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Research Article

Modeling and Analysis of Relationship between Quailty Cost and Sales Revenue using System Dynamics

Shang Shanshan
College of International Business, Shanghai International Studies University,
Shanghai 200083, China

Abstract: The aim of this study is to analyze the relationship between quality cost and sales revenue so that to give some guidance to managers and researchers. By establishing system dynamics model which is realized by the Venism, the paper analyzes the relationship between quality cost and sales revenue. The paper proves the relationship that with the enhancement in the quality level, the prevention and appraisal cost increases and with the increase in prevention and appraisal cost, the failure cost decreases. By the SD model, the paper proves that the quality cost has direct influence on the sales revenue of the enterprises. The paper verifies that with more investment in the quality cost, the sales revenue increases greatly and with more investment in quality cost, quality level enhancing, the ratio of quality cost and sale revenue will reduce.

Keywords: Quality cost, quality level, sales revenue, system dynamics

INTRODUCTION

In the 1950s, the American quality management expert J.M. Juran and A.V. Feigenbaum proposed the conception of Cost of Quality (CoQ), which means the formation of the subject of quality of cost (Stelian, 2010). With the competition on quality become serious and serious, the enterprises have to invest more to improve the quality in order to gain the competence advantage. However, people do not have a comprehensive understanding on the practical meaning and significance of the cost of quality (Shuki, 2010; Arvind and Dixit, 2011a). The quality of the products is critical to the enterprise economic performance, in the long run, it is even more important, therefore, it is essential to measure the effectiveness of the quality management system from the standpoint of operation process (Arvind and Dixit, 2011b; Feigenbaum, 2001). The aim of quality cost management is to provide a effective method to evaluate the effectiveness of quality management system so that to reduce the cost and improve the quality. Quality cost management system is put into practice in a lot of countries in the world, especially in Europe and America and many famous international enterprises also implement the quality cost management system such as IBM, GE (Yehiel, 2009). China introduced the quality cost management system in the 1980s and the system was tried in some enterprises in Harbin, Zhuzhou, Guilin and Shanghai (Schiffauerova and Thomson, 2006; Darshak, 2008). But from the experts' investigations, we can see that there are lot problems in the execution process, according to the survey from Leslie, only 30% of the enterprises implement the quality cost management system in some form (Sower *et al*., 2007). And from the investigation by You Jianxin and his group from 1990 to 2003, only a few companies carried out quality cost management and the companies implement which can implement effectively are even fewer (David and Ram, 2002; Malchi and McGurk, 2001).

With no doubt, quality cost management is very important, but the application of quality cost management is not broad. Each enterprise cares a lot on its sales performance and quality management is a complicated system, which is fussy for the implementation, but enterprises can't give up quality management for its complexity, since quality cost is critical and it has impact on the sales. So the objective of this study is to analyze relationship between quality cost and sales revenue to give guidance to researchers and enterprise managers, by establishing system dynamics model.

LITERATURE REVIEW

The research on quality mainly focuses on three aspects: the research on the CoQ conception model; the research on the CoQ category and component; and the research on the mathematic model on the relationship between quality cost and quality level:

The research on the CoQ conception model: There are mainly three models: Feigenbaum's model (Bamford and Land, 2006), Juran's model and the model under zero defect (Amar *et al*., 2008). Feigenbaum put forward that with the enhancement in

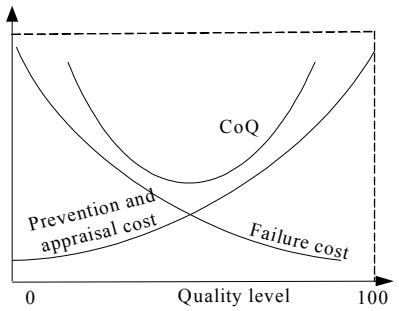

Fig. 1: Feigenbaum's model

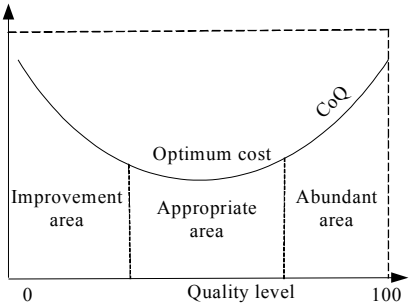

Fig. 2: Juran's model

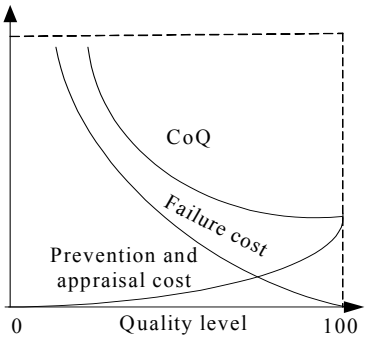

Fig. 3: Zero defect model

the quality level, the prevention cost and the appraisal cost increases, but the failure cost decreases and the prevention and appraisal cost will reach a balance point with the failure cost, where the total quality cost is a minimum, as shown in Fig. 1. Juran's CoQ model is similar to but not the same as Feigenbaum's model, in Juran's model, it only describes the total quality cost, as shown in Fig. 2. Juran didn't delineate the prevention cost, the appraisal cost and the failure cost, he only shows the general relationship between the total quality cost and the quality level. In Juran's model, the total quality cost is classified in to the improvement area, the appropriate area and the abundant area and in the in appropriate area, the total quality cost is lower. The zero defect model, as shown in Fig. 3, however, insists that the higher quality level, the lower total quality cost, so the lowest quality cost will appear if the quality level reaches 100% qualified rate, which comply to taguchi's opinion that is with no improvement in quality level, no cost will be reduced.

Table 1: The main CoQ category

Model	Category
P-A-F model	Prevention cost + appraisal cost + failure cost
Crosby's model	Conformance cost + non-conformance cost
Opportunity cost model	Prevention cost + appraisal cost + failure cost + opportunity cost
ABC model	Value added + non value added

The research on the CoQ conception model only proposes the general relationship between quality cost and the quality level, but not establishes the detailed and precise mathematical model on the relationship between quality cost and the quality level, but it shed the light and give guidance for the later researchers, laying the foundation for the further research to establish a mathematical model by using the statistical method.

The research on the CoQ category and component: Plunkett and Dale (1987) first propose the P-A-F category model (Jeffery, 2003) which is most popular and the most indexed model. There are mainly four famous CoQ categories in the research paper, as shown in Table 1 (Roya *et al*., 2012; Weisinger *et al*., 2006; Gamal *et al*., 2004; Khanna *et al*., 2004), they are P-A-F model, Crosby's model, opportunity cost model and ABC model. Actually, the Crosby's model is the same as the P-A-F model; they are just under different name.

The research on the mathematic model on the relationship between quality cost and quality level: Researchers have established a lot of mathematical model on the relationship between quality cost and quality level, such as Taguchi function, the K.K. Govil model, the model based on exponential function, model under the influence of learning effect, the model in the light of reliable theory and the model base grey Markov. Gamal S. Weheba and Ahmad K. Elshennawy proposed a revised model according to Feigenbaum's quality cost model and the characteristics of the production process (Reza *et al.*, 2012).

From the review we can see that the methodology researches use are always abstract mathematical method and almost all the researchers and experts do not pay any attention to the relationship between quality cost and sales revenue which is an important part that enterprises care about. Therefore, this study takes a deep analysis on the relationship between quality cost and sales revenue by taking use of system dynamics method.

System Dynamics (SD) is a systematic and comprehensive method that includes analysis and inference by taking both the qualitative and quantitative way (Lalit and Dabade, 2006). Only a few researchers take use of system dynamics method when doing quality cost research, (Behdad *et al*., 2009) analyses the relationship between the four components of quality

cost which are prevention cost, appraisal cost, internal failure cost and external failure.

THE ESTABLISHEMENT OF SD MODEL

Structure analysis: The paper analyses the relationship between quality cost and sales revenue from the viewpoint of quality level which is also the connection of the two parts. It is well known that with the increase in prevention cost and appraisal cost, the quality level will be enhanced and the higher the failure cost, the lower the quality level. Besides, according to Juran and Feigenbaum's theory which is also the classic theory that this paper will conform to, the curve of the total quality cost is a parabola, as quality level improves, the total quality cost first decreases, but when the quality level reaches a certain level when the quality level is enough and just perfect for the enterprise, the total quality cost will begin to increase. Simultaneously, in the view of customers, the higher the quality level is, the more satisfied the customers will be, which will lead to increase in sales revenue, as a result, the enterprise will invest more in prevention and appraisal cost, which will enhance the quality level and the failure cost will reduce. The interaction between these elements is shown in Fig. 4.

Therefore, with the improvement in quality level of the products, the customers will show higher satisfaction, which will exert a positive impetus in the market, so that more and more potential customers will become real customers and the sales revenue will increase. From the analysis we can see that there is a quite complicated interact relationship between quality cost and sales revenue.

The boundries of the model: According to the structure analysis, the paper divides the whole system into four subsystems: the quality cost subsystem, the production system, the customer subsystem and the enterprise performance subsystem.

- **The quality cost subsystem:** This subsystem explores the quality cost and its interaction with the customer subsystem, the production system and the enterprise performance subsystem. The prevention and appraisal cost are greatly influence the quality level.
- **The production system:** This subsystem is mainly about the production process and its interaction with the other three subsystems. The qualified products, the quality level have great impact on the failure quality cost and the quality level directly influences sales rate, sales volume and the customers' satisfaction.
- **The customer subsystem:** This subsystem is mainly about the elements related to customer and its interaction with the other three subsystems. The major goal of the enterprise is to produce the products that can meet customers' satisfaction, since if the quality of the product doesn't reach customers' expectation, the complains, claims and returns will occur, which of course will result in increase in failure cost and bad impact on enterprise's image which may lead customer loss and sales decrease. So in order to keep sales revenue, the enterprise should take efforts in quality improvement.
- **The enterprise performance subsystem:** This subsystem mainly focuses on the business performance under the influence of quality cost subsystem, the production system and customer subsystem. If enterprise sales well, then it will expand investment in production and quality improvement, which will also promotes customers' satisfaction.

Thus, these four subsystems interact and constraint each other by the inputs and outputs of the subsystems and the running of each subsystem not only depends on the internal structure of the subsystem, but also depends on the elements from other subsystems.

The elements and indicators in these threes subsystems are listed in Table 2.

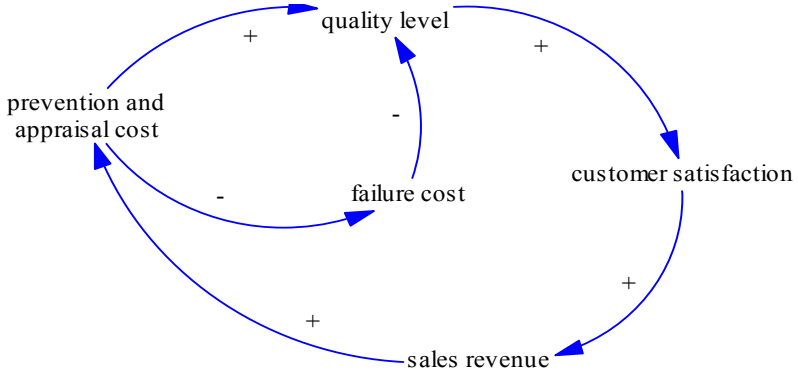

Fig. 4: Cause and effect diagram

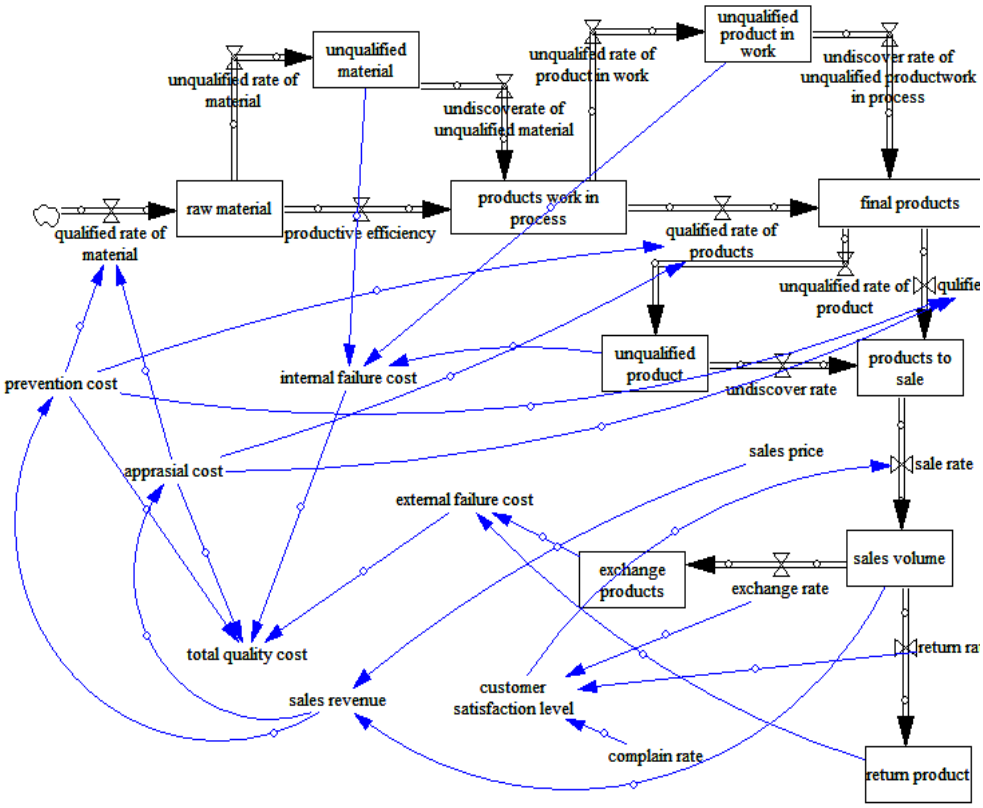

Fig. 5: Simulation model

Table 2: Elements and indicators

Subsystem	Elements	Indicators
The quality cost subsystem	Prevention cost	Cost on prevention plan
		Cost on device maintenance
		Cost on training related to quality
		Cost on the establishment of quality management system and improvement
		Cost on supplier evaluation and selection
	Appraisal cost	Cost on raw material test
		Cost on the test of work in product
		Cost on process control
		Cost on the final product test
	Internal failure cost	Failure cost of waste product
		Failure cost of rework
		Failure cost of stop working
		Failure cost of degraded product
	External failure cost	Maintenance cost
		Claim cost
		Return and exchange fees
		Discount for defective
Production subsystem	Quality level	The probability of qualified products
	Productive efficiency	Number of products per time
	Production to sale	The total number of qualified products and the unqualified that are not discovered
	Discover rate	The probability of the unqualified products that are discovered by the enterprise
	Products work in process	Number of products in process
	Final products	Number of products to sale
	Unqualified production	The number of products that is not qualified
Customer subsystem	Customer satisfaction	Level of service satisfaction
		Level of quality satisfaction
		Complaint rate
		Exchange rate
		Return rate
Performance subsystem	Enterprise performance	Sales price
		Sale rate
		Sales volume
		Sales revenue

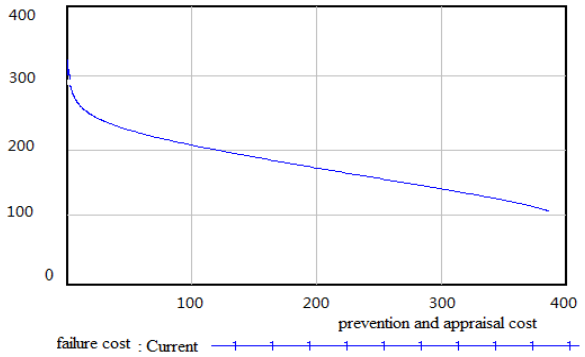

Fig. 6: The relationship between prevention and appraisal cost with failure cost

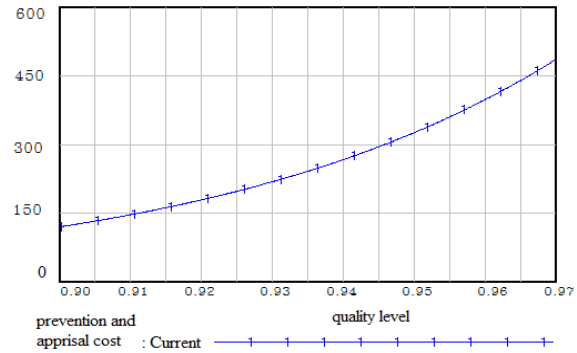

Fig. 7: The relationship between prevention and appraisal cost with the quality level

The simulation of the model: Base on the foregoing analysis, the paper establishes the systematic dynamics simulation model as shown in Fig. 5.

MODEL TEST AND SIMULATION ANALYSIS

Model test: There are many kinds of test for system dynamics simulation model, such as model structure test, model behavior test and the hidden policy test. This study adopts the model structure test and parameter test to confirm the confidence of the model.

Model structure test: The model structure test is realized by comparing the simulation model and the practice to confirm the correctness and rationality of the simulation model. The simulation model should not betray to the fact and the related general knowledge, the relationship between the variables in the simulation model should comply to the related literature.

The simulation model established in this study is under the guidance of related literatures, so the simulation model is in accordance with the related knowledge and theory.

Test on the relationship of parameters: According to the related theories, with the increase in prevention an appraisal cost, the failure cost will decrease, the higher the prevention an appraisal cost, the higher the quality level. Therefore, by taking use of practical data, the model gets the trend curve of prevention and appraisal cost and failure cost as shown in Fig. 6 which shows the relationship between prevention and appraisal cost with failure cost and Fig. 7 which shows the relationship between prevention and appraisal cost with the quality level, from which we can see that the relationship gets from the simulation model complies with the related theories and literatures.

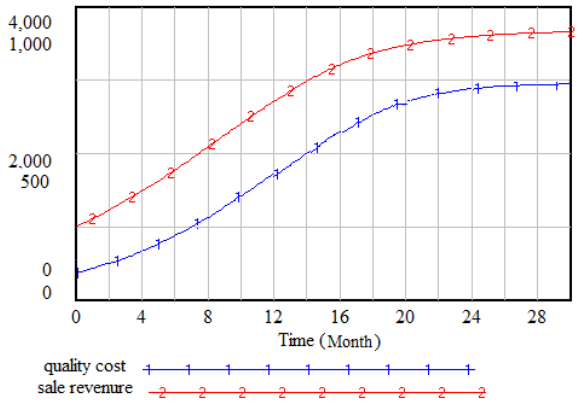

Fig. 8: Quality cost and sales revenue

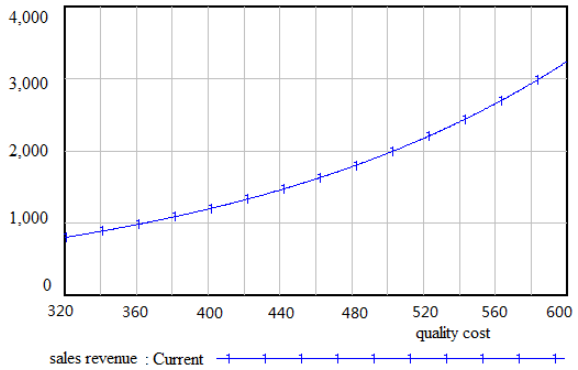

Fig. 9: Quality cost vs sales revenue

SIMULATION RESULTS AND RECOMMENDATIONS

The simulation mode gets the simulation results as shown in Fig. 8 and 9. From Fig. 8, we can see that as time of quality cost management goes on, the quality cost and sales revenue all remarkably increase at first and then the increase rate slow down and tend to be stable, besides the increase in sales revenue is significantly higher than the increase in quality cost. From Fig. 9 in which the abscissa represents quality cost and the ordinate represents sales revenue, we can also derive that with more and more investment in quality cost, the sales revenue also increases greatly and the

ratio of quality cost to sales revenue presents a trend of gradual decrease.

According to Fig. 8 and 9, it can be concluded that quality cost management is of great significance and importance to the enterprise, so the enterprise should take special effort on the implementation of quality cost, so the paper proposes the suggestions as follows:

- The enterprise leaders and managers should first attach importance on the quality cost management and implementation. Quality cost management has direct influence on the enterprise performance; therefore the enterprise should take the quality cost management into practice in an all-around manner. But the premise to implementation is the support from top management, only when the top management totally realizes the importance of the quality cost management can smoothly propels the exertion.
- All the employees should get training on quality cost. In order to assure the quality cost management well underway, all the employees should get the training on quality cost, only when the employees understand the content and the meaning of quality cost, can they better understand the role and the responsibility they take in the quality cost management and better take quality cost management into practice.
- Enterprise should collect the data related to quality cost in time. The related data is the basis and foundation to implement quality cost management, without related data, the enterprise will not know how to implement quality cost management and with no idea on how to improve the quality. Thus it is advised that enterprise collect the related data as soon as possible by the assistance of information system.

CONCLUSION

The importance of quality cost management has gotten agreement from experts and scholars and the researches on quality cost are also more and more in recent years. The research topic goes from the conception model establishment in the early times and the classification and category research in the medium term, to the establishment of mathematical model. However, only few researches focus on the relationship between quality cost and sales revenue which is a most important performance indicator. So this study analyses the relationship between quality cost and sales revenue by taking use of system dynamics model and put forward suggestions to enterprise for better implementation of quality cost management. The simulation model this study established can also be adopted to do related analysis on all the other elements in the model.

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