# An exploratory study on status of cost of quality in different industries

1Mihir Thakorbhai Patel, 2Dr. Darshak A. Desai
1Lecturer, 2Professor & Head
1Bhailalbhai & Bhikhabhai Institute of Technology,
2G H Patel College of Engineering & Technology

***Abstract* - The purpose of this paper is to capture the status of implementation of Cost of Quality (CoQ) in various manufacturing as well as service industries and also to check the scope and success of the CoQ. Design/methodology/approach – The methodology of critical analysis involves selection and classification of about 88 research articles on implementation of CoQ in different manufacturing as well as service industries. The selected articles were classified by: articles distribution based on year of publication, publication database, various journals, contribution of authors, continent, based on focus industry, purpose of CoQ, methodology/tools used to improve CoQ and various performance indicators used in CoQ in different industries. Then after, future extents of research openings were inferred in light of noteworthy discoveries. Discuss – Very few researches have been carried out to measure overall success of implementing CoQ in industries. This paper will provide value to students, researchers and practitioners of CoQ by way of providing insight into the implementation of CoQ in manufacturing and service industries. Findings – The literature revealed that: Very few works were undertaken on the implementation of CoQ in various manufacturing industries like ceramic, paper, gems & jewellery, cement, furniture, stone, fertilizer, forging, paper and surface treatment industries and hotel, education institute and hospital in service industry. Most of the researchers have implemented Prevention, Appraisal & Failure (PAF) model and determined total CoQ for cost reduction. Very few researchers have integrated of six Sigma with CoQ.**

***keywords* - CoQ, Cost of poor Quality, Cost of Quality, Models of CoQ, PAF**

## I. INTRODUCTION

Quality has turned out to be one of the vital elements for almost all manufacturing and service companies that aim to win sufficient orders. Therefore, enhancing quality is considered to be one of the important approaches to attain customer loyalty in today's complex global competitive environment (Khaled Omar and Murgan 2014). In addition to product and service quality, organizations want to be competitive on costs, and knowledge of quality costs helps managers to justify the investment in quality improvement and assists them in observing the effectiveness of their efforts (Nasario De Sousa and Filipe Duarte Junior, 2016). This can only happen by decreasing the costs needed to accomplish quality, and decreasing of these costs is only possible if they are identified and measured. Therefore, measuring and reporting the cost of quality (CoQ) should be considered an important issue for managers (Andrea Schiffauerova and Vince Thomson, 2006; W.-H. Tsai & Hsu, 2010).

Great outflows of time, money, and resources are wasted each year due to inefficient or nonexistent quality levels prevailing in the industry (Peter E. D et. al., 2010). In order to increase end user satisfaction and the value of the products/services delivered to the market, organization's need to balance the quality and costs (Özkan and Karaibrahimoğlu 2013). Quality costs are a measure of the costs specifically associated with the achievement or non-achievement of product or service quality (Jaju, Lakhe, and Bhagade 2010). Cost of quality information can be used to measure major opportunities for corrective action and to provide incentives for quality improvement (Wudhikarn 2012).

Quality Costing was first presented in literature by Juran (1951) and Feigenbaum (1956), in an attempt to define both the costs that are related to the quality of products and also the costs that appear when quality is not achieved (Evrikleia Chatzipetrou and Odysseas Moschidis 2018). The Cost of poor-quality literature typically deals with manufacturing or service organizations in continuous or repetitive business processes in which identical or similar activities and work phases are repeated in the same sequence or order, batch after batch or customer after customer (Malmi, Järvinen, and Lillrank 2004). Regardless of which quality costing approach is utilized, the main idea behind the CoQ analysis is the associating of improved activities with associated costs and customer expectations, thus allowing targeted action for reducing quality costs and increasing quality improvement benefits (Akhade and Jaju 2009).

## II. WHAT IS COQ?

CoQ was first introduced in 1951 under the name of the 'cost of poor quality' by Joseph Juran. Joseph Juran and Gryna, (1993) define quality as "fitness for purpose," whereas for P. B. Crosby, (1979) it is "conformance to requirements," and according to W. Deming, (1986) quality is "uniformity with respect to a correct target."

American Society for Quality Control (ASQC, 1971) defined quality costs as the costs incurred in ensuring quality, together with the loss incurred when quality is not accomplished.

As per statistics, Cost of poor quality is 10 percent of sales for companies who are at "Six Sigma" level, about 15 percent to 20 percent of sales for companies who are at "four sigma" level and about 20 percent to 30 percent of sales for companies who are at "three sigma" levels (Prashar 2014).

CoQ is a financial measurement that expresses vital information in the language of management (Weinstein, Vokurka, and Graman 2009).

The "cost of quality" isn't the price of producing a quality product or service. It's the cost of NOT creating a quality product or service. Every time work is redone, the cost of quality increases (Akhade and Jaju 2009).

As per W.-H. Tsai & Hsu, (2010) "CoQ is usually understood as the sum of conformance plus non-conformance costs, where cost of conformance is the price paid for prevention of poor quality (for example, inspection and quality appraisal) and cost of non-conformance is the cost of poor quality produced by product and service failure (for example, returns and rework)".

Quality costs represent the difference between the actual cost of a product or service and what the reduced cost would be if there were no possibilities of substandard service, failure of products, or defects in their manufacture (J. Campanella 1999).

The costs of quality are ``those costs that are incurred to prevent a shortfall in quality and a failure to meet customer requirements, as well as costs incurred when quality does in fact fail to meet customer requirements'' (Harrington 1999).

The cost associated with quality management activities (prevention and appraisal) plus the cost associated with deviations (Burati, Farrington, and Ledbetter 1992a).

Poor quality costs are those costs that arise as a result of unnecessary work, i.e. all work that did not have to be done if the process was perfect from the beginning (Andersson and Ryfors 2000).

Cost of quality (CoQ) is usually understood as the sum of the price paid for prevention of poor quality and the cost incurred due to product and service failure (Venkata Subramanian Narasimhan 2013).

As per quality experts CoQ means, "The costs that arise due to deficiencies and failures, we are having a faulty business" (Axelsson and Skogum 2016).

## III. Success stories of CoQ

IV. Hesford & Dale (1991) have qualified key problem areas, helps them to decide on the allocation of resources to identify and resolve specific problems in British aerospace industry. They reduced CoQ by one third in one year. Bernard J. Payne (1992) has identified and monitored the major areas that do not contribute any added value to the organization. He increased output by 25% and reduced workforce by 25% over the last 18 month. Knock (1992) found problem during installation, commissioning and the ensuing warranty period were handled by the local marketing division, and sub- sequent claimed back from the manufacturing division. He reduced CoQ from 13.5 to 3.7 percent in eight years. Jeeves (1993) has reduced total quality cost from 18.5 to 11.5% in manufacturing industry.

V. Manas Chakraborty, Symu Koul (2010) have been illustrated the significance of incorporating CoQ principles in software solutions and to evaluate its impact on business in HCL company. Appraisal cost reduced from 10% to 6%, prevention cost increased from 3% to 4%, internal failure reduced from 6% to 3% in three months. Chopra & Garg (2012) have implemented and estimated cost of quality system in textile industry and they improved CoQ/sales down from 9.93 to 7.56% and CoQ/profit reduced from 95 to 76%. Teli, Majali, Bhushi, Gaikwad, & Surange (2013) had analyzed CoQ cost parameters in Automobile industry and from that they evaluated supplier from different suppliers. Shahid Mahmood and Nadeem Ishaque Kureshi (2014) have examined how effectively the cost appraisal system proposed measures the cost of poor quality (CoPQ) in a construction project. They successfully decreased CoPQ by about 24 percent while labor productivity and profitability increased by about 17 and 11 percent. Prashar (2014) has been demonstrated the systematic application of Six Sigma tools for identification and reduction of cost of poor quality and from that he reduced rejection rate of cooling fan assembly from 9 percent to almost 0 percent. Shahid Mahmood and Shahrukh (2015) have identified and measured CoPQ at construction projects to initiate prompt corrective actions. They reduced CoPQ from 40.43% to 16.65%, labor productivity improved by 16.88% and profitability increased by 10.45%. Zahar, Barkany and Biyaali (2016) have used cost of quality model to estimate the CoQ-related activities at a clinical laboratory located in Morocco. They found that 83% of total COQ was spent on costs of 'good quality' (prevention and appraisal), while 17% was spent on costs of 'poor quality'.

## VI. CoQ Models

The P-A-F Model is the most commonly accepted model on Quality Costing. It categorizes costs under three noteworthy classifications (Prevention, Appraisal and Failure Costs), and manages to capture all the costs related to the quality system and the inspection of products, as well as the costs incurred when the product fails to meet the requirements (Chatzipetrou and Moschidis 2017).

The cost categories of Crosby's model (Crosby, 1979) are similar to the P-A-F scheme. Crosby sees quality as "conformance to requirements", and therefore, defines the cost of quality as the sum of price of conformance and price of non-conformance (Crosby, 1979). One thing which prior presented models haven't been considered is opportunity and intangible costs. These costs can be projected as a loss of profit, sales or any opportunity, which have been lost as a result of low quality. Sandoval- Chaves & Beruvides (1998) have divided opportunity losses into three components: underutilization of installed capacity, poor material handling and poor delivery of service (Matti Takala 2015).

Activity Based Costing is a relatively new administrative and cost accounting approach that was originally introduced by Copper and Kaplan in 1988. ABC estimates the product/service costs by allocating the cost to the exercises associated with the creation procedure. Every movement's cost is estimated by a cost driver which is a factor that causes an activity's cost (Khataie & Bulgak 2013).

Process cost model was developed by Ross. It is focusing on process rather than product and service, and it's measuring total conformance and non-conformance costs for particular process. Costs can be measured in every step of the process, and then analyzed if further efforts on failure prevention activities or process redesign are needed (Matti Takala 2015).

The Taguchi loss function is a quadratic representation of the losses incurred by expanding deviation from the ideal or target value. This function can be used to determine the point at which the misfortunes exceeds costs (Badri, Davis, Davis, Davis, & Davis, 2012).

The generic model of cost of quality models (Ehsan Ayati, 2013; Matti Takala, 2015; Omar, 2014)and cost categories are shown in table1.

Table 1. Cost of Quality models and cost categories

| Generic model | Cost/activity categories | Examples of publications describing, analyzing or developing the model |
|---|---|---|
| P-A-F models | Prevention + Appraisal + Failure | Carson (1986), Abdul-Rahman (1993), Malik, Khalid, Zulqarnain & Iqbal (2016), Whitehall (1986), Jeeves (1993), Guinot Evans & Badar, (2016), Mahmood, Ahmed, Panthi, & Kureshi (2014), Banasik & Beruvides (2012), Wudhikarn (2012), Hesford & Dale (1991), Axelsson & Skogum (2016), (Farooq et al. 2017; Kiran 2017)(Pursglove and Dale 1995)(Vukovic M, Gvozdenovic BS, Rankovic M, McCormick BP, Vukovic DD, Gvozdenovic BD, Kastratovic DA, Marković SZ, Ilic M 2015)(Barouch and Bey 2017)(Chang, Young, and Park 1996)(Hisham M.E., Abdelsalam 2009)(Chopra and Garg 2012)(Chatzipetrou and Moschidis 2017)(Eldridge, Balubaid, and Barber 2006)(Gouws and Wolmarans 2002)(Sedevich Fons 2012)(Kiani et al. 2009)(Kim and Nakhai 2008)(Krishnan 2006)(Collinl, Santos, and Chatfield 2007)(Roden and Dale 2001)(Modarress and Ansari 1987)(Bland, Maynard, and Herbert 1998), (Knock 1992) (Kerfai, Ghadhab, and Malouche 2016) (Pursglove and Dale 1996) (Desai 2008) (Bowman 1994) (Houston and Keats 1998) (Jaju, Mohanty, and Lakhe 2009) (Mukhopadhyay 2004) (Omurgonulsen 2009) (Peimbert-Garcia, Limon-Robles, and Beruvides 2016), (Rosenfeld 2009) (Tummala, Chin, and John 2002) (Tye, Halim, and Ramayah 2011) (Mark Hall 2001) (Chansiri Singhtaun & Rungnapa Hattayanon 2017) (Shahin and Rezaei 2017) (Teli, Majali, Bhushi, and Surange 2014) (Zahar, Barkany, and Biyaali 2016) (Demirors, Yildiz, and Gucegliogl 2000) (V.V.Kale & Dr.S.B.Jaju 2013)(Grace Mukondeleli Kanakana, Ben Van Wyk 2015) (Teli et al. 2013) (Rathindra Nath De 2010) (Manas Chakraborty, Symu Koul 2010) (Omolo Dan 2017)(Andersson and Ryfors 2000) |
| Crosby's model | Conformance + non-conformance | Beshah, Gidey, & Leta (2017), Birhanu Beshah (2015), Slaughter, Harter, & Krishnan (1998), Jorgenson & Enkerlin (1992) |
| Opportunity or intangible cost models | Conformance + non-conformance<br>Conformance + non-conformance + opportunity<br>Tangibles + intangibles | Rodin & Beruvides (2012), Diego A. Sandoval-Chavez & Mario G. Beruvides (1998), Lawrence P. Carr (1992), Matti Takala (2015) |
| ABC models | Value-added + non-value-added | Özkan & Karaibrahimoğlu (2013), Xiaobing Liu, Fajing Cui, Qiunan Meng & Ruilin Pan (2008), W. H. Tsai (1998) |
| Process Cost Model | Conformance + non-conformance | J. Marsh (1989), (Goulden and Rawlins 1995), Crossfield & Dale, (1990) |
| Taguchi loss function model | Loss of sales revenue due to poor quality + process inefficiencies + losses when a quality characteristic deviates from a target | Wu, Chen, & Tang (1998), Freiesleben, (2008), Naidu (2008) |

## V. RESEARCH METHODOLOGY ADOPTED FOR STUDY

The aim of the review was to capture a snapshot of the variety of research being conducted in the field of CoQ implemented in manufacturing as well as in service industries. For this reason, every one of the articles published in peer reviewed journals containing "Cost of Quality" and "Cost of Poor Quality" in the title and also keywords are assessed. For that editorials, news reports, book reviews, viewpoints, textbooks, and unpublished working papers are excluded. The review covers journal articles published between 1986 and 2019 and masters and doctoral dissertations from 1986 and 2019.

Main focus of the research on CoQ in various industry case studies taking into consideration, it would be hard to merge the literature under any specific disciplines. Hence peer reviewed journal databases are chosen and explored to deliver a comprehensive bibliography on CoQ literature. The included journals are from well reputed publishers like Emerald, ScienceDirect, Inderscience, Taylor & Francis, Springer and ASCE Publication and IEEE conference papers. These databases that cover a wide range of case studies of process, chemical, textile, plastic, paper, steel manufacturing, auto, aerospace, electric and electronics, construction, software industries case studies. There are about 88 research case studies taken for the critical review and analysis of measuring the success of CoQ in manufacturing as well as service industry.

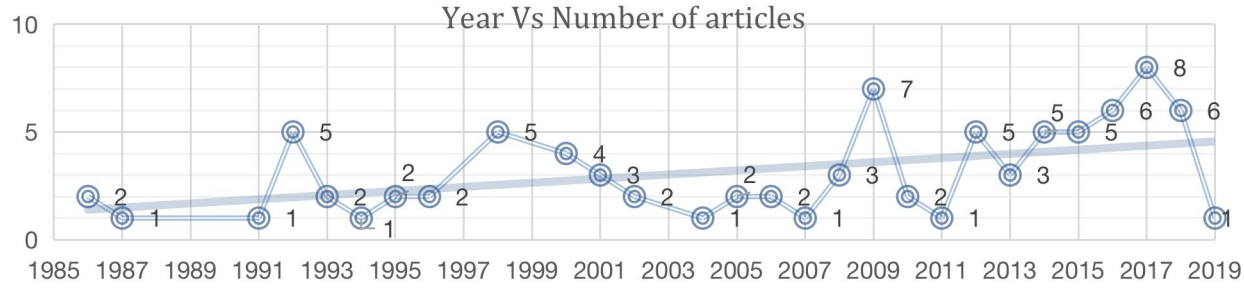
(Whitehall 1986; Carson 1986; Modarress and Ansari 1987; Hesford and Dale 1991; Lawrence P. Carr 1992; Jorgenson and Enkerlin 1992; Burati, Farrington, and Ledbetter 1992b; Bernard J. Payne 1992; Knock 1992; Jeeves 1993; Abdul-Rahman 1993; Bowman 1994; Pursglove and Dale 1995; Goulden and Rawlins 1995; Pursglove and Dale 1996; Chang, Young, and Park 1996; Bland, Maynard, and Herbert 1998; Houston and Keats 1998; Diego A. Sandoval-Chavez & Mario G. Beruvides 1998; Slaughter, Harter, and Krishnan 1998; W. H. Tsai 1998; Patrick Barber, Andrew Graves, Mark Hall, Darryl Sheath 2000; Love and Li 2000; Demirors, Yildiz, and Gucegliogluo 2000; Andersson and Ryfors 2000; Mark Hall 2001; Roden and Dale 2001; Malchi and Mcgurk 2001; Tummala, Chin, and John 2002; Gouws and Wolmarans 2002; Mukhopadhyay 2004; Aynur Kazaz and M. Talat Birgonu 2005; Krishnan 2006; Eldridge, Balubaid, and Barber 2006; Collinl, Santos, and Chatfield 2007; Kim and Nakhai 2008; Desai 2008; Xiaobing Liu et al. 2008; Mills, Love, and Williams 2009; Rosenfeld 2009; Kiani et al. 2009; Hisham M.E., Abdelsalam 2009; Omurgonulsen 2009; Jaju, Mohanty, and Lakhe 2009; Sim et al. 2009; Peter E. D. Love, David J. Edwards, Hunna Watson 2010; Manas Chakraborty, Symu Koul 2010; Rathindra Nath De 2010; Tye, Halim, and Ramayah 2011; Rodin and Beruvides 2012; Sedevich Fons 2012; Wudhikarn 2012; Banasik and Beruvides 2012; Chopra and Garg 2012; Özkan and Karaibrahimoğlu 2013; Teli et al. 2013; V.V.Kale & Dr.S.B.Jaju 2013; Teli, Majali, Bhushi, and Surange 2014; Shahid Mahmood and Nadeem Ishaque Kureshi 2014; Prashar 2014; Teli, Majali, Bhushi, and Gaikwad 2014; Mahmood et al. 2014; Birhanu Beshah 2015; Shahid Mahmood, Shahrukh 2015; Vukovic M, Gvozdenovic BS, Rankovic M, McCormick BP, Vukovic DD, Gvozdenovic BD, Kastratovic DA, Marković SZ, Ilic M 2015; Grace Mukondeleli Kanakana, Ben Van Wyk 2015; Matti Takala 2015; Guinot, Evans, and Badar 2016; Axelsson and Skogum 2016; Malik et al. 2016; Peimbert-Garcia, Limon-Robles, and Beruvides 2016; Kerfai, Ghadhab, and Malouche 2016; Zahar, Barkany, and Biyaali 2016; Barouch and Bey 2017; Chatzipetrou and Moschidis 2017; Kiran 2017; Omolo Dan 2017; Chansiri Singhtaun & Rungnapa Hattayanon 2017; Shahin and Rezaei 2017; Farooq et al. 2017; Beshah, Gidey, and Leta 2017; Odysseas Moschidis, Evrikleia Chatzipetrou 2018; Evangelos Psomas, Christina Dimitrantzou, Fotis Vouzas 2018; Duarte et al. 2018; Sawan, Low, and Schiffauerova 2018; Pattanayak, Prakash, and Mohanty 2019; Wan Seon Shin, Jens J. Dahlgaard 2018; Arash Shahin 2018)

## VI. Classification framework

1. Articles distribution based on Year of publication
2. Distribution by publication database
3. Distribution based on various journals
4. Contribution of authors
5. Distribution of articles based on continent
6. Distribution of articles based on scale
7. Articles distribution based on focused industry
8. Purpose for the CoQ
9. Methodology/Tools used for improving CoQ
10. Various performance indicators used to measure cost parameters of CoQ in different industries

### 6.1. Articles distribution based on Year of publication

Figure 1 shows the distribution of 81 CoQ published articles over the period from 1986 to 2019. Up to the year 2019, the number of publications made in CoQ analyzed case study in different manufacturing & service industries. The measurement




and

Figure 1. Distribution of articles year Vs. number of publications

analysis of CoQ in different industries were highly fluctuated year by year but overall trend of implementation of CoQ case studies are increasing nature. However, statistics shows a decline from 2009 to 2010. But in the last five years, i.e., from 2014 to 2017, the publication rate is appreciable and reached a maximum.

### 6.2. Distribution by publication database

The considered articles are from reputed paper publishers. Those are ASCE, Emerald, IEEE, Inderscience, other publications, ScienceDirect, Springer, Tylor & Francis and their percentage contribution are 4.55%, 35.23%, 6.82%, 7.95%, 13.64%, 6.82%, 1.14% and 23.86% respectively (88 articles of CoQ analyzed in various industry). The most contributor,

Emerald and Tylor & Francis publication database have published fifty-two articles regarding CoQ research during the said period as shown in Figure 2.

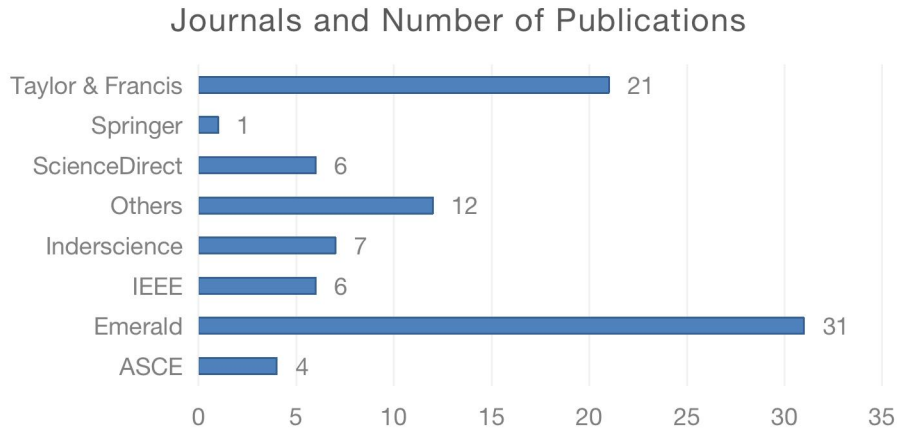



Figure 2. Distribution articles by number of publications

### 6.3. Distribution based on various journals

The list of articles were obtained from various presumed publications. The principle descriptor of looking article utilized is cost of quality and cost of poor quality. The content of each article was reviewed and to separate in the form out in which CoQ is measured and analyzed in various manufacturing and service industries. International Journal of Quality & Reliability Management (IJQRM) from Emerald publication found highest (Eleven) CoQ case study. The list of journals is appeared in Table 2.

Table 2. List of journals with at least one article in the study

| Journal Name | No | Journal Name | No |
|---|---|---|---|
| **Emerald** | **31** | **ASCE** | **4** |
| Built Environment Project and Asset Management | 1 | Journal of Construction Engineering and Management | 4 |
| Benchmarking: An International Journal | 1 | **Tylor & Francis** | **21** |
| International Journal of Contemporary Hospitality Management | 1 | Construction Management and Economics | 3 |
| International Journal of Productivity and Performance Management | 3 | Engineering Management Journal | 2 |
| International Journal of Quality & Reliability Management | 12 | IIE Transactions | 1 |
| Measuring Business Excellence | 1 | International Journal of Production Research | 1 |
| Meditari Accountancy Research | 1 | Production Planning & Control | 2 |
| The TQM Journal | 5 | Quality Engineering | 1 |
| The TQM Magazine | 5 | Quality Management Journal | 1 |
| Engineering, Construction and Architectural Management | 1 | The Engineering Economist | 2 |
| **ScienceDirect** | **6** | Total Quality Management | 1 |
| International Journal of Production Economics | 1 | Total Quality Management & Business Excellence | 7 |
| Total Quality Management: Key Concepts and Case Studies (Book) | 1 | **Inderscience** | **7** |
| Omega | 1 | International Journal of Manufacturing Technology and Management | 1 |
| Journal of Continuing Education in The Health Professions | 1 | International Journal of Productivity and Quality Management | 3 |
| Journal of Cleaner Production | 1 | International Journal of Quality Engineering & Technology | 2 |
| Computers & Industrial Engineering | 1 | International Journal of Services and Operations Management | 1 |
| **IEEE** | **6** | **Others** | **12** |
| PICMET - 2015, Portland | 1 | Pharmaceutical Engineering | 1 |
| ICE & IEEE International Technology Management Conference -2015, The Hague | 1 | Summer Magazine | 1 |

| | | | |
|---|---|---|---|
| International Seminar on Business and Information Management - 2008, Wuhan | 1 | International Conference on Industrial Engineering and Operations Management, Dhaka | 1 |
| International Conference on Engineering, Technology and Innovation (ICE) -2014, Bergamo | 1 | Journal of Electronics Manufacturing | 1 |
| Proceedings of the 26th Euromicro Conference-Informatics: Inventing the Future-2001 | 1 | International Journal of Managing Value and Supply Chains | 1 |
| International Conference on Emerging Trends in Engineering and Technolog, Nagpur | 1 | Communications of the ACM | 1 |
| **Springer** | **1** | Proceedings of the Institution of Mechanical Engineers | 1 |
| Journal of The Institution of Engineers (India): Series C | 1 | HCL Technologies Ltd Report | 1 |
| | | Thesis | 4 |

### 6.4. Contribution of authors

B. G. Dale is leading author for CoQ measurement and analysis in various industries. Numbers of researchers have contributed more than one case study regarding CoQ's case study in various industry, are shown in figure 3.

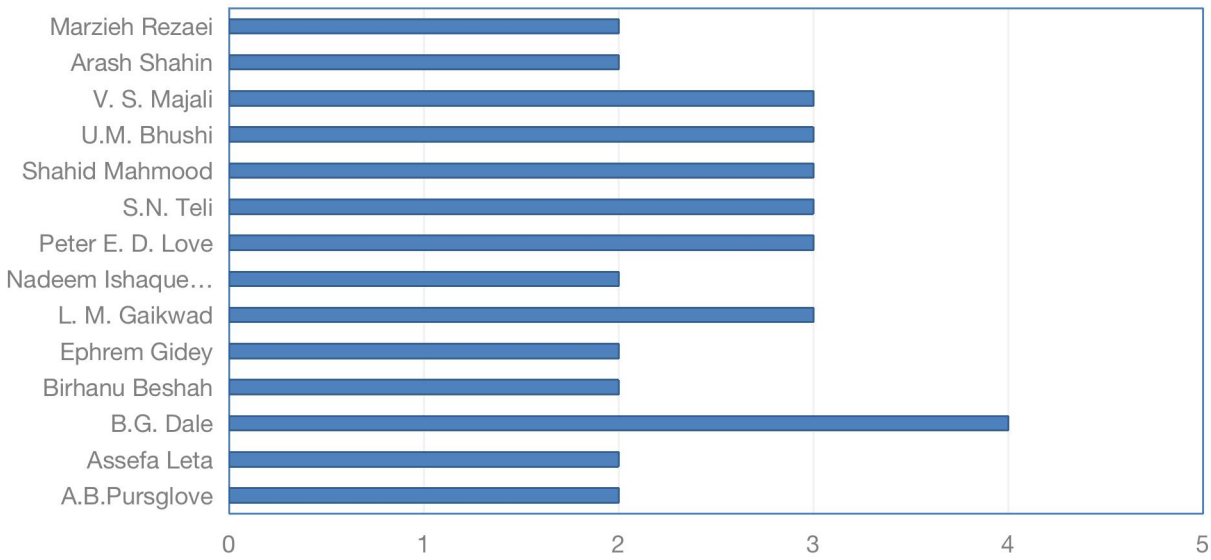



Figure 3. Authors' contribution in CoQ implementation

### 6.5. Distribution of articles based on continent

The CoQ analyzed and measured in manufacturing as well as service industries is highest in Asia region (34.09%, out of 88 articles). Remaining CoQ analyzed and measured in variety of industries in Europe (23.86%, out of 88 articles), America (13.64%, out of 88 articles), Africa (6.82%, out of 88 articles) and Australia (3.41%, out of 88 articles) also. Articles in which, researchers did not specify the region (18.18%, out of 88 articles).

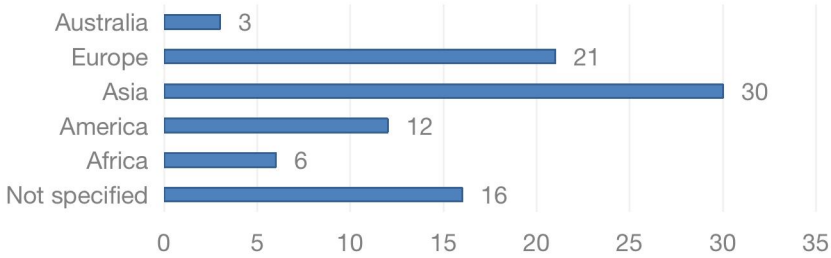



Figure 4. Distribution of articles based on continent

The CoQ was analyzed and measured in India in variety of industries are 12 out of 88 articles (13.64%). Whereas in 59 articles researchers was analyzed and measured other than India country. In 17 articles, researchers did not specify the region for the CoQ case study.

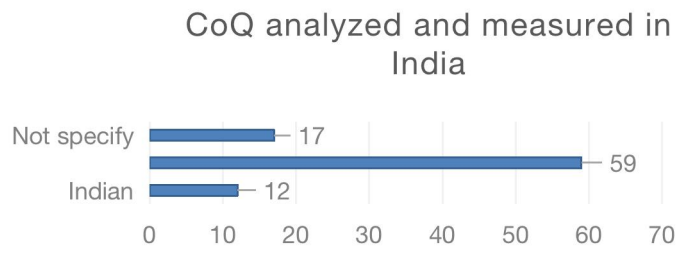



Figure 5. CoQ Analyzed and measured in India

### 6.6. Articles distribution based on focused industry

The case studies of implementation of CoQ in various industries are illustrated in figure 6. The CoQ has mostly used by different researchers in general engineering companies (17.05%, out of 88 articles). In India researchers have analyzed and measured CoQ in Auto ancillary industry (25%, out of 12 case study), General engineering industry (25%, out of 12 case study), process industry (8.33%, out of 12 case study), software (16.67%, out of 12 case study) and textile and clothing industry (16.67%, out of 12 case study).

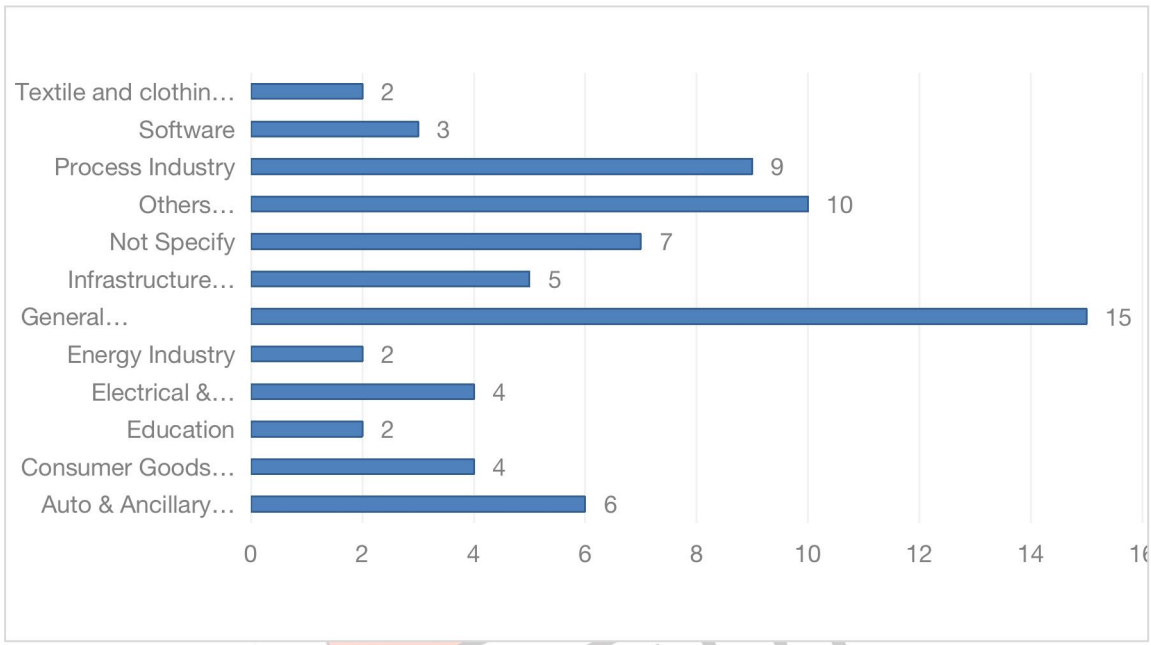



Figure 6. Articles distribution based on focused industry

In India, CoQ has mostly used by different researchers in general engineering companies and Auto & Ancillary industry (25%, out of 12 articles). Other industries/fields include textile & clothing, process, software industry.

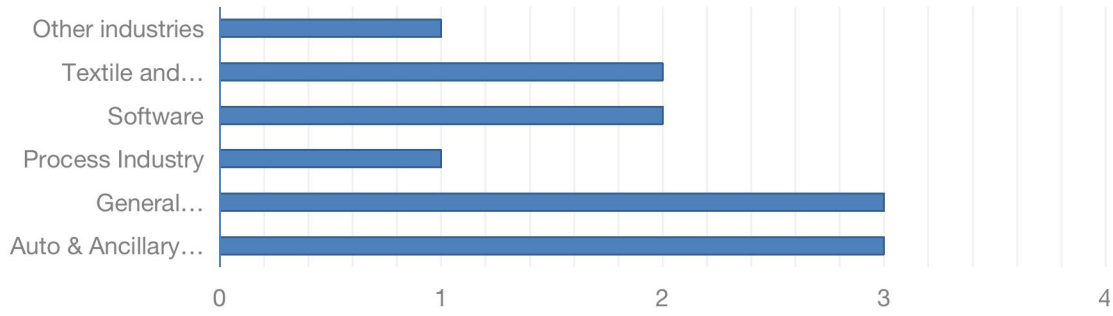



Figure 7. Distribution based on focused industry in India

### 6.7. Purpose for the CoQ

Three most important objectives behind CoQ measuring and reporting are: overall quality improvement; setting cost reduction targets and measuring progress; and improving control of quality activities (Uyar 2008). Omachonu, Suthummanon, & Einspruch, (2004) have examined the components of quality cost (internal failure, external failure, appraisal cost, and prevention cost) in the context of two key manufacturing inputs, materials and machines.

From the literature review, most of researchers have analyzed the various cost parameters of CoQ to know the cost status (cost Analysis) in specific industry (60.22%, out of 88 case study). In 29 articles out of 88, researchers analyzed CoQ and through appropriate tools and techniques applied and also shown cost saving in particular duration. While in 6 articles out of 88, various researchers implemented CoQ for the cost analysis, cost saving and Quality improvement.

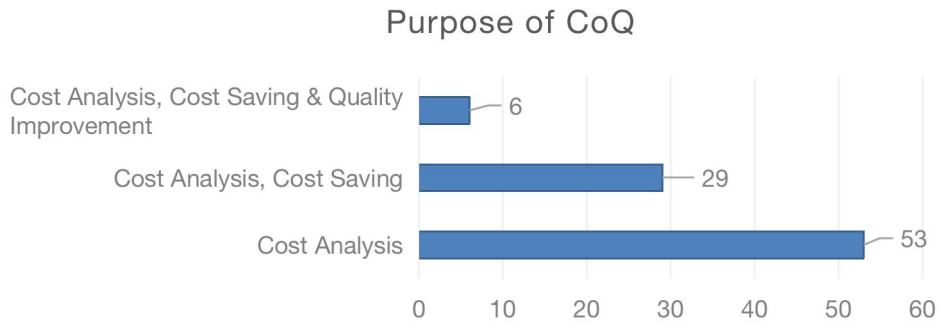



Figure 8. Purpose of CoQ

### 6.8. Methodology/Tools used for improving CoQ

K. L. Smart et al., (1996) have implemented TQM, Poka-yoke in technical communication means producing documentation to minimize the CoQ costs and enhance the desirability of their products. Chansiri Singhtaun & Rungnapa Hattayanon (2017) have integrated quality cost analysis with the Six Sigma approach. They have implemented quality cost analysis to indicate the quality status and quality cost behavior of the organization, and to identify areas of quality improvement and quality cost reduction. Six Sigma approach is implemented to improve product quality and process capability. Chopra & Garg, (2012) have applied a Pareto analysis to analyze on present quality costs. This analysis shows that wastages, expense on in-process inspection, salaries and discount cost categories are responsible for 82.19 percent of total quality costs. Andersson & Ryfors (2000); Hisham M.E., Abdelsalam (2009); Jaju et al., (2009); Omolo Dan, (2017); Omurgonulsen (2009) have used regression model to estimate the total quality cost. They also observed relation between the quality costs like internal failure cost, external failure cost, prevention and appraisal cost.

Methodology and tools used with CoQ differed from problem to problem and industry to industry. There are no fixed tools and methodology are used for specific problem and specific industry. So, Methodology and tools are used based on type of problem and industry. From the literature review the highest tools used by different researchers in CoQ case studies are statistical analysis (9 articles out of 88), Pareto analysis (8 articles out of 81) Cause and effect diagram (7 articles out of 81), and Regression analysis (9 articles out of 81). The Six Sigma and TQM methodology were used with CoQ by different researcher in their case studies.

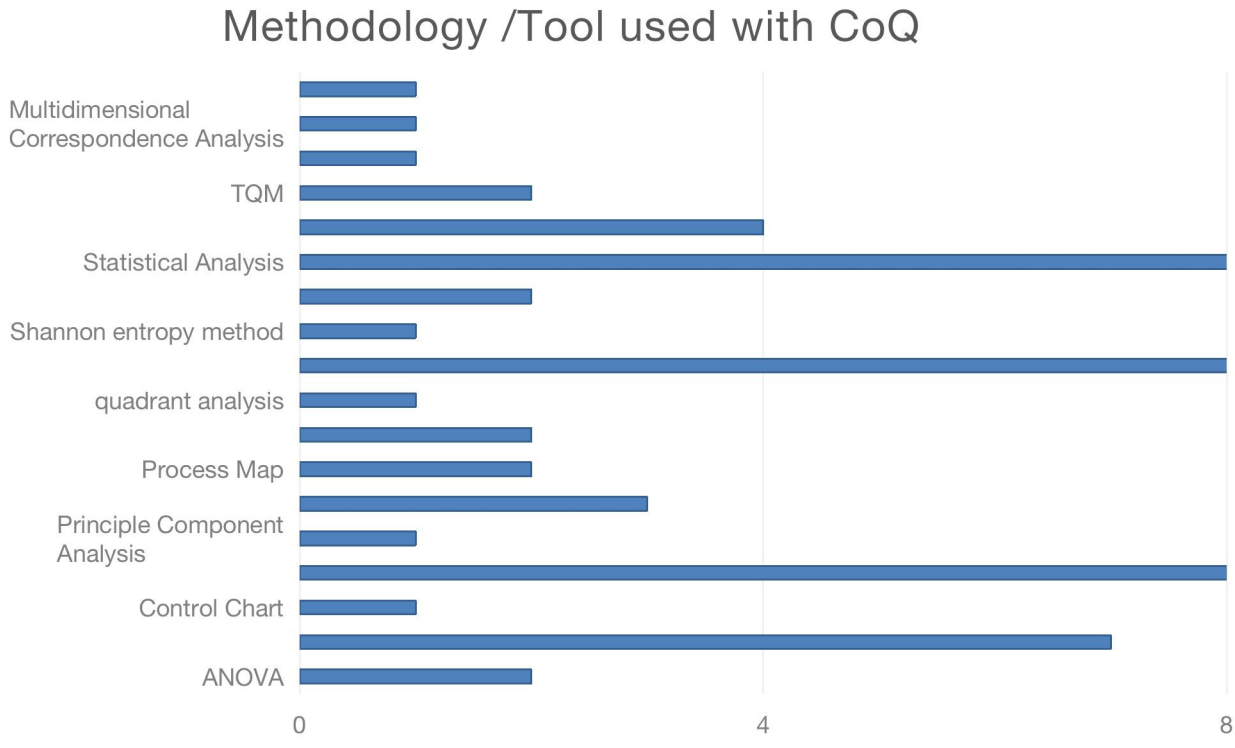



Figure 9. Methodology/Tool used with CoQ

### 6.9. Various performance indicators used to measure cost parameters of CoQ in different industries

The most commonly accepted Quality cost is divided into four categories i.e. prevention, appraisal, internal failure, and external failure costs.

Prevention costs as the expenses of preventing defects and non-conformities from happening. Prevention costs are those resulting from quality activities used to avoid deviations and inaccuracies (Jafari 2011). The cost of measuring, evaluating and auditing product and service to ensure their conformance to predefined specifications. It involves market researches, supplier capability improvement plans, employee training programs, preventive maintenance tasks, Quality Management System implementation activities, etc.

Appraisal costs are "the expenses related with estimating, assessing, and inspecting products or services to assure conformance to quality standards and performance requirements". Appraisal techniques are used for the check and validation (Kiani et al. 2009). It includes quality audits, production control, process acceptance, inspection of material, inspection of production, product acceptance, prototype inspection, continuous supplier verification etc.

Internal failure costs are "Costs associated with defects that are found before to transfer of the product to the customer. They are costs that could disappear if no existed in the product prior to shipment (Krishnan 2006). It covers cost associated with scrap, rework, retesting, re-inspection, downgrading caused by defects, design changes, downtime caused by defects, failure analysis, etc.

External failure costs ate "Costs occur when products or services fail to reach design quality standards but are not detected until after transfer to the customer" (W. H. Tsai 1998). It covers product recall, customer service, product liability cost, complaint adjustment, warranty cost, discount due to defects, reputation loss cost, lost sales etc.

This article has taken 81 research papers in CoQ implemented in various manufacturing and service industry. In these case studies the various researchers taken different CoQ cost parameters were shown in appendix.

After determination of CoQ parameters and detailed metrics we can estimate CoQ global metrics and eventually construct CoQ model and study its performance. We suggest a mixture of global and detailed metrics. The latter actually represent the elements of CoQ and how the performance of these elements are measured. Some examples of detailed metrics are given in Table Global quality metrics measure global performance. Some examples are given in Table III. Return on quality (RoQ), defined as the increase in profit divided by the cost of the quality improvement program, and is the most frequently mentioned global metric in the context of CoQ.

N.M. Vaxevanidis, G. Petropoulos, J. Avakumovic, 2009; Schiffauerova & Thomson, 1979; Shafii & Wan Siti Khadijah, 2012 have been given detailed CoQ cost metrics and global CoQ cost metrix as shon in table.

Table 3 CoQ Detail Matrix

| **Detailed metrics** | |
|---|---|
| Cost of assets and materials | Cost of reworks |
| Cost of preventive labor | Percent of repeat sales |
| Cost of appraisal labor | Time between service calls |
| Cost of defects per 100 pieces | Number of non-conforming calls |
| Cost of late deliveries | Number of complaints received |
| Cost of assets | |

Table 4. CoQ Global Matrix

| **Global metrics** |
|---|
| $\text{RoQ} = \dfrac{\text{increase in profit}}{\text{cost of quality improvement program}}$ |
| $\text{Quality rate} = \dfrac{[\text{input - (quality defects + startup defects + rework)}]}{\text{input}}$ |
| $\text{Process quality} = \dfrac{(\text{available time - rework time})}{\text{available time}}$ |
| $\text{CoQ}_f = \dfrac{\text{external failure cost}}{\text{total cost of quality}}$ |
| $\text{Percentage of sale} = \dfrac{\text{CoQ detailed cost}}{\text{Total sale}}$ |
| $\text{Percentage of cost} = \dfrac{\text{CoQ detailed cost}}{\text{Total cost}}$ |
| $\text{Percentage of revenue} = \dfrac{\text{CoQ detailed cost}}{\text{Total revenue}}$ |

From the literature review (88 articles of real case study of CoQ), the different cost metrics used by different researchers were Percentage of cost, Percentage sales, Total CoQ, Percentage of Revenue, Percentage of CoQ with specific activity, RoQ, $\text{CoQ}_f$, CoQ Process, CoQ after sales, CoQ of rework, Percentage of development cost. Highest cost metrics were used by

researchers are Total CoQ (36, out of 88 articles), Percentage of sales (16, out of 88 articles), Percentage of Cost (15, out of 88 articles) and Percentage of Revenue (8, out of 81 articles). Others cost metrics like RoQ, $CoQ_f$, CoQ Process etc. are selected were very rare.

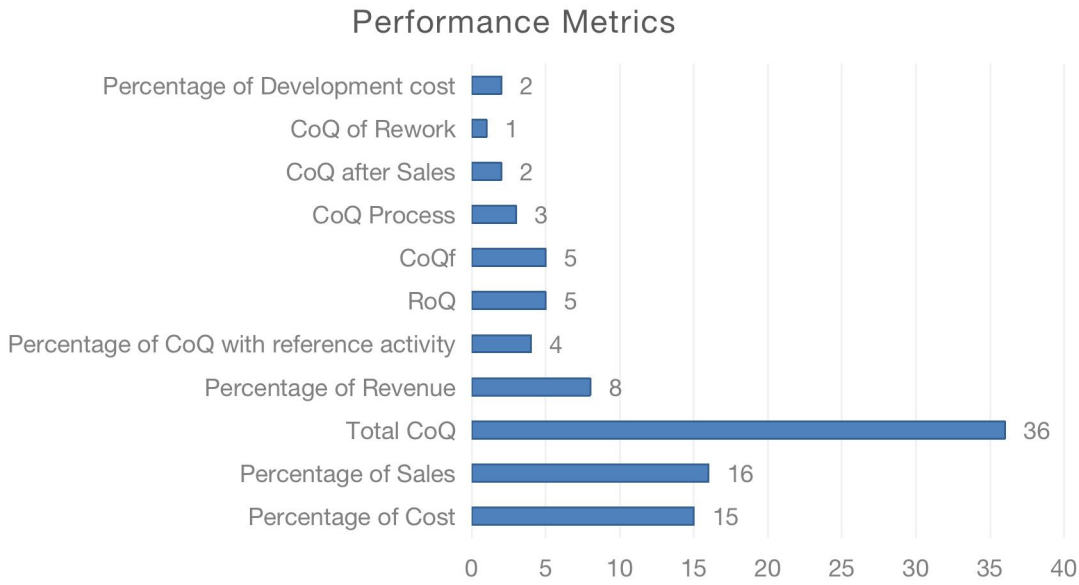



Figure 8. CoQ Performance Metrics

## VII. Concluding Remarks

The purpose of this study was to examine and analyze of CoQ in various manufacturing and service industries worldwide and to check the scope and success of CoQ. A range of publication databases (1986-2019) are searched to provide a comprehensive listing of journal articles on CoQ implementation in manufacturing and service industries case studies. Based on implementation of CoQ in various industries total of 81 articles were collected and the information on a series of variables collected were further reviewed and classified. This is one of the unique study of review that covered real case studies of CoQ in various manufacturing and service industries. The categorized review in the study will provide better understanding of the present state of research in the discipline.

### 7.1 Significant findings:

The following findings have been identified by the researchers in the current literature review on Cost of Quality.

1. CoQ is mainly used for current status of costs; setting cost reduction targets and measuring progress; and improving control of quality activities.
2. Through CoQ cost parameters recording and analysis, researchers saved huge amount of cost saved in particular period of time.
3. The CoQ was implemented in various manufacturing and service industries like auto and ancillary industries, cloths and textile industries, process industries, software industries, construction industries, general engineering industries, electrical and electronics industries, energy industries, consumer goods industries.
4. Most of researchers used PAF models for capturing the CoQ cost parameters for measuring the current cost status or reducing the cost or for improving control of quality activity.
5. It is observed that year 2017 holds the highest (9.09%, out of 88 articles) and second 2009 year (7.95%, out of 88 articles) regarding year of publication.
6. Implementation of CoQ in manufacturing & service industries were in General manufacturing industries which holds the highest percent (20.45%, out of 88 articles) followed by other manufacturing & services industries (11.36%, out of 88 articles) and process industries (10.23%, out of 88 articles). Few implementations of CoQ were observed in ceramic, paper, gems and jewellery, education, healthcare, cement, furniture, stone, fertilizer, forging, paper and surface treatment industries.
7. In Asia continent CoQ implemented in various industries holds the highest percentage 34.09 and followed by Europe holds 23.86.
8. Authors like B.G. Dale (4 articles) has done significant research in implantation of CoQ in various industries.
9. Most of researchers (60.22%, out of 88 articles) have implemented CoQ in various industries to know the status of various cost parameters of CoQ. In remaining articles, researchers have implemented CoQ to analyze the various CoQ cost parameters, for cost saving and for improving Quality.
10. Case study-based research were reported in around 88 articles. The CoQ implementation emphasized approach without any combination (e.g. TPM, TQM, Lean, etc.) holds around in 36 case study (44.44%). The most tools used are statistical analysis, Pareto analysis, Cause and effect diagram and regression analysis. Six sigma methodology was highest combined with CoQ.

11. Most of the researchers, total CoQ, percentage of sales and percentage of cost were widely used as cost metrics.
12. The cost parameters selected by various researches for CoQ varied from industry to industry and problem to problem.
13. After implementation of CoQ in most of the industries they gained breakthrough saving in various costs.

### 7.2 Gaps in the current literature on CoQ and agenda for future research

The following gaps have been identified by the researchers in the current literature review on CoQ in various industries.

1. There is no generalization models for CoQ implementation in various manufacturing and service industries to capture status of cost or saving cost or for improving control of quality activity for a given problem or scenario.
2. The most important issue is, there is no generalized model for Six Sigma implementation in manufacturing industries and no clear picture of the cost parameters usages in each part of CoQ cost.
3. Crafting a learning environment for the employee's to recognize and record the various cost parameters of CoQ.
4. CoQ implementation in various manufacturing and services industries are significant, but among them very few CoQ implementation reported in ceramic, paper, gems and jewellery, cement, furniture, stone, fertilizer, forging, paper and surface treatment industries, education, hospital, banking industries are very few.
5. Very few researcher have been taken CoQ as performance indicator parameters with Six Sigma, CoQ used to capture cost parameters in different perspective like appraisal, prevention, internal and external failure.

## REFERENCES


[1] Abdul-Rahman, Hamzah. 1993. "Capturing the Cost of Quality Failures in Civil Engineering." *International Journal of Quality & Reliability Management* 10 (3): 20–32.

[2] Akhade, G. N., and S. B. Jaju. 2009. "Development of Methodology for Collecting Quality Cost in Technical Institute." In *2009 Second International Conference on Emerging Trends in Engineering & Technology, Nagpur*, 798–801. IEEE.

[3] Andersson, Sofie, and Sara Ryfors. 2000. "Poor Quality Costs : A Case Study in VBS." Göteborg University, Sweden.

[4] Andrea Schiffauerova and Vince Thomson. 2006. "Cost of Quality : A Survey of Models and Best Practices." *International Journal of Quality and Reliability Management* 23 (6): 647–69.

[5] Arash Shahin, Marzieh Rezaei. 2018. "An Integrated Approach for Prioritizing Lean and Agile Production Factors Based on Costs of Quality with a Case Study in the Home Appliance Industry." *Benchmarking: An International Journal* 25 (2): 660–76.

[6] Axelsson, Louise, and Sandra Skogum. 2016. "Cost of Poor Quality - Development of a Tool for Identification and Quantification of CoPQ." Chalmers University of Technology, Gothenburg, Sweden.

[7] Aynur Kazaz and M. Talat Birgonu. 2005. "Determination of Quality Level in Mass Housing Projects in Turkey." *Journal of Construction Engineering and Management* 131 (2): 195–202.

[8] Badri, Masood A, Donald Davis, Donna Davis, Donald Davis, and Donna Davis. 2012. "International Journal of Quality & Reliability Management, 26 (9), 881-893." 17 (2010): 460–71.

[9] Banasik, Marcus A., and Mario G. Beruvides. 2012. "A Case Study of the Costs of Quality: Water Utilities." *Engineering Management Journal* 24 (2): 3–14.

[10] Barouch, Gilles, and Christoph Bey. 2017. "Cost of Quality and Process Model: Improving Accounting Tools for Attaining Higher Environmental Efficiency." *Journal of Cleaner Production* 181: 192–200.

[11] Bernard J. Payne. 1992. "Accounting for Improvement." *TQM Magazine* 4 (2): 95–98.

[12] Beshah, Birhanu, Ephrem Gidey, and Assefa Leta. 2017. "National Cost of Quality in Ethiopian Import–Export." *Total Quality Management and Business Excellence* 28 (1–2): 118–29.

[13] Birhanu Beshah, Ephrem Gidey and Assefa Leta. 2015. "Modelling Macroeconomics of Quality." *Internation Journal Productivity and Quality Management* 16 (1): 114–26.

[14] Bland, F. Merle, John Maynard, and David W. Herbert. 1998. "Quality Costing of an Administrative Process." *TQM Magazine* 10 (5): 367–77.

[15] Bowman, R A. 1994. "Inventory: The Opportunity Cost of Quality." *IIE Transactions* 26 (3): 40–47.

[16] Burati, James L., Jodi J. Farrington, and William B. Ledbetter. 1992a. "Causes of Quality Deviations in Design and Construction." *Journal of Construction Engineering and Management* 118 (1): 34–49.

[17] Burati, James L., Jodi J. Farrington, and William B. Ledbetter. 1992b. "Causes of Quality Deviations in Design and Construction." *Journal of Construction Engineering and Management* 118 (1): 34–49.

[18] Carson, J.K. 1986. "Quality Costing — A Practical Approach." *International Journal of Quality & Reliability Management* 3 (1): 54–63.

[19] Chang, Seog Ju, Hyun Young, and Eui H. Park. 1996. "Quality Costs in Multi-Stage Manufacturing Systems." *Computers & Industrial Engineering* 31 (112): 115–18.

[20] Chansiri Singhtaun & Rungnapa Hattayanon. 2017. "An Application of Quality Cost Analysis as a Tool for Quality Management." *Internation Journal of Productivity and Quality Management* 22 (2): 205–22.

[21] Chatzipetrou, Evrikleia, and Odysseas Moschidis. 2017. "An Exploratory Analysis of Quality Costing in Greek F&B Enterprises." *The TQM Journal* 29 (2): 324–41.

[22] Chopra, Arvind, and Dixit Garg. 2012. "Introducing Models for Implementing Cost of Quality System." *TQM Journal* 24 (6): 498–504.

[23] Collinl, Ramdeen., Jocelina Santos, and H.K.c Chatfield. 2007. "Measuring the Cost of Quality in a Hotel Restaurant Operation." *International Journal of Contemporary Hospitality Management* 19 (4): 286–95.

[24] Crossfield, R. T., and B. G. Dale. 1990. "Mapping Quality Assurance Systems: A Methodology." *Quality and Reliability Engineering International* 6 (3): 167–78.

[25] Demirors, O., O. Yildiz, and a. Selcuk Guceglioglu. 2000. "Using Cost of Software Quality for a Process Improvement Initiative." In *Proceedings of the 26th Euromicro Conference. EUROMICRO 2000. Informatics: Inventing the Future, Maastricht, Netherlands*, 2:286–91.

[26] Desai, Darshak A. 2008. "Cost of Quality in Small- and Medium-Sized Enterprises: Case of an Indian Engineering Company." *Production Planning & Control* 19 (1): 25–34.

[27] Diego A. Sandoval-Chavez & Mario G. Beruvides. 1998. "Using Opportunity Costs to Determine the Cost of Quality : A Case Study in a Continuous-Process Industry." *The Engineering Economist: A Journal Devoted to the Problems of Capital Investment* 43 (2): 107–24.

[28] Duarte, Patricia, Jwen Fai Low, Andrea Schiffauerova, and Patricia Duarte. 2018. "Balancing Risk and Revenue : Cost of Quality within the Banking Industry." *International Journal of Quality & Reliability Management* 35 (10): 2181–94.

[29] Ehsan Ayati. 2013. "Quantitative Cost of Quality Model in Manufacturing Supply Chain." Concordia University, Montreal, Quebec, Canada.

[30] Eldridge, Steve, Mohammed Balubaid, and Kevin D. Barber. 2006. "Using a Knowledge Management Approach to Support Quality Costing." *International Journal of Quality & Reliability Management* 23 (1): 81–101.

[31] Evangelos Psomas, Christina Dimitrantzou, Fotis Vouzas, Nancy Bouranta. 2018. "Cost of Quality Measurement in Food Manufacturing Companies : The Greek Case." *International Journal of Productivity and Performance Management* 67 (9): 1882–1900.

[32] Evrikleia Chatzipetrou and Odysseas Moschidis. 2018. "A Multidimensional Longitudinal Meta-Analysis of Quality Costing Research." *International Journal of Quality & Reliability Management* 35 (2): 405–29.

[33] Farooq, Muhammad Arsalan, Randolph Kirchain, Henriqueta Novoa, and Antonio Araujo. 2017. "Cost of Quality: Evaluating Cost-Quality Trade-Offs for Inspection Strategies of Manufacturing Processes." *International Journal of Production Economics* 188: 156–66.

[34] Freiesleben, Johannes. 2008. "A Proposal for an Economic Quality Loss Function." *International Journal of Production Economics* 113 (2): 1012–24.

[35] Goulden, Clive, and Louise Rawlins. 1995. "A Hybrid Model for Process Quality Costing." *International Journal of Quality & Reliability Management* 12 (8): 32–47.

[36] Gouws, D.G., and H.P. Wolmarans. 2002. "Quality Cost in Tertiary Education: Making Internal Failure Cost Visible." *Meditari Accountancy Research* 10 (1): 87–108.

[37] Grace Mukondeleli Kanakana, Ben Van Wyk, Jan-Harm C Pretorius. 2015. "Framework Assessment for Costs of Poor Quality in Higher Education Processes." In *2015 Portland International Conference on Management of Engineering and Technology (PICMET), Portland*, 1133–36.

[38] Guinot, Jeff, Dustin Evans, and M. Affan Badar. 2016. "Cost of Quality Consideration Following Product Launch in a Present Worth Assessment." *International Journal of Quality and Reliability Management* 33 (3): 399–413.

[39] Harrington, H. James. 1999. "Performance Improvement: A Total Poor-Quality Cost System." *TQM Magazine* 11 (4): 221–30.

[40] Hesford, M. G., and B. G. Dale. 1991. "Quality Costing at British Aerospace Dynamics: A Case Study." In *Proceedings of the Institution of Mechanical Engineers, Part G: Journal of Aerospace Engineering*, 205:53–57.

[41] Hisham M.E., Abdelsalam, Medhat M. Gad. 2009. "Cost of Quality in Dubai: An Analytical Case Study of Residential Construction Projects." *International Journal of Project Management* 27 (5): 501–11.

[42] Houston, Dan, and J. Bert Keats. 1998. "Cost of Software Quality: A Means of Promoting Software Process Improvement." *Quality Engineering* 10 (3): 563–73.

[43] J. Campanella. 1999. *Principles of Quality Costs Principles, Implementation and Use*. ASQ Quality Press,Milwaukee.

[44] J. Marsh. 1989. "Process Modeling for Quality Improvement." In *Proceedings of the Second InternationalConference OnTotalQualityManagement*, 111–21. IFS Publication, Bedford.

[45] Jafari, Amirhosein. 2011. "PAF Model for Quality Cost Estimation in Mass-Housing Projects," no. Ci: 523–30.

[46] Jaju, S. B., R. P. Mohanty, and R. R. Lakhe. 2009. "Towards Managing Quality Cost: A Case Study." *Total Quality Management & Business Excellence* 20 (10): 1075–94.

[47] Jaju, S B, R R Lakhe, and S S Bhagade. 2010. "Development of Empirical Quality Cost Model for a Manufacturing Industry." *International Journal of Productivity and Quality Management* 6 (1): 48–70.

[48] Jeeves, Andrew. 1993. "Accounting for Quality." *The TQM Magazine* 5 (4): 21–25.

[49] Jorgenson, Daniel M., and and E. Michael Enkerlin. 1992. "Managing Quality Costs with the Help of Activity-Based Costing." *Journal of Electronics Manufacturing* 2 (4): 152–60.

[50] Joseph Juran and Gryna. 1993. *Quality Planning and Analysis*. 3rd Ed. McGraw-Hill, New York.

[51] K. L. Smart, K. Bell DeTienne and K. K. Seawright. 1996. "Assessing the Cost of Quality in Technical Communication." *IPCC 96: Communication on the Fast Track. IPCC 96 Proceedings, Saratoga Springs, NY, USA*, 322–28.

[52] Kerfai, Nejla, Bahia Bejar Ghadhab, and Dhafer Malouche. 2016. "Performance Measurement and Quality Costing in Tunisian Manufacturing Companies." *TQM Journal* 28 (4): 588–96.

[53] Khaled Omar, Mohamed, and Sharmeeni Murgan. 2014. "An Improved Model for the Cost of Quality." *International Journal of Quality & Reliability Management* 31 (4): 395–418.

[54] Khataie, Amir H., and Akif A. Bulgak. 2013. "A Cost of Quality Decision Support Model for Lean Manufacturing: Activity - based Costing Application." *International Journal of Quality & Reliability Management* 30 (7): 751–64.
[55] Kiani, Behdad, Hadi Shirouyehzad, Fahime Khoshsaligheh Bafti, and Hamidreza Fouladgar. 2009. "System Dynamics Approach to Analysing the Cost Factors Effects on Cost of Quality." *International Journal of Quality & Reliability Management* 26 (7): 685–98.
[56] Kim, Seokjin, and Behnam Nakhai. 2008. "The Dynamics of Quality Costs in Continuous Improvement." *International Journal of Quality and Reliability Management* 25 (8): 842–59.
[57] Kiran, D.R. 2017. *Cost of Quality. Total Quality Management.* India: BSP Books Pvt. Ltd.
[58] Knock, Allan. 1992. "Information Holds the Key." *The TQM Magazine* 4 (2): 99–102.
[59] Krishnan, Suresh Kumar. 2006. "Increasing the Visibility of Hidden Failure Costs." *Measuring Business Excellence* 10 (4): 77–101.
[60] Lawrence P. Carr. 1992. "Applying Cost of Quality to a Service Business." *Sloan Management Review* 33 (4): 72.
[61] Love, Peter E. D., and Heng Li. 2000. "Quantifying the Causes and Costs of Rework in Construction." *Construction Management and Economics* 18 (4): 479–90.
[62] Mahmood, Shahid, Syed M. Ahmed, Kamalesh Panthi, and Nadeem Ishaque Kureshi. 2014. "Determining the Cost of Poor Quality and Its Impact on Productivity and Profitability." *Built Environment Project and Asset Management* 4 (3): 296–311.
[63] Malchi, Guy, and Helen Mcgurk. 2001. "Increasing Value through the Measurement of the Cost of Quality (COQ): A Practical Approach." *Pharmaceutical Engineering* 21 (3): 92–96.
[64] Malik, Tahir Mumtaz, Rameez Khalid, Ali Zulqarnain, and Syed Amir Iqbal. 2016. "Cost of Quality: Findings of a Wood Products ' Manufacturer." *The TQM Journal* 28 (1): 2–20.
[65] Malmi, Teemu, Pekka Järvinen, and Paul Lillrank. 2004. "A Collaborative Approach for Managing Project Cost of Poor Quality." *European Accounting Review* 13 (2): 293–317.
[66] Manas Chakraborty, Symu Koul, Suresh Sundararajan and Dr Usha Thakur. 2010. "Cost of Quality -Needs Your Attention Not Sometimes But Always." *HCL Technologies Ltd.*
[67] Mark Hall, Cyril Tomkins. 2001. "A Cost of Quality Analysis of Building Project: Towards a Complete Methodology for Design and Build." *Construction Management and Economics* 19 (7): 727–40.
[68] Matti Takala. 2015. "The Cost of Poor Quality in Cartonboard Deliveries." Tampere University of technology, Finland.
[69] Mills, Anthony, Peter E. Love, and Peter Williams. 2009. "Defect Costs in Residential Construction." *Journal of Construction Engineering and Management* 135 (1): 12–16.
[70] Modarress, Batoul, and A. Ansari. 1987. "Two New Dimensions in the Cost of Quality." *International Journal of Quality and Reliability Management* 4 (4): 9–20.
[71] Mukhopadhyay, Arup Ranjan. 2004. "Estimation of Cost of Quality in an Indian Textile Industry for Reducing Cost of Non-Conformance." *Total Quality Management and Business Excellence* 15 (2): 229–34.
[72] Naidu, N. V R. 2008. "Mathematical Model for Quality Cost Optimization." *Robotics and Computer-Integrated Manufacturing* 24 (6): 811–15.
[73] NASARIO DE SOUSA and FILIPE DUARTE JUNIOR. 2016. "Dynamic Quality Cost Model Based on Complexity Theory." *International Journal of Quality & Reliability Management* 33 (5): 633–53.
[74] Odysseas Moschidis, Evrikleia Chatzipetrou, George Tsiotras. 2018. "Quality Costing and Quality Management Maturity in Greece : An Exploratory Multi-Dimensional Data Analysis." *International Journal of Productivity and Performance Management* 67 (1): 171–91.
[75] Omachonu, Vincent K., Sakesun Suthummanon, and Norman G. Einspruch. 2004. "The Relationship between Quality and Quality Cost for a Manufacturing Company." *International Journal of Quality and Reliability Management* 21 (3): 277–90.
[76] Omar, Mohamed Khaled. 2014. "An Improved Model for the Cost of Quality." *Internation Journal of Quality & Reliability Management* 31 (4): 395–418.
[77] Omolo Dan. 2017. "Cost of Quality and Organizational Performance in Sugar Manufacturing Firms in Kenya." School of Business University of Nairobi.
[78] Omurgonulsen, Mine. 2009. "A Research on the Measurement of Quality Costs in the Turkish Food Manufacturing Industry." *Total Quality Management & Business Excellence* 20 (5): 547–62.
[79] Özkan, Serdar, and Yasemin Zengin Karaibrahimoğlu. 2013. "Activity-Based Costing Approach in the Measurement of Cost of Quality in SMEs: A Case Study." *Total Quality Management & Business Excellence* 24 (3–4): 420–31.
[80] P. B. Crosby. 1979. "Quality Is Free." McGraw-Hill, New York.
[81] Patrick Barber, Andrew Graves, Mark Hall, Darryl Sheath, Cyril Tomkins. 2000. "Quality Failure Cost in Civil Engineering Projects." *International Journal of Quality & Reliability Management* Vol. 17 (4/5): 479–92.
[82] Pattanayak, Amiya Kumar, Anand Prakash, and R P Mohanty. 2019. "The Management of Operations Risk Analysis of Estimates for Cost of Quality in Supply Chain : A Case Study." *Production Planning & Control* 0 (0): 1–16.
[83] Peimbert-Garcia, Rodrigo E., Jorge Limon-Robles, and Mario G. Beruvides. 2016. "Cost of Quality Modeling for Maintenance Employing Opportunity and Infant Mortality Costs: An Analysis of an Electric Utility." *The Engineering Economist-A Journal Devoted to the Problems of Capital Investment* 61 (2): 112–27.
[84] Peter E. D. Love, David J. Edwards, Hunna Watson, and Peter Davis. 2010. "Rework in Civil Infrastructure Projects: Determination of Cost Predictors." *Journal of Construction Engineering and Management* 136 (3): 275–82.
[85] Prashar, Anupama. 2014. "Adoption of Six Sigma DMAIC to Reduce Cost of Poor Quality." *International Journal*

*of Productivity and Performance Management* 63 (1): 103–26.
[86] Pursglove, A. B., and B. G. Dale. 1996. "The Influence of Management Information and Quality Management Systems on the Development of Quality Costing." *Total Quality Management* 7 (4): 421–32.
[87] Pursglove, A.B., and B.G. Dale. 1995. "Developing a Quality Costing System: Key Features and Outcomes." *Omega* 23 (5): 567–75.
[88] Rathindra Nath De. 2010. "Quality Costing: An Efficient Tool for Quality Improvement Measurement." In *Proceedings of the 2010 International Conference on Industrial Engineering and Operations Management Dhaka, Bangladesh*, 21–29.
[89] Roden, S., and B. G. Dale. 2001. "Quality Costing in a Small Engineering Company: Issues and Difficulties." *The TQM Magazine* 13 (6): 388–400.
[90] Rodin, Wayne A., and Mario G. Beruvides. 2012. "A Cost of Quality Economic Analysis of a Six Sigma Program at a Government Contractor." *EMJ - Engineering Management Journal* 24 (2): 30–39.
[91] Rosenfeld, Yehiel. 2009. "Cost of Quality versus Cost of Non-Quality in Construction: The Crucial Balance." *Construction Management and Economics* 27 (2): 107–17.
[92] Sawan, Rema, Jwen Fai Low, and Andrea Schiffauerova. 2018. "Quality Cost of Material Procurement in Construction Projects." *Engineering, Construction and Architectural Management* 25 (8): 974–88.
[93] Sedevich Fons, Leonardo A. 2012. "Integration of Quality Cost and Accounting Practices." *The TQM Journal* 24 (4): 338–51.
[94] Shahid Mahmood, Shahrukh, Azam Ishaque. 2015. "Innovative System to Determine Hidden Cost of Poor Quality to Enhance Labor Productivity and Profitability for Construction Entrepreneurs, a Case Study." In *International Conference on Engineering, Technology and Innovation (ICE) & IEEE International Technology Management Conference, The Hague*.
[95] Shahid Mahmood and Nadeem Ishaque Kureshi. 2014. "Reducing Hidden Internal Failure Costs in Road Infrastructure Projects by Determination of Cost of Poor Quality, a Case Study." In *International Conference on Engineering, Technology and Innovation (ICE), Bergamo*, 1–10.
[96] Shahin, A., and M. Rezaei. 2017. "Prioritising Agility Capabilities Based on Cost of Quality Using Integrative Approach of Shannon Entropy, House of Quality and Quadrant Analysis - With a Case Study in Home Appliance Industries." *International Journal of Services and Operations Management* 28 (3): 359–72.
[97] Sim, H.K., Mohamed Khaled Omar, Y.J. Kong Jackie, and C.S. Bong. 2009. "Cost of Quality for an Automotive Industry: A Survey and Findings." *International Journal of Manufacturing Technology and Management* 17 (4): 437–52.
[98] Slaughter, Sandra A., Donald E. Harter, and Mayuram S. Krishnan. 1998. "Evaluating the Cost of Software Quality." *Communications of the ACM* 41 (8): 67–73.
[99] Teli, S. N., V. S. Majali, U. M. Bhushi, L. M. Gaikwad, and V. G. Surange. 2013. "Cost of Poor Quality Analysis for Automobile Industry: A Case Study." *Journal of The Institution of Engineers (India): Series C* 94 (4): 373–84.
[100] Teli, S.N., V.S. Majali, U.M. Bhushi, and L.M. Gaikwad. 2014. "Assessment of Supplier Quality Cost in Automobile Industry." *International Journal of Quality Engineering and Technology* 4 (1): 1–20.
[101] Teli, S.N., V.S. Majali, Umesh M. Bhushi, and V.G. Surange. 2014. "Impact of Poor Quality Cost in Automobile Industry." *International Journal of Quality Engineering and Technology* 4 (1): 21–41.
[102] Tsai, Wen-Hsien, and Wei Hsu. 2010. "A Novel Hybrid Model Based on DEMATEL and ANP for Selecting Cost of Quality Model Development." *Total Quality Management & Business Excellence* 21 (4): 439–56.
[103] Tsai, Wen Hsien. 1998. *Quality Cost Measurement under Activity-Based Costing. International Journal of Quality and Reliability Management.* Vol. 15.
[104] Tummala, Rao, K. S. Chin, and W. K. John. 2002. "An Activity-Based Costing Model to Reduce COPQ." *Quality Management Journal* 9 (3): 32–47.
[105] Tye, Lee Hoon, Hasliza Abdul Halim, and T. Ramayah. 2011. "An Exploratory Study on Cost of Quality Implementation in Malaysia: The Case of Penang Manufacturing Firms." *Total Quality Management & Business Excellence* 22 (12): 1299–1315.
[106] Uyar, Ali. 2008. "An Exploratory Study on Quality Costs in Turkish Manufacturing Companies." *International Journal of Quality & Reliability Management* 25 (6): 604–20.
[107] V.V.Kale & Dr.S.B.Jaju. 2013. "Development of Methodology For Collecting Quality Cost in Rubber Processing Industry." In *Sixth International Conference on Emerging Trends in Engineering and Technolog, Nagpur*, 128–30.
[108] Venkata Subramanian Narasimhan. 2013. "A Study on the Factors That Affect the Implementation of COQ." Concordia University, Montreal, Quebec, Canada.
[109] Vukovic M, Gvozdenovic BS, Rankovic M, McCormick BP, Vukovic DD, Gvozdenovic BD, Kastratovic DA, Marković SZ, Ilic M, Jakovljevic MB. 2015. "Can Didactic Continuing Education Improve Clinical Decision Making and Reduce Cost of Quality? Evidence From a Case Study." *Journal of Continuing Education in the Health Profession* 35 (2): 109–18.
[110] W. Deming. 1986. *Out of Crisis: Quality, Productivity and Competitive Position.* Cambridge University Press, Cambridge, UK.
[111] Wan Seon Shin, Jens J. Dahlgaard, Su Mi Dahlgaard-Park & Min Gyu Kim. 2018. "Total Quality Management & Business Excellence A Quality Scorecard for the Era of Industry 4 . 0." *Total Quality Management* 29 (9–10): 959–76.
[112] Weinstein, Larry, Robert J. Vokurka, and Gregory A. Graman. 2009. "Costs of Quality and Maintenance:

Improvement Approaches." *Total Quality Management & Business Excellence* 20 (5): 497–507.
[113]Whitehall, F.B. 1986. "Review of Problems with a Quality Cost System." *International Journal of Quality & Reliability Management* 3 (3): 43–58.
[114]Wu, Chin-Chung, Zhuoning Chen, and Geo-Ry Tang. 1998. "Component Tolerance Design for Minimum Quality Loss and Manufacturing Cost." *Computers in Industry* 35 (3): 223–32.
[115]Wudhikarn, R. 2012. "Improving Overall Equipment Cost Loss Adding Cost of Quality." *International Journal of Production Research* 50 (12): 3434–49.
[116]Xiaobing Liu, Fajing Cui, Qiunan Meng, and Ruilin Pan. 2008. "Research on the Model of Quality Cost in CIMS Environment." In *International Seminar on Business and Information Management, Wuhan*, 368–71.
**[117]**Zahar, Mouna, Abdellah El Barkany, and Ahmed El Biyaali. 2016. "Cost of Quality in Healthcare: A Case Study in a Clinical Laboratory." *International Journal of Productivity and Quality Management* 17 (4): 536–48.

## APPENDIX

### 1. Cost components: Prevention Costs

| | |
|---|---|
| Design & development of equipment cost | Repair & Maintenance cost |
| Calibration cost | Inspection equipment cost |
| Quality training | Quality improvement programme |
| Quality Audit & Registration | Data base maintenance |
| Process Control | Vendor evaluation |
| Reliability development tools | Requirement analysis |
| System development | System management |
| Process monitoring cost | Development and ratings |
| Cost of motivating | Cost of re-examination |
| Quality surveys and planning | Design review |
| Routine customer visits | Quality circle expenses |
| | |

### 2. Cost components: Appraisal Costs

| | |
|---|---|
| Receiving inspection | Laboratory testing and inspection |
| In-process inspection | Field testing |
| Final inspection | Inspection and test equipment |
| Stock evaluation | Quality audit |
| Design review | Code inspection |
| Usability testing | Data analysis |
| Cost of research on dropout | Cost of feedback |
| Inspection at vendor's plants | Prototype inspection |
| Continuous supplier verification | Evaluation of field stock |
| Data processing | Contract review |
| Order review | Expenditure monitoring |
| Supplier monitoring | Following up suppliers for delayed deliveries |
| External auditing of the quality assurance system | Comprehensive inspections |
| Operation verification costs | Cost of evaluations of goods and services |
| Purchasing verification costs | |

### 3. Cost components: Internal Failure Costs

| | |
|---|---|
| Scrap | Rework |
| Repair | Rescheduling due to downtime |
| Overtime to cover production losses | Yield loss |
| Troubleshooting | Down grading |
| Retest | Extra operations |
| Re-inspection | Defect Analysis |
| Failure Analysis | Design changes |
| Typing errors | Supplies not in stock |
| Waiting for repairs | Absences |
| Turnover | Payroll error |
| Error in account | Defective purchased material |
| Tooling age and conditions | Worker error |
| Machine breakdown time | Programme error |
| Premium cost of transport | Premium cost of sub contract |
| Extra WIP | Supplier problems |
| Work accidents | Delay cost |
| Purchasing failure | Operations failure |

| | |
|---|---|
| Stores write-off for damaged obsolete items | Machine idle hours |
| Excess inventory levels | Corrective action |
| Material Review | Fixing Errors |
| Updating Documents | Reporting |

**4. Cost components: External Failure Costs**

| | |
|---|---|
| Lost profit | Lost sales |
| Loss of goodwill | Warranty |
| Product recalls | Complaints |
| Cost of time invested by staff for non-conformance | Handling cost |
| Litigation | Heavier dealer discount |
| Cost of legal proceedings | Cost of depollution |
| Cost of nuisance | Replacement costs |
| Customer services | Discount due to defective product |
| Waiting time for service | Misleading instruction for use |
| Returned material repair | Penalty for short shipment |
| External Error | Legal costs |
| Compensation and fines | Auction |
| Loss of government grant | Handling & transportation damage |
| Loading error | Wrong transportation mode |