Application of the Delphi Technique to Improve the Implementation of Cost of Quality in Industry

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Abstract

Cost of Quality (CoQ) has become a familiar concept across industries and its' popularity is evident in the number of featured international academic publications. This research utilized previously published work, action research and the Delphi technique to identify the activities required to plan, execute, check and improve a CoQ implementation program. Action research was facilitated through a series of brainstorming sessions with seven researchers from the University of Johannesburg. The Delphi Technique was conducted in three stages: during the first stage experts were identified and invited to partake in the study, and during stages, two to three the research questions were distributed to the select participants and agreement amongst the experts was assessed. The study identified the following important activities required to plan a CoQ program, namely the quantification of errors in financial terms; the development of a CoQ management policy; definition of roles and responsibilities and a rewards and recognition system; specification of the attainable CoQ targets and key performance indicators; and identification of the stakeholder reporting requirements. The research contributes to the current body of knowledge of cost of quality by identifying the activities needed to plan and implement a CoQ program in the industry.

Keywords
Cost of Quality, Delphi Technique

1. Introduction

Cost of Quality (CoQ) has become a well-recognized concept across industries as demonstrated by the significant and increasing number of academic publications featured globally. The implementation of a CoQ program assists companies to identify non-value adding activities and provides an opportunity for process and cost improvement (Guinot, Evans and Badar, 2016). The concept has its origin in the manufacturing industry, but with time, it has developed and found application in different sectors (Laporte *et al.*, 2012). Xerox Corporation was one of the first companies that implemented cost of quality outside manufacturing, and its' implementation contributed significantly to the company being awarded the prestigious Malcolm Baldrige quality award in the 1980s.

Literature contends that companies that do not assess the cost of quality of their operations or systems lack the drive for quality improvement and they swiftly run out of improvement innovation (Sower, Quarles and Broussard, 2007; Murumkar *et al.*, 2018). The implementation of cost of quality promotes quality management as one of the integral parameters of business, and the business that is serious about quality enjoys an improved relationship with customers which ultimately translates to profit. Despite the benefits associated with the adoption of CoQ, the concept is not fully adopted across industries (Sower, Quarles and Broussard, 2007; Kaur, 2009; Murumkar *et al.*, 2018). Sower, Quarles and Broussard (2007) attempted to identify the reasons behind the poor adoption of CoQ as the business improvement strategy; the reasons included the poor involvement of leadership, the lack of commitment amongst departments and the shortage of processes to facilitate the implementation of CoQ. According to Basak and Viswanadhan (2015), the challenges leading to the poor adoption of CoQ as a business strategy are much more than the involvement of leaders and the commitment between departments. Some of the factors influencing CoQ implementation are the challenges associated with the literature of CoQ, the definition of cost of quality, and the use of models to assess quality costs in industries.

Various studies present the reasons behind the poor adoption of CoQ as the business strategy, but offer no clear direction to deal with the challenges preventing companies from full embracing CoQ (Sower, Quarles and Broussard, 2007; Kaur, 2009; Daunorienė and Staniskiene, 2016). Schiphorst (2016), however, focused on defining the processes and strategies to implement and manage CoQ. The implementation of CoQ includes an assessment of existing quality challenges in the organization, which is expressed in financial terms, as well as senior management commitment.

Sailaja, Basak and Viswanadhan (2015) suggest the inconsistency in the definition of CoQ as one of the challenges leading to the poor adoption of CoQ. Nelson (2011) defines CoQ as the expenses that would not exist if activities were performed correctly. Vanagas (2006) defines CoQ as the cost of establishing and maintaining the quality management system; whereas Schiffauerova and Thomson (2006) label CoQ as the total cost of conforming to the quality requirement plus the cost of non-conformance. The differences in the CoQ definition make it difficult to clearly understand what should and should not be included in the CoQ calculation.

Another significant challenge facing the industry is to select the appropriate cost of quality model to meet the business objectives (Sailaja, Basak and Viswanadhan, 2015). CoQ models have evolved extensively over time from the first model presented by Juran in the 1950s (Schiffauerova and Thomson, 2006). Juran's CoQ model aims to find the optimal CoQ level whilst the prevention-appraisal-failure (P-A-F) cost model strives to reduce the cost of quality (Sower, Quarles and Broussard, 2007). The P-A-F model attempts to eliminate failure cost whilst reducing appraisal costs by investing in prevention cost, and it is one of the most widely applied models in industry (Kaur, 2009). Each CoQ model has its limitations and advantages, and the focus of the current research is not to suggest the most optimal CoQ model but to provide possible solutions to improve the implementation of CoQ as a management strategy.

1.1 Research Objectives

The research expands on the work published by (Makhanya, Nel and Pretorius, 2019). The publication identified multiple reasons impacting the adoption of CoQ which included the lack of top management support, monitoring and feedback from operational activities and awareness. The current research has two objectives, namely (1) to map the challenges affecting the adoption of CoQ in the Plan-Do-Check-Act cycle; and (2) to brainstorm the possible solutions that may assist the adoption and implementation of a CoQ program.

2. Research Methodology

The research used action research, brainstorming sessions, Plan-Do-Check-Act (PDCA) cycle and the Delphi technique to identify improved methods for implementing CoQ in the industry (Macdonald, 2012). Action research is different from the traditional research approach in the sense that it allows the collaboration of individuals with the same interest throughout the research process (Tripp, 1990; Kemmis, McTaggart and Nixon, 2014). Action research is aimed at providing solutions to social issues and policy development and expands knowledge about the practice from a people perspective. The principles of action research made it a suitable strategy for the current research despite the critics presented in (Tripp, 1990). Critique of action research includes the lack of features of scientific research and the lack of repeatability and reproducibility. The applications of action research and benefits associated with this form of enquiry are presented in Kemmis, McTaggart and Nixon (2014, pp. 21–25) and include learning from people with first-hand experience and the ability to resolve social issues.

2.1 Plan-Do-Check-Act Cycle

The Plan-Do-Check-Act (PDCA) cycle dates back to the 1920s from quality management practice by Walter Shewhart and W. Edward Deming based his continuous improvement teachings in Japan during the 1950s on the PDCA cycle (Foster, 2013). The current research adopted the PDCA cycle to map the challenges affecting the implementation of CoQ as identified in the literature. The first process was to analyse each challenge as per Makhanya, Nel and Pretorius (2019) and to allocate them in the PDCA cycle. The planning phase of the PDCA cycle included the majority of the issues affecting the implementation of CoQ, and the Do phase contained the second-highest number of factors affecting the implementation of CoQ. The last two phases (Check and Act) had the smallest number of issues.

2.2 Brainstorming

The brainstorming sessions were divided according to the categories of the PDCA cycle. For each PDCA category, the factors influencing the implementation of CoQ were translated into objectives. Using the literature, the subsequent process was to define each goal, and the action research team continued to formulate ideas that could help achieve each goal. The main aim of brainstorming was to create as many ideas as possible to accomplish each goal without

testing each idea's effectiveness. Regular meetings (7 meetings (2 boardroom and 5 Microsoft teams meetings)) and reassessment of each step of the PDCA cycle facilitated the brainstorming sessions. The ideas produced during this process were converted to the Delphi research questionnaire, which in turn was given to three independent quality experts to check the authenticity and terminology of each question.

2.3 Delphi Technique

The Delphi Technique has its origin in the ancient Greek prophecies, and during the 1960s the methodology was used by the RAND Corporation to improve business processes (Galanis, 2018); the literature cites the RAND Corporation as the major role player in the advancement of the Delphi technique (Hsu and Sandford, 2007). Fletcher (2014) defines the Delphi technique as a decision-making tool that allows independent experts to participate in the discussions without face-to-face interaction. The Delphi approach belongs to the focus group family, and nominal groups are both instruments of consensus building. However, to participate in the research, the Delphi technique does not require the experts to be in the same room, and they do not have to know one another. The technique does not seek to generate correct or incorrect responses, which is considered the main deficiency of the Delphi process (Fletcher, (2014). The ultimate goal of using the Delphi technique is not to get the right or wrong response, but to consolidate expert opinions.

3. Data Collection

Figure 1. illustrates the methodological approach adopted in the present study. The first method that was applied was action research, followed by the processes of the Delphi technique. Action research was performed in partnership with seven University of Johannesburg researchers who are also quality management practitioners from various sectors. The participants came from the cement industry, the motor industry, the petroleum sector and the transportation industry. The first process in action research was to review and reflect on the challenges affecting the implementation of CoQ as identified from the literature by Makhanya, Nel and Pretorius (2019), and then map these challenges in the Plan-Do-Check-Act cycle. The second process converted the challenges into goals and provided the literature definition for each goal. Step 3 was to generate ideas that can be used to achieve each goal using brainstorming.

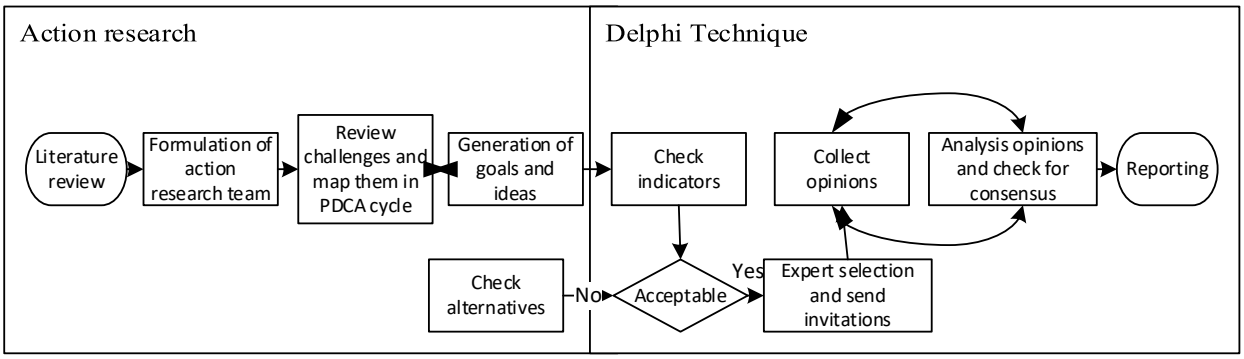

Figure 1. Research Process

The brainstorming sessions led to the Delphi technique process which consisted of five sub-processes. The sub-processes included the checking of indicators, selection of experts, data collection, data analysis and checking for agreements. According to Day and Bobeva (2005), the following indicators should be assessed before using the Delphi technique: (a) is there is an urgent need to find answers? (b) is there is no other way to find answers? and (c) are there are resources to support the study? The researchers did not find an alternative method that could be used to collect expert opinions in the implementation of CoQ. Hence, the Delphi technique was selected to collect the data in the current research.

The second sub-process in the Delphi technique was the selection of the experts. Despite the common use of the word expert, the literature is not clear on the requirements for defining such a person. Ibiyemi, Adnan and Daud (2016) describe an expert as someone who is a specialist in the field with no mention of the specific characteristics. Other authors use educational background, the number of years in the position, and registrations with professional bodies as criteria to define the expert in their studies (Sitlington and Coetzer, 2012); and the current research applied a similar strategy. The research employed academic sources from the University of Johannesburg, the ResearchGate online platform, and practitioners from both the private and public sector to find people who specialize in both quality management and cost of quality. A critical process in the Delphi technique is data collection procedures. To collect

data in the current research, the potential experts were first invited to participate in the study. An invitation letter containing the purpose of the study and the type of support required was distributed to 36 potential participants by e-mail and via the ResearchGate online platform. Subsequently, a total of 20 experts agreed to participate in the research.

Normally the Delphi technique begins with open-ended questions where the experts are expected to provide the ideas which could be used to deal with the issues at hand (Boulkedid *et al.*, 2011; Ibiyemi, Adnan and Daud, 2016). During the brainstorming sessions with the action research team, the first set of ideas was developed, and these were translated into a questionnaire to initiate the Delphi technique's first data collection. There was a total of 49 questions in the questionnaire of which 23 questions were planning-related, 14 were execution-related, 8 were control-related and 4 were acting-related questions.

The first reiteration in the current study was based on the close-ended questions in which the expert panel was asked to respond to a rating scale of 1 representing very low and 5 representing extremely high. In the second round of the Delphi iteration, the consensus questions amongst the participants were omitted. The median from the first round was included in the second round and the participants were asked if they would like to rethink their answers based on the input from the collective responses. According to Sitlington and Coetze (2012), it is important to determine the number of iterations upfront and to inform the potential participants thereof. However, the literature does not provide a consensus on the number of iterations required for the Delphi study (Boulkedid *et al.*, 2011), and in theory, the iterations continue until the experts reach a consensus (Hsu and Sandford, 2007). Ibiyemi, Adnan and Daud (2016) cited studies that had iterations ranging from one to ten rounds. According to Hsu and Sandford (2007) and Ibiyemi, Adnan and Daud (2016), two and three iterations are the most common number of reiterations. A large number of iterations leads to panel member exhaustion and a high number of drop-offs (Boulkedid *et al.*, 2011). The current study targeted two to three rounds depending on the agreement and to prevent fatigue of panel members.

The fourth and fifth steps of the Delphi technique involve the analysis of the data and deduction of the meaning from the panel feedback. The classic Delphi study begins with qualitative data analysis which leads to statistical approaches (Day and Bobeva, 2005; Ibiyemi, Adnan and Daud, 2016). The current research employed descriptive statistics, namely median and the interquartile range, as the methods of assessing responses from the panel members (Ramos, Arezes and Afonso, 2016). Green (2014) suggests the degree of central tendency like mode and mean as the statistical tools to assess the agreements among panel members; however, the mode and mean are sensitive to data outliers. In other studies, where 51% or 75% of the panel members selected the same choice, the item is regarded as having reached the consensus (Hsu and Sandford, 2007; Ibiyemi, Adnan and Daud, 2016).

Due to its robustness and tolerance to outliers, this study employed the interquartile range (IQR) as the method to determine the level of consensus amongst the panel members (Ramos, Arezes and Afonso, 2016). The IQR seeks to explain the distribution of the middle fifty per cent of the data set, considering the data set range. The first method of measuring the IQR is to group the data set from the lowest to the highest, find the median, calculate the first quartile, calculate the third quartile, and then deduct the third quartile from the first quartile. The IQR of less or equal to 1 indicates that almost the same choice of the rating was chosen by the panel members. The IQR of less or equal to1 does not imply that the members of the panel agree with the object, but rather that they agree with one another. The median was used to calculate the amount of significance for each question or action, and based on the group responses, a high median indicates significant levels of relevance, and a low median shows lower significance levels.

4. Results and Discussion

As shown in Table 1., the research consists of two Delphi technique rounds. A total of 20 experts was requested in the first round to share their views on the ideas produced during the brainstorming sessions, and they were asked to provide feedback within two weeks. 14 of the 20 invited experts replied and 7 ideas achieved consensus. In the second round, the seven ideas that reached consensus were excluded in further assessment.

Table 1. Consensus building

Parameters	**Round 1**	**Round 2**
Invitations	20	14
Responses	14	9
Number of IQR≤ 1	7	4

The median scores of all items that had IQR > 1 were included in the second round; how each expert reacted to each item and the experts were asked if they would reconsider their responses. Again, the experts were requested to respond within two weeks to submit their input in the second round. Only nine experts replied to the call in the second round and four factors had an IQR of 1. Consequently, the iteration process was paused in round two due to the high number of drop-offs. The following sections discussed the distribution of experts' opinions.

4.1 Numerical Results

The PDCA cycle planning stage contained most ideas with 23 items numbered I1 to I23 as indicated in Figure 1. and Table 2. Table 2. provides the median, the IQR, the consensus-based items and those items that did not reach consensus. Most items (13) were considered to have a very high impact with a median of 4 on CoQ program planning. Seven of the 23 items (I4; I7; I10; I11; I20; I21 and I23) achieved consensus with the IQR less than or equal to one.

Table 2. Planning Phase of the PDCA

In this section, we require your views on the impact of the listed actions for effective planning of the cost of quality program. Please rate both the impact for each action independently on the scale of 1 = very low; 2= low; 3= high; 4 = very high and 5 = extremely high.

Goals	Explanation	#	Actions	Median	IQR	Consensus
Awareness or knowledge	Knowledge is a composition of factors like information and skills which can be acquired through education	I1	Conduct cost of quality training to the management team	4	3	No
		I2	Conduct meetings with management to create awareness of the cost of quality	4	2	No
		I3	Conduct benchmarking with companies who have implemented the cost of quality programs	4	2	No
Management support	Management plays a critical role in the adoption and implementation of any improvement in organisations.	I4	Quantify quality errors in financial terms	4	1	Yes
		I5	Describe the benefits of implementing the cost of quality program to the company's financial position	5	3	No
Strategic alignment	Strategic alignment is the process of linking quality management with organisational structures and the business environment.	I6	Define how the cost of quality links to business objectives and visions.	4	2	No
		I7	Develop cost of quality management policy	4	1	Yes
Employee involvement	The process of linking people to the business goals, values, and ensuring that people play a role in decision making in the workplace.	I8	Create a multidisciplinary team to develop strategies to implement the cost of quality programs within the organization	4	3	No
		I9	Define the cost of quality training requirements for everybody in the organization	4	2	No
		I10	Define the roles and responsibility	4	1	Yes
		I11	Define reward and recognition for teams and individuals who demonstrated effective support of the cost of quality program	3	1	Yes

Goals	Explanation	#	Actions	Median	IQR	Consensus
Resource allocation	The process of defining activities and assigning resources as per demand for each activity.	I12	Define the activities required for the implementation of the cost of quality.	3	2	No
		I13	Define requirements for each activity (time, cost, machines, and skills)	4	2	No
		I14	Conduct risk assessment	4	2	No
Accounting support	Quality managers should work with accountants to reveal the level of COQ in the company.	I15	Map the existing cost element in the cost of quality model	4	2	No
Communication requirement	The method of defining stakeholders, effect and interest in the COQ	I16	Identify stakeholders who will be affected by the cost of quality program	3	3	No
		I17	Identify the influence and Interest for each stakeholder	3	2	No
		I18	Identify communication methods	3	2	No
Positive Attitudes	The way people feel or think about a particular subject	I19	Identify business processes that will be affected by the implementation of cost of quality and implement change management	3	2	No
Key performance indicators (KPI)	KPIs are measurable estimations used to gauge the advancement in accomplishing a particular objective.	I20	Defined clear and achievable cost of quality targets	4	1	Yes
		I21	Identify stakeholders reporting needs	3	0	Yes
		I22	Specify the leading and lagging Key Performance Indicators (KPI)	4	1	Yes
		I23	Specify data source for each KPI	3	2	No

There was a total of 14 items in the doing phase of the PDCA as represented in Table 3., and four of the 14 elements (I29; I30; I31 and I32) achieved consensus with an IQR ≤ 1. The ratings of each item by the team of experts are presented in Figure 2.

Table 3. Doing phase of the PDCA

We need your opinion in this section on the impact of the actions listed for the successful implementation of the cost of quality program. For each action, please rate each effect individually on the scale of 1 = very low; 2 = low; 3 = high; 4 = very high and 5 = extremely high.

Goals	Explanation	#Idea	Ideas	Median	IQR	Consensus
Define quality activities	The process of identifying the international standards, techniques and procedures required to sustain the product or service quality.	I24	Define quality attributes for all requirements	4	3	No
		I25	Define customer requirement	4	3	No
		I26	Define enablers to support the requirements	3	2	No
Define a process for quality improvement	Process for quality improvement involves the establishment of data collection methods, analysis and closing the existing gaps.	I27	Quality audits	4	2	No
		I28	Management reviews	4	2	No
		I29	Trend analysis	4	1	Yes
		I30	Customer feedback	4	1	Yes
Manage communication	The process of collecting and distributing the information is	I31	Provide regular feedback to stakeholders	4	1	Yes

Goals	Explanation	#Idea	Ideas	Median	IQR	Consensus
	required by all the relevant stakeholders.	I32	Collect performance-related information	4	1	Yes
Involve employees	Employee involvement is a process of empowering employees, building capacity and team players.	I33	Visual management (display result)	4	3	No
		I34	Gemba walks	3	3	No
		I35	Coaching	4	2	No
Departmental cooperation	According to Sower, Quarles and Broussard (2007), the successful implementation of CoQ requires the companies to break down berries between departments.	I36	Hold joint meets	4	3	No
		I37	Develop the service level agreement between stakeholders	4	2	No

The checking phase of the PDCA cycle consisted of 8 items as illustrated in Table 4., none of the items in this category received consensus or had an IQR ≤ 1. The IQR of these items ranged from 2 to 3 which indicated the mixed feelings of the participants about the nine items from the expert panel.

Table 4. Checking phase of the PDCA

In this section, we require your response to the impact of the listed actions for effectively controlling the implementation of the cost of quality program. Please rate both the impact and effort for each action independently on the scale of 1 = very low; 2= low; 3= high; 4 = very high and 5 = extremely high

goals	Explanation	Idea#	Ideas	Median	IQR	Consensus
Disclose areas of improvement	Identify the areas of improvement, establish the root cause of the problems	I38	Plan vs actual trend analysis	4	2	No
		I39	Quality Audits	4	3	No
		I40	Document review	3	2	No
		I41	Scatter plot diagram	3	2	No
		I42	Process flow	3	2	No
		I43	Brainstorming	4	2	No
		I44	Check sheets	4	2	No
		I45	Fish born diagrams	3	3	No

Table 5., shows the rating of items related to the acting phase of the PDCA cycle which contained three items (I47, I48 and I49). The expert panel had mixed views on the effectiveness of the three items in the implementation of the COQ program. I47 had the widest range of views (IQR = 3), which indicates that there was significant variation in the way the experts considered the item. In the same way, I48 and I49 had an IQR of 2 respectively, which demonstrates mixed views on the importance of the two items in the implementation of the CoQ program.

Table 5. Acting phase of the PDCA

In this section, we require your views on the impact of the listed actions for effectively improving the cost of quality programs. Please rate both the impact for each action independently on the scale of 1 = very low; 2= low; 3= high; 4 = very high and 5 = extremely high.

Goals	Explanation	#Idea	Ideas	Median	IQR	Consensus
Recommend for improvement	Creation of the strategy to sustain the desired performance	I47	Document what went right and what went wrong	3	3	No
		I48	Detail the gap in the performance this should include employees, suppliers, processes and customers	4	2	No

Goals	Explanation	#Idea	Ideas	Median	IQR	Consensus
		I49	Detail specific action required to improve dissatisfactory performance	4	2	No

4.2 Graphical Results

The final distribution of expert opinions on the planning phase of the PDCA for each item is shown in Figure 2. Item 5 was classified as having an exceptionally high impact (median = 5), but the experts did not agree (IQR = 3) on the impact of Item 5. In the planning of the CoQ program, eight items (I11; I12; I16; I17; I18; I19; I20 and I23) were classified as having a high impact (median = 3). Five items (I7; I11; I20; I21 and I22) were identified to have extreme values that, due to the robustness inherent in IQR, did not affect the results.

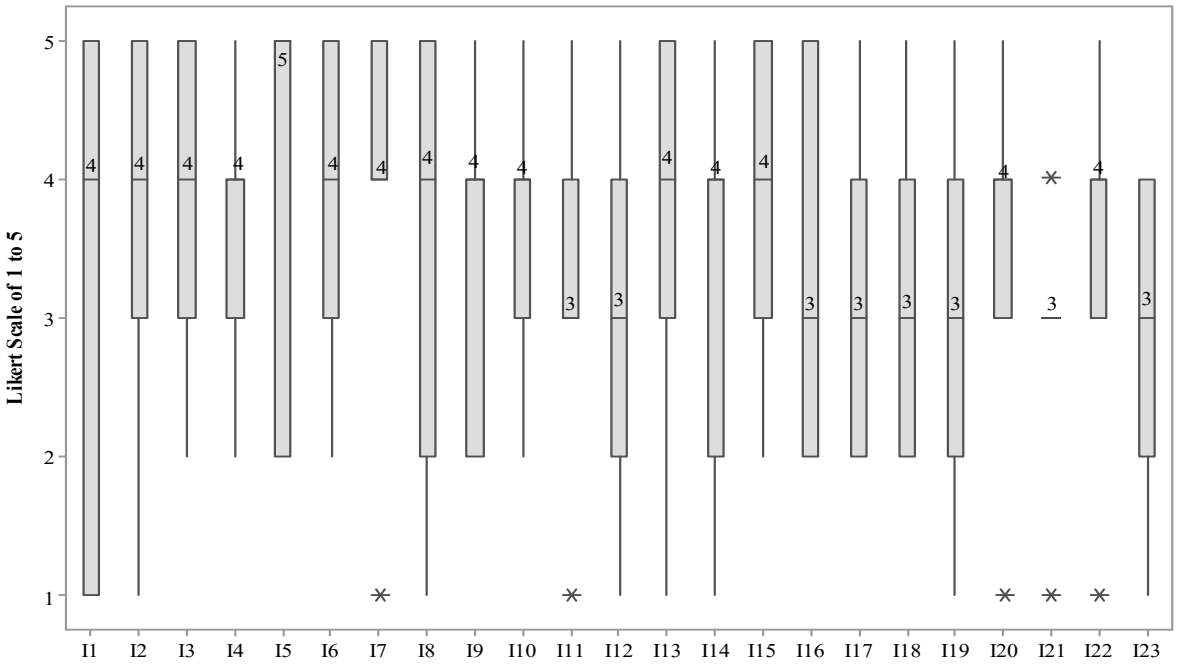

Figure 2. Experts opinions Planning phase of PDCA

In the doing phase of the PDCA, most items (12 items) were considered to have a very high impact (median = 4) (Figure 3.). Only two items (I26 and I34) were rated as having a high impact on the implementation of the CoQ program (median = 3). The high rating indicates the importance of the 14 items in the CoQ program; however, the level of importance will differ from one company to another which was indicated by the spread of views (IQR >1 in Table 3.) among the panel members.

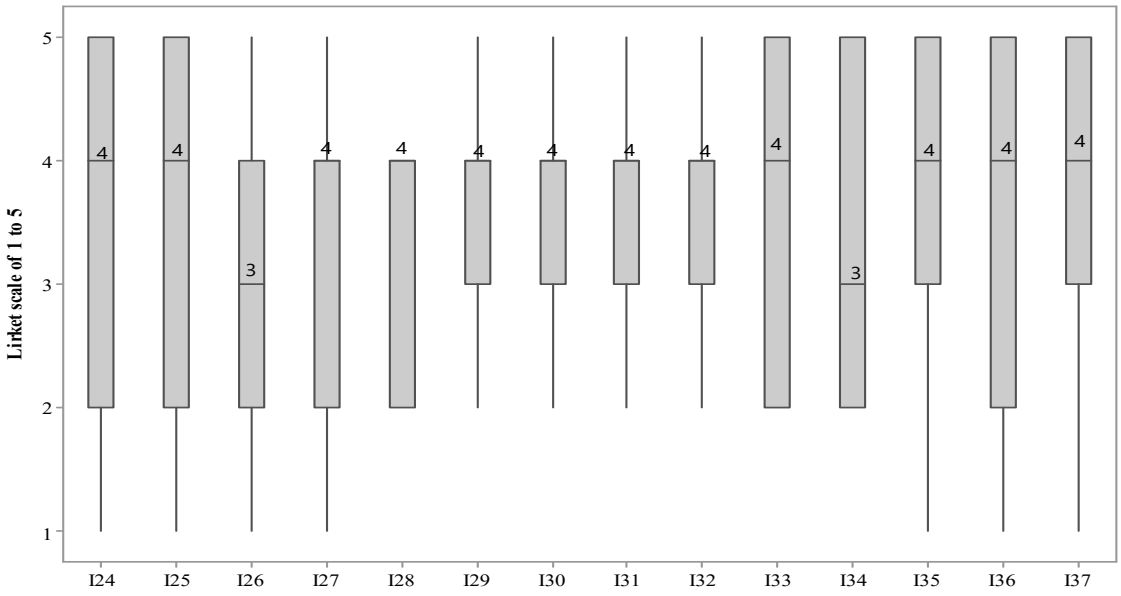

Figure 3. Expert opinions doing phase of PDCA

The majority (4 items) in the checking phase of the PDCA had a high rating (median = 3, Figure 3) and the experts had mixed views about the importance of the items IQR>1 (Table 4). A total of 4 items (I38; I39; I44; I45) was rated very high (median = 4) in the monitoring and controlling of the CoQ program. Again, the importance of the 4 items will differ from one company to another which was demonstrated by the big spread of opinions (IQR >1) from the expert panel.

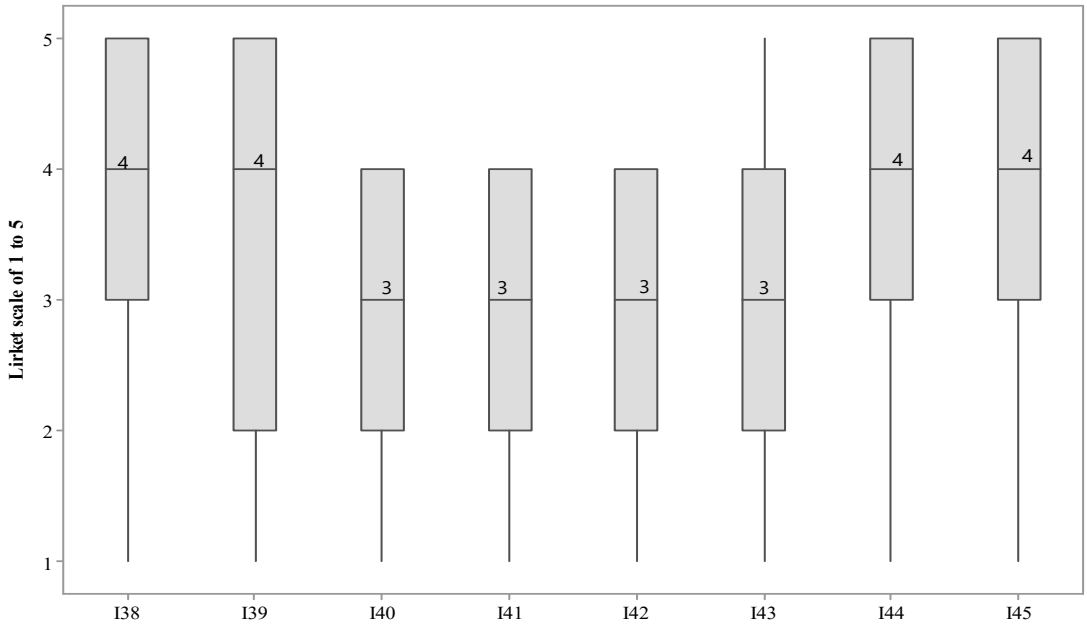

Figure 4. Expert opinions checking phase of PDCA

The acting phase of the PDCA cycle consisted of three items (Figure 5) and all items were rated very high (median=4). Despite the high rating of the three items, the experts did not agree (IQR >1 in Table 5) on the level of importance of the items in the implementation of the CoQ program. The three items should be considered when implementing the CoQ program, but the impact will vary from one organization to another.

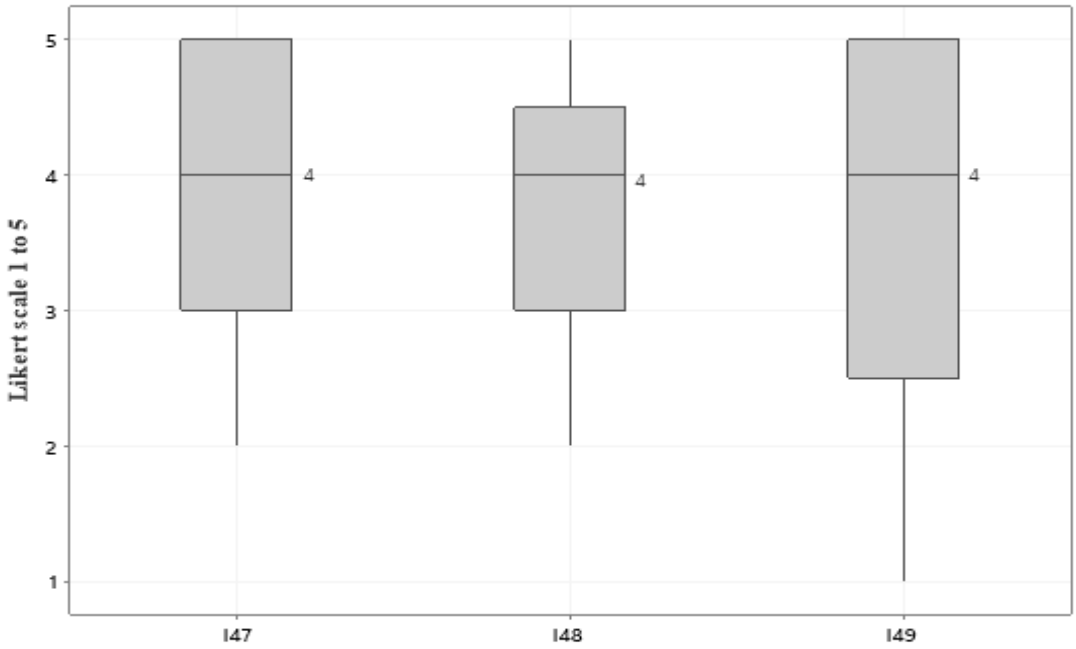

Figure 5. Experts opinions acting phase of PDCA

4.3 Proposed Improvements

This research has both practical and theoretical implications. The findings confirm the claims by Sower, Quarles and Broussard (2007) and Taidi (2015) that companies should express their quality errors in financial terms. The expert panel rated the quantification of quality errors in financial terms very high. There was also a general agreement among the participants that the expression of quality errors in monetary terms was one of the important activities in the planning of the CoQ activities. In practice, companies should express their level of quality in financial terms and set targets to continually reduce the financial impact of poor quality. Investment in CoQ should be driven from a strategic level by company policies (Cermakova and Bris, 2017). In support of this finding, there was general agreement among panel members that in practice the cost of quality management policy should be developed by companies as one of the efforts to implement CoQ. As the basis for planning of the deployment of the CoQ program, the panel members agreed that, in practice, companies should develop clear roles and responsibilities for the program; implement reward and recognition programs; identify stakeholders and their needs; set realistic and workable targets; develop a clear understanding of both leading and lagging key performance indicators (KPIs).

Quality management special CoQ is all about improving customer experience and improving business image (Mantri and Jaju, 2017). The findings in this research confirm those of earlier studies, and the panel members reached an agreement that companies should constantly gather feedback from customers during the cost of the quality program execution. In practice, customer feedback should form the basis for improving the CoQ program. In addition, the expert panel agreed that companies should collect performance rated information, provide regular feedback to stakeholders, and conduct performance trend analysis during the CoQ implementation.

4.4 Validation

The researchers believe that the combination of action research and the Delphi technique eliminates the criticism of action research employed as an independent research methodology (Kemmis, McTaggart and Nixon, 2014). The Delphi technique is considered to play an important role in the development of theory and policy, and as such, this work contributes to the advancement of the practice of cost of quality (Fink *et al.*, 2019). Despite the insights provided,

the expert panel did not reach a consensus on the activities needed to monitor and improve the implementation of the cost of quality program. Future research is required to investigate in detail the set of activities required to plan, implement, control, and improve the cost of the quality programs.

5. Conclusion

The study identified from the literature the factors affecting the implementation of CoQ and employed action research to map the factors in the PDCA cycle. Consequently, action research identified a list of activities that could improve the planning, execution, monitoring and improvement of the CoQ program; and the Delphi technique was used to validate the results of the action research based on expert opinions. The Delphi technique consisted of two rounds and the panel of experts reached a consensus on 11 items (7 planning and 4 execution). To plan the CoQ program, we concluded that companies should consider quantifying quality errors in financial terms; develop a cost of quality management policy; define roles and responsibilities; define a rewards and recognition program; define the clear and attainable cost of quality targets and identify the reporting needs of stakeholders and specifying the leading and lagging key performance indicators (KPI).

To implement the COQ program, the expert panel acknowledged that companies should consider collecting feedback from customers; provide regular feedback to stakeholders, gather performance-related information and monitor performance trends. Despite the high rating of items, the checking and improvement phase of the PDCA cycle did not reach an agreement. The research has contributed to the body of knowledge by identifying the activities needed to plan and implement a Cost of Quality program.

References

Boulkedid, R. et al. (2011) 'Using and reporting the Delphi method for selecting healthcare quality indicators: A systematic review', PLoS ONE, 6(6). doi: 10.1371/journal.pone.0020476.

Cermakova, M. and Bris, P. (2017) 'Managing the costs of quality in a Czech manufacturing company', Scientific Papers of the University of Pardubice, Series D: Faculty of Economics and Administration, 24(41), pp. 6–18.

Daunorienė, A. and Staniskiene, E. (2016) 'The quality costs assessment in the aspect of value-added chain', Quality Innovation Prosperity, 20(2), pp. 119–144. doi: 10.12776/QIP.V20I2.746.

Day, J. and Bobeva, M. (2005) 'A generic toolkit for the successful management of delphi studies', Electronic Journal of Business Research Methods, 3(2), pp. 103–116.

Fink, D. et al. (2019) 'Delphi Method : Strengths and Weaknesses The Delphi Method in Social Research - Epistemologi-', Metodoloski zvezki, 16(2), pp. 1–19. Available at: https://ibmi.mf.uni-lj.si/mz/2019/no-2/Fink2019.pdf.

Fletcher, A. J. and Marchildon, G. P. (2014) 'Using the delphi method for qualitative, participatory action research in health leadership', International Journal of Qualitative Methods, 13(1), pp. 1–18. doi: 10.1177/160940691401300101.

Foster, S. T. (2013) Managing Quality Intergating the Supply Chain. 5th edn. New York: Pearson.

Galanis, P. (2018) 'The Delphi method', Archives of Hellenic Medicine, 35(4), pp. 564–570. doi: 10.1093/med:psych/9780190243654.003.0007.

Green, R. A. (2014) 'The Delphi Technique in Educational'. doi: 10.1177/2158244014529773.

Guinot, J., Evans, D. and Badar, M. A. (2016) 'Cost of quality consideration following product launch in a present worth assessment', International Journal of Quality and Reliability Management, 33(3), pp. 399–413. doi: 10.1108/IJQRM-07-2014-0100.

Hsu, C. C. and Sandford, B. A. (2007) 'The Delphi technique: Making sense of consensus', Practical Assessment, Research and Evaluation, 12(10), pp. 1–8.

Ibiyemi, A. O., Adnan, Y. M. and Daud, M. N. (2016) 'The validity of the classical Delphi applications for assessing the industrial sustainability-correction factor: an example study', Foresight, 18(6), pp. 603–624. doi: 10.1108/FS-04-2016-0016.

Kaur, P. (2009) 'Current Cost of Quality Management Practices in India in the Era of Globalization: An Empirical Study of Selected Companies.', Decision (0304-0941), 36(1), pp. 73–99. Available at: http://search.ebscohost.com/login.aspx?direct=true&db=buh&AN=47388479&site=ehost-live&scope=site.

Kemmis, S., McTaggart, R. and Nixon, R. (2014) The action research planner: Doing critical participatory action research, The Action Research Planner: Doing Critical Participatory Action Research. doi: 10.1007/978-981-4560-67-2.

Laporte, C. Y. et al. (2012) 'Measuring the Cost of Software Quality of a Large Software Project at Bombardier Transportation: A Case Study', Software Quality Professional, 14(3), pp. 14–31. Available at: http://rube.asq.org/software-quality/2012/06/project-at-bombardier-transportation.pdf.

Macdonald, C. (2012) 'Understanding PAR A Qualitative Research Methodology .pdf', Canadian Journal of Action Research, 13(2), pp. 34–50. Available at: file:///C:/Users/Christelle/Downloads/37-Article Text-89-1-10-20120913.pdf%0Ahttps://pdfs.semanticscholar.org/3b78/ecfe0b4a0a7591d2ea068c71e8ea320ff451.pdf.

Makhanya, B. B. S., Nel, H. and Pretorius, J. H. C. (2019) 'A Systematic Literature Review of the Implementation of Cost of Quality', IEEE International Conference on Industrial Engineering and Engineering Management, 2019-Decem, pp. 726–730. doi: 10.1109/IEEM.2018.8607298.

Mantri, S. and Jaju, S. (2017) 'Cost of quality management in indian industries: A practical insight', International Journal for Quality Research, 11(3), pp. 491–506. doi: 10.18421/IJQR11.03-01.

Murumkar, A. et al. (2018) 'Integrated Approach of Cost of Quality and Six Sigma', Global Meet on Advances in Design, Materials & Thermal Engineering, Saraswati College of Engineering, Kharghar, Navi Mumbai, (January).

Nelson, K. (2011) 'A Case For Using the Cost of Quality Approach To Improve ERP Implementations', SAIS 2011 Proceedings.

Ramos, D., Arezes, P. and Afonso, P. (2016) 'Application of the Delphi Method for the inclusion of externalities in occupational safety and health analysis', Dyna, 83(196), pp. 14–20. doi: 10.15446/dyna.v83n196.56603.

Sailaja, A., Basak, P. C. and Viswanadhan, K. G. (2015) 'Hidden Costs of Quality: Measurement & Analysis', International Journal of Managing Value and Supply Chains, 6(2), pp. 13–25. doi: 10.5121/ijmvsc.2015.6202.

Schiffauerova, A. and Thomson, V. (2006) 'A review of research on cost of quality models and best practices', International Journal of Quality and Reliability Management, 23(6), pp. 647–669. doi: 10.1108/02656710610672470.

Schiphorst, J. (2016) 'MASTER ' S THESIS How to Manage Cost of Quality ? How to Manage Cost of Quality ?'

Sitlington, H. and Coetzer, A. (2012) 'Using the Delphi Technique to Identify Components of a Tertiary Strategic HRM Curriculum Using the Delphi Technique to Identify Components of a Tertiary Strategic HRM Curriculum', eCulture, 5(1), pp. 1–7.

Sower, V. E., Quarles, R. and Broussard, E. (2007) 'Cost of quality usage and its relationship to quality system maturity', International Journal of Quality & Reliability Management, 24(2), pp. 121–140. doi: 10.1108/02656710710722257.

Tripp, D. H. (1990) 'Socially Critical Action Research', Theory Into Practice, 29(3), pp. 158–166. doi: 10.1080/00405849009543449.

Vanagas, P. (2006) 'Limitation of Quality Cost Models in Agriculture', 2(1), pp. 7–12.

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