Diagnosis of Quality Problems in a Footwear SME

Humberto N. Teixeira, Isabel S. Lopes and Sérgio D. Sousa

***Abstract*—This article presents the results of a study conducted in a footwear SME. The study aimed to characterize the state of quality in the company highlighting weaknesses and areas for improvement. The methodology employed makes use of a set of tools for data collection and analysis such as interviews, flowcharts, process analysis diagrams, defects registry matrix, Failure Modes and Effects Analysis (FMEA) and cause and effect matrix. Based on the gathered data, the company procedures in quality management and the production process performance are described and analyzed. Besides reflecting the quality state in the organization the study also allowed to prioritize the elimination of causes that are responsible for poor performance.**

***Index Terms*—Continuous Improvement, Diagnosis, Quality Management, Self-assessment, SMEs**

I. Introduction

Quality management self-assessment is a useful tool for supporting organizations continuous improvement [2]. The ISO 9004 [6] defines self-assessment as a comprehensive and systematic review of an organization's activities and results, referenced against a chosen standard. Ahmed *et al*. [1] emphasize the holistic nature of the self-assessment process. It must be implemented to improve the overall performance of the organization and not only to improve products or services' quality [13]. Through self-assessment the organization is constantly questioning the way things are being done, which helps to keep up the company competitive level [2]. Thus, an organization should use self-assessment to identify improvement and innovation opportunities, set priorities and establish action plans with the goal of sustained success [6].

Self-assessment reports should focus on weaknesses and relevant causes, since the aim is to plan remedies [4]. The information obtained from self-assessment can also be used to stimulate comparisons and share learning across the organization. Comparisons can be made between the processes of the organization, between its different units or with other organizations [6].

According to Conti [5], self-assessment conducted by organizations autonomously, to achieve their own purposes and following their own rules, is divided into two kinds: management audits and diagnostic self-assessment. Karapetrovic and Walter [7] stress that the traditional audit methodology designed to test the quality assurance systems falls far short of enabling continuous improvement. In turn, Conti [5] emphasizes that diagnostic self-assessment aims performance improvement. This author also points out that self-assessment should never be enslaved to the Excellence Models rules.

Most of self-assessment tools available (surveys, audit list, etc.) do not have universal acceptance, since they are developed based on the requirements of a particular type of industry and their assessment criteria are derived from specific quality models advocated by a quality specialist or a combination of quality models [8].

Conti [5] underlines that excellence requires differentiation and competition also in the area of organizational assessment models and argues that, even if starting with a "standard" model, the adaptation to the characteristics of the organization should be always pursued. In other words, the models should be customized.

The choice of self-assessment approach depends on diverse factors such as the time that the company wants to spend, the monetary cost it is willing to accept, the quality of the results, the company's culture or the objective to be achieved by this exercise [2]. These factors are particularly important when intending to apply self-assessment in SMEs context.

Sturkenboom *et al*. [9] highlight that self-assessment instruments to evaluate the performance of SMEs, should not be too complex. According to these authors, in order to develop an assessment instrument appropriate to SMEs the following situations have to be considered:

- The larger the number of key elements, the more complex becomes the instrument;
- The more criteria of the instrument are related to the "ideal TQM" organization, the larger will be the gap between the criteria used and the current situation;
- Most SMEs do their job pretty well, however, their definition of quality is more or less static, aimed at satisfying their current customers.

The adequacy of self-assessment based on Excellence Models to the reality of SMEs, companies that often reveal low maturity in quality management has been questioned by several authors. According to Biazzo and Bernardi [3] the

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adoption of this type of self-assessment is an inappropriate choice for SMEs due to their level of complexity. After carrying out a study in seven SMEs in northern England, Wilkes and Dale [12] concluded that the language of the EFQM Excellence Model needs to be simplified to better fit the SMEs specific characteristics and observed that these companies do not know how to take advantage of self-assessment based on its criteria. Sturkenboom *et al*. [9] stress that the self-assessment tools based on Excellence Models are too sophisticated for most SMEs due to the informal way that quality related initiatives are developed in this type of organizations. Sometimes, less experienced organizations tend to attribute too high scores, creating an optimistic image, or may be discouraged by obtaining low scores [11].

In this article, the state of quality of a medium-sized enterprise is depicted through the use of a set of tools that provides a quick and easy reading of the data. The main goal was to identify gaps that must be resolved primarily in order to increase the level of quality and achieve cost reduction.

The presented study was undertaken as part of the Master's thesis in Industrial Engineering concluded at University of Minho [10]. The study uses a set of processes and sub-processes to analyze companies' performance in quality planning, control and improvement (Juran Trilogy). Based on the literature review, it was found that there is a very small number of quality management diagnostic models adapted to SMEs' specific needs. Therefore, it is expected that the methodology used in this study may contribute to achieve progress in this area. It should be noted that the study focuses only on quality management and not on the entire business process.

At first, a survey of all relevant information about the company was conducted, including the number of employees, the main sections and departments, the types of products manufactured, the raw materials used and the main activities (operations and controls) of the production process. A flowchart, a diagram of process analysis and a defects registry matrix have been drawn, after understanding the sequence and the relationship between productive activities. Then, individual interviews were conducted to a group of employees. Interview guides were created from a previously defined list of quality management processes. During the distribution of the questions, the functions performed by the interviewee were taken into account. Later, some of the predetermined quality management processes and sub-processes have been subject to a FMEA analysis. Based on the information collected through the FMEA form, a cause and effect matrix was developed, in order to summarize the causes and effects of failures (problems) and prioritize the elimination of the causes. Finally, the description and analysis of the information gathered through the several tools was performed.

The study description begins with a brief presentation of the company and its production process.

II. Company and Production Process Presentation

This study was performed in a SME that develops, manufactures and markets safety footwear. Currently, the company's products are exported to several countries. The company has 172 employees in its workforce spread over various departments. The organizational chart presented in Fig. 1, shows the departments in which the company is divided and the main activities undertaken in each department.

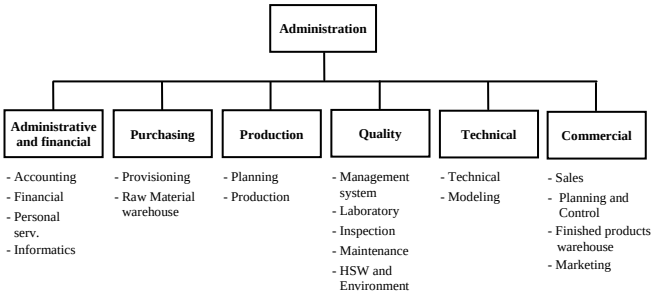

Fig. 1: Organizational chart.

The organization is certified according to the NP EN ISO 9001:2008 and holds a Research, Development and Innovation (RDI) certification in accordance with the standard NP 4475:2007.

Due to the wide variety of models manufactured by the company, this study will focus only on one product family. The process analysis diagram presented in Fig. 2 shows the sequence of activities identified during the analysis of the production process of shoes. In order to provide a more detailed analysis of the production process, a flowchart representing the production section where each activity is performed and the main equipment used in the different operations has also been drawn during the study. The product realization activities are mostly combined operations (CO) that is, an operation with an inspection (or control) mechanism embedded. During these operations, tasks are carried out aimed at manufacturing the product and a visual inspection is conducted in order to identify potential defects caused prior to or during the operation. This inspection is performed by the operator while handling the product or its components (self-inspection). The remaining operations (O) are product realization activities of cutting and sewing sections and other operations in which the product is not modified. The production process has also three control (or inspection) posts (C). The inspection of raw materials and product components takes place in the first control post. After receiving the raw materials and product components, the quality inspector compares them with a standard sample to ascertain any differences and verifies whether the quantities and technical specifications are correct. This inspection occurs at the raw materials warehouse. In the second control post, the production inspectors perform a 100% inspection, in order to prevent that defective products reach the assembly section. Finally, in the finishing section, an inspection of all final products is performed by comparing each product with a standard sample, previously approved by the client and by the company.

When raw materials or product components are received and during the production process, samples are taken for further laboratory analysis. The sampling frequency is stated in the Inspection and Test Plan (ITP) and in the Laboratory Test Plan (LTP).

The cutting, sewing and assembly activities are often subcontracted to external companies. However, the first series of first orders and the new models are produced

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internally. After being inspected, the unfinished items manufactured by subcontracted suppliers follow the usual route within the company production process until they are converted into finished products.

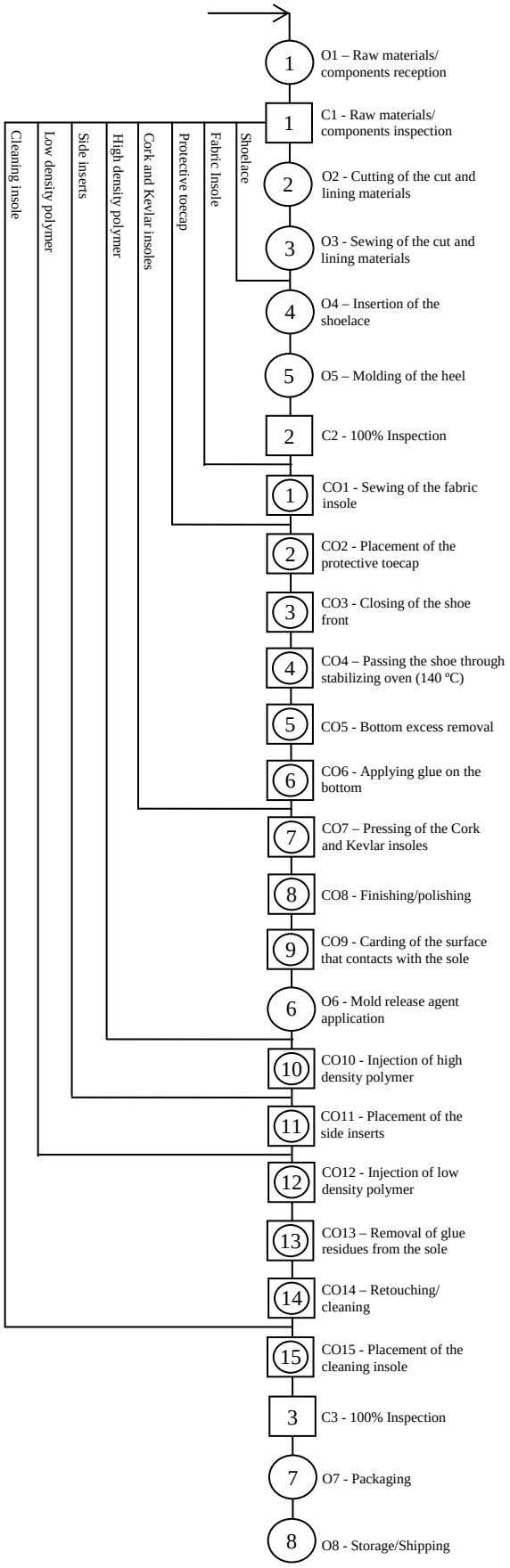

Fig. 2: Process analysis diagram of the selected product family.

III. Quality Management Processes

The quality management processes (Table I) have been defined with reference to the Juran Trilogy. These processes are used to analyze the company performance in the Quality Planning, Quality Control and Quality Improvement.

TABLE I
CONSIDERED PROCESSES FOR QUALITY MANAGEMENT

Quality Function	Process
A. Quality Planning	A.1. Suppliers qualification A.2. Definition and communication of the raw materials/components or subcontracted services requirements to the supplier A.3. Definition of the specifications/acceptance criteria and critical features of the product A.4. Customer requirements survey and product features validation to meet customer requirements A.5. Survey and verification of the compliance with the statutory and regulatory requirements applicable to the product A.6. Preliminary studies on the processes capability (products) or skill (services) and operating conditions A.7. Ensure that who is involved in the processes have the necessary capabilities and knowledge to the products realization A.8. Identification of potential problems (that may arise in the product realization) and solutions
B. Quality Control	B.1. Planning of inspection and testing in the production B.2. Inspection and testing of raw materials/components and control of subcontracted services B.3. Calibration /verification of measurement, inspection and testing equipments (MITEs) B.4. Identification and treatment of nonconforming product B.5. Corrective actions to sporadic problems B.6. Verification of the process capability
C. Quality Improvement	C.1. Identification of improvement opportunities C.2. Priorities definition C.3. Analysis of opportunities for improvement C.4. Definition and planning of improvement actions C.5. Verification/ monitoring of the effectiveness of improvement actions

The information concerning the processes of quality management was collected through interviews. The interviewees were the Quality Manager, the Assistant to the Quality Manager and the Production Manager.

Based on the data collected during the interviews, it was found that, in general, the quality management procedures are appropriate and well executed by the company. The quality management tasks are mostly performed in accordance with documented procedures and/or work instructions. During the control actions defects registry forms are filled. When corrective and improvement actions are implemented, their effectiveness is verified and records are maintained. However, the fact of not being determined the process capability indexes for the product features that must be controlled is highlighted as a weakness.

The analysis of the quality management processes allows to obtain a deeper understanding of the company which was useful to carry out one of the steps of diagnosis study, the FMEA (section V).

IV. Defects Registry Matrix

A matrix designated by defects registry matrix was used in order to represent, for a given period, the defects caused by each operation and by the company's suppliers, as well as the places where the defects are detected (activities and customers).

In this study the defects registry matrix shows the percentage of defective products from the selected product family found on inspection per type of defect. An extract of the designed matrix is presented in Fig. 3.

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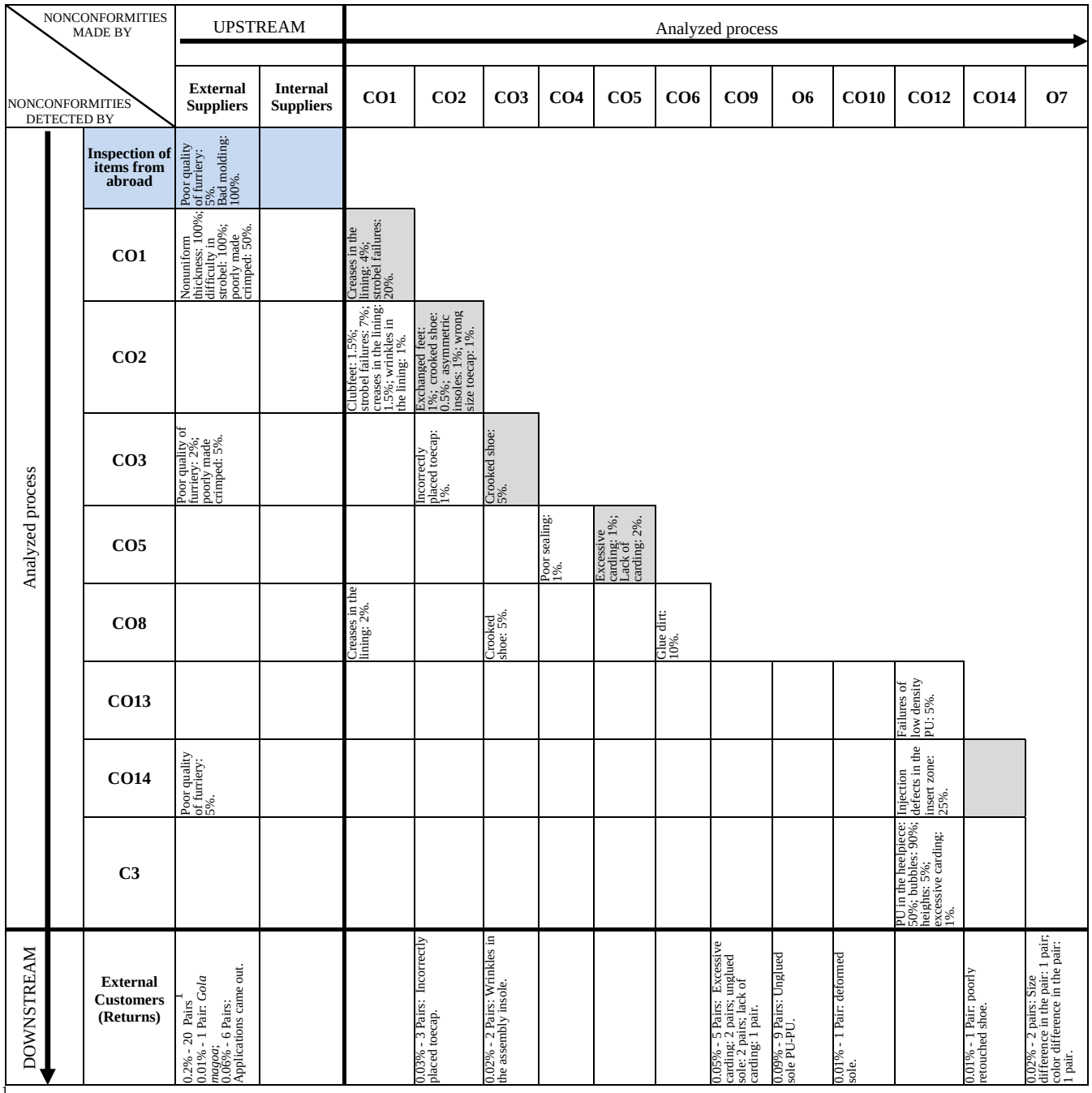

[1]Broken applications: 11 pairs; torn lining: 8 pairs; torn synthetic: 1 pair.

Fig. 3: Extract from the defects registry matrix of the selected product family.

The presented data were obtained based on company records for the period from January 21, 2010, to September 27, 2011. It should be noted that the cutting and sewing activities were performed by external suppliers, whereas the remaining activities have been executed internally.

Items manufactured by external suppliers are received and inspected at the assembly section. If they are deemed to comply should be addressed to the operation CO1 (Fig. 2). However, in the data collection period the percentage of items with "bad molding of the heel" is 100%. As a result, it was necessary to repeat this operation before sewing the fabric insole.

The defects that are caused by the service supplier and by the supplier of raw materials and components have been recorded in the matrix column "external suppliers", while those produced by the company are presented in the column concerning the operation that originated them.

In the last row of the matrix, is shown the percentage of products returned by the customer per defect type. The data indicate that the total percentage of returns is 0.5%. It can also be seen that more than 50% of the returns are driven by defects caused by the suppliers.

V. FMEA

In order to measure the company's procedures effectiveness, some of the quality planning and quality control processes and sub-processes (Table II) were subjected to a FMEA analysis.

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TABLE II
PROCESSES AND SUB-PROCESSES TO BE CONSIDERED IN THE FMEA

Quality Function	Process or Sub-process
A. Quality Planning	A.1. Suppliers qualification A.1.2. Implementation of suppliers qualification method A.2. Definition and communication of the raw materials/components or subcontracted services requirements to the supplier A.2.3. Communication of the raw materials/components requirements to the supplier A.2.4. Communication of the subcontracted services requirements to the supplier A.6. Preliminary studies on the processes capability (products) or skill (services) and operating conditions A.7. Ensure that who is involved in the processes have the necessary capabilities and knowledge to the products realization A.8. Identification of potential problems (that may arise in the product realization) and solutions
B. Quality Control	B.1. Planning of inspection and testing in the production B.1.3. Capability verification of measurement, inspection and testing equipment B.2. Inspection and testing of raw materials/components and control of subcontracted services B.2.1. Inspection and testing of raw materials/components B.2.2. Control of subcontracted services B.3. Calibration /verification of measurement, inspection and testing equipments B.3.2. Implementation of the calibration /verification plan B.3.3.Validation of the calibration /verification results B.4. Identification and treatment of nonconforming product B.4.1. Identification of nonconforming product B.4.2. Treatment of nonconforming product B.6. Verification of the process capability

The FMEA team included all the interviewees. For each of the analyzed processes and sub-processes failure modes were determined, as well as their effects, causes and frequency. The selected processes and sub-processes are those that relate to more practical aspects of the companies' performance and at the same time, those that represent tasks (repeatedly or periodically executed in the products development) which if not well executed might have a negative effect on the product quality. As an example, Table III presents the FMEA analysis of the sub-process A.1.2.

TABLE III
FMEA OF THE SUB-PROCESS A.1.2

Process or Sub-process	Failure Modes	Failure Effects	Failure Causes	Frequency
A.1.2. Implementation of suppliers qualification method	Do not rank suppliers as planned.	Need to perform rework; Loss of product quality due to rework; Need to transport the orders by plane to meet deadlines.	Need to meet profit margins; Need to meet deadlines; Difficulty in finding suppliers that are specialized in certain services.	Quarterly.

VI. CAUSE AND EFFECT MATRIX

In this study the cause and effect matrix is used as synthesis tool, which aims to identify improvement areas through the analysis of the root causes that are responsible for performance gaps. It also allows prioritizing the elimination of the causes.

The causes and effects identified in the FMEA analysis were represented in a cause and effect matrix. An extract of the resulted matrix is presented in Table IV.

TABLE IV
EXTRACT FROM THE CAUSE AND EFFECT MATRIX

Failure Effects		Failure Causes: Do not choose the best classified supplier to meet profit margins	Do not choose the best classified supplier to meet deadlines	Difficulty in finding suppliers that are specialized in certain services	Sending insufficient or confusing information to the supplier	Delays in sending samples to the supplier	Lack of monitoring of the first orders in the subcontracted supplier	Failures in the production planning	Problems with molds	Inattention of the workers involved in the production process	Low technical skills	Inefficiency of the training provided to the workers involved in the production process	The workers do not have enough information about the tasks they perform	Lack of accompaniment of the workers involved in the production process	Deficiencies in the production process that can not be corrected	Production equipment in poor working condition	Inspectors' inattention	Lack of control means	Difficulty in identifying defects in the raw materials or components	Difficulty in identifying defects in the products made by the subcontracted supplier	The subcontracted supplier does not notice changes in the usual request	Lack of monitoring of the calibration/ verification plan	Lack of self-control	Pressure of production
Need to perform rework	9	1	3	3	3					3	3	3	3	1	3	1	1	3	9	3	9			
Loss of product quality due to rework	3	3	3	3	3					3	3	3	3	3	3	3	9	9	9	3	9			
Need to transport the orders by plane to meet deadlines	3	1		1																				
Delays in completion of orders	9				3	3	1	9	3	1	3					9	3	1		1	3			
Failure to meet the deadlines agreed with the customer	9				3	3	1	9	3	3	3					9	3	1		1	3			
Failure by the supplier to meet the delivery dates	9				3	3	1																	
Service poorly performed by the supplier	3				3	9	3																	
Production breaks	9							9	3	3	9	3	3	3	3	9	3	1	3					
Defect in the product	9							3	9	9	3	9	3	3	9	3	9	9	9	9			9	9
Failure to detect nonconformities	3																	9				3		
Using MITEs that need revision or adjustment	3																					9		
Late identification of defects	9																						9	9
Customer returns	9																							9
The company gets a bad reputation due to defects in the product	9																							9
		21	**36**	**39**	**165**	**111**	**39**	**270**	**162**	**216**	**216**	**171**	**99**	**81**	**153**	**306**	**201**	**192**	**243**	**135**	**171**	**36**	**162**	**324**

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The cause and effect matrix presents the scores assigned by the Quality Manager and the Assistant to the Quality Manager to each effect and cause-effect relationship. The effects were scored according to the severity level, using the weights 1 (low), 3 (middle) and 9 (high). In the case of the cause-effect relationships, the degree of the relationship between the effect and each associated cause was scored using the weights 1 (weak relationship), 3 (average relationship) and 9 (strong relationship). Afterwards, was calculated what was named the cause elimination priority level (EPL). This indicator is determined by multiplying the weight assigned to each effect by the weights located in the same row of the matrix and the values are then added column by column. The causes EPL results are presented in the last row of Table IV.

In the last row of the matrix, the cells were flagged with the yellow, orange and red colors. Table V establishes the correspondence between the colors and results for this case study.

TABLE V
COLOR CODIFICATION BASED ON ELIMINATION PRIORITY LEVEL

Result	Priority Level	Color
1-100	Low	Yellow
100-200	Average	Orange
> 200	High	Red

The cause and effect matrix showed that “pressure of production” is the cause which has the higher EPL. Often the need to meet the production objectives puts great pressure on employees that can result in product defects, late identification of defects, customer returns and bad reputation of the company. All these effects are rated as high severity.

The other high EPL causes are the following:

- Production equipment in poor working condition;
- Failures in the production planning;
- Difficulty in identifying defects in the raw materials or components;
- Inattention of the workers involved in the production process;
- Low technical skills;
- Inspectors’ inattention.

These causes have in common the fact that they all can lead to the defects appearing in the product and may therefore generate significant losses to the company.

VII. CONCLUSION

The present study intended to characterize the quality state in a SME. The methodology tools application has highlighted strengths, weaknesses and areas for improvement in the way the company manages quality. Furthermore, this study also provided an opportunity to test and refine a new methodology.

Based on the FMEA analysis, some failures in the company performance have been identified**,** as well as the respective effects, causes and frequency. Afterwards, a cause-effect matrix was used to prioritize causes for elimination. Eliminating or simply reduce the occurrence of the causes with higher EPL can contribute to achieve important improvements.

Time constraints prevented the acquisition of a thorough understanding of the company and particularly about their products. However, it is believed that the study objectives were met, since that was possible to successfully implement all steps of the methodology. Furthermore, it is thought that the developed methodology was able to reflect with some accuracy the state of quality in the organization.

The methodology used in this study 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 the product quality and their causes, providing companies with information to enable them to set priorities for improvement.

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