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Process Cost Model for Construction Quality Measurement: Feedback and Case Study

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Abstract

A Quality Management system implemented in any construction project addresses various issues and helps achieve customer satisfaction through improved construction processes. The assessment of quality improvement (quality measurement) in a company therefore becomes important. This paper reports a study on the "Process Cost Model" as a tool to measure quality improvement. The study is based on questionnaire surveys and in-depth interviews conducted in the United States and Hong Kong. The feedback regarding the feasibility and practicality of the proposed "Process Cost Model" is presented in the paper. A case study showing how the proposed PCM can be used to measure quality improvement for a construction process is also presented.

Keywords Quality cost, Process Cost Model, Continual Improvement, BS 6143, Hong Kong, USA

1. Introduction

In recent years, continual improvement has received much attention in the construction industry. One of the reasons for this trend could be the result of the release of the Year 2000 version of the international standard ISO 9000 – Quality Management Systems (QMS). This latest version of the standard has made *continual improvement* a mandatory requirement and therefore fulfillment of this requirement becomes important.

Many measuring tools commonly used for measuring quality improvement in the manufacturing industry can be applied, with some modifications, to the construction industry. The traditional model for measuring quality costs (prevention, appraisal and failure costs) has received much attention in the manufacturing industry. However, its application in the construction industry has been found to be unsuitable, based on the study done by Aoieong *et al.* (2002). In this study, the Process Cost Model (PCM) described in the British Standard BS 6143 Part: 1 (BSI 1992) was proposed to be used to measure quality improvement for construction processes. The model involves the capturing of the cost of conformance (COC) and the cost of nonconformance (CONC) of a particular process, or processes. The process cost, i.e. the total of COC and CONC, can then be obtained by monitoring the process for a specific period of time. Since both COC and CONC offer opportunities for improvement, areas for improvement can then be identified. The correlation between the two standards (ISO 9000 and BS 6143) has been previously reported by Aoieong and Tang (2002). Thus, the objectives of this paper are (1) to obtain a general opinion from the industry as to the feasibility of using the process cost model for measuring quality improvement, and (2) to show, with a case study, how the proposed PCM can be used to measure quality improvement in construction processes.

2. Feedback on the proposed process cost model from the industry

2.1 Summary of findings in surveys

Two questionnaire surveys, one in the US and one in Hong Kong, were conducted by sending out questionnaires to approximately 550 members in the directory of the Construction Management Association of America and to 163 construction-related firms in Hong Kong. In the US, a total of 43 firms responded to the questionnaire survey, yielding a response rate of about 8 per cent. In Hong Kong, a total of 34 firms responded to the questionnaire survey, yielding a response rate of 21 per cent. The respondents were asked if the presented model was feasible and practicable for construction processes after reading Figure 1 presented in the questionnaire.

Process Model for "Concreting" (Proposed by the authors of this paper)

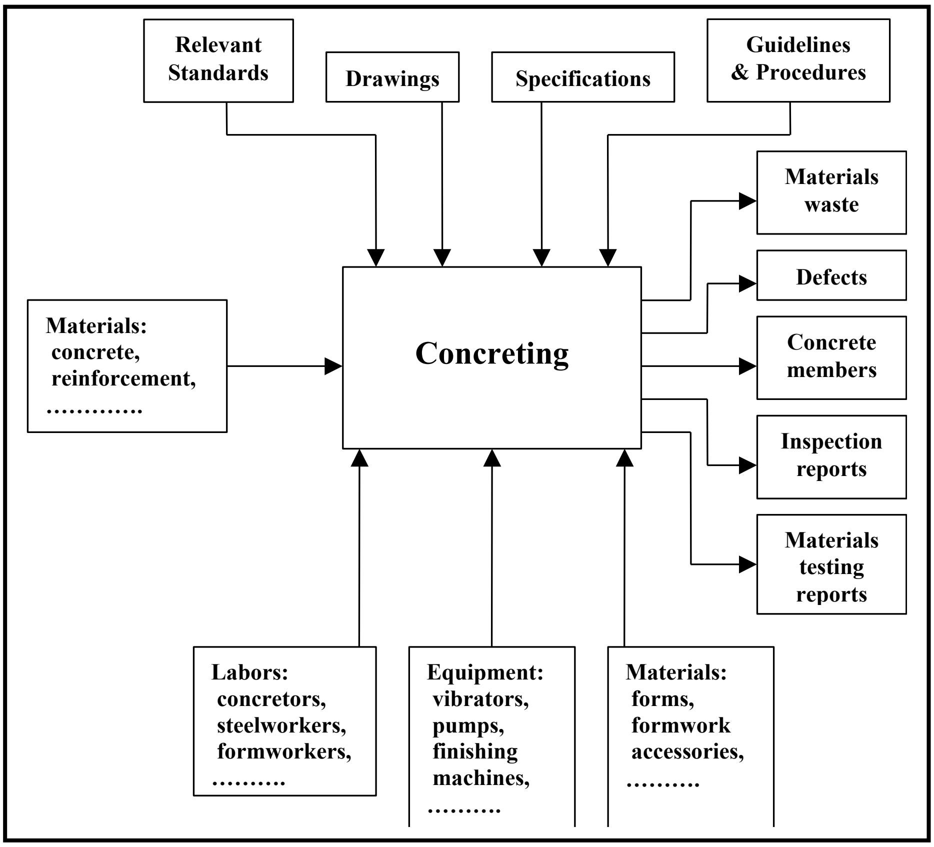

Figure 1: Brief description of the "Process Cost Model" in the questionnaire

A majority of the respondents (79% in the US & 74% in HK) indicated that the model is feasible and only 12% in the US and 21% in HK indicated 'not sure' in their responses. Among the few respondents who considered the model as not feasible, two responded with explanations. One respondent believed that the model could only be applied to the manufacturing industry while the other indicated that the model was not applicable because he was from an engineering consulting firm. The explanations provided were an indication of their incomplete understanding of the Process Cost Model. In fact, the Process Cost Model can be applied to any processes or services including management processes such as the design process. In terms of practicality of applying the model in construction processes, 30% of respondents in the US felt that the model were practicable. The responses to this question in HK were more positive; 58% of respondents felt that the model was practicable. The reason for this could be that most of the respondents' firms in Hong Kong were certified to ISO 9000 and therefore the concept of process improvement was more familiar to them. Most respondents indicated that the lack of time and resources to implement was the main reason for the model to be impractical. There were, however, positive comments too. One respondent expressed that the COC and CONC could be easily defined. Another respondent expressed that the model is practicable because a process's boundaries is flexible and this allows the management to define the boundaries according to their own situations. Table 1 summarizes the responses.

The respondents were then asked to select the best person(s) to provide data related to COC and CONC. Due to differences in local practices, the title "Quantity surveyor (QS)" was added to the selection list in the survey questionnaire conducted in Hong Kong. For COC, project manager and site superintendent were selected by the US respondents as the best persons while the HK respondents chose project manager and

QS. Similar results were also obtained for CONC with increased percentages in the categories of owner and site inspector. Because the costs of non-conformance are sensitive data, the increased involvement of owner and inspector (owner's representative) is to be expected. The responses are summarized in Table 2.

Table 1: Feasibility and Practicality of the process cost model

	% of respondents			
	Feasibility		Practicality	
	US	HK	US	HK
YES	79%	74%	30%	58%
NO	9%	6%	26%	6%
NOT SURE	12%	21%	44%	35%

Table 2: Best person(s) to provide Cost of conformance and Cost of nonconformance data

	% of respondents			
	Cost of conformance		Cost of nonconformance	
	US	HK	US	HK
Owner	17%	18%	29%	21%
Project manager	76%	61%	74%	55%
Site superintendent	52%	27%	57%	24%
Site inspector	12%	39%	19%	36%
Quantity surveyor	N/A	55%	N/A	61%
Prime Contractor	45%	48%	48%	42%
Subcontractor	36%	24%	29%	18%
Others	14%	9%	10%	3%

When the respondents were asked if they would consider applying this concept in their future projects, a big difference was observed from the two groups. While only 24% of respondents in the US indicated positively, the figure was almost doubled in Hong Kong. This result clearly showed that the firms in Hong Kong were more open to new concepts and were more willing to pursue continual improvement in construction processes. The responses to this question are shown in Table 3. Typical reasons for choosing 'No' & 'Not sure' were 'too costly', 'don't know how' and 'not useful' as shown in Table 4. Other reasons were mostly resources related. One respondent in Hong Kong, a senior quality manager, replied that the management would not believe in this concept. Another respondent in Hong Kong, a QS representing a client, pointed out that it was unlikely that the contractors and consultants would provide such cost data. In the US, however, close to 50% of the respondents who checked 'No' and 'Not sure' explained that the nature of their works were mainly construction management and therefore thought that the Process Cost Model was not directly applicable. This is in fact a misconception because the model can be applied to construction management process, as has been mentioned earlier. Indeed, the Process Cost Model can be applied to site operations as well as management processes.

Table 3: Application of the Process Cost Model in future projects

	% of respondents	
	US	HK
YES	24%	47%
NO	26%	22%
NOT SURE	50%	31%

Table 4: Reasons for 'No' & 'Not sure' to future application of the Process Cost Model

	% of respondents	
	US	HK
TOO COSTLY	22%	13%
DON'T KNOW HOW	19%	25%
NOT USEFUL	19%	19%
OTHERS	47%	50%

2.2 Summary of findings in interviews

In order to obtain more information regarding quality measurements in construction firms, further in-depth interviews with construction professionals were conducted in both the US and Hong Kong. A total of 15 (6 in the US and 9 in Hong Kong) interviews were conducted. The results of the interviews are presented in the following paragraphs.

Out of all 6 interviewees in the US, 5 indicated that the PCM was feasible for application to construction processes because of its simplicity and flexibility. However, 3 of them were not sure about the practicality of the PCM for the following reasons.

1. Since such a cost measurement system has never been tested and implemented before, it is quite difficult to foresee whether there will be money saved after the implementation.
2. The resources, particularly the site staff, involved will be tremendous if an accurate figure of CONC is required.
3. "Fire fighting" is still a better method because quick decisions can be made. Moreover, there are other tools available and to stick to just one method may be too rigid.
4. Since tight control is usually exercised on site, no significant defect cost is anticipated in a project and therefore the Process Cost Model might not be useful. On the other hand, if the defect cost of a project is significant, its origin can be easily traced.

Since most of the reasons given above have been traced to the fact that the PCM is only a proposed concept, it is understandable why it has led to skepticism. Other reasons mentioned are all related to problems of resources. Nevertheless, three interviewees expressed their enthusiasm in applying the concept to their own construction projects in the future. One interviewee pointed out that quality measurement was not essential because defects could be reduced to a minimum level if subcontractors were carefully selected. He further believed that subcontractors should be warned that their contracts could be terminated by reason of serious and repetitive defects. Another interviewee indicated that the PCM was not practical because its implementation would divert his attention from concentrating on preventive measures. Moreover, the reduction of defect costs was not his priority because of its insignificance. The quality manager from an ISO certified company, however, believed that the PCM was both feasible and practical. He expressed that nonconformity items on site were not too difficult to capture if site personnel such as inspectors, foremen and quality control staff made an effort to keep the records. Some of them kept these types of records anyway. This quality manager also expressed his belief that the application of this concept to construction industry was innovative and agreed that the US construction industry in general had to do more in order to be competitive. However, the implementation of such a system had to be initiated by a top management committed to quality.

In the interviews conducted in Hong Kong, all interviewees shared the view that applying the model (PCM) in the construction industry was much more feasible than applying the traditional Prevention-Appraisal-Failure (PAF) model. They further expressed that when applying the PCM model, the resource level required in quality costs measurement would be more flexible due to the fact that the number of processes selected for monitoring could vary according to the resources available. Moreover, when applying the PCM model, the timing for quality costs measurement was less rigid because performance was only measured at selected periods. Three interviewees, who were quality managers, expressed their willingness to apply the concept to their construction projects. However, they also pointed out that this initiative had to be supported by the top management as well as project managers and other site staff. Two interviewees, who were quantity surveyors, believed that the collection and estimation of the cost of non-conformance would not impose any significant extra burden on the site staff. Moreover the cost of conformance could be easily extracted from the bill of quantities. Nevertheless, a few interviewees were still skeptical about the practicality of the PCM giving similar reasons as those listed above (1-4).

In the PAF model, in order to capture the total quality costs of a project, it would require the full cooperation of all subcontractors. All interviewees agreed that, unlike the PAF model, the number of subcontractors involved in implementing the PCM could be kept to a minimum, depending on the processes selected. For example, the number of subcontractors involved in the concreting process could be as low as three. This will make the collection of cost data easier. In addition, the two interviewees from certification bodies (certification officers) in Hong Kong believed that the PCM could be used as a simple tool to measure process improvement, which is a requirement as stipulated in the year 2000 edition of the ISO 9000. The latter emphasizes process approach besides client satisfaction and continual improvement. Yet, they shared the view that it might be too early to comment on the new approach since so far none of the contractors in the industry have used it as a tool to satisfy the new ISO requirements.

3. Case study

In order to test the feasibility and practicality of the proposed process cost model, the concreting process of the construction of a series of pile caps was selected as a case study. Its detailed description can be found in the paper by Tang *et al.* (in press). The following paragraph provides a brief description of the case study.

A typical concreting process includes formwork, reinforcement and concrete placing. The COC and CONC of the concreting process for the construction of 30 pile caps were obtained from the Quantity Surveyor, the Site Engineer and the Resident Engineer of the project. Typical COC items related to the concreting processes are labour, materials and material testing. The COC for each typical pile cap is shown in Table 6.

Table 6: Cost of conformance (COC) per pile cap

	Cost (HK$)	Remark
Formwork	11,536	Labour + Materials
Reinforcement	49,432	Labour + Materials
Concrete (including blinding)	75,720	Labour + Materials
Water-stop	117	
Movement joint	1,807	Joint filler, sealant + dowel bars
Material testing	75	Reinforcement
	300	Concrete
Total Cost of conformance:	138,987	

In the collection of CONC, a form containing a checklist of all the common defects was used to facilitate the site staff in the cost data collection process. The number of occurrence of each type of defects was recorded and the cost required for the remedial work was then estimated. The total process costs (COC + CONC) of pile caps 1 through 30 were tabulated and presented in Table 7. From Table 7, a graph of the process cost and the pile cap number (1 to 30) was then plotted. A linear regression equation for these 30 points on the graph was found to have a negative slope, indicating continual improvement of the process cost.

4. Conclusion

In order to determine the effectiveness of quality management systems, quantifying quality improvement is essential. The authors have proposed a “Process Cost Model” for measuring the quality costs of construction projects. Based on the feedback obtained from surveys and interviews, the majority of respondents in both the US and Hong Kong indicate that the PCM is feasible for application to construction processes because of its simplicity and flexibility. It is encouraging to see that 24% of the respondents in the US and 47% in Hong Kong expressed they would consider applying this new approach in their future projects. In order to validate the practicality of the proposed model, a case study on the concreting of pile caps has been briefly discussed. It can be seen that the PCM is simple and practicable; once the process cost of a particular construction process is obtained, the contractor can use it as a benchmark for continual improvement of the process.

Table: 7 Total Process Cost for pile caps

Pile Cap	Cost of Conformance ($)		Cost of Nonconformance ($)		Total Process Cost ($)
1	138,987	96.45%	5,115	3.55%	144,102
2	138,987	99.78%	302	0.22%	139,289
3	138,987	99.86%	188	0.14%	139,175
4	138,987	99.83%	240	0.17%	139,227
5	138,987	98.05%	2,771	1.95%	141,758
6	138,987	99.93%	94	0.07%	139,081
7	138,987	99.95%	73	0.05%	139,060
8	138,987	99.96%	52	0.04%	139,039
9	138,987	99.84%	229	0.16%	139,216
10	138,987	99.95%	73	0.05%	139,060
11	138,987	99.95%	73	0.05%	139,060
12	138,987	99.93%	94	0.07%	139,081
13	138,987	99.96%	52	0.04%	139,039
14	138,987	99.96%	52	0.04%	139,039
15	138,987	99.98%	21	0.02%	139,008
16	138,987	99.93%	104	0.07%	139,091
17	138,987	99.96%	52	0.04%	139,039
18	138,987	99.93%	94	0.07%	139,081
19	138,987	99.95%	73	0.05%	139,060
20	138,987	99.95%	63	0.05%	139,050
21	138,987	99.96%	52	0.04%	139,039
22	138,987	99.89%	156	0.11%	139,143
23	138,987	99.89%	156	0.11%	139,143
24	138,987	99.88%	167	0.12%	139,154
25	138,987	99.97%	42	0.03%	139,029
26	138,987	99.90%	135	0.10%	139,122
27	138,987	99.95%	63	0.05%	139,050
28	138,987	99.96%	52	0.04%	139,039
29	138,987	99.97%	42	0.03%	139,029
30	138,987	99.97%	42	0.03%	139,029
Avg.	138,987	99.75%	357	0.25%	139,344

5. Reference

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