DEVELOPMENT OF QCOST MANAGEMENT SYSTEM FOR MEASURING COSQ (COST OF SERVICE QUALITY)

[1]SANG-CHUL LEE, [2] KWANG HYUK IM
[1]Department of Big Data Management, Korea Christian University, Seoul, Korea
[2]Department of Electronic Commerce, PaiChai University, Daejeon, Korea
E-mail: [1]leecho@kcu.ac.kr, [2]khim@pcu.ac.kr

ABSTRACT

The purpose of this research is to develop Qcost management system (QMS) and to propose a methodology for measuring the cost of service quality. Firstly, an appropriate framework is proposed for capturing quality costs and detailed analysis is carried out to characterize quality cost in a service company. This research demonstrates the calculation of quality cost based on process classification framework and 6 sigma methodologies. Secondly, QMS is developed through the process of the systems development methodologies, such as requirement analysis, system analysis & design, implementation and test. To test the QCMS, this research analyzed the Qcost in a service company. With this system, companies can control and manage their cost of poor process performance and finds some managerial insights which can help improve the efficiency within the corporation.

Keywords: *Management System, Quality Cost, Service Industry, Key Performance Indicator, Process Classification Framework*

1. INTRODUCTION

Quality is a strategic imperative for many successful organizations. Quality is a 'total concept' involving everybody and everything within the organization. When overall quality costs are minimized, a quality system's contribution to profits is effectively maximized [1]. Quality improvement continues to be a major concern for many companies

Measuring the Cost of Quality (COQ) has been the most effective methods for estimating the success of a quality management program since 1960's [2]. Researches show that COQ reached 30% of total US manufacturing costs [3]. COQ have an effect profitability, operating costs, and consumer needs [4]. Organizations endeavor to increase profitability by reducing the operating costs incurred from poor-quality products, services and processes [5-6]. The purpose of COQ is to change problems of quality into the "language" of upper management. Problems of quality defined as the number of defects have little influence on top managers, who are generally more concerned with financial performance [7].

COQ is a significant cost driver that companies need to control effectively for sustaining competitive advantage [4]. With information of COQ, manager identifies major opportunities for cost reduction and estimates the relative importance of quality problems [8]. COQ represents the difference between the actual cost of a product or service and what the reduced cost would be if there is no possibility of substandard service, product failure or defects in their manufacture [9]. Total COQ is defined as the difference between the actual cost of a product or service and what the cost could be if the quality was perfect by Chiadamrong [10].

In summary, COQ is a financial measurement that shows crucial information in the language of management. While workers and supervisors typically speak in the language of 'things', top management focuses on the processes and procedures that have a financial impact on the business. A report of COQ allows an company to indicate how all departments' affect COQ. It helps managers exact areas of high quality costs, increases efforts to improve, and facilitates an organized approach to productivity and cost improvements [11]. However, many companies in service industries face with a difficulty of the insufficient of COQ in service area. The reason for this insufficient of COQ is a lack of sufficient methods for quantifying cost in each process of service industries.

The purpose of this research is to develop Qcost management system (QMS) and to propose a

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

methodology for measuring the cost of service quality. This research demonstrates the calculation of quality cost based on Process Classification Frameowrk (PCF) and 6 sigma methodologies. To test the QCMS, this research analyzed the Qcost in a service company.

2. LITERATURE REVIEW

2.1 Cost of Quality Model

Quality costs have been the subject of many articles since they were propounded by Juran in the 1950s [6]. Quality costs are divided into four categories: prevention costs, appraisal costs, and internal failure costs, external failure costs. Generic COQ models consist of these cost categories in Table 1 [12].

Table 1: Generic Model & Cost Categories

Generic model	Cost/activity categories
(P-A-F) model	Prevention + appraisal + failure
Crosby's model	Conformance + non-conformance
Process cost models	Conformance + non-conformance
ABC models	value-added + non-value-added

Most COQ models are based on the prevention–appraisal–failure (PAF) approach. The PAF model is the most widely used model for determining COQ [13-14]. The total COQ curve shows the sum of the other two curves (failure cost and prevention + appraisal cost), and the location of the minimum point on the total COQ curve, regarded to as the optimum point which depends on the shapes of the two lower curves [15].

The cost categories of Crosby's model are similar to the PAF model. Crosby sees quality as "conformance to requirements", and therefore, defines the cost of quality as the sum of conformance and non-conformance costs [16].

The process cost model developed by Ross [17] and first used for quality costing by Marsh [18] represents quality cost systems that focus on process rather than products or services. Process cost is the total cost of conformance and non-conformance for a particular process. The cost of conformance is the actual process cost of producing products or services first time to the required standards by a given specified process, whereas cost of nonconformance is the failure cost associated with the process not being executed to the required standard [19].

An activity-based costing (ABC) model was developed by Cooper and Kaplan [20] to solve this problem. Under ABC, accurate costs for various cost objects are achieved by tracing resource costs to their respective activities and the cost of activities to cost objects. The ABC approach is actually not a COQ model. It is an alternative approach that can be used to identify, quantify and allocate quality costs among products, and therefore, helps to manage quality costs more effectively.

2.2 Six Sigma

Six Sigma is a business management strategy, originally developed by Motorola, USA in 1986 [21]. Six Sigma seeks to improve the quality of process outputs by identifying and removing the causes of defects (errors) and minimizing variability in manufacturing and business processes. Six sigma is an activity to reduce the COPQ (Cost of Poor Quality). The term Six Sigma originated from terminology associated with manufacturing, specifically terms associated with statistical modeling of manufacturing processes.

After a six sigma, companies are interested in quality cost. Quality cost is a way to evaluate effectiveness and economics of quality management activities to make good quality product economically. These six sigma activities and quality cost management took place mainly in the manufacturing industry and was low in service industry.

2.3 Process Classification Framework

Service is composed of processes. To calculate cost of service quality cost, typical Key Performance Indicators (KPI) for each process are necessary. To develop a service-oriented Qcost model, this research uses PCF which is the most used process framework developed by APQC (American Productivity & Quality Center). PCF develops a common language to define work processes comprehensively and without redundancies. Companies are using it to support benchmarking, manage content, and perform other important performance management activities [22]. Especially, this research uses PCF of utilities among industry-specific PCF developed by APQC. Processes of Utilities is shown in Figure 1.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

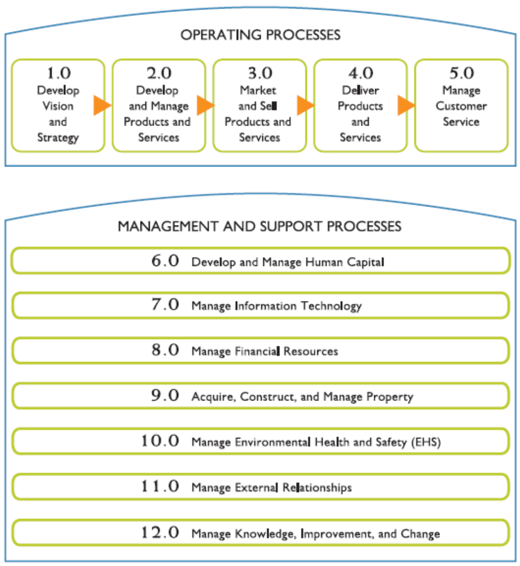

Figure 1: PCF of Utilities

3. METHOD AND PROCEDURE

3.1 Method

This paper develops the COSQ(Cost of Service Quality model), based on process as follow:

$$\mathrm{COSQ} = \sum_{i=1}^{12} P_i \tag{1}$$

where P_i denotes Qcost of Process i, which is composed by PCF of utilities.

1) Calculate Qcost of process

If Qcost of all KPIs in each process is measurable, then Qcost for all KPIs in each of the 12 process can be measured as follows:

$$P_i = \sum_{j=1}^{n} p_{ij} \tag{2}$$

where p_{ij} refers to the Qcost of KPI_j in process i. However, since it is difficult to calculate Qcost of all indicators, we, therefore, calculate the Qcost of all processes by multiplying the Qcost of KPI in each process with the number of KPIs involved.

$$P_i = w_i Max(P_{ij}) \tag{3}$$

where w_i is the number of subjects that are being tested for standard weight of Qcost for process, $Max(P_{ij})$ is to the highest Qcost existing in the subjects being selected.

2) Calculate Qcost of KPI

Qcost for each KPI consists of the following parts. The level of sigma to be improved in each process multiplies Qcost per sigma for each KPI.

$$p_i = c_{ij} \times \sum_{k=1}^{n} s_{ijk} \tag{4}$$

where c_{ij} is Qcost per a sigma for KPI_{ij}, s_{ijk} is sigma level to be improved in each branch.

3) Calculate improvement of sigma level for each branch

The sigma level to be improved for each branch is calculated with the difference between the current sigma level and the target sigma level.

$$s_{ijk} = \frac{d_{ijk} - d_{ij.}}{\sigma_{ij.}} \tag{5}$$

where $d_{ij.}$ is indicator value for 6 sigma level in KPI_{ij}, d_{ijk} is indicator value for each branch, $\sigma_{ij.}$ is a sigma level of KPI_{ij}.

However, there are different methods to calculate the target sigma level of KPIs for each branch. First, statistically, medium and standard deviation can be used, setting 3 sigma as the medium. Second, setting the branch with the best sigma level of each KPI as six sigma. In such occasion, the target level for quality improvement is defined. Third, based on 80:20 Mckinsey Approach, the upper 20% of the branches are set as six sigma.

In this research, the current sigma level of upper 20% of all branches is set to be six sigma, and the quality level of each branch is analyzed accordingly. The sigma level of the branch with the poorest performance is set to be 2 sigma, rather than 0 sigma. Thus, the sigma level to be improved can be calculated as follows:

Value of indicator can be divided as follow equation, according the purpose of indicator is to maximize or minimize. In case the current sigma level is over 6 sigma (i.e. the sigma level to be improved is less than 0), the value of the sigma level to be improved will be set as 0.

$$\begin{bmatrix} if\ max, s_{ijk} = \frac{3rd(d_{ij.}) - d_{ijk}}{\sigma} \\ if\ min, s_{ijk} = \frac{d_{ijk} - 12th(d_{ij.})}{\sigma} \\ IF\ s_{ijk} < 0, s_{ijk} = 0 \end{bmatrix} \tag{6}$$

Journal of Theoretical and Applied Information Technology
15th November 2018. Vol.96. No 21

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Current sigma level is calculated as follow:

$$\begin{bmatrix} if\ max, s_{ijk} = 6 - \frac{3rd(d_{ij.})-d_{ijk}}{\sigma} \\ if\ min, s_{ijk} = 6 - \frac{d_{ijk}-12th(d_{ij.})}{\sigma} \end{bmatrix} \qquad (7)$$

4) Calculate 1 sigma level

In order to analyze improvement of sigma level for each branch, it is initial to calculate 1 sigma level for 6 sigma level. Two approaches are divided when defining maximization or minimization indicators.

$$\begin{bmatrix} if\ max, \sigma = \frac{|3rd(d_{ij.})-\min(d_{ij,})|}{4} \\ if\ min, \sigma = \frac{|12th(d_{ij.})-max(d_{ij,})|}{4} \end{bmatrix} \qquad (8)$$

3.2 Procedure

The procedure developing COSQ is as follows.

1) Calculate 1 sigma level to define 6 sigma level
2) Calculate current sigma level for each branch
3) Calculate improvement of sigma level
4) Calculate sigma level for KPI
5) Calculate sigma level for Process
6) Calculate COSQ for company

4. EXPERIMENTAL RESULT

Based on the above methodology, this research developed a COSQ model and adapts it to a utility company.

1) Calculate 1 sigma level to define 6 sigma level

First, the data are defined as follows to analyze Qcost. P_i is cost for 12 process, p_{ij} is Qcost of measured KPI for process i , s_{ijk} is improvement of six sigma level for each branch and d_{ijk} is indicator value for each branch in Table 2.

Table 2: Transformation Indicator Value To Sigma

Process	KPI	Branch 1	Branch 2	Branch 3	…	Branch k
Process1(P1)	Indicator 11	d111	d112	d113	…	d11k
	Indicator 12	d121	d122	d123	…	d12k
	Indicator p1j	d1j1	d1j2	d1j3	…	d1jk
Process 2	Indicator p2j	…	…	…	…	…
…	…	…	…	…	…	…
Process Pi	Indicator pij	dij1	…	…	…	dijk

↓

Process	KPI	Branch 1	Branch 2	Branch 3	…	Branch k
Process 1(P1)	Indicator 11	s111	s112	s113	…	s11k
	Indicator 12	s121	s122	s123	…	s12k
	Indicator p1j	s1j1	s1j2	s1j3	…	s1jk
Process 2	Indicator p2j	…	…	…	…	…
…	…	…	…	…	…	…
Process Pi	Indicator pij	sij1	…	…	…	sijk

The value of indicator i and rank of 14 branches is shown as Table 3.

Table.3: Data of Indicator i In 14 Branches

	B1	B2	B3	..	B11	B12	B13	B14
Indicator i	685	911	657	..	2,843	831	1,611	293
Rank	10	8	11	..	1	9	3	14

As the purpose of indicator i is to minimize, we calculate 1 sigma level by equation (8).

$$\sigma = \frac{|12th(d_{ij.}) - \max(d_{ij,})|}{4} = \frac{|602 - 2{,}483|}{4} = 560$$

2) Calculate current sigma level for each branch

Current sigma level for each branch is shown as Table 4.

Table.4: Current Sigma Level For Each Branch

	B1	B2	B3	..	B11	B12	B13	B14
Indicator i	685	911	657	..	2,843	831	1,611	293
Current sigma	5.9	5.4	5.9	..	2	5.6	4.2	6.6

For example, current sigma level for B1 is calculated by equation (7).

$$s_{ijk} = 6 - \frac{d_{ijk} - 12th(d_{ij.})}{\sigma} = 6 - \frac{685 - 602}{560} = 5.9$$

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

3) Calculate improvement of sigma level

Improvement of sigma level for each branch is shown as Table 5.

Table.5: Improvement Of Sigma Level For Each Branch

	B1	B2	B3	…	B12	B13	B14	Sum
Indicator i	685	911	657	…	831	1,611	293	
Improvement sigma	0.1	0.6	0.1	…	0.4	1.8		13.7

For example, improvement of sigma level for B1 is calculated by by equation (6).

$$s_{ijk} = \frac{d_{ijk} - 12th(d_{ij.})}{\sigma} = \frac{685 - 602}{\sigma 560} = 0.1$$

4) Calculate sigma level for KPI

Sigma level of KPI for each branch is shown as Table 6.

Table.6: Sigma Level For KPI

	B1	B2	B3	…	B12	B13	B14	Sum
Indicator i	685	911	657	…	831	1,611	293	
Qcost (M)	0.135	0.501	0.089	…	0.372	1.637		12.456

For example, if cost per a indicator value is 1,623won, then cost of 1 sigma is 0.9 million won. Improvement of sigma level for B1 is calculated as follow:

$$Qs_{ijk} = c_{ij} \times s_{ijk} = 0.9M \times 0.1 = 0.135M$$

Total cost of quality for indicator i is calculated by by equation (4).

$$p_i = c_{ij} \times \sum_{k=1}^{n=14} s_{ijk} = 0.9M \times 13.7 = 12M$$

5) Calculate sigma level for Process

Sigma level for Process is calculated by equation (3).

$$P_i = w_i Max(P_{ij}) = 10 \times 12\text{M} = 124\text{M}$$

6) Calculate COSQ for company

Based on the above formula, total improvement sigma and Qcost for each branch is shown in Table 7 and COSQ in the Company is shown in Table 8.

Table 7: Total Improvement Sigma And Qcost For Each Branch

Branch	Improvement sigma		Qcost	
	value	rank	value	rank
B1	1.9	1	33	1
B2	6.1	8	130	4
B3	6	7	187	6
B4	4.7	4	76	2
B5	8.7	11	321	9
…	…	…	…	…
B11	12.2	14	404	12
B12	10	12	337	10
B13	7.3	10	164	5
B14	4.2	3	111	3
Sum	92		3,465	

A standard weight is given to each 5 process to indicate the relative importance. The result reveals that Manage Financial Resource takes the largest portion of 76.96%. Therefore, it is initial to manage indicators of financial resource first for higher efficiency. In particular, results of each branch show that there are even 4 branches who are at only 2 sigma level.

Table 8: COSQ In The Company

		Standard weight for each process	Qcost	Qcost for the process	Rate
OPERATING PROCESS	Market and Sell Products and Services	6	19	114	0.1
	Deliver Products and Services	34	398	13,542	13.05
	Manage Customer Services	10	12	125	0.12
MANAGEMENT AND SUPPORT PROCESSES	Manage Financial Resources	29	2,754	79,862	76.96
	Acquire, Construct, and Manage Property	36	281	10,130	9.76
Total		118	3,465	103,773	100

Deliver Products and Services seizes for 13.39% while Acquire, Construct, and Manage Property seizes 9.72%. The relative large portion of Deliver Products and Services mainly contributes to its nature that it is one of the most frequent activities that are conducted in the company.

5. DEVELOPMENT OF MANAGEMENT SYSTEM OF COSQ

This research develops QMS through the process of the systems development methodologies, such as requirement analysis, system analysis & design, implementation and test. This research develops the system configuration diagrams, interface design diagrams and manual of user and administrator. Final, QMS is implemented. To test QMS, this research analyzes Qcost in a service company. The company is utility service company and it has 14 branches and various processes for customer service. QMS is developed with the following procedures.

1) We collected customer (a service company)'s requirements. They wanted to estimate and analysis the quality cost considering cost of poor process performance.
2) We investigated the processes, key performance index(KPI), cost structure, etc of the company.
3) We evaluated current six sigma level and qcost of a specific process and a KPI of a specific branch. And, we made qcost evaluation modules and analysis modules.
4) We analyzed and designed data entities and relationships and developed qcost management system.
5) We applied and tested this system to the service company.

The company has many branches and employees. So, we developed QMS based on web environment. We used Apache web server, Tomcat, MySQL DB, and PHP5. Table 9 shows development environment.

Table 9: Development Environment

Environment	Language and Tools
Web Server	Apache
WAS	Tomcat
DB	MySQL
Language	PHP, HTML, JavaScript

QMS evaluate and manage sigma level and Qcost of the company. Also, the system manages qcost by various processes and Qcost by KPI(Key Performance Index). For this, we have to manage various original data and data driven from original data. Figure 2 shows data entities and relationships between data entities for the system.

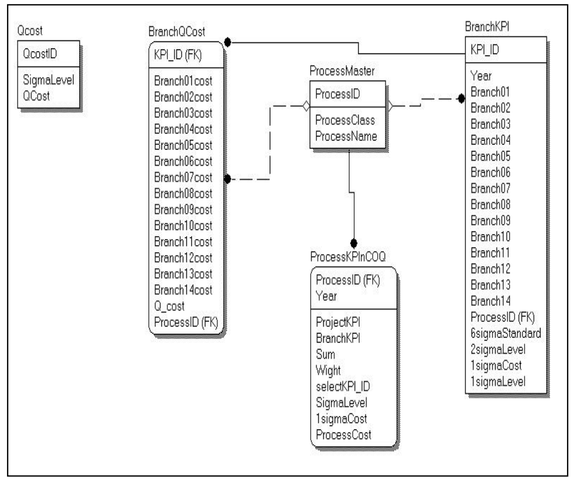

Figure 2: Entity-Relationship Diagram

Managers want to check the whole situation the company is in. So, the system provides the managers with module showing total Qcost of the company. Figure 3 shows total sigma level and Qcost of the company.

Figure 3: Sigma Level and Qcost

Figure 4 shows Qcost by various processes. There are two process group – operating process group and management and support process group. Operating process group include 5 processes –

Journal of Theoretical and Applied Information Technology
15th November 2018. Vol.96. No 21

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

"develop vision and strategy", "develop and manage products and services", "market and sell products and services", "deliver products and services", and "manage customer service".

Management and support process group includes 7 processes – "develop and manage human capital", "manage information technology", "manage financial resources", "acquire, construct and manage property", "manage environmental health and safety (EHS)", "manage external relationships", and "manage knowledge, improvement, and change".

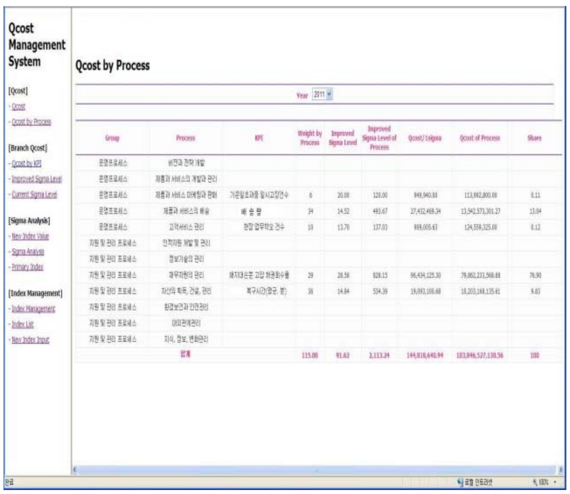

Figure 4: Qcost By Process

The system shows improved sigma level, improved sigma level of process, Qcost/1sigma, Qcost of process and share by process.

When we want to know sigma level and qcost of branches, we can select current sigma level and improved sigma level menu. Figure 5 shows current sigma level by processes and branches and Figure 6 shows improved sigma level by processes and branches. We can compare the current sigma level and improved sigma level by processes and branches.

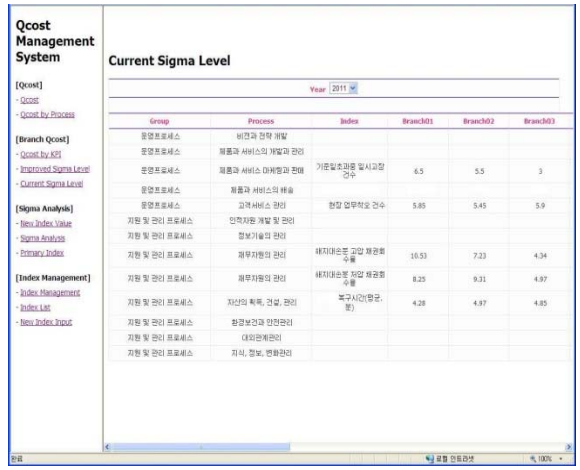

Figure 5: Current Sigma Level

6. CONCLUSIONS

The purpose of this research is to develop QMS and to propose a methodology for measuring COSQ in service industries. Based on a field study on utilities service, this research tested the COSQ of this company by specifying the Qcost on 14 different branches within the company. Firstly, the current Qcost originates from the sum of Qcost of 12 process. KPI for each process is induced. Qcost of all 12 process is tested in 14 branches. Through the research, the company oriented Qcost model is developed.

Secondly, QMS is developed to estimate and analysis the quality cost considering cost of poor process performance in service industries. QMS is developed through the process of the systems development methodologies, such as requirement analysis, system analysis & design, implementation and test.

However, there are still limitations for our research. Due to the characteristic of the sample company, COSQ model developed in this research may be difficult to adapt in all service industries. Thus, specific task characteristics of other service industry corporations should be taken into consideration in the future when using this model. Furthermore, this research examined the total Qcost by indicating KPIs of different processes, however, there may be other indicators that may have the influence on total Qcost.

ACKNOWLEDGMENTS:

This work was supported by the research grant of PaiChai University in 2018.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

REFRENCES:

[1] J.M. Freeman, "Estimating Quality Costs", *The Journal of the Operational Research Society*, Vol.46, No.6, 1995, pp. 675-68.

[2] M. Zahar, A.E. Barkany and A.E. Biyaali, "Managing Cost of Quality in Laboratory of Water Analysis", *Modern Applied Science*, Vol. 9, No. 2, 2015, pp. 199-205.

[3] T.L. Albright and H.P. Roth, "The Measurement of Quality Costs: An Alternative Paradigm", *Accounting Horizons*, Vol. 6, No. 2, 1992, pp. 15-27.

[4] S.K. Srivastava, "Towards Estimating Cost of Quality in Supply Chains", *Total Quality Management & Business Excellence*, Vol. 19, NO. 3, 2015, pp. 193-208.

[5] A.V. Feigenbaum, "Total Quality Control", *Harvard Business Review*, Vol. 34, No. 6, 1956, pp. 93-101.

[6] J.M. Juran, "Quality Control Handbook", McGraw-Hill, New York, 1951.

[7] G.S. Wasserman, and J.M. Lindland, "A Case Study Illustrating the Existence Of Dynamics in Traditional Cost-Of-Quality Models", *Quality Engineering*, Vol. 9, No. 1, 1996, pp. 119-128.

[8] J.R. Evans and W.M. Linsday, "The Management & Control of Quality", 6th edition, International Thomson Publishing, Mason, OH, 2005.

[9] J. Campanella, "Principles of Quality Costs", 3rd ed. ASQ Press. Milwaukee, WI, 1999.

[10] N. Chiadamrong, "The Development of an Economic Quality Cost Model", *Total Quality Management & Business Excellence*, Vol. 14, No. 9, 2003, pp. 999 - 1014.

[11] L. Weinstein, R.J. Vokurka and G.A. Graman, "Costs of Quality and Maintenance: Improvement Approaches", *Total Quality Management & Business Excellence*, Vol. 20, No. 5, 2009, pp. 497-507.

[12] A. Schiffauerova and V. Thomson, "A Review of Research on Cost of Quality Models and Best Practices", *International Journal of Quality & Reliability Management*, Vol. 23, No. 6, 2006, pp. 647-669.

[13] J.J. Plunkett and B.G. Dale, "Quality Costing: A Study in the Pressure Vessel Fabrication Section of the Process Plant Industry", *Quality Assurance*, Vol. 9, 1983, pp. 93-96.

[14] F. Machowski and B.G. Dale, "Quality Costing: An Examination of Knowledge, Attitudes, and Perceptions", *Quality Management Journal*, Vol. 5, No. 3, 1998, pp. 84-95.

[15] H.M.E. Abdelsalam and M.M. Gad, "Cost of Quality in Dubai: An Analytical Case Study of Residential Construction Projects", *International Journal of Project Management*, Vol. 27, 2009, pp. 501-511.

[16] P.B. Crosby, "Quality is Free: The Art of Marking Quality Certain", McGraw-Hill, New York, 1979.

[17] D.T. Ross, "Structured Analysis (SA): A Language for Communicating Ideas", *IEEE Transactions on Software Engineering*, Vol. 3, No. 1, 1977, pp. 16-34.

[18] J. Marsh, "Process Modeling for Quality Improvement", *Proceedings of the Second International Conference on Total Quality Management*, IFS Publications, Bedford, 1989, pp. 111-121.

[19] L.J. Porter and P. Rayner, "Quality Costing for Total Quality Management", *International Journal of Production Economics*, Vol. 27, No. 1, 1992, pp. 69-81.

[20] R. Cooper and R.S. Kaplan, "Measure costs right: Make the right decisions", *Harvard Business Review*, Vol. 66, No. 5, 1998, pp. 96-103.

[21] G. Tennant, "SIX SIGMA: SPC and TQM in Manufacturing and Services", Gower Publishing, 2001.

[22] APQC, The electronic utilities process classification framework, https://www.apqc.org/pcf (2008)