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A Methodology for Quality Problems Diagnosis in SMEs

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***Abstract*—**This article proposes a new methodology to be used by SMEs (Small and Medium enterprises) to characterize their performance in quality, highlighting weaknesses and area for improvement. The methodology aims to identify the principal causes of quality problems and help to prioritize improvement initiatives. This is a self-assessment methodology that intends to be easy to implement by companies with low maturity level in quality. The methodology is organized in six different steps which includes gathering information about predetermined processes and sub-processes of quality management, defined based on the well-known Juran's trilogy for quality management (Quality planning, quality control and quality improvement) and, predetermined results categories, defined based on quality concept. A set of tools for data collecting and analysis, such as interviews, flowcharts, process analysis diagrams and Failure Mode and effects Analysis (FMEA) are used. The article also presents the conclusions obtained in the application of the methodology in two cases studies.

***Keywords*—**Continuous improvement, Diagnosis, Quality Management, Self-assessment, SMEs

I. Introduction

OVER the years there has been an increase in global competition among various sectors as a result of fast, deep and frequent changes all over the world and, therefore a fast technological innovation and proliferation of offered products (particularly in terms of variety and possibility of customization). In this market context, to ensure competitiveness, companies have to continually seek best practices in order to improve processes, products and services and to achieve agile and flexible costumer services and competitive costs. The quality of processes, products and services is an important factor in business strategies, and therefore has been changed to suit the reality that businesses face. Then, companies have to continually improve their processes through the implementation of adequate methodologies and tools.

To identify potential improvements in quality area, organizations need first to characterize their current state. Philip Crosby [1] was the first to propose a method to analyze the organizational maturity in quality management, which is a matrix with different development stages (uncertainty, awakening, enlightenment, wisdom, certainty) for six different categories: management understanding and attitude, quality organization status, problem handling, cost of quality as a percentage of sales, quality improvement actions, summary of company quality posture.

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Since the 90s, many companies have used the models underlying the quality awards, such as the Deming Prize, Japan Prize Malcolm Baldrige National Quality Award (MBNQA) in USA and European Quality Award based on the European Foundation for Quality Management (EFQM) in Europe, as a means of identifying and implementing initiatives of Total Quality Management or TQM [2].

According to Conti [3], Both the EFQM and the Malcolm Baldrige models are lacking in self-assessment. Conti, who was involved in the development of the EFQM model, recognized that there are two types of assessment:

- Assessments aimed at estimating the maturity level of the organization in quality management like award-based assessment and management audits;
- Assessments aimed at improving performance which involves the entire organization in the search for opportunities of improvement (diagnostic approach).

When a company wants to compare itself with other companies and when preparing to apply for an award, it is useful to perform an award-like assessment. However, when the aim is improvement, the diagnostic aspects of assessment must be the centre stage, once at first glance scoring and diagnosis may seem compatible, they are not [4]. Award assessment focuses on company strengths and scoring while diagnosis focuses on searching for the causes of problems. The study of improvement area as an important variable in the context of implementation of self-assessment has not received sufficient attention in the literature [5].

Conti [3, 4] advocates a kind of self-assessment organization called "diagnostic self-assessment" or "right-left assessment" which means identifying cause and effects links. This assessment is intended to improve performance by identifying the causes that have led to performance gaps, and obstacles to the achievement of objectives for improvement. In short, what Conti proposes is an approach to conduct a self-assessment based on any standard model such as the EFQM or the Malcolm Baldrige model starting by the effects, avoiding scoring beyond the area.

The adequacy of self-assessment based on models of excellence to the reality of SMEs has been questioned by some authors. Small and medium enterprises that are not certified do not have in most cases an organized quality management system that can be audited against the requirements of ISO 9001 quality standard or by models of Excellence [6], whose broad criteria are at a too high level for companies in most cases with low level of maturity in quality. Biazzo and Bernardi [7] consider that adopting this kind of self-assessment is an inappropriate choice for SMEs, given their level of complexity. Self-assessment based on excellence models is too sophisticated for most SMEs, due to the informal way that the quality-related initiatives are developed in such organizations [8]. Thus, for effective use of self-assessment

companies need to gain some experience in TQM. Sometimes, less experienced organizations tend to assign too high scores, creating an optimistic picture, or may be discouraged by obtaining very low scores [9]. The implementation of self-assessment based on models of excellence usually involves many people and requires a high investment in resources [9]. For this reason, the process may not be practicable for organizations with few resources.

In this paper, a diagnostic methodology for SMEs is proposed in order to identify quality management problems to be solved firstly to increase quality level and reduce costs. It is not the purpose of the methodology to assess the business model of organization, such as the EFQM model. A business model addresses the whole company focusing on mission and strategic goals. This project aims to define a diagnostic methodology to characterize the quality management function of companies and to exhibit quality problems. With the application of the methodology organizational or management problems concerning quality will be revealed.

The remainder of the paper is organized as follows. In the next section, the assessment items of the methodology are described. Then, in section III, the steps of the methodology are presented in details. In section IV, results of two case studies are discussed. The last section presents the conclusions.

II. Assessment Items

Once the objective was to create a methodology easy to implement even by people with little knowledge in quality management, predetermined assessment items to carry out the diagnosis was considered. Following the same logic of the EFQM model which includes enablers and results criteria, the assessment items are divided in two categories: processes of quality management and results.

A. Processes and sub-processes

A set of processes and sub-processes have been defined to assess the quality management system of a company based on Juran's Trilogy. Juran's trilogy is one of the key contributions of Joseph Juran, one of the most important contributors to modern quality management [10]. Inspired in the financial function, Juran suggested that quality management should be organized into three equally important functions: quality planning, quality control and quality improvement.

Quality planning acts proactively, designing products, services, and processes that meet customers' needs and expectations, avoiding costly deficiencies and optimizing company performance. Quality control function consists in ensuring that established goals are achieved during operations. The third function, Quality improvement, aims to create breakthroughs to unprecedented levels of performance.

According to [10], the Juran's trilogy is a system for managing not just quality, but also for managing innovation, and provides hands-on operational information about how to go about organizing and implementing a quality management program within an organization. Godfrey and Kenett [11] believe that the Juran's trilogy is the most simple, complete and pure representation of managing for quality ever devised.

In this work, the quality functions of Juran was analyzed and expanded incorporating in each function processes and sub-processes that are thought to be important for achieving the goal of each one. The processes and sub-processes were defined based on experience and also on quality standard such as ISO 9004.

Table I, II and III presents respectively the processes and sub-processes for quality planning, for quality control and for quality improvement analysis.

TABLE I
PROCESSES FOR QUALITY PLANNING ANALYSIS

Processes	Sub-processes
1-Supplier Qualification	- Method for supplier qualification - Method Implementation
2- Definition and communication of requirements to suppliers	- Definition of requirements for raw materials - Communication of requirements for raw materials - Definition of requirements for outsourced services - Communication of requirements for outsourced services
3- Product specification/acceptance criteria and critical characteristics	- Definition of product specification/acceptance criteria - Definition of critical characteristics of the product
4- Customer requirements and product characteristics	- Survey of customer requirements - validation of product characteristics against costumer requirements
5- Statutory and regulatory requirements	- Survey of statutory and regulatory requirements for the product - Verification of compliance of statutory and regulatory requirements for the product
6 - Preliminary studies about the capability (products) of processes or skill (service) and operating conditions	
7- Ensure that those involved in the processes have the necessary ability and knowledge	
8- Identification of potential problems (that may appends in product realization) and solutions	

B. Results

The other assessment item of the methodology to diagnosis quality problems is "Results". To define the results to be analyzed, the most comprehensive definition of product or service quality was taking into consideration: "quality is the capacity to achieved customer satisfaction". In this definition, the term quality involves two complementary aspects, quality of design and quality of conformance. Quality of Design is achieved in the design phase taking into consideration customers' requirements in order to create a product with fitness for use. It is in the design phase that characteristics such as reliability, performance, durability and aesthetic are defined and assigned to the product.

TABLE II
PROCESSES FOR QUALITY CONTROL ANALYSIS

Processes	Sub-processes
1-Planning of inspections and testing in production	- Definition of Characteristics to control - Definition of control methods - Capability of measuring, inspection and testing equipments
2- Inspection and testing of raw materials / components and control of outsourced services	- Inspection and testing of raw materials / components - Control of outsourced services
3- Calibration/verification of measuring, inspection and testing equipments	- Planning calibration/verification - Implementation of the calibration/verification plan - Validation of calibration/verification results
4- Identifying and processing nonconforming product	- Identification of nonconforming product - Processing of nonconforming product
5- Corrective actions for sporadic problems	- Identification of sporadic problems - Sporadic problems analysis - Defining and implementing corrective action - Verification of corrective actions effectiveness

Quality of conformance is achieved during the manufacturing process and is the degree of product conformity with the specifications defined in the design phase.

TABLE III
PROCESSES FOR QUALITY IMPROVEMENT ANALYSIS

Processes
1-Identification of improvement opportunities
2- Setting Priorities
3-Defining and implementing improvement actions
4 – Verification / monitoring of the effectiveness of improvement actions

Therefore, the methodology includes three categories of results: 1- customer satisfaction; 2- nonconforming products and 3- nonconforming raw materials/components and outsourced services. Customer satisfaction assesses both quality of design and quality of conformance, and the two other categories assess only quality of conformance. About quality of conformance, the aim is also to evaluate the efficiency of the production system in identifying and dealing with nonconforming products or defects. It is for this reason that the third category of results is included.

Each category includes a set of results to be analyzed, as shown in Table IV.

III. METHODOLOGY

A. Methodology steps

The methodology described in this paper can be applied by external consultants during the study of a company or the company itself as an instrument of self-diagnosis. Its implementation will highlight weak points and improvement areas. Based on this information the company will be able to define priorities and develop strategies to performance improvement in quality management.

TABLE V
PROCESSES AND SUB-PROCESSES CONSIDERED IN FMEA

Quality planning	Quality control
1-Supplier Qualification - Method Implementation	1-Planning of inspections and testing in production - Capability of measuring, inspection and testing equipments
2- Definition and communication of requirements to suppliers - Communication of requirements for raw materials - Communication of requirements for outsourced services	2- Inspection and testing of raw materials / components and control of outsourced services - Inspection and testing of raw materials / components - Control of outsourced services
6 - Preliminary studies about the capability (products) of processes or skill (service) and operating conditions	3- Calibration/verification of measuring, inspection and testing equipments - Implementation of the calibration/verification plan - Validation of calibration/verification results
7- Ensure that those involved in the processes have the necessary ability and knowledge	4- Identifying and processing nonconforming product - Identification of nonconforming product - Processing of nonconforming product
8- Identification of potential problems (that may appends in product realization) and solutions	

The methodology is organized in different steps, as shown in Fig. 1, which can be in some case performed simultaneously. The first step consists in collecting general data about the company. This step is particularly relevant for external consultants. Following this steps, interviews are conducted in order to collect information about processes and sub-processes of quality management. Step 3 consists in developing a Failure Mode and Effect Analysis (FMEA) about processes and sub-processes. Once a cause can originate different failures modes and effects, a cause and effect matrix is built in step 4, based on information collected in FMEA, to identify the causes that must be removed first due to their onerous or critical consequences. To complete the study, data about company results is collected in step 5. All the information collected and analyzed following the proposed methodology is recorded in a final report (step 6).

In following sections, all the steps of the methodology are described in detail. If the diagnosis is made by an entity external to the company, steps 1, 2 and 6 can be simplified.

Fig. 1 Methodology steps

B. General data collection

General information about the company, such as the manufacturing product, raw materials, number of employee, sections/departments and organizational structure is collected and registered in the first step of the methodology. This information will be useful in next steps, especially in the second step, to select employees to be interviewed and the questions to which they will be invited to answer, based on the performed functions.

The production process is also described and represented by a flowchart that indicates the manufacturing process tasks, including control activities, and manufacturing sections where they are performed. It aims to represent all the products flow between sections or even between machines.

C. Interviews

The aim of interviews is to collect objective information about the process and sub-processes defined in section II. A description of how the company performed each process and sub-processes will be made, based on information provided by respondents and also on the documents used in the company. Previously, interview guides may be prepared, selecting the appropriate subjects for each respondent and following the 5W1H tool to define questions for each sub-process. In this process of gathering information, the company documents should also be consulted to complete the survey. The opinion of respondent, if given, regarding the performance of each process will also be registered to be analyzed in the next step of the methodology.

D. FMEA development

In order to analyze the effectiveness of processes and sub-process of quality management, the methodology involves the development of a FMEA. This FMEA is performed for processes and sub-processes that are realized periodically or repeatedly in product realization. The selected processes and sub-processes are presented in Table V.

For each considered process and sub-process, the failure modes, failure causes, its consequences or effects, and frequencies are identified and registered in an appropriate form. The information is gathered and discuss in a meeting with all employees involved directly or not in the quality process. In addition, company records, which describe events that have affected the quality of products, should also be consulted to complete the analysis.

E. Development of a cause and effect matrix

The cause and effect matrix, such as the one represented in Fig. 2, will summarized the information obtained in the FMEA and will allow determining the most important causes in term of their consequences. Different types of effects and causes of failure modes identified in FMEA are now registered in the cause and effect matrix. The causes are placed in the columns and the effects are placed in the rows.

For each effect, a weight will be assigned to indicate the severity of the effect. A scale of three levels may be considered, assigning 9 for the worst effect and 1 for the less badly effect.

On the intersection of rows with the columns, the relationships between the causes and the effects are assigned, considering the values 9, 3 and 1 and giving the greatest value to a very strong cause and effect relationship, and the lowest value to a less strong relationship.

In the last row of the matrix, a rating is determined for each cause, multiplying the relationships value by the weight of the effects and adding results for each cause.

This calculated rating provides information about the priority of elimination of the cause based on its consequences. In addition, a color code with three colors can be used for segregating the causes based on their criticalities.

Effects \ Causes		Cause 1	Cause 2	Cause 3	Cause 4	Cause 5	Cause 6	Cause 7	Cause 8
Effect 1	3		3				9		
Effect 2	9				1				3
Effect 3	3	3		3		9			
Effect 4	1		9				1		
Effect 5	3				9			1	
Effect 6	9	3			1			3	
		36	**18**	**9**	**45**	**27**	**28**	**30**	**27**

Fig. 2 Cause and effect matrix

F. Collecting data about company results

This step can be started at the beginning of the methodology implementation. It aims to collect information about the results classified in three categories: customer satisfaction, nonconforming products, nonconforming raw materials/components and outsourced services.

About customer satisfaction, information will be collected in the company concerning indicators used, their actual values and tendencies.

In order to collect and record information about nonconforming items and their distribution in the process in terms of occurrence and detection, Defects Registry Matrices are developed.

First, process analysis diagrams (Fig. 3) are drawn for each type of products in the company to identify the tasks that are performed to obtain the finished product. The tasks are classified into three types of actions: operations (O) which represent a value-added task, controls (C) which represents a control task, and combined task (CO) where the operator performed both an added-value and a control task.

If the company produces a high diversity of products, an ABC analysis may be performed to identify products of higher invoicing.

Then, the study may focus only these products.

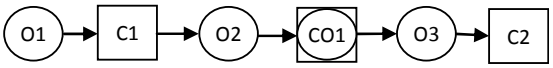

Fig. 3 Process analysis diagram

For each product, the number and type of defects is gathered in each control station. If defects are not usually recorded, then forms must be developed and implemented in the manufacturing process. The information collected in a defined time interval will be recorded in the Defects Registry Matrix (Fig. 4). For each type of defects, the matrix will record the station where it was detected and the station where the defect was originated (a previous workplace, internal supplier or external supplier) and also its frequency. Since the cost of quality is higher the more downstream the defect is detected, the matrix will provide interesting visual information and will allow planning improvement in order to detect defects as soon as possible and to reduce its frequency.

This matrix (inspired by a matrix of Kaizen Institute), in addition to being used in the diagnosis phase, may be used to monitor further improvements.

NONCONFORMING ORIGINATED IN / NONCONFORMING DETECTED BY		Upstream		Analyzed Process			
		External Supplier	Internal supplier	O1	O2	CO1	O3
Analyzed process	C1						
	CO1						
	C2						
Downstream	Internal supplier						
	External supplier						

Fig. 4 Defects Registry Matrix

The study of nonconforming items can be completed with the identification of the time spend in rework task, the number or percentage of products that need to be reworked, the number or percentage of product which are rejected.

IV. Case studies

The diagnostic methodology was applied at the same time period by a research student in two companies that will be designated by company A and company B.

Company A is a small and non-certified company that produces woven fabrics, company B is a medium company of the footwear industry, that have a quality management system implemented and is certified according to ISO 9001:2008 standard.

The sequence of steps to implement the methodology was similar in both case studies as well as the number of company visits. The researcher carried out 4 visits in each company. In The first visit, the organizational chart was requested and a survey of all relevant information about the company was conducted, namely the number of employees, departments or major sections, the types of products manufactured, raw materials used, and operations and controls of the production process. In the second visit, individual interviews were conducted with a group of employees. Previously, a general guideline from the list of predetermined processes of quality management was created. Subsequently, based on the organizational chart the distribution of questions was made, taking into account the functions performed by the interviewee.

Also at the second visit to company A the research student implemented forms to collect information to fill in the defects registry matrix. In company B, it was not necessary, since the company already register this information. Then, in this case the defect registry matrix was filled in based on the registry forms of the company.

FMEA forms were filled in based on information and comments of the respondents during interviews and the cause and effect matrix was filled with the help of the company managers at the third visit.

A final report was generated after the application of all the step of the methodology. The final report was presented at the fourth visit to the managers which recognized the usefulness of the methodology and planed improvement actions based on the observations and conclusion of the study.

Company B performs records relating to events with negative impact on product quality, while the company A did not have any records. The access to this data, in the case of company B, allows more reliable results in FMEA, in particular as regards the frequency of the failure modes.

Through the application of the methodology in the two companies, it was concluded that the FMEA process should be carried out in a meeting with all the involved people in order to produce a better analysis. Concerning the cause and effect matrix, it was observed that a topic could sometimes be placed in the column (as a cause) and also in the raw (as an effect). For example, an effect of a failure mode of a quality planning process can be a cause of a control planning process. In order to overcome this situation, one possible solution could be to separate the analysis by quality functions. Therefore, a cause and effect matrix would be made for quality planning and another would be made for quality control.

In addition concerning the cause and effect matrix, it would be relevant to try to reduce the subjectivity associated with the assigning of scores, performing the assessment based on objective data. It is recommended therefore that the matrix is periodically reviewed, with the collaboration of the heads of each department.

V. Conclusion

The methods of quality management adopted by large companies cannot in general be implemented directly in SMEs due to their distinctive features. The difference between best quality practices and their implementation in these firms indicates a huge opportunity for improvement in SMEs, particularly those with low level of maturity in quality.

With the conclusions obtained in both case studies, it was verified that the objectives set out in the work are fulfilled. The proposed methodology is effective to identify both quality management gaps and problems in companies. Gaps are identified based on the predetermined assessment processes and sub-processes and problems are identifies based on FMEA and cause and effect matrices. The results analysis also contributes to identify opportunity of improvement, in particular through the proposed quality registry matrix.

Besides being a diagnostic tool, the proposed methodology also allows a non-certified company to become familiar with quality management and its processes.

The proposed methodology could also be used by companies to perform Benchmarking with other companies of the same or of a different sector of activity.

The methodology presented in this paper is substantially different from most assessment models available in the literature, since its purpose is not to score the organizations performance, nor determine their maturity level. It is intended that its implementation will mainly contribute to highlight weaknesses, particularly the performance gaps that can affect product quality and their causes, providing companies with information to enable them to set priorities for improvement.

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