Justifying the Cost of Quality in Construction Projects: An insight into the base of iceberg

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This thesis is dedicated to my parents, siblings,

colleagues and my respected teachers!

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ABSTRACT

Construction projects are intricate and manifold in nature therefore achieving higher quality standards has long been a problem. Several quality management techniques exist in the literature to overcome this problem, cost of quality (COQ) is one of the emerging technique adopted from manufacturing industry. For implementation of COQ in construction, several studies have attempted to quantify different components of quality cost using various methods but their main focus lies in visible failure cost i.e. tip of ice berg. This research carries out a complete quantitative study of each component of visible and as well the hidden quality costs, or the base of iceberg, in the construction industry of Pakistan by applying the modified prevention appraisal and failure (PAF) model on primary data collected from 25 building projects. The findings of the research highlight the unfamiliarity and passive attitude of local construction firms towards quality management systems, incurring higher failure cost as a result. Most part of this cost remains hidden and unknown to the higher management, despite its severe impact on project performance, customer satisfaction and organization reputation in a highly competitive market place. Therefore, these costs must be eliminated. This is first of its nature study in the context of local construction industry and recommends the management strategies to knock out the failure cost.

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LIST OF ABBREVIATIONS

COQ	**Cost of Quality**
COPQ	**Cost of Poor Quality**
CONC	**Cost of Non Conformance**
TCOQ	**Total Cost of Quality**
VCOQ	**Visible Cost of Quality**
QPMS	**Quality Performance Management System**
TQM	**Total Quality Management**
TPC	**Total Project Cost**
PAF	**Prevention Appraisal and Failure**

Chapter 1

INTRODUCTION

1.1 Background

Construction projects are capital intensive and characterized by long and complex processes of design, execution and project management. Due to this intricacy, accomplishment of adequate quality standards has long been a problem (Rosenfeld, 2009). A lot of material, money and resources are wasted because of ineffective quality standards, such as wastage and rework (Heravi and Jafari, 2014). The most important concern of construction firms is how to attain a balance between the desired level of quality and the expenditures associated with it. The assessment of cost of quality (COQ) can help attain this balance (Abdelsalam and Gad, 2009). Rosenfeld (2009) reported that a smart investment in COQ can save a significant part of the costs of non-quality (CONQ).

Despite the fact that the idea of COQ is exceptionally old yet not many studies have been conducted on measurement of COQ. Different researchers have attempted to determine the COQ by using different models in manufacturing industry but only a few studies pertaining to construction industry. In the construction industry, assessment of COQ got the attention in early 1980s (Kazaz et al., 2005). Plunkett and Dale (1988) analyzed the different known to-date-models and identified there weaknesses and strengths and set out the basis for prevention, appraisal and failure (PAF) cost model which classifies the quality cost into mentioned components. It was recognized as the basic framework for classifying the quality costs by British Standard Institute (BSI) in 1992 and it is extensively used for identifying and classifying COQ (Glogovac and Filipovic, 2016; Kazaz et al., 2005).

Barber et al. (2000) analyzed the COQ in construction projects using the traditional PAF model but the main focus of study was failure cost. Rosenfeld (2009) compared the cost of quality against cost of non-quality in construction and found that those firms who invested more in COQ incurred slightly less cost as quality failure.

Tawfek et al. (2012) using a neural network model to assess the COQ in construction industry of Egypt analyzed the factors affecting cost of quality in construction and found out that project duration and their planned COQ to be the most important. Heravi and Jafari (2014) studied the quality related cost in construction industry of developing country of Iran by using the PAF model and found that the optimum level of COQ was estimated as 7.4% of total project cost. Another Irani study applied the cost of quality on Qom monorail project and discovered that the initial investment in the cost of quality reduced the failure cost to as low as 0.05% of total project cost (Jafari and Love, 2013).

Mahmood and Ishaque (2013) measured the cost of internal failure on a concrete bridge project and observed a sufficient reduction in nonconformance cost after implementing a quality cost system. Al-Tmeemy et al. (2012) identified the contractors' perceptions on the significance of the quality cost system and the barriers in the implementation of the system. Management attention and quality awareness were found to be the most significant benefits of implementing a quality cost system.

Moreover, previous studies were more focused on the physical cost of rework and material wastage. No particular effort has been put to point out the intangible costs associated with quality nonconformance in construction. This includes cost of change orders, variations, time extensions, devaluation of the firm’s reputation, project delays, loss of customers, increased overheads. The purpose of this study is to fill this research gap by justifying the cost of quality against the cost of physical and nonphysical consequences that may occur due to poor quality in construction projects. The main focus of this study will be on intangible losses that arises due to poor quality in construction projects. The investments will be equated against the economic benefits to give the project stakeholders a better understanding of the effectiveness of quality cost systems.

1.2 Research Objectives

The objectives of this research are as follows:

- To identify the most occurring prevention, appraisal and failure costs in projects
- To identify the tangible and intangible hidden costs of quality nonconformance in construction projects
- To develop framework for measurement of hidden quality cost in construction projects
- To compare the cost of quality against the cost of poor quality

1.3 Scope of Study

Due to lack of awareness of quality costing concept in construction industry, very little or no data is available; therefore, scope of this study is limited to identification of tangible and intangible losses and the costs associated with it in low to mid-range building projects.

1.4 Relevance to National Needs

Pakistan is a developing country and construction is one of the emerging industry in the country with economic growth of 4.24% in recent years. The construction sector has strong influence on 40 building material industries; it maintains investments and helps in climate growth and poverty declination by creating employment opportunities for poor household. It provided jobs to 5.5% of the total working labour force or to 2.3 million persons including males and females during 2003-04 (Khan et al. 2008). Poor quality has always been a major concern of construction industry. According to the Love et al. (2017) and Barber et al. (2000), quality nonconformance cost could be as high as 20% of the total project cost. The findings of this study will help the local firms to improve the quality performance of construction projects by eliminating the quality failures on early stage this will save a handsome amount of money which eventually contributes towards the smooth project delivery, company reputation and customer satisfaction.

1.5 Advantages

The implementation of this research will help

- To improve the quality of products in construction
- To reduce the time and cost overruns in construction projects
- To reduce the rework, variations, change orders and overheads
- To enhance company reputation and satisfied customers
- To improve the project cash flow
- To reduce the project disputes, delays, litigations and arbitrations

1.6 Organization of Thesis

- Chapter 1 includes about the background, problem statement, research objectives, scope and limitations of the study. It provides a general overview.
- Chapter 2 discusses about previous studies have been done related to the topic, extensive literature review is carried out to identify the quality costs, and to explain quality models and, previous efforts to quantify such a costs.

- Chapter 3 describes the methodology adopted to perform in order to capture the costs of poor quality in construction. It also describes about the tools and techniques used in this research.
- Chapter 4 explains the results obtained from the analysis that is carried out after gathering data from the experts.
- Chapter 5 describes that how objectives of the research are achieved. Final conclusions and recommendations are presented.

LITERATURE REVIEW

2.1 Background

This chapter discusses the past work done related to the research being carried out. It entails a discussion on the quality management, quality in construction, concept of cost of quality, non-conformance and hidden quality costs. In addition, linking the literature together for research purpose, this chapter deepens the knowledge about the general perception of quality management in construction.

The word "Quality" is taken from a Latin word "Qualitas" which means the fitness for use (Khalek et al., 2016). Quality means distinctive things to various individuals and it is more related or connected to customer needs and satisfaction (Defeo and Juran, 2010). Quality is the esteem customers get from items (Harrington, 1987). It is meeting or going beyond the requirement of clients. (Daddow and Skitmore, 2005). Customers assess the performance of construction projects based upon the achieved quality (Žileska–Pančovska et al., 2016). Since the concept of quality is subjective and related to the perception of people, it is mostly assessed through customer satisfaction and profitability.

2.2 Quality and Customer Satisfaction

Quality is one of the most significant constraints of construction projects as it attracts customer satisfaction and helps in better financial management (Khalek et al., 2016). Companies acquiring higher quality standards have more satisfied clients, which in turn leads to better financial performance (Iyer and Kuksov, 2010; Shah and Regassa, 2010). Customers expect more quality at lower cost, so to attain this objective, contractors must consider the quality-cost trade off (Farooq et al., 2017). Many companies promote quality as the central customer value and consider it to be a pivotal success factor for accomplishing competitiveness (Schiffauerova and Thomson, 2006). A dissatisfied customer eventually deserts the firm, all the while spreading harmful publicity about it (Sansalvador and Brotons, 2017).

2.3 Quality and Profitability

Better quality increases the ability of a business to earn profit (Shah and Regassa, 2010). According to famous iron triangle, improving quality needs more time and money. It is important to directly link quality issues with bottom line costs. Therefore, the most important concern of construction firms is to achieve a balance between the desired level of quality and the expenses associated with it. A smart investment in assuring quality can save a significant part of the failure costs which eventually adds to the firm's profit (Mahmood, 2010; Rosenfeld, 2009). Associating quality, conformance and shortcomings to profits is the way to drive true change (Defeo and Juran, 2010). Better quality not only saves money and time but it can also earn intangible benefits like better firm reputation, satisfaction and loyalty of customers.

2.4 Quality in Construction

Construction projects are more intricate and manifold in nature as compared to other industries, Therefore, it is harder to complete the projects within the scheduled time, cost and required quality standards (Al-Tmeemy et al., 2011; Khalek et al., 2016; Mahmood and Ishaque, 2013; Rashed and Othman, 2015; Žileska–Pančovska et al., 2016). Quality is a vital integrant of construction project (Aliakbarlou et al., 2017) but the concept of quality is weak in construction and it continues to be treated like an enigma (Barlow, 2009; Khalek et al., 2016; Rashed and Othman, 2015). To remain competitive in market, companies should invest heavily in quality and take necessary measures in order to achieve steady improvement (Glogovac and Filipovic, 2016).Since quality failures can result in material wastage, rework and cost overruns and it is a burden; it decreases profitability and slows down productivity (Mahmood and Ishaque, 2013; Mahmood and Kureshi, 2015). Failures generate variations and change orders (CO) (Rosenfeld, 2009), CO can further cause delays, rework, wastage of material, cost overrun and loss of productivity (Sun and Meng, 2009), which eventually lead to disputes, poor contract management, loss of image, loss of sales and customers, litigation and arbitration (Mhando et al., 2017; Oyewobi et al., 2016).

Quality nonconformance data has not been recorded earlier in construction (Lundkvist et al., 2014). Different firms use different ways to record quality nonconformance. Some firms relate it with percentage of rework and material wastage. Measuring quality in monetary terms is common in manufacturing industry. In the construction industry, increasing attention to measuring quality cost has been given to improving the overall construction quality since the early 1980s (Kazaz et al., 2005). To attain a balance between the desired level of quality and its expenses, evaluating the cost of quality (COQ) provides directions to improve quality and decline relevant costs (Abdelsalam and Gad, 2009).

2.5 Overview of COQ

COQ is defined as the cost sustained by the manufacturer, by the user and by the community, associated with the quality of a product or a service as well as the expenses incurred due to failure to meet the desired quality level (Cheah et al., 2011). Juran (1951) defined quality cost as *"all those costs which would disappear if there were no shortcomings"* (Sellés et al., 2008). It is necessary to exclude poor quality costs, but this is only possible if these costs are detected and assessed, that is to say, if quality costs are measured and scrutinized (Jaju et al., 2009). COQ assesses organization's quality performance, emphasizes the area which requires improvement and it is helpful in continuous improvement, and enforcement of Total Quality Management (TQM) (Al-Tmeemy et al., 2012; Glogovac and Filipovic, 2016). The evidence shows that companies that do adopt COQ methods are successful in reduction of total project costs, construction failures, material waste and unnecessary use of resources, enhancement in quality standards and ability of failure analysis which enables the company to apply possible remedies to prevent future reoccurrence. (Cheah et al., 2011; Glogovac and Filipovic, 2016; Schiffauerova and Thomson, 2006; Taggart et al., 2014). Quality cost should be planned with extreme care and there should be an optimum range of prevention and appraisal activities because an excessive investment in quality costs is inefficient. Above that level, the benefits are minor, and thus do not redeem the extra costs (Rosenfeld, 2009).

In construction industry, COQ is an important factor of the total cost but separating the quality costs from other costs has become very challenging and time consuming (Barber et al., 2000). Lack of management interest, nonexistence of system and lack of knowledge are the main barriers in implementing the quality cost systems in construction (Al-Tmeemy et al., 2012). Therefore, there is need to evaluate, track and relocate the cost spent on quality related activities (Barlow, 2009). But today's accounting system lacks the ability of tracking quality costs in construction and the original cost of quality remains concealed (Mahmood and Kureshi, 2015). Therefore, to capture quality costs there is need of a well-defined quality cost framework. Various researchers suggested different quality cost models according to the needs of different industries. The next section briefly discusses these models.

2.6 COQ Models

Feigenbaum (1956) developed the concept of COQ, by introducing a dollar based reporting system (Schiffauerova and Thomson, 2006). But according to Farooq et al. (2017), Juran (1951) was the one who presented the idea of quality costing. Feigenbaum (1956) later suggested the now widely used quality cost classification of prevention, appraisal and failure costs (Harrington, 1987). Since then, various models have been developed to track the quality cost. An overview of different COQ models is given in

Table 2-1.

Schiffauerova and Thomson (2006) categorizes quality cost models into four groups of generic models. These includes PAF model, opportunity cost model, activity based cost and process cost model.

Table 2-1 also contains those models (Abdul-Rahman, 1993; Aoieong et al., 2002) which were applied on construction projects. All these models have their own advantages and disadvantages just as QPMS model is simple and adoptable but Abdul-Rahman (1995) stated that QPMS model does not examine the effect of failure on time-related cost. Abdul-Rahman (1993)'s quality cost matrix is focused on failure cost and it does not cover other quality costs (Aoieong et al., 2002). Similarly Krishnan (2006) stated about the most widely PAF model, that it does not incorporate the hidden component of quality cost. It is evident from previous studies that quality cost models are still in evolving phase and it is a big area of improvement.

This study will use the modified form of most common prevention appraisal failure (PAF) model which not only comprise visible COQ but there hidden portion as well. The prime objective of the study is to effectively apply this technique to construction sector with main focus on hidden COQ. The next section entails a detail discussion on different components of PAF model and most common quality costs in construction by linking the literature together for research purpose.

Table 2-1: Summary of Generic COQ Models

Sr.	Model	Approach	Comments	References
1	Quality Performance Management System (QPMS)	Quality costs can be identified using quality management activities and 11 rework causes	• No track of effect of failure on time-related cost, • Specific cause of failures cannot be traced.	(Abdul-Rahman, 1995; Aoieong et al., 2002; Burati and Farrington, 1987; Davis et al., 1989)
2	Quality performance tracking system (QPTS)	WBS and quality costs were affiliated using cost codes. This coding is helpful in identifying the sources of failures.	• Specific causes of deviation were not recorded.	(Aoieong et al., 2002; Davis et al., 1989)
3	Quality cost matrix	Quality cost matrix was developed containing columns like cost of activity, specific problem and cause of problem.	• Only nonconformance cost was recorded • Origin of deviations were not recorded	(Abdul-Rahman, 1993; Aoieong et al., 2002; Schiffauerova and Thomson, 2006)
4	Opportunity cost models	Quality costs consist of prevention, appraisal and cost of missed opportunity	• Cost of conformance + Cost of nonconformance + Intangible	(Cheah et al., 2011; Sandoval-Chavez and Beruvides, 1998; Yang, 2008)
5	Quality loss model	Introduced a new category of quality loss. Quality loss is prevention and appraisal costs that fail to achieve their objectives	• Too much paperwork was hindrance to implementation of this model.	(Giakatis et al., 2001; Schiffauerova and Thomson, 2006)
6	Prevention Appraisal Failure Model	Quality costs equal to prevention + appraisal + failure (internal, External)	• Difficulty in distinguishing between prevention n appraisal activities • Intangible losses are not covered	(Barlow, 2009; Farooq et al., 2017; Heravi and Jafari, 2014; Rosenfeld, 2009; Yang, 2008)

2.7 PAF Model

PAF model is the most commonly used technique to quantify the COQ (Aoieong et al., 2002; dos Reis Almeida, 2011; Farooq et al., 2017; Heravi and Jafari, 2014; Kazaz and Birgonul, 2005; Schiffauerova and Thomson, 2006). It was accepted as the basic framework for classifying the quality costs by British Standard Institute (BSI) in 1992 and it is extensively used for identifying and classifying COQ (Kazaz et al., 2005). It classifies the COQ into conformance (prevention, appraisal) cost and cost of failure (internal, external) or nonconformance cost (Barlow, 2009).

2.7.1 Cost of Conformance

Cost of conformance is the amount paid for prevention of poor quality (e.g. inspection and quality appraisal) (Mahmood and Kureshi, 2015). Appraisal and prevention costs are inevitable, and must be borne by construction companies and firms if their products/services are to be delivered right the first time (Josephson et al., 2002). Investment in conformance activities will reduce nonconformance costs because more errors are discovered at an earlier stage (Heravi and Jafari, 2014). But high cost of conformance (prevention, appraisal) is one of the side effects of executing and sustaining a quality management system (Oladokun et al., 2017). However, these costs are a familiar amount and can be restricted (Barlow, 2009). Conformance cost is further divided into prevention and appraisal costs.

2.7.1.1 Prevention Cost

It is defined as Cost of conformance is the amount paid for prevention of poor quality (e.g. inspection and quality appraisal) (Mahmood and Kureshi, 2015).. These activities prevent the occurrence of failures by assuring to meet the quality and customer satisfaction standards, these consist of education and training, equipment maintenance and quality management systems etc. (Abdul-Rahman et al., 2014; Farooq et al., 2017).

Prevention cost is the most important as it can reduce every other quality cost. Appraisal cost will be decreased as such activities become less mandatory. Internal and external failure costs will be reduced, as there will be less failures. By spending 1% more on prevention efforts, the failure costs of construction can be reduced from 10% to 2% (Kazaz et al., 2005).

Based on the previous research regarding COQ, different prevention, appraisal, failure costs have been identified. The sources used for searching the literature included Science Direct, ASCE, Taylor & Francis Online, Emerald Insight and Google Scholar. Semantic technique and keywords were used in searching process. A total of 25 research publications from different journals of project management, and construction engineering and management published between the years 1999-2017 have been found relevant. This particular period is selected to focus on the recent trends. The identified most common prevention costs are shown in Table 2-2.

Table 2-2 : Identified Prevention Costs

Rank	**Cost**	**Reference**	**Frequency**
1	Cost of instruction and Training, Education on quality-related issues	(Abdelsalam and Gad, 2009; Al-Tmeemy et al., 2011; Chen and Yang, 2003; dos Reis Almeida, 2011; Giakatis et al., 2001; Hall and Tomkins, 2001; Heravi and Jafari, 2014; Juran and Godfrey, 1999; Kazaz et al., 2005; Love and Irani, 2003; Mahmood, 2010; Malik et al., 2016; Rosenfeld, 2009)	13
2	Cost of accreditation and selection of suppliers and subcontractors	(Al-Tmeemy et al., 2011; Barlow, 2009; Chen and Yang, 2003; dos Reis Almeida, 2011; Heravi and Jafari, 2014; Juran and Godfrey, 1999; Kazaz et al., 2005; Love and Irani, 2003; Mahmood, 2010; Rosenfeld, 2009)	10
3	Cost of preparing plans	(Cheah et al., 2011; Chen and Yang, 2003; Giakatis et al., 2001; Heravi and Jafari, 2014; Jafari and Love, 2013; Krishnan,	9

		2006; Mahmood, 2010; Malik et al., 2016; Rosenfeld, 2009)	
4	Cost of internal quality audits	(Al-Tmeemy et al., 2011; Giakatis et al., 2001; Juran and Godfrey, 1999; Krishnan, 2006; Love and Irani, 2003; Malik et al., 2016; Rosenfeld, 2009)	7
5	Cost of quality manager	(Abdelsalam and Gad, 2009; Chen and Yang, 2003; Jafari and Love, 2013; Kazaz et al., 2005; Krishnan, 2006; Rosenfeld, 2009)	6
6	Cost of quality control equipment	(Chen and Yang, 2003; dos Reis Almeida, 2011; Jafari and Love, 2013; Mahmood, 2010; Malik et al., 2016; Rosenfeld, 2009)	6
7	Cost of review of design & specification	(Chen and Yang, 2003; Heravi and Jafari, 2014; Krishnan, 2006; Love and Irani, 2003; Mahmood, 2010; Rosenfeld, 2009)	6
8	Maintenance & operating costs of routine process control	(Barlow, 2009; Chatzipetrou et al., 2017; Juran and Godfrey, 1999; Malik et al., 2016; Rosenfeld, 2009)	5
9	Cost of quality assurance staff members	(Abdelsalam and Gad, 2009; dos Reis Almeida, 2011; Krishnan, 2006; Rosenfeld, 2009)	4
10	Cost of purchasing control planning	(Chen and Yang, 2003; Rosenfeld, 2009)	2
11	Cost of root cause analysis	(Jafari and Love, 2013; Rosenfeld, 2009)	2
12	New product review	(Juran and Godfrey, 1999)	1

2.7.1.2 Appraisal Cost

The cost of assessing the accomplishment of quality standards are known as appraisal costs (Aoieong et al., 2002; Tawfek et al., 2012). These are the costs incurred to assure that quality is delivered according to the desired standards, it includes the activities like equipment testing, inspections, material testing, audits, etc. (Farooq et al., 2017). Most common appraisal costs are identified from the literature and mentioned in Table 2-3.

Table 2-3 : Identified Appraisal Costs

Rank	Costs	References	Frequency
1	Material inspection and testing	(Abdelsalam and Gad, 2009; Chatzipetrou et al., 2017; dos Reis Almeida, 2011; Giakatis et al., 2001; Heravi and Jafari, 2014; Jafari and Love, 2013; Juran and Godfrey, 1999; Krishnan, 2006; Mahmood, 2010; Malik et al., 2016; Özkan and Karaibrahimoğlu, 2013; Rosenfeld, 2009; Yang, 2008)	13
2	Product inspection and testing	(Barlow, 2009; Chen and Yang, 2003; Giakatis et al., 2001; Heravi and Jafari, 2014; Juran and Godfrey, 1999; Krishnan, 2006; Mahmood, 2010; Malik et al., 2016; Özkan and Karaibrahimoğlu, 2013; Rosenfeld, 2009; Yang, 2008)	11
3	Cost of operating and maintaining equipment	(Abdelsalam and Gad, 2009; Barlow, 2009; dos Reis Almeida, 2011; Hall and Tomkins, 2001; Jafari and Love, 2013; Juran and Godfrey, 1999; Krishnan, 2006; Özkan and Karaibrahimoğlu, 2013; Rosenfeld, 2009; Yang, 2008)	10
4	In-process inspection and testing	(Chatzipetrou et al., 2017; dos Reis Almeida, 2011; Heravi and Jafari, 2014; Juran and Godfrey, 1999; Krishnan, 2006; Mahmood, 2010; Rosenfeld, 2009; Yang, 2008)	8
5	Cost of external quality audits	(Al-Tmeemy et al., 2011; Giakatis et al., 2001; Jafari and Love, 2013; Juran and Godfrey, 1999; Love and Irani, 2003; Malik et al., 2016; Rosenfeld, 2009)	7
6	Document reviews	(Juran and Godfrey, 1999; Yang, 2008)	2
7	Evaluation of stock	(Juran and Godfrey, 1999)	1

2.7.2 Cost of Nonconformance

Cost of nonconformance is the cost caused by product and service failure. Cost of Poor Quality (COPQ) is the aggregate of all costs that would disappear if the job is done right first time (Mahmood and Ishaque, 2013). Harrington (1987) defines nonconformance cost as all the costs sustained by the firm and the client because the output did not meet the desired standards and customer needs. Failure costs are further divided into internal and external failure cost.

2.7.2.1 Internal failure cost

It is the cost incurred on correcting the detected errors before dispatching to the client. The costs emerging within a firm due to nonconformance or defects at any stage of the quality loop (Tawfek et al., 2012). Internal failures are the most expensive constituent of the total visible quality-related costs (Rosenfeld, 2009). It includes the cost of rework, material, labour, increased project cost and expense and cost of scraps. Different internal failure costs were identified from literature and presented in Table 2-4.

Table 2-4 : Identified Internal Failure Costs

Rank	**Costs**	**References**	**Frequency**
1	Reworks and corrective actions	(Abdelsalam and Gad, 2009; Barlow, 2009; Cheah et al., 2011; Chen and Yang, 2003; Giakatis et al., 2001; Hall and Tomkins, 2001; Heravi and Jafari, 2014; Hwang and Low, 2012; Juran and Godfrey, 1999; Keane et al., 2010; Krishnan, 2006; Mahmood, 2010; Mahmood and Kureshi, 2015; Malik et al., 2016; Manzoor Arain and Sui Pheng, 2005; Mhando et al., 2017; Oyewobi et al., 2016; Özkan and Karaibrahimoğlu, 2013; Rosenfeld, 2009; Simpeh et al., 2012; Sun and Meng, 2009; Yang, 2008)	22
2	Cost of scrap and demolition	(Barlow, 2009; Chatzipetrou et al., 2017; Cheah et al., 2011; Chen and Yang, 2003; Giakatis et al., 2001; Hall and Tomkins, 2001; Hwang and Low, 2012; Juran and Godfrey, 1999; Keane et al., 2010; Krishnan, 2006; Mahmood, 2010; Mahmood and Kureshi, 2015; Malik et al., 2016; Manzoor Arain and Sui Pheng, 2005; Mhando et al., 2017; Oyewobi et al., 2016; Özkan and Karaibrahimoğlu, 2013; Rosenfeld, 2009;	20

		Simpeh et al., 2012; Sun and Meng, 2009; Yang, 2008)	
3	Cost of product repairs	(Cheah et al., 2011; Giakatis et al., 2001; Heravi and Jafari, 2014; Jafari and Love, 2013; Krishnan, 2006; Mahmood, 2010; Malik et al., 2016; Rosenfeld, 2009; Yang, 2008)	9
4	Cost of changing due to nonconformance	(dos Reis Almeida, 2011; Jafari and Love, 2013; Juran and Godfrey, 1999; Krishnan, 2006; Mahmood and Kureshi, 2015; Malik et al., 2016; Rosenfeld, 2009)	8
5	Cost of material wastage	(Barlow, 2009; Giakatis et al., 2001; Krishnan, 2006; Mahmood, 2010; Mahmood and Kureshi, 2015; Malik et al., 2016; Simpeh et al., 2012; Yang, 2008)	8
6	Failure analysis	(Chatzipetrou et al., 2017; Juran and Godfrey, 1999; Krishnan, 2006; Mahmood and Kureshi, 2015; Malik et al., 2016; Yang, 2008)	6

2.7.2.2 External failure cost

External failure cost arises when the poor quality product is dispatched to the client (Farooq et al., 2017). Warranty recalls, product retrieves and complains are the typical examples of external failures. External failure cost causes hidden and intangible losses to the firms, these are the most difficult to identify and estimate. Identified most common external failure costs are given in Table 2-5.

Table 2-5: Identified External Failure Costs

Rank	**Costs**	**References**	**Frequency**
1	Cost of warranty works	(Barlow, 2009; Cheah et al., 2011; Chen and Yang, 2003; dos Reis Almeida, 2011; Giakatis et al., 2001; Hall and Tomkins, 2001; Juran and Godfrey, 1999; Mahmood, 2010; Mahmood and Kureshi, 2015; Malik et al., 2016; Özkan and Karaibrahimoğlu, 2013; Rosenfeld, 2009; Simpeh et al., 2012; Sun and Meng, 2009; Yang, 2008)	14
2	Cost of customer complaints	(Barlow, 2009; Cheah et al., 2011; Chen and Yang, 2003; dos Reis Almeida, 2011; Giakatis et	13

		al., 2001; Hall and Tomkins, 2001; Juran and Godfrey, 1999; Mahmood, 2010; Mahmood and Kureshi, 2015; Malik et al., 2016; Özkan and Karaibrahimoğlu, 2013; Rosenfeld, 2009; Simpeh et al., 2012; Sun and Meng, 2009; Yang, 2008)	
3	Legal costs, compensations	(Barlow, 2009; dos Reis Almeida, 2011; Hall and Tomkins, 2001; Juran and Godfrey, 1999; Mahmood and Kureshi, 2015; Rosenfeld, 2009; Simpeh et al., 2012; Sun and Meng, 2009)	7
4	Cost of time invested in handling post-occupancy	(Rosenfeld, 2009; Simpeh et al., 2012; Sun and Meng, 2009; Yang, 2008)	4
5	Cost of penalties due to nonconformance	(dos Reis Almeida, 2011; Giakatis et al., 2001; Juran and Godfrey, 1999; Rosenfeld, 2009)	4
6	Revenue losses	(Juran and Godfrey, 1999)	1

Although PAF model is the most commonly used and universally accepted but it has some deficiencies. Sometimes it is difficult to uniquely categorize costs into prevention, appraisal, internal failure and external failure costs (Aoieong et al., 2002; Krishnan, 2006). Original PAF model does not incorporate intangible and hidden quality costs such as 'loss of reputation' and 'loss of sales' (Krishnan, 2006). Hidden quality cost is the most significant part of the total COQ. A classic assumption of the PAF model is that investment in preventive and appraisal activities will reduce failure costs, but research has proved that too much investments in quality cost are wasteful (Heravi and Jafari, 2014).

2.8 Application of COQ in Construction

A few case studies have attempted to figure the COQ in construction projects (Jafari and Love, 2013). Literature indicates that there is low level of awareness about quality costs in construction and it is difficult to differentiate between different quality costs (Aoieong et al., 2002; Krishnan, 2006).Therefore, most construction firms do not calculate all three components of quality costs, instead main focus is on failure costs (Heravi and Jafari, 2014). To get a better vision of quality cost systems in construction, this study not only listed different quality cost but also tabulated the quantified of previous authors with prime focus on construction projects. A total of 24 studies containing data of 49 projects were examined. To assess the recent trends in construction industry the studied period was kept between 2000 – 2017. The COQ determined by various researchers have been summarized in

Table 2-6.

It is evident from

Table 2-6 that companies tend to invest low in COQ with population mean of 5.57% of total project cost, and least in appraisal activities with less than 2% of project cost. Although it is believed that investments in prevention activities is beneficial (Heravi and Jafari, 2014). Cost of failure shares the largest portion of total COQ with population mean of 7.58%. There is a large dispersion in the data as population standard deviation is 7.57% which is due to number of factors.

The dispersion of data can be justified as

- Heravi and Jafari (2014) stated that different researchers used different approaches to quantify the failure costs. Love (2002) and Love et al. (2010) used the questionnaire survey technique. Hall and Tomkins (2001), Mills et al. (2009), Giakatis et al. (2001) and Abdelsalam and Gad (2009) used inspection of documents and observation of field data. Mahmood and Ishaque (2013), Barber et al. (2000) and Jafari and Love (2013) used the field data collection technique. Cheah et al. (2011) did the action research. Kazaz and Birgonul (2005) did the structured interviews with householders to quantify the different quality costs.
- The above studies were conducted in different localities. Mahmood (2010), Malik et al. (2016) and Mahmood and Kureshi (2014) conducted their case studies on construction projects in developing country of Pakistan and found a much higher value of direct and indirect failures. Love et al. (2010), Love and Edwards (2005) and Love and Li (2000) calculated the rework cost of Australian construction industry, where failure percentages were lesser than Mahmood (2010). Jafari and Love (2013) calculated the COQ of a monorail project in Iran. Area of study for Barber et al. (2000) and Hall and Tomkins (2001) was UK.

- Different type and nature of projects were studied. Kazaz and Birgonul (2005), Heravi and Jafari (2014), Mills et al. (2009), Hall and Tomkins (2001) and Abdelsalam and Gad (2009) studied building projects.
- Mahmood and Kureshi (2014) calculated the quality costs on a road infrastructure project. Jafari and Love (2013) studied the monorail project. Forcada et al. (2016) study was on urban renewal project.
- Most of the studies (Aiyetan, 2014; Forcada et al., 2016; Josephson et al., 2002; Kakitahi et al., 2014; Love, 2002; Love and Edwards, 2005; Love et al., 2010; Love and Li, 2000; Simpeh et al., 2012) were focused only on rework and failure costs. Some authors also incorporated the indirect cost of failure. Only a few studies (Abdelsalam and Gad, 2009; Cheah et al., 2011; Heravi and Jafari, 2014; Jafari and Love, 2013; Malik et al., 2016; Rosenfeld, 2009) attempted to quantify all the components of PAF model.

Table 2-6: Percentage of Quality Costs from Literature

References	Studied Project	Prevention	Appraisal	Total COQ	Internal Failure	External Failure	Total COPQ
Mahmood and Kureshi (2014)							15.07%-36.44%
Marzuki and Wisridani (2014)	Project 1	0.30%	0.88%	1.18%	1.03%		1.03%
	Project 2	0.86%	1.79%	2.65%	1.03%		1.03%
	Project 3	0.95%	2.32%	3.27%	0.55%		0.55%
Mahmood and Ishaque (2013)							40.43%-16.65%
Jafari and Love (2013)		0.46%	2.32%	2.78%	0.05%		0.05%
dos Reis Almeida (2011)							1-7%
Love et al. (2010)					5.07%	5.22%	10.29%
Abdelsalam and Gad (2009)		0.26%	1.44%	1.70%	0.70%		0.70%
Rosenfeld (2009)	Project 1	0.67%	0.78%	1.45%	0.5%	1.59%	2.09%
	Project 2	0.27%	0.72%	0.99%	1.34%	2.52%	3.86%
	Project 3	0.35%	0.64%	0.99%	0.89%	3.06%	3.95%
	Project 4	0.76%	1.4%	2.16%	1.08%	0.76%	1.84%
	Project 5	0.51%	2.16%	2.67%	0.87%	1.06%	1.93%
	Project 6	1.27%	0.47%	1.74%	0.56%	1.72%	2.28%
	Project 7	0.75%	1.27%	2.02%	1.07%	0.87%	1.94%
	Project 8	0.89%	0.89%	1.78%	1.05%	1.05%	2.1%
Mills et al. (2009)							4%
Kazaz et al. (2005)	High rise			17.7%			10.27%
	Medium			24.79%			11.1%
	Single-story			20%			13.23%
Barber et al. (2000)	Scheme 1						15.76%

	Scheme 2						23.00%
Kakitahi et al. (2014)	Rooms				3.53%		3.53%
	Health center				8.02%		8.02%
	Housing				2.04%		2.04%
	3C Houses				0.65%		0.65%
	3B Houses				0.47%		0.47%
Hall and Tomkins (2001)				12.68%			5.84%
Forcada et al. (2016)							28.00%
Love and Edwards (2005)					6.40%	5.90%	12.30%
Love et al. (2017)							23.75%
Josephson et al. (2002)					4.40%		4.40%
Simpeh et al. (2012)	Architect				1.08%	0.33%	1.41%
	Contractor				2.00%	0.59%	2.59%
	Engineer				3.42%	6.22%	9.64%
	QS				5.18%	3.71%	8.89%
	PM				4.33%	2.00%	6.33%
Love (2002)	New Building				6.10%	7.70%	13.80%
	Renovation				7.29%	5.60%	12.89%
	Fit-out				7.78%	6.10%	13.88%
	Refurbish				4.95%	5.81%	10.76%
	Combine				3.33%	0.66%	3.99%
Aiyetan (2014)					0.6-5%		0.6-5%
Love and Li (2000)	Residential				3.15%		3.15%
	Industrial				2.40%		2.40%
Giakatis et al. (2001)		6.29%	2.95%	9.24%	1.05%		1.05%
Cheah et al. (2011)		0.95%	0.98%	1.93%			3.91%
Malik et al. (2016)		2.09%	1.68%	3.77%	5.60%	1.64%	7.24%
Mean		**1.10%**	**1.42%**	**5.77%**	**2.85%**	**3.31%**	**7.58%**
Standard Deviation		**1.41%**	**0.70%**	**6.98%**	**2.30%**	**2.56%**	**7.57%**

2.9 Hidden Cost of Poor Quality or ‘Base of Iceberg’

COQ are tangible expenses on prevention and appraisal, whereas internal and external failure costs are either visible or easily quantifiable. These, however, are only part of the picture, or rather the ‘tip of the iceberg’, since the visible failure costs are always followed by considerable hidden costs (Feigenbaum, 1991; Rosenfeld, 2009). These costs are the significant part of the quality costs, they remain hidden like the immerse ‘base of the iceberg’ (Sansalvador and Brotons, 2017). Spanish Association of Accountancy and Business Administration (AECA 1998) has recommended that those costs which are not normally taken into account, or are not clearly recorded in the financial records, should be considered as hidden costs (Sellés et al., 2008). These include the cost of accelerating the project in case of delays to failure, cost of loss of sales if poor quality product is delivered to customers, cost of customer dissatisfaction, cost of productivity loss and interruption in project flow due to failure events, etc. Cost quality Iceberg is presented in Figure 2-1.

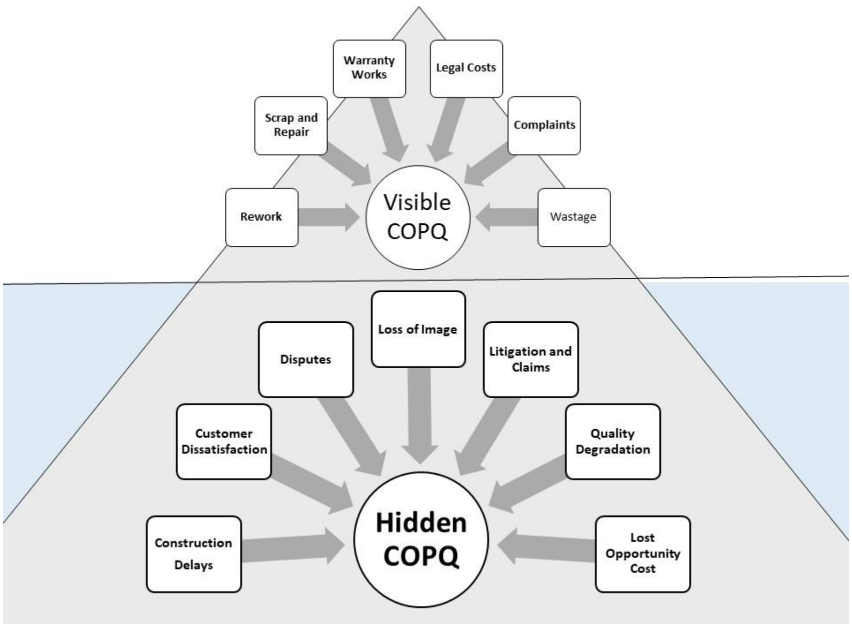


Figure 2-1: Cost of Qualiity Iceberg (Krishnan, 2006)

Hidden quality cost can hurt an organization badly, as it is higher than all other visible quality costs. Also, it is difficult to track as it remains concealed. (Cheah et al., 2011). Yang (2008) noted that failure costs are either under-rated or never actually uncovered. Failure costs incorporating hidden cost can go beyond the total estimated cost of the project (Mahmood, 2010). Mahmood and Kureshi (2015) found that traditional quality costs are three times less than the hidden quality cost.

Different researchers attempted to quantify the hidden COQ in different industries. Cheah et al. (2011) implemented the COQ model on wooden manufacturing company and found that the visible quality cost was 5.64% while the hidden quality cost was 8.78% of the total sales volume. Krishnan (2006) developed a hidden quality cost model whose application on a packaging company reveals that hidden quality cost was significant portion of total COQ. Giakatis et al. (2001) calculated the quality cost of a printing company and found that the invisible quality costs are three time greater than the traditional quality cost. Mahmood and Ishaque (2013) applied the COQ technique on a public-sector construction project and was able to reduce the COPQ from 40.43% to 16.65%.

This study will justify the investments made in quality by uncovering the hidden cost of poor quality in construction sector. To achieve this objective, an extensive literature review is done to identify the most common hidden costs of poor quality. Around 60 research papers published between 2000 - 2017 were reviewed from which 26 were found relevant. Most of the selected publications were about construction projects. After careful analysis of the published research papers, articles and journals, a total of 31 hidden quality cost factors were identified. To rank the factors a, statistics analysis using frequency and magnitude was performed. Since there are few studies pertaining to hidden COQ in construction. A pilot survey was designed using the google forms to get the opinion of experts where they were asked to rank the factors on a five-point Likert scale. The survey forms were sent through email to different academics and field experts around the world. The combine score of literature and survey was used and different statistical analysis were performed. The short-listed factors are given in Table 2-7.

Table 2-7 : Selected Hidden Quality Factors

Rank	**Factor**	**Nature**
1	Waste of time/ delays	Tangible
2	Loss/dissatisfaction of customer	Intangible
3	Variations	Tangible
4	Project cost overrun	Tangible
5	Loss of image	Intangible
6	Loss future business/sales	Intangible
7	Disputes	Tangible + Intangible
8	Productivity lost	Tangible
9	Quality degradation	Intangible
10	Litigation and claims	Tangible + Intangible
11	Lost opportunity cost	Intangible

The short-listed hidden quality factors consist of both tangible and intangible part. Factors like ‘loss of customer’ and ‘loss of image’ can perfectly be characterized as intangibles, while the factors like ‘delays’ and ‘cost overrun’ are tangible and could easily be calculated with reasonable accuracy. ‘Disputes’ and ‘litigation and claims’ are those factors which fall in between both the categories. A portion of these costs can be calculated using data from documents and site reports but these also consist of some intangible losses like relation with contractor and reputation loss etc.

Chapter 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter discusses about the methodology that was adopted in the research. It is divided into two sections, in the first step, a detailed literature review was conducted to get a wide introduction on the subject topic. Most common costs of qualities were identified and a global preliminary questionnaire survey was conducted to rank the factors according to their importance. The second section describes about the project data collection. Data on tangible quality cost was collected using site reports, progress reports, estimation sheets and other related documents. Data on Intangible portion of the quality costs was collected through a questionnaire survey filled by the project stakeholders. Later, data was analyzed for a detailed assessment of the respondents.

3.2 Research Design

This study targets the quantification of all components of PAF. Additionally, it also calculates the mysterious hidden cost of failures. To achieve these objectives, an extensive literature review has been done to understand and identify different components of PAF. It was followed by a pilot survey. Then, a modified PAF model is developed and data collection is done. Lastly, data is analyzed and results are presented and discussed. Further details are discussed in subsequent section. Flow chart of the followed research methodology is shown Figure 3-1.

Figure 3-1 : Flowchart of research methodology

3.3 Model Development

Quality cost (prevention, appraisal) and internal failure costs (rework, scrap, material) are visible and can be also quantified with sufficient accuracy. Further, the external and hidden failure costs consist of both tangible and intangible losses. Tangible costs are easier to reckon than intangible costs, because it is apparent that intangible costs are not measurable (Farooq et al., 2017). Therefore, hidden costs should be assessed with a fair accuracy. For this purpose, it can further be divided into tangible and intangible hidden quality cost categories. This split helps in differentiating between the portions of total quality costs based on the convenience to measure. The proposed model is shown in Figure 3-2.

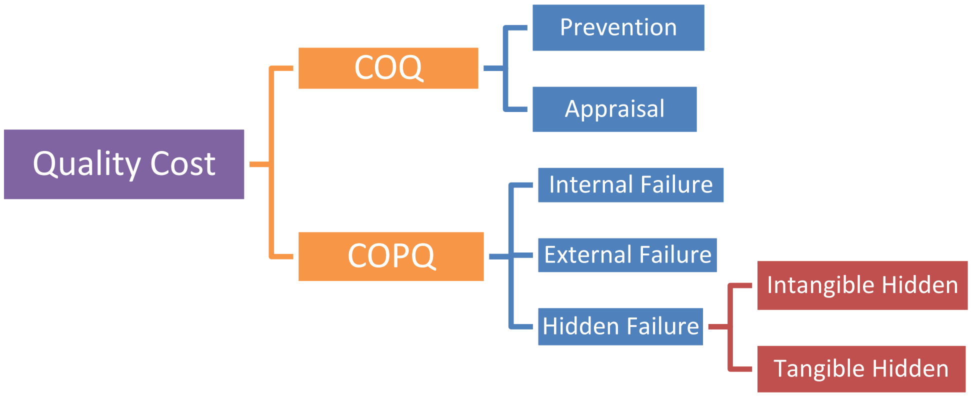


Figure 3-2 : Modified PAF model

The total quality cost consists of costs of quality and poor quality. It can be mathematically defined as Equation 1 where *TCOQ* is total cost of quality, *COQ* is cost of quality and *COPQ* is cost of poor quality.

$$TCOQ = COQ + COPQ \qquad Equation\ 1$$

Further, *COQ* can be bifurcated into cost of prevention (C_p) and cost of appraisal (C_a) as given in Equation 2. Also, *COPQ* can be estimated by summing the costs of internal (C_{if}) and external (C_{ef}) failures, and hidden intangible (C_{ih}) and tangible (C_{th}), as given in Equation 3.

$$COQ = C_p + C_a \qquad Equation\ 2$$

$$COPQ = C_{if} + C_{ef} + C_{ih} + C_{th} \qquad Equation\ 3$$

The cost breakdowns of *COQ* in the form of C_p and C_a are well established in the literature. In that, their measurement mechanisms and assessment techniques are well documented (Krishnan, 2006; Rosenfeld, 2009). Same is the case with the two constituent parts of *COPQ*; C_{if} and C_{ef} (Cheah et al., 2011; Sun and Meng, 2009). But the novelty of this study is the introduction of hidden intangible (C_{ih}) and tangible (C_{th}) costs of failure. In order to further break down the C_{ih} and C_{th}, an extensive literature review has been performed. Around 60 research papers published between the years 2000 – 2017 were reviewed of which 26 were found relevant. Most of the selected publications dealt with the construction projects. After a careful analysis, a total of 31 hidden quality cost factors are identified. To rank the hidden quality costs, a statistical analysis using frequency of appearance and its magnitude in a particular paper was performed and the score was normalized.

3.4 Data Collection

3.4.1 Questionnaire Survey

To solicit the significance of identified factors, practicing and research experts around the world were engaged through email and social networking websites. This survey, developed in Google® Forms, consisted of two sections; the first section collected respondent information such as their qualification, industry they belong to, job description, professional experience and country of origin. The second section inquired the importance of cost factors in terms of hidden COQ. The respondents were required to answer on a Likert scale of 1-5, based on their experience. The survey was distributed to over 400 respondents, out of which 104 responses were received and 102 were found valid.

3.4.2 Project Data Collection

In order to quantify and validate the developed model, which constituted factors shortlisted through literature and survey, data was collected from real projects. For this purpose, a project data collection instrument, having three sections, was prepared. The first section collected the general project data such as description, location, budgeted cost, etc. The second section collected data about the tangible portion of TCOQ. For ease of data entry, this section was subdivided into different segments as data may come from different related departments. In the final section, the data on intangible cost was collected.

The set of respondents for this data collection included project personnel such as site engineers, quantity surveyors and project managers. Where it was possible, accounts and procurement departments were also consulted. The respondents, who were directly involved in recording and providing data, were taken into confidence by assuring the anonymity of their personal and project information. The material, labour and equipment costs incurred on correcting the nonconformance was calculated using the quantities from detailed estimates, while the intangible cost was worked out based on the judgment of respondents. This methodology is quite different from Love and Li (2000), and Love and Edwards (2005) who collected the data using the post project interviews. But their methodology has been objected by Hall and Tomkins (2001) due to its dependence upon the memory of participants. However, the methodology applied in current study is relatively more accurate due to reliance upon the direct field data.

ANALYSIS OF FINDINGS

In this chapter the findings of this research will be discussed. It explains the methods of analysis that are performed on the collected data and the results obtained. The chapter also reports findings from the model proposed in this research. Data from 25 mid-rise buildings from across Pakistan was collected. A total of 102 field experts were also surveyed for data collection.

4.1 Shortlisting of Hidden Quality Costs

After successfully conducting the survey, responses were sorted out and survey score was normalized. Table 4-1 gives a general overview of respondent demography. Afterward, spreadsheets were prepared by giving different weighting to literature and survey scores. Finally, ANOVA was performed to check if there is any significant difference between various combinations of these scores.

Table 4-1: General respondent demography

Respondent Demography		Frequency	Percentage
Education	Bachelors	53	52
	Masters	40	39
	PhD	9	9
Field of specialization	Construction	36	35
	Engineering	38	37
	Architect	6	6
	Project Management	22	22
	Others	40	39
Area of work	Industry	56	55
	Academics	46	45
Experience	Less than 1	25	25
	1-5 Years	58	57
	5-10 Years	11	11
	More than 10 year	8	8
Country	Pakistan	44	43

	Qatar	6	6
	India	7	7
	Bahrain	6	6
	Norway	5	5
	Others	34	33

The *p*-value (1.0) came out to be insignificant, so to avoid any bias, 50-50 weighting combination was used. Further, the reliability of data was checked through Cronbach's alpha calculated, which resulted in $\alpha = 0.94$. This suggests that the data is highly reliable for further analysis. The shortlisted factors are given in Table 4-2.

Table 4-2 : Selected Hidden Quality Costs

Rank	**Factor**	**Nature**	**Literature score**	**Survey score**	**Total Scor**	**Cumulative**
1	Waste of time/ delays	Tangible	0.0901	0.0427	0.066	0.0664
2	Loss/dissatisfaction	Intangible	0.0901	0.0342	0.062	0.1285
3	Variations	Tangible	0.0826	0.0342	0.058	0.1869
4	Project cost overrun	Tangible	0.0676	0.0342	0.050	0.2378
5	Loss of image	Intangible	0.0676	0.0342	0.050	0.2886
6	Loss future	Intangible	0.0631	0.0342	0.048	0.3373
7	Disputes	Tangible + Intangible	0.0526	0.0342	0.043	0.3806
8	Productivity lost	Tangible	0.0405	0.0342	0.037	0.4180
9	Quality degradation	Intangible	0.0405	0.0342	0.037	0.4554
10	Litigation and claims	Tangible + Intangible	0.0450	0.0256	0.035	0.4907
11	Lost opportunity cost	Intangible	0.0315	0.0341	0.032	0.5236

The shortlisted hidden quality factors consist of both tangible and intangible parts. Factors like 'loss of customer' and 'loss of image' can perfectly be characterized as intangibles, while the factors like 'delays' and 'cost overrun' are tangible and could easily be calculated with reasonable accuracy. 'Disputes' and 'litigation and claims' are those factors which fall into both the categories. A portion of these costs can be calculated using data from documents and site reports but these also consist of some intangible losses.

4.2 COQ Versus COPQ

Using the developed instrument, data was collected from 25 different mid-rise building projects across the country. The geographical distribution of the projects is such that they sufficiently represent the practices of entire counstruction industry of Pakistan. In order to collect more reliable and recent data, different projects which were in execution stage or just recently completed were selected and to simplify the analysis, COQ was assumed to vary linearly throughout the project life cycle.

After critical analysis, it was found that most of the firms (13) invested less than 1% of total project cost (TPC) in COQ, while only few firms (5) invested more than 3%. The maximum invested COQ was 5.897% of TPC. This shows the lack of interest of local industry in implementing and scrutinizing COQ. This was expected as most of the participants revealed that their organizations do not formally calculate the COQ and they are not following any particular quality cost system. This was mainly because the higher management of these organizations trusts their technical capabilities owing to their experience. Hence, no need of spending cost to find out another cost was felt, which is in line with the findings of Cheah et al. (2011). It was also mentioned by Al-Tmeemy et al. (2012) that this lack of awareness causes the firms to invest low in COQ because they do not anticipate an attractive benefit (Glogovac and Filipovic, 2016).

The collected data on visible COPQ appears to strengthen this misconception; in 80% projects, the visible COPQ is less than 3% of the TPC, as shown in Figure 4-1 (a) and (b). It might give an impression that there is no need to invest in quality because even by spending less in COQ, firms are still getting lower failure costs.

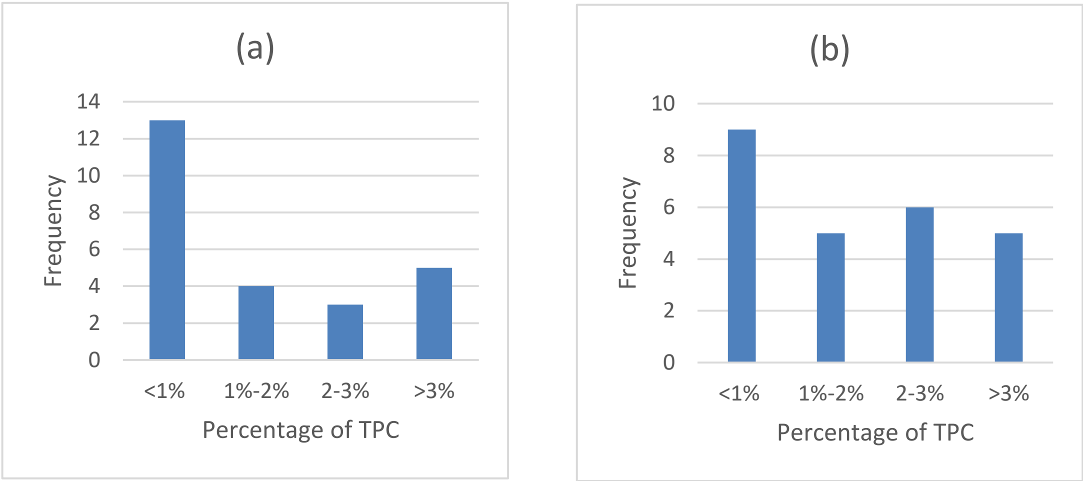


Figure 4-1: (a) COQ; (b) COPQ

Similarly, Figure 4-2 presents total visible COQ of studied projects, where it can be seen that in almost half of the projects, COQ is greater than the visible portion of COPQ. But, it should be lesser because theoretically TCOQ is minimized to the point where the COQ equals the COPQ (Kazaz et al., 2005). This phenomenon is graphically given in Figure 4-3. However, this misconception is nullified as average visible COPQ is 0.358% greater than COQ. Although the difference is small, it lies on the left side of the quality conformance diagram as shown in Figure 4-3. This means that companies are investing a larger part of TCOQ in correcting defects which is highly unfavorable (Abdelsalam and Gad, 2009). Since, this visible COPQ is always accompanied by some hidden loss, which is much more than the visible part, it remains concealed and not generally captured in company's accounting systems (Mahmood and Kureshi, 2015).

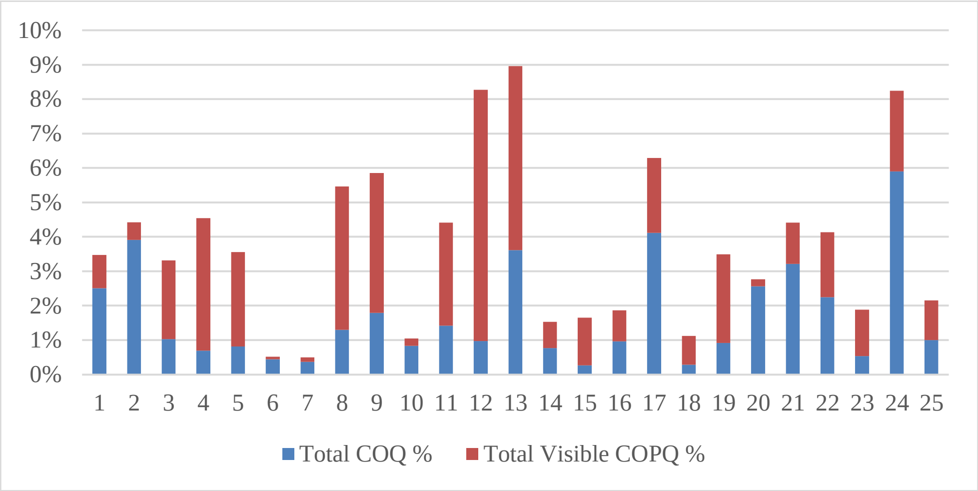


Figure 4-2: COQ vs Visible COPQ

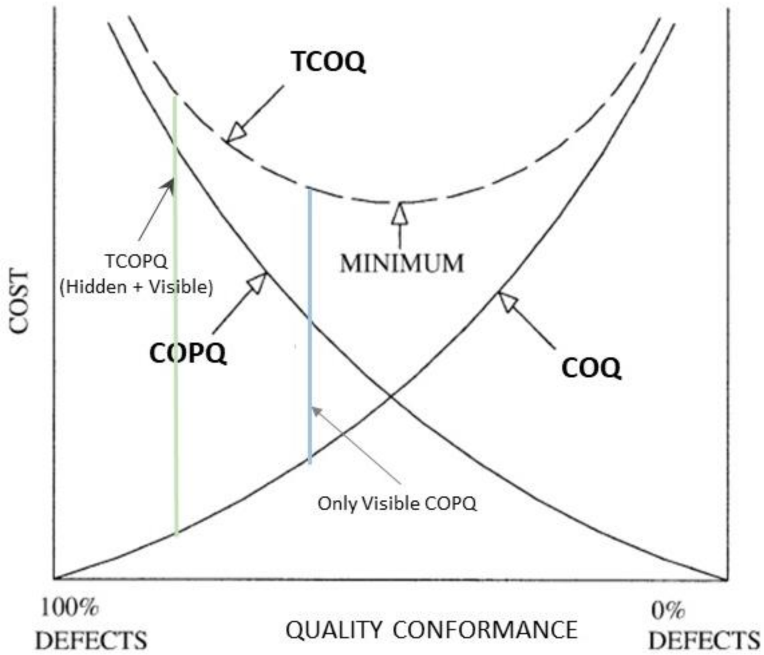


Figure 4-3: COQ versus quality level adapted from Kazaz et al. (2005)

During this process, it was discovered that most of the firms are only aware of the visible costs and they do not bother to incorporate the hidden consequences of failures. Hence, they remain oblivious of the significance of COQ system and its effects on project performance (Sellés et al., 2008). Figure 4-4 supports the hidden cost or 'base of iceberg' assumption as in most of the projects, COPQ – incorporating the hidden failure cost, goes beyond the invested COQ. On average, the visible portion of COPQ is 2.056%, while hidden COPQ amounts to 8.045% of the TPC. This represents a ratio of visible to hidden failure cost of 1:3.91 which nearly matches the assumption of Rosenfeld (2009) who used the factor of 4 for external and 2 for internal failure costs to make adjustment for hidden failure. Likewise, the hidden portion of TCOQ is 2.143 times greater than the visible portion of TCOQ (including both COQ and visible COPQ). This value falls in between 3 (Giakatis et al., 2001) and 1.6 (Cheah et al., 2011). By incorporating the hidden failure cost, the COPQ rise from 2.056% to 10.101% of TPC and difference between COQ and COPQ rises to 8.40%. This worsen the situation as it further pushes the line toward the left of the optimum point on quality conformance diagram shown in Figure 4-3.

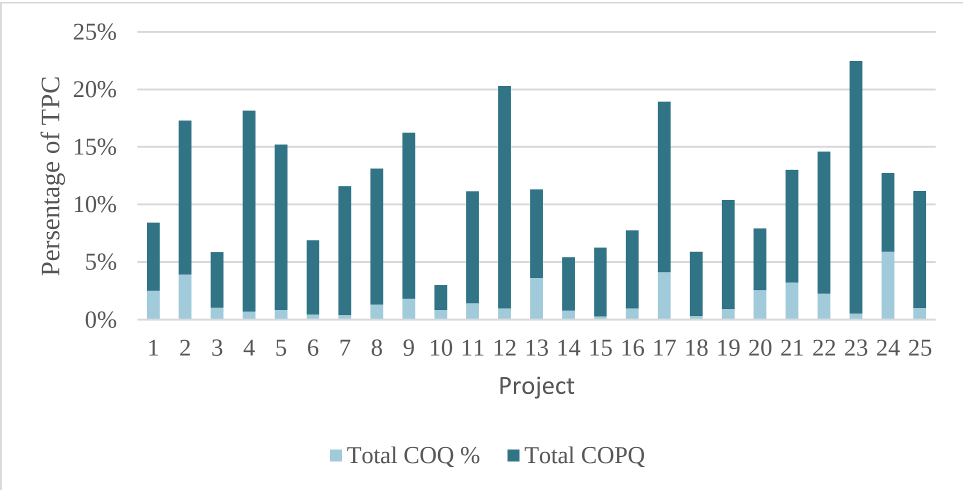


Figure 4-4: TCOQ vs TCOPQ

This indicates a poor performance of local industry in terms of quality due to a considerable average COPQ amount. It may seem to be a mere percentage of TPC but in reality, it refers to the loss of loyal customer or image in a highly competitive market. Hence, it must be eliminated by the enhancement of quality management practices in projects.

4.3 Total Cost of Quality

The average TCOQ for the all the projects is found to be 12.76% of the TPC. According Abdelsalam and Gad (2009), this percentage is considered a relatively higher one and reflects that the TCOQ in this study is large compared to the best practices of COQ which is around 1% of TPC. This could be mainly because the local construction industry is more manual and labor intensive, and there is no quality standardization in projects. But when compared with the study of a building project in a highly developed country of UK (Hall and Tomkins, 2001), results are arguably closer. Although, the TCOQ found by this study should be greater as the study is conducted in a developing country while incorporating the hidden failure cost, the difference is due to the sample size and data collection technique. The above-mentioned study was conducted on a single building project and site staff manually recorded nonconformance data from the start of the project to the end. On the contrary, the current study was conducted on a relatively larger sample with only few interactions with the project key personnel. Therefore, some of the smaller events may be overlooked as they were never documented in the progress reports of studied projects. Thus 'true' cost of failure may be slightly higher than the current finding.

The breakdown of TCOQ uncovers the expected outcome that the failure costs take up the largest share with 68% as hidden and 17% as visible portion. External failure cost was least among the failure costs owing to the fact that most of the projects were in execution or closure phase, and according to definition, these costs occur when defective product is delivered to the customer. Hence, they may incur in future throughout the defect liability period which can further increase the failure cost.

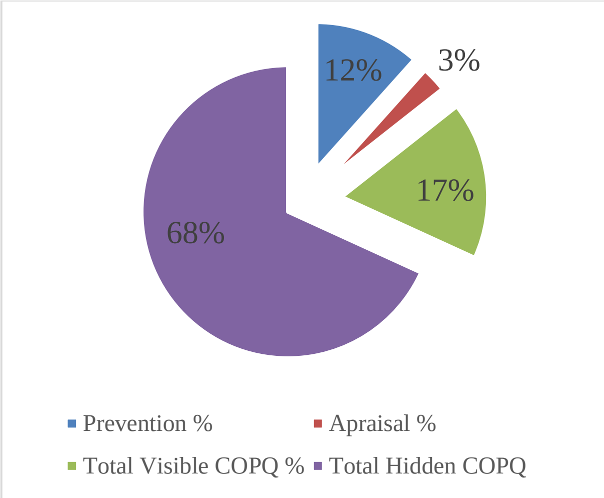
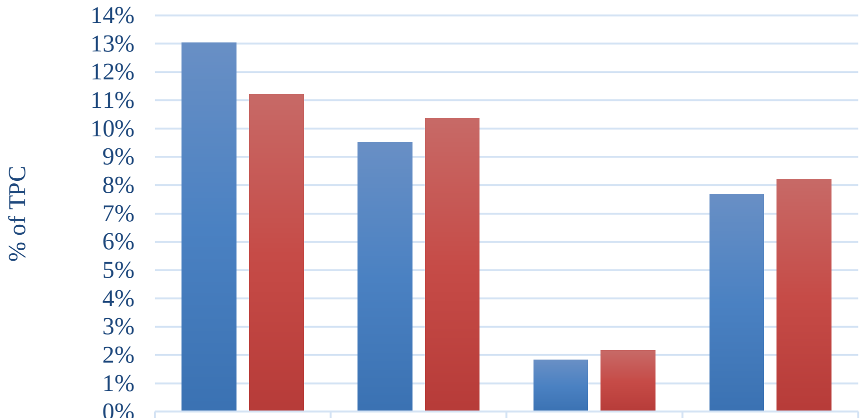


Figure 4-5: Cost % of TCOQ

On the other hand, COQ only shares 15% in TCOQ, whereas appraisal activity with the least 3% of TCOQ, as shown in Figure 4-5. Abdelsalam and Gad (2009) reported a similar finding where appraisal cost came out to be the least among COQ. However, COQ value is lower than the findings of previous studies in the developed countries. One reason is the poor categorization of PAF components for construction industry; it is difficult to decide whether a particular activity comes under COQ. Another reason can be underestimation of the COQ due to data collection technique. Lastly, it is also the passive attitude of firms towards COQ, as majority of firms never felt the need of conducting training on quality related issues. Similarly, in some of the projects, there was no specialized quality management staff as other project personnel were supposed to perform the additional duty of quality assessment. It highlights a huge area of improvement in the local construction industry, where the companies can improve their quality performance and reduce failure cost by following the classic assumption of PAF model of investing more in COQ. But a question arises, is this assumption really justified? For this purpose, projects with lesser and greater values of COQ are segregated and graphs are plotted. On average, companies invested around 2% of TPC in COQ. Figure 4-6 presents an interesting result; by investing more than 2% of TPC as COQ, total failure cost as well as the hidden and visible failure costs go down. But on the contrary, TCOQ goes up. This means that although firms are getting lesser failure cost, their total quality related costs increase from around 11% to 13% of TPC. However, this situation is favorable than the opposite and is recommended in previous research, where it is stated that the point of minimum TCOQ and convergent point, where COQ equals COPQ, may vary when real world data is used (Abdelsalam and Gad, 2009; Kazaz et al., 2005).

COQ and COPQ also vary with respect to project size, height of building and percentage completion. In larger projects, these values are smaller in term of percentage of TPC. This is because of the fact that 1% of a larger project is a much larger value in terms of money than that 1% of smaller project. For example, in projects greater than 20 million PKR, TCOQ is 9.782% while in projects lesser than 20 million PKR, TCOQ is 14.826%. Such as larger projects cost 8.46 million PKR while smaller projects cost 1.20 million PKR as quality costs, on average. Similarly, it varies in exact same fashion with respect to building height. It is due to fact the TPC increases with increase in the number of floors of a building. Likewise, COQ and COPQ are lesser in projects which are in initial stage and higher in those projects which are either completed or in finishing stage as more valuable resources are utilized in final stage.



	TCOQ	COPQ	Visible	Hidden
COQ > 2%	13.026%	9.518%	1.828%	7.690%
COQ< 2%	11.222%	10.376%	2.163%	8.213%

Figure 4-6: Comparison of COQ at 2

4.3.1 Optimum Value of COQ

In the classic view of PAF, optimum value of COQ, as shown in Figure 4-3, is such lowest value of TCOQ above which benefits are marginal (Heravi and Jafari, 2014; Kazaz et al., 2005). Finding the optimum level is not a simple task, therefore a number of methods exist in the literature. Kazaz et al. (2005) and Heravi and Jafari (2014) found the optimum value by plotting the second degree polynomial quality cost curves against level of achievement of quality. But there was a remarkable difference between these results. Similarly, Rosenfeld (2009) with relatively a smaller sample used the linear regression technique and output was much smaller than other studies. Since different methods yield different results, there is no standard method which determines the optimum level with fair accuracy. Furthermore, Krishnan (2006) argued that finding the optimal value is not harmonized with continuous improvement principle of total quality management (TQM). Also, it was unveiled by some responses that optimum value would not be the same for different projects. The reason behind this is that after every failure event, the cause of failure can be found by ‘root cause analysis’ which is a prevention cost. This will not only rectify the defect but will also prevent the future reoccurrence in similar projects.

A similar conclusion was reached at during the data collection; quality is not solely dependent on invested COQ because it does not necessarily mean that every prevention and appraisal activity will add value to project, there will be some quality activities which will not be successful in achieving objectives, these activities are termed as quality or opportunity loss (Cheah et al., 2011; Giakatis et al., 2001). So, there is a need of not only reducing the failure cost but also eliminating the quality loss. Furthermore, it is also dependent on labor skill, construction method and technical capabilities. For example, firms which are highly experienced in building construction, and have well experienced labor and staff, incur lesser labor related failure costs. For them, investing in trainings and seminars for already familiar work environment seems wasteful and will be termed as quality loss. The collected data demonstrates a similar trend; the invested COQ in project 3 is 3.906% and the failure cost came out to be 13.391%. On the contrary, in project 13, investment of 3.615% caused only 7.695% failure as shown in Figure 4-3. Therefore few other factors should also be considered while assessing the optimum value of COQ.

CONCLUSION AND RECOMMENDATION

This research identified and quantified the COQ in construction industry, using PAF model while giving special attention to uncover the mysterious hidden costs of failures as they remain under the surface and yet amount the largest among the failure costs. Novelty of the study lies in quantification of every component of PAF as previous studies on construction industry were focused only on the visible failure cost. For this purpose, an additional category of hidden cost is added to the conventional PAF model and COQ data of 25 building projects was collected. The results support the assumption as hidden failure cost was 2.143 times greater than traditional visible quality costs. In addition, it was demonstrated that how badly COPQ can hurt an organization and how COQ data can be used to improve the quality performance. Although, the current study satisfactorily achieved the main objectives, there are some areas of improvement which should be addressed by future research.

The main hurdle in conducting this study was the ambiguous categorization of prevention, appraisal and failure costs for construction industry. They are well developed in manufacturing industry, but construction industry still lacks a proper framework. Although, a literature review was done to overcome this problem, there is still a need to adequately categorize PAF costs. Future research may identify cost that fall under different categories of PAF by involving the field experts. Secondly, the data was collected with help of a survey instrument under limited interactions with the project personnel. However, it was objected by Cheah et al. (2011) and Rosenfeld (2009) that data can be underreported as there is tendency to hide truth owing to the blame culture of organization. Therefore, more accurate assessment can be done by regular observation of field data and making quality cost as an integral part of daily site reports. Further, due to no training culture in majority of the projects, there was a severe lack of familiarity with the COQ concept. So, regular training and seminars should be conducted to spread awareness and information. Likewise, for the purpose of highlighting the severity of matter, intangible quality cost was calculated by semi-quantitative method due to subjectivity involved. Future study may be carried out by developing a practical quantification proposal for different intangible factors as done by Sellés et al. (2008) for lost image. Moreover, the current study was limited to main contractor and client's cost. Subcontractor's cost should also be considered. Lastly, it is recommended that design and bidding procedure should also be evaluated from quality point of view, as quality is not the concern of only execution phase; planning and design have huge impact on the quality achieved during execution phase.

The finding of study will help to improve quality awareness within organizations since stakeholders would be aware of impact of failures on an organization. It also proposed a quality framework for implementation of COQ in building projects as tradition accounting systems are inadequate to capture the quality cost. Contractors can use the information to achieve higher quality standards at lower cost than their competitors. Finally, it also laid a foundation for future research on hidden quality cost for construction projects.

References:

Abdelsalam, H. M., & Gad, M. M. (2009). Cost of quality in Dubai: An analytical case study of residential construction projects. *International Journal of Project Management, 27*(5), 501-511.

Abdul-Rahman, H. (1993). Capturing the cost of quality failures in civil engineering. *International Journal of Quality & Reliability Management, 10*(3).

Abdul-Rahman, H. (1995). The cost of non-conformance during a highway project: a case study. *Construction Management and Economics, 13*(1), 23-32.

Abdul-Rahman, H., Al-Tmeemy, S., Harun, Z., & Ye, M. (2014). The major causes of quality failures in the Malaysian building construction industry.

Aiyetan, O. A. (2014). Rework cost on building projects in the south western part of Nigeria. *Journal of Construction Project Management and Innovation, 4*(1), 755-769.

Al-Tmeemy, S. M. H., Abdul-Rahman, H., & Harun, Z. (2012). Contractors' perception of the use of costs of quality system in Malaysian building construction projects. *International Journal of Project Management, 30*(7), 827-838.

Al-Tmeemy, S. M. H. M., Abdul-Rahman, H., & Harun, Z. (2011). Future criteria for success of building projects in Malaysia. *International Journal of Project Management, 29*(3), 337-348.

Aliakbarlou, S., Wilkinson, S., & Costello, S. B. (2017). Exploring construction client values and qualities: are these two distinct concepts in construction studies? *Built Environment Project and Asset Management*(just-accepted), 00-00.

Aoieong, R. T., Tang, S., & Ahmed, S. M. (2002). A process approach in measuring quality costs of construction projects: model development. *Construction Management & Economics, 20*(2), 179-192.

Barber, P., Graves, A., Hall, M., Sheath, D., & Tomkins, C. (2000). Quality failure costs in civil engineering projects. *International Journal of Quality & Reliability Management, 17*(4/5), 479-492.

Barlow, P. L. (2009). Cost of Quality in the Construction Industry. *International Journal of Cost Engineering*.

Burati, J. L., & Farrington, J. J. (1987). *Costs of quality deviations in design and construction*: Bureau of Engineering Research, University of Texas at Austin.

Chatzipetrou, E., Chatzipetrou, E., Moschidis, O., & Moschidis, O. (2017). An exploratory analysis of quality costing in Greek F&B enterprises. *The TQM Journal, 29*(2), 324-341.

Cheah, S.-J., Shah, A., Shahbudin, M., Fauziah, & Taib, M. (2011). Tracking hidden quality costs in a manufacturing company: an action research. *International Journal of Quality & Reliability Management, 28*(4), 405-425.

Chen, C.-C., & Yang, C.-C. (2003). Total-costs based evaluation system of supplier quality performance. *Total Quality Management & Business Excellence, 14*(3), 325-339.

Daddow, T., & Skitmore, M. (2005). Value management in practice: an interview survey. *The Australian Journal of Construction Economics and Building, 4*(2), 11-18.

Davis, K., Ledbetter, W. B., & Burati Jr, J. L. (1989). Measuring design and construction quality costs. *Journal of Construction Engineering and Management, 115*(3), 385-400.

Defeo, J. A., & Juran, J. M. (2010). *Juran's Quality Handbook: The Complete Guide to Performance Excellence 6/e*: McGraw Hill Professional.

dos Reis Almeida, R. A. S. (2011). Evaluation and modelling of the costs of non-quality in the Portuguese construction industry.

Farooq, M. A., Kirchain, R., Novoa, H., & Araujo, A. (2017). Cost of quality: Evaluating cost-quality trade-offs for inspection strategies of manufacturing processes. *International Journal of Production Economics, 188*, 156-166.

Feigenbaum, A. V. (1956). Total quality-control. *Harvard business review, 34*(6), 93-101.

Feigenbaum, A. V. (1991). Total quality control. *New York: McGraw-Hill, 1991, 3rd ed./rev. 40th anniversary ed.*

Forcada, N., Alvarez, A. P., Love, P. E., & Edwards, D. J. (2016). Rework in Urban Renewal Projects in Colombia. *Journal of Infrastructure Systems, 23*(2), 04016034.

Giakatis, G., Enkawa, T., & Washitani, K. (2001). Hidden quality costs and the distinction between quality cost and quality loss. *Total Quality Management, 12*(2), 179-190.

Glogovac, M., & Filipovic, J. (2016). Quality costs in practice and an analysis of the factors affecting quality cost management. *Total Quality Management & Business Excellence*, 1-24.

Hall, M., & Tomkins, C. (2001). A cost of quality analysis of a building project: towards a complete methodology for design and build. *Construction Management & Economics, 19*(7), 727-740.

Harrington, H. J. (1987). *Poor-quality cost*. Retrieved from

Heravi, G., & Jafari, A. (2014). Cost of quality evaluation in mass-housing projects in developing countries. *Journal of Construction Engineering and Management, 140*(5), 04014004.

Hwang, B.-G., & Low, L. K. (2012). Construction project change management in Singapore: Status, importance and impact. *International Journal of Project Management, 30*(7), 817-826.

Iyer, G., & Kuksov, D. (2010). Consumer feelings and equilibrium product quality. *Journal of Economics & Management Strategy, 19*(1), 137-168.

Jafari, A., & Love, P. E. (2013). Quality costs in construction: case of Qom Monorail Project in Iran. *Journal of Construction Engineering and Management, 139*(9), 1244-1249.

Jaju, S., Mohanty, R., & Lakhe, R. (2009). Towards managing quality cost: A case study. *Total Quality Management, 20*(10), 1075-1094.

Josephson, P.-E., Larsson, B., & Li, H. (2002). Illustrative benchmarking rework and rework costs in Swedish construction industry. *Journal of Management in Engineering, 18*(2), 76-83.

Juran, J., & Godfrey, A. B. (1999). Quality handbook. *Republished McGraw-Hill*, 173-178.

Juran, J. M. (1951). *Quality Control Handbook*: McGraw-Hill.

Kakitahi, J. M., Alinaitwe, H. M., Landin, A., & Rodrigues, M. J. (2014). A comparison of construction related rework in Uganda and Mozambique. *Journal of Construction Project Management and Innovation, 4*(1), 770-781.

Kazaz, A., & Birgonul, M. T. (2005). The evidence of poor quality in high rise and medium rise housing units: a case study of mass housing projects in Turkey. *Building and Environment, 40*(11), 1548-1556.

Kazaz, A., Birgonul, M. T., & Ulubeyli, S. (2005). Cost-based analysis of quality in developing countries: a case study of building projects. *Building and Environment, 40*(10), 1356-1365.

Keane, P., Sertyesilisik, B., & Ross, A. D. (2010). Variations and change orders on construction projects. *Journal of legal affairs and dispute resolution in engineering and construction, 2*(2), 89-96.

Khalek, H. A., Aziz, R. F., & Sharabash, E. A. (2016). Applications and Assessment of Quality Management in Construction Projects.

Krishnan, S. K. (2006). Increasing the visibility of hidden failure costs. *Measuring business excellence, 10*(4), 77-101.

Love, P. E. (2002). Influence of project type and procurement method on rework costs in building construction projects. *Journal of Construction Engineering and Management, 128*(1), 18-29.

Love, P. E., & Edwards, D. J. (2005). Calculating total rework costs in Australian construction projects. *Civil engineering and environmental systems, 22*(1), 11-27.

Love, P. E., Edwards, D. J., Watson, H., & Davis, P. (2010). Rework in civil infrastructure projects: Determination of cost predictors. *Journal of Construction Engineering and Management, 136*(3), 275-282.

Love, P. E., & Irani, Z. (2003). A project management quality cost information system for the construction industry. *Information & Management, 40*(7), 649-661.

Love, P. E., Irani, Z., Smith, J., Regan, M., & Liu, J. (2017). Cost performance of public infrastructure projects: the nemesis and nirvana of change-orders. *Production Planning & Control*, 1-12.

Love, P. E., & Li, H. (2000). Quantifying the causes and costs of rework in construction. *Construction Management & Economics, 18*(4), 479-490.

Lundkvist, R., Meiling, J. H., & Sandberg, M. (2014). A proactive plan-do-check-act approach to defect management based on a Swedish construction project. *Construction Management and Economics, 32*(11), 1051-1065.

Mahmood, S. (2010). Cost of poor quality in public sector projects. *Journal of Marketing and Management, 1*(1), 70.

Mahmood, S., & Ishaque, A. (2013). *Innovative system to determine hidden cost of poor quality to enhance labor productivity and profitability for construction entrepreneurs, a case study*. Paper presented at the Engineering, Technology and Innovation (ICE) & IEEE International Technology Management Conference, 2013 International Conference on.

Mahmood, S., & Kureshi, N. (2015). A Literature Review of the Quantification of Hidden Cost of Poor Quality in Historical Perspective. *Journal of Quality and Technology Management, 11*, 01-24.

Mahmood, S., & Kureshi, N. I. (2014). *Reducing hidden internal failure costs in road infrastructure projects by determination of Cost of Poor Quality, a case study*. Paper presented at the Engineering, Technology and Innovation (ICE), 2014 International ICE Conference on.

Malik, T. M., Khalid, R., Zulqarnain, A., & Iqbal, S. A. (2016). Cost of quality: findings of a wood products' manufacturer. *The TQM Journal, 28*(1), 2-20.

Manzoor Arain, F., & Sui Pheng, L. (2005). The potential effects of variation orders on institutional building projects. *Facilities, 23*(11/12), 496-510.

Marzuki, P. F., & Wisridani, M. (2014). Identifying Contractors' Planned Quality Costs in Indonesian Construction Projects. *Journal of Engineering and Technological Sciences, 46*(4), 368-380.

Mhando, Y. B., Mlinga, R. S., & Alinaitwe, H. M. (2017). Quantitative Analysis of the Effects of Variations in Public Building Projects. *International Journal of Construction Engineering and Management, 6*(1), 22-33.

Mills, A., Love, P. E., & Williams, P. (2009). Defect costs in residential construction. *Journal of Construction Engineering and Management, 135*(1), 12-16.

Oladokun, M. G., Fashina, A. Y., & Mac-Barango, D. O. (2017). COST EFFECTIVENESS OF QUALITY MANAGEMENT SYSTEM IN A REINFORCED CONCRETE FRAME CONSTRUCTION COMPANY. *Journal of Technology Management and Business, 4*(1).

Oyewobi, L. O., Oyewobi, L. O., Jimoh, R., Jimoh, R., Ganiyu, B. O., Ganiyu, B. O., . . . Shittu, A. A. (2016). Analysis of causes and impact of variation order on educational building projects. *Journal of Facilities Management, 14*(2), 139-164.

Özkan, S., & Karaibrahimoğlu, Y. Z. (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), 420-431.

Plunkett, J. J., & Dale, B. G. (1988). Quality costs: a critique of some 'economic cost of quality' models. *International Journal of Production Research, 26*(11), 1713-1726. doi:10.1080/00207548808947986

Rashed, A., & Othman, M. (2015). *Implementing quality management in construction projects.* Paper presented at the Industrial Engineering and Operations Management (IEOM), 2015 International Conference on.

Rosenfeld, Y. (2009). Cost of quality versus cost of non-quality in construction: the crucial balance. *Construction Management and Economics, 27*(2), 107-117.

Sandoval-Chavez, D. A., & Beruvides, M. G. (1998). Using opportunity costs to determine the cost of quality: A case study in a continuous-process industry. *The Engineering Economist, 43*(2), 107-124.

Sansalvador, M. E., & Brotons, J. M. (2017). Development of a quantification model for the cost of loss of image with customer complaints. *Total Quality Management & Business Excellence*, 1-15.

Schiffauerova, A., & Thomson, V. (2006). A review of research on cost of quality models and best practices. *International Journal of Quality & Reliability Management, 23*(6), 647-669.

Sellés, M. E., Rubio, J. A., & Mullor, J. R. (2008). Development of a quantification proposal for hidden quality costs: Applied to the construction sector. *Journal of Construction Engineering and Management, 134*(10), 749-757.

Shah, A., & Regassa, H. (2010). Return on quality—quality's impact on customer satisfaction, revenue growth, profitability and cost efficiency. A cross national comparative analysis of Japanese and American manufacturers in the auto industry. *Marketing Management Journal, 20*(2), 163-179.

Simpeh, E. K., Ndihokubwayo, R., & Love, P. (2012). *Evaluating the direct and indirect costs of rework.* Paper presented at the Proc., 8th ICEC World Congress.

Sun, M., & Meng, X. (2009). Taxonomy for change causes and effects in construction projects. *International Journal of Project Management, 27*(6), 560-572.

Taggart, M., Koskela, L., & Rooke, J. (2014). The role of the supply chain in the elimination and reduction of construction rework and defects: an action research approach. *Construction Management and Economics, 32*(7-8), 829-842.
Tawfek, H. S., Mohammed, H. E.-D. H., & Razek, M. E. A. (2012). Assessment of the expected cost of quality (COQ) in construction projects in Egypt using artificial neural network model. *HBRC journal, 8*(2), 132-143.
Yang, C.-C. (2008). Improving the definition and quantification of quality costs. *Total Quality Management, 19*(3), 175-191.
Žileska–Pančovska, V., Blaževska-Stoilkovska, B., & Hanák, T. (2016). Management of Human Resources and Quality in Materials Supply Process in Construction Projects.

APPENDIX: Data Collection Instrument

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Project Details

Project Title: ____

No. of Story: _____________________ Location: ______________

Contractor: _____________________ Client: ________________

Total Est. Cost: _________________ Est. Duration: __________

Estimated completion till date (in percentage): __________________%

Estimated cost spent till date: _________________________________/-

Reporting Date: _________________ Project Star Date: __________

SECTION II: Tangible Costs

Quality Assurance and Quality Control Department

1. Salary of QA/QC Manager: ____
2. Salary of QA/QC Staff (other than Mngr.): ___________________________
3. Cost of providing training aids, any instruction ever happened on site or arranging seminars on work: _______________________________________
4. Cost of Audits
    a. Internal audits: ____
    b. External audits: ____

Testing and Inspection

5. Cost of laboratory material testing
    a. In house: ____
    b. External: ____
    c. Onsite testing (if any): _______________________________________
    d. Final after build test: ____
6. Cost of testing and inspection equipment
    a. If company own it (then detail of eqp.): _________________________

    ____
    b. If rented (then rent): ____

7. Cost of anything purchased or procured by the company during project due to failure/rework/variation
   a. Due to rework or failure: ____________________________________
   b. For material inspection or testing: _____________________________
8. Maintaining cost of testing and inspection equipment: ____
9. Cost of reviewing any new material/equipment by going to market (e.g. Rent, TA/DA, cost of quotations): _______________________________________

Planning

10. Cost and time invested in bidding, accrediting or selection of 'sub-contractor' and 'supplier': ____
11. Time invested by any person in re-planning in case of rework or verification:
    a. Approx. Time :__________________
    b. Person Salary or Wage: ____________

Rework and Variations

12. Rework Events
    a. Description: ____
       ____
    b. Total Cost on Rework:____

If total rework cost is not calculated then fill below (if already mentioned move to next point)

i. Total Quantity: ____________________________________

ii. Per unit rate (with material, labour): ____________________

13. Cost of Demolition of rejected work:

a. Material: ____

b. Labour:____

14. Approx. cost of wasted material (other than above event, based on personal judgement): ____

15. Variations or change orders (formal or informal)

a. Description: ____

____

b. Approx. additional cost of variation or change order: ____________

____

16. Cost loss due to low standard finishing (personal estimate): ____

Disputes Claims or Litigation

17. If any dispute happened or claimed filed by client or any contracting party on any issue

a. Expenditure: ________________________

b. Claimed amount (if any): ______________

c. Retained Person for disputes: ___________

d. Time invested by that person;___________

e. Person's salary:______________________

Delays and Cost Overrun

18. If any slowdown of productivity of labour due to rework, overwork or any failure, is observed.

    a. Total hours wasted: ___________

    b. Avg. wage: __________________

19. Delays on project

    a. Total delayed days:________________________________

    b. Avg. site cost per day: _____________________________
    (E.g. 20/day labors, avg. wage 900/day/lab)

20. Project cost overrun from original contract estimate: ____________________

21. Cost of any opportunity or benefit which can be gained if no variation or quality failure had happened: _______________________________________

Section III: Intangible Costs

Quality nonconformance has a negative impact on project and business success. The tangible losses (e.g. rework, delays) due to poor quality, are followed by some intangible losses (e.g. loss of customer, relationship with client) which are the most important. This research aims at quantification of these intangible losses. Different factors have been identified from literature that contributes to non-conformance cost in construction. Please contribute to this survey using your work experience that if the quality non-conformance mentioned in section 1 had any intangible loss associated with them on this project and how much impact those factors had on total cost of project.

Sr.	**Factor**	**Impact (Yes/No)**	**If Yes then how much impact it had on cost in term of percentage of total project cost?**							
			0.5%	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%	If more
1	Dissatisfaction of customer									
2	Loss of image									
3	Loss of future business									
4	Litigation/Dispute									

Comments / reason (if any):

____

____

____

Hidden and intangible Costs of poor Quality in Projects

Dear Sir/Madam,
This survey is being carried out as part of MS research titled "Justifying the cost of poor quality in construction: An insight into the base of the ice-berg". The research aims at identifying the hidden cost associated with poor quality in construction projects. This elementary survey will help to identify and rank the most important hidden and intangible quality losses that may add extra cost to the project.

Your contribution towards this research is highly appreciated. Please be assured that the data will only be used for study purpose and no personal information will be disclosed at any forum/level.

Please click next to continue and complete the survey and remember to click submit at the end. In case of any inquiry, please feel free to contact.

Regards,
Nouman Khadim
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School of Civil & Environmental Engineering
National University of Sciences & Technology (NUST)
Islamabad, Pakistan
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*Required

Personal Information

1. **Please indicate your highest academic qualification** *

Mark only one oval.

- ( ) B.Tech/ BS. Tech
- ( ) B.Sc/ B.Eng/BS
- ( ) MS/MSc/M.Eng/Mphill
- ( ) M.Tech/MS.Tech
- ( ) PhD/D.Eng
- ( ) Other: ________________

2. **Please indicate your field of work (Please select all that may apply)** *
Tick all that apply.

- [ ] Construction Industry
- [ ] Architect
- [ ] Project Management
- [ ] Engineering
- [ ] Manufacturing
- [ ] Textile
- [ ] Business Administration
- [ ] Computer/Software
- [ ] Automobile
- [ ] Chemical
- [ ] Medical
- [ ] Food Industry
- [ ] Other: ____________

3. **Please indicate your area of work** *
Mark only one oval.

- ( ) Industry/Field
- ( ) Academics

4. **Please indicate your years of professional experience** *
Mark only one oval.

- ( ) Less than 1 Year
- ( ) 1-5 Years
- ( ) 5-10 Years
- ( ) 11-15 Years
- ( ) More than 15 years

5. **Country** *

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Hidden Costs of Poor Quality

Poor Quality cost are those costs that would disappear if work is done right at first time. Hidden cost are the cost which indirectly occur due to quality failures and accounting systems are unable to capture them. Rate these factors in according to there importance and impact on project.

6. **How much important do the following factors is in term of hidden or indirect losses of delivering poor quality in projects**

1- (VERY LOW) 2-(LOW) 3-(MEDIUM) 4- (HIGH) 5-(VERY HIGH)

Mark only one oval per row.

	1	2	3	4	5
Cost of Customer Complaints					
Increase in Contingency					
Increased Project Risk					
Recruiting New Professionals					
Productivity lost					
Loss of Project time Float					
Poor Safety Conditions					
Finanacial Difficulties					
Project Cost Overrun					
Non-conformance Events not Reported					
Customer Incurred cost					
Cost of Accelerating					
Unnecessary/Excessive Procurement					
Logistic Delays					
Waste of time/ delays					
Variations/Change in Project					
Disputes					
Quality Degradation					
Loss management cost					
Loss future business/sales with customer					
Mental Stress/ Low morale					
Lost Opportunity cost					
Loss/ dissatisfaction of Customer					
Complete Project Failure					
Interruption in Project Flow					
Interlinked Activity in Project					
Increased Overheads					
Extension of Time					
Litigation and Arbitration					
Loss of reputation of firm					