Fundamentals of Quality Concept: Literature Review

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Abstract

Quality is defined predominantly as one of the companies' key processes. It's declined on many structural levels and interacts necessarily with other functions in order to achieve the overall performance of the system. The purpose of quality management is to maintain a desired level of excellence in production and services in order to satisfy the customer. However, the concept of quality as we know it today has not been the same, it has undergone enormous changes starting with quality control and focusing today on achieving the global excellence of the company. In this context, this paper will describe the evolution of quality control as a key factor in the company and how we can transform this concept to global performance by using fuzzy logic as a new approach for reasoning and taking into account operator experience and uncertain information to describe a manufacture system and then optimize its performance in term of product quality and process reliability.

Keywords
Quality control, Total quality management, Fuzzy logic.

1. Introduction
In a quickly changing economic context, the major challenge for the companies was always to continue improving their competitiveness and continuously dominating their market share. Therefore, companies focused more and more on the criteria of industrial performance, which is mainly linked to the customer, namely cost, time, quality, and service to meet the increased requirements of the end customer.

In this context, quality has become today a very popular notion in human culture towards products as an important goal since the needs of consumers have been integrated into the decision loop. Quality is currently considered as the main and strategic function of the company to raise new challenges for the global competitive position. Quality has also become an necessary element to ensure that a company's products meet the needs of its customers, regardless of their field of activity or size. Therefore, this observation requires permanent improvement of all their processes to guarantee the expected performance, reliability and to achieve customer satisfaction, in order to ensure their sustainability and their technological monitoring.

From this point, quality should be considered as a key business process which is integrated with other processes such as the production process and the maintenance process. It should not be limited to a particular function or a single department of the company.

1.1 Objectives

In this paper, we will present different definitions and notions of quality and the associated concepts in the context of an industrial or service company. Then we will take a look at the evolution of this concept from quality control to total quality. Finally, we will discuss the function and the role of quality and its impact on the various strategic levels of the company as well as the various issues of quality management and how we can find a suitable solution for actual quality problems by using new methods especially fuzzy logic.

2. Definition of Quality Concept: Literature Review

Quality is found in all tangible and concrete forms of processes. Quality has also been a reflection of human civilization's progress in technology and science, an ever-growing demand from human society for better quality goods and services, and a resulting effort to satisfy customer demands (Mukhrejee 2019). Quality is associated with the whole environment around us, judged in terms of performance, parameters, and characteristics of the concerned product. Thus, quality is often evaluated in relation to the following entities: raw material, processes (integrating the technology used), products, services, work environment (Safety, hygiene, etc.), the ecological approach and respect of the environment.

Many authors have tried to give a precise definition of quality. The most laconic speak about "suitability for use" or "compliance with requirements", others speak about "exceeding customer needs and expectations throughout the product life cycle", for example in the ISO standard 9000 we give a precise definition of quality (AFN, 2000), "the degree to which a set of inherent characteristics of an object fulfils requirements.". These are the requirements of users (or customers). They can be individuals, companies, public or private services, internal services (notion of internal customer).

The definition of quality concepts is also proposed by D. A. Garvin (1987) through 5 approaches:

- The first approach (Transcendent approach) is mainly inspired by philosophy and conceives quality as the idea of excellence or perfection. This perspective is based on the managerial theme of excellence and the continuity of quality management efforts.
- The second approach is qualified as a product-based approach. According to this approach, quality is seen as a set of attributes of a good or a service that can be assessed against certain criteria. It states that great quality can only be achieved by a very high cost.
- The third approach is that of the user (User based approach) which defines quality as combination of attributes or features that bring the greatest satisfaction possible for a given customer.
- The fourth approach is seen from the supply side of producers (Manufacturing based approach) and refers to production management system where quality is seen as compliance. According to this approach, we can relate quality to notions of reliability (in the context of product design) and control (in that of manufacturing). In addition, this approach pursues a very specific goal: controlling quality costs, in particular through preventive investments.
- The fifth concept is expressed in terms of economic value (Value based approach) and gives a definition of quality in terms of cost. A quality product is a product that provides performance for an acceptable price.

Beyond the synthesis of D. A. Garvin, it is now possible to propose a sixth approach, qualified as a strategic one (Strategic based approach) where quality is seen as an element of differentiation of product or service relative to the competition.

3. The Evolution of Quality Concept

Until the 1970s, we mainly spoke about quality control or inspection. It consists of measuring, examining, testing or gauging one or more characteristics of a product and comparing the results with specified requirements. Products are checked one by one, or by sampling to ensure desired conformity for each characteristic. Customers can exercise quality oversight by verifying if requirements are respected, this is called inspection. The customer goes to the manufacturer and follows the control process to certify process satisfaction.

However, quality control and inspection can pose two challenges. First, the quality of control depends on the human factor, and this can cause reliability risk, leading to tensions and conflicts between those who manufacture and those who control. Also, the workers are oriented towards the quality of the product and not on the quality expected by customers.

In this context, the concept of quality progress, in order to promote cost control for organizations. The main objective is to have high quality for a low cost. The goal is to achieve about 100% conformity, without waste and without disposal. This requires reliable information on the production process and no longer only on the product. Therefore, the operator who makes the product doesn't have to control the product itself, but must control the production process, and what has become the goal. Through this evolution, multidimensional quality is created. We act at the same time on quality, cost, delivery, safety and morale. We are talking about quality assurance.

However, the development of this new step of quality control has a weak point, which is competition. It takes a lot of time to set up but also to apply it within organizations. This phase does not make it possible to meet the requirements of the competition. Other companies know how to do it too, with few or without defect in a short period of time.

Finally, quality has evolved in order to identify and meet the latent needs of customers. Quality in this case is about meeting the needs of these customers before they realize them. This means that quality depends on innovation. The dilemma associated with development regards that innovation is expensive for organizations. In addition, they must be rapid and relevant during these developments.

The total quality management system or Total Quality Management (TQM) is then developed. According to ISO 8402, total quality management is *"a way of managing an organization, focused on quality, based on the participation of all its members and aimed at long-term success through customer satisfaction and benefits. For members of the organization and for society".* Total quality for organizations is a policy that permanently mobilizes all its members in order to improve the quality of products and services, but also the quality of its operation.

Total quality is a part of a continuous improvement process, it concerns all processes of organizations. Continuous improvement is a concept inspired by the DEMING cycle. It means that the quality must constantly been improved. It should not stay fixed but evolve all the time.

In this context, Zonnenshain and Kenett (2020) affirmed that the quality has evolved through six stages which are the quality of the product, the quality of the process, the quality of the service, the quality of the management, the quality of the design and the quality of the information. The latter is fundamentally related to the development of the Enterprise Resource Planning (ERP) and the Manufacturing Execution System (MES) software. Thus, Sisodia and Forero (2019) have proposed a roadmap allowing a transition to Quality 4.0 where the last phase is linked to data management. The authors also discussed the importance of creating value within the company by enabling people to receive the right data and share it with colleagues at every level of the hierarchy.

4. The Pioneers of Quality Approach

The notion of quality is a developed concept since the first civilizations. Already in Antiquity, some countries were recognized as specialists in a product or technique (in architecture, for example). Quality, in the modern sense, really appeared with mass production. It was mostly initialized by the United States.

Walter A. Shewhart is an American physicist and statistician, Researcher at Bell Laboratories; he published two important books (Economic Control of Quality of Manufactured Product in 1931 and, above all, Statistical Method from the Viewpoint of Quality Control in 1939). His main concern was to maintain the quality of a product produced in series. The key to this control lies in the statistical control of variations in product characteristics. If these variations are too large, the user cannot be satisfied. We must therefore seek the causes of the variations and curb them. This research requires the collaboration of many people and various departments in the company. Shewartis thus led to carry out a complete description of all the phases of what is today called total quality management.

A disciple of Shewart, William Edward Deming adopted the methods to assess to what extent the objects produced fell within the limits of acceptable variations. It is one of the most important players in integrating quality into the business process. His thinking is characterized by real data analysis, supported by a system of deep knowledge. With it, the customer becomes the center of the business. He remains famous today for the strength of his synthetic spirit. Deming's 14 points are an example of the excellence of his thinking for synthesizing the whole movement of total quality.

Joseph M. Juranis is considered the co-founder of the modern quality movement. Applying Shewhart's theories for many years, J. Juran shared his experience by publishing quality control handbook in 1951 which proposes for management three objectives which are: process planning, ensuring its stability and finally trying to improve the level of performance. Juran's philosophy in quality concept contains several inseparable messages. The founding principle of its philosophy is the certainty that quality owes nothing to chance, it must be planned, and this planning is the responsibility of the top management. He is convinced that the majority of quality problems are due to mistakes made by managers rather than wrong execution.

Armand Valin Feigenbaum is an American quality expert. He is the inventor of Total Quality Control which is named now TQM (Total Quality Management). For Armand, quality is a business process and not just a technical one. He defines quality control as *"a system of coordination between quality maintenance and improvement efforts to allow the production of goods or services at the optimum economic level in order to satisfy customers"*. However, Armand Feigenbaum maintains that quality does not mean the best at all costs. You have to be the best compared to your competitors in order to satisfy the customer's demand. Thus, there is no need to look for a big difference between what the customer wants and what the company offers (as long as the product offered exceeds the customer's expectations).

5. Quality process in the different structural levels of the company

"The quality process is not carried out by a single department in the company, all departments and employees who compose this system have a role to obtain the desired quality of products and services in the company" (Gogue 2000). Thus, the quality process can be used in the different structural levels of the company with the objective of carrying out specific quality activities. In this sense, this process can shared at different levels : strategic, tactical and operational (Marcotte 1995), (Gentil et al. 2001), (Pujo and Pillet 2002).

The strategic level of the company integrates quality activities relating to quality planning concept, policy and quality objectives. It also contains all quality activities relating to certification according to the ISO9000 standard. Quality management at this level must therefore define a general quality policy containing internal requirements relating to product quality and quality improvement planning. The purpose of the quality planning is, on the one hand, to specify the control process control, according to the importance in relation to the risks incurred, in particular for the quality of the product or service, and on the other hand, to make the good choices concerning the quality methods and tools to use and thus support their deployment in the company at the tactical and operational levels. This quality plan is carried out in collaboration with the production planning, the maintenance planning, etc. which will integrate the constraints resulting from this activity.

In the same sense, the IEC62264 standard, in its parts 1 and 2 **(**IEC/ISO62264-1 2003), **(**IEC/ISO62264-2 2004)**,** shows that the role of the quality process at ERP management level (strategic) consists in defining the “right” procedures to be applied to maintain the quality. Quality in relation to customer requirements from product design to marketing and delivery.

On the tactical level of the company, the quality process operates more specifically on technical processes such as production and maintenance. This process encompasses quality activities relating to the concepts of quality control and improvement. The aim of quality process, at this level, is to control the quality of the products and the quality of the production processes in the broad sense. The related activities ensure the satisfaction of quality requirements, the identification of quality problems, and verification of quality actions.

According to the objectives defined at the strategic level, the establishment materials, among the methodologies or the approaches most used, it consists in planning the actions which will make it possible to plan the quality activities

according to the quality improvement planning defined at the higher level, and the quality control activities planned on the lower-level processes. The management of products and resources of quality concept can be adjusted according to this quality plan. This planning of quality activities must be carried out in line with the production process.

On the other hand, the IEC62264 standard, in its part 3 **(**IEC/ISO62264-3 2007**),** shows that the role of the quality process at the MES level (Manufacturing Execution System) also consists in verifying the quality actions in order to guarantee the respect of the expected performances, the production system and the product. Indeed, the quality process at this tactical level creates a link between the strategic level and the operational level in order to follow, in real time, the progress of all production activities.

On the operational level of the company, the objective of the quality process at this level is to put in place activities and materials to verify that the results of the technical processes comply with the specified requirements in terms of quality. It is about achieving quality control and dealing with non-conformities related to the process or to the product itself. Thus, quality activities at this level are supported by the implementation of quality methods and tools. These methods and tools allow the implementation of corrective and preventive actions which are launched in accordance with the quality plan defined above. These actions lead to activities relating to the notion of improving the quality of manufactured products and their production processes. Some of these activities are integrated into the production line, so of course they need to be coordinated with the production activities. In the same sense, the IEC62264 standard, in its part 3 **(**IEC/ISO62264-3 2007), shows that the quality process is theoretically integrated into the production control system. The role of quality at this level of the business is to monitor the product / process, carry out control and act on non-conformities and defects.

Thus, in the literature, the different models associated with integrated industrial management strategies treated by Bahria et al. (2020) can be classified as follows:

- Integration problems of maintenance and production.
- Integration problems of production and quality.
- Integration issues of maintenance and quality.
- Simultaneous management of maintenance, production and quality within the same framework of optimizing final product quality.

In the next part, we will focus on the integration of production, maintenance and quality into the industrial management of the company.

6. Interaction between quality, maintenance and production

Production planning, maintenance management and quality control are three main functions of production process, but which in the past were optimized separately, whereas today interact with each other. Many researchers believe that when the three tasks are not considered simultaneously, they are not globally optimal (Farahani and Tohidi 2020).

Production planning is the process of identifying resources that an organization needs for future production operations. Production planning is generally done at three levels: strategic level (long term), tactical level and operational level (production schedule).
The objectives of production planning are :

- SYNCHRONIZE the manufacture of products, the arrival of materials, the arrival of tools and the use of resources ;
- OPTIMIZE delivery dates, stocks and resources ;
- REACT by managing the hazards (disturbed mode).

In papers that focus on production planning, in general, two main issues are considered. The first is to determine the amount of economic output and the level of stock. The second is that of scheduling and sequence of production operations, which assigns production capacity and determines the sequence of production operations and their starting time. These two issues are included in tactical and operational production planning respectively. Most planning models assume that machines are always available and able to ensure a continuous flow of production ; however, in an actual production environment, the machine occasionally breaks down or stops for preventive maintenance actions and therefore may not be available at any given time. In this case, it turns out that it is not

optimal to carry out production planning on the machines, regardless of deterioration, possible breaks and scheduled shutdowns (Farahani and Tohidi 2020).

Maintenance includes all technical and management activities during the life cycle of an equipment, the purpose is to maintain or restore the equipment. It can perform the expected task with an acceptable level of quality. In maintenance planning, the first priority is to keep the equipment in good condition to avoid the manufacture of non-conforming products and defects. But when an unplanned shutdown occurs due to a sudden machine failure, the production schedule will not be executed properly and the delay will be augmented. In this case, changing the production schedule in an emergency usually imposes a high cost. Maintenance in this context seeks to reduce process variations and helps ensure a quality product. The additional maintenance will lead to a considerable increase in costs and the delayed maintenance increases the variability of the process. Maintenance planning is the best balance between maintenance costs and quality.

The choice of a maintenance policy is generally limited by production scheduling decisions, quality control and inventory state, so the specific interaction of maintenance with production planning and quality control is a recent notion. In the short term, production scheduling seeks to affect operations and their sequence without sudden equipment failure. In the long term, overall planning aims to compensate for demand if the equipment is shut down by determining the optimal level of inventory.

Scheduling preventive maintenance can interfere with optimal delivery time. When equipment is not in good condition for production, the quality of the products coming out of the process will not be acceptable by the customer.

The aim of quality control is to achieve a level of quality respecting the characteristics of the product, customer requirements and the process capacity. The purpose of a quality control system is to ensure that the level of quality is optimal and the costs of defects are minimized (Farahani and Tohidi 2020).

According to Bahria et al. (2020), the performance of production systems largely depends on the integration of maintenance, production and quality. The joint consideration of these functions results in insignificant savings in operational costs on the one hand and an improvement in the efficiency of the production system on the other hand. Despite of the close link between production, maintenance and quality, these main aspects of the production system have traditionally been modeled separately. Indeed, the production units start up in a “under control” state, producing compliant articles of acceptable quality. However, and after a while, they go “out of control” and start producing non-conforming items.

In practice, preventive maintenance (PM) should reduce the frequency of going “out of control” as well as the production of defective units. Hadidi et al. (2012) examine models that integrate different aspects of repair, quality, production and inventory, they divide the integration approach into two categories, the first category is the interdependent models which consider the one of the three tasks of the production system (production, maintenance, quality) as a target and other tasks as a constraint, and the second category consists of integrated models that simultaneously optimize two or three tasks of a system as a target , and the decision variables concern all the tasks (production, maintenance and quality).

7. Issues related to quality management in manufacturing system

To guarantee a better quality of products and services, companies and organizations must use various quality tools mentioned above. However, in an industrial context, information on different processes is generally imperfect and presents a margin of uncertainty due to fuzzy data based on operator experience.

Monitoring evolution of product quality is based on defining the links between product quality parameters, material flow and the state of process entities (interaction between quality and the various functions of the business). Therefore, the dilemma of cost and level of product quality is a critical issue for the majority of industrial companies.

Statistical process control techniques, especially control charts, are popular tools for tracking and analyzing the quality improvement process. Control charts measure against the centerline and upper and lower control limits of a process and allow corrective action to be taken based on lean six sigma principles.

However, this may not be very adequate when the quality characteristics include properties requiring the use of linguistic variables (for example, very poor, poor, average, good, and very good) rather than simply identifying them as conform or non-conform (José et al. 2020).

When humans subjectivity play an important role in defining quality characteristics, traditional control charts cannot be applied because they require precise data. By applying fuzzy logic to control charts, flexibility in control limits becomes possible, which is not possible in traditional control charts, where control limits are more inflexible. This fact gives managers more options and flexibility in the management of production processes, markets and customers (Gülbay et al. 2004).

8. Introduction to fuzzy logic applied to quality management

Humans have the ability to think continuously, they make decisions based on what they see in their environment and based on their unique experience. Thus, their thoughts cannot enter into the logic usually used by computer tools, namely binary logic. To capture all the inaccuracies inherent in human thought, some scientists such as Professor Zadeh have developed a new logic with the help of many mathematical tools : fuzzy logic.

The modeling of a fuzzy system must take into account human logic which is complex and relative to managing a imperfect knowledge. This loss of information may be due to inaccuracies or uncertainties during observations or to a lack of rigor during modeling or due to a bad approach in the processing of the data.

These imperfections can be from different natures, which there are three main ones :

- *Uncertainty :* there is doubt about the validity of a knowledge, this can come from a lack of reliability in relation to the intermediary or in case of forecasts ;
- *Imprecision :* this notion refers to the incomplete description of a state of reality by a proposition ;
- *Incompleteness :* the inability to obtain certain information results in an absence of knowledge. The phrase "the majority of companies in this sector achieve margins of around 25%" illustrates the incompleteness problem well, since the company in question is not necessarily part of the majority.
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In classical logic, these imperfections in knowledge imply the elimination of data because they couldn't be added in mathematical model which is based on certain data, while fuzzy logic will make it possible to process them and thus preserve the information they contain. Even if the goal is to have the simplest representation possible, a balance must be struck between keeping imperfect knowledge for their additional information and not over complicating the model for better handling.

Modeling systems by using fuzzy logic is a powerful technique for non-linear, uncertain and sophisticated systems because normal modeling methods can not be applied to fuzzy data and numbers. Fuzzy models use logical connectors to establish qualitative relationships between model's variables. This structure makes the models clear for interpretation and analysis. The fuzzy approach is based on uncertain linguistic expressions rather than probabilistic, statistical or numerical perturbation approaches (Abdüsselam et al. 2005).

9. Discussion and Conclusion

Quality has undergone enormous changes since its appearance from the first civilities. It has moved from the pursuit of compliance to the pursuit of excellence in rapidly changing industrial fields. Quality in the company is considered as a process that fits into the different structural levels of the company. At each structural level, this process brings together a set of quality activities that take place either in the design level of this process or in its operational one. These quality activities are supported by the implementation of quality approaches, methodologies and methods which, in general, represent means to operate the activities.

However, the past decade has seen significant advancements in connectivity, mobility, analytics, scalability, and data. There is even talk of the fourth industrial revolution, or industry 4.0, the industry has digitized its operations and, in doing so, transformed its efficiency, the performance of the supply chain and innovation. This revolution

even gave birth to completely new economic models. This is a solid foundation for overhauling quality management 4.0 is not so much about technology but how it improves culture, collaboration, skills and leadership for improving organizational performance and gain operational efficiency excellence.

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