INVESTIGATING THE RELATIONSHIP BETWEEN QUALITY AND COST OF QUALITY IN A WHOLESALE COMPANY

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Abstract

The objective of this research is to extend understanding of variables that impact quality and cost of quality. The Prevention-Appraisal-Failure (PAF) model is employed to evaluate the cost of quality (COQ) and to determine the level of quality that minimizes the total COQ. The PAF models are developed in the framework of three major operational inputs; material, machine, and labor; the model is as well expanded for the company as one. It provides a conceptual view of the cost of quality and quality perspectives for researchers and practicing managers. The result confirms that the quality enhances along with the failure cost decrease as a result of increasing in appraisal cost plus prevention cost. Finally, it provides critical suggestions for investments in appraisal and prevention activities for material, machine and labor to minimize total cost of quality and to accomplish a satisfactory level of quality.

Keywords: Appraisal cost, Cost of quality, Failure cost, PAF model, Prevention cost

Introduction

In recent years corporations have been focusing much attention on quality management. There are many aspects on quality management but this research focuses on the cost of quality. The concept of cost of quality originated in manufacturing settings, in the 1950s, as a means of justifying staff functions responsible for quality management [1]. A number of organizations are now seeking both theoretical advice and practice evidence about cost of quality and the implementation of quality costing system [2]. Over the past few decades, the concept of cost of quality has been studied in several literature including Crosby [3], Plunkett and Dale [4, 5, 6], Diallo, et al., [7], Willis [8], Dale and Plunkett [9, 10], Zhao [11], Griffith [12], Schiffauerova and Thomson [13], Kulkarni [14], and Aurora et al., [15]. The costs associated with quality are divided into four categories: prevention, appraisal, internal failure, and external failure (Gryna [1], Harrington [16, 17, 18], Campanella [19, 20]). Prevention costs are the costs with the purpose of the prevention of future losses (e.g. training, quality planning, and preventive maintenance of machine etc.). Appraisal costs are the expenditures with the intention of measurement and assessment of the process (e.g. inspection, quality check, third party audits, measuring devices, reporting systems, etc). Internal failure costs are those costs incurred prior to the delivery of the products. These costs include the resources need to complete additional tasks and any costs involved in rework due to inadequate processes. External failure costs arise after a company supplies the product to the customer, such as customer service costs, product recall, and customer returns warranty.

The traditional theory of cost of quality hypothesizes an opposite relationship between quality and failure cost as well as a theory hypothesizes that quality and appraisal cost plus prevention cost are directly related. To further facilitate understanding of cost of quality relationship, the cost of quality model (PAF model) are analyzed and presented in Figure 1

[1]. The basic assumptions of the PAF model is that the appraisal costs and failure costs will reduce as a result of the investment in prevention and appraisal activities. The objective of the model is to determine the level of quality that minimizes total cost of quality (Abdelsalam, H., and Gad, M. [2], Plunkett and Dale [4, 5, 6], Grimm and Fox [21], Feigenbaum [22], Gray [23]).

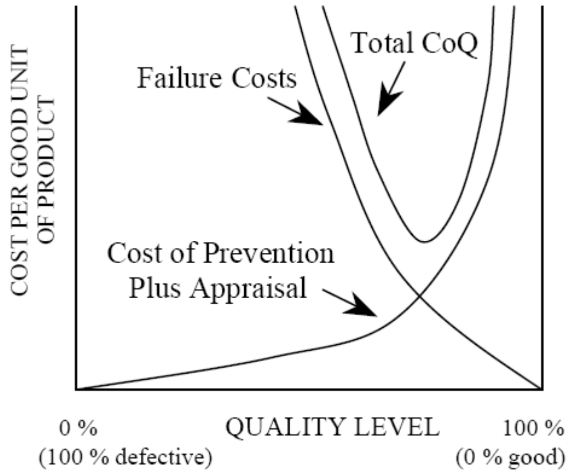

Figure1. Cost of quality model (PAF) (Gryna, 1999)

The PAF model consists of three lines: failure cost, costs of appraisal plus prevention, and cost of quality. It illustrates that the failure costs will decreases as a result of an increasing in the costs of appraisal plus prevention. When the quality of product is at 100% conformance, the failure cost reaches zero point. In order to develop cost of quality strategy, it is vital to seek a balance point at which the cost of quality is minimal. From a prescriptive standpoint, this point could be used to establish and justify the scale of quality assurance and control efforts.

Although there is an enormous amount of cost of quality data being collected in various industries today, the unfortunate fact is that little of it is ever analyzed [15]. In 1985, Rosander[27] studied the customer costs as a separate COQ category. Heskett et al. [26] proposed the interpretation of internal and external failure costs to acknowledge the differences between service and manufacturing in 1995. Youngdahl and Kellogg [28] developed a preliminary classification scheme for customers' costs of service quality that resulted in seven distinct quality assurance behaviors. It provided insight into customers' roles in service quality.

In this research, a correlation analysis is employed to determine the impact of changes in the cost of quality components to the quality using a real data from a flower wholesale company in the United State over a period of 24 months. Furthermore, the data is used to develop the PAF model to identify the right amount of investment in prevention and appraisal activities. In order to apply cost of quality system to improve quality and to reduce cost of quality, it is important to understand a framework that clarifies the relationship between cost of quality components and quality for major operational inputs. A company allows making proper decisions concerning with reducing cost of quality, and improving quality because of these affiliations are clearly understood. In other word**,** the management enables to create appropriated quality strategy for reducing cost and improving productivity.

This research is intended to apply the PAF model for a wholesale company. There are three objectives: (1) to test the relationships between the cost of quality components and the level of quality for material, machine input, labor, and company as one; (2) to use the PAF model to evaluate the cost of quality; and (3) to determine the optimum value for the cost of quality. Specifically, this research is attempted to answer following questions:

a) Is there a negative relationship between appraisal cost plus prevention cost and failure cost for material, machine, labor, and the company?
b) Is there a positive relationship between appraisal cost plus prevention cost and the level of quality for material, machine, labor, and the company?
c) Is there a negative relationship between failure cost and level of quality for material, machine, labor, and the company?
d) How much the company should be invested in appraisal and prevention activities for material, machine, and labor?

Methodology and Conceptual Framework

The integration of the cost of quality concept and the quality's level for four key aspects: material, machine, labor, and the company are concerned for this research. In this study, twenty-four months of cost of quality data were collected from a flower wholesale company. The company is located in Miami, South Florida. It had about 27 employees and annual sales of approximately US$1.2 million per year. The flowers are imported from Thailand, Europe, and South America to distribute in the USA. To increase the value of the products and services and to increase customer satisfaction, the cost of quality system has been initiated in the company. In order to set up a cost of quality program, the method for estimating cost of quality data is developed. The data consist of cost of quality categories (appraisal cost, prevention cost, internal failure cost, and external failure cost), total sales, and quality information for machine, material, labor, and company as a whole. The number of labor, machine and material involved in any given operation activities are also included in this research. With the aim of measure labor quality performance, a set of questionaire was developed to gather customer attitude associated with both satisfactory and unsatisfactory service encounter. It is important to note that only one question in the questionaire was used this research. This is because the main objective of the questionaire developent was used for another study. For each encounter, the respondents answered an important question "Please indicate your level of satifaction of the services" (0-none, 1-very little, 2-a little, 3-some, 4-a lot, 5-very much). The question was asked to identify the service performance for the purpose of examining the labor quality. Prior to obtaining the sample data the questionnaire is required to develop and to test for reliability and validity. Personal interviews were conducted to verify respondents's understanding of the survey instrument. Using Cronbach's alpha to test internal consistency, values of 0.87 were obtained. Over 250 samples were conducted for this analysis. The survey data was transformed in to level of labor quality (% of customer satisfaction associated with the labor activities). To determine the relationship (Pearson Correlation Coefficient Analysis) between the cost of quality elements and quality, the Minitab software is employed.

There are three main reasons for using the PAF model as a based for this research: 1) it is easy to be understood; 2) the application of the model on different company circumstance is effortless; and 3) the accessibility of data needed to apply this model is uncomplicated. Figure 2 presents a conceptual framework which is developed by integrating the PAF model with four major aspects: material, machine, labor, and the company.

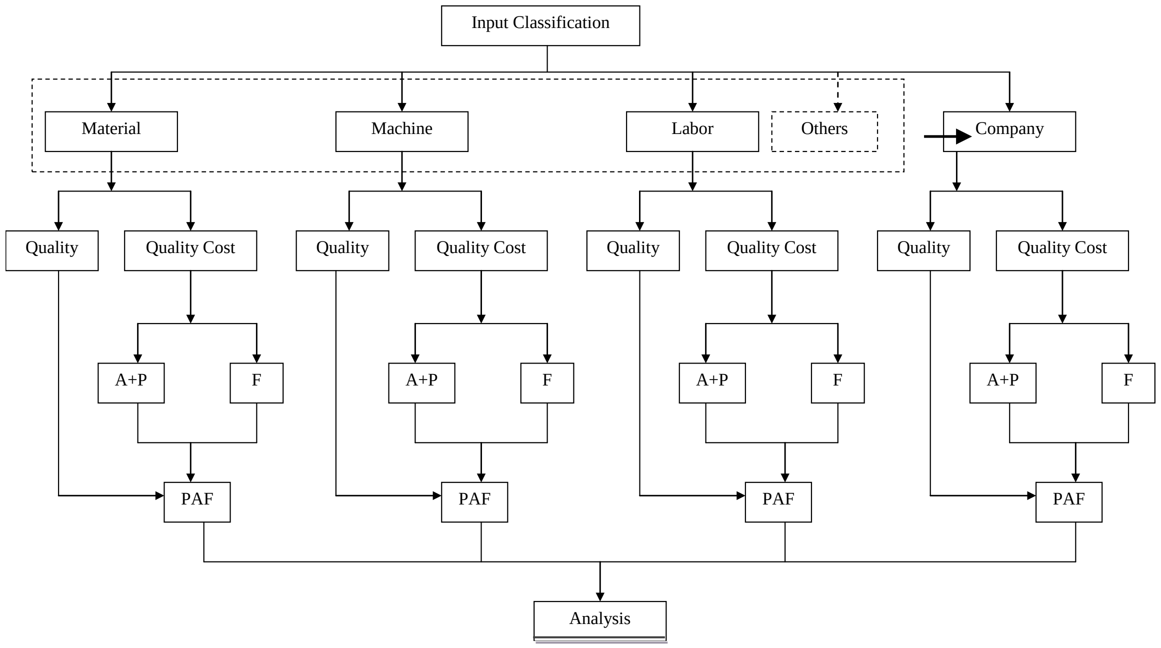

Figure 2. Conceptual framework for the research

The notations in the analysis are presented as the following:

Input:

M = material input

M/C = machine input

L = labor input

O = other inputs

$$Input = M + M/C + L + O$$

Cost of Quality:

Prevention cost:

P = prevention cost

P_M = prevention cost for material

$P_{M/C}$ = prevention cost for machine

P_L = prevention cost for labor

P_O = prevention cost for other inputs

$$P = P_M + P_{M/C} + P_L + P_O$$

Appraisal cost:

A = appraisal cost

A_M = appraisal cost for material

$A_{M/C}$ = appraisal cost for machine

A_L = appraisal cost for labor

A_O = appraisal cost for other inputs

$$A = A_M + A_{M/C} + A_L + A_O$$

Internal failure cost:

IF = internal failure cost

IF_M = internal failure cost for material

$IF_{M/C}$ = internal failure for machine

IF_L = internal failure cost for labor

IF_O = internal failure cost for other inputs

$$IF = IF_M + IF_{M/C} + IF_L + IF_O$$

External failure cost:

EF = *external failure cost*

EF_M = *external failure cost for material*

$EF_{M/C}$ = *external failure cost for machine*

EF_L = *external failure cost for labor*

EF_O = *external failure cost for other inputs*

$$EF = EF_M + EF_{M/C} + EF_L + EF_O$$

Cost of Quality for Material (COQ_M):

The cost of quality for material contains the combination of appraisal cost and prevention cost (e.g. raw material inspection and supplier quality evaluation) and failure costs (e.g. loss, return, customer complains, and rework) associated with the raw material. The relation can be expressed as the following:

$$COQ_M = P_M + A_M + IF_M + EF_M$$

Cost of Quality for machine ($COQ_{M/C}$):

The cost of quality for machine comprises of the sum of appraisal cost and prevention cost (e.g. machine calibration and preventive maintenance) and failure costs (e.g. repairing of machine) associated with the machine. The relation can be expressed as follows:

$$COQ_{M/C} = P_{M/C} + A_{M/C} + IF_{M/C} + EF_{M/C}$$

Cost of Quality for labor (COQ_L):

The cost of quality for labor consists of the sum of appraisal cost and prevention cost (e.g. training, activities to assurance that the most efficient operations) and failure costs (e.g. labor cost for rework) associated with the labor. The relation can be expressed as the following:

$$COQ_L = P_L + A_L + IF_L + EF_L$$

Cost of Quality for other input (COQ_O):

The cost of quality for other inputs is the summing up of appraisal cost and prevention cost and failure cost associated with other inputs excluding material, machine and labor. The relation can be expressed as follow:

$$COQ_O = P_O + A_O + IF_O + EF_O$$

It is important to note that the cost of quality for other inputs is not included in this research. This is because the other input accounts for only 6% of the total inputs. Besides, the other inputs are already included in the analysis for the company as a whole.

Cost of Quality for company (COQ):

The cost of quality for the company comprises of the summation of appraisal cost and prevention cost (e.g. inspection, quality planning, and training) and failure cost (e.g. scrap and rework) related with all operations for the company. The relation can be expressed as the following:

$$COQ = COQ_M + COQ_M + COQ_M + COQ_M$$

$$COQ = P_M + A_M + IF_M + EF_M + P_{M/C} + A_{M/C} + IF_{M/C} + EF_{M/C} + P_L + A_L + IF_L + EF_L + P_O + A_O + IF_O + EF_O$$

The "quality" for this research is defined as the following:

Quality of Material: The quality of material is the level to which the raw material matches to the requirements (% raw material conformance).

Quality of Machines: The quality of machine is the availability rate of machine (% machine availability).

$$\text{Machine availability} = \frac{\text{Loading time- breakdown - set up time loss}}{\text{Loading time}}$$

$$\text{Loading time} = \text{Planed operation time} - \text{Breaks} - \text{Planned maintenance}$$

Quality of Labor: The quality of labor is a customer satisfaction level to the service's performance associated with the labor activities (% customer satisfaction).

Quality of Company: The quality of company is the percent of products that meet the requirements (% product conformance).

Results and Discussions

Table 1 demonstrates the relationship between appraisal cost plus preventive cost and failure cost, appraisal cost plus preventive cost and quality, and failure cost and quality for material, machine, labor, as well as company. The Pearson Correlation Coefficient values and signs explain the direction and the power of the relationship between the two variable sets.

Table 1. The Pearson Correlation Coefficient among the Variables

The relationship	Material	Machine	Labor	Company
Appraisal cost + Prevention cost vs. Failure cost	-0.629 *p = 0.000*	-0.607 *p = 0.307*	-0.522 *p = 0.000*	-0.537 *p = 0.000*
Appraisal cost + Prevention cost vs. Quality	0.620 *p = 0.000*	0.549 *p=0.000*	0.574 *p=0.000*	0.565 *p=0.003*
Failure cost vs. Quality	-0.615 *p = 0.000*	-0.594 *p = 0.003*	-0.654 *p =0.000*	-0.647 *p =0.000*

Hypothesis 1. Is there a negative relationship between appraisal cost plus prevention cost and failure cost?

Table 1 indicates that there is a negative relationship between appraisal cost plus prevention cost and failure cost for material, labor and company. The Pearson Correlation Coefficient for material, labor, and company is –0.629 (*p =0.000*), -0.522 (*p = 0.000*), and –0.537 (*p = 0.000*), respectively. This means that when the appraisal cost and prevention cost increase, the failure cost decreases for material and labor. In other words, the failure cost will decline as a result of the company expends more budgets on appraisal and prevention activities for material and labor. However, at 95% confident interval, the relationship between appraisal cost plus prevention cost and failure cost for machine is not significance.

Hypothesis 2. Is there a positive relationship between appraisal cost plus prevention cost and quality?

The significant relationship between quality and the combination of appraisal cost and prevention cost for all elements are discovered. The correlation coefficient is 0.620 (*p = 0.000*), 0.574 (*p = 0.000*), 0.549 (*p = 0.000*), and 0.565 (*p = 0.000*) for material, labor, machine, and the company, respectively (Table 1). This implies that the level of quality is increased as a result of an escalating of appraisal cost and prevention cost for material, machine, and labor. Consequently, if a company expends additional of its budget on appraisal and prevention activities for material, the percent of raw material conformance will be improved. Likewise, as a company expends more of its budget on appraisal and prevention activities for labor and machine, the level of customer satisfaction and percent of machine availability are also increased. Accordingly, the level of quality for the company (% product conformance) will be improved as a result of an increasing of the appraisal cost and prevention cost for material, machine, and labor.

Hypothesis 3. Is there a negative relationship between failure cost and level of quality?

Comparable to the study conducted by Carr and Ponoemon [24] as well as Vincent, et al., [25] this research confirms that the failure cost has a negative relationship with quality for all elements. The correlation coefficient is -0.615 (*p = 0.000*) for material, -0.594 (*p = 0.003*) for machine, -0.654 (*p = 0.000*) for labor, and -0.647 (*p = 0.000*) for the company (Table 1). It can be concluded that there is an opposite relationship between level of quality and failure cost. This means that the level of quality will enhances as a result of a reduction of failure cost. Once a company obtains a high percent of raw material conformance, a large percent of machine availability, and a high level of customer satisfaction, these lead to decrease in scrap, rework, return, and customer complaints.

Despite the fact that all relationships are the similar trend for material, machine, labor, and the company, the degree of the relationships are slightly different. The research also finds that the relationship between failure cost and quality is the strongest one. Additionally, this study found that there are strong relationships between failure cost and quality for labor, material, and machine, in descending order.

The PAF Model Development

Since the PAF model provides a graphical representation of the relationships, it is employed to gain better understand of the result implication. The comparisons between the theoretical PAF model (Figure 1) with the PAF models for material (Figure 3), machine (Figure 4), labor (Figure 5) and the company (Figure 6) are performed in this section. The research shows that the shapes of the cost of quality curves are slightly different from the theoretical model (Figure 1). However, they behave in the same manner. In other words, the level of quality enhances and failure costs slightly decrease for all elements because of an increasing in prevention and appraisal costs.

For illustration, relating to material (Figure 3), if the company spends US$0.35 in appraisal and prevention activities, failure cost is around US$0.85, the total cost of quality is approximately US$1.20 (for a product value of US$1,000) and the quality is about 90% raw material conformance. In the case of the expenditures for appraisal and prevention activities raise to US$0.40, failure costs decrease roughly to US$0.60, the total cost of quality decrease to US$1.0 (for a product value of US$1,000) and the quality of material increases to roughly 94% raw material conformance. Moreover, if the company spends its budget on appraisal and prevention activities increase more than US $0.45, the failure cost slightly decrease (lesser than US$0.60) while the level of quality increase (greater than 94% raw material conformance). However, the total costs of quality continuously increase (larger than US$1.0). This circumstance implies that the minimum cost of quality for material input is found at approximately 94% of raw material conformance, or the expenses for the appraisal and prevention activities is at US$0.40 per US$1,000 product value. With respect to the PAF model for machine input, the corporation should invest US$0.25 per US$1,000 product value in appraisal and prevention actions, or 94.5% machine availability. Regarding to the labor input, the minimum cost of quality is found at 96% customer satisfaction, or US $0.22 per $US1,000 product value investments for appraisal and prevention activities. Regarding with the company, the expenditures in appraisal and prevention activities should be at US$0.90 per a product value of US$1,000. It can be concluded that the optimum point is found at this point.

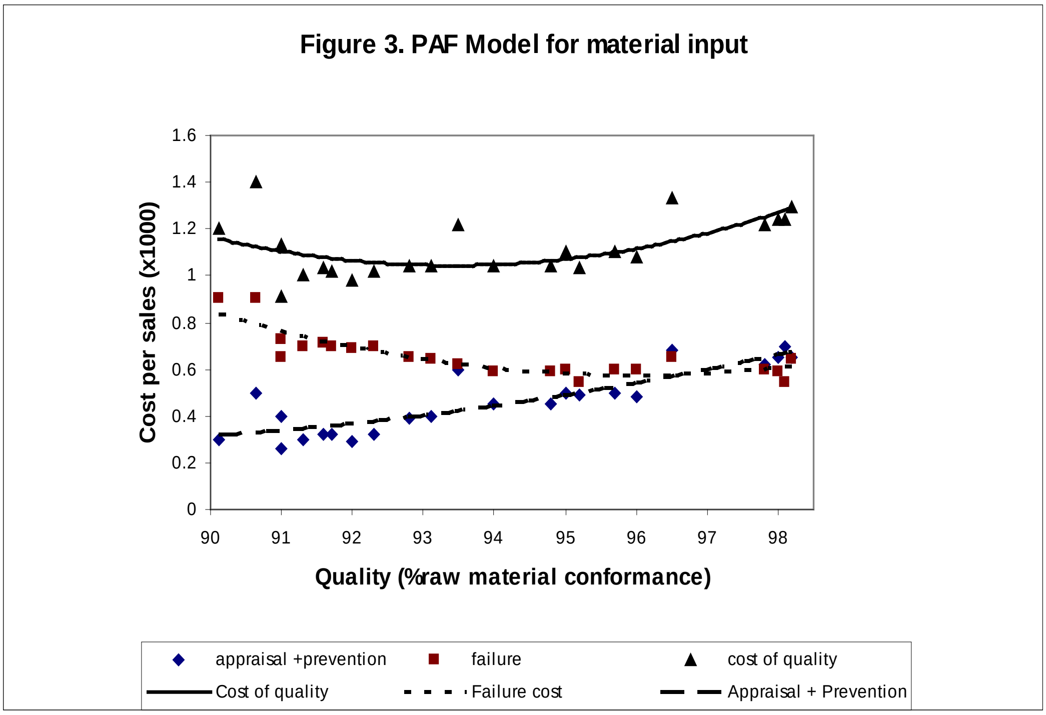

Figure 3. The PAF model for material input

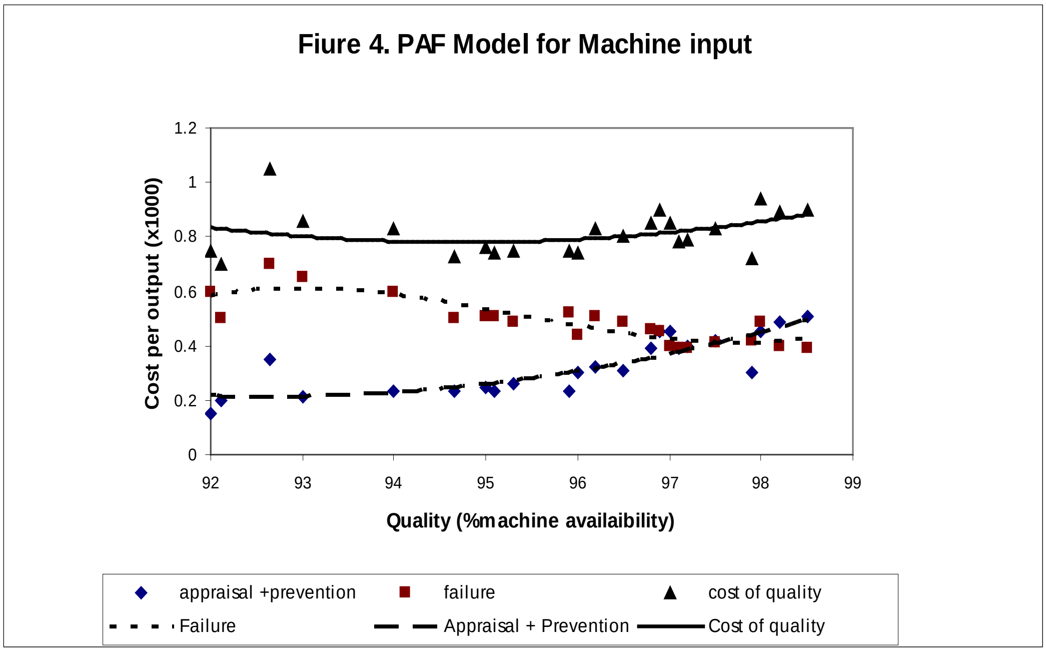

Figure 4. The PAF model for machine input

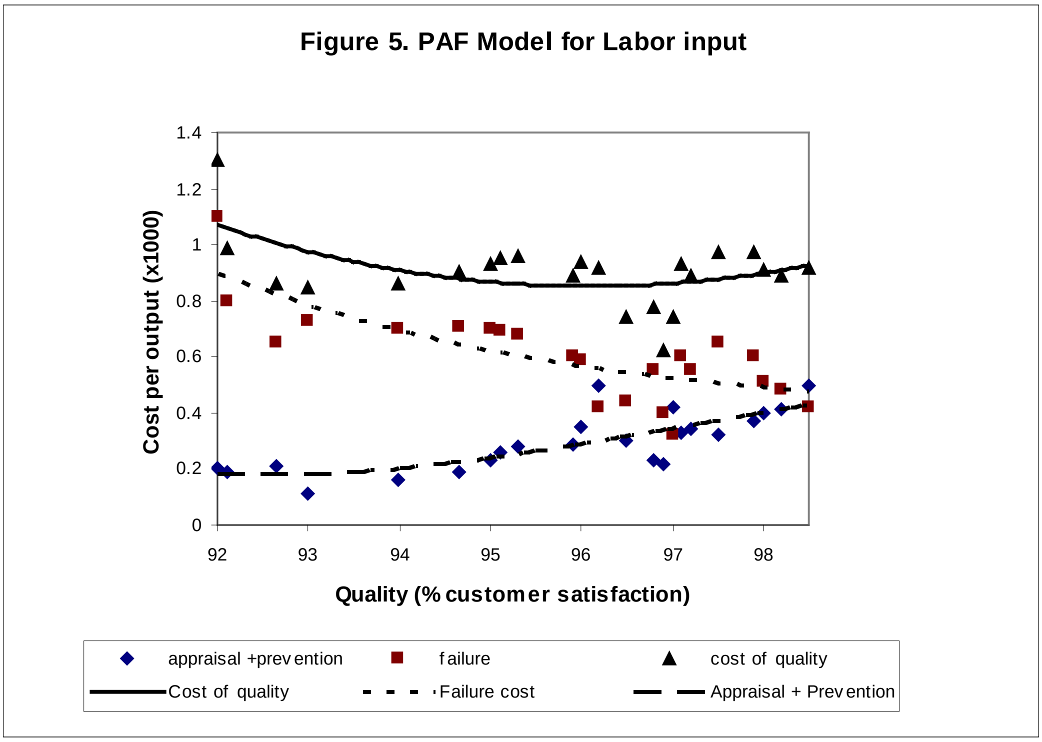

Figure 5. The PAF model for labor input

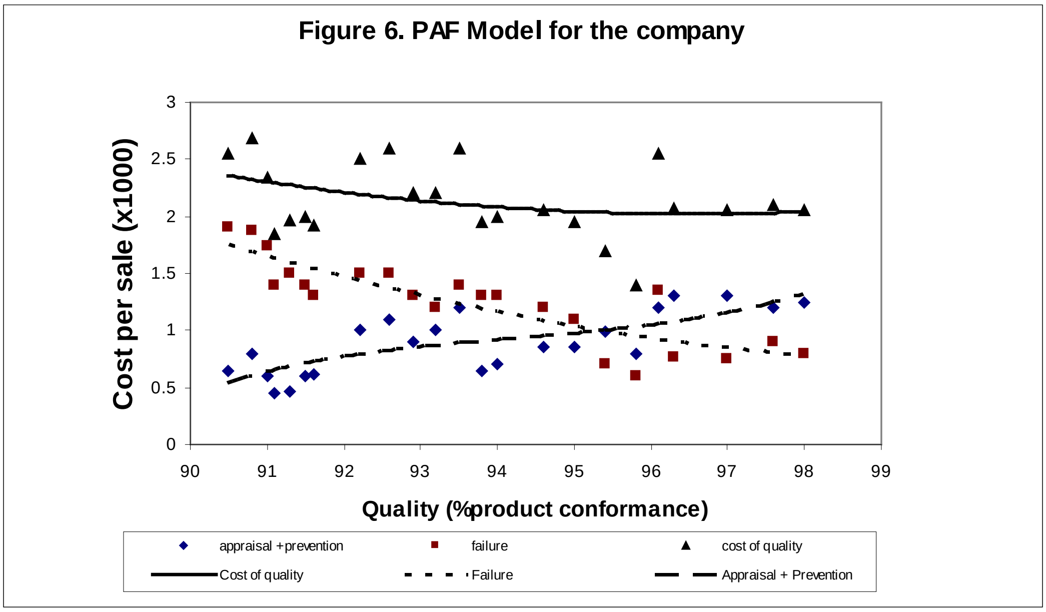

Figure 6. The PAF model for the company

Implementing the PAF Model: Implications for Decision-Making

With respect to this research, the PAF model is a management tool for decision-making concerning with the operations. In order to minimize the cost of quality, the levels of quality should be operated at 94% conformance for material (US$0.40 per US$1,000 product value should be invested in appraisal and prevention activities), 94.5% for machine availability (investment in appraisal and prevention activities are approximately US$0.25 per US$1,000 product value) and 96% for customer satisfaction (investment in appraisal and prevention activities per US$1,000 product value is US $0.22). With respect to a company, the PAF model suggests that the appropriate investment in appraisal and prevention is around US$ 0.90, at 97 % product conformance.

As discussed earlier, the management enables to use the PAF models to identify a proper level of investment required to achieve the desired level of quality. The training, redesign of products and processes, quality planning, and machine calibration are significance examples of the investments for prevention and appraisal activities. Especially, if a company expends more budgets in prevention activities (training, control of raw material, and preventive maintenance of machine), the level of quality is improved. Moreover, a level of product quality is improved due to a lower inspection level is required. In other words, this circumstance leads to reduce the appraisal cost. It is concluded that since the company increases both prevention cost and appraisal cost, the internal failure cost and external failure cost will be decreased because of fewer errors. The benefits from such investments are savings in the cost of poor quality, and increases in sales revenue because of an enhancement in customer satisfaction, and increases in new customers.

Conclusions

The results confirm that as appraisal cost plus prevention cost increases, quality enhances and failure cost decreases. Under different operational environments, the shapes of the cost of quality curves could be different. Hence, in order to minimize cost of quality and to improve quality, the PAF model should be carefully considered. The results show as follows: (1) there is a negative relationship between appraisal cost plus prevention cost and failure cost for material, labor, and company; (2) there is a positive relationship between appraisal cost plus prevention cost and quality for all factors; (3) there is a negative relationship between failure cost and quality for all components; and (4) the PAF models suggest that a proper expenditure for appraisal and prevention activities for material, machine, and labor is US$0.40, US$0.25, and US$0.22 (per product value of US$1,000), respectively. This investment will lead to minimize the total cost of quality for the company. Understanding the cost of quality is extremely important in establishing a quality management strategy. After integrating the PAF model with the major operational inputs, the right amount of money to invest in quality assurance (appraisal and prevention activities) can be defined. Theoretically, the investment in quality assurance is based on the law of diminishing returns, that is, organizations should spend as much as on quality assurance is justified by the cost of the defects being repaired. When the cost of quality assurance exceeds the cost of the defect, the expenditures are too much.

With the exploring of the PAF model for material, machine, and labor inputs at a flower wholesale company, the management can use the results in developing a proper cost of quality strategy. To identify causes of problems and to pinpoint improvement priorities are other advantages of the cost of quality information. In summation, understanding cost of quality and the PAF model helps companies to develop quality management system as a useful tool that improves their products, service, as well as decreases cost of quality. This leverage is crucial in achieving the goals of a successful organization.

In reality, it is hoped that this research provides extended existing knowledge regarding cost of quality and quality. Concerning with this research, the cost of quality for other inputs was not included because they are accounted for only 6% of the total cost. Nevertheless, by including the cost of quality for other inputs for the study, the most favorable value for investment will be more precise than the one in this article. To expand more understanding in the field, three recommendations for further research are suggested: 1) a comparison of the PAF models for manufacturing and service sectors should be studied, 2) the PAF models for profit organization and non-profit organization ought to be explored and 3) other critical inputs, and such as energy input must be included in an analysis.

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