Quality Cost Analysis for a Cement Industry: A Case Study

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***Abstract*— In a global competitive market, meeting customers' requirements is not enough for organizations that are striving for success and welfare. Another goal has to be meet which is the cost challenge. Enterprises need to offer highest quality at the lowest price. To achieve this, organizations must identify potential sources of savings by making an effective control of manufacturing costs. Since quality costs constitute a significant part of these costs, it becomes an imperative for companies to track, quantify and rationalize quality related costs by developing a measurement system adapted to their activities. Most companies, however, are unaware of the quantum of their quality cost and therefore underestimate it. In this context, appears the need to present quality cost as an effective tool of highlighting deficiencies in the system by giving an insight to the huge impact of quality cost on the bottom line as well as on the financial position of the organization. This paper presents a case study conducted in a cement industry that gives awareness and guidance to what requires attention of top management.**

***Keywords*—** *Quality costing system, manufacturing costs, non-quality, bottom line, top management.*

1. Introduction

To grow and compete successfully in a fiercely competitive market, organizations must measure and control all components of manufacturing costs by making a strong control of the utilization of process resources.

Knowing and determining the sources of losses allows to managers to properly identify the areas of improvement, to better justify the investments to be made and evaluate the return on investment ROI.

The cost of quality analysis is considered as one of the most effective management tool for gathering and analyzing the expenses in maintaining quality in a manufacturing process and also the non-value added expenses [1].

In spite of the academic interest on the subject, only minorities of industries are found practicing the COQ management and many industrial managers ignore the importance of related methodology for organizational improvements.

2. Literature review

Quality is widely recognized as a crucial key to survive and thrive in the global marketplace. If it is managed properly, it will not only guarantee the effectiveness of the organization but also increase its efficiency and boost its profits by reducing costs.

To implement successfully a quality improvement program, it is necessarily to check the merit of each improvement activity proposed and choose the optimal ones that lead to highest quality with the lowest possible cost, which is only possible if quality-related costs are identified, measured and reported.

Quality costing is therefore an important tool that assists companies to improve quality of products/services while making savings; it is regarded as an essential indicator/metric for measuring quality performance for the entire supply chain.

In a broader sense, we can define the quality cost as monetary measure that shows the expenses allocated by an organization in achieving and maintaining good quality as well as the wastage and losses incurred in managing the poor quality.

That concept was first presented by Joseph M. Juran in the first edition of the "Quality Control Handbook" published in 1951.He defined the quality cost as all costs in the organization that shouldn't exist if things were done the first time.

He demonstrated the important link between

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financial position of an organization & quality costs and proved that an optimum quality level exists.

The concept was expanded on by Armand Feigenbaum in 1956 in his book “Total Quality Control” when he developed the 4 quality cost categories that are commonly referred to today (Prevention, appraisal internal & external failures cost). He believed that the quality costs on average amount between 25 to 30% of annual sales [2].

He affirmed that so much extra work is performed in correcting mistakes wish cost companies a lot and that there is effectively a “hidden plant” within any factory.

In 1979, Philip Crosby introduced a new concept in his book “Quality is free”. He stated that doing things wrong costs more than doing things right the first time (cost of rework, scrap...).A good quality system payback its cost and make saving returns. Quality pay back more benefits than its costs thus quality is free.

Since then, the Cost of Quality concept has been continuously developed and several researches were carried out in this regard such as Plunkett and Dale (1987), Sandoval-Chavez and Beruvides (1998), Krishnan et al. (2000), Chiadamrong (2003) and many others.

3. Quality cost models

Despite the development of several modern COQ models since Juran's work, the most used ones are: the Prevention - Appraisal - Failure (PAF) Model, Crosby’s Model, the Process Cost Model (PCM), Opportunity Cost model, and ABC model.

- *PAF model:*

The more popular used one is the PAF model developed by Feigenbaum (1956) which distinguish quality costs into Prevention, Appraisal and Failure categories.

Prevention costs are associated with activities taken to prevent poor quality, appraisal costs represent the activities taken to control the level of quality attained by the process, and failure costs are costs that results from poor quality.

- *Crosby’s Model :*

Crosby sees quality as “conformance to requirement” and therefore classifies the cost of quality into two categories: cost of conformance and the cost of non-conformance.

The cost of conformance is the money spend by an organization to avoid poor quality and includes prevention and appraisal costs while cost of non-conformance are the money wasted on poor quality and includes internal and external failure costs.

- *Intangible / opportunity cost model*

Intangible costs are costs that can be only estimated. For example profit not earned losses in productivity, customer goodwill or drops in employee morale. While these costs do not have a firm value, managers often attempt to estimate the impact of the intangible costs

- *Process cost model :*

The process cost model is a model developed by Ross in 1977 and first used for quality costing by Marsh in 1989.This model focuses on process rather than products; it is based on gathering costs of conformance COC and non-conformance CONC of each process in the supply chain.

- *ABC cost model :*

ABC cost model is a costing approach that was developed by Cooper and Kaplan of Harvard Business School in 1980. This model allows assigning costs according to objects (departments, services, products, etc.), and based on activities performed for each object. More specifically, the assignment of costs through ABC occurs in two stages: firstly resource costs are assigned to activities, and then costs of activities will be traced to cost objects.

COQ models can be compared based on their categories, principle and orientation. Table 1 illustrates these differences.

Table.1- Quality cost elements of the burning process

Model	Orientation	Principle	Cost categories
PAF Model	Activity-oriented	▪ The basic supposition is that investment in prevention and appraisal activities will reduce failure costs ▪ Not suitable for some branch activity	prevention + appraisal + failure
Crosby's model	Activity-oriented	Similar to the P-A-F model with different terminology	conformance + non-conformance
Opportunity or intangible cost models	Intangible costs and cost of losing opportunities oriented	An expended model that consider the losing opportunities / profits not earned in addition to the prevention, appraisal and failure categories	prevention + appraisal + failure + opportunity
Process cost models	Process-oriented	▪ This model recognizes the importance of process cost measurement ▪ Presents a more integrated approach to quality than a P-A-F model	conformance + non-conformance
ABC Model	Activity-oriented/ focus on assigning cost to each activity	An activity-oriented for the cost assignment view and process-oriented for the process view	value-added + non-value-added

Indeed there is no uniform quality model and what should be included under the umbrella of costs of quality [3]. Consequently every organization should implement its own model and determine quality costs components that are suitable to its needs and situation.

4. Case study: Cement industry

4.1. Profile of the organization

The Case study was conducted within a cement industry; the company is already certified ISO 9001:2008 and preparing for the transition to ISO 9001:2015.

Despite the fact that there is a great interest in reducing costs given the atrocious competition of the cement sector. Company A (we keep the company name confidential and we refer to it as company A) doesn't measure, reduce and optimize cost of quality.

However, it stated that quality related costs are systematically reduced through the continuous improvement activities implemented.

To prioritize these activities, company A uses usual key performance indicators and metrics such as % breakdown, % energy consuming, rate flow etc.

The main issues that arise are:

- How much profit the organization is losing through poor quality?
- Is the only use of usual KPI helps to make optimal prioritization of improvement activities?
- How much the improvement activities implemented reduce losses incurred by internal inefficiencies and if there is a return on investment?
- On what basis the company allocates budget of the quality program?

4.2. Study intent and methodology

The main objectives of the study are as follows:

- Identify, measure and quantify quality cost of a manufacturer company and highlight the financial wastage due to non-quality on the overall quality cost as well as on the organizational bottom line;
- Recognize the importance of the quality cost metric as an improvement driver and a financial indicator for reducing costs and increasing the profit of organizations.

Quality cost analysis can be realized on the organization, department or on a process. For this study, we have chosen to make the analysis on “The burning process” since it constitutes 87% of the total manufacturing cost. Accordingly any reduction of that cost will influence positively the overall quality cost as well as the organizational bottom line.

The methodology adopted is to develop a specific list of quality cost elements which are adapted to the process studied and are relevant to the organization, after the elements have been agreed by organization specialists the next step is to collect the data from different sources, quantify them and putting a cost on each element identified.

After that, a Pareto analysis should be applied so as to find critical costs which are responsible for major expenses on quality costs, analyze the root causes of the losses and finally identify improvement area and suggest remedial solutions in order to reduce quality costs and improve the efficiency of the company.

4.3. Data collection & categorization

During this step, a specific list of quality cost elements based on PAF model was developed. The elements of conformance and non-conformance cost identified are listed in table 2.

Table.2- Quality cost elements of the burning process

Conformance costs	Prevention	Quality Training
		Quality administration
		Internal quality audits
		Preventive production
	Appraisal	Inspection & test equipment
Non-conformance costs	Internal failure	Rework
		Heat over-consumption
		Power over-consumption
		Machine breakdown
		Water over-consumption
		Downgrading
	External failure	Returned good (Since the company A sells clinker to other firms, we can consider the clinker returned as an external failure of that process)

It is recommended to establish a consistent measuring system with the involvement of various departments. The data related to costs was gathered form different sources, the main are: the general and analytical accounting, technical reports, and administrative documents.

This may seem like an easy step at first, but measurement are not always obvious; when it comes to establish the total quality costs there are some difficulties related to the fact that the accounting system is not conceived in such way to highlight these costs. Moreover, some costs are not quantifiable; they can only be estimated which makes the analysis of quality costs to be a subjective one [4]

Data related to prevention appraisal and external failure costs were communicated by the financial and quality department while the internal failures costs required calculation that occurs in two stages: Firstly, the quantification of losses and then the assignment of cost of each item.

To calculate the losses, it was necessary first to update some nominal values in order to get more accurate results. For this reason, it was required to make a statistical analysis of the data of 4 successive years considering each equipment and product separately.

For example, the statistical analyze of electricity consumption of kiln 1 shows that 95% CI for μ is between (31,637; 33,010) which means 7kWh/ton of difference than nominal value fixed by the organization. The summary report of kWh analysis of kiln 1 is presented in figure 1.

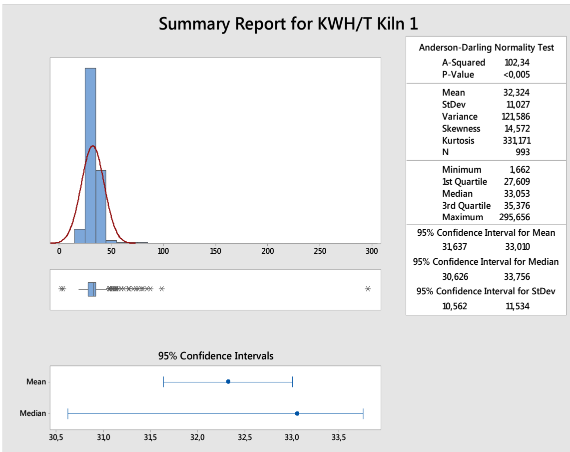

Figure 1: Summary report for kWh/T of kiln 1

After that, it was necessary to determine the calculation formula to quantify each internal failures item. The formulas are listed in table 3.

Table.3- Formula of calculation of internal failure Components

Breakdown	To calculate this cost, each breakdown of the period studied should be analyzed separately = ∑ (Breakdown maintenance cost + Loss sales)
Downgrading	The accounting is done for each production batch = ∑ [(Real flow rate per hour - Nominal flow rate)* Planned production time (hrs.)] * Energy cost per ton
Rework (Unburnt clinker is used to produce low quality cement)	The calculation is made for all batches that failed to meet established specifications. = Losses due to the management and the storage of unburnt clinker
Power over-consumption	The accounting is done for each production batch = (Real power consumption per ton - Nominal power consumption per ton)* tonnage produced* cost of kWh
Heat over-consumption	The accounting is done for each production batch = (Real heat Consumption per ton - Nominal heat consumption per ton taking into account the raw mixture)* tonnage produced * Cost of Mj
Water over-consumption	This item is calculated per day taking into consideration the tonnage produced =(Real water consumption - Nominal water consumption)* Cost of m3 of water

Costs related to the burning process of 12 months (1year) are presented in the following table:

Table.4- Quality cost of the burning process

	Cost category	Value (KDH)	Percentage %
Prevention	Training costs	46,0	0,02%
	Quality administration	4500,0	2,32%
	Internal quality audits	250,0	0,13%
	Preventive production	6000,0	3,09%
	Total prevention cost	10796,0	5,56%
Appraisal	Inspection & test equipment	54000,0	27,83%
	Total appraisal cost	54000,0	27,83%
Internal failure	Breakdown	87751,4	45,22%
	Downgrading	15808,3	8,15%
	Rework	6903,8	3,56%
	Electricity over-consumption	10092,0	5,20%
	Heat over-consumption	8501,9	4,38%
	Water over-consumption	26,3	0,01%
	Total internal failure cost	129083,7	66,53%
External failure	Returned goods	157,8	0,08%
	Total external failure cost	157,8	0,08%

4.4. Data analysis & discussion of findings

The distribution of different categories is shown in the figure 2. It has been found that the internal failure cost is higher than the other costs with 66.5%. The appraisal cost was found to be 27.8% and the prevention cost was 5. 6%.The lowest quality cost is external failure cost with just 0.1%. This result shows the quantum and the impact of internal failure cost on the quality costs specifically and on the bottom line in general. This gives a clear picture to quality management to focus on that component.

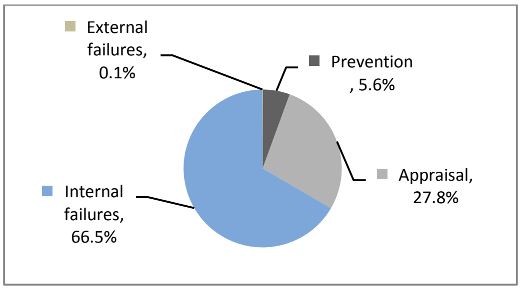

Figure 2: Distribution of quality cost categories

The bar char in the figure 3 illustrates a Pareto analysis of all identified costs components in the burning process of 12 months. The Pareto shows that out of the 12 elements gathered, only few items found responsible of considerable part of the total quality cost.

The chart confirms that more than 80% of the total quality cost comes from three major causes. It is found that breakdown (45.2%), the inspection & test equipment (27.8%) and the downgrading (8.1%) are the critical elements. This gives the orientation to quality management to emphasis more on these items to assess the overall quality cost. It also highlights the huge impact of the internal failures on the bottom line and points out the gold mine of improvements.

A systematic monitoring and root cause analysis of these top priority cost elements will provide a clear focus on the areas where the quality improvement activities to be strengthened and by eliminating these losses, the organization can improve its profit margin.

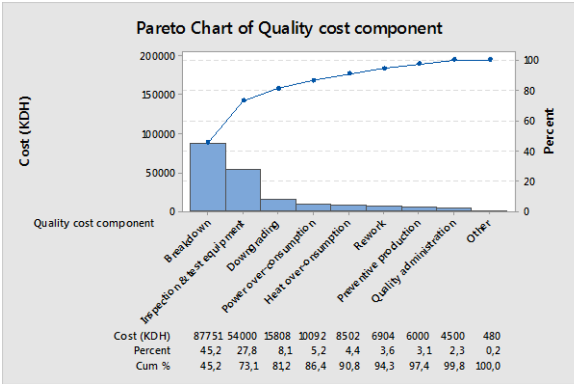

Figure 3: Pareto analysis of Quality costs

Since internal failures cost constitutes 66.5% of the total quality cost it was necessary to make a Pareto analysis of that component (figure 4). The Pareto shows that the breakdowns and downgrading are found responsible of 80.2% of the internal failures cost.

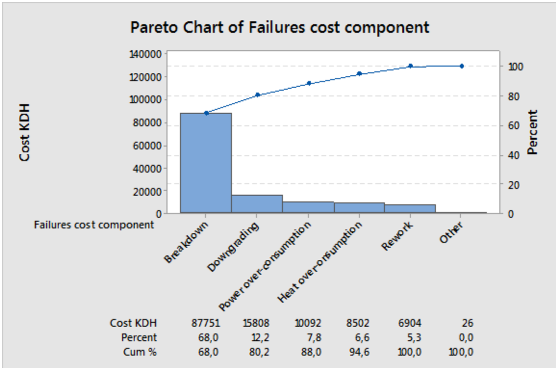

Figure 4: Pareto analysis of failures costs

4.5. Improvement actions & Recommendations

Several Root Cause Analysis sessions were held to investigate events that caused the major losses. Every employee has received basic training in the relevant techniques needed for these sessions. The solutions and recommendations generated are described as bellow:

Table.5- Optimization actions of total quality cost of the burning process

Critical items	Optimization actions	Benefits
Inspection	▪ Improving quality control by determining the critical points of control ▪ Setting up quality costing metrics and add it to usual used KPI ▪ Implementation of a quality improvement program based on the analysis of the new KPI ▪ Schedule quarterly management reviews to track progress of improvement action and their impact.	▪ Perform an effective and efficient control and thus reduce the cost related to failures.
Breakdown	▪ Schedule sufficient duration and devote an adequate budget to perform all necessary maintenance work in the annual maintenance shutdown ▪ Program problem-solving meetings to develop corrective and preventive actions for all significant quality incidents ▪ Training staff in quality tools such as 5 why, fishbone analysis, process mapping etc.	▪ Increase efficiency and effectiveness of the annual maintenance shutdown ▪ Increase machine availability/ productivity and meet market demand ▪ Improve employees skills thus their performance and that of the company
Downgrading	▪ Improve performance of crushers and grinders by making a study of events that impact their availability (The downgrading is due to breakdown of upstream machines)	▪ Decrease production losses due to low speed
Heat consumption	▪ Enhance the utilization of alternative fuel in the combustion; ▪ Find the optimal combination of combustion components that can produce more energy and release less greenhouse gas emissions	▪ Enhance the utilization of alternative fuel and therefore reduce expenses related to heat consumption ▪ Reduce greenhouse gas emissions
Power consumption	▪ Program operational hours taking into account constraints of the peak and off-peak hours(Linear program)	▪ Reduce expenses related to electricity

5. Conclusion

To gain a competitive advantage, organization must constantly strive to lower their costs in order to offer competitive prices, as well as improving quality of their products/services to meet consumer requirements. To achieve this, organizations need to invest in implementing a COQ system suitable with their branch of activity, environment, needs and situation.

Besides, it is an imperative to develop an adapted method for identification and measurement of quality costs, and set up a key performance indicator dashboard and reporting system including COQ metrics to communicate performance in term of quality costing.

A study was conducted in a manufacturing firm with regard to highlight the importance of COQ as a driver of improvement. The study findings points up the fact that internal failures cost constitutes 66.5% of the total quality cost, external failures cost is 0.1%, prevention cost is 5.6% and appraisal cost is 27.8% %.

A Pareto analysis was carried out to determine critical quality costs. It has been found that breakdowns, downgrading and inspection are more prominent and requires to be reduced or eliminated by understanding root causes and setting up remedial solutions.

Using this tool the company can justify investment in prevention activities to top management since failures costs are tied to prevention. It also helps to show the quantum of losses and realize the value of prevention and the return on investment.

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