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A LITERATURE REVIEW OF THE QUANTIFICATION OF HIDDEN COST OF POOR QUALITY IN THE HISTORICAL PERSPECTIVE

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ABSTRACT

Cost of Poor Quality (COPQ) is the sum of all costs that would disappear if the job is done right the first time. COPQ mostly remains hidden because normally it is not quantified and recorded in the existing accounting systems. Management fails to initiate timely corrective actions due to lack of knowledge about their hidden losses. It adversely affects the cost, scope and schedule of projects. These losses cannot be reduced unless they are measured or quantified. Many studies have been conducted on quantification of quality costs in the manufacturing and construction industries, which have been summarized in this study to provide a holistic perspective of all such research studies carried out in the last 40 years starting from 1975 to 2014. Based on the review of 42 pertinent literatures on COPQ it can be inferred that COPQ ranges from 16.91% to 26.90% of company's revenue. This study has investigated on the ranges of hidden quality costs and the extent by which they can be reduced. The existing quality cost measurement systems are not standardized and yet to attain maturity. Therefore, there is a big room for development and implementation of quality cost measuring system especially in the construction industry. It has opened new avenues for future research in the quantification of quality costs.

Keywords: Cost of Poor Quality, Quality Costs, Construction Industry, Project Management.

1) INTRODUCTION

Cost of poor quality is still a mystery for most of the manufacturing and construction organizations. Incidents of quality failure during work processes result in material and labor wastage, requiring reworks and additional time, material and labor. These failure costs are normally not measured and not reflected in company accounts separately. Therefore, they remain buried in the accounting figures and the management remains unaware about the extent of losses and the gravity of their problems. The cost of poor quality (COPQ) cannot be traced or identified using the existing accounting reports and auditing system (Barbara et al., 2008; Evans and Lindsay, 2005; Retnari et al., 2010). Rao et al. (2010) state that putting a cost figure on quality is a difficult job and accounting is unable to capture the “true” cost of quality (COQ). The top level management is mainly concerned with the overall cost and is unaware of the extent of their hidden losses on account of poor quality. Although the concept of COQ is now very old but very few studies have been conducted on measurement of quality costs. The construction industry is almost a neglected area in this regards. The available literature has been explored in this study to summarize the findings of fifty seven pertinent literatures carried out on measurement of COQ from 1975 to 2014.

2) LITERATURE REVIEW

According to Harrington (1987), in the early 1950s, Feigenbaum developed a dollar-based reporting system called “quality cost” while working for General Electric. Campanella (1990) and Rao et al. (2010) state that it was Juran who gave rise to the concept of quality costs in his first Quality Control Handbook, wherein he tells his famous analogy of “gold in a mine.” Still, Barbara et al. (2008), and Evans and Lindsay (2005) contend that the concept of “COQ” and “cost of non-quality” was developed by Frank Gryna in the 1950s, with the objective of presenting to top executives the language of quality translated into monetary value. However, it is largely accepted that the traditional COQ concept was developed by W.J. Masser in his 1957 article, “The quality manager and quality costs,” when he subdivided the quality costs into prevention, appraisal, and failure. Lending further validity to the COQ concept, the American Society of Quality Control formed the Quality Cost Committee in 1961 to make the business community aware of quality costs so that businesses might improve their quality through the measurement of quality costs (Campanella, 1990). Two years later, the US Department of Defense adopted the quality cost program in 1963. Finally, Feigenbaum (1977) further developed the COQ model in his classic book Total Quality Control.

2.1) Cost of Quality

COQ is usually understood as the sum of conformance and non-conformance costs, where cost of conformance is the price paid for prevention of poor quality (e.g. inspection and quality appraisal) and cost of non-conformance is the COPQ caused by product and service failure (e.g. rework and returns) (Schiffauerova and Thomson, 2006). Juran (1951) has suggested that the COQ can be understood in terms of the economics of the end-product quality or in terms of the economics of the conformance to standards. In his book, Quality is Free, Crosby (1979) defined the COQ as having two main components: the cost of good quality (or the cost of conformance – prevention and appraisal costs) and the COPQ (or the cost of non-conformance – internal and external failure costs). Furthermore, Crosby (1983/1987) stated that no subject has received more attention from quality professionals over the past years than COQ. Retnari et al. (2010) contend that working out the COQ in monetary terms allows an organization to evaluate the extent to which its resources are being used in order to mitigate the adverse effects of poor processes. Such information can help an organization determine the potential savings that can be gained by improving its processes. From the management accounting perspective, economic issues are predominant. As Dobbins and Brown (1991) puts it, "The true language of management is accounting, and money is only the accent." COQ analysis enables organizations to identify measures and control the consequences of poor quality. The major goal of a COQ approach is to improve the bottom-line by eliminating poor quality (Mohandas and Raman, 2008). Quality costs are not able to be obtained with a basic mathematical function, but instead are dependent on the support processes, like maintenance and human resources, which are also major contributors to the total COPQ. The major quality costs are exacerbated by incapable support processes. COQ, after its recognition, can be reduced through structural approaches (Retnari et al., 2010).

2.2) Cost of Poor Quality

COPQ is the cost associated with providing poor quality products or services, due to failure to conform to the quality standards of customer requirements. Harrington (1987) defines COPQ as all the costs incurred by the company and the customer because the output did not meet specifications and/or customer expectations. Crosby (1979) states that

"Quality is free; it's not a gift, but it is free. What costs money are the un-quality things – all the actions that involve not doing jobs right the first time." According to Raddatz and Klemme (2006) failure costs are incurred when it becomes necessary to rectify the variation/defects that crop up after execution of a job or rework of an unsatisfactory job in order to achieve the required specifications. This cost can be divided into internal and external failure costs.

2.2.1) Internal Failure Costs

Internal failure costs are those costs associated with product failure before its delivery to the external customer. They include the net cost of scrap, spoilage, rework, material wastage, labor wastage, overheads associated with production, failure analysis, supplier rework, scrap, re-inspection, retest, down time due to quality problem, opportunity cost, or other product downgrades (Harrington, 1987; Pyzdek, 2003; Rao et al., 2010).

2.2.2) External Failure Costs

External failure costs crop up after delivery of the project to the customer within the warranty or "defects liability period." Examples include deterioration of executed work, complaints of malfunctioning devices, complaints associated with repair, and replacement of non-conforming defective parts. Warranty charges, customer complaint adjustments, returned merchandize, product recalls, allowances, and product liability costs are also external failure costs. Furthermore external failure costs include direct and indirect costs such as labor, travel associated with the investigation of customer complaints, inspection of warranty, field-tests, and repairs (Harrington, 1987; Pyzdek, 2003; Rao et al., 2010).

2.3) Hidden Cost of Quality

Feigenbaum (1977) pointed out that, "a certain 'hidden' and non-productive plant exists to rework and repair defects and returns, and if quality is improved, this hidden plant would be available for increased productivity". It is often claimed in the quality literature that total quality costs are very considerable, typically between 10-40 percent of turnover. That is why these costs are also known as the ''hidden factory'' or ''the gold mine'' (Dahlgaard et al., 1998). Companella (1990) states unfortunately, accounting systems were never designed to demonstrate the impact of the quality of performance on overall operating costs. That is why many of these costs have remained hidden for so long (p-15). Cheah et. al. (2011) have also confirmed that the traditional accounting systems are incapable to track quality costs. Furthermore, Determination of hidden quality cost reveals the potential and opportunity for improvement.

Rosenfeld (2009) states that quality failures bear substantial hidden costs. Although they cannot be easily measured, they exist, they cost and they hurt. Among other things, such hidden costs include deterioration of the company's reputation, loss of customers, project delays, increased overheads and liability payments. According to Cheah et. al.. (2011) many managers are unaware of a hidden factory in their companies that are producing poor quality costs round the clock, mainly because conventional accounting systems do have capacity to evaluate them.

Özkan & Yasemin (2012) with the help of a case study of "manufacturing sector" suggest that organizations with the use of COQ/Activity Based Costing, may be able to detect hidden costs and monitor the areas of poor performance that require improvement along with managing quality-related costs and, consequently, gain competitive advantage by improving the quality and reduce costs.

Rosenfeld (2009) contends that both internal failure and external failure are accompanied by many hidden, unrecorded and indirect costs and consequential damages. When an internal failure (i.e. defective work) is detected during the work process, the personnel on site often perform the necessary rework without reporting to anyone, and without leaving any written records. They use the resources, such as labor, materials and equipment available on site, but attribute their cost as if it were a natural part of the normal course of the project. Moreover, in many cases the rework necessitates extension of the project duration (which, in turn, entails additional overhead and financing costs), but, again, the extension is not attributed formally to quality problems. Hence, the true cost of internal failures remains hidden, which in reality is substantially higher than the costs assessed.

Rao et al (1996) states that cost of quality calculations do not capture all the cost. There are implied and hidden costs that make COQ useless. According to Abbasnejad (2013) despite best effort some of the poor quality costs remain hidden and are very difficult to identify and evaluate. These are the consequences of failure costs and errors that cannot be foreseen and assessed like loss of goodwill, loss of future business, loss of motivation etc. The hidden costs of poor quality can be between three and ten times the visible costs (Ross, 1998, cited in Tsai, 1998).

Giakatis et al. (2001) and Yang, (2008) observed that the hidden quality costs were three times more than the conventional quality costs whereas Petty (1997) contend that hidden costs of poor quality can be between three and ten times the visible costs.

Most researchers have a unanimous view that the scale of the hidden quality costs is so big that it cannot be ignored (Campanella, 1999; Wood, 2007). Kim and Liao (1994) stress that in some cases hidden quality costs are the biggest contributor of total quality costs and can lead to corporate failure. Despite importance of hidden quality costs, there are still very few practical examples to evaluate these hidden costs. According to Cheah et. al. (2011) development of the quality cost model has created a greater awareness regarding the impact of hidden quality costs on the company performance.

Campanella (1999) and Tsai (1998) are of the view that PAF (Prevention, Appraisal, & Failure costs) model does not assess all the quality-related activities adequately, especially the hidden costs. According to Cheah et. al. (2011) and Tannock and Saelem (2007) hidden quality costs can be many times higher than the tangible quality costs, their determination is difficult and thus remain buried. This argument further strengthens the iceberg hypothesis, which resembles the hidden cost of poor quality with the larger part of iceberg that remains concealed below the waterline.

Quality improvement can be evaluated by measuring the COPQ, which reveals the hidden costs of time wastage, needless service charges and materials wastage. (Shepherd, 2001).

2.4) Losses Due to Cost of Poor Quality

Superville et al. (2003) are of the view that quality problems conversion into dollar terms reflect quality cost; it provides a more expressive tool to project managers to determine the level of cost of quality in their organizations. Cost of quality provides necessary information about failure incidents and process weaknesses to learn lessons for future projects (Love et al. -1999b).

54% of the construction defects generate due to human factors like unskilled workers or inefficient supervision of construction activities, while 12% of the construction defects are due to material and system failures (Opfer 1999). Hagan (1985) is of the view that 90% quality cost comprises of appraisal and failure costs. Raymond et al. (2002) have concluded that quality costs reflected as percentage of total project costs are relatively high in the construction industry. However, measurement of quality costs is usually difficult due to the complex nature of construction processes. The U.S. construction industry is losing over $15 billion per year due to failure in maintaining quality, and rework costs. The total quality failure cost is actually more than twice the measured cost due to unmeasured additional costs for other quality failures (CII-1989).

A number of researches have been conducted to assess the COPQ in manufacturing and construction industry. The literature survey was carried out on Google, Google Scholar, University data Base, Higher Education commission data base and 57 studies could be found on measurement of COPQ. The COPQ concluded by various researchers with respect to company revenues or project costs are listed in chronological order as under:

1) Dobbins (1975) found that quality-related costs ranged from 5 to 25% of annual turnover or operating costs of an organization.
2) Moyers and Gilmore (1979), the cost of poor quality determined was 38%
3) Crosby (1984) the COPQ was between 20 to 35%
4) Hansen (1985) conducted a study on three building projects. He concluded COPQ of 11% for two projects and 5.5% for the third project. He himself was not satisfied with the results and stated to be underestimated.
5) Wheelright and Hayes (1985) concluded a quality cost of 30%.
6) Burati and Farrington (1987), conducted a cost of quality study of nine construction projects of various types/ sizes and concluded that quality deviations cost was 12.4% of the contract value.

7) Harrington (1987, P-2) stated that COPQ can be as high as 40% of company revenues.
8) Raab -1987 concluded that quality costs remained between 20 to 25% of company revenue.
9) According to Morse et al (1987, p-29) quality costs were observed to be from 10 to 20% of production cost.
10) Ittner, (1988) stated that, most of the manufacturing companies have not given a strategic importance to quality costing and controls, the COQ can amount to 25 per cent of sales turnover.
11) Juran (1989) contend that one third of revenues get lost in quality costs.
12) Hammarlund et al. (1990a, b) conducted a study from 1986-1989 on construction of a community service project. Entire project life cycle was studied. He recorded1460 incidents of quality failures and worked out failure cost of about 6 % of production cost.
13) Quality failure costs can be reduced to one third with the implementation of a cost-effective Quality Management system (Dale and Plunkett-1990).
14) Cnuddle (1991) stated that cost of non-conformance ranged from 10% to 20% in the construction project cost.
15) Terry (1991) has contended that it has become a universal truth that in case of TQM movement in any organization, there is at least 20% waste waiting to be addressed by an effective total quality program. This figure has been established by the gurus of quality based after rigorous research.
16) According to Atkinson et al., (1991) the average European manufacturing company functions with a COPQ of about 15 to 25% of turnover. This number increases to 40 to 50% in the service sector, this cost goes even higher in some public sector organizations. Generally, quality costs generated through administrative process account for more than that of production processes due to ''hidden costs''. A ripple effect can occur such that errors caused in one department can trigger work in another.
17) COQ consumes about 25% of the company resources (Ravitz, 1991). COQ information is useful to identify opportunities of improvement through corrective actions
18) Berry and Parasuraman (1992) observed cost of quality to be between 10 to 30% of company revenues
19) Abdul-Rahman (1993) established a quality cost matrix and estimated that total cost of non-conformance is 6% of the estimated project cost

with the assumption that this rate remains constant throughout construction period. This figure failed to include the full extent of rework, variations resulted due to clients instructions. Design errors or omissions contributed to 30% of the cost of non-conformance. He concluded a non-conformance cost of 5% on a highway project and 6% of the contract value on a water treatment project.

20) According to McNealy (1993), an organization's major non-quality costs are administrative and management related. Administration and management costs are mistakenly considered the ''cost of doing business''. Consider the fact that over 40 separate companies in the USA, UK, Canada, Europe and Asia, varying in size from $10 million to $500 million in sales, have determined that their cost of non-quality averages over 20% of gross sales
21) According to Crosby COQ is 40% of a company's turnover, and it is required to be less than 2.5%. (Jeeves, 1993)
22) Dale and Oakland (1994) calculated COQ of 5 to 25% of company revenues.
23) Research studies carried out in business, industry and public sector show that cost of failures mostly falls between 20 and 40% of the organization's total cost of sales (Maycock and Shaw, 1994).
24) Nylen (1996) found that poor quality cost was reduced to 10% of the contract value after application a quality management system in a railway project.
25) Willis and Willis (1996) tested their COQ system on a heavy industrial project as a case study. They concluded that the total COQ was 12% of total labor expenditures for design and construction (i-e 8.7% prevention + 3.3% appraisal cost). They concluded that more focus on prevention activities leads to reduction of appraisal and internal failure costs.
26) According to Sörqvist (1997) managing to reduce cost of poor quality in an organization is one of the best ways to increase profitability and competitiveness. The cost of poor quality usually remains between 10% and 30% of total turnover.
27) Hidden costs of poor quality can be between three and ten times the visible costs (Petty, 1997). Unfortunately, many business decisions are still made only based on the information from the visible costs.
28) Besterfield (1998) observed that a minimum of 20% quality costs are always present in the system
29) In a survey of Australian manufacturing firms, it was found that 48% of respondents measured COQ but only 41% of these used all four

(Appraisal, Prevention, Internal and External Failure) cost categories (Wheldon and Ross, 1998).

30) It is often claimed in the quality literature that total quality costs are very considerable, typically between 10-40% of turnover. This is why these costs are also known as the ‘‘hidden factory’’ or ‘‘the gold mine’’ (Dahlgaard et al., 1998)
31) The hidden costs of poor quality can be between three and ten times the visible costs (Ross, 1998, cited in Tsai, 1998).
32) According to Harrington (1999) in most of the cases, PQC works out to more than 40% of sales price, for example, PQC of IBM was reported to be between 20 and 40% of revenues before start of their quality improvement process.
33) Another study conducted by Love and Li (1999), on 12 engineering projects and two building projects in Australian, show that rework costs reduced from 5% to less than 1% on commencement of quality certification.
34) Harrington (1999) could not find any organization where the COPQ was less than 20% of sales, he mostly found it to be more than 100% of sales. The statement is not understandable, how can the losses be more than 100% in a sustainable business?
35) Josephson and Hammarlund (1999) after study of building projects concluded the costs of rework as 2% to 6% of their contract values.
36) Love et al. (1999) has reported rework as percentages of total value of work for a major project of construction of residential apartment blocks. They show that the percentages are much below 10% for most types, although percentages of 10.59 and 35.7 and reported for two categories.
37) Failure costs are estimated to fall between 10% and 30%, with most analyses putting them at around 20% (Nylen, 1999).
38) According to Williams et.al (1999) quality costs can be between 5 to 25%.
39) Barber et al. (2000) implemented a COQ system and evaluated quality failures costs on two infrastructure road projects in UK. In the first study of nine weeks, 188 failure incidents were recorded having cost of 16% of the weekly budget. Second study lasted for four weeks, in which 50 failure incidents were observed with cost of 23% of weekly budget.
40) Harry et al (2000) concluded quality costs ranging from 20 to 30% of company turnover

41) Love and Li (2000), worked out costs of rework on residential and industrial building in Australia, it was 3.15% and 2.40% of the contract value. Complete project life cycle was observed for data collection.
42) Hall and Tomkins (2001) developed a methodology for assessment of cost of quality and tested on a building project in UK. The observed a quality failure cost of 5.84% of the contract value and cost of good quality (prevention and appraisal costs) were reported to be 12.68% of the contract value.
43) Giakatis et al. (2001) conclude quality cost of 5 to 30%.
44) Giakatis et al. (2001) observed that the hidden quality costs were three times more than the conventional quality costs.
45) Josephson et al. (2002) conducted study from 1994 to1996 on seven construction projects in Sweden and recorded 2,879 failure incidents with the costs of rework 4.4% of the construction cost.
46) Love (2002b) performed a study and collected cost of rework from 161 construction projects in Australia. Mean direct and indirect rework cost of 6.4 and 5.6% respectively of the original contract value were concluded.
47) Raymond et al. (2002) has revealed that the Construction Industry Institute USA (CII, 1989) carried out a research to identify and evaluate the costs of rework incurred for rectification of quality deviations in nine construction projects. The deviation cost was found to be 2.4% of the total project cost.
48) Superville et al., (2003) worked out average 30% quality costs of company revenues.
49) James and William (2005) claim the quality costs fall between 20 to 40% of company production cost.
50) Kazaz et al. (2005) tested his model for evaluating total quality cost at a big housing project in Turkey. The reported cost of total quality was 16.75% of the total cost to project.
51) According to Kent (2005) quality costs fall between 5 to 25% of production cost.
52) Singhal (2006) is of the view that cost of quality mostly range between 24 to 40% of company output cost.
53) Rodchua (2006), concluded that COQ ranges from 2.5 to 5% of company revenues.
54) Barbará et all (2008) observed that quality costs normally fall between 10 to 40% of total production cost.
55) Cheah et. al. (2011) have concluded that quality costs evaluated in the traditional accounting system were 5.64% of the sales revenue,

whereas the hidden quality cost amounted to 8.78% of sales revenue. It is 1.6 times more than the cost based on the PAF model, and the total quality cost works out to 14.42% of the sales revenue.

56) Simpeh et al. (2012) used questionnaires to collect data for evaluation of the costs of rework from 78 construction firms, they worked out direct and indirect costs of rework as 2.93% and 2.20% of the contract value respectively.

57) Mahmood et al. (2014) and Mahmood and Kureshi (2014) implemented a cost of quality system on a road infrastructure project and succeeded in reducing the percentage of COPQ to the executed work value from 40.43 to 16.65% in a 60 days study period. The independent variables used were material, labor, machinery, and overheads, whereas COPQ was the dependent variable. There was a consistent trend of reduction of COPQ, for each of the variable studied. The labor productivity also improved by 16.88% and profitability increased by 10.45%.

According to Harrington (1999) Poor-quality cost are not uniform among the organizations; variation in the quality costs is due to product complexity, the technology used, use pattern of the product by the customer, the components of PQC that are considered, and the level of sophistication of the quality system within the organization. Uniformity lacks among the researchers about definitions and factors of COPQ to be measured as part of COQ improvement system. Therefore, most of the studies are not comparable (Oyewobi et al.-2011). There are also conflicts in the methods of quality cost measurements, data collection and its interpretations (Love, 2002b).

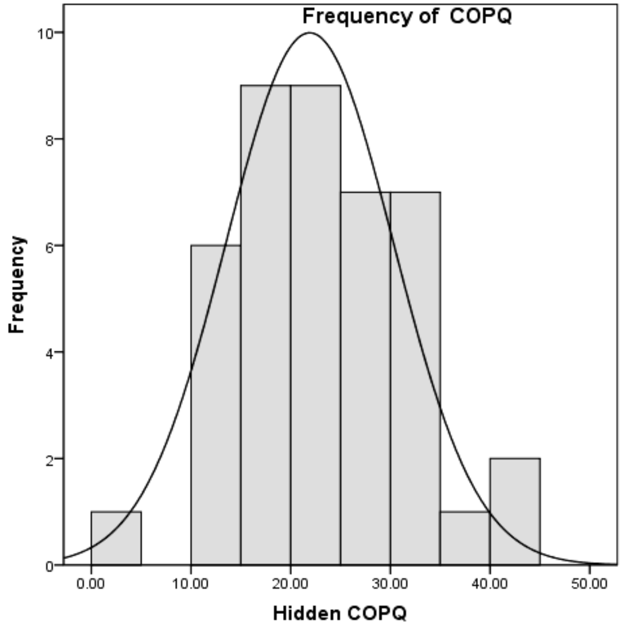
3) FINDINGS AND ANALYSIS

Out of 57 studies, only 42 five a range of COPQ and according to summary of 42 researches conducted by various researchers in forty years from 1975 onwards (Table 3.1), the COPQ ranges from 16.91 to 26.90% of company revenues with a mean of 21.91% and standard deviation of 8.38. The average COPQ concluded by each of the 42 researches has been used to generate a histogram as shown in Figure 3.1 It shows a central tendency with almost a bell shaped curve or normal distribution curve. The mean mode and median are almost equal; it supports the validity of the concept and the COPQ concluded by various researchers. The standard deviation is 8.38 due to which the histogram is showing a big spread, or wider shape of bell.

Table 3.1: Summary of 42 researches conducted by various researchers in forty years from 1975 to 2014.

Sr. No.	Researchers	% COPQ		Mean
		From	To	
1)	Dobbins (1975)	5.00	25.00	15.00
2)	Moyers and Gilmore (1979)	38.00	38.00	38.00
3)	Crosby (1984)	20.00	35.00	27.50
4)	Hansen (1985) building projects	11.00	11.00	11.00
5)	Wheelright and Hayes (1985)	30.00	30.00	30.00
6)	Harrington (1987, P-2)	40.00	40.00	40.00
7)	Morse et al (1987, P-29)	10.00	20.00	15.00
8)	Burati and Farrington (1987), construction project	12.40	12.40	12.40
9)	Raab – 1987	20.00	25.00	22.50
10)	Ittner, (1988) manufacturing companies	25.00	25.00	25.00
11)	Juran (1989)	33.33	33.33	33.33
12)	Cnuddle (1991) construction project	10.00	20.00	15.00
13)	Ravitz, 1991	25.00	25.00	25.00
14)	Terry (1991)	20.00	20.00	20.00
15)	Berry and Parasuraman (1992)	10.00	30.00	20.00
16)	McNealy (1993)	20.00	20.00	20.00
17)	Jeeves, 1993	40.00	40.00	40.00
18)	Maycock and Shaw, 1994	20.00	40.00	30.00
19)	Dale and Oakland (1995)	5.00	25.00	15.00
20)	Nylen (1996) Railway project	10.00	10.00	10.00
21)	Willis and Willis (1996) heavy industry project	12.00	12.00	12.00
22)	Sörqvist (1997)	10.00	30.00	20.00
23)	Besterfield (1998)	20.00	20.00	20.00
24)	Dahlgaard et al., 1998	10.00	40.00	25.00
25)	Atkinson et al. – 1999 manufacturing company	15.00	25.00	20.00
26)	Harrington (1999)	20.00	40.00	30.00
27)	Love et al. (1999) Building project	10.59	35.70	23.15
28)	Nylen, 1999	10.00	30.00	20.00
29)	Williams, et al., (1999)	5.00	25.00	15.00
30)	Barber et al. (2000) road projects	16.00	23.00	19.50
31)	Harry et al (2000)	20.00	30.00	25.00
32)	Hall and Tomkins (2001) building project	12.68	12.68	12.68
33)	Giakatis et al. (2001)	5.00	30.00	17.50
34)	Superville et al., (2003)	30.00	30.00	30.00

Sr. No.	Researchers	% COPQ		Mean
		From	**To**	
35)	James and William (2005)	20.00	40.00	30.00
36)	Kazaz et al. (2005) building project Turkey	16.75	16.75	16.75
37)	Kent (2005)	5.00	25.00	15.00
38)	Rodchua (2006)	2.50	5.00	3.75
39)	Singhal (2006)	24.00	40.00	32.00
40)	Barbará et al. (2008)	10.00	40.00	25.00
41)	Cheah et al. (2011)	14.42	14.42	14.42
42)	Mahmood et al. (2014) Road project	16.65	40.43	28.54
Mean	Standard Deviation 8.38	16.91	26.90	21.91



Mean = 21.91
Std. Dev. = 8.384
N = 42
Mode = 20.00
Median = 20.00

Figure3.1: Histogram of mean COPQ concluded from 42 researches from 1975 to 2014

Various researchers have also suggested the lowest possible percentage or required range of COPQ/organizational revenues i-e 2.81% to 3.85% with an average of 3.33% as summarized in **Table- 3.2**:

Table 3.2: Required percentage of COQ based on research from1987 to 2012.

Sr. No.	Researchers	% COPQ		Mean
		From	To	
1)	Morse et al. (1987, P-29)	2.50	2.50	2.50
2)	Crosby (1990, P-2)	4.00	5.00	4.50
3)	Companella (1990, P-36)	2.00	4.00	3.00
4)	Abdul-Rehman et al. (1996)	5.00	6.00	5.50
5)	Josephson and Hammarlund (1999)	2.00	6.00	4.00
6)	Love and Li (2000)	2.40	3.15	2.78
7)	Raymond et al. (2002)	2.40	2.40	2.40
8)	Josephson et al. (2002)	4.40	4.40	4.40
9)	Superville et al., (2003)	2.00	2.00	2.00
10)	Rosenfeld (2009)	2.00	4.00	3.00
11)	Simpeh et al. (2012)	2.20	2.93	2.57
Mean	Standard Deviation 1.10	2.81	3.85	3.33

The histogram of mean values of required COPQ (given in Table 3.2) has been shown in Figure 3.2. Again the mean mode and median have very close values, the spread is very little due to low value of standard deviation 1.10. Therefore, the conclusions drawn from the 11 researches are strongly supported.

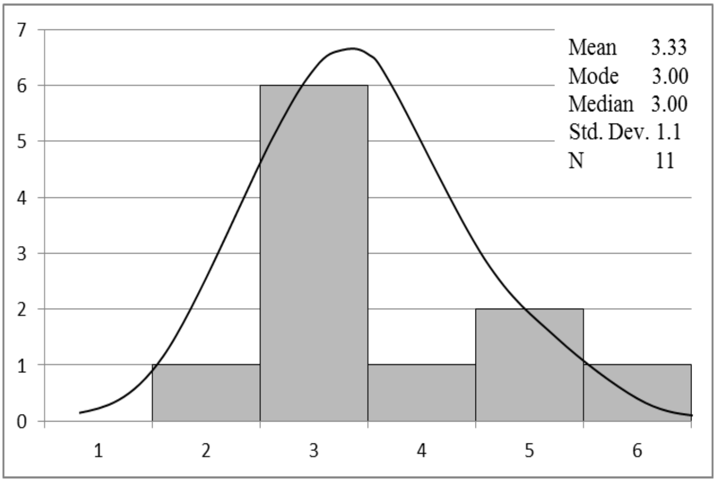


Figure 3.2 Histogram showing average minimum COPQ required as per results of 11 researches given in table-3.2

There is a big difference between population mean of COPQ (21.91%) and required mean COPQ (3.33%), therefore, it is a big opportunity to reduce COPQ. According to Rumane (2011) failure costs drop by 2 to 10% with an increase of 1% in prevention cost.

Starting from 1975 till 2014, in a time period of about 40 years, total 57 research studies could be found in the literature, in which the quality costs have been measured and concluded. The frequency of studies in chronological order has been shown in Figure- 3.3. It shows that most of the research work has been carried out in five years between 1998 and 2002 making about 35% of all the research work. After 2002 there are very few studies available on quality costing, it also reflects a decline in popularity of quality cost measuring concept and negative trend in its implementation and improvement.

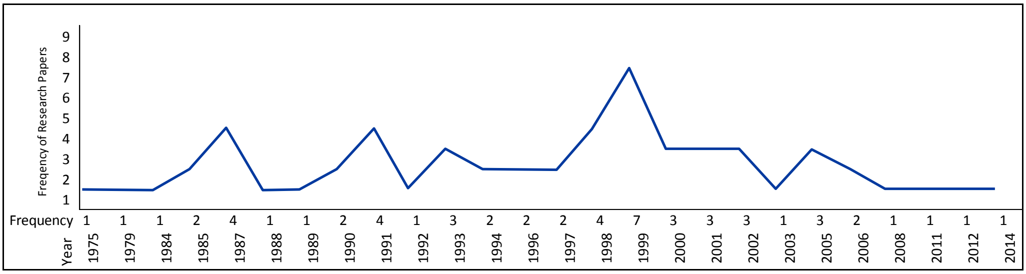


Figure-3.3 Quantum and frequency of research on quality cost measurement from 1975 to 2014

Most of the studies were focused on manufacturing sector, out of 57 only 17 Studies pertain to quality cost measurement in construction industry making about 30 %, and out of 17 only three were focused on road infrastructure projects i.e., only 5% of all the research studies. Many researchers are of the view that the existing quality cost systems are not standardized and yet to attain maturity. There are many shortcomings in the quality cost systems used by various researchers. Therefore, there is a big room for development and implementation of quality cost measuring system in construction industry especially in road infrastructure projects.

4) CONCLUSIONS

According to summary of 42 various researches spanned over forty years from 1975 onwards the COPQ ranges from 16.91 to 26.90% of company revenues with a mean of 21.91% and standard deviation of 8.38. The quality failure cost mostly remains hidden because, they are not measured separately. The COPQ is required to be between 2.81% to 3.85% of company revenues with a mean of 3.33% as concluded by various 11 researchers from 1987 to 2012.

A Total of 57 studies could be found on measurement of COPQ in 40 years, most of the studies pertain to manufacturing sector, only 17 studies (about 30%) pertain to construction industry, and out of the 17 only three (5% of all the research work) were focused on road infrastructure projects. Most of the researchers concede that the existing quality cost systems have many shortcomings; they are un-standardized and yet to attain maturity.

There is big gap between the existing hidden COPQ with a mean of 21.91% and the required mean value of 3.33%. It is a big cause of concern and also an opportunity for reduction of COPQ by devising a mechanism to carry out quantification of quality failure costs. The values of maximum and minimum COPQ can be used as benchmark to evaluate the improvement during measurement of quality costs on the construction projects or manufacturing concerns.

5) FUTURE RESEARCH

Construction sector plays a very vital role in the development of any country’s economy and poverty alleviation by job creations in many dependent and interconnected industries. So far very few studies have been conducted on measurement of quality failure costs. The construction industry is losing a considerable part of their precious resources on account of COPQ without being noticed. Therefore, there is a need to develop a Quality Cost Measurement System, for its implementation during project execution, so that project management could know the extent and source of quality failure costs and take corrective/preventive measures to stop the leakage of their resources. Reduction in quality failure costs will ensure completion of projects within the triple project constraints (Cost, Scope and Time) along with improvement in productivity of resources and profitability of construction companies.

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