Determining the cost of poor quality and its impact on productivity and profitability

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Abstract

Purpose – The purpose of this paper is to examine how effectively the cost appraisal system proposed measures the cost of poor quality (COPQ) in a construction project. The paper first formulates how COPQ can be measured and later clarifies the relationship between COPQ, labor productivity, and profitability.

Design/methodology/approach – In order to measure COPQ, the researchers prepared data entry forms for recording COPQ items on a daily basis and formulated the cost contribution of lost material, lost man-hours, lost machinery hours, and lost overhead on the overall COPQ for the project. The proposed method was then applied in a case study.

Findings – The results showed that, for the 60-days study period, COPQ decreased by about 24 percent while labor productivity and profitability increased by about 17 and 11 percent, respectively, after the implementation of COPQ measuring system. This study further supports the use of the COPQ system in construction projects as a mechanism to facilitate continuous improvement.

Originality/value – COPQ is a major cost that is often ignored in construction projects due to the difficulty of measuring it. This paper presents a COPQ measuring and recording system capable of identifying COPQ. The implementation of the system is shown to increase productivity and profitability as demonstrated by the project used for the case study.

Keywords Project management, Productivity, Labor productivity, Construction industry, Profitability, Cost of poor quality, Construction project

Paper type Technical paper

1. Introduction

A construction project is a one-time activity with a specified time period, budget and defined scope. A project, irrespective of its size or magnitude, must be completed under three constraints -cost, time, and scope. These constraints are often referred to as the "Triple Constraints of Project Management" (Deming, 1982; PMBOK, 2008). Completing construction projects within these specified triple constraints, while maintaining quality, is a big challenge for project managers.

The cost of poor quality (COPQ) cannot be traced or identified using the existing accounting reports and auditing system (Barbará *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. On the other hand, mid-level managers work with both frontline workers and top level managers, making both the management of workers and costs responsibilities placed

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on mid-level managers. Thus, COPQ remains hidden, unable to be extracted using the traditional accounting system. This all means that the extent of adverse effect attributable to COPQ is not realized entirely by many project managers.

COPQ quantifies and translates failure incidents into dollar terms, which are better understood by upper management. The existing accounting systems are unable to measure and record COPQ, leaving it a hidden cost for construction projects. COPQ cannot be controlled until it is identified and measured.

The main purpose of this research is to determine the effectiveness of the COPQ measuring system as it pertains to the reduction of internal failure costs and the subsequent effect on productivity and profitability.

The objectives of the research are to:

(1) develop a method to measure the COPQ;

(2) apply the method on a construction project; and

(3) determine how effective such a method is at reducing internal failure costs.

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, Barbará *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 COQ

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 COPQ

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.

2.3 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).

2.4 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).

2.5 The hidden factory

Campanella (1990) states that 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. 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."

The hidden losses on account of COPQ estimated by various researchers are summarized in Table I.

The population mean of 27.53 percent with a standard deviation of 6.46, as shown in Table I, is a very high cost of failure; it is more than a quarter of a project amount. According to Campanella (1990), total quality costs can be reduced to 2-4 percent of sales. Crosby (1990) contends that it should not be more than 4-5 percent of the total project. Morse and Poston (1987) state that quality costs can be reduced to 2.5 percent of sales. Therefore, there is a big opportunity for cost reduction on account of COPQ.

2.6 Measurement of COQ

According to Deming (1982), the objective of "never ending improvement" in total quality management (TQM) cannot be achieved without measurement. Speirs and Nash (1995) contends that a business is not under control if measurements are not carried out, and there is no basis on which to implement improvement. Osman and Abdel-Razek (1996) have contended that "you won't be able to manage what you cannot measure." It is the measurement which triggers the improvement processes. Rao *et al.* (2010) contend that the COQ is at best an educated estimate of the cost and not a precise measure. However, Deming (1982) stated that cost analysis for quality is not effective and that measuring quality costs to seek optimum defect levels is evidence of a failure to understand the problem. Quality costs need to be measured, not only for management control, but also for the development of quality thinking within the organization.

According to Rao *et al.* (2010) many critics of the concept of measuring COQ are concerned that hidden costs associated with external failure are not reported.

		COPQ (%)	
	Low	High	Mean
Researchers	10	40	25
Barbará *et al.* (2008)	33.33	33.33	33.33
Juran (1989)	20	40	30
Evans and Lindsay (2005)	20	30	25
Harry *et al.*	20	35	27.5
Crosby (1984)	25	25	25
Atkinson *et al.* (1991)	20	25	22.5
Raab (1987)	40	40	40
Harrington (1987)	10	20	15
Morse and Poston (1987)	24	40	32
Singhal (2006)	38	38	38
Moyer and Gilmore (1979)	30	30	30
Wheelright and Hayes (1985)	10	30	20
Berry and Parasuraman (1992)	5	25	15
Dale and Oakland (1994)	20	20	20
Besterfield (1998)	5	25	15
Williams *et al.* (1999)	5	30	17.5
Giakatis *et al.* (2001)	30	30	30
Superville *et al.* (2003)	5	25	15
Kent (2005)	2.5	5	3.75
Rodchua (2006)	22.23	32.83	27.53
SD		6.46	

Table I. Average COPQ according to various researchers

Lost opportunities, customer dissatisfaction, and negative customer referrals are certainly costs relating to poor quality. A customer also has to pay higher maintenance costs due to premature failure of products delivered by the contractor. External failures not only cause inconvenience and mental stress but also a loss of time and money. External failure cost can be very high; it can even be more than the cost of the original project (Shahid and Sajid, 2010).

The measurement of COQ quantifies the problem in a language understood by upper level management, and it helps to identify major opportunities for cost reduction and customer satisfaction (Raddatz and Klemme, 2006).

3. Research methodology

3.1 Research instrument

The methodology is based on calculating the cost incurred in a construction project because of poor quality. The COPQ is comprised of the cost of all the losses that are a result of unutilized equipment and labor time, lost material due to rework, and lost days in overhead for activities in the critical path. The following mathematical equation has been proposed for assessment of COPQ for all losses during construction:

$$COPQ = \sum RMT \times MQ + \sum RMH \times MHQ + \sum RMC \times MCQ + \sum RT \times TQ \quad (1)$$

RMT is the unit rate of material, *MQ* the quantity of lost material, *RMH* the rate of man hours, *MHQ* the quantity of lost man hours, *RMC* the rate for machinery hours, *MCQ* the quantity of lost machinery hours, *RT* the rates of overheads per day, and *TQ* the number of days lost in any activity on critical path.

Data entry forms for measuring COPQ were developed based on the information available in literature, including unstructured interviews with management accountants, project managers, and cost accountants. It comprises of data entry forms created in Excel spread sheet to enter the COPQ data on a daily basis and construct summarized reports.

4. Application

4.1 Project description

The project used for the case study was a bridge on a storm water stream being constructed as a public sector project in Pakistan at a budgeted cost of 600,000 US dollars. The project commenced in May 2011 with a planned completion schedule of four months. The scope of project included diversion of the rain water stream, excavation for the foundation, securing the raft foundation, erecting abutment walls, pre-stressed concrete girders, placing deck slabs, installing concrete railings, earth filling along the approaches to the bridge, and construction of an approach road.

4.2 Data collection

Researchers identified and evaluated losses on account of internal failure costs or COPQ, which were recorded by project professionals and reported to project management for initiation of corrective actions. The purpose was to identify cost centers for opportunities of improvement, in order to ensure optimum utilization of resources and prevent losses on account of COPQ. The data entry forms for measuring COPQ were distributed to site staff working at various activities to record the losses on a daily basis. Training was given to the site and office staff for entering the data before starting data collection. Four independent variables machinery, labor, material, and project overheads, were assessed with "Total COPQ" being the dependent variable. The components were recorded for machinery, labor and material being used at the project and their cost was estimated on the basis of respective unit rates, whereas, the fixed monthly cost of management was considered as project overheads and the time delay (number of days) in completion of critical activity was assessed in monetary terms as loss. The COPQ was recorded continuously for 60 days in the months of May and June 2011. Excel spread sheets were used to compile the COPQ data and construct summarized reports. Separate sheets were used to enter cost data with the respective dates and references for each cost category.

4.3 Data analysis

The 60 days study period was divided into four quarters consisting of 15 days each in which the first quarter was considered to be benchmark period. The benchmark was established with a summary report of the first 15 days. Measurements and results from the benchmark period were not communicated to the project management. The management were apprised of the recorded COPQ during the second 15 days on a weekly basis. The data from the four quarters was analyzed using Excel and SPSS software to compute mean, standard deviation, and variance. The software packages were also used for plotting time series graphs, doing trend analyses, creating pie charts, and correlation analysis to check whether the COPQ measurement system was successful in reducing the COPQ in the case study.

4.4 Results

The monsoon season started early in the first week of June which not only disrupted the work but also damaged some of the completed work. Scarcity of allocated funds was also a constraint. “Availability of required funds for the project” has been assessed to be the most important success factor by Shahid *et al.* (2012). The COPQ data from the study period of four quarters (15 days each) were analyzed and discussions are presented in the ensuing sections.

4.5 The benchmark

The internal failure costs recorded for machinery, labor, overheads, and material in the first quarter is considered as the benchmark for comparison with other time periods. The measurements are plotted and shown in Figure 1 for the first 15 days, whereas the COPQ measurement data of all 60 days is presented in a tabular format in Appendix 1.

It can be observed from Figure 1 that COPQ started reducing, even before the management was apprised of the results, during the benchmark period. The improvement in quality can be attributed to the realization by the workers of their weaknesses, while measuring COPQ during the benchmark period. The COPQ of all the study periods can be seen in Appendix 2.

It can be seen from Table II and Appendix 2 that there is a considerable loss, averaging $2009 per day, on account of COPQ. There is a significant variation and spread in mean, mode, and median, as well as the observed high and low values. The mean values of the benchmark were compared with the mean values of the three subsequent quarters studied. The overall losses on account of COPQ as percentage of work value are 40.43 percent with a standard deviation of 23.92, much more than the population mean of 27.53 percent with a standard deviation of 6.46 as identified in the literature review.

It can be observed from Figure 2 that the main contributor to COPQ is machinery followed by labor, material, and overheads. The increase in overhead cost, due to delay in completion of critical activities, is a big and often ignored problem.

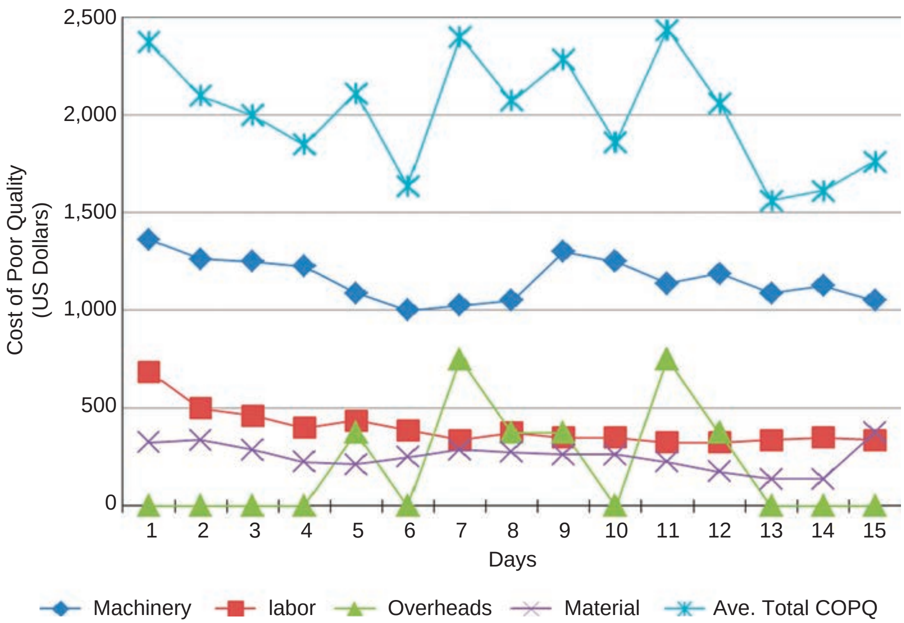


Figure 1.
Cost of poor quality recorded in the first fortnight (benchmark period)

Table II.
Benchmark of losses on account of COPQ as a percentage of value of executed work

Total cost of poor quality in the benchmark period	USD 30,138
Value of work done during the benchmark period	USD 74,538
COPQ as percentage of value of work executed	40.43%

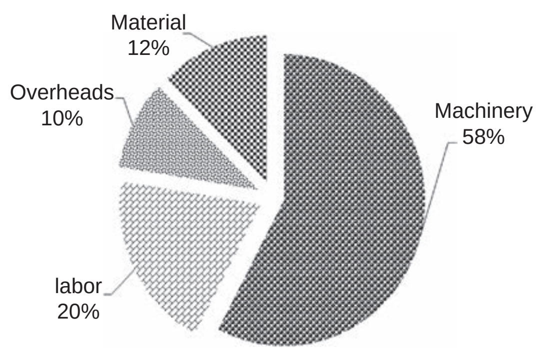


Figure 2.
Percentage share of components of total COPQ

The COPQ measured after the benchmark period, in the form of summary report, was shared with the project management on a weekly basis for the duration of the study. Problematic areas indicated by high COPQ alerted the management to take prompt corrective action. For example, whenever an equipment was sitting idle, COPQ on the account of machinery would be giving high values. This would then prompt corrective action from the management after finding the reason for the contributing COPQ factors. Setting priorities and initiating corrective actions to control the losses on account of COPQ were the goals that were hoped to be obtained by the sharing the COPQ data with project management. Wastages and losses started to reduce with the identification of problem areas and monetary emphasis being placed on internal failure incidents. The improvement observed in reduction of losses in the three study quarters, in comparison to benchmark period, is shown in Figure 3.

COPQ has reduced through each successive quarter with the improvement in quality. The mean Total COPQ reduced from \$2009 per day to \$1,054 per day, constituting a very significant reduction of 47.53 percent. Compared to the benchmark, machinery losses reduced by 48.14 percent, labor along with overheads reduced by 50 percent and material had a reduction of 38.75 percent in the fourth quarter.

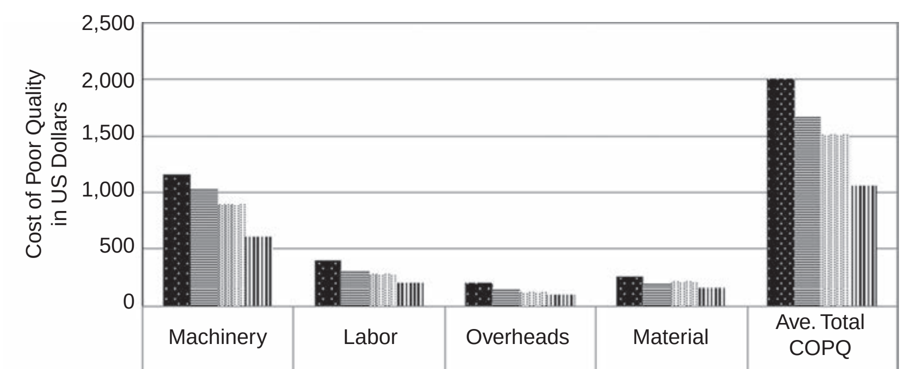
A decline in COPQ can be seen, even in the benchmark period. The COPQ continued to reduce in subsequent quarters, with a noticeable downward trend. There are comparatively less spikes and smaller spikes in the last quarter, which indicates that the system is stabilizing and moving toward a normal distribution curve.

4.6 Trend analysis

Equations of the trend lines shown in Figure 4 are represented as shown below:

$$\text{Benchmark period COPQ} = 2{,}216 - 25.85\,\text{No.of days}$$
$$\text{2nd Fortnight COPQ} = 1{,}984 - 39.11\,\text{No.of days}$$
$$\text{3rd Fortnight COPQ} = 2{,}080 - 71.92\,\text{No.of days}$$
$$\text{4th Fortnight COPQ} = 1{,}278 - 27.95\,\text{No.of days}$$

A low intercept, which represents the loss constantly being faced by the project due to COPQ, is desirable. It is evident from the above equations that the intercept has reduced considerably over the four quarters. It reduced by 10.04 percent in the second quarter but increased by 4.83 percent in the third quarter and again reduced by 38.55 percent in the last quarter in route to a total reduction of 42 percent. The trend



	Machinery	Labor	Overheads	Material	Ave. Total COPQ
Bench Mark	1,160	398	200	252	2,009
1st Quarter	1,021	308	150	192	1,671
2nd Quarter	895	273	125	212	1,504
3rd Quarter	602	198	100	154	1,054

Figure 3.
Comparison of mean values of COPQ in four quarters of the study period

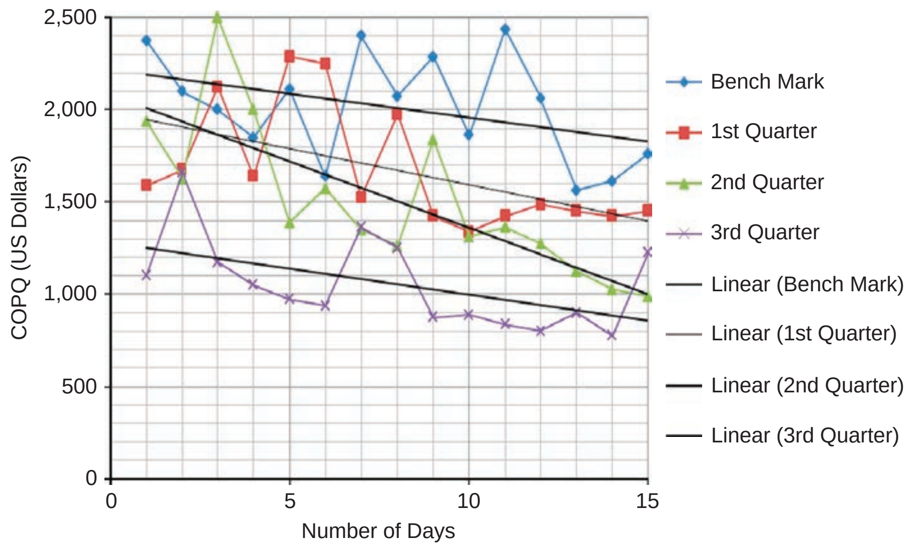


Figure 4.
Scatter plot of daily total COPQ recorded in four quarters

line gradient is negative for all variables with the greatest gradient of the trend line being found in the third quarter, followed by the second quarter, then the benchmark, and finally the last quarter. Therefore, it can be predicted that the COPQ will continue to reduce when the COPQ identification and measurement system is in place.

It can be observed from analysis of the COPQ data recorded for the four quarters (Appendix 2) that the average values of all four independent variables, and one dependent variable, have dropped continuously through each successive quarter. The spread of all the variables has also reduced considerably in the third quarter, when compared to the benchmark. The standard deviation and the mean have both reduced as well. Also, the mode and the median have become more similar. These results taken together signify that the system has moved toward a normal distribution after the implementation of the quality program.

According to the results shown in Table III, there is a considerable reduction of about 39 to 50 percent in losses for all the independent variables, and there is about a 48 percent reduction in the losses of the dependent variable (Total COPQ). The percentage of Total COPQ to Work value has also been brought down from 40.43 to 16.65 percent with an improvement of about 59 percent.

As observed in Figure 5, there is a consistent reduction in the losses on account of COPQ, to the value of work executed. There is a significant gain in value of work

Table III.
Details of reduction achieved in COPQ at the end of 60 days study period

	Cost in US Dollars		
COPQ components	Benchmark	4th quarter	% reduction
Machinery	17,400	9,025	48.13
Labor	5,962.5	2,975	50.10
Overheads	3,000	1,500	50.00
Material	3,775	2,312.5	38.74
Total COPQ	30,138	15,813	47.53
% of work value	40.43	16.65	58.82

executed at the end of the 60 days study period. The losses have been reduced from 40.43 to 16.65 percent with a standard deviation of 19.62 percentage points. The COPQ percentage losses are much less than the population mean of 27.53 percent as identified in the literature review.

4.7 Relationship between Total COPQ, labor productivity, and profitability

As evident from Table IV, labor productivity continued to improve in every quarter, coinciding with the reduction of COPQ. The overall improvement in labor productivity is 16.88 percent. Expenditure on labor also declined in successive quarters due to effective management.

Likewise, profitability continuously increased in the study period of 60 days, as seen in Table V. The input expenditure was also reduced due to reduction in losses on account of COPQ. The overall improvement in profitability is 10.45 percent, which is a significant improvement.

From Figure 6, it is observed that Total COPQ has a very high intercept value of 48.66 percent, when a lower value would be better. High intercept values are required

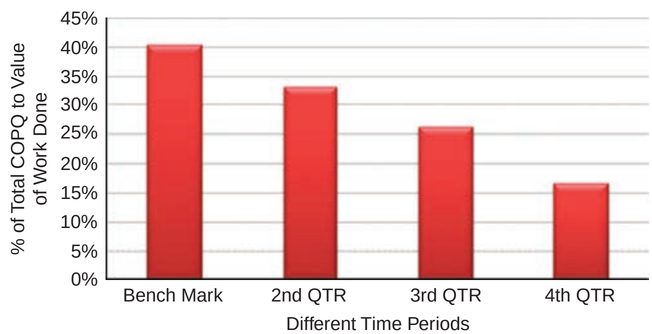


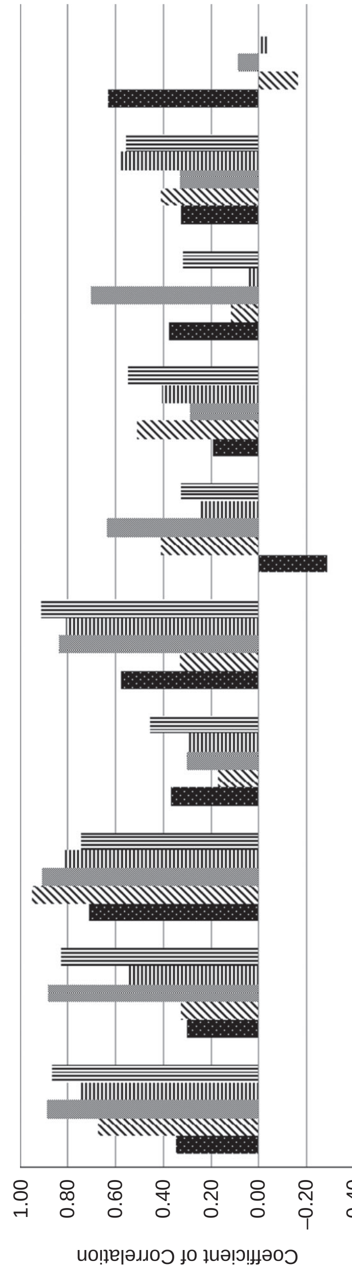
Figure 5. Reduction in total COPQ as a percentage of work executed

Table IV. Labor productivity analysis

Study period		Cost in US Dollars Expenditure on labor	Amount of executed work	% of labor expenditure	Productivity (%)	Improvement (%)
1	Benchmark	20,647	74,538	27.70	361	
2	2nd quarter	20,297	75,734	26.80	373	3.36
3	3rd quarter	21,329	86,003	24.80	403	8.06
4	4th quarter	22,512	94,988	23.70	422	4.64

Table V. Profitability analyis

Study period		Cost in US Dollars Cost of inputs	Amount of executed work	% of input expenditure	Profit (US $)	Profitability (%)	Improvement (%)
1	Benchmark	65,369	74,538	87.70	13,427	114	
2	2nd quarter	64,071	75,734	84.60	17,106	118	3.66
3	3rd quarter	71,038	86,003	82.60	22,073	121	2.42
4	4th quarter	75,421	94,988	79.40	28,878	126	4.03



	TCOPQ-Machine	TCOPQ-Labor	TCOPQ-O/heads	TCOPQ-Material	Machine-Labor	Machine-O/heads	Machine-Material	Labor-O/heads	Labor-Material	O/heads-Material
Benchmark Period	0.34	0.30	0.71	0.37	0.58	−0.29	0.19	0.38	0.33	0.63
2nd Quarter	0.67	0.33	0.95	0.37	0.33	0.41	0.51	0.12	0.41	−0.17
3rd Quarter	0.89	0.88	0.91	0.30	0.84	0.64	0.29	0.70	0.33	0.09
4th Quarter	0.75	0.55	0.82	0.29	0.81	0.24	0.40	0.04	0.58	−0.04
All 3 Quarters	0.864	0.828	0.746	0.454	0.912	0.324	0.548	0.316	0.554	0.000

Figure 6.
Correlation between independent and dependent variables

for the labor productivity and profitability, which are 336.6 and 110.15 percent, respectively. Total COPQ has a negative slope of 7.82 percent for its trend line, which means that it is decreasing with every quarter. Labor productivity and profitability both have positive gradients in their trend lines, 21.29 and 3.86 percent, respectively. A consistent, gradual, and linear improvement in the performance can be observed from the trend lines shown in Figure 6.

5. Conclusion

COPQ started reducing right from the Benchmark period. This could be explained using the concept of Hawthorn Effect. Hawthorn Effect states that because the workers knew that they were being studied, they made fewer mistakes. The percentage of COPQ to the executed work value reduced from 40.43 to 16.65 percent in the 60 days study period. The mean total COPQ of 16.65 percent, achieved at the end of the study period, is much less than the population mean of 27.53 percent as investigated in the literature review section. Therefore, there is a significant improvement in the reduction of project losses.

Analysis of the four quarters also shows a consistent trend of reduction of COPQ in each successive quarter, for each of the variable studied. It has also been observed that in the study period of 60 days the labor productivity improved by 16.88 percent and profitability increased by 10.45 percent.

The COPQ measurement and recording system successfully achieved its objective of reducing losses on account of COPQ in an experimental study of a construction project. It has been established that internal failure incidents translated to monetary or dollar terms draw the attention of management, thereby leading to corrective action. Timely corrective actions and better management not only reduced overall losses on account of COPQ, but also improved the labor productivity and profitability of the company. The measurement and recording system of COPQ also identified the cost centers and problem areas while pointing out the employees responsible for the poor quality. With this accountability system, workers became more vigilant and careful to conserve resources. This study has validated the COPQ measuring system and the methodology adopted, therefore it can be used for other construction projects with slight modifications.

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(The Appendix follows overleaf.)

Appendix 1

15 days study periods		Head of account	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
			Number of days of study period														
1	1 to 15 days (Bench mark)	Machinery	1,362.5	1,262.5	1,250	1,225	1,087.5	1,000	1,025	1,050	1,300	1,250	1,137.5	1,187.5	1,087.5	1,125	1,050
		Labor	687.5	500	462.5	400	437.5	387.5	337.5	375	350	350	325	325	337.5	350	337.5
		Overheads	0	0	0	0	375	0	750	375	375	0	750	375	0	0	0
		Material	325	337.5	287.5	225	212.5	250	287.5	275	262.5	262.5	225	175	137.5	137.5	375
		Ave. Total COPQ	2,375	2,100	2,000	1,850	2,112.5	1,637.5	2,400	2,075	2,287.5	1,862.5	2,437.5	2,062.5	1,562.5	1,612.5	1,762.5
2	16 to 30 days (2nd fortnight)	Machinery	987.5	1,100	1,137.5	1,100	1,062.5	1,037.5	1,062.5	1,100	937.5	900	987.5	1,000	950	950	1,000
		Labor	350	337.5	325	337.5	312.5	312.5	275	312.5	312.5	287.5	275	262.5	312.5	312.5	300
		Overheads	0	0	375	0	750	750	0	375	0	0	0	0	0	0	0
		Material	250	237.5	287.5	200	162.5	150	187.5	187.5	175	150	162.5	225	187.5	162.5	150
		Ave. Total COPQ	1,587.5	1,675	2,125	1,637.5	2,287.5	2,250	1,525	1,975	1,425	1,337.5	1,425	1,487.5	1,450	1,425	1,450
3	31 to 45 days (3rd fortnight)	Machinery	1,062.5	1,075	1,200	1,000	900	1,087.5	875	812.5	912.5	825	875	775	687.5	687.5	650
		Labor	312.5	325	350	375	300	275	225	250	300	250	262.5	237.5	225	187.5	212.5
		Overheads	375	0	750	375	0	0	0	0	375	0	0	0	0	0	0
		Material	187.5	225	200	250	187.5	212.5	250	200	250	237.5	225	262.5	212.5	150	125
		Ave. Total COPQ	1,937.5	1,625	2,500	2,000	1,387.5	1,575	1,350	1,262.5	1,837.5	1,312.5	1,362.5	1,275	1,125	1,025	987.5
4	46 to 60 days (4th fortnight)	Machinery	737.5	850	775	675	637.5	587.5	637.5	537.5	500	562.5	500	475	525	462.5	562.5
		Labor	200	250	237.5	225	200	200	187.5	200	200	187.5	175	175	200	175	162.5
		Overheads	0	375	0	0	0	0	375	375	0	0	0	0	0	0	375
		Material	162.5	187.5	162.5	150	137.5	150	162.5	137.5	175	137.5	162.5	150	175	137.5	125
		Ave. Total COPQ	1,100	1,662.5	1,175	1,050	975	937.5	1,362.5	1,250	875	887.5	837.5	800	900	775	1,225

Note: Cost in USD

Table AI.
Data set of COPQ recorded on one project in 60 days

Appendix 2

	Total	Highest	Lowest	Statistic SD	Mean	Mode	Median
Machinery							
Bench mark	17,400	1,362.5	1,000	111.02	1,160	1,250	1,137.5
1st quarter	15,312.5	1,137.5	900	71.13	1,020.83	1,100	1,000
2nd quarter	13,425	1,200	650	163.65	895.00	875	875
3rd quarter	9,025	850	462.5	115.71	601.67	637.5	562.5
Labor							
Bench mark	477	55	26	7.68	31.80	27	28
1st quarter	370	28	21	1.99	24.67	25	25
2nd quarter	327	30	15	4.28	21.80	24	21
3rd quarter	238	20	13	1.92	15.87	16	16
Over heads							
Bench mark	240	60	0	22.30	16.00	0	0
1st quarter	180	60	0	22.68	12.86	0	0
2nd quarter	150	60	0	18.52	10.00	0	0
3rd quarter	120	30	0	13.73	8.00	0	0
Material							
Bench mark	302	30	11	5.51	20.13	23	20
1st quarter	230	23	12	3.31	15.33	13	15
2nd quarter	254	21	10	3.08	16.93	20	17
3rd quarter	185	15	10	1.40	12.33	13	12
Ave. Total COPQ							
Bench mark	2,411	200	125	23.92	160.73	168	166
1st quarter	2,005	183	107	25.90	133.67	114	122
2nd quarter	1,805	200	79	33.13	120.33	#n/a	109
3rd quarter	1,265	133	62	19.62	84.33	#n/a	78

Note: Cost in US Dollars

Table AII. Statistic of the five variables for the four study periods

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