bad decisions about actions.

A *third* requirement for good inspections is that they be enabling. That is, they must actually measure something useful. More often than not, inspection are taken at easy-to-access places in the process rather that at true points of impact in a process. It is critical to think hard about process and to create an inspection system that portrays the real system that is of the interest for quality improvement efforts.

From a practical organization viewpoint, inspections should be done by qualified people using capable devices in stable, properly maintained environments. Often it is best to keep inspection personnel separate from production personnel to avoid conflict in interest.

[22] William D. Mawby, "Integrating inspection management into your quality improvement system" (2006)

Remuneration and rewards for inspection personnel should emphasis problem finding, but also communication of these findings back to appropriate personnel. Without some mechanism for using the inspection results to improve quality, there is really no value added for doing even a great inspection job. When inspection systems are more automatic and less based on human faculties, it is important to have some independent way to assess that they are still operating correctly.

4.4 Objectives of Inspection[23]

Inspection may be conducted in accord with the following purposes:

- Discovering defects;
- Reducing defects;
- Eliminating defects.

The objective of inspection is closely related to the nature of the abnormality to be detected. Inspection for discovering defects is designed to identify defects resulting from abnormal processing. Inspection for eliminating defects in turn depends on detecting errors during processing and taking immediate corrective action in order to avoid such error-originated defects.

4.4.1 A Defect

A defect is ``a deviation of one quality feature from its level or desired status which occurs with severity enough to lead a product or service far from requirements of use usually desired or reasonably predicted' ' (ASQC, 1983). A defect, therefore, is usually understood as an imperfection of an object of production (product/service). An error in turn might be defined as an imperfect execution of some activity which may lead to damage to the object, the agents of production or the planning.

[23] Paulo Ghinato, „Quality control methods" (1998)

When the inspection methods are designed to discover or reduce defects, it is usual to have defects classified according to severity of damage. Military Standard 105-D (1963), for instance, classifies defects as `critical', `major' and `minor'. The essence of this classification conveys the idea that some defects might be tolerable depending on the severity.

When the inspection methods are to eliminate defects, it seems unnecessary to classify defects since they are not to be tolerated. However, a classification of errors is necessary in order to identify the type of defect and to propose a suitable counter solution.
According to Shingo (1986), each inspection method has a different objective (Fig-3):

- Judgment inspection is used to discover defects;
- Informative inspection is used to reduce defects;
- Source inspection is used to eliminate defects.

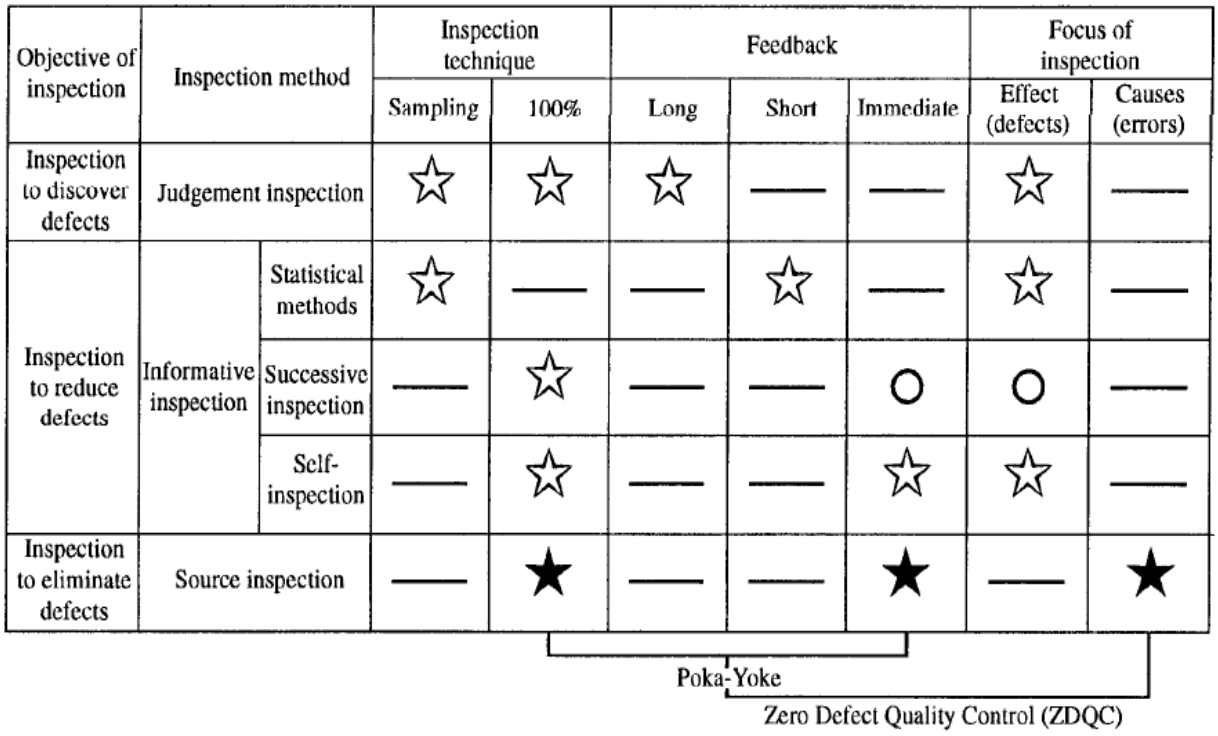


Figure-3 "Characteristics of quality control methods (after Shingo, 1986)". [23]

4.5 Inspection Methods[24]

4.5.1 Inspection to discover defects: Judgment inspection

This method might be effective for discarding defective products; it exerts a very limited impact upon wastes arising from producing defective goods, which is one of the seven great wastes proposed by Ohno (1988) and Shingo (1981). The judgment inspection method is based solely on detecting defects in the products rather than detecting errors during processing. It focuses on effects rather than causes.

It is common to have this method applied to batches (by 100% or sampling) soon after the processing. Therefore, in the case of detecting defects, the information is transferred to the person in charge of processing when there is no chance to correct it any more or when corrective action can no longer avoid large amounts of defectives. This inspection method concentrates its efforts on detection of defects instead of errors, and thus it may be compared with an autopsy and the issuing of a death certificate.

4.5.2 Inspection to reduce defects: Informative inspection

The second type of inspection process is the informative inspection, so called because as soon as a defect occurs all relevant information is transmitted to the person in charge of that particular process and immediate corrective action is adopted. This inspection method suggests that continuous correction and improvement of processing lead to a gradual decrease of defect rate.

Although informative inspection is superior to judgment inspection in its ability to reduce defects, it is important to recognize that it is still ineffective for the implementation and functioning of zero defects.
Therefore, no matter how effective the inspection method is, at least one defect must occur before corrective action is started.

[24] Paulo Ghinato, „Quality control methods“ (1998)

Shingo (1986) prefers presenting the informative inspection methods in three classes:

- Statistical Quality Control (SQC);
- Successive Inspection System (SuIS);
- Self-inspection System (SIS).

4.5.3 Inspection to eliminate defects: Source inspection

Essential to the method of source inspection is the identification and control of the causes of defects. Human errors are quickly detected and corrected, and thus the conditions for occurrence of defects are eliminated. Therefore, the effective utilization of source inspection depends on acknowledging the existence of cause-and-effect relationships between errors and defects, the identification of errors and the application of counteractive techniques. The main differences between source inspection on the one hand and informative and judgment inspections on the other are better understood from the viewpoint of control function.

The control cycle (feedback loop) of judgment and informative inspection methods unfolds according to the following steps: (Fig-4)

- An error (cause) happens but is not noticed;
- A defect (effect) consequently occurs and is then detected;
- Feedback is prompted;
- Corrective action is implemented.

In source inspection, the control function occurs as a smaller loop, focusing on cause rather than effect (Fig-4):

- Error (cause) takes place and is detected;
- Feedback is promoted at the error stage;
- Proper corrective action is then implemented.

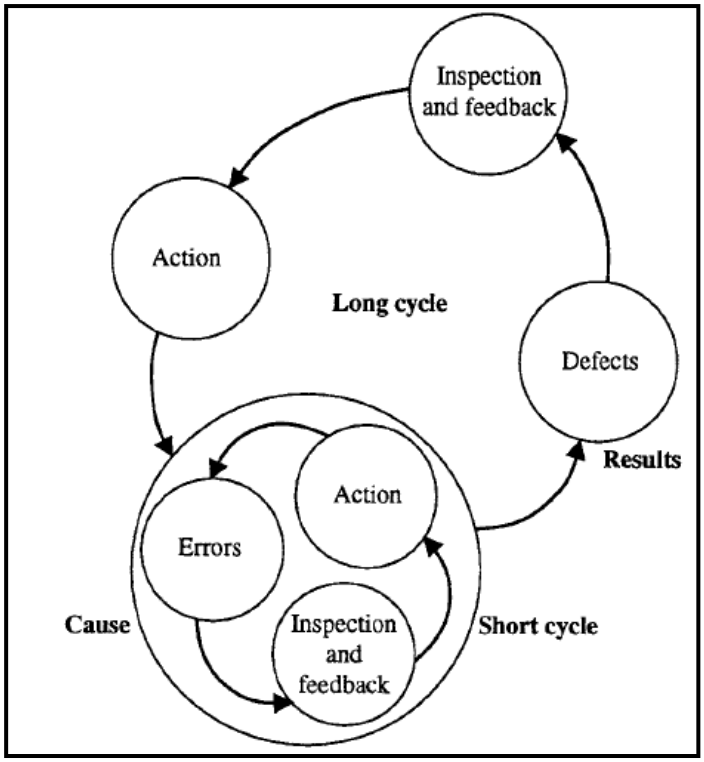


Figure- 4 "Control function and inspection methods" [25]

Therefore, putting the focus of control on the cause of abnormalities, the corrective actions are always directed to processing (agents) rather than to product (subject of production) as it occur in long control cycles of judgment and informative inspections. This strategy makes it possible to accomplish zero defects.

[25] Paulo Ghinato, „Quality control methods" (1998)

4.6 Where should Inspection occur?[26]

Deciding of the location of inspection points is done by the planners early in the product development cycle, when the manufacturing process is planned. It is usually different for each situation and, among other things, depends on the requirements to satisfy customer. Inspection should be considered for several situations (Figure 5).

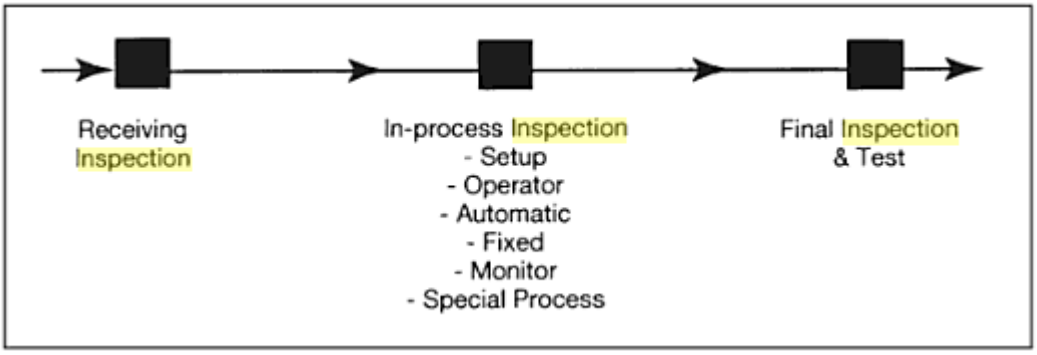


Figure-5 Typical Locations of Inspection in the Process[26]

If receiving inspection is used, inspection stations are located in the receiving area where parts and materials from suppliers are first seen. Based in relationship established with suppliers, receiving inspection may be considered unnecessary.

IN-PROCESS INSPECTIONS

As Dr Deming pointed out, inspection should not wait until a product is finished to determine problems and make corrections. In-process inspection gives an early warning and a chance to correct problems before loss occurs. There are several types of in-process inspections.

Set-up and first pieces inspection are of high priority to minimize the risk nonconforming products. Properly set-up, many processes run with desired consistency for the production run. It is important that sufficient part s be selected for inspection. A large sample, maybe 25 parts, is needed to establish that the process is set at target or nominal values. Also, the large sample will assess if variation is properly controlled. This can be a good predictor on well-controlled processes.

[26] William Winchell "Inspection and measurement in manufacturing" (1996)

Inspection and tests by the production operator are intended to give timely feedback so that the process can be kept in fine-tune. Feedback is immediate and there is an opportunity for instant correction of problems.

Automatic inspection and tests provide strategically placed information that can be used to drive process control devices that regulate the process. As mentioned previously, errors inherent in inspection by humans are eliminated by this equipment. Although still in use, there is a trend to eliminate **fixed inspection stations at points during the process** in favor inspections placed close to where the quality characteristic is determined. In this way, the information gained can be used to regulate the process in a timely manner.

Monitoring specific operations by patrol inspectors is still in use. But, trend is to integrate inspection into the production process and use information from it for regulating the process.

Special process inspection is performed on products when it's not feasible to inspect certain quality characteristics. Rather, the settings of the process that make the characteristics are closely monitored. An example of this is the plating of parts where variables of the process, such as pH values can be tracked.

FINAL INSPECTIONS AND TESTS

The final assessment is made as to whether requirements of the customer are met. Requirements pointed out in specifications are checked. Also looked at is whether all operations have been completed and processing is satisfactory. Several approaches are used. Sometimes a 100% inspection is used on products that have critical applications. In other cases, sampling is used. There is a trend toward using more automated inspection equipment to better handle complicated checks.

4.7 Solutions

A *Sensor* (American Heritage Dictionary 1985) is a device that receives and responds to a signal or stimulus. Sensors now exist for just about every type of inspection that one could wish to measure. These sensors can send and store data into databases where they can be analyzed with computer programs, or they can be somewhat intelligent in their own right.[27]

Inspections that at one time could only be done by humans can now be accomplished by sophisticated cameras using pattern recognition system. Inspections can be made simultaneously in a dozen different wavelengths and the information integrated in the blink of an eye. Computers allow one to analyze and design acceptance sampling plans that exactly meet the process conditions while still providing needed guarantees. Fast statistical methods can be used on process inspection almost immediately to create adaptive control schemes and even change the process design in response to events.

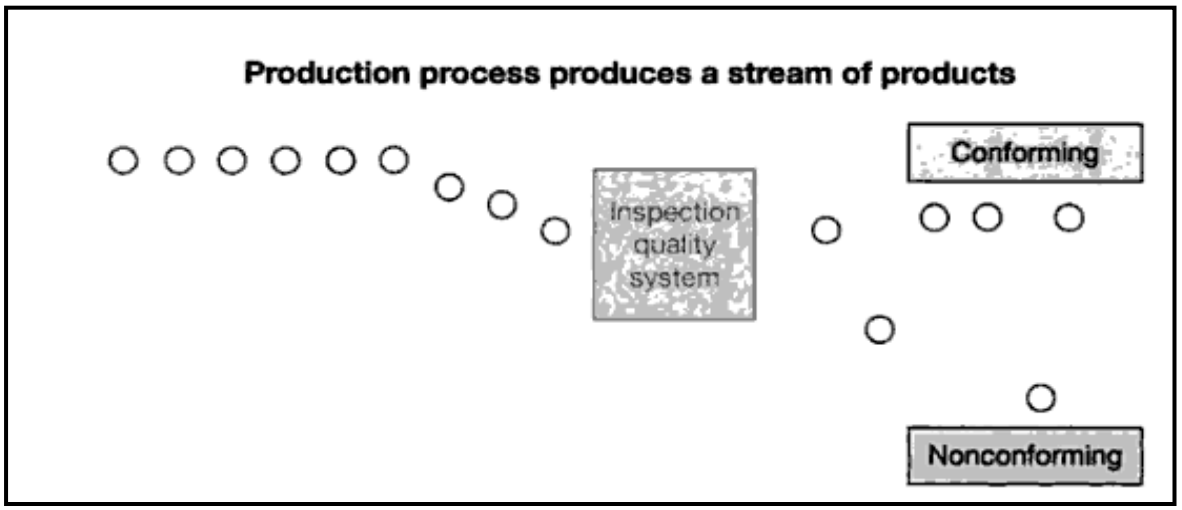


Figure-6 "The ideal inspection system acts as an intelligent filter to detect and divert nonconformities based on their match to specifications"[28]

[27] William D. Mawby, "Integrating inspection management into your quality improvement system" (2006)

[28] William D. Mawby, "Integrating inspection management into your quality improvement system" (2006)

Fundamentally, a manufacturer would like to manage its quality to meet its targets in a timely fashion with lowest cost. Inspection process quality management approaches propose that this can be accomplished by enacting a combination of adjustment policies that react quickly to process changes, control policies that create changes over a long time, and product sorting that culls bad product.[27] Figure-6 visualizes the integration of inspection systems.

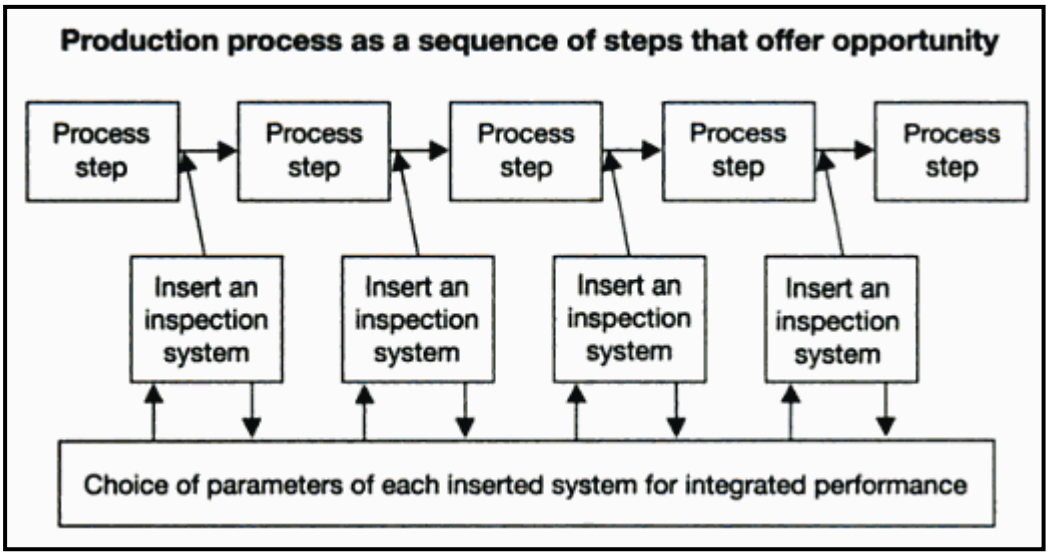


Figure-7 "The Integration of Inspection Systems"[27]

4.7.1 Automated Inspection[29]

Automated inspection and gauging systems can help companies to improve overall product quality and grow their business while reducing manufacturing costs, helping them to become more competitive in this difficult business climate. Whether they are producing automotive, medical, consumer, or virtually any other product, all companies have some type of quality inspection or gauging as part of their production process.

[29] Philip Smith "Automated Inspection and Gauging Improves Quality and Reduces Cost" (2009)

As **machine vision inspection cameras** and **laser-gauging sensors** have become more cost effective, many companies are **implementing automated inspection** and **gauging systems** in their facilities. These systems can be as simple as standalone **cameras or sensors integrated into existing machinery**, or as specialized as custom-designed and built turnkey **automated inspection machines**. No matter what type of system is ultimately selected, automated inspection and gauging offers companies many benefits over the older manual processes and they can help companies to compete more effectively for new business.

4.7.1.1 Types of Systems

There are four principle types of automated inspection and gauging systems. **First**, machine vision cameras or precision laser measurement sensors can be integrated into a company's existing machinery or process. This is the most basic and the lowest cost way to get started.

Next, these same vision cameras or laser sensors could be installed inside of enclosures with light guarding, a pass-through conveyor, a reject device, and controls to separate good products from bad products. These entry-level automated inspection and gauging systems are available from qualified integrators and suppliers that have programming, design, and build experience. **Third**, turnkey automated inspection and gauging systems are highly customized machines with multiple cameras or lasers and are designed specifically for a single part or a closely related family of parts. These machines are sometimes referred to as sorting machines because some of them can run 24/7 unattended. They usually include automatic feeder bowls, material handling, reject containment, good box full counters, packing, and labeling options.

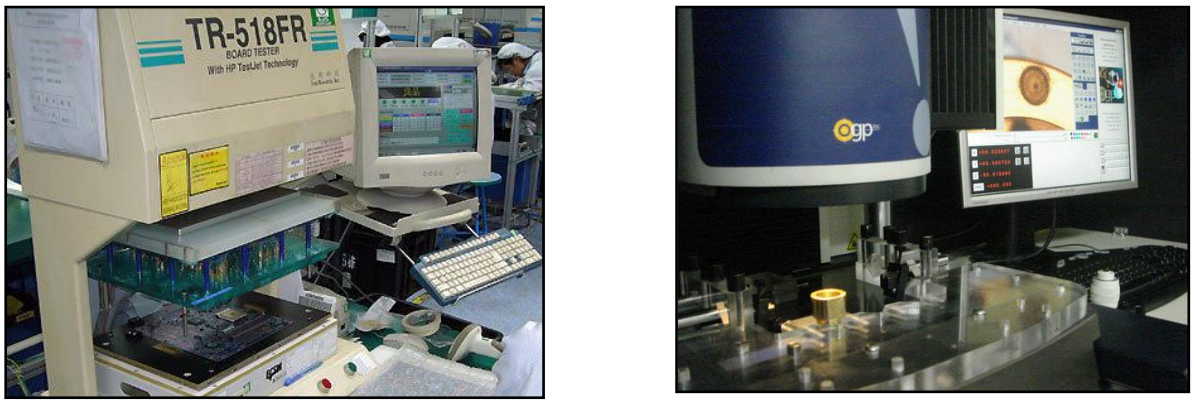


Figure-8 "Automated Inspection"[30]

[30] Automated Testing - http://img.tomshardware.com/us/2006/09/06/taiwans_new_economy_is_sink_or_swim/board-tester.jpg (2006)

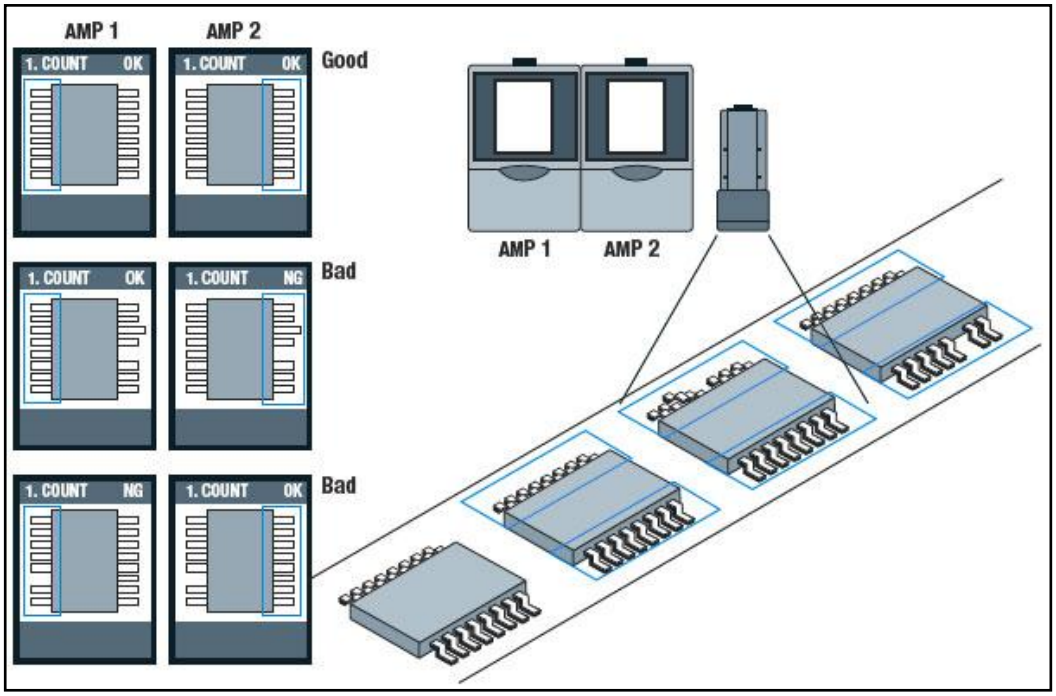


Figure 9 – "Automated Visual Inspection of Lead"[31]

Finally, the most flexible type of automated inspection and gauging systems utilize robots to move either the part or the camera/laser around for multiple inspections on more complex parts. These systems can be designed to process the widest variety of parts because the robots are programmed to accurately move to a large number of positions. Additionally, the robots can be equipped with end-of-arm grippers for double duty as the systems' load/unload pick-and-place device for even more flexibility. Robotic and turnkey automated (sorting) inspection and gauging systems are available from specialty machine manufacturers and the most experienced integrators.

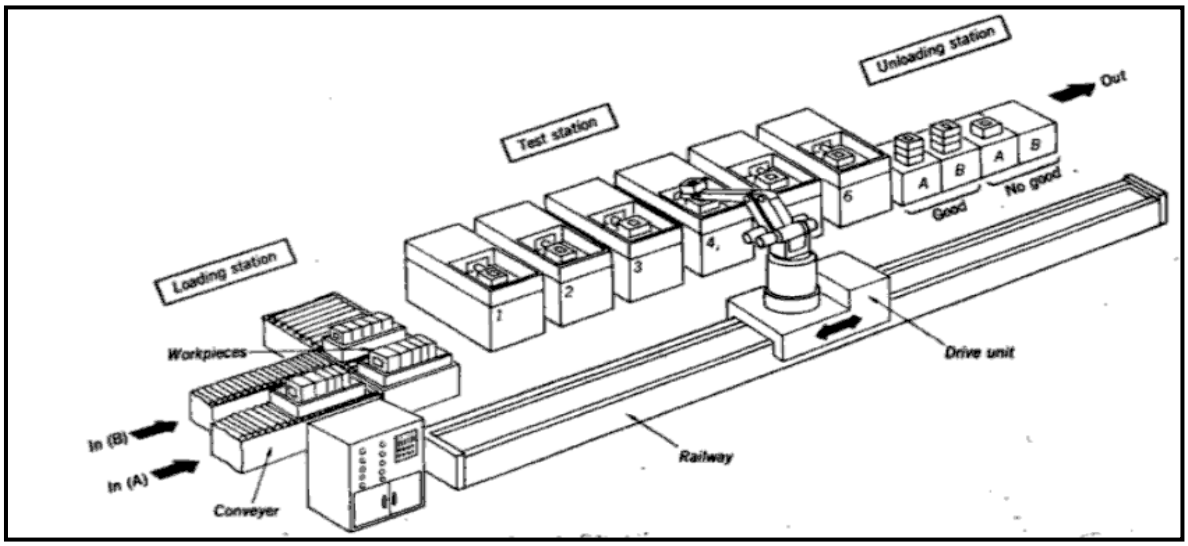


Figure – 10 "Complete inspection line utilizing a traveling robot. (Courtesy of Hitachi)[32]

[31] Automated Visual Inspection - http://www.omron-ap.com/news_center/pic/product22_pic02.jpg (2009)

[32] Stanley L.Robinson, Richard K.Miller – „Automated Inspection and Quality Assurence" (1989)

5. QUALITY CONTROL

Quality control is becoming a key success factor in many industrial areas. The need for high quality in production processes gives new impetus to the development and application of advanced control strategies for processes which, up to now, have been controlled with "classical" techniques.[33]

As the technologies used in the production become more advanced, quality control techniques also have to keep pace. It is not sufficient anymore to just inspect the end product and control the quality from the observations of the inspector. Quality control has to be systematically introduced from the very beginning of production, or at the design stage and followed up till the finished product has been put into performance. Quality control thus deals with the whole system of production or service and the methods which are employed to establish and achieve desired standards of quality and performance.[34]

5.1 Definitions

Quality control is the use of techniques and activities to achieve, sustain, and improve the quality of a product or service.[35]

Quality Control (QC) refers to the operational activities put in place to control the quality of a product or service. These include such activities as providing clear decisions and directions, constant supervision by experienced individuals, immediate review of completed activities for accuracy and completeness, and accurate documentation of all decisions, assumptions, and recommendations. Quality control procedures, if followed, should ensure that the work is done correctly the first time.[36]

[33] F. Lorito, "Adaptive Quality Control For Springs Production", (1997)

[34] Jain P.L.Jain "Quality control and total quality management" (2001)

[35] Dale H.Besterfield, "Quality Control" (1994)

[36] Dustin J. Haas, "Guidebook for Quality" – "http://www.oregon.gov/ODOT/HWY/QA/docs/qa_guidebook.pdf"

Quality control may generally be defined as a system that is used to maintain a desired level of quality in a product or service.[37]

5.2 How to Proceed with Control?[38]

Dr.Taylor used to describe control with these words, "plan-do-see". What word "see" mean? To Japanese middle school students, it simply means to look at, and that does not convey Taylor's meaning. So we have rephrased it as follows: "plan-do-check-action" (PDCA). This is what we call the Control Circle, (Figure – 10) and it must be made to move in the right direction. Control is to be organized based on these six categories, which have proven successful.

The six steps are:

1. Determine goals and targets — P
2. Determine methods of reaching goals
3. Engage in education and training. — D
4. Implement work.
5. Check the effects of implementation. — C
6. Take appropriate action — A

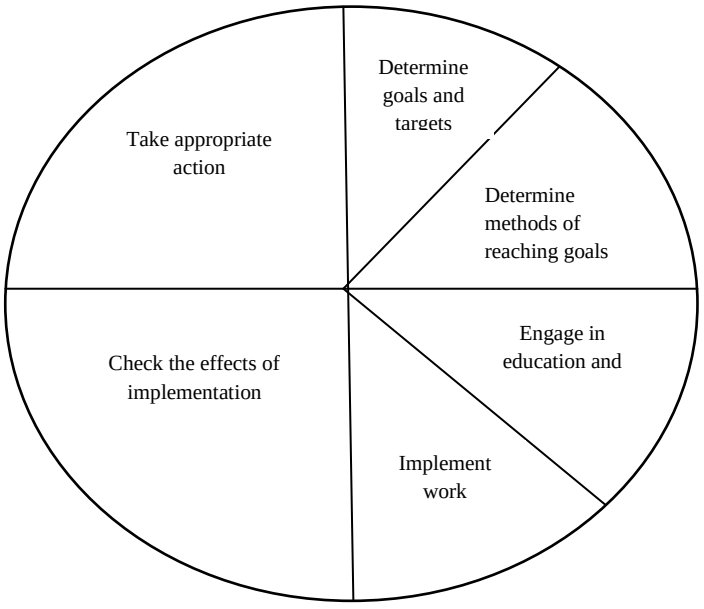


Figure-11 "Control Circle" [38]

[37] Amitava Mitra, "Fundamentals of Quality Control and Improvement" (1993)

[38] Kaoru Ishikawa, "What is Total Quality Control?" (1985)

5.3 Quality Control through Standardization[39]

Effective quality control and reliability can be largely achieved through adequate system of standardization. **Quality control** and **standardization** are synonymous each supplementing the other. Like quality control, standardization can be applied at every stage such as design, raw and in-process material selection and control, methods, process control, tooling design, equipment selection, production methods and techniques, stage inspection and final inspection as discussed below:

I. *Preparation of technical specifications* Standards can be adopted design and technical specifications can be prepared such that they are short, precise, positive and unambiguous and quantifiable with measurable characteristics.

II. *Preparation of standards on procedures and equipment used for inspection and testing* Test procedures, design of tools and gauges, testing and inspection of gauges, defect analysis and review can be laid down as standards.

III. *Preparation standards on manufacturing processes, methods and tooling* These standards if prepared *can* be very useful in streamlining production, avoiding wasteful practices and lowering costs.

IV. *Preparation of codes of practice to be used for guidance during manufacture or inspection* Initially, when a new process or technique is introduced, codes of practice which are based on established practices elsewhere can be useful in reducing trials and standardizing the process for the shop floor application.

V. *Preparation of standards on types and design of final products* In many cases of engineering products, such as machine tools, pumps, valves, electric motors, etc. it is possible to standardize the design of products at national or group levels for adoption by all concerned.

Standardization when properly adopted can be helpful in the prevention of defective items, defects or rejections, improving production yield and in **maintaining effective quality control**.

[39] Jain P.L.Jain "Quality control and total quality management" (2001)

5.4 Quality Control Techniques and Tools

Experts agree that, for quality programs to be effective, everyone must assume responsibility for quality. The argument is that the people doing the job are best equipped to recognize and correct quality problems quickly and effectively. It follows that all members of an organization should understand the tools that are useful in **quality control**.[40]

Percentage of QC Techniques Implemented In U.S. Firms by Manufacturing Activity

Control Procedures	*Design & Engineering*	*Research & Development*	*Manufacturing Process*	*Finance/ Accounting*	*Administration*	*Supportive Areas*	*Not Used (N/U)*
Nonstatistical QC							
Cause-and-effect diagram	17	16	41	7	7	16	33
Checklist	23	9	53	13	15	17	18
Statistical QC							
Fundamental methods							
Scatter diagram	5	2	14	1	N/U	5	54
Pareto charts	26	20	59	18	16	19	17
Frequency histogram	29	28	69	11	13	20	7
X and Rm charts	8	6	44	N/U	1	13	31
$\bar{X}$ and R charts	13	11	76	2	3	17	13
$\bar{X}$ and s charts	5	4	21	N/U	1	6	43
c charts	N/U	N/U	N/U	N/U	N/U	N/U	N/U
C charts	3	1	26	2	2	5	50
u charts	N/U	N/U	N/U	N/U	N/U	N/U	N/U
U charts	2	N/U	15	N/U	N/U	4	47
P charts	7	6	50	3	4	11	26
nP charts	4	2	24	1	N/U	2	50
Process capability	N/U	N/U	64	N/U	N/U	2	N/U
Intermediate methods							
100% Inspection	5	1	34	10	2	16	10
Sampling inspection	3	1	92	5	4	47	2
Advanced methods							
Correlation/regression	25	27	39	4	2	13	24
Analysis of variance	24	24	23	4	2	10	24
Multivariate analysis	8	18	15	1	1	3	50
Design of experiment	30	31	30	1	1	9	28
Reliability techniques	29	21	24	1	1	10	35
Operations research techniques	8	6	9	4	2	4	50

Table – 2 "QC Techniques in U.S. Firms"[41]

5.4.1 Non-statistical Quality Control

In the non-statistical quality control class, these three are most common: Checklists, cause-and-effect (or fish bone) diagrams and cost of quality. These tools are easily used and provide effective representations of quality problems.[41]

[40] Atkinson, Anthony A, "*Special quality control tools" (1990)*

[41] Modarress Bataoul, Ansari A. "QC Techniques in U.S. Firms" (1989)

Check lists consists of a representative listing of factors (such as materials, component parts, or processes) for monitoring and controlling the product in development stages.[42]

Sl. No.	Description	Setting	Remarks
1	Buchholtz alarm		
2	Buchholtz trip		
3	OTI alarm		
4	OTI trip		
5	WTI alarm		
6	WTI trip		
7	OLTC - OSR -t rip		
8	WTI/RTD repeater at control room		
9	Low oil level alarm		
10	REF relay		
11	Differential relay		
12	Back up O/C relay for current		
13	Back up O/C relay for time		
14	Back up earth fault relay for current		
15	Back up earth fault relay for time		
16	O/V relay for Voltage		
17	O/V relay for time		
18	Instantaneous O/V for voltage		
19	Over fluxing relay for Voltage		
20	Over fluxing relay for frequency		
21	Over fluxing relay for time		
22	Fan for over current		
23	Oil pumps for over current		
24	Setting of arcing horn gap		

Figure – 12 "Check list"[43]

Cause-and-effect (Fish bone) diagrams are used to identify the causes of an observed problem and to organize thinking about how to solve it. The problem is represented as the spine of the diagram. Factors believed to directly cause the problem are represented as ribs .joining into the spine. Sub-factors contributing to each main factor are shown as sub-ribs joining into the main ribs.[42]

[42] Modarress Bataoul, Ansari A. "QC Techniques in U.S. Firms" (1989)

[43] http://electricalandelectronics.org/wp-content/uploads/2008/09/check-list-for-transformers.png

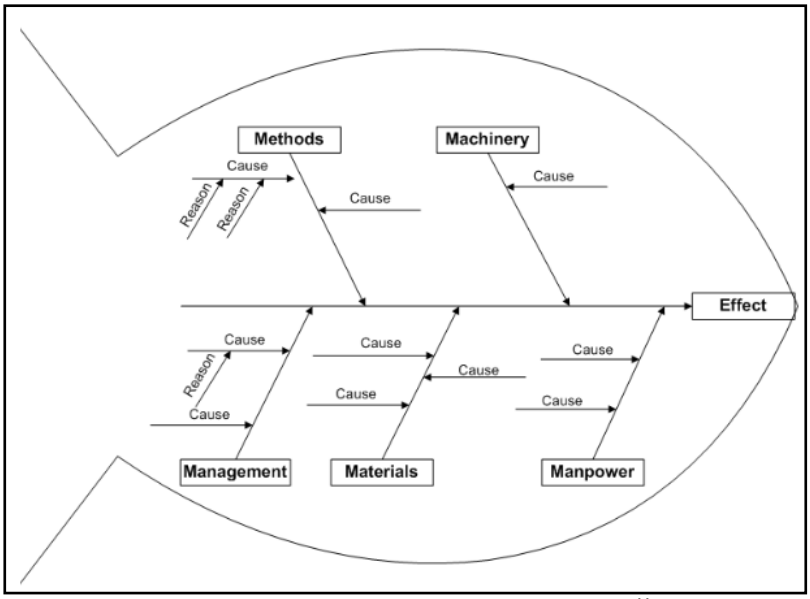


Figure – 13 "Cause-and –Effect Diagram"[44]

The **cost-of-quality method** identifies four costs of quality: prevention, detection, internal failure, and external failure. The idea is to minimize the total cost of quality. Quality experts differ on how this is done. Philip Crosby believes that one dollar spent on prevention will always generate more than one dollar of savings in detection and failure costs. Other experts, like Joseph Juran, believe that there is a balance. Resolving these issues is both a problematic and empirical issue. Some organizations' misuse this tool by arguing that quality costs should be some fraction; say five per cent of sales. That, however, is a perversion of this approach to quality control, since this criterion implies that quality costs are properly set in reference to some outside variable.[42]

[44] http://fishbone-diagram.org/wp-content/uploads/2009/04/fishbone-diagram.gif

5.4.2 Statistical Quality Control[45]

SQC techniques deal with a collection, analysis and interpretation of data related to the causes of variation in quality characteristics. SQC techniques can be categorized in three levels: fundamental, intermediate and advanced. Fundamental SQC techniques include scatter diagrams, Pareto histograms, frequency histograms; attribute control charts, and variable control charts.

Scatter Diagram

Improving quality characteristics necessitates finding the extent of the relationship between one cause and another or the relationship between two factors affecting quality, by using a scatter diagram.

The simplest way to determine if a cause and effect relationship exists between two variables is to plot diagram.[46]

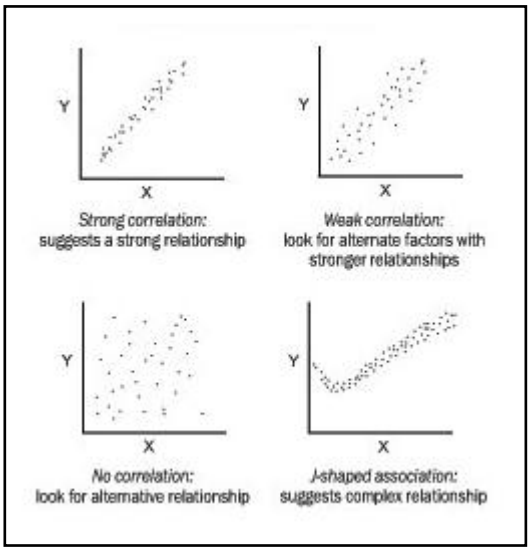


Figure – 14 "Scatter Diagram"[47]

[45] Modarress Bataoul, Ansari A. "QC Techniques in U.S. Firms" (1989)

[46] Dale H.Besterfield, "Quality Control" (1994)

[47] http://www.qaproject.org/images/scatterdiagraminterpretatio.jpg

The Pareto Histogram

The Pareto histogram assumes that a few problems are always significant in severity and frequency of occurrence. In either case, the problems are costly. The histogram indicates the factor that creates the most serious problem and should be solved first to reduce cost and improve productivity. The Pareto histogram is used by 59% of firms for manufacturing process, 26% for design, 20% for R&D, 19% in supportive areas, 16% for administration, and 18% for finance and accounting. (Table-2)

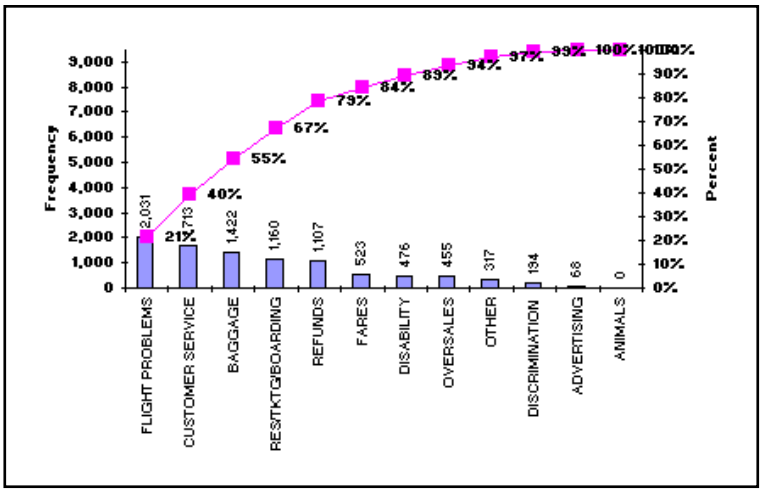


Figure- 15 "Pareto Histogram"[48]

Although frequency and Pareto histograms help in product and process analysis, their use is limited because they do not separate the causes of variations. Control charts are the most powerful tools to detect the causes of variation.

The Frequency Histogram

The technique is a process for arranging information derived from product characteristics in numerical order and frequency. It aids quality improvement by revealing information about the normality of the distribution, central tendency, and standard deviation.

Any process contains multitude of variables, such as raw materials, operations, machines, etc., that may be the source of two variables: common causes and special causes. If only common causes of variation are present, the output of a process forms the systematic pattern of a

[48] http://www.spcforexcel.com/files/images/airlinepareto.gif

normal distribution. But if special causes of variation are present, the process output is not stable over time and its pattern is not predictable. Using the frequency histogram identifies the presence if special causes of variations.

Control Charts

Control charts are time based graphics comparisons of actual product-quality characteristics with predetermined limits (defined by design engineers) for the product. An important distinction in the technical use of these charts is that between variable control charts and attributes control charts.

Control charts are excellent decision makers because the pattern of the plotted points will determine if the idea is a good one, poor one, or has no effect on the process.[46]

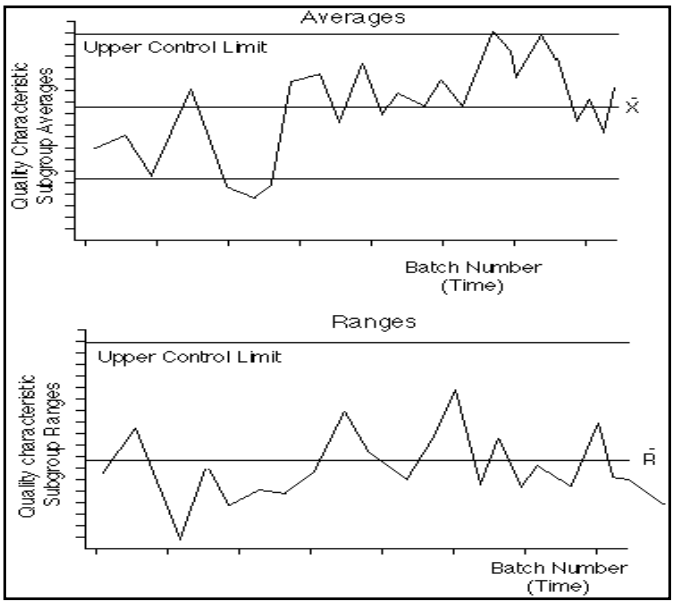


Figure – 16 "Control Chart"[49]

[49] http://www.ifm.eng.cam.ac.uk/dstools/gif/contro.gif

Variable Control Charts

Variable control charts include: X and Rm charts, $\bar{X}$ and R charts, and $\bar{X}$ and s charts. These techniques identify an actual measured quality characteristic, such as dimension, and indicate if the process is controlled and the product is consistent.

Attribute Control Charts

Attribute control charts identify relative values for products that should be visually confirmed, such as a cracks or missing components. Attribute charts are divided into defects and defectives, with two sub classifications of equal sample size and unequal sample size.
Control charts with equal sample size are called "c-charts", for one defect per sample, and "C-charts" for multiple defects per sample.

Attribute control charts for controlling the number of defects for unequal sample-size are "u-charts", for one defect per unit, and "U-charts", for multiple defects for unit. Control charts are used to determine if the products in question are within specifications, but they cannot determine if the process is capable producing products satisfactorily.

Intermediate SQC Methods

Intermediate SQC techniques, including 100% inspection and sampling inspection, are used to make after-the-fact decisions (such as a whether to ship the finished product to the customer or to scrap it), or as a complementary actions to fundamental techniques. Such decisions are necessary when materials are received from a preceding sub process or from an outside vendor.
Analyses of questionnaires showed that 34% of respondents use 100% inspection for process control, and 16% are using it for supportive areas; 92% use sampling for process control and 47% for supportive areas. These two techniques are not used by many firms for other manufacturing activities.(Table – 2)

Advanced SQC Methods

Advanced statistical methods, such as **correlation/regression**, **analysis of variance**, **experimental design**, **multivariate analysis**, various methods of operations research, and **reliability engineering techniques**, are used by engineers and industrial statisticians for solving complicated problems. An example would be selection optimum level of factors which quality of products. These techniques help to analyze the interaction of factors in design and R&D and help to reduce the variability inherent in the manufacturing process, where workers have minimal need for control charts and inspections.

5.5 End Control (Final Inspection & Test)

Final inspection is in fact the last inspection of the product that you will perform before dispatch but it may not be the last inspection before delivery. The term final inspection has three meanings:

- The inspection carried out on completion of the product- afterwards the product may be routed to storage areas rather than to a customer.
- The last inspection carried out before dispatch – afterwards you may install the product and carry out further work.
- The last inspection that you as a supplier carry out on the product before ownership passes to your customer – this is the final inspection of all inspections.

In place of the term final inspection, the term *product acceptance* is more appropriate and tends to convoy the purpose of the inspection rather than the stage of the inspection.[50]

5.5.1 Final Inspection Procedure[51]

There are two aspects to final inspection. One is checking what has gone before and the other is accepting the product.

[50] David Hoyle, "Automotive quality systems handbook" (2000)

[51] David Hoyle, "ISO 9000 pocket guide" (1998)

Final inspection and *test checks* should detect whether:

- All previous inspections and checks have been performed.
- The product bears the correct identification, part numbers, serial numbers, modification status etc.
- The as-built configuration is the same as the issue status of all parts, sub-assemblies, assemblies etc. specified by the design standard.
- All recorded nonconformities have been resolved and remedial action taken and verified.
- All inspection and test results have been collected.
- Any result outside the stated limits is either subject to an approved concession, an approved specification change or a retest which shows conformance with requirements.

Final inspection also serves as a final process control point, since it provides a positive evaluation of the effectiveness of the process control built into the production process flow. Feedback to preceding control process points provides a close-loop corrective action system for continuous process improvement.[52]

[52] Jack M. Walker, "Handbook of manufacturing engineering" (1996)

6. QUALITY AUDITS

The quality audit is a management tool used to evaluate, confirm, or verify activities related to quality. A properly conducted quality audit is a positive and constructive process. It helps to prevent in the organization being audited through the identification of activities liable to create future problems. The quality audit is a key factor in the management of the quality system of any organization, since it provides the data for evaluating and improving the effectiveness of that system. It is also the fundamental technique used for a "management review" of "management audit" frequently required by national and international procurement quality standards.[53]

6.1 Definitions

Quality audit is a systematic and independent examination, to determine whether the quality activities and related results comply with the planned arrangements and whether these arrangements are implemented effectively and are suitable to achieve objectives.[54]

The **quality audit** is intended to ensure that our business processes are designed and operated in such a way that the customer's contract requirements (both stated and implied) are met.[55]

Quality audit is a documented activity aimed at verifying by examination and evaluation that the applicable elements of the quality assurance program have been established, documented and implemented effectively in accordance with specified requirements.[53]

[53] Charles A.Mills "The Quality Audit" (1989)

[54] B. Scott Parsowith, „Fundamentals of quality auditing" (1995)

[55] David Wealleans, „The quality audit for ISO 9001:2000" (2005)

6.2 Internal & External Audits

Internal or **self audits** are also known as *"First-Party Audits"*. It is performed within your own company. This can be central group office auditing one of the plants, auditing within a division, local audits within the plant, or any number of similar combinations. There are no external customer-supplier audit relationship here, just internal customer and suppliers.[56]

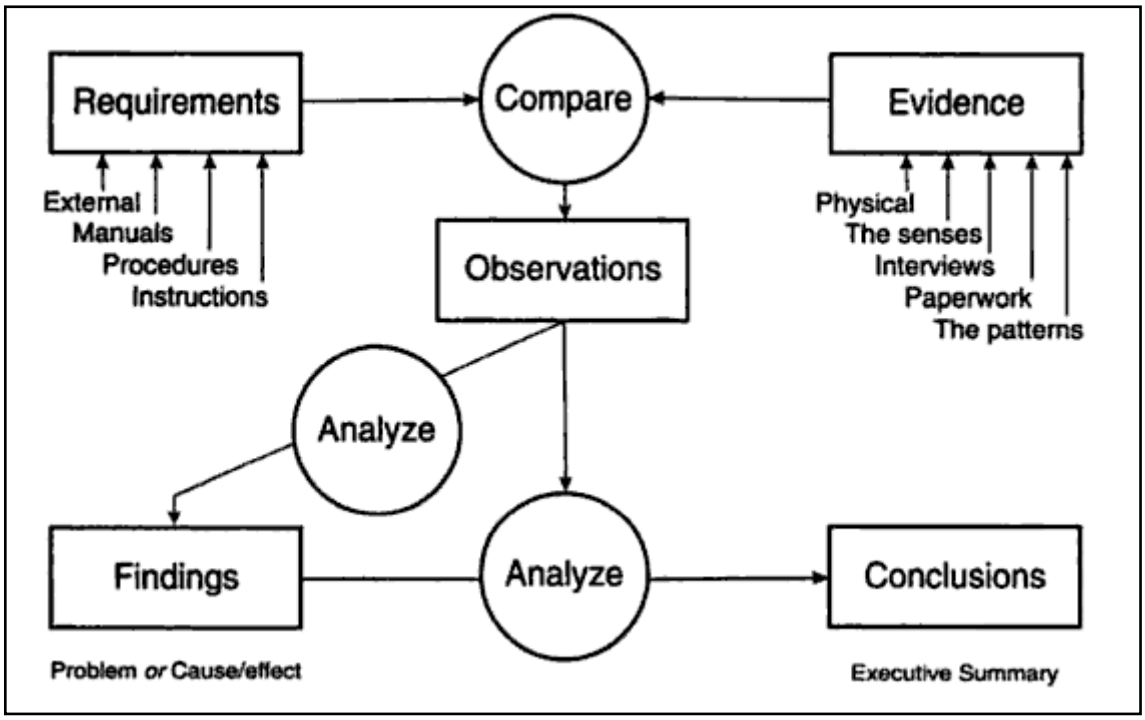


Figure – 17 "General Model for Auditing"[56]

The audit may be conducted by an individual or a team selected from audit specialist, managers, executives, etc. Normally, internal quality audits are involved with evaluating the conformance of the various activities to the quality program and the effectiveness of the quality system.[57]

[56] Dennis R. Arter, „Quality audits for improved performance" (2002)

[57] Charles A.Mills "The Quality Audit" (1989)

External audits are also known as "*Second-Party Audits*". A customer performs a second part audit on a supplier. A contract is in a place and goods are being, or will be, delivered. If you are in the process of approving a potential supplier through the application of these auditing techniques, you are performing a supplier survey. A survey is performed before the contract is signed; an audit is performed after the contract is signed.[56]

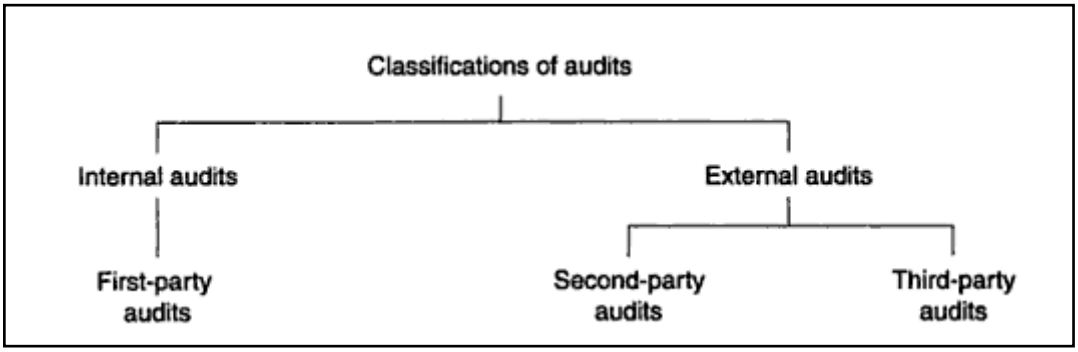


Figure – 18 "Classification of Audits"[58]

Regulators and registrars perform ***third - party audits***. Government may examine your operations to see if regulations are being obeyed. Through these regulatory audits, the consumer public receives assurance that the laws are being obeyed and the products are safe. Registration audits are performed as a condition of joining or being approved. Done properly, this registration promotes better business practices and greater efficiencies.[59]

6.3 Types of Audits

There are three primary types of audits that are described as follows:

6.3.1 System Audit

A system audit is a comprehensive audit involving all parts of a quality system to include quality management principles and practices, quality system structure and components, quality system operational procedures and instructions, quality system documentation, quality

[58] James P. Russell, „The ASQ auditing handbook" (2005)

[59] Dennis R. Arter, „Quality audits for improved performance" (2002)

system performance and mechanisms for continuous improvement of the quality system. While system audits focus on, and normally reveal, high-level issues related to the design and management of quality systems, quality system audits also encompass audits of selected individual processes as well as products\services.[60]

6.3.2 Process Audit

A process audit evaluates established procedures. It is an audit of in-process control of operations or a series of operation. It verifies that process procedures and work instructions exist, that they are appropriate, and they are being followed under standard conditions, rushed conditions, and adverse conditions.

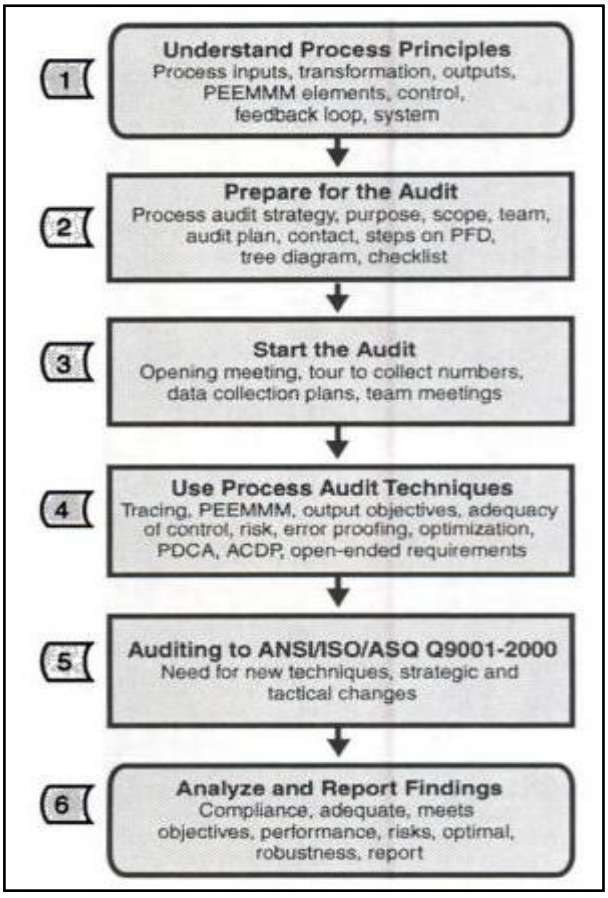


Figure – 19 "Process auditing detailed steps"[61]

[60] D. W. Benbow, A. K. Elshennawy, H. F. Walker "The certified quality technician handbook" (2003)

[61] J. P. Russell, „The Process Auditing Techniques Guide" (2003)

6.3.3 Product Audit

A product audit is even more detailed than process audit with respect to a focus on ensuring the product or service being audited will meet customer expectations. Product or service audits include the product\service design, operational specifications, research and development or test data, trials or performance data, customer satisfaction data, and failure data. Product audits are, however, commonly completed by business – to – business customers purchasing products\services as a final check or approval following the design and development of these new product\services from another company or other vendor outside their company or by another division, department, or work center within their own company.[62]

6.4 Planning the Quality Audit[63]

The activities for a quality audit by the auditing organization cover a wide gamut of functions involving actions and reactions from the three parties that will be involved in the audit- the client, the auditee, and the auditing organization itself. These activities include the following;

1. Determining implications of the quality audit.
2. Understanding the resources needed for the audit.
3. Scheduling the audit.
4. Sequencing the quality audit functions.
5. Preparing or gathering working papers for the audit.
6. Determining the sampling procedures to be used in the audit.
7. Interpreting the quality audit observations.
8. Reporting the results of the audit.
9. Requesting and following up on corrective action.

[62] D. W. Benbow, A. K. Elshennawy, H. F. Walker "The certified quality technician handbook" (2003)

[63] Charles A.Mills "The Quality Audit" (1989)

6.5 Reporting the Quality Audit

The report showing the results of a quality audit is the raison d'etre of that audit. It is the product of audit activity, with all other audit activities simply being means to this end. And the quality audit report, whether for an external or an internal audit, must satisfy the needs of the customer, i.e. of the client. This principle applies regardless of the relationships between the client, the auditor and the auditee. In all cases, decisions about the distribution of an audit report rest with the client.[63]

Reporting the Quality Audit	
Verbal Reports	- During the Audit - Audit Debriefing
Letter Form	- Client - Recommendation - Auditee Approval - Auditee Nonapproval
Written Report	- Daily - External Client Management - Report - Executive review
Graphic Presentation	- Composite Audit Reports - Decision Sampling Report - Monthly Audit Reports - Performance Chart - Corrective Action Report

Table – 3 "Reporting the Quality Audit"[63]

Reports are presented in both **verbal** and **documented** forms. **Clarity** and **accuracy** are key requirements for every report, and the reporting **format** and **language** should be designed to readily convey the desired message to the recipient. Thus it may be necessary to use more than one type of report to satisfy differing needs. This could complicate the preparation of reports. However, with modern word processing equipment and personal computers, a variety of format presentations can be easily preset to minimize the labor involved in those preparations.[63]

7. QUALITY CIRCLES

Quality circles (QCs) can be broadly defined as the meeting of minds during a quality journey to attain customer satisfaction through continuous improvement and teamwork. Besterfield (1994) suggests that this journey must entail a clear understanding of the role of the customer (internal and external), and the involvement and commitment of employees at all levels of an organization.

In addition, intense customer focus, a keen spirit of continuous improvement, strong process focus, coordinated teamwork and proactive employee participation are active ingredients for a QC culture to take root. Employee involvement should go beyond the mere request for suggestions on quality improvement. It should encourage employees to pursue their innovative ideas, work and learn with other team members to solve identified problems creatively, and to improve the work systems for efficiency and effectiveness' sake.[64]

7.1 Definitions

The quality circle is a small group to perform quality control activities voluntarily within the same work shop. This small group carries on continuously as a part company-wide quality control activities self-development and mutual development control and improvement within the workshop utilizing quality control techniques with all the members participating.[65]

Quality Circles are small groups consisting of 5-10 employees from the same work area who meet regularly and voluntarily to identify and solve work related problems.[66]

Quality circles are a formal, institutionalized mechanism for productive and participative problem-solving interaction among employees. Small groups of workers engage in a continuing cooperative study process to uncover and solve work related problems.[67]

[64] Mark Goh„Quality Circles“, (1999)

[65] Kaoru Ishikawa, “What is Total Quality Control?” (1985)

[66] Franz J.Brunner, Karl W.Wagner, “Taschenbuch Qualitaetsmanagement” (2008)

[67] O. L. Crocker, J. S. Leung Chiu, C. Charney, “Quality circles” (1984)

7.2 The Concept of Quality Circles[68]

The concept of Quality Circle is primarily based upon recognition of the value of the worker as a human being, as someone who willingly activates on his job, his wisdom, intelligence, experience, attitude and feelings. It is based upon the human resource management considered as one of the key factors in the improvement of product quality & productivity. Quality Circle concept has three major attributes:

- Quality Circle is a form of participation management.
- Quality Circle is a human resource development technique.
- Quality Circle is a problem solving technique.

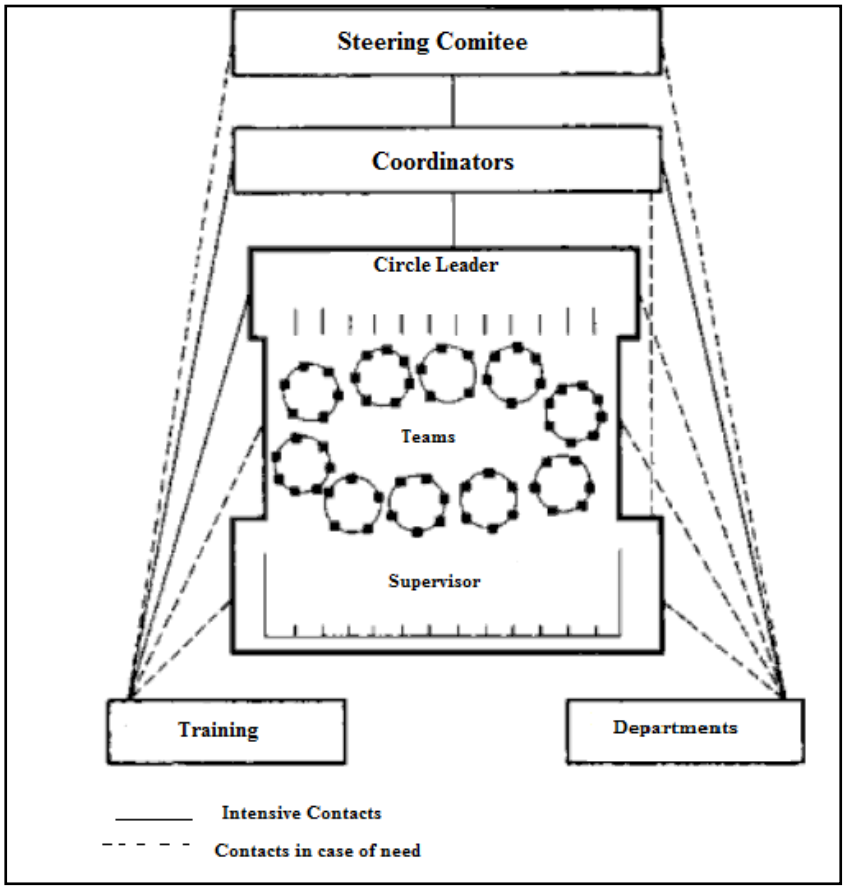


Figure – 20 "Quality Circles Organization"[69]

[68] Kumar Mishra, "ISO and Quality Circles" – "http://www.mahapwd.com/isoandqualitycircle/qc.htm"

[69] Franz J. Brunner, "Japanische Erfolgskonzepte" (2008)

7.3 Formation of Quality Circle[70]

The following basic elements constitute the structure of the quality circle:

I. Top Management
II. Steering committee
III. Coordinator
IV. Facilitator
V. Leader
VI. Members
VII. Non-members

The success of the quality circles depends solely on the attitude of the top management and plays an important role to ensure the success of implementation of quality circles in the organization. Steering committee called middle management consists of chief executive heads of different divisions or a coordinator plays a positive role in quality circles activities for the success of the efforts.

The meetings are conveyed at least once in one to two months interval. Coordinator also acts as facilitators is an individual responsible for coordinating and directing the quality circles activities within an organization and carries out such functions as would make the operations of quality circles smooth, effective and self-sustainable. Facilitator also acts as a catalyst, innovator, promoter and teacher and is nominated by the management. Leader of the quality circles is chosen by the members among themselves and they may decide to have a leader by rotation since the members are the basic elements of the structure of quality circle. Members of the quality circles are the small group of people from the same work area or doing similar type of work whereas non-members are those who are not members of the quality circle but may be involved in the circle recommendation.

[70] F Talib, M Ali, „Impact of Quality Circle" (2003)

7.4 Objectives[71]

The objectives of Quality Circles are multi-faced.

A) **Change in Attitude.**
- From "I don't care" to "I do care"
- Continuous improvement in quality of work life through humanization of work.

B) **Self Development**
- Bring out 'Hidden Potential' of people
- People get to learn additional skills.

C) **Development of Team Spirit**
- Individual Vs Team – "I could not do but we did it"
- Eliminate inter departmental conflicts.

D) **Improved Organizational Culture**
- Positive working environment.
- Total involvement of people at all levels.
- Higher motivational level.
- Participation Management process.

7.5 Basic Problem Solving Techniques

The following techniques are most commonly used to analyze and solve work related problems.[71]

1) Brain storming
2) Pareto Diagrams
3) Cause & Effect Analysis
4) Data Collection
5) Data Analysis

The Quality Circles also are expected to develop internal leadership, reinforce worker morale and motivation, and encourage a strong sense of teamwork in an organization.

[71] Kumar Mishra, "ISO and Quality Circles" – "http://www.mahapwd.com/isoandqualitycircle/qc.htm"

A variety of benefits have been attributed to Quality Circles, including higher quality, improved productivity, greater upward flow of information, broader improved worker attitudes, job enrichment, and greater teamwork.

Problem quality circles often suffer from unrealistic expectations for fast results, lock of management commitment and support, resistance by middle management, resentment by non participants, inadequate training, lack of clear objectives and failure to get solutions implemented.

7.6 Benefits of Quality Circle Activities[72]

The best way to describe the benefits employees obtain from their participation in quality circles is to quote their feelings.

- Quality circles develop a team atmosphere.
- It provides for easy exchange of ideas in a small group rather than in a large meeting.
- Helps inter-group cooperation and relationships.
- Reduces defects.
- Gives a better understanding of job requirements.
- Gives a means of bringing problems to light.
- Meeting in closed rooms gives the opportunity for frank and open discussions.
- Helps to develop leadership.

7.7 Challenges in Quality Circles[73]

The major challenges in sustaining the quality circles are;

1. Lack of understanding what Quality Circles may cause management to be reluctant to initiate circles, act upon circle suggestions; or being eager for quick solutions, may implement these suggestions too early.

[72] Ira B.Gregerman, "Introduction to Quality Circles" (1979)

[73] Sathish Chandran, "Quality Circles" - http://www.dqg.org/pdfdata/06.Wipro%20Consulting%20Services_QQ0808.pdf

2. Lack of clear purpose or direction; without having a clear purpose it is difficult to be a productive team.

3. Lack of volunteers; under circumstances like this, the employee at times is reluctant to be part of the team and the team loses focus.

4. Lack of support from Management and loss of interest in the project that the circle is working on is also a hindrance in the success of the circle.

5. Without empowerment and support of the management staff, circles will not have the resources provided to them to be successful.

8. CONTINOUS PROCESS IMPROVEMENT

Quality is a never ending quest and Continuous Process Improvement (CPI) is a never ending effort to discover and eliminate the main causes of problems. It accomplishes this by using small-steps improvements, rather than implementing one huge improvement. The Japanese have a term for this called "kaizen" which involves everyone, from the hourly workers to top-management.[74]

Continuous Process Improvement (CPI) is viewed as vital in today's business environments. CPI is one of the core strategies towards manufacturing excellence, as it appears, for example, within the context of ``world-class manufacturing'' or ``total quality management". Furthermore, CPI as a concept is nothing difficult to understand or new. Bessant and Caffyn (1997) define the concept as ``an organization-wide process of focused and sustained incremental innovation". Many tools and techniques are developed to support these processes of incremental innovation.[75]

8.1 Definitions

Continuous improvement is a management philosophy and system that organize employees and processes to maximize customer value and satisfaction.[76]

Most, if not all, definitions of CI include statements about what CI activities seek to accomplish. The most frequently stated intentions include "organizational effectiveness and competitiveness" and "enhanced customer satisfaction". Outcome criteria of greater specificity, such as cost reduction, flexibility, and reduced cycle time are also considered.[77]

[74] Clark, D. R, "CPI" (2008) – "http://www.nwlink.com/~Donclark/perform/process.html"

[75] J. de Leede , J. K. Looise, "Continuous improvement and the mini-company concept" (1999)

[76] H. Czarnecki; B. J Schroer; M. Adams; M. S Spann, "CPI" (2000)

[77] S. J. Hamid Noori, J. L. Michela, "The dynamics of continuous Improvement" (1996)

8.2 The Continuous Improvement Process[78]

As a total management system, continuous improvement provides a set of tools and techniques that can result in outstanding performance if implemented completely over a period of several years. One of the most significant components of continuous process improvement is its goal of compressing time in every way possible.

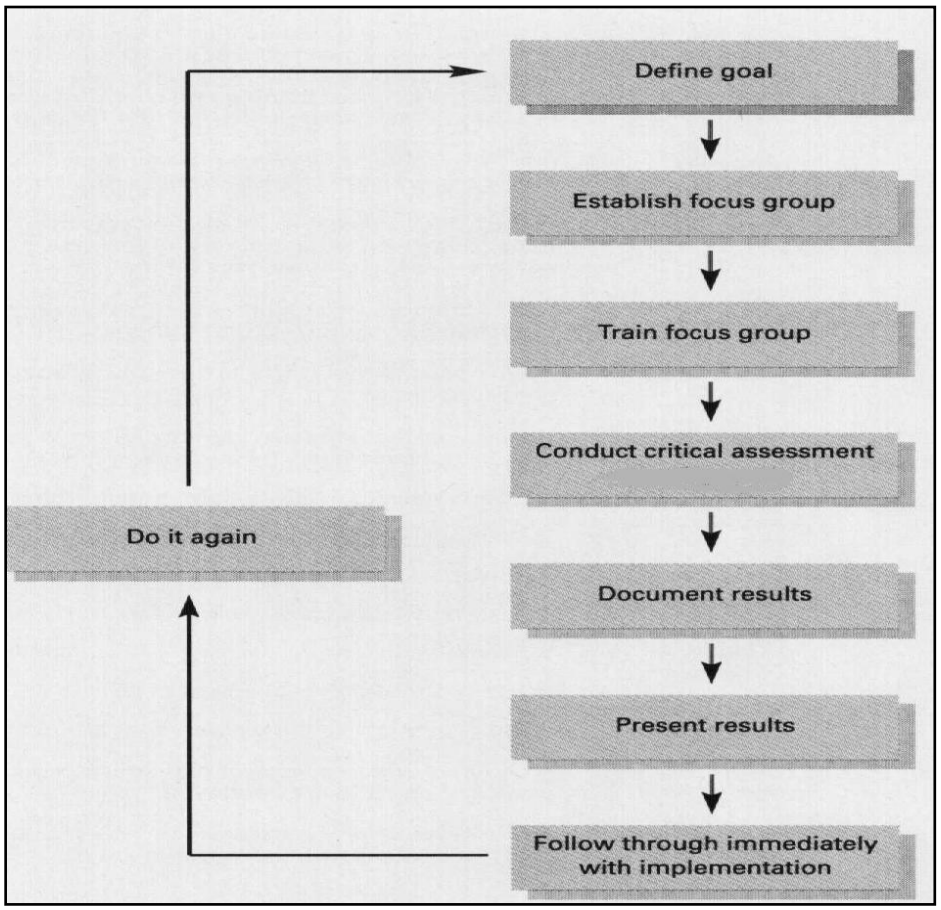


Figure – 21 "Continuous Process Improvement Phases"[78]

Figure – 19 shows the phases in a continuous improvement process. With CPI, employees become part of a process in which decisions are a team effort. In order to provide employees with the necessary tools, constant employee training must be the foundation of any CPI effort.

[78] H. Czarnecki; B. J Schroer; M. Adams; M. S Spann, "CPI" (2000)

CPI also requires a dedication to following through with immediate implementation. Management must be tolerant, supportive and allow for failures. This demonstrates a total commitment to CPI. Successes, as well as failures, should be published to show that the employees' efforts are supported and to give them the momentum to try again.

8.3 Continuous Process Improvement Techniques and Tools

In this section, it is going to be studied some techniques and helping tools of CPI, such as Kaizen, Six-Sigma, The CEDAC approach and some other helping tools.

Five S's	1. Simplify—separate and eliminate unnecessary things. 2. Straighten—arrange the essential things in order so they can be easily accessed. 3. Scrub—keep machines and work area clean. 4. Stabilize—make cleaning and checking a routine practice. 5. Sustain—standardize the first four S's so the process is never ending.
Five whys	Ask "why" five times of a problem. By repeating "why" five times, you can expose the real root cause of the problem rather than merely respond to the symptoms.
Visual factory	A shop floor concept in which the same information is made easily available and understandable for each operator to use in achieving continuous improvement. Examples of visual factory techniques are color-coded dies, labels in kanban areas and shadow boxes for tooling.
Teams	The continuous improvement process changes the focus from traditional management and department controls to team building through process change.
Quality tools	Typical quality tools include flowcharts, frequency histograms, Pareto diagrams, cause and effect diagrams, and control charts.
Poka-yoke	Various sized guide pins, alarms, limit switches, counters, and checklists and other simple, low cost devices that eliminate or reduce defects by preventing mistakes.
Seven wastes of manufacturing	1. Overproduction—producing more product than needed. 2. Waiting—idle operator or machine time because the process is not balanced. 3. Transportation—material movement that does not directly support value added operations. 4. Nonvalue added processing—any process that does not add value to a product. 5. Excessive inventory—any excess of supplies required to produce product. 6. Useless motion—movement of people or machines that does not add value. 7. Making defective parts—repairing products to fulfill customer requirements.
Total productive maintenance	A companywide equipment maintenance program that covers the entire equipment life cycle and requires participation by every employee.
Single minute exchange of dies	A technique or process that allows the production of a wide product mix without slowing output or creating higher costs associated with the waste of setup.
Work balancing	Matches work content to takt time to maximize operator efficiency.
Cell layout	The proper placement of machines to achieve an operational objective and compress time.
One-piece flow	Operators focus on one part through the process before starting the next part. Dramatically reduces handling and transportation and provides immediate feedback about overlooked defects.
Kanban	A mechanism that links production activity to customer demand. A kanban system controls the production of the required parts in the required quantities and at the required time.

Table – 4 "Continuous Process Improvement Tools"[78]

A brief description is of tools is given in (Table- 4) and some of these tools will be examined in the following sections.

8.3.1 Kaizen

Kaizen is a Japanese word for the philosophy that defines management‘s role in continuously encouraging and implementing small improvements involving everyone. It is the process of continuous improvement in small in small increments that make the process more efficient, effective, under control, and adaptable. Improvements are usually accomplished at little or no expense, without sophisticated technique or expensive equipment. It focuses on simplification by breaking down complex processes and then improving them.[79]

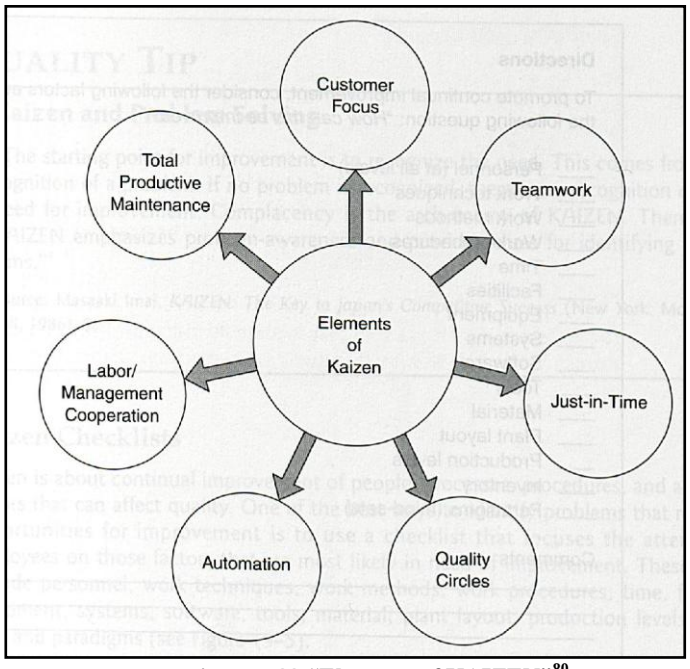


Figure – 22 “Elements of KAIZEN”[80]

The Kaizen improvement focuses on the use of:[79]

1. Value-added and non -value-added work activities.
2. *Muda*, which refers the seven classes of waste – over-production, delay, transportation, processing, inventory, wasted motion, and defective parts.

[79] D.H.Besterfield, C.B.Michna,G.H.Besterfield,M.B.Sacre, “Total Quality Management” (2003)

[80] David L.Goetsch,Stanley B.Davis, „Quality Management“ (2003)

3. Principles of motion study and the use of cell technology.
4. Principles of materials handling and use of one-piece flow.
5. Documentation of standard operating procedures.
6. The five S's for workplace organization, which is five Japanese words that mean proper arrangement (Seiko), orderliness (seiton), personal cleanliness (seiketso), cleanup (seiso), and discipline (shitsuke).
7. Visual management by means of visual displays that everyone in the plant can use for better communications.
8. Just-in-time principles to produce only the units in the right quantities, at the right time, and with the right resources.
9. Poka-joke to prevent or detect errors.
10. Team dynamics, which include problem solving, communications skills, and conflict resolution.

Kaizen relies heavily on a culture that encourages suggestions by operators who continually try to incrementally improve their job or process. An example of a Kaizen-type improvement would be the change in color of a welding booth from black to white to improve operator visibility. The change results in small improvement in weld quality and a substantial improvement in operator satisfaction. The PDSA cycle described earlier may be used to help implement Kaizen concepts.[79]

8.3.2 Six-Sigma[81]

Six-Sigma has been launched all over the world and many companies testify to its pivotal role in their success. Well-known examples of Six Sigma companies include Motorola, General Electric, AlliedSignal (now Honeywell), ABB, Lockheed Martin, Polaroid, Sony, Honda, American Express, Ford, Lear Corporation and Solectron.[82]

[81] D.H.Besterfield, C.B.Michna,G.H.Besterfield,M.B.Sacre, "Total Quality Management" (2003)

[82] Bengt Klefsjo, H.Wiklund, R.E.Edgeman,"Six-Sigma" (2001)

Statistical Aspects

According to James Harrington, "Six-sigma was simply a TQM process that uses process capability analysis as a way of measuring process." Sigma, **σ**, is the Greek symbol for the statistical measurement of process variability, because the smaller the deviation value, the less variability in the process. Figure- 21 shows a process that is normally distributed and centered with upper and lower specification limits (USL and LSL) established at ± 6 **σ**. For this situation, 99, 9999998% of the product or service will be between specifications, and the nonconformance rate will be 0,002 parts per million, or 2, 0 per billion. The situation diagrammed represents a process capability index (Cp) of 2, 0. A Cp of 1.33 has been a de facto standard. Table -5 shows the percent between specifications, nonconformance rate, and process capability for different specification limit locations.

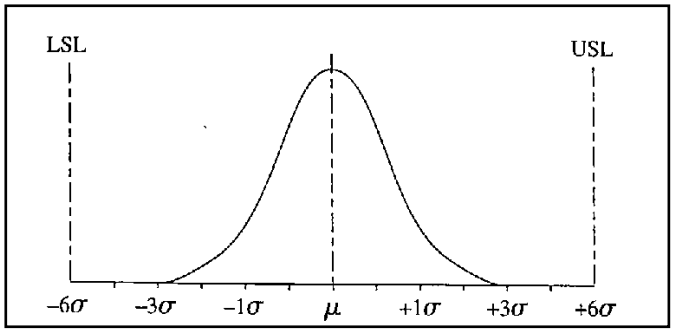


Figure – 23 "Nonconformance rate when process is centered"

According to the six-sigma philosophy, process rarely stay centered- the center tends to "shift" above and below the target **σ**. Figure- 22 shows a process that is normally distributed, but has shifted within a range of 1,5 **σ** above and 1,5 **σ** below the target. For the diagrammed situation, 99, 9996600 % of the product and service will be between specifications and nonconformance rate will be 3,4ppm.

Specification Limit	*Percent Conformance*	*Nonconformance Rate (ppm)*	*Process Capability (C_p)*
±1σ	68.7	317300	0.33
±2σ	95.45	485500	0.67
±3σ	99.73	2700	1.00
±4σ	99.9937	63	1.33
±5σ	99.999943	0.57	1.67
±6σ	99.9999998	0.002	2.00

Table – 5 "Nonconformance rate and process capability"

This off-center situation gives a process capability index (Cpk) of 1,5 with 1,0 being the de facto standard. Note that the index is calculated differently, and therefore, has a different symbol (Cp vs. Cpk).

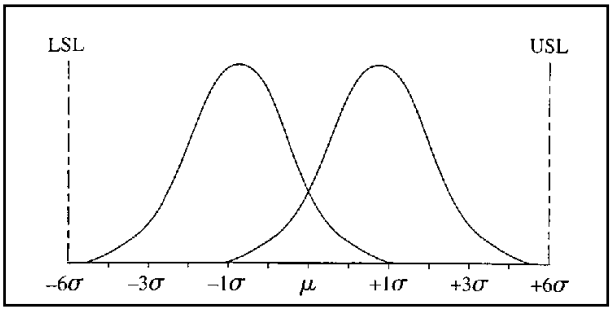


Figure – 24 "Nonconformance rate when process is off center ± 1.5 σ"

Table-6 shows the percent between specifications, nonconformance rate, and process capability for different specification and limit locations. The magnitude and type of shift is a matter of discovery and should not be assumed ahead of time. None of the case studies in the literature have indicated a shift as great as 1,5 **σ**. The automotive industry recognized the concept in the mid-1980's, evaluated it and deemed in unacceptable. In fact, the original work of six-sigma was based on only a few empirical studies of a single process.

Specification Limit	*Percent Conformance*	*Nonconformance Rate (ppm)*	*Process Capability (C_{pk})*
±1σ	30.23	697700	– 0.167
±2σ	69.13	308700	0.167
±3σ	93.32	66810	0.500
±4σ	99.3790	6210	0.834
±5σ	99.97670	2330	1.167
±6σ	99.9996600	3.4	1.500

Table – 6 "Nonconformance rate and process capability when the process is off center ± 1.5 σ"

The DMAIC Concept

DMAIC – Incremental improvement of existing processes.

(Define, Measure, Analyze, Improve, Control)

1. **Define**: identification of the problem, of objectives and scope of the project
2. **Measure**: analysis and measurement of the current performance of the process
3. **Analyze**: analysis and recording of the main causes
4. **Improve**: selection of problem-solving strategies
5. **Control**: standardization of the situation, continuous improvement

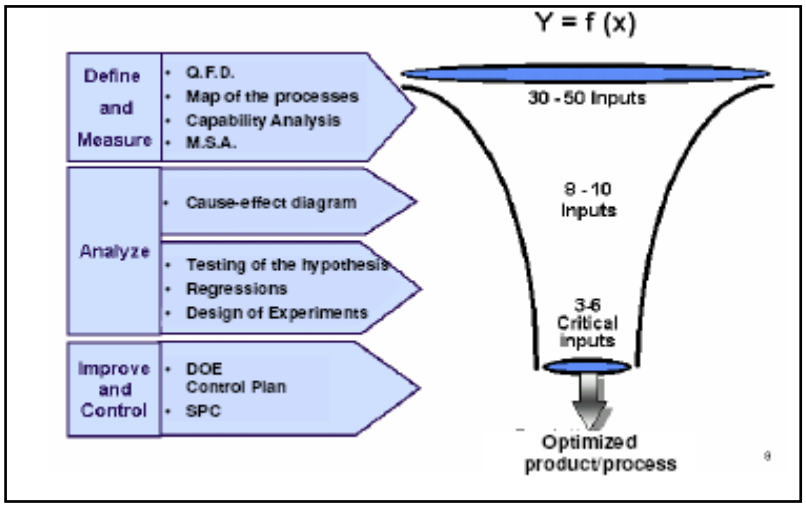


Figure – 25 "The DMAIC Concept"[83]

8.3.3 The CEDAC Approach[84]

CEDAC is acronym for *Cause-and-Effect Diagram with the Addition of Cards*. It was originally developed by Dr. Ryuji Fukuda of Sumitomo Electric, a Japanese manufacturing firm. Its purpose is to facilitate continual improvement in the workplace.

CEDAC is based on the supposition that three conditions must exist in order for continual improvement to occur. Fukuda explains these conditions as follows:

- *A reliable system*. For continual improvement to occur there must be a standardized, reliable system. A system that is reliable will yield the same results regardless of who uses, provided it is applied properly and according to standard procedures.

[83] Fiat Internal Sources

[84] David L.Goetsch,Stanley B.Davis, „Quality Management" (2003)

- *A favorable environment.* Continual improvement will not occur unless an environment favorable to it exists. The keys to creating and maintaining environment favorable to continual improvement are leadership and education. Leadership manifests itself in the form of commitment, both to the concept of continual improvement and the allocation of the necessary resources. Education is how employees become skilled in the use of the improvement system. The higher the density of employees who are skilled in the use of improvement, the better.

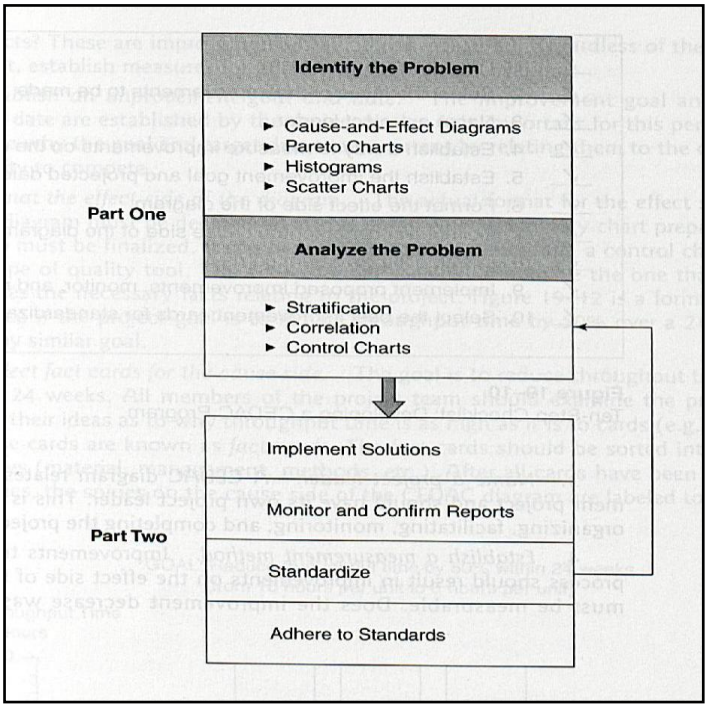


Figure – 26 "The CEDAC System"

- *Practicing as teams.* Like all endeavors requiring skills, continual improvement strategies must be practiced. Because in a total quality setting work is performed by teams of employees it is important for team members to practice together.

8.4 Other Continuous Process Improving Tools[85]

Followings are some tools that are also very supportive and effective in process improving.

[85] Fiat Internal Sources

8.4.1 5 ‘S’

Definition

This is the name of a workplace improvement method developed in Japan. The 5 ‘S’ are the initials of the Japanese words that express the basic concepts of the method.

Its purpose

- Instill a general mental attitude keeping the workplace clean and tidy, making minor but continuous improvements to working conditions
- improve productivity and quality, reducing search times and non value added activities
- Reduction of searching times
- Reduction of quality problems
- Creation of a safer, more comfortable environment
- Involvement of everybody in improvement activities

Method of application

The 5 ‘S’ approaches are:

- **methodical**: it defines principles and rules to be applied
- **permanent**: must be constantly applied to guarantee good results

8.4.2 5 WHYS

Definition

A Problem-solving tool intended to trace the root causes of an abnormal phenomenon through a consecutive set of questions (whys) which must be answered. Stopping at the first why’s, there is a risk of not tracing the real cause of the problem.

It is applied in:

- Breakdowns analysis.
- Analysis of sporadic defects.
- Analysis of chronic losses due to specific causes.

Its purpose

- Identify the 'root' cause of a specific problem so as to eliminate it completely.
- Get people used to asking themselves questions and finding answers, i.e. using their own intelligence. One of the many definitions of intelligence is in fact the ability to ask oneself and answer questions.

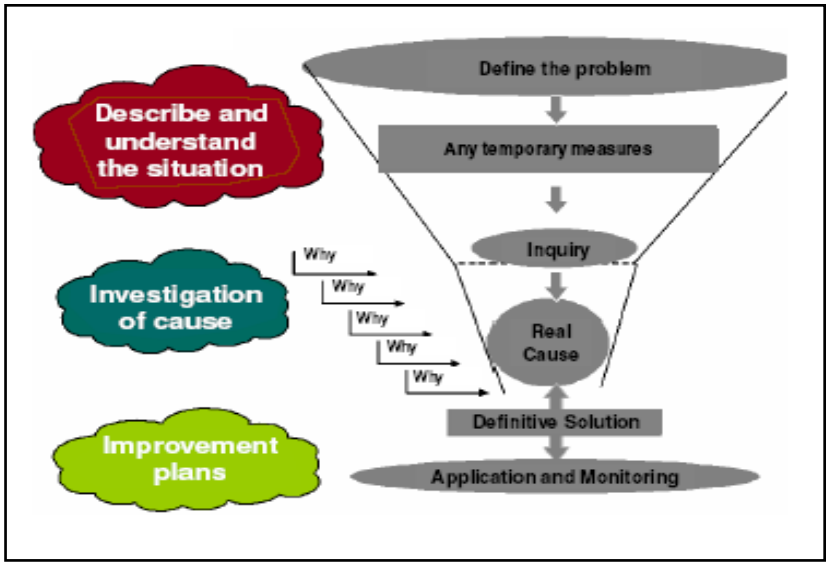


Figure – 27 "5WHYS"

Points requiring particular attention

- Go into minimum details in order to establish the real cause (there are no limits on the levels)
- Precisely describe all the causes (even those that prove to be incorrect) and actions (even those that it is decided not to apply) to keep control of the analyses made
- Use data rather than generic expressions
- For each cause, identify actions that will eliminate these for ever

8.4.3 Poka Yoke

Definition

A technique for preventing human errors, when carrying out any production activity. The solutions adopted should be as simple as possible and of reduced cost, defined starting from the outset, from attentive design of the workplace, of equipment and, in particular, of the product. In this way, Poka Yoke at **zero cost** are possible.

The underlying conviction of Poka Yoke is that production of even a single faulty part is not acceptable and the zero cost quality is obtained only by preventing defects and never recovering these.

Its purpose

Prevent errors or to highlight the error when this occurs using specific devices.

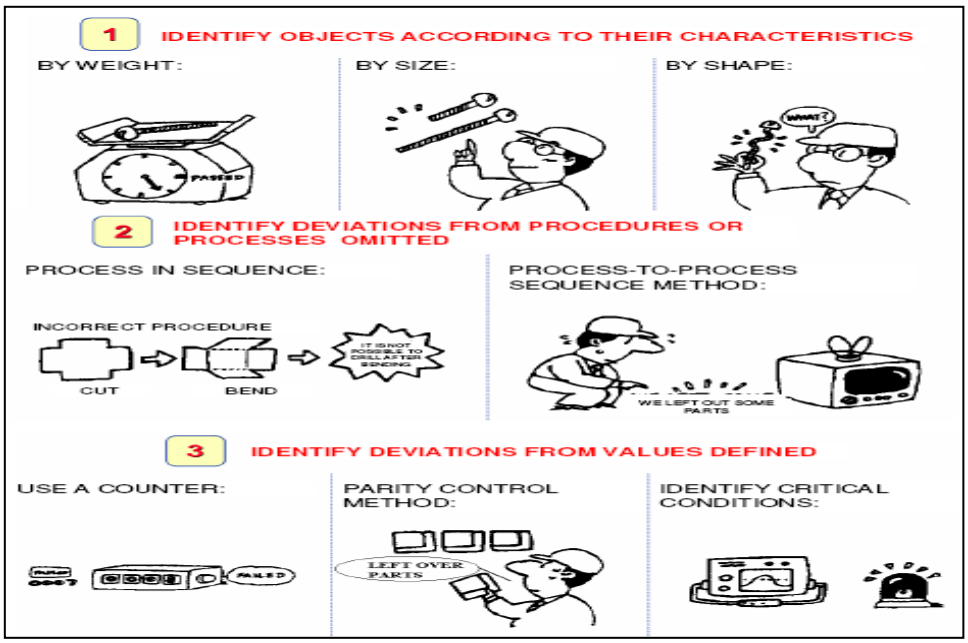


Figure – 28 "Poka Yoke"

8 principles for application of Poka Yoke

1. Build quality in the processes
2. All errors and defects due to inattention can be eliminated
3. Stop making mistakes and start doing things correctly
4. Don't search excuses: think how to avoid errors
5. 60% hope of success is sufficient – apply your idea immediately!
6. Errors and defects can be reduced to zero when everyone cooperates in eliminating these.
7. Ten heads are better than one
8. Find the real cause of the problem using the 5W1H method.

9. SUPPLIER QUALITY

Supplier quality has a large and direct impact on the quality positioning of reseller organizations. The growing attention to this area of quality management reflects an understanding that **a firm's quality performance (output) can only be as good as the quality performance of its suppliers (input)**. This suggests an increasing tendency towards supplier development by organizations as supplier quality integration is found to be critical dimension of quality excellence.[86]

Effective integration of suppliers into the reseller value chain is now seen as a key factor for achieving and maintaining superior quality positioning. As the strategy of supplier integration becomes more widespread, methods and criteria of their selection assumes a more critical dimension.[86]

9.1 Definitions

Supplier quality represents the ability to meet or exceed current and future customer (i.e. buyer and eventually end customer) expectations or requirements within critical performance areas on a consistent basis.[87]

Effective **supplier management** has been defined as the ``organization of the optimal flow of high quality, value for money materials or components to manufacturing companies from a suitable set of innovative suppliers"[88]

[86] S.Nwankwo,B.Obidigbo,F.Ekwulugo, "Allying for quality excellence" (2002)

[87] R. M. Monczka, R. B. Handfield, L. Giunipero, "Purchasing and Supply Chain Management" (2008)

[88] M. Szwejczewski, K. Goffin, R. Pfeiffer, B. LohmuÈller, F. Lemke**,"** Supplier management in German manufacturing companies" (2001)

9.2 Supplier Management[89]

Supplier management comprises a multi-level process. The *first steps*, supplier identification and supplier limitation, are also called supplier pre-qualification. Based on a specific need it is a matter within the framework of supplier identification to identify these vendors who offer the required procurement object. For this purpose the procurement market to be considered is first marked out and is searched for potential suppliers who produce the desired procurement object or who are in the position to do so.

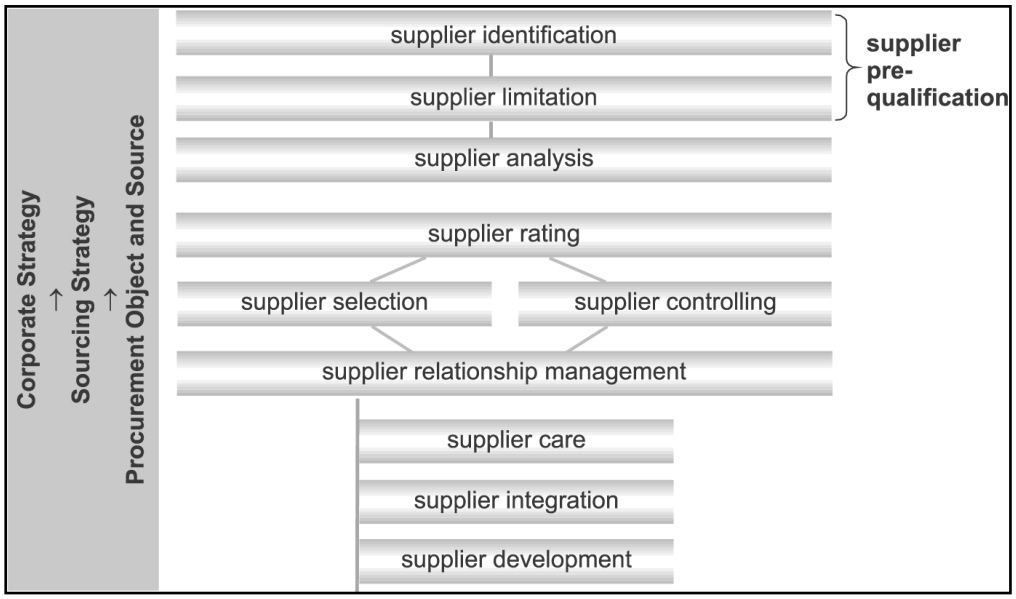


Figure – 29 "Process of Supplier Management"[89]

Owing to the complexity of the following steps not all potential suppliers can be considered and a *supplier limitation* is required. Moreover, preferably specified information about the vendors (e.g. self-information), prepared by the procurement marketing research is demanded.

In the *supplier analysis* the results of procurement research and self-information and, if necessary, auditing are gathered and processed for the final supplier rating. A profile examination of the economic, ecological and technical capacity of potential suppliers is carried out. In case the information presented by the supplier's questionnaire is insufficient, audits are a proved means of fine selection in preparation for evaluation and selection of suppliers.

[89] R. Lasch, C. G. Janker," Supplier selection and controlling using multivariate analysis", (2004)

Supplier rating is the systematic and extensive evaluation of the supplier's efficiency for the selection of new suppliers and the control of suppliers within the vendor master. Based on requirements planning, the specification of the procurement object, the identification of different sources as well as the evaluation of these alternatives, the final decision-making process is reached with the supplier's selection. *Supplier controlling* is the regular examination of the efficiency of the supplier-buyer connection. Here, companies are able to uncover deficits of the supplier in time and introduce corresponding counteractive measures. Together with the integration and development of existing suppliers this step is called supplier relationship management.

It is clear from the literature that supplier management has an important role and there are two key issues to be considered:[90]

(1) *The trend in the supplier base* - the tendency for leading companies to reduce their number of suppliers (due to the advantages it offers);

(2) *Manufacturers' sourcing policies* - the approach taken i.e. whether or not companies are willing to reduce their supplier base to the extent that they mainly have ``single-source'' suppliers.

9.3 Supplier Partnership[91]

Partnering is a long term commitment between two or more organizations for the purpose of achieving specific business goals and objectives by maximizing the effectiveness of each participant's resources. The relationship is based upon trust, dedication to common goals and objectives, and an understanding of each participant's expectations and values. Benefits include improved *quality*, increased *efficiency*, *lower cost*, increased opportunity for *innovation*, and the *continuous improvement* of products and services. There are three key elements to a partnering relationship: *long-term commitment*, *trust*, and *shared vision*.

[90] M. Szwejczewski, K. Goffin, R. Pfeiffer, B. LohmuÈller, F. Lemke**,"** Supplier management in German manufacturing companies" (2001)

[91] D.H.Besterfield, C.B.Michna,G.H.Besterfield,M.B.Sacre, "Total Quality Management" (2003)

- *Long-Term Commitment.* Long –term commitment provides the needed environment for both parties to work toward continuous improvement. There must be total organizational involvement from CEO to workers.

- *Trust.* Trust enables the resources and knowledge of each partner to be combined to eliminate an adversarial relationship. Partners are then able to share information and accept reduced control. The parties should have access to each other's business plans and technical information, such as product and process parameters. The strength pf partnering is based on fairness and parity. Both parties become mutually motivated when "win-win" solutions are sought rather than "win-lose" solutions.

- *Shared Vision.* Shared goals and objectives ensure a common direction and must be aligned with each party's mission. Employees of both parties should think and act for their common good.

9.3.1 Responsibilities of a Supplier Partnership

Responsibilities of a Supplier Partnership	
Manufacturer	**Supplier**
1. Process-achievable specifications.	**1.** Evaluate process capability to meet customer's specification.
2. Clear standards – Quality, Quantity and Delivery.	**2.** Evaluate standards\methods.
3. Clear line of communication.	**3.** Clear line of communication.
4. Notification of organizational changes.	**4.** Notification of organizational changes.
5. Discussion of potential changes in requirements.	**5.** Discussion of potential changes in requirements.
6. Assist supplier in solving quality, production problems.	**6.** Notify customer of quality, production problems and capacity.
7. Provide timely feedback and corrective action.	**7.** Provide timely feedback and corrective action.
8. Provide audit schedule.	**8.** Notify customer of sourcing or process changes.
9. Share audit results.	**9.** Close feedback loop.
10. Resolve supplier questions.	**10.** Inform customer of new process and\or materials.
11. Commit to continuous improvement program.	**11.** Commit to continuous improvement program.

Table – 7 "Responsibilities of a Supplier Partnership "[92]

In order to have a true partnership, each side must be committed to meeting certain responsibilities. This is the core of any successful agreement. Neither side should feel as though they are being taken advantage of. It is important to stress that a partnership must achieve:[92]

- **100% Quality**
- **100% Delivery**
- **100% Quantity**
- **100% of the time.**

9.4 Supplier Selection[93]

Once the decision has been made to outsource, then the supplier must be selected. Following are ten conditions for selection and evaluation of suppliers.

1. The supplier understands and appreciates the management philosophy of the organization.

2. The supplier has a stable management system. In determining this condition, several questions should be asked: Is there a quality policy statement that includes objectives for quality and its commitment to quality? Is the policy implemented and understood at all levels of the organization? Is there documentation that indicates who is in the charge and responsible for quality in the organization? Is there a member of top management with the authority to execute a quality system?

3. The supplier maintains high technical standards and his capability of dealing with future technological innovations.

4. The supplier can provide those raw materials and parts required by the purchaser, and those supplied meet the quality specifications.

5. The supplier has the capability to produce the amount of production need or can attain that capability.

6. There is no danger of the suppler breaching corporate secrets.

7. The price is right and the delivery dates can be meet. In addition, the supplier is easily accessible in terms of transportation and communication. There must be also a system to trace the product or lot from receipt and all changes of production delivery.

8. The supplier is sincere in implementing the contract provisions. Does the supplier have a system for contract review, and does, that system include a contract review or requirement

[92] P.L. Grieco Jr. "Supplier Certification 2" (1992)

[93] D.H.Besterfield, C.B.Michna,G.H.Besterfield,M.B.Sacre, "Total Quality Management" (2003)

and how differences between the contract and/or accepted order requirements should be resolved? Farther does the system the inclusion of amendments? Also, does the system include maintaining records of reviewed contracts?

9. The supplier has an effective quality system and improvement program such as ISO/QS 9000.

10. The supplier has a track record of customer satisfaction and organization credibility. A recent study by Andersen, the University of Cambridge, and Cardiff Business School found Japan to be the leader in the number of world class automotive supplier plants, but the U.S. held the top of three supplier positions. Of the 13 supplier plants identified as "world class", five were from Japan.

The preceding conditions go beyond evaluating a supplier on the basis of quality, price, and delivery. It is recommended that a large organization send a multifunctional team to assess these supplier conditions. The team may wish to score each condition on a scale 1 to 5. Small organizations may wish to use a written questionnaire and survey potential suppliers by mail.

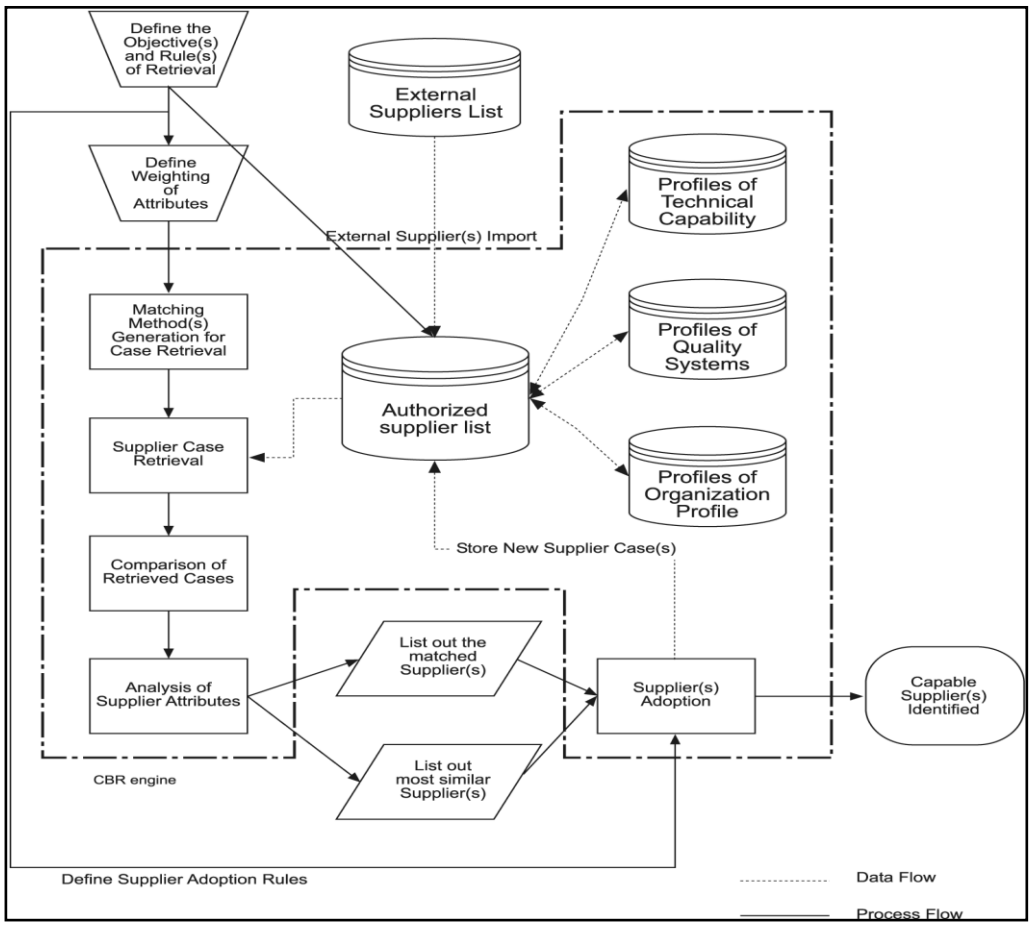


Figure – 30 "Supplier Selection Workflow"[94]

[94] K.L.Choy, W.B.Lee, "A generic supplier management tool for outsourcing manufacturing" (2003)

9.5 Supplier Certification[95]

After supplier selection and approval, the next step is the certification process, which starts after the supplier begins shipment of the product. This process has been described by the Customer/Supplier Technical Committee of ASQ, which developed following eight certification criteria:

1. The customer and supplier shall have agreed upon specifications that are mutually developed, justifiable, and ambiguous. Rarely do specifications contain all the information needed for manufacturing a product. With new products, the design team can significantly impact lead times and quality by working with customer. However, for those products traditionally manufactured by company and which are now being transferred to the supplier, several considerations should be made. In addition to design specifications, manufacturing, assembly, and packaging instructions should also be considered.
2. The supplier shall have no product-related lot rejection for a significant period of time, say, one year, or significant number of lots, say 20.
3. The supplier shall have no non product-related rejections for a stated period of time, say, three months, or number of lots, say five. Non product-related nonconformities such as the wrong count or a billing error are not serious as product-related ones and are usually correctable in a short period of time.
4. The supplier shall have no negative non product-related incidents for a stated period, say, six months, or number of lots, say ten. This criterion covers incidents of problems that occur even though inspection and tests showed conformance of specifications. Most likely the supplier would have been notified of the incident by memorandum or other written communications.
5. The supplier shall have a fully-documented quality system. ISO 9000 is an excellent model to build a system even if registration is not the goal.
6. The supplier shall have successfully passed an on-site system evaluation. This evaluation could be by third party such as an ISO 9000 registrar or by a second party – the customer. Details on system audits are covered in Chapter 10.
7. The supplier must conduct inspections and tests. Laboratory results are used for batch processes, and statistical process control (SPC) is used for piece part production.
8. The suppliers shall have the ability to provide timely inspection and test data. Because this documentation is necessary when the product arrives, it must be sent by computer or courier.

There are a number of benefits to certification. First, it eliminates receiving inspection, which allows the supplier to ship directly to stock. Second, a customer/supplier partnership is created, with each partner being responsible for its own appropriate quality. Finally, the number of suppliers is reduced to a manageable level, thus further reducing overhead costs.

[95] D.H.Besterfield, C.B.Michna,G.H.Besterfield,M.B.Sacre, "Total Quality Management" (2003)

SUPPLIER CERTIFICATION	
GOAL	**ACTION**
Total Quality Management	Ensure that the entire manufacturing cycle from design review through customer receipt meets quality standards established by the customer.
Quantity	Process and produce the lowest possible quantity by manufacturing on-time. The smaller the quantity, the easier it is to control.
Supplier Partnership	Establish a relationship based on a win/win philosophy.
Logistics	Simplify the control and movement of material between functions and activities. Incorporate standard objectives.

Figure – 31 "Goals of Supplier Certification"[96]

9.6 Supplier Rating[97]

The customer rates suppliers to:

- Obtain in overall rating of supplier performance.
- Ensure complete communications with suppliers concerning their performance in the areas in quality, service, delivery, and any other measure the customer desires.
- Provide each supplier with a detailed and factual record of problems and for corrective action.
- Enhance the relationship between the customer and supplier.

A successful supplier rating system requires three key factors:
(1) an internal structure to implement and sustain the rating program, **(2)** a regular and formal review process, and **(3)** a standard measurement system for all the suppliers. A supplier rating system (often referred to as a second system) is usually based on quality, delivery, and service; however some customers have added other categories, such as machine ability and cost. These categories may also have subcategories.

[96] P.L. Grieco Jr. "Supplier Certification 2" (1992)

[97] D.H.Besterfield, C.B.Michna,G.H.Besterfield,M.B.Sacre, "Total Quality Management" (2003)

These basic categories weighted, with quality usually given the greatest weight. A score is given to each category by means of numerical value or a letter grade, which can be converted to a numerical value. Table-9 shows a supplier scorecard for a head stacks assembly developed by Corner Peripherals, a manufacturer and marketer of storage solutions for the computer industry. Objective criteria and weights were established for each of the categories of quality, process control and technology, support, delivery, product technology, lead time and purchasing. The table illustrates a comparative analysis of its suppliers.

Item: Head stack assembly						
Period: 4Q94		*Supplier A*	*Supplier B*	*Supplier C*	*Supplier D*	*Supplier E*
QUALITY PERFORMANCE	MAXIMUM POINTS	ACTUAL POINTS	ACTUAL POINTS	ACTUAL POINTS	ACTUAL POINTS	ACTUAL POINTS
Line returns	30	27.66	29.61	28.11	28.71	28.65
PPM deduction (Maximum−10)		− 10	− 10	− 10	− 10	− 10
Certified yield multiplier		0.9	0.94	0.87	0.85	0.72
Penalty: Field issues (Maximum−15)						
Stop shipment (Maximum−15)						
Line purge (−5 each time)						
Subtotal (0–30)	30	15.894	18.433	15.756	15.904	13.428
Process control	8	6.5	6.5	5.5	5	6
Process technology	6	5.2	4	5.2	4.8	4.6
Sustaining technical support	6	2.3	1.6	3.5	4	2.8
On-time delivery	20	20	18	19	19	18
Product technology	10	9.7	6.7	9.1	7.4	8.2
Lead time	15	13	13	13	13	13
Purchasing and material support	5	5	3	2	5	2
Performance matrix total	100	77.594	71.233	73.056	74.204	68.028
Price index = target price/actual price	1	0.878	0.947	1	0.905	0.967
SCORE = performance matrix × price index	100	68.127	67.457	73.056	67.154	65.783
Total Cost of Supply = ((100 − SCORE)/100) + 1	1	1.3187	1.3254	1.2694	1.3285	1.3422

1.0 = perfect
2.0 = worst possible

Table – 8 "An Example Supplier Scorecard"[98]

9.7 Achieving world-class supplier quality[99]

Figure - 30 presents a hierarchy of activities that, **when executed properly**, supports world-class supplier quality performance, and will help ensure the achievement of current and future quality expectations. These activities are presented across three dimensions: (1) implementation complexity, which refers to the skill, time and resources required to execute

[98] D.H.Besterfield, C.B.Michna,G.H.Besterfield,M.B.Sacre, "Total Quality Management" (2003)

[99] R. J. Trent, R. Monczka, "Achieving world-class supplier quality" (1999)

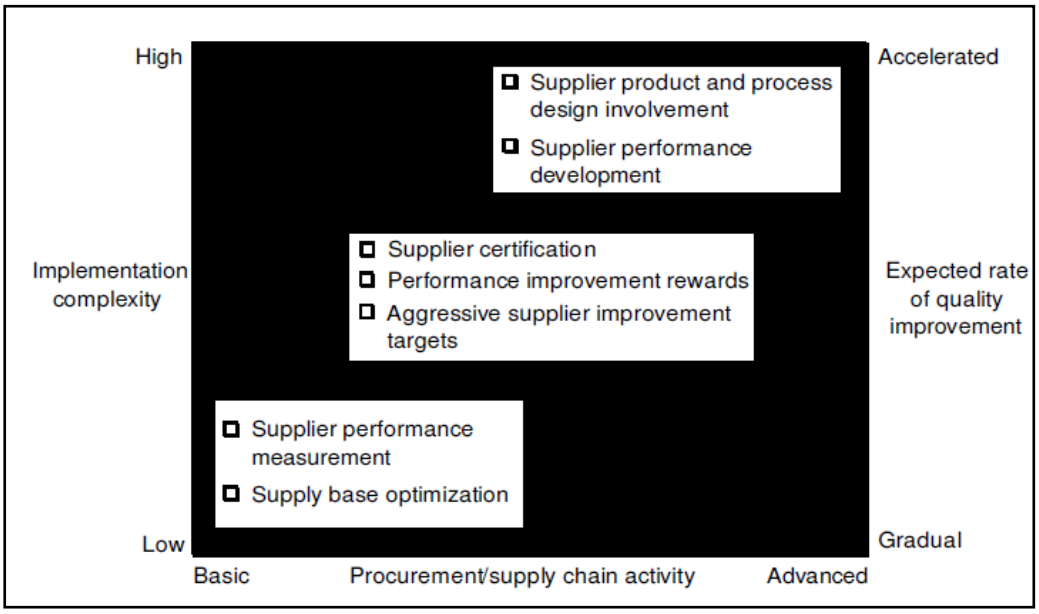


Figure – 32 "Achieving world-class supplier quality"

successfully a particular activity; (2) the rate of quality performance improvement expected from successfully executing a particular activity; and (3) whether the activity is basic, moderate or advanced. One way to approach the topic of supplier quality management is to ask a series of questions regarding an organization's sourcing practices. The answers to these questions[100] will provide insight concerning how well positioned a firm is to realize the highest levels of supplier quality.

[100] Appendix C

10. ASSIGNING QUALITY FUNCTIONS WITH THE PRODUCTION PROCESS

10.1 Introduction

In this chapter, it is going to be showed, examined and assigned all the quality functions which were discussed in the previous chapters. The quality functions will be studied and showed on an automobile manufacturing process. Here, the main idea will be **not** to show how an automobile is produced or what the manufacturing techniques are, but the **main goal** is going to be; the presentation of these functions, methods and their main duties in order to **improve** and **make better** the manufacturing process.

These quality functions are **not** a manufacturing techniques or methods. The good understanding and successful **implementing** of these functions can make the manufacturing processes very **high-quality** and **efficient**. Here the definition of high quality and efficiency can be explained as minimum defects, minimum mistakes and maximum high-quality of manufactured products. This is also the **main aim of this thesis**, to create a quality process which is improving the manufacturing systems to reach the zero-defect manufacturing or in other words to achieve world-class manufacturing level.

10.2 Definition of Production Process

Quality is very important topic in today's manufacturing world. Every company is trying to improve and progress their quality. Automobile manufacturers are one of them. Automobile production is a very complex and multivariable task. It differs from company to company and from production processes and used methods. But only one thing is not changing**, improving the quality**. In the coming part, the simplest, general automobile production process will be explained, and then one sub-process; like 'montage' will be selected, and tried to assign the quality functions.

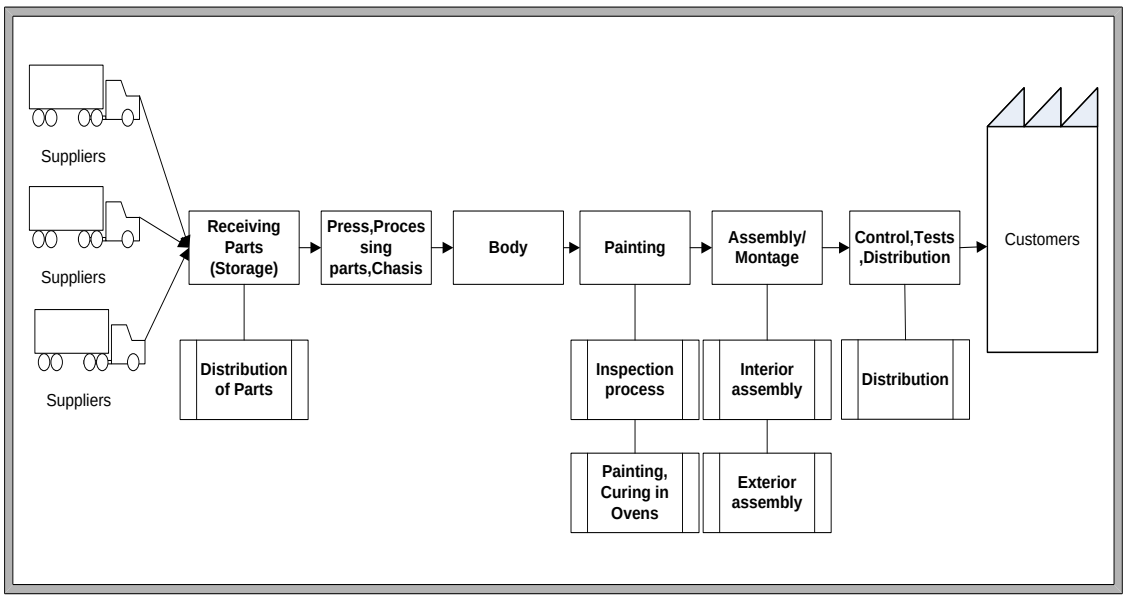


Figure – 33 "Basic Automobile Manufacturing Process"

As it can be seen in figure – 31, the raw materials and parts are coming to the plant from the suppliers. In some plants these parts are going directly to the needed departments or buildings, in others can be centralized in the plant. After the distribution of the material and parts, processing starts. When chassis is done, the main body is composed. Next level is painting, which is very complex process and needs deep inspections and controls. Following the painting, montage starts, interior parts, such as steering wheel, seats, etc. and exterior parts are combined with the body. When the last controls, end- inspections and tests are done an automobile is ready for the distribution to the customer.

10.3 Selecting a Sub-process and Assigning the Quality Functions

This part consists of explanation, how the studied quality functions in the previously chapters, can help and improve the manufacturing process to achieve high-quality and zero defect production level. In order to explain better, a small part of the montage process is selected and drawn, where assignment of functions will take place.

10.3.1Assigning Quality Functions

By achieving specific standards in quality, first thing to do is to **plan** the quality, and to plan the management of quality. In whole manufacturing process and also in every core process **quality planning** is involved. Quality planning should start from the top management and transmitted to all employees and workers of the process.

The processes, using methods and tools, customers, customer's requirements, specifications of products and etc. should be intensely examined and determined. After that a **planning of quality** should start, and main goal of that should be; how can be '**desired level of quality'** involved in every process of manufacturing. Which method, tool, or management type should be assessed with process? How will be these facts explained to the workers? How will these methods and desired goals standardized? Who are the target customers and their requirements? How can be customers satisfied in most effective way? Etc. All these questions and their answers build the **quality planning** and are the columns of this quality function.

10.3.2 Sub-Process and Quality Functions

Figure – 32 represents a part of montage\assembly process. Montage\assembly process is very large and complex process. Normally it consists of much more processes and it is longer than in figure – 32. But as it is told before, this is just small illustration for the assigning the quality functions. Now let's investigate all points in the Figure – 32.

A. The point A comprises **quality control** and **quality inspection**. These gates can be called as "quality gates", which can be found at the **end of process**, in the **middle**, or **between processes**. At these points, coming vehicles are checked, inspected and controlled before starting a new progression. These gates are not visual, but the workers should know that is a point where inspection and control happens. As an example, before assembly of wiring systems, sockets and holes for the wires should be controlled and checked. It can slower a little bit the production line, but then it will decrease the time by the end control and last tests. These control and inspections are usually visual and can be done by the workers or when respectively bigger problem or defect is occurred, than it can be done by the team leader.

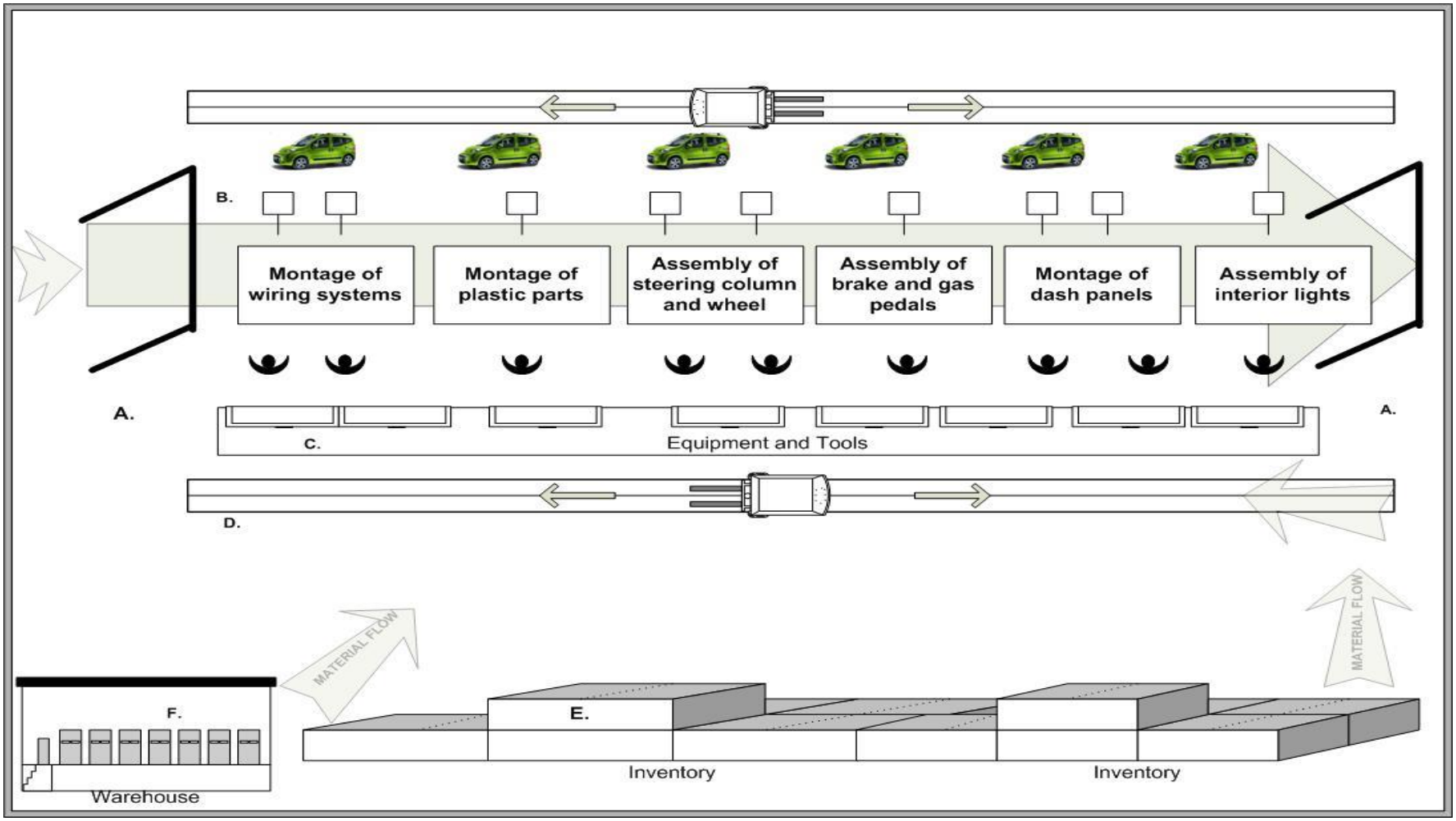


Figure – 34 "A part of montage\assembly process"

B. The point B represents panels, on which whole process is described, all kaizen results and improvements are written, instructions and description of them are graphically showed, and the names and their jobs of the workers who are processing this job.

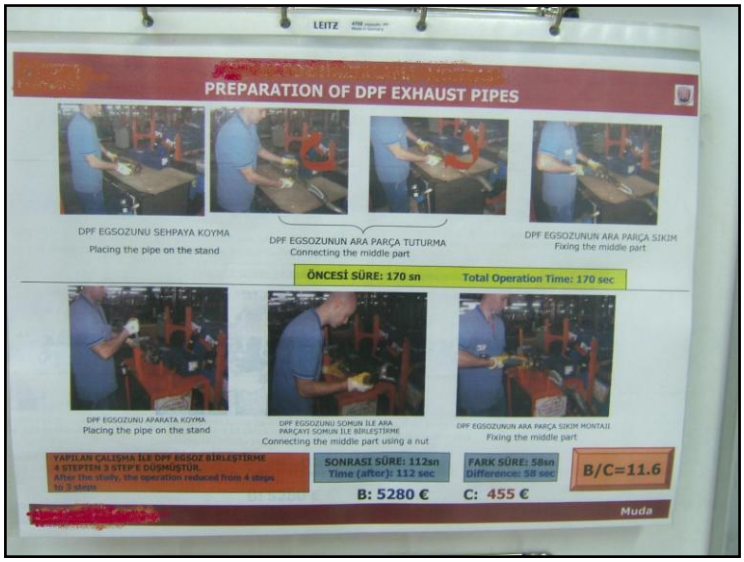


Figure – 35 "Panels"[101]

Some workers find these panels unnecessary, but it helps a lot when small problems are occurred in order to solve them quickly.

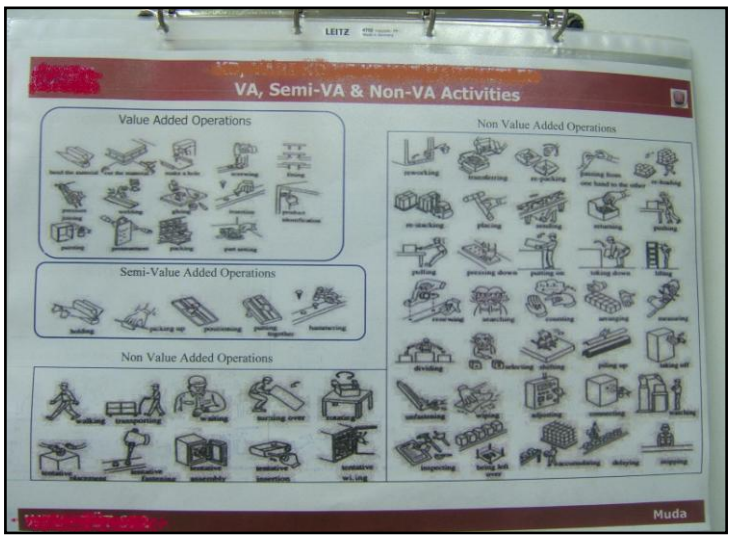


Figure – 36 "Panels"[100]

These panels are a result of **Continuous Process Improvement** activities. In other words all results from CPI actions are exposed in these panels, which is very important for the quality improvement.

[101] Tofas, Fiat Internal Sources

C. Non-defective processes or high-quality products require superior material and tools. In order to achieve that, **supplier quality** and **material management** have large role. Here the most important thing is that the materials and tools are not defected or damaged. The other important issue is that, all coming materials should be there in **time** and in right **sequence**. When these conditions are secured, the production line gets faster. The most effective solution for the material management is **supplier partnerships**, or **certification of suppliers**. Other solutions can be as; incoming material **audits**, control and inspection of tools and materials (SPC), JIT and JIS. At this point **supplier quality**, **audits** and **inspection** take great part.

D. All needed materials and tools, should be right in the place and time before the worker starts doing the process. Workers should not loose time while searching or taking the tools, and that requires specific **distribution** of them. It can be done by using forklifts or manually by the workers who are responsible for this. Also there should be very good synchronization and parallelism with the production planning and warehouse management (department). More issues about this point will be discussed in "improvements" section.

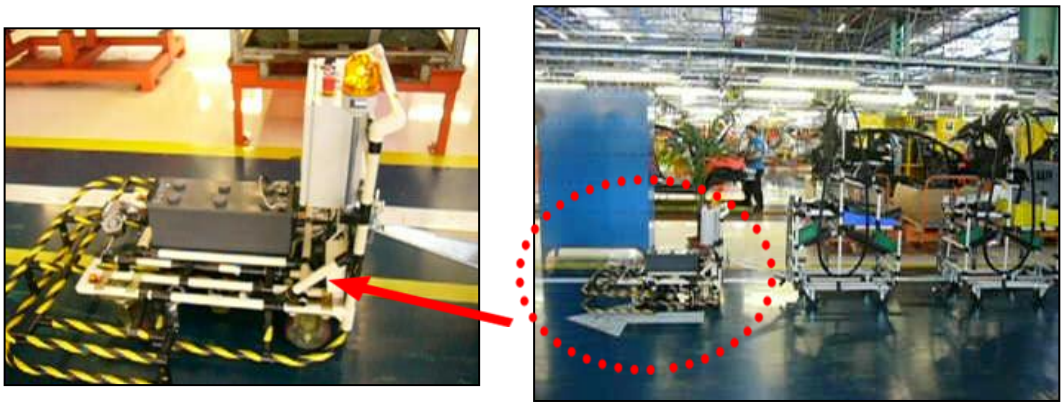
E. & F. By these points important quality functions are **supplier management**, **quality inspections** and **audits**. The main goal by incoming materials and tools should be **to reduce** the incoming material controls and inspections. In order to achieve that, supplier partnerships, selecting and certification of them are very significant. The goal of the company should be 0 stocks. That needs very good communication and participation with the suppliers. Another point is control and inspection of the materials. They must be controlled (SPC) and checked before any procedure. Material audits can be also very useful. For the distribution of the materials and material flow to the production line, the best practices are JIT and JIS.

While achieving the high-quality level, there are also some functions that cannot be directly showed on the shop-floor. These are **Continuous Process Improvement, Quality Circles** and **Quality Audits.** The concept of continual improvement should be adopted by whole employees of the plant. The workers should be encouraged to improve processes and bring some new ideas. Also a group of engineers and workers should be grounded as quality circles, who will work just on one process and try to improve that. All the results and improvements should be documented and displayed.

10.4 Improvements

In this section, some improvements and possible changes will be showed, that can be done in order to achieve world class manufacturing level.

First one can be by the point D. about distribution of the materials to the shop-floor, instead of using forklifts it can be used "Automated Tractors" which are carrying the kits and tools.



Another thing is moving material cart, which synchronously moves with the production car.

Figure – 37 "Material Cart"[102]

[102] Fiat Internal Sources

By doing this, the **cost** of one worker which is using the forklift and the **gas cost** can be reduced. Also forklifts are **scracthing** and **making dirty** the floor.

Second improvment can be on the point **B.** on the panels. In oreder to save some area on the board a folders can be used. For example, 30 Documents can be exhibited without covering much area on the board.

Figure – 38 "Board Folders"[103]

The *last* improvement can be applied on **workers** and **team leaders**. A **concept** or rules can be developed, except of Kaizen's and regular improvement actions, that every worker who works on his\her specific process, should bring 5 new ideas, improvements or change something during month, which affects process better as it was. Also team leaders should bring some ideas that will improve the process. These must not be some very varying or effectual improvements, can be **small**, **basic** but **practical** changes, which will create a **continual improvement** and changing the processes in superior way. These improvements should be than documented and written or presented on the panels with the names of the workers and team leaders.

[103] Fiat Internal Sources

11. WORLD CLASS MANUFACTURING – Methods and Tools for the Fiat Auto Production System[104]

11.1 Introduction

Fiat Auto has decided to raise its standards to World Class level, as reflected in the World Class Manufacturing (WCM) route map. Together with leading European and Japanese experts, Fiat has defined their Production System that embraces the entire organization of the factory, involving quality system, maintenance system, cost management and logistics with an evolutionary perspective.

This system is based on systematic aggression of all types of wastes and losses, applying methods and standards with rigor and involving everyone.

Fiat wants to be a world-class manufacturer where:

- Awareness of **safety** is an essential value
- The **voice of the customer** is heard in the workshop
- Leaders have a **passion for standards**
- **No form of waste** is accepted
- **Methods** are applied **strictly and tenaciously**
- All **faults are made visible**
- **People involvement** is the driving force of change.

11.2 FAPS: Production System and WCM

The definition and introduction of the **Fiat Auto Production System** (FAPS) is a major innovation program intended to wrought far-reaching changes in our way of producing in order to achieve World Class Manufacturing (WCM) **standards of excellence**.

Fiat set the objective to build up a structured system that defines methods and tools able to promote long-lasting, systematic improvements that eliminate not only waste but also the related sources.

[104] Tofas, Fiat Internal Sources

Fiat have compared their performance with that of other manufacturers that have enjoyed considerable success in the automotive sector, in particular, the Toyota system, created by Taiichi Ohno, which has promoted a sevenfold increase in the productivity of the Japanese company in the last 25 years.

Fiat have worked hard inside the company to identify the most effective ways of adopting lean systems, applying a structured, systematic approach in order to overstep the practice of isolated, often difficult to repeat improvements.

Fiat finally carried out an improvement route map of Fiat Auto Manufacturing performance to enable all plants to achieve continuously better results. Effective application of tools and methods is sustained by:

- **People involvement:** everyone must firmly believe in the entire program;
- **Investment in their skills,** as a key lever for the success of the overall framework.

As indicated by Prof. Yamashina, **the resulting cultural change** helps people to see things from a different point of view and to think as men of action and to act as men of thought.

'Loss identification depends on your eyes; people improve their eyes as they learn'[105]

11.2 World Class Manufacturing

WCM represents the **level of excellence of the entire logistic production cycle** measured according to the methods applied and the performance achieved by best-in-class companies worldwide. The experience acquired by these companies has lead to the definition of **World Class Manufacturing (WCM)**, based on the following concepts:

- **Total Quality Control** (TQC),
- **Total Productive Maintenance** (TPM),
- **Total Industrial Engineering** (TIE),
- **Just In Time** (JIT).

[105] By Prof. Hajime Yamashina

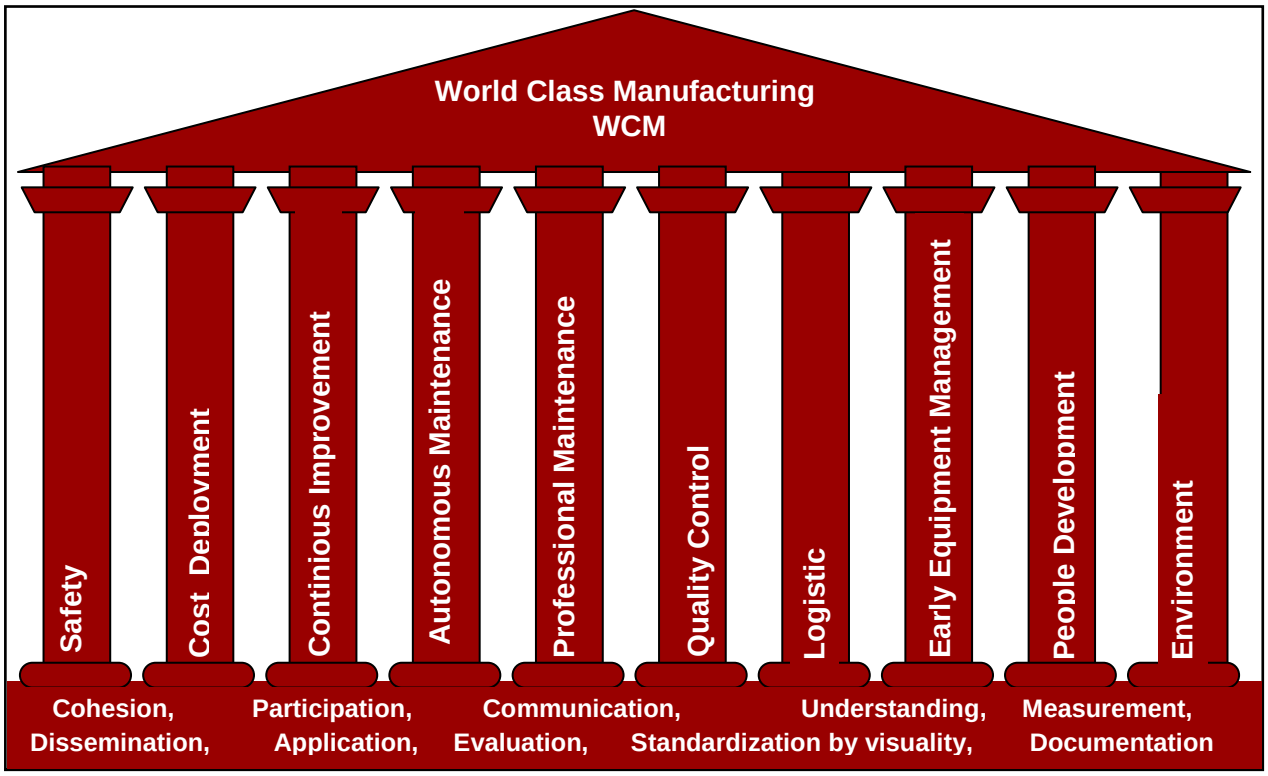


Figure – 39 "World Class Manufacturing"

The level reached by each company is certified by external experts and is achieved through continuous improvement of performance and constant involvement of all levels of the company.

11.2.1 Mission

Fiat Auto Manufacturing has set itself the objective of improving the performance of the corporate Operating System to a level of excellence able to achieve World Class competitiveness. A goal that can be achieved only through wide-scale people development and an organization able to:

- ✓ Attack all types of waste and loss
- ✓ Involve all those who operate at all levels of the organization
- ✓ Apply methods and tools rigorously
- ✓ Deploy and standardize the results achieved.

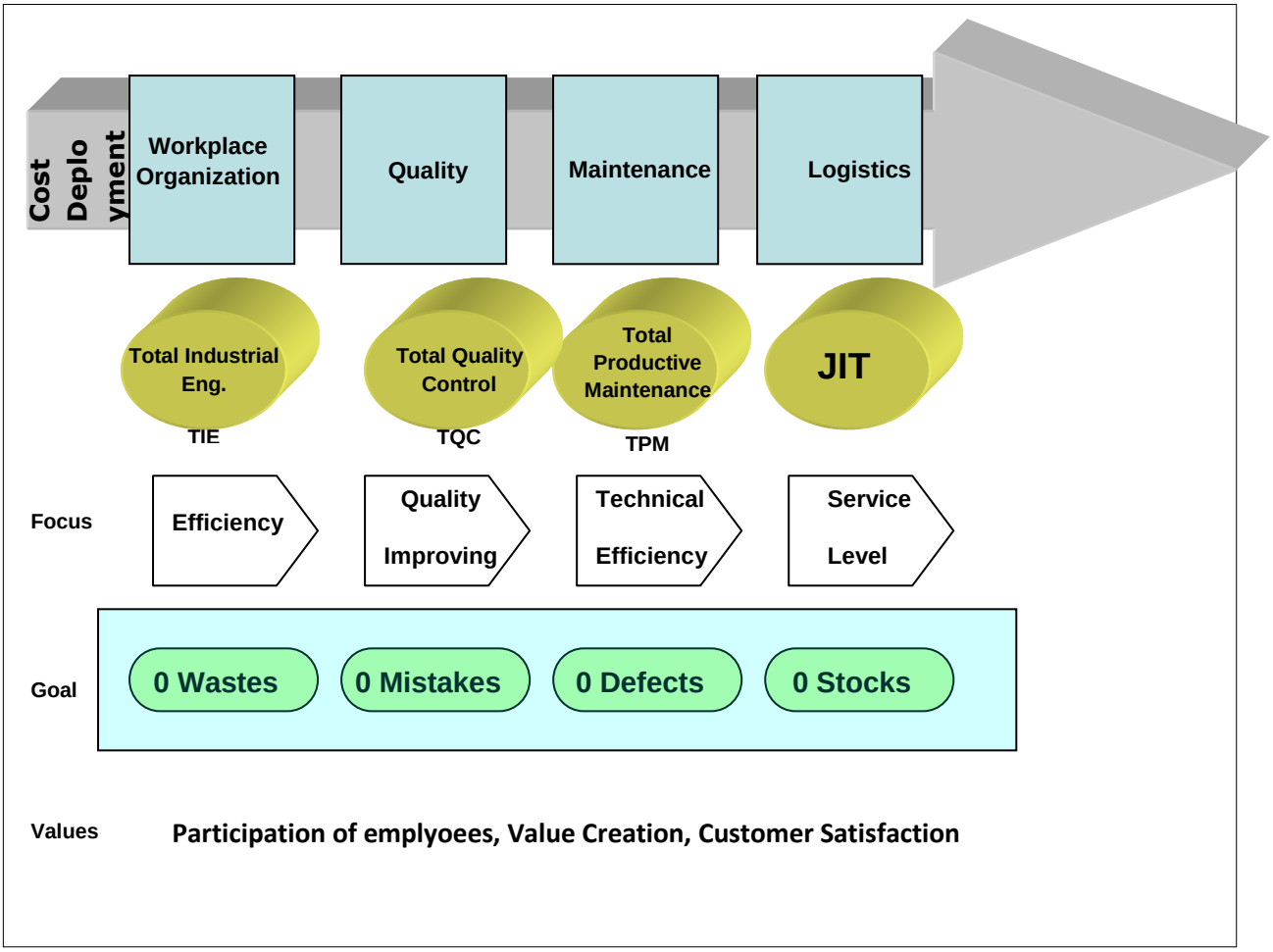


Figure – 40 "WCM Structure and Aims"

11.2.2 FAPS –Fiat Auto Production System

An **integrated model,** which optimizes all production-logistic processes, and promotes continuous improvement of essential factors such as quality, productivity, safety, delivery. Application of the system is supported by an **Audit System** and it is structured according to objectives, achievement of which is measured on the basis of suitable **Key Performance Indicators** (KPI).

Purpose

Maximize production system performance in accordance with logistic plans and defined quality objectives through:

- Improvement of processes
- Improvement of product quality
- Control and gradual reduction of production costs
- Flexibility in meeting market and customer requirements
- Involvement and motivation of people who operate on industrial processes.

Application of the Production System allows Management to concentrate on improvement instead of dealing with daily problems.

The Production System

A structured set of methods and tools applied throughout the company, involving all employees, in order to promote a **radical improvement in production system performance**, to assure that the product is delivered to the customer by the times and with the quality required, also eliminating not value added activities and any other type of loss or waste of human resources, equipment, materials and energy.

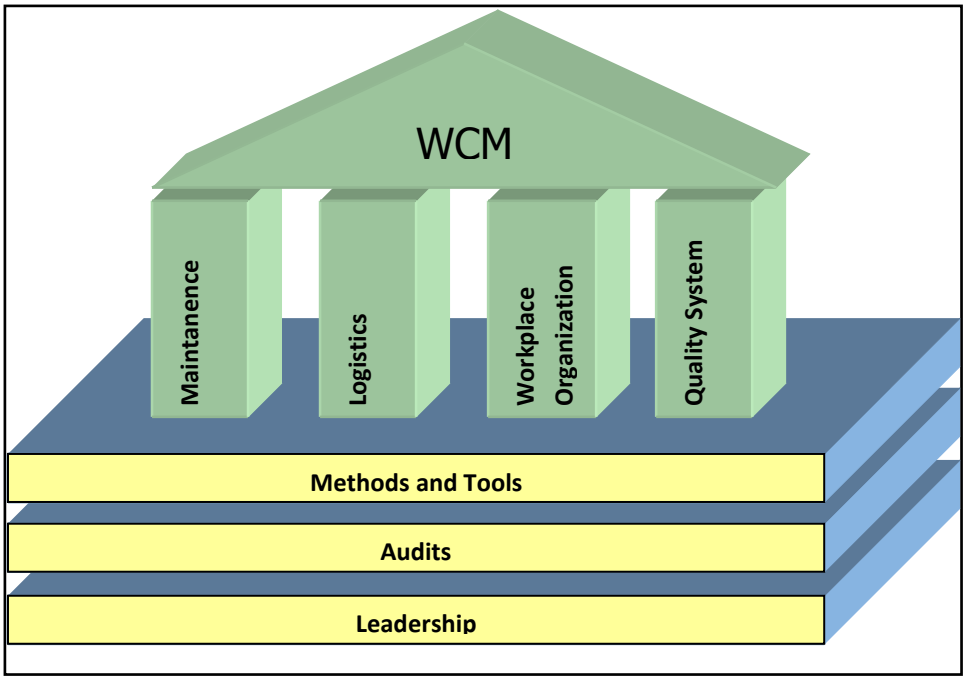


Figure – 41" Basics of World Class Manufacturing"

The Production System

A structured set of methods and tools applied throughout the company, involving all employees, in order to promote a **radical improvement in production system performance**, to assure that the product is delivered to the customer by the times and with the quality required, also eliminating not value added activities and any other type of loss or waste of human resources, equipment, materials and energy.

The **Fiat Auto Production System** aims to achieve significant efficiency and customer satisfaction results, taking as reference the methods applied by best practice competitors, structured and defined in World Class Manufacturing. Therefore, WCM is both the reference and arrival point of Fiat Auto Manufacturing and establishes the standards of excellence to be achieved when defining the **objectives** of each Plant, Operating Unit and in subsequent **assessment** of performance.

11.3 Methods and Tools

The methods and tools presented in the guide are the offshoot of in-depth discussions with practical and theoretical experts of international renown, but stem first and foremost from valorization of our experience, constructed with fatigue, and to which many of you have contributed as stakeholders in the change and to whom I would like to express my most sincere thanks.[106]

11.3.1 Tools

The table below shows the main relationships between the methods described and the operating tools used. The tools used to apply each method are indicated.

[106] Lucciano Massone – Fiat Production System Development

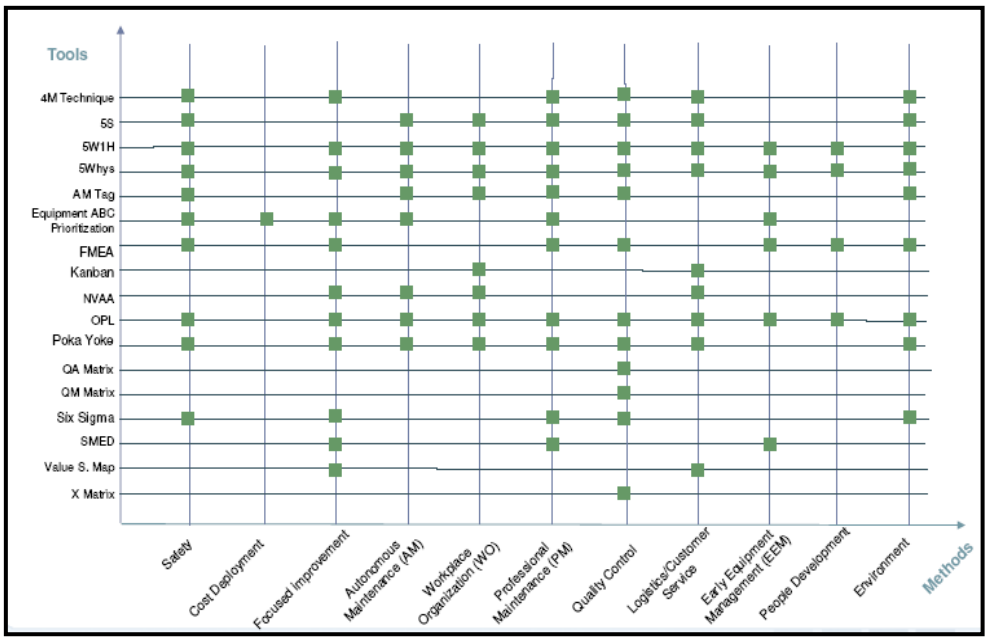


Table – 9 "Used Methods and their Tools"

11.3.2 Methods

In this section, **11 methods**, which are **core** of the whole production system of Fiat, Bursa, will be presented. Every method has **7 steps** in order to apply it and itself **assessmen**t levels. These methods constitute the **World Class Manufacturing** by Fiat and are applied very successful as well as in every small detail (Process). Due to the security policy, the 7 steps will be presented only of one method, which is **autonomous maintenance**.

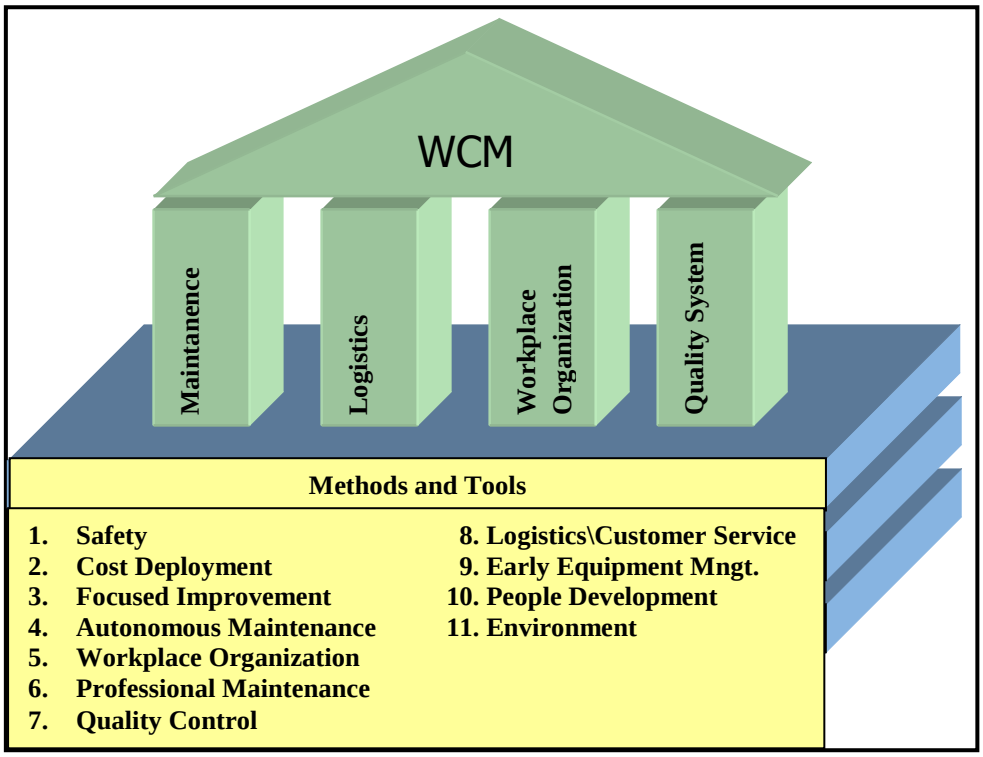


Figure – 42 "Methods of WCM"

11.3.2.1 Safety

It is applied to meet operators' requirements, promoting continuous improvement of safety at the workplace.

Purposes are:

- Drastically reduce the number of accidents.
- Develop a culture of prevention as regards safety.
- Constantly improve workplace ergonomics.
- Develop specific professional skills.

Main activities are:

- Periodic internal audits of equipment safety.
- Risk identification and assessment.
- Systematic analysis of accidents.
- Technical improvements to machines and to the workplace.
- Education, training and control.

Expected Results:

- Workplace Improvement
- Elimination of conditions for potential accidents

11.3.2.2 Cost Deployment

It is applied, so that the management can apply an effective improvement plan addressing major causes of losses with maximum energy, applying the most correct methods with the greatest impact.

Purposes are:

• Scientifically and systematically address the main items of loss of the plant production-logistics system

• Quantify potential expected economic benefits

• Direct resources and managerial commitment toward activities with the greatest potential.

Main activities are:

• Localization of losses (losses/processes matrix)

• Identification of sources of losses (source of losses/consequences matrix)

• Valorization of losses (source of losses/cost matrix)

• Selection of methods for eliminating losses (losses/solutions matrix)

• Valorization of expected benefits (costs/benefits matrix)

Expected Results:

- Objective knowledge of the main causes of loss.
- Improvement of managerial skills towards clear understanding of priorities and planned management of activities and benefits.
- Improvement of the ability to plan all the skills necessary for application of the methods chosen.

11.3.2.3 Focused Improvement

It is applied to eliminate the main items of loss identified previously through Cost Deployment and to avoid dedicating commitment and resources to non-priority problems.

Purposes are:

• Drastically reduce major production system losses, eliminating process inefficiencies.

• Eliminate non-value added activities in order to increase product cost competitiveness.

• Develop specific professional problem-solving skills.

Main activities are:

• Define the activities to be carried out, objectives and resources for project implementation.

• Train the groups and monitor project progress.

• Implement the projects.

• Provide the groups with the necessary specialist support.

• Certify and actualize results.

Expected Results:

A significant reduction of costs through:

- Improvement of overall equipment effectiveness (OEE).
- Reduction of set-up times.
- Reduction of waste.
- Professional growth and acquisition of the method.
- Development of a wide-spread improvement-driven attitude.

11.3.2.4 Autonomous Activities – Autonomous Maintenance (Capital-intensive areas)

It is applied:

• Because equipment is often in deteriorated conditions

• Because machine efficiency does not comply with objectives

• Because people's motivation can certainly be improved.

Purposes are:

Improving the global efficiency of the production system:

• stopping accelerated deterioration and restoring and maintaining basic conditions

• involving people

• improving product and equipment skills

• promoting cooperation between leaders and maintenance technicians

Main activities are:

• Creation of the teams, training and preparation for the activity

• Initial cleaning (cleaning for inspection and for knowledge)

• Elimination of sources of contamination and inaccessible areas

• Definition and application of efficient, sustainable cleaning, inspection, lubrication and re-tightening cycles.

• Improvement of inspection methods through development of operators' skills

• Focus operators' activities also through product quality control

Expected Results:

- Improvement of overall equipment efficiency (OEE) and of product quality
- Extension of the useful life of the equipment
- Improvement of climate, motivation *Autonomous Activities – Autonomous Maintenance (AM-Capital-intensive areas)*

7 Steps of Autonomous Maintenance

These are the seven steps of this method, which are going to be presented more deeply.

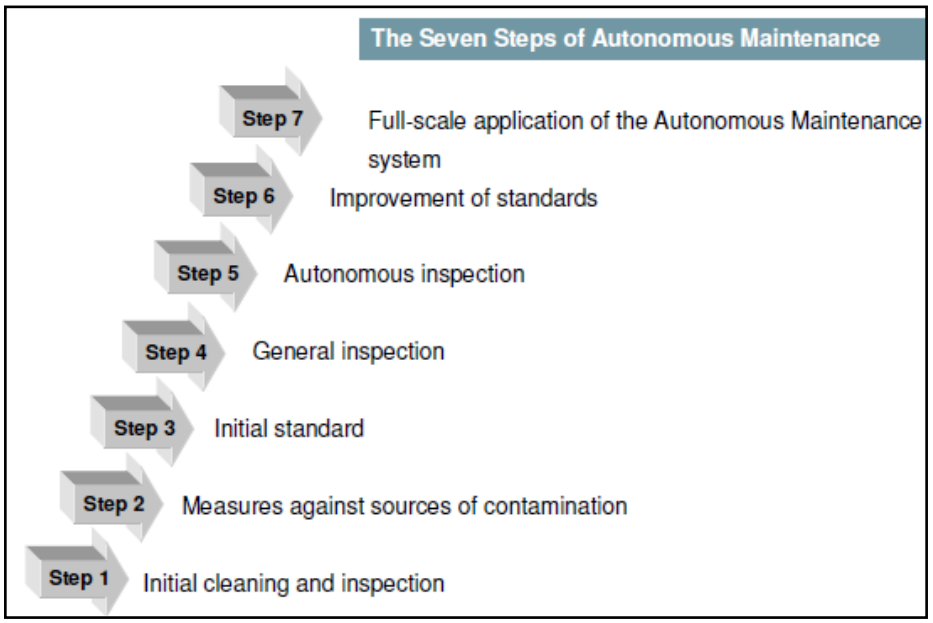
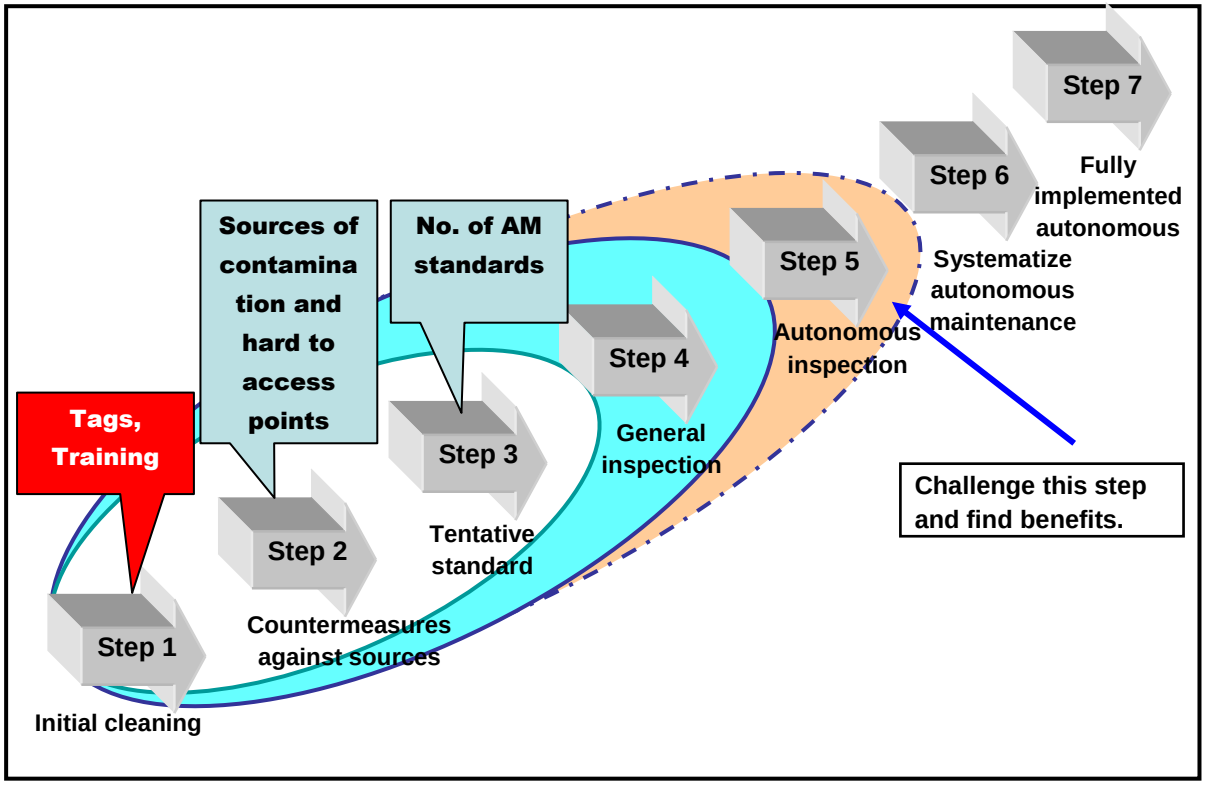


Figure – 43 "7 Steps of Autonomous Maintenance"



By the **Step 1**; Classifications of the place and machines, trainings, meetings, and initial cleanings are done.

METHOD OF CLASSIFICATION (A-B-C Analysis)

Equipment Name : LINE 6 (KOMATSU) UNIT : PRESS DATE :30/10/2006

Category	#	Assessment Topic	Assessment Score			Evaluation Criteria
Impact to Production	1	Equipment Use (Full rate)	(10)	5	(1)	If 3 Shift work : 10 If 2 Shift work : 5 If 1 Shift work : 1
	2	Alternate Equipment for the Production Facilities	(10)	5	1	No alternative equipment is: 10 It is hard (manual) production facilities if any: 5 There are alternatives, and setup is shorter: 1
	3	Effect of Failure of Other Equipment	(10)	5	1	Main production will stop in 15 minutes: 10 Main production will stop within 1 hour: 5 2 hours after the main production stops: 1
	4	MTTR (Average Repair Time)	(10)	5	1	> 30 min is: 10 11 - 29 min is between: 5 < 10 min is : 1
	5	MTBF (Failure Frequency)	10	(5)	1	1 is more than a day: 10 Values between the sub-top: 5 Is less than 1 per week: 1
	6	Impact on Product Quality of Equipment	10	(5)	1	Impact on the quality of equipment products too: 10 The effects of equipment, low product quality: 5 No effect on product quality of equipment: 1
Cost	7	Each of the coarseness Cost Breakdown	(10)	5	1	Cost of cheapness > 10.000€ : 10 Cost of cheapness = 1.001€ - 9.999€ : 5 Cost of cheapness < 1.000€ : 1
	8	Total Monthly Cost of Equipment Failure (Energy, Indirect Materials, Production Loss etc.).	(10)	5	1	€ 2000 more than the: 10 € 501 - € 1999 is between: 5 € 500 is less than 1
Safety	9	Safety Risk	(10)	5	1	The risk is big: 10 Risk is small: 5 Risk is not: 1
	10	Environment Risk	10	5	(1)	The risk is big: 10 Risk is small: 5 Risk is not: 1
General Evaluation Score			81			Equipment Class : (AA) A B C

- Total score is **80** points and above: AA
- Total score **60 - 79** score is between: A
- Total score **40 - 59** score is between: B
- Total score **39** points and below: C

Figure – 44 "Meetings and trainings"

- Meetings are about the process. (review results for losses, tags, etc,)
  - Attendance included:
  - Line/Area leaders
  - Technical organisation leader(s)
  - Maintenance Leader
  - AM/PM Specialist
    - Others as appropriate depending on specific AM step/activities
  - Daily meetings includes:
  - Review for daily losses
  - Anomaly Tags review

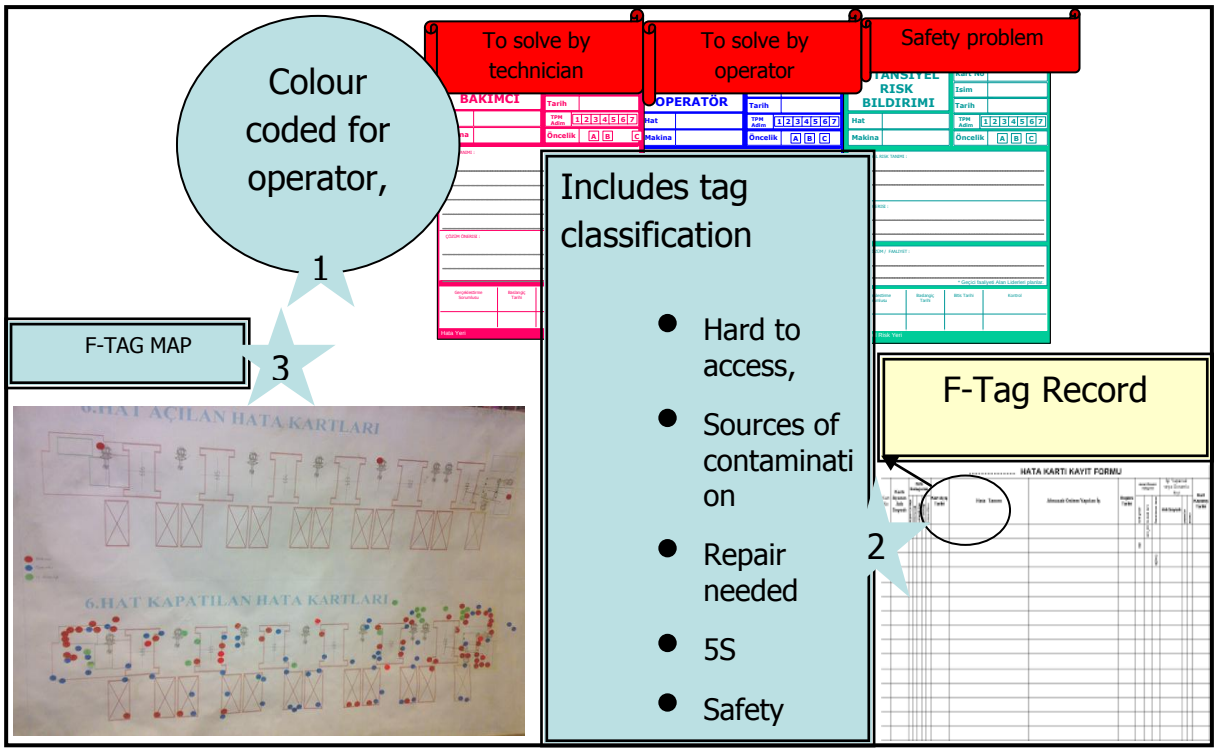
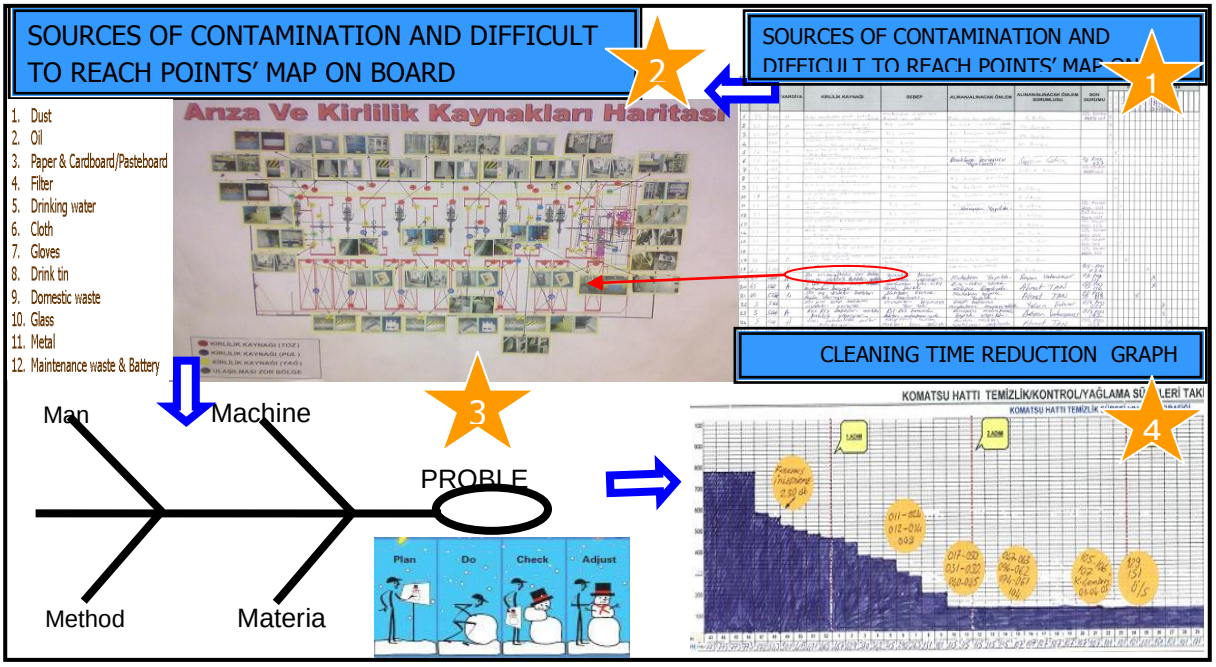
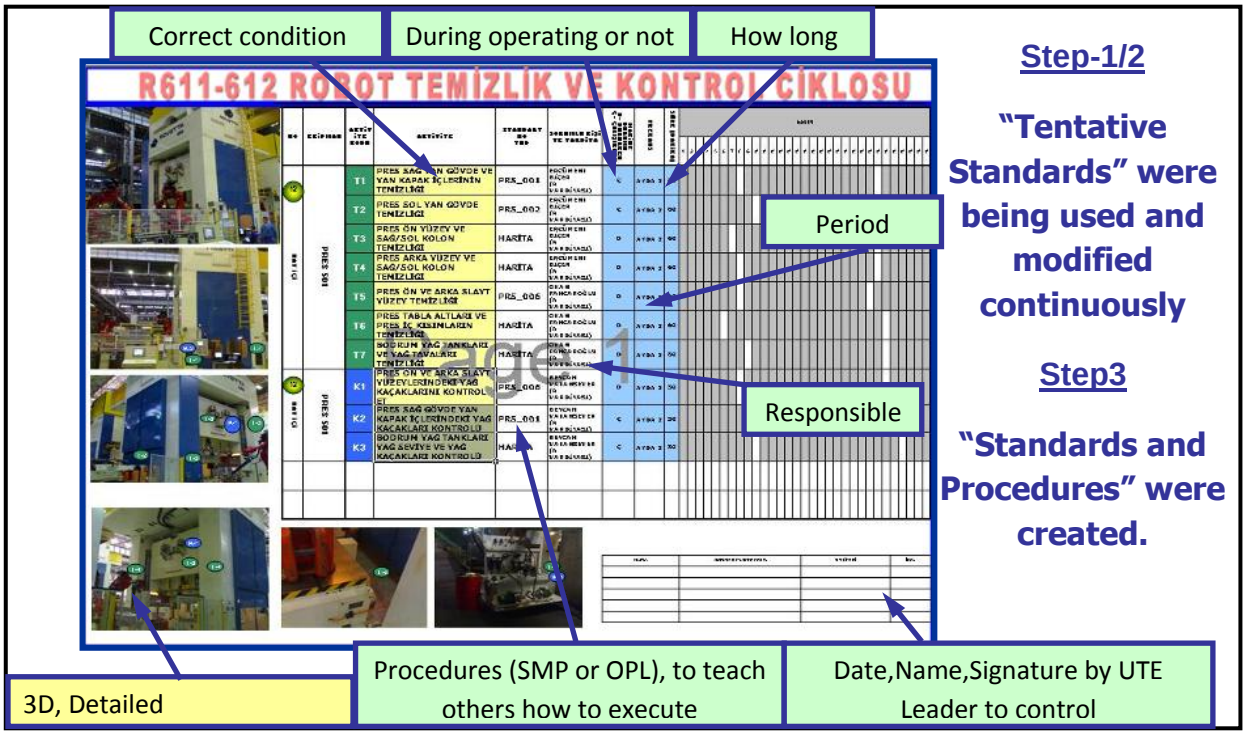


Figure – 45 "Tag classification"

By the **Step 2**; sources of contamination and hard to reach points are determined and mapped.



By the **Step 3**; Standards and procedures are created and started to applying.



The **Steps 4 – 7** are about **standardizing** and repeating the first three steps. In these steps **systemizing** and **implementation** are done.

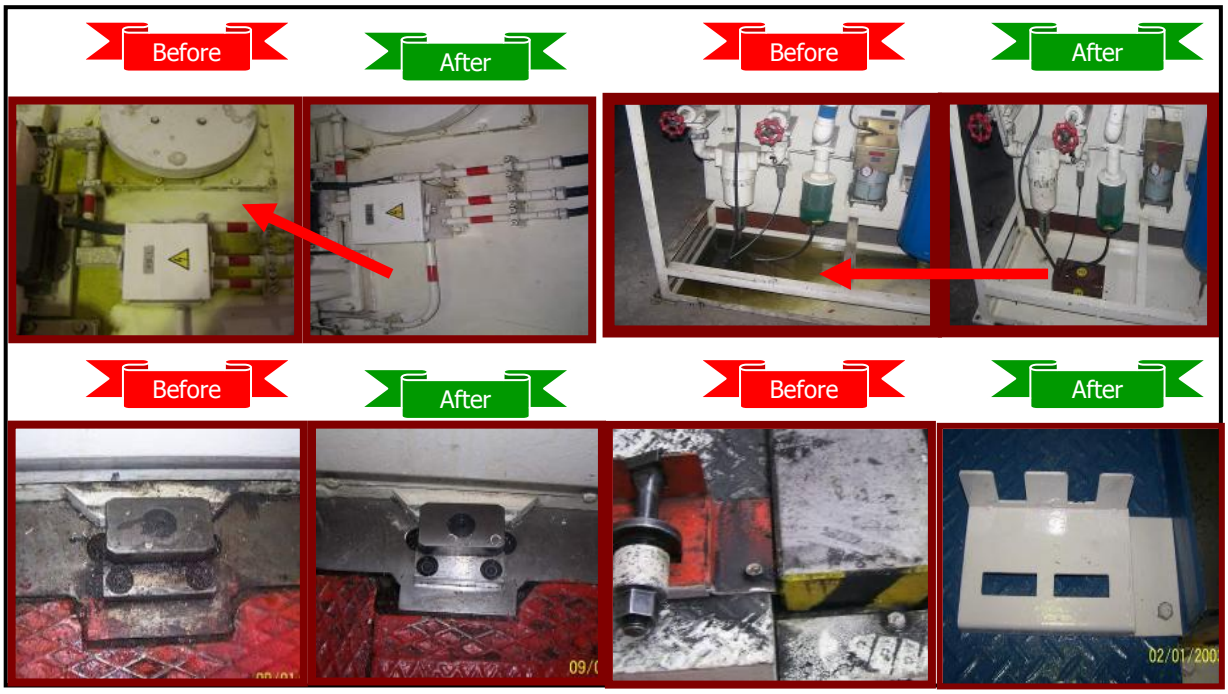


Figure – 46 "Before\After Examples"

Autonomous Maintenance Assessment Levels

0. There are no activities to involve operators in daily maintenance and improvement.

1. Model machines for AM from the AA machines of which breakdown losses are the major ones due to the lack of basic conditions, have been chosen and Step 1 ~ Step 3 has been implemented to correct standards. A system for auditing that the steps have been correctly followed is in place.

2. Step 4 for model machines. Step 1 ~ Step 3 for all AA class machines have been completed. Cost and benefit analysis proves benefit of AM.

3. Step 5 for the model machines. Step 1 ~ Step 4 to all AA class machines. Step 1 ~ Step 3 to A class machines.

4. Step 6 for model machines. Step 5 for AA class machines. Step 1 ~ Step 4 to (AA + A) class machines.

5. Step 7 for model machines. Step 6 for AA class machines. Step 1 ~ Step 5 for (AA + A) class machines. Autonomy starts to take place from model machines, gradually A class machines and then up to B class machines.

11.3.2.5 Autonomous Activities – Workplace Organization (Labor-intensive areas)

It is applied:

- Because workplaces, materials and equipment are often downgraded, dirty and untidy.
- Because product quality is achieved with too many inspections and reworking.
- Because people's motivation can certainly be improved.

Purposes are:

Improve production system efficiency and productivity:

- Restoring and maintaining basic conditions.
- Eliminating non-value added activities.
- Involving people.
- Improving product and equipment skills.

Main activities are:

- Setting up of the teams, training and preparation for the activity.
- Elimination of everything that is not necessary, tidying and cleaning.
- Definition and application of maintenance cycles.
- Analysis and elimination of non-value added activities.
- Improvement of work cycles and of product quality through development of operators' skills.

Expected Results:

- Elimination of labour and material losses.
- Improvement of product quality through application of a sturdy, error-proof process.
- Improvement of productivity and suitable process costs.
- Ergonomics and safety on the job.

11.3.2.6 Professional Maintenance (PM)

It is applied:

- Because there is a high number of defects.
- Because no systematic Preventive Maintenance activities are carried out.
- Because faults are seldom analyzed.
- Because there is little cooperation between operators and maintenance staff.

Purposes are:

- Increase machine efficiency by improving maintenance skills and using Fault Analysis techniques.
- Facilitate cooperation between operators and maintenance staff in order to achieve Autonomous Maintenance objectives.

Main activities are:

- Deployment, control and fault analysis.
- Improvement of maintenance staff skills.
- Definition of economically sustainable Planned Maintenance plans.
- Support of operators engaged in Autonomous Maintenance (elimination of tags and improvement of inspection skills).
- Application of new maintenance techniques.

Expected Results:

- Reduction of machine faults.
- Improved Overall Equipment Efficiency (OEE).
- Increase in the percentage of Planned Maintenance.
- Definition of a Preventive Maintenance plan.

11.3.2.7 Quality Control

It is applied:

- Because customer satisfaction is not appropriate.
- Because sometimes faulty products reach customers.

• Because reject and reworking costs are high.

Purposes are:

• Guarantee product quality for customers, minimizing costs.

• Define production system conditions able to prevent occurrence of nonconformities.

• Maintain the conditions defined in order to guarantee conformity in time.

• Improve operators' knowledge of quality problem solving.

Main activities are:

•Deployment of defects, reworking and rejects in order to analyze the origin of non - conformities (QA matrix).

• Definition of operating conditions able to guarantee the quality desired and process capability (QM matrix).

• Set-up, training and management of improvement teams.

• Compilation of the X matrix and definition of Q Points and of prevention and maintenance cycles **(capital-intensive areas).**

• Definition of Standard Operating Procedures – SOP **(labor-intensive areas).**

Expected Results:

• Improved customer satisfaction.

• A significant reduction in defects, rejects and reworking and therefore in the costs of non quality.

• Deployment of problem solving skills.

• Increase in product quality improvement proposals.

11.3.2.8 Logistics / Customer Service

It is applied:

• Because stocks of material at the plant are high with heavy financial charges

• Because there is a considerable risk of damage and obsolescence also due to the condition of the containers and the need for sequencing.

• Because production has to be rescheduled frequently due to shortage of materials.

Purposes are:

• Establish JIT conditions inside the plant and with suppliers.

• Considerably reduce stock levels.

• Level volumes and production mix and improve line saturation.

• Minimize internal handling, also with direct deliveries by suppliers to the assembly lines.

• Integrate the sales networks, manufacturing and purchasing.

Main activities are:

• Application of the Value Stream Map to identify losses and opportunities

• Improvement of the internal and external planning system, of layout and containers

• Deployment of the main materials handling methods (synchronous JIT, Kanban, full for empty, FIFO, shared external transport, etc.)

Expected Results:

• Prompt filling of orders.
• Reduction of stocks and work in process.
• Reduction of damage and obsolescence of materials.
• Improvement of plant logistics skills

11.3.2.9 Early Equipment Management

It is applied:

• Because new equipment start-up times are often longer than expected

• Because equipment is not designed to optimize recurrent costs.

Purposes are:

- Start new equipments in the times defined.
- Guarantee fast, stable start-up.
- Reduce Life Cycle Cost (LCC).
- Design equipment that is easy to maintain and inspect.

Main activities are:

- Formal insertion of EEM in the product development process through specific design reviews.
- Definition of quotes and specifications of supply consistent with users needs (operation, maintenance, inspection, and disposal).
- Integration with suppliers in designing with a man-machine approach.

Expected Results:

- Reduced life costs of the equipment.
- Reliable, maintainable, accessible, easy to inspect, clean, low noise equipment.
- Definition of economically sustainable Preventive Maintenance cycles in the design phase.
- Fast set-up and start-up.
- High product quality.

11.3.2.10 People Development

It is applied:

- Because skills and methods of work are often unable to guarantee error free operations.
- Because of shortcomings in the skills assessment and improvement system.
- Because knowledge and motivation to improve are insufficient.
- To permit targeted support of the skills required for development of other methods and of improvement projects.

Purposes are:

• Provide correct knowledge and skills for each workplace through a structured training system.

• Develop the roles of maintenance technician, technologist, and specialist as the main agents of training.

• Assure simple, effective documentation of knowledge and operating skills owned and developed that are to be deployed and maintained.

Main activities are:

• Mapping of skills required and possessed.

• Analysis of gaps and definition of training plans.

• Development of tools (One Point Lesson) and of training skills.

• setting up of the Training Center with the necessary materials and equipment.

Expected Results:

• Application of Quality Control for effective process control by operators: improvement of quality.

• Good maintenance skills: improvement of efficiency.

• Application of Autonomous Maintenance: knowledge and application of cleaning, inspection and lubrication by operators.

• Zero human errors: application and deployment of error-proofing techniques (Poka Yoke).

• Reduction of the risk of accidents.

• Improvement of climate and motivation.

11.3.2.11 Environment

It is applied to meet the needs of operators and of civil society, guaranteeing correct management of the environment.

Purposes are:

- Comply with environmental management requirements and regulations.
- Develop a culture of prevention as regards the environment.
- Continuously improve the conditions of the working environment, also over and above regulatory and legal obligations.
- Develop specific professional skills.

Main activities are:

- Periodic internal audits on the impact of the factory on the surrounding environment.
- Identification and prevention of risks.
- Application of ISO 14000 standards.
- Technical improvements to equipment.
- Training, education and control.

Expected Results:

- Reduction in energy consumption.
- Reduction in the generation of polluting substances and noise.
- Increase in the amount of material recycled.
- Improvement of the working environment.
- Elimination of the conditions for potential environmental accidents.

11.4 Key Performance Indicators (KPI) System

The Fiat Auto Production System has been structured with a clear **objective-oriented approach** in which these objectives must be **measurable, shareable and monitored** continually throughout the entire organization. Therefore, a KPI (Key Performance Indicator) model consisting of homogeneous families of indicators has been developed:

- Cost (C)
- Quality (Q)
- Productivity (P)
- Safety (S)
- Human Resource (HR)
- Production System (PS)
- Delivery (D)
- Stock (S)

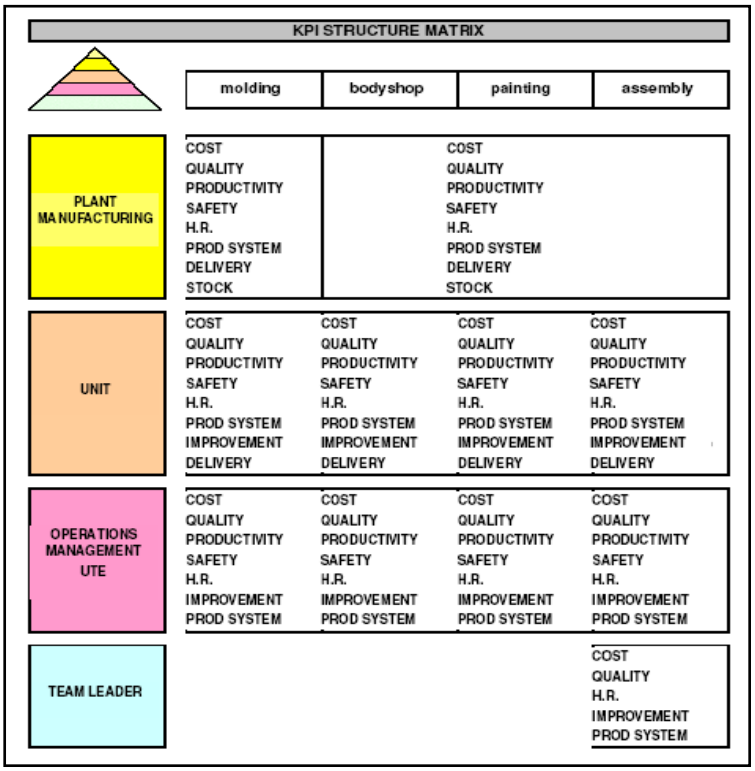


Figure – 47 "KPI Structure Matrix"

The indicators have been selected referring to:

- The levers on which each level is able to operate to influence the trend of the indicator.
- Best practices taken from outside the Fiat Auto organization, amongst acknowledged WCM companies.

As the production processes carried out by Fiat Auto Manufacturing differ considerably, the KPI have been personalized for the Bodywork plants and for the Stamping pole. The deployment has been defined, starting from Manufacturing Management down to the individual Domain Teams.

11.5 Audit System

The FAPS Audit System is one of the major elements for **assessing, guiding and supporting** application of the Fiat Auto Production System according to the path towards World Class Manufacturing. It is intended to monitor the trend of results (through the KPI) and to guide the management to the correct application of Production System methods.

To do this, both periodic **self audits**, carried out by plant management in order to monitor progress of the activities of the Pillars, and **external audits**, by independent managers for certifications of the levels achieved, are planned. The Audit System, as envisaged by WCM, comprises:

• **10 technical criteria** (Pillars), each referring to a precise methodology, organized in 7 application steps.

• **10 managerial criteria,** to support Pillar technical criteria, necessary for optimal application of the Production System.

12. CONCLUSION

In today's manufacturing environment and also in other professions, quality is becoming a significant constraint, and most desirable attribute by the customers. Producing non-qualified products or services will not only decrease the profits but will also reduce the customer numbers which is the most unwanted case by the producers.

Achieving high-quality manufacturing or world-class level is not simple task, especially in automobile industry. It requires deep involvement of all employees and workers, time, experience and significant know-how. Companies ought to improve their processes and products continuously, in order to keep customers requirements satisfied. This improvement can be obtained with the proper quality management and using quality tools (functions).

Quality functions, explained in previous chapters, can be very effective and significant on the manufacturing processes. With the accurate usage and involvement, they can improve and develop the processes in better-quality. They cannot solve all problems, but can reduce the rate of getting defect or problem, and create standards in manufacturing processes.

As a conclusion, companies should consider the quality and quality management very importantly and try to assign quality functions in every process they are doing. Standardizing and continuously improvement will provide better quality and as a result of that, bigger market shares.

13. APPENDIX

Appendix A – General Information about TOFAS, Fiat, Bursa[107]

Tofas, established in 1968 by the late Vehbi Koç, founder of the Koç Group, and jointly owned by Koç Holding and Fiat S.p.A., is today one of Fiat Auto's three globally strategic production hubs. Tofas is a global player and the only Turkish producer exporting both cars and light commercial vehicles throughout the world, such as the compact sedan Fiat Linea, in addition to the Doblo and Fiat's signature model, the Minicargo/Fiorino from its Tofas Bursa plant. Tofas assures it's position in the automotive value chain by its incorporation of the key links of employment and production in terms of contribution to the national economy as well as its service-focused representiveship of key global automotive brands. Tofas bears the distinction of being the only firm outside of Italy to represent the entire Fiat brand range under one company, providing local sales and after-sales service of international standards for Fiat automobile and light commercial models, inclusive of the Alfa Romeo, Lancia, Ferrari and Maserati brands.

Tofas celebrated its 40th year in 2008 with an outstanding first half-year performance, and minimized the effects of the crisis through preventive measures in the second half of the year; ending the year with record unit production of 268,000 at its Bursa plant. 2008 investments raised year-end plant production capacity to 400,000 units. So, in summary, despite the global economic crisis, Tofas surpassed forty-year vehicle sales records with local and international sales figures totaling 277,843 units. This represented a 23.8% performance increment over the previous year, resulting in net profit of 175.8,000,00 TL and confirming the firm's major contribution to the national economy with a turn-over of 4,798,000,000 TL.(TL=Turkish Lira)

The local car and LCV market shrank from 594,753 units in 2007 to 494,023 units in 2008. The Tofas car market share dropped from 13% in 2007 to 12.4% in 2008. Although price controls maintained in the face of stiff competition led to a drop in the car market share of the firm from 10.2% to 8.7%; release of the Fiorino's new versions initiated the light commercial vehicle market share rise from 17.1% to 18.3%; Tofas maintained third place in the total car+LCV market during this period with an overall market share of 12.4%; while Turkish market sales unit dropped by 12.6% against the previous year, and end of year production unit totals finalized at 68,000.

In 2007, Tofas received the "World Class Manufacturing" Project bronze award, and the title of the most successful Fiat Group production hub in 2007, this achievement was the product of continuous improvement initiatives at the firm since 1984. Further intensive initiatives throughout 2008 brought Tofas the silver award in 2009, providing the corporation with the distinction of being the first and only production hub within the Fiat Community to attain this award level.

[107] Tofas, - "http://english.tofas.com.tr/Icerik.aspx?id=31"

Appendix B – General Information about Prof.Hajime Yamashina

Professor Hajime Yamashina is member of both Kyoto University Engineering Sciences and Royal Swedish Academy of Engineering Sciences and recognized world-wide as a leading expert in World Class Manufacturing. He acts as advisor for many major industrial organizations. His extensive experience working with Japanese and Western companies has given him unique insights, which allow him to import Japanese best practices and techniques to suit Western organizations.

Appendix C – Achieving World Class Supply Quality (Questions)

- Have we reduced our supply base to a manageable level?
- Do we measure supplier quality performance?
- Are we establishing aggressive supplier improvement targets?
- Do we reward superior supplier performance and improvement?
- Do we certify supplier processes and methods?
- Are we committing the necessary resources to supplier development?
- Are we involving suppliers early in product and process development?

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