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Development of Quality Cost Models within a Supply Chain Environment

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Development of Quality Cost Models within a Supply Chain Environment

By

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Development of Quality Cost Models within a Supply Chain Environment

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DECLARATION OF CO-AUTHORSHIP / PREVIOUS PUBLICATION

I. Co-Authorship Declaration

I hereby declare that this dissertation incorporates material that is result of joint research, as follows: In all cases, the key ideas, primary contributions, data analysis and interpretation, were performed by the author, and the contribution of co- authors and Dr. Micheal Wang as advisor.

In chapter three, four and five Dr. Rieger Fritz has reviewed and provide feedback about the contents.

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Dissertation Chapter	Publication title/full citation	Publication status*
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ABSTRACT

Determining the quality cost is one of the best ways that can assist industrial or business organizations to know clearly the investment and return of their quality improvement efforts. The information provided by accurate quality cost calculation is also a significant tool that can assist our assessment of the effectiveness of quality management system, as well as identification of quality issues within the organization and creation of opportunities for improvement.

It has been noted that there is insufficient research regarding calculating cost of quality using a standard cost elements model .There is a need for a methodology to describe and develop a quality cost model using international standard.

The purpose of this research is to show the development of a quality cost model that includes all possible quality cost components such as Prevention, Appraisal and Failure (P.A.F). This research studies various quality cost models, based on reviewing and analyzing these models a generic quality cost model is developed. The proposed model can be used as a tool to calculate various quality costs. In addition, it is used to determine the most failure cost. A case study is used to validate the proposed model. In this case, the implementation shows that the model is able to identify and quantify the hidden cost related to the quality in products assembly plant. Also, it identify the potential improvement opportunities within the plant.

The expected significance of this research is to develop a quality cost model that can bring a light to the status of a quality system .The analysis of the outcome will be a significant management tool that helps to identify the non-value adding activities.

DEDICATION

To my parents, my wife, my children Lila, Omima, Sarah, Fatima, and Aisha,

My brothers and sisters, and all those who made this work possible

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1-1 Background

Quality improvement program such as total quality management (TQM) and six sigma are systematic approaches to solving production problem. There are many tools and techniques management can use in order to compete in market share .Cost of quality is just one of these tools. The main goal of quality management system and six sigma technique is customer satisfaction by providing a defect free product and reducing failure rate.

Manufacturing a quality product, providing a quality service or doing a good job with a high degree of customer satisfaction is not enough. The cost of achieving these goals must be known. For all successful organizations, making the customer accept and buy its product is not an easy job. They need to work harder to design a quality system for the whole organization and also they need to spend a lot of money to make sure that every process during the production line is within the required standard. At the end, the goods or the service must meet the customer requirements. On the hand, organizations want to get some profit from its business. As they produce better products, they get a higher profit. So the logical questions here would be how much they should spend to meet the customer's expectations and at the same time make a profit. This is because it is not reasonable to say that the organizations have to spend money to make excellent goods without focusing on how they can get back the money that they have already spent during the manufacturing process. If they don't take this into account they may lose their business. Determining the cost of quality is one of the best ways that help the organizations to know clearly about how much they spend on each product and what is the balance between quality and cost.

1-2 Motivation

In response to the growing competition many manufactures have been forced to reassess their quality and production system and search for new ways to produce higher quality products while reducing operating costs. Adopting and implementing quality costing program is one of the tools manufacturers can use to achieve these goals. Quality costing is a measurement of improving quality performance. Cost of quality is generally believed to be one of the powerful methods to evaluate the customer satisfaction and helps justify and steer investment in preventing activities which lower the entire cost of the company.

It has been noted that there has been insufficient research regarding the modeling of quality cost. There is a need for a methodology to describe and develop quality cost model to measures the improvement process.

1-3 Objective and problem statement

Many companies are promoting quality as the central customer value and regard it as a key concept of their strategy in order to achieve the competitive edge. Measuring and reporting quality cost is the first step in quality improvement programs.

The objective of this research is to develop a quality cost model that would include all possible cost elements using British standard as cost guidance .The analysis of the results will bring a light about the status of a quality system .Also it will help determining the problem area, opportunities, saving and action priorities and the most effective factor of failure cost on total quality cost.

1-4 Research scope and limitations

The scope of this research focuses on measuring and collecting quality costs that associated within any business process in a manner consistent with the pursuit of continuous improvement and concept of total quality management and lean manufacturing. The cost model represented the only costs elements that listed in the British standard.

1-5 Organization of the dissertation

The dissertation is arranged as follows, chapter one presents the introduction and the objective of this research. In chapter two literature survey is discussed. Then the proposed quality cost methodology has been described in chapter three. A case study has been implemented to validate the model in chapter four. Chapter five presents the cost analysis and conclusions and future recommendations is discussed in chapter six.

Chapter 2 Literature Survey

2-1 Introduction to Quality Cost Development.

One of the earliest writings pertaining to the general concept of cost of quality can be found in Dr. J.M. Juran's first quality control book (1951) chapter 1, " The Economics of quality" most other papers and articles of that time dealt with more narrow economic applications. Among the earliest articles on quality cost system is Dr. W. J Masser's 1957 "the quality manager and quality cost". In 1963 the U.S Department of Defence issued MIL-Q-9858 A, a quality program requirement, making cost of quality a requirement for many Government contractors .This document helped to focus attention on the implementation of cost of quality measurement. In 1967, ASQ quality cost committee published "Quality Costs –what and how to detail what should be contained in a quality cost program. Moen (1998) proposed an approach focusing on customer requirements for computing the cost of poor quality of the manufactured product. He divided poor quality cost into two groups: direct poor quality cost and indirect poor quality cost. Direct poor quality costs are costs that are directly perceived and both internally (before shipment) and externally (after shipment) by the company. The composition of this direct poor quality cost is made up by direct failure cost, consequence cost and lack of process efficiency cost. Taguchi's loss function is used for estimation of direct failure cost, Activity Based Costing (ABC) is used for the consequence cost, and comparing to the main competitors or to theoretical performance or using competitive/functional benchmarking is used for the lack of process efficiency cost. The indirect poor quality cost contains three categories: customer incurred cost, intangible cost and environmental cost. DeFeo (2001) presented four majors steps in measuring the cost of poor quality: (1) identify activities resulting from poor quality;(2)

decide how to estimate cost; (3) collect data and estimate cost; (4) analyze results and decide on next step. In the identification of the activities step, he suggested using keywords such as rework, waste, fix, return, scrap, complaint, repair, expedite, adjust, refund, penalty, waiting, and excess. In second step, two strategies for estimating costs can be used both individually and together: the total resource approach and unit cost approach. He also proposed to collect personal opinions and judgment about the relative magnitude of time spent or costs for poor quality in addition to generally recorded data. At the final step, the result of cost of poor quality estimation can be adopted for further activities such as making decision in selecting the quality improvement project and identifying the most costly aspects of a specific problem. Williams and Amber (2002) determined the way to solve the tradeoff between the protecting customers from a failure product and controlling manufacturing cost by developing the mathematical cost model. They considered and minimized the cost of overall manufacturing test that are comprised of the cost of the testing in the manufacturing process and the cost of the test escapes. The cost of test escape in their research has been assembled from the cost of repair failure product and cost to the cost that customers experience. Oppermann Ele (2003) put an effort into decreasing quality cost of an electronic production by using a mathematical model of quality cost consisting of defect subsequent cost, inspection cost and rejection cost as a measurement system in the selection of the inspection strategies (no inspection/statistical process control (SPC)/100% inspection) for different technological processes. Chen and Tsou (2003) developed the economically mathematical model, which works on the process of quality improvement to maximize net earnings. The model was established using the function of sale increased by quality investment. Shiau (2003) established the methodology for decision-making support in allocating inspection stations in a manufacturing system that produces products with rapidly changing customer requirements. The criterion in his research was the minimum unit cost of the product sold to the customer. The unit cost contains the cost of manufacturing the products, cost of inspection and cost of nonconforming product (i.e., rework cost, discard cost, replacement cost, repair cost and quality loss cost). He calculated quality loss cost by employing Taguchi's quadratic loss function. Duffuaa (2004) improved the quality of a chemical process by reducing process variability with respect to saving manufacturing cost. They calculated cost of poor quality by adopting Taguchi's quadratic loss function. The Taguchi's quality engineering was integrated with statistical process control (SPC), engineering process control (EPC) to find the optimum point at which corrective action should be taken after the output variables deviate from the target. Their case study results showed the significant percentage of saving of poor quality loss. Sharma (2005) presented the method in estimation of cost of poor quality used for prioritizing Six Sigma project. He tried to solve the shortcoming of inadequate measurement at the initial of the project. His approach was performed by deployment of FMEA. The estimated cost of poor quality of failure was calculated from risk priority number, average cost to resolve failure, effort hours to resolve failure and the potential reduction in failure. Khataie (2013) introduces a novel cost of quality (COQ) decision support model (DSM), which can help management to track the effect of changing each incorporated value added (VA) and non-value added (NVA) activity on each other's cost as well as on the quality costs in real time. Heravi (2014) explained how to achieve a balance between the desired level of quality and the expenses associated with it.

2-2 Quality Cost Definitions

A cost of quality defined in BS 54778: Part 2 BS 6143 Part 1 and 2 and as “The expenditure incurred by the producer, by the user, by the community associated with product or service”. Quality related cost is defined in BS 4778: as “the expenditure incurred in defect prevention and appraisal activities plus losses due the internal and external failure”.

The definition of cost quality has been changing in recent years. In early 1980, the cost of quality were perceived as the cost of running the quality assurance department , plus scrap, rework , testing and warranty costs , it is now widely accepted that they are the cost incurred in the design , implementation , operation and maintenance of an organization’s quality management system. Although , like many terms in Industrial Engineering there is no specific definition for quality costing and most the writers are in disagreement on what should be included in quality costing definition . Barrier (2002) noted that cost of quality refers just to cost of non-conformance. Crosby (1986) stated that “quality costing is the price of non-conformance or the price of poor quality. The ASQ Quality Costs Committee (2013) stated that the "cost of quality" isn't the price of creating a quality product or service. It's the cost of not creating a quality product or service. Every time work is redone, the cost of quality increases.

2-3 Review of Cost of Quality Models

Many authors have developed quality costs models. These models are categorized according to various parameters as shown in Table 1 and 2.

Table 1 Classified quality costs approach

Category	Concept	Publications developing or dealing with the model
Based on the relation between cost of quality and quality level	Cost of quality decrease with higher quality level.	Wasserman and lindland 1997, Sower et al., 2007, Kim and Nakhai, 2008, Walid Abdul-kader ,Ozhand Ganjavi and Solaiman 2010, Mohamed Khaled Omar and Sharmeeni Murgan 2013.
Based on type of industry	Cost of quality are more popularly implemented in manufacturing as compared to service industry	Bamford and land 2006, Tiwari el al. 2007 Ramdeen et al. 2007,Green and Trevor 2007, Keqin Ai 2014
Based on Quality metrics	The relation between cost of quality and six sigma, knowledge management, supply chain and other tools are very effective	Rajiv Kumarma and Dinesh Kumar 2007 Steve Eldridge and Mohammed Balubaid 2008 Rodin Wayne 2013 , Guangyu Mu 2013.

The other category is based on the interrelationship between costs components. Cost of quality can be classified into four groups of generic models. These are P-A-F (Prevention, appraisal, failure) or Crosby's model, opportunity cost models process cost model, ABC (activities based costing) models and Taguchi loss Function model.

Table 2 Generic cost of quality models and cost categories

Generic Model	Cost /activity categories	Publications developing or dealing with the model
P-A-F	Prevention + appraisal +failure.	Feigenbaum (1956), Purgslove and Dale (1995), Merino (1988), Chang et al. (1996), Sorqvist (1997), Purgslove and Dale (1995), Tatikonda and Tatikonda (1996), Bottorff (1997), Israeli and Fisher (1991), Gupta and Campbell (1995), Burgess (1996), Dawes (1989), Sumanth and Arora (1992), Morse (1983), Weheba and Elshennawy (2004), etc.
Crosby's Model	Conformance + non-conformance	Suminsky 1994, Denton and Kowalski 1988
Opportunity or Intangible cost Model	Prevention, appraisal, Failure opportunity	Sandoval –Chavez and Beruvides 1998, Modarres and Ansari 1987, Carr (1992), Malchi and McGurk (2001), Alzaman et al. (2010), Ramudhin et al. (2008)
	Conformance and non conformance opportunity	Carr 1992 , Malchi and Mc Gurk 2001
	Tangible + intangible	Juan 1975

ABC Model	Value –added + non-value added	Cooper,1989, Tasi 1998 Enkerlin 1992 Cooper (1988), Cooper and Kaplan (1988), Tsai (1998), Jorgenson and Enkerlin (1992), Dawes and Siff (1993), Hester (1993), Feng et al. (1996), Qian and Ben-Arieh (2008), Zhang and Fuh (1998), Ben-Arieh and Qian (2003), Ou-yang and Lin (1997), Park and Kim (1995), Lewis (1995), Ozbayrak et al. (2004), Park and Simpson (2005), Chen and Wang(2007), Tornberg et al. (2002), Tseng and Jiang (2000), H'Mida et al. (2006), Cooper et al. (1992), Ong (1995), Aderoba (1997), Niazi et al. (2006), Creese et al. (1992), Khataie and Bulgak (2013)
Taguchi loss function model	Loss of sales revenue due to poor quality + process inefficiencies + losses when a quality characteristic deviates from a target	Soumaya and Jacqueline (1998), Chin-C et al. (1998), Jia (2007), Johannes (2008), Naidu (2008)

Source: Adopted from Schiffauerova and Thomson (2006)

2-3-1 P-A-F Model concept

Most cost of quality models are based on P-A-F classification. This model Classified cost of quality into four categories:

1-Prevention cost:

The cost of all activities specifically designed to prevent poor quality in products or services, for example the cost of new product review, quality planning, quality improvement and quality training.

2-Appraisal cost:

The cost associated with measuring, evaluating or auditing products or service to make sure everything is in conformance to quality standard and performance requirement. These costs include the costs of calibration of measuring and test equipment and the cost of associated suppliers and materials.

Internal failure costs:

The costs that occur before delivering the product to the customer. These costs usually happen on the production line for example, in scrap, rework, testing and material review.

External failure costs:

The costs occurring after delivering the product to the customer, for example, product recalls, warranty claims, customer's returns.

3- P-A-F Model curves

The prevention and appraisal cost are considering to be controllable quality cost while the internal and external failure costs are uncontrollable. Figure 2 shows the relationship between the controllable costs and uncontrollable costs.

As the controllable costs of prevention and appraisal costs increase, the uncontrollable costs of internal and external failure decrease. At some point the cost of prevention and appraisal defects exceeds the cost of correcting for product failure. This point is the optimum quality cost point. There are some elements called indirect quality cost for example customers dissatisfaction cost.

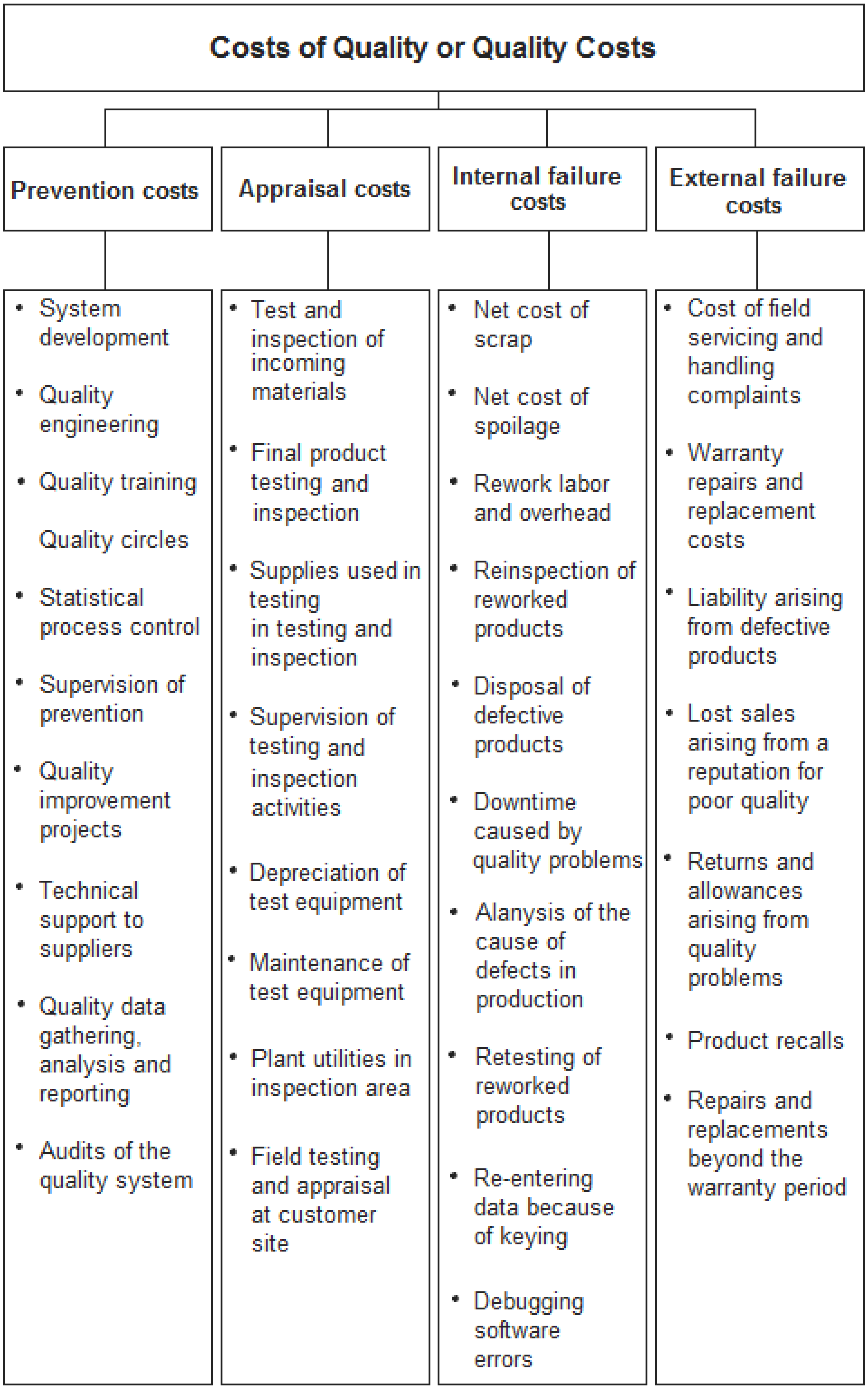
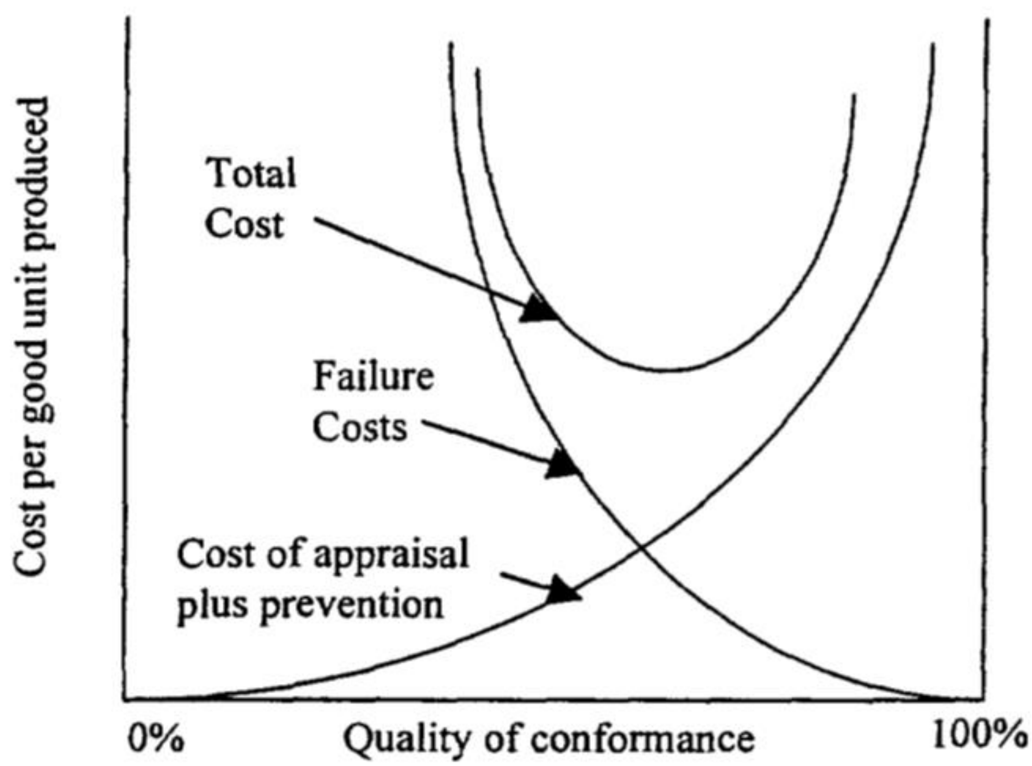


Figure 1 quality cost elements

These costs are high when the defect level is high. These costs are affecting the total quality cost. As shown by figure 2 the optimum point has moved to the right which indicates the need for a lower product defect level. A lower product defect level can be obtained by increasing the prevention and appraisal costs, which subsequently lowers the external failure costs.

2-3-2 Crosby's quality cost Model concept

Crosby defines the cost of quality as "the sum of price of conformance and price of non-conformance (Crosby, 1975). The price of conformance is the cost involved in producing a good quality in the first time. The price of non-conformance is the money wasted when the products or the services fail to meet the standard.



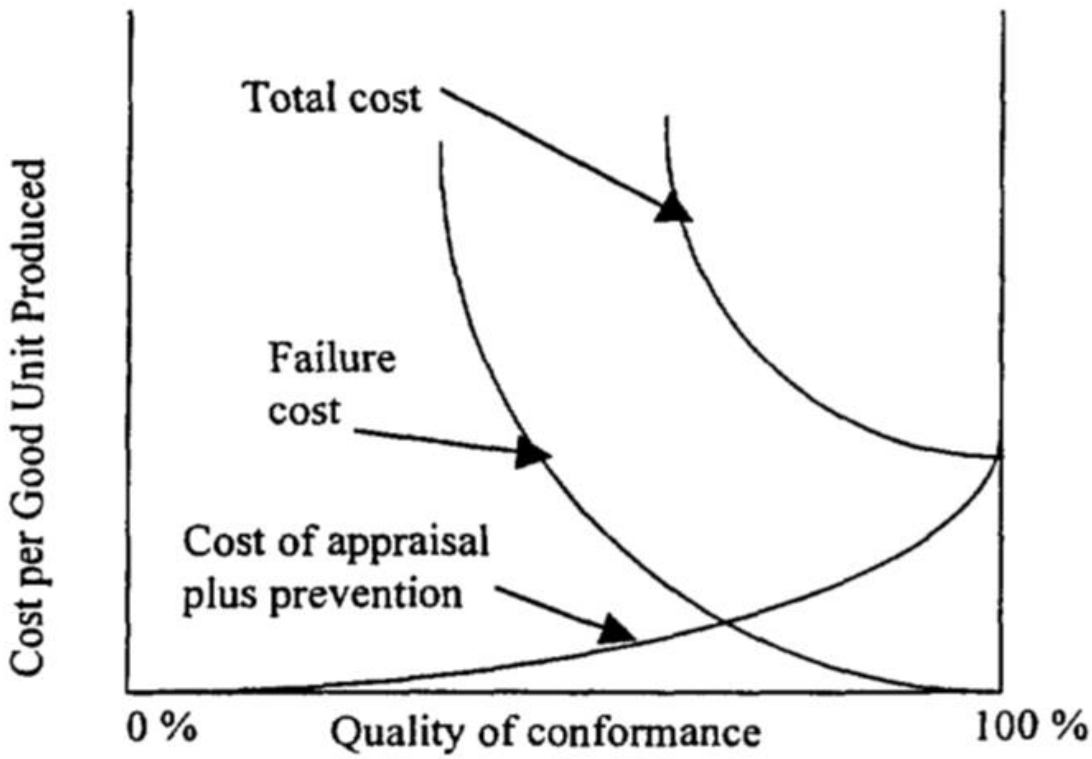


Figure 2 Juran's Model Revised (Juran and Gryna, 1993)

2-3-3 Opportunity and intangible costs concept

Intangible costs are costs that can be only estimated for example profit not earned losses in productivity, customer goodwill or drops in employee morale. While these costs do not have a firm value, managers often attempt to estimate the impact of the intangible costs

2-3-4 ABC Model concept

This model was developed by Coop (1980) .Under this model, accurate costs for various cost objects are achieved by tracing resource costs to their respective activities and the cost of activities to cost objects.

2-4 Economics cost Model

Quality costs have been covered under the broad headings of financial measures and evaluation of quality management practices. Most of the studies considered quality costs as an integral part of the quality system. In addition, there are numerous economics cost models have applied operation research techniques or simulation approach to estimate the quality cost. However, all these models deal with the subject as integrated cost model. Since all the cost components are integrated into single model. Both the associated manufacturing cost and quality losses are considered during model development.

2-5 Manufacturing cost model

Manufacturing Cost defined as the expenses assigned to specific convert or raw materials into products. In order to estimate the selling price all the following costs and the margins must be determined. The traditional cost and price structure for a manufactured product is shown in figure3 and 4. Prime cost is the sum of direct labor and direct material. Prime cost when summed manufacturing overhead yields factory cost or cost of goods manufactured. The total product cost is obtained by adding selling expense, general and administration expense, and contingencies to the factory cost.

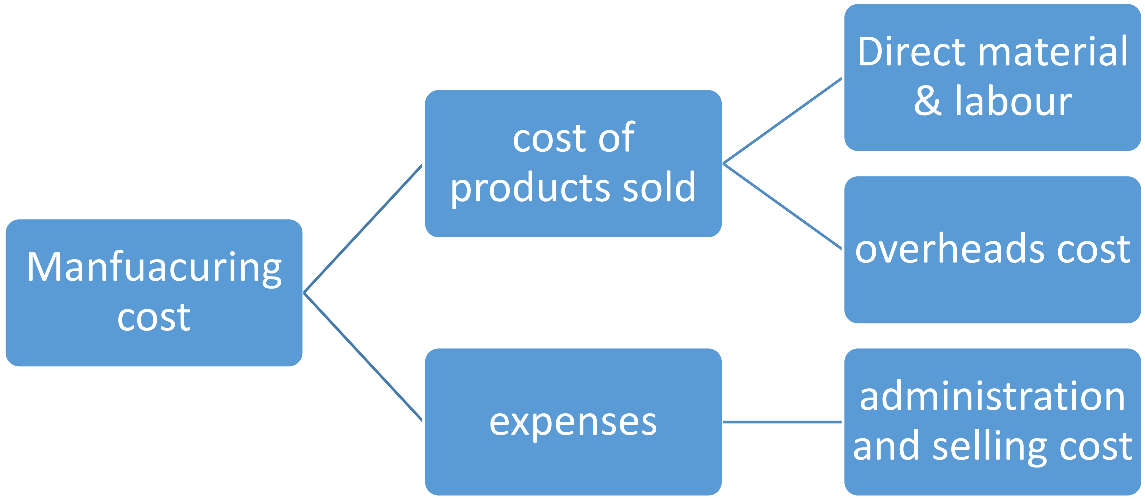


Figure 3 Components of manufacturing cost

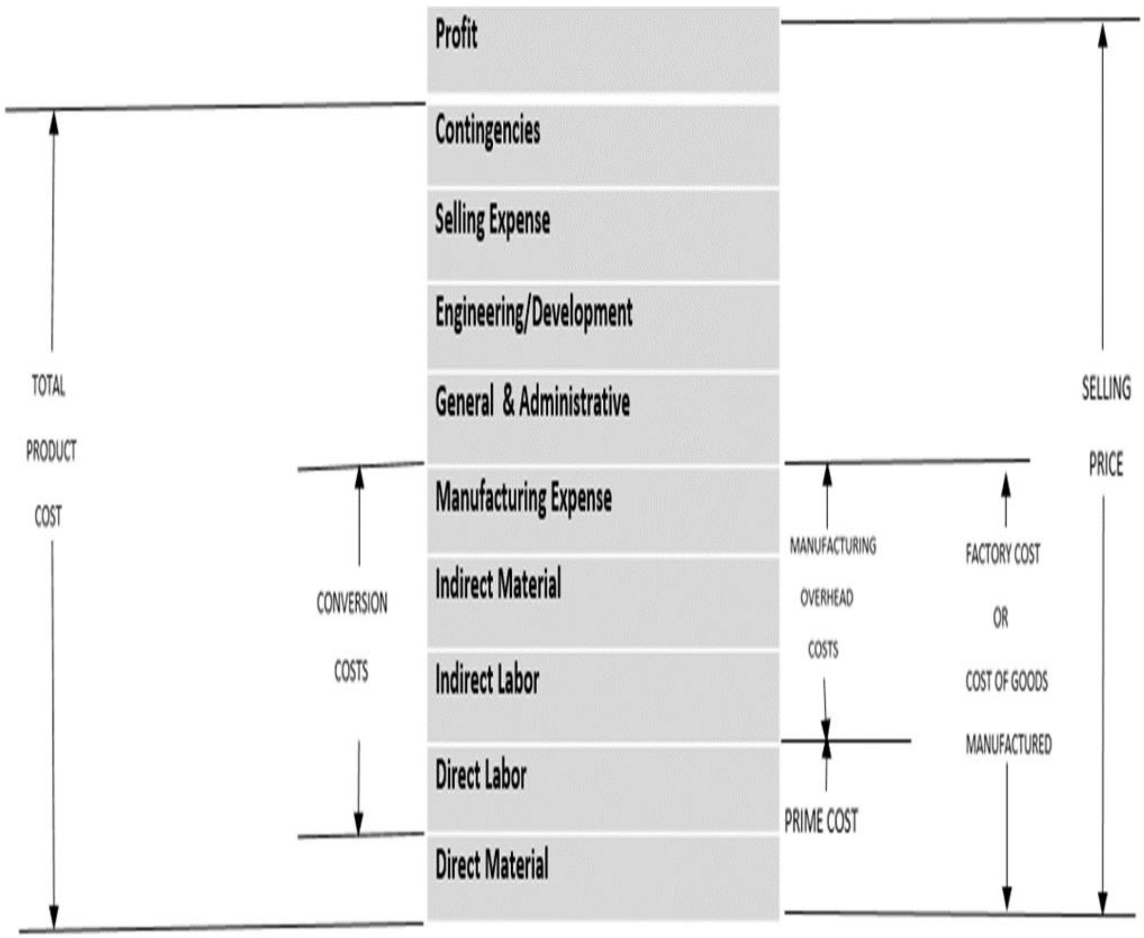


Figure 4 Manufacturing cost/price relationships

1-Material cost is the cost of raw material required to manufacturing process

Material cost =direct material cost + indirect material cost + extra cost due to defective product

2-Labour cost is the cost of direct labour and indirect labour involved in the production activities and included wages and salaries.

Cost of labour = direct labour cost incurring from operation normal unit + direct labour cost incurring from operation rework unit + indirect labour cost

3-Machine and set-up cost .it included all the costs related to running the manufacturing machine and the cost of preparing and setup the machine.

In addition, material handling cost should be added to this category.

All these three costs are the major components of any cost model. Some researchers may add another or remove cost elements.

Manufacturing cost model = labour cost + material cost +machine cost set-up cost

+ Material handling cost.

This manufacturing cost model does not express the issues of the quality or shows any opportunities for improvement. It just helps the manufacturer to know how much it cost to produce one unit. Also it will assist to estimate the margins profit.

2-6 Cost of quality and accounting system

Unfortunately accounting systems do not have the ability to measure cost of quality .They were not designed to demonstrate the impact of the quality of performance on overall operating costs. That is why some of costs have remained hidden. However, the support of the accounting system is vital whenever financial and accounting matters are involved. In fact, the accounting department is responsible for any accounting matters, including cost of quality systems. The role of the quality department is to provide guidance and support to the accounting department. The cost of quality system must be integrated into the accounting system. This will speed the learning process and reduce confusion. Ideally, the cost of quality will be so fully integrated into the cost accounting system that it will not be viewed as a separate accounting system at all, it will be a routine part of cost reporting and reduction.

The ideal cost of quality accounting system will simply aggregate quality costs to enhance their visibility to management and facilitate efforts to reduce them.

2-7 Benefits of quality improvement

Poor quality of products and processes has direct impact on the finance of the company in both the company's top line (revenues) and its bottom line (profits). During development, i.e., the design and manufacturing phase (as depicted in Figure 4), poor quality causes late delivery, added test time, added development time to correct problems found, and additional people being added to try to overcome the problems encountered. This adds significantly to development costs, reducing the bottom line. Once poor quality products are delivered to customers, word of that poor quality quickly spreads, and results in reduced sales, from some who will return products they are not satisfied with, and from others who will never buy a poor quality product in the first place. This reduces ongoing revenues, often significantly, thus impacting both the top and bottom lines. With poor quality product in the field, customer support issues will quickly grow, and this will in turn require additional engineering support people to be assigned. These added support and engineering costs would add to development costs, often for prolonged periods of time, further reducing the bottom line. Poor quality products also imply a poor quality company, affecting the reputation of the company.

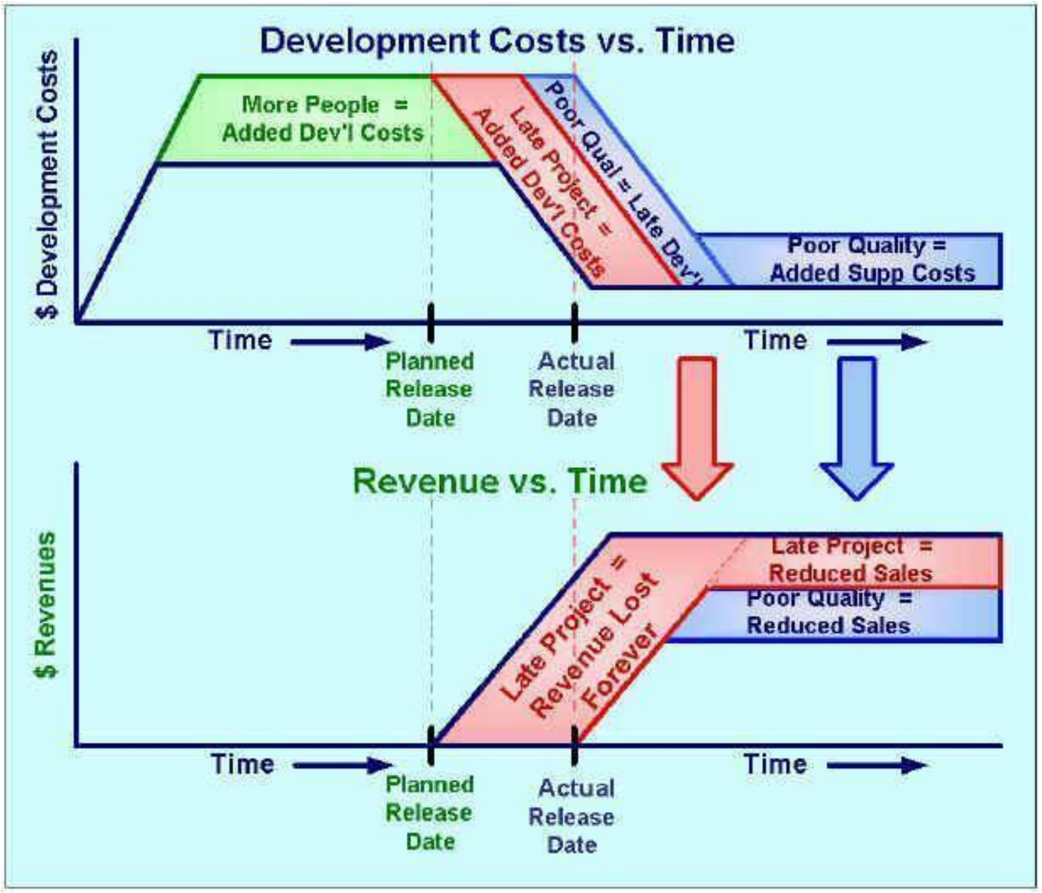


Figure 5 Effect of poor quality on financial benefits

With the fact that poor quality products tremendously affect monetary benefits, many companies consider quality improvement as one of the most important business strategies and adopt quality improvement program into their organization.

2-8 the significance of quality cost

Measuring cost of quality can enable companies to know the impact of their quality systems on business performances. One of the reasons for tracking cost of quality is to translate the Quality issues like number of defective parts to the language of dollars that management use. This information will make it easier for the company in the budgeting process and cost control (Evans and Lindsay 2002). Also it will help focusing on areas of high expenditure and wastage and identifies potential problem area, cost reduction and improvement opportunities. Juran and Godfery (1999) stated that the objective of identification and measurement in cost associated with poor quality are:

- To quantify the size of quality problem in terms of money
- To identify the opportunities for reduction in cost of poor quality
- To identify the opportunities for customer satisfaction and associated threats to sale revenues
- To provide a means of tracking the progress and results of quality improvement activities
- To adjust quality goals with other organization goals.

Chapter 3 Proposed Quality Cost Model Methodology

3-1 Introduction

Traditionally quality performance has been reported to management in terms of rejection and defective products reports. This vital information is often difficult to analyze and interpret in terms of cost. As a result. Cost saving opportunities may be overlooked. Successful business requires financial planning and control. It is advisable that quality failure be presented in financial terms.

3-2 Quality Cost Model

The model is based on BS 6143 standard and targeted to identify the opportunities for cost reduction by focus on failure costs in attempt to drive them to zero also to invest in the prevention activities in order to reduce the appraisal cost.

The proposed model goes through a series of steps:

1- Select a process and define its boundaries.

2- Specify resources and the date needed.

3- Collect the costs of each process using the BS6143 as guide of quality costs and the proposed Mathematical models Eq1 to Eq13 which represent the elements of quality cost.

4- Analyze the result and implement the improvement.

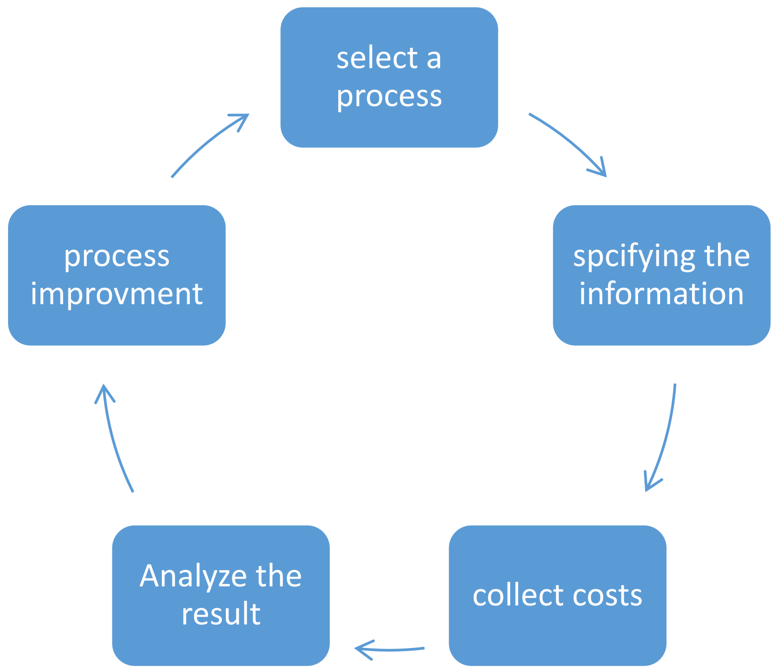


Figure 6 Quality cost model

3-3 The objective of the proposed quality cost model are:

1- Quantify the size of quality problem in language that will have impact on upper management.
2- Identify major opportunities for cost reduction.
3- Identify opportunities for reducing customer dissatisfaction and associated threats to produce salability.
4- Expand budgetary and cost controls.

3-4 the steps of implementing the model

A quality model process goes through many steps as shown in figure 3;

1-Choose a process to be analyzed. It would be much better if the model is applied primary to a specific area such as a production line or a department. So, we have opportunity to solve any issues which may occur in the quality cost calculation before implementing in the entire factory.

2- Define the process and its boundaries. In this step, the study areas (production line, department) is divided into sub area to make it the cost collection easier.

3 - Flowchart the process and identify the input and the output. In this step a flowchart is used to illustrate the various operation, which is a method of describing a process in picture.

4- Cost collection. When the study area is determined and flowchart is prepared the cost collection process then start. It would be useful if a guide of cost elements is prepared prior to collection process. The collection process requires cooperation and participation from all departments in the organization especially from quality control department and account department. This step consists of two phases:

A**)** Specifying the information resources

In this phrase information sources are determined whether it's direct from department and units or indirect by questionnaire (oral, written)

B) Coding

To make it easier to collect the various cost, a coding system is used which will divide the cost into number of categories and each category will have a code represent the costs as follows:

Prevention cost [A]

Appraisal cost [B]

Internal failure cost [C]

External failure cost [D]

A number is added to the code to show the sub costs of each element for example

(A1) means quality planning

(B6) final inspection

The letter (A) is coding to prevention costs

The coding system has many advantages such as:

1-It distinguishes between various costs.

2-Easier the collecting process.

5- COST CALCULATION

Prevention cost: these costs mainly occurs with the quality control activities department

These costs depend on the estimation of the time that spent on these activities

QEC: Quality engineering cost. These costs are including the activities related to quality plans.

X_1 = Number of employees responsible on quality function

X_2 = Number of working hours.

X_3 = Percentage of the time developed to this activity.

X_4 = Average salaries.

$$QEC = \left(\frac{X_4}{X_2}\right)\prod_{i=1}^{3} Xi \qquad (1)$$

CMC: maintenance and calibration of production equipment used to evaluate quality**.**

These are the costs of maintenance and calibration

X_5 = The cost of maintenance and calibration of equipment.

X_6 = Number of equipment.

$$CMC = \prod_{i=5}^{6} Xi \quad (2)$$

SQC: Supplier quality assurance**.** These are the costs of any activities that confirm the quality of the supplier

$$SQC = \prod_{i=7}^{8} Xi \quad (3)$$

X_7 = Number of employees.

X_8 = Average salaries.

TQC: Training. These are the costs of any quality training programs.

X_9 = Number of training staff.

X_{10} = The cost of one hour training.

X_{11} = Number of hours spent on training.

X_{12} = The cost of training material.

X_{13} =The cost of external training.

$$TQC = \prod_{i=9}^{11} Xi + (X_{12} + X_{13}) \quad (4)$$

AQC: Audit. These costs are including the activities related to the auditing of the quality system

X_{14} = Number of auditors.

X_{15} = Number of visits.

X_{16} = The number of hours in one visit.

X_{17} = Average salaries.

X_{18} =Number of working hours in a month.

$$AQC = \left(\frac{X_{17}}{X_{18}}\right)\prod_{i=14}^{16} X_i \quad (5)$$

APPRAISAL COST these costs associated with the quality control activities such as measuring, and evaluating the quality system

LAC: Laboratory acceptance testing**.** These costs associated with inspection of any new material

X_{19} = The cost of the lot.

X_{20} = Percentage of the cost of the lot.

$$LAC = \prod_{i=19}^{20} X_i \quad (6)$$

INC: Inspection and test**.** These costs associated with the inspection process

X_{21} = Number of full time employees.

X_{22} = Average salaries.

X_{23} = Number of senior staff.

X_{24} = Number of working hour.

X_{25} =The percentage of the time spent on performing this element.

X_{26} = Average salaries.

$$INC = \prod_{i=21}^{22} Xi + \left(\frac{X_{26}}{X_{24}}\right) \prod_{i=23}^{25} Xi \quad (7)$$

IPC: In-process inspection (non-inspectors). These costs associated with the inspection process during the production line

X_{27} = Number of employees.

X_{28} = Number of working hour.

X_{29} = The percentage of the time spent on performing this element.

X_{30} = Average salaries.

$$IPC = \left(\frac{X_{30}}{X_{28}}\right) \prod_{i=27}^{29} Xi \quad (8)$$

RTC: Review of test and inspection. This cost included the cost of reviewing **and** checking the quality reports.

X_{31} = Number of seniors staff.

X_{32} = Number of working hour.

X_{33} = The percentage of the time spent on performing this element.

X_{34} = Average salaries.

X_{35} =Number of full time employees.

X_{36} = Average salaries.

$$RTC = \left(\frac{X_{34}}{X_{32}}\right) \prod_{i=31}^{33} Xi + \prod_{i=35}^{36} Xi \quad (9)$$

Internal Quality Cost l these costs resulting from product or services not conforming to requirement prior delivery to the customers.

SC: Scrap**.** These costs included the cost of the material, labor and overhead of any fail to confirm quality requirement

X_{37} = The value of the scrap.

X_{38} = The overhead cost.

$$SC = \prod_{i=37}^{38} Xi \qquad (10)$$

RRC: Rework and repair**.** These costs associated with any activity or rework or repair any failure

X_{39} = Number of employees.

X_{40} = Average salaries.

X_{41} = The total price of the units.

X_{42} = The labor cost.

$$RRC = \prod_{i=39}^{40} Xi + X_{41} + X_{42} \qquad (11)$$

External Failure cost. These costs included any failure cost may occur after delivering the product or the service to the customers.

CMC: Complaints. The cost of dealing with the customers complains such as investigating and solving any problem

X_{42} = Number of employees.

X_{43} = Number of working hour.

X_{44} = The percentage of the time spent on performing this element.

X_{45} = Average salaries

$$CMC = \left(\frac{X_{45}}{X_{43}}\right) \prod_{i=42}^{44} X i \qquad (12)$$

WRC: Warranty replacement the expenses of repairing the product during the warranty period.

X_{46} = Number of products

X_{47} = Price of the unit.

$$WRC = \prod_{i=46}^{47} X i \qquad (13)$$

Total quality cost

=QEC+MCC+SQC+QTC+LAC+INC+IPC+RTC+SC+RRC+CMC+WRC

Chapter 4 Case studies

4-1 Introduction

A case study has been done in a TV assembly factory located in Libya. The production process for the model (2931) has been chosen. It has the following production line:

1-Auto insertion stage,

2 -manual insertion stage

3- Final assembly stage.

The data collection was gathered from different departments. The BS6143 guide has been used to collect the costs. In order to achieve the most efficient quality costs, it was necessary to analyze the different quality costs (i.e. prevention cost, internal failure, etc.).

4-2 Field of the case study

The company started businesses as trading company in 1990 with the capital worth is ten million L.D. Its main business was importing and exporting electronic goods and service after sales throughout the country.

In 1996 the company developed its business after carrying out feasibility study in the Libyan market, which pointed out the need for producing TVs in Libya. Since then, the company grew as trading and industrial company.

In 1998 the company had received two plants, one of them in ELZAWIA to produce TV's and the another one in TAJORA to produce DVDs

The company now has another three plants:

1. Computer set plant in Tripoli.
2. PC board and speakers in ELMAYA.
3. Radio set plant in JADO.(closed since 2009)

The TV assembly factory

The factory produces TV sets. The product has a very good reputation in the market and gained customers satisfaction. The following points give more details about factory:

1. The factory started operation in 1998.
2. The total area 80,000m^2.
3. There are 570 employees.

The goal of the factory is to produce TV sets with high quality that satisfy the customer and meet his expectation and requirement. To achieve this goal a quality system has been applied through the following steps:

1. Prepared the factory to receive the ISO (9002)
2. Adopt the continuous improvement philosophy across all levels in the factory.
3. Each employee is responsible for the quality of his work.
4. The factory is committed not to use any material of product that may cause any environmental hazard.

4-3 Authorities and responsibility of the management

1. Selecting department's managers.
2. To draw the quality policy and objective.
3. Review and controlling quality system.

- Head of quality control department.

1. Design training program for and maintain the manpower assignment
2. Plan control quality activities.
3. Evaluating the production process.

- Head of production department.

1. Set up production plan for the factory according to objective.
2. Set up day to day production program.
3. Solving any problem that may occur in production line.

- Head of maintenance department.

1. Set up the maintenance department.
2. Provide the tools, equipment's and spare parts maintenance.

- Head of material department.

1. Inventory management and select the material handle equipment
2. Managing the material flow during the production system

- Head of management administration department.

1. Implement the labour laws. Figure 7 shows the organization structure.

4-4 The production system:

There are some steps that the factory proceed with before starting manufacturing:

- A one year plan based on the market need and the budget
- Discuss the specific needs and requirements.

- Place the order from outsources
- When the material arrival, the production process well then start. The factory applies batch production system by one shift a day to produce a specific amount according to the production plan through the following production lines.

1. Auto – insertion stage – one line.
2. The manual insertion stage – four lines.
3. Final assembly stage – four lines.

Each model must go through the three stages stated above.

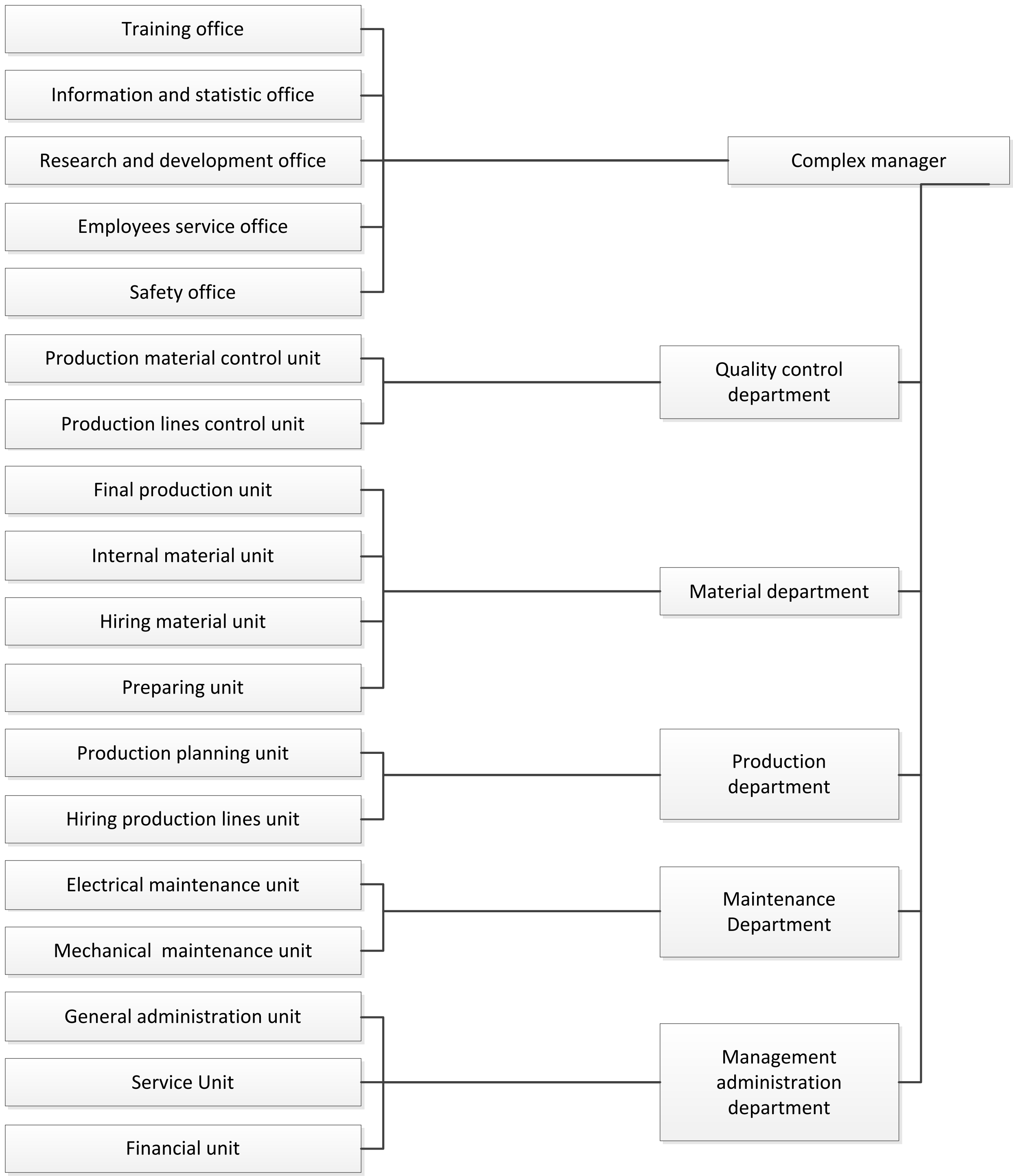


Figure 7 Organization structure

4-5 The Components of the TV'S

The TV is a device that combines a tuner, display, and speakers for the purpose of viewing television. It made of the following components as showed in table 3

Table 3 Components of T.V

PARTS	**SOURCE**
Plastic material	Local
PCB and speaker	PCB and speaker plant in ELMAYA
Electronic component	International companies
Wax	Local
Packaging the cover	Local

4-6 Material flow

The materials start move from the main storage to the auto insertion store, semi produced product store and a final assembly line on daily or weekly basis. The final product is stored in the finished product store. The figure 8 shows material flow.

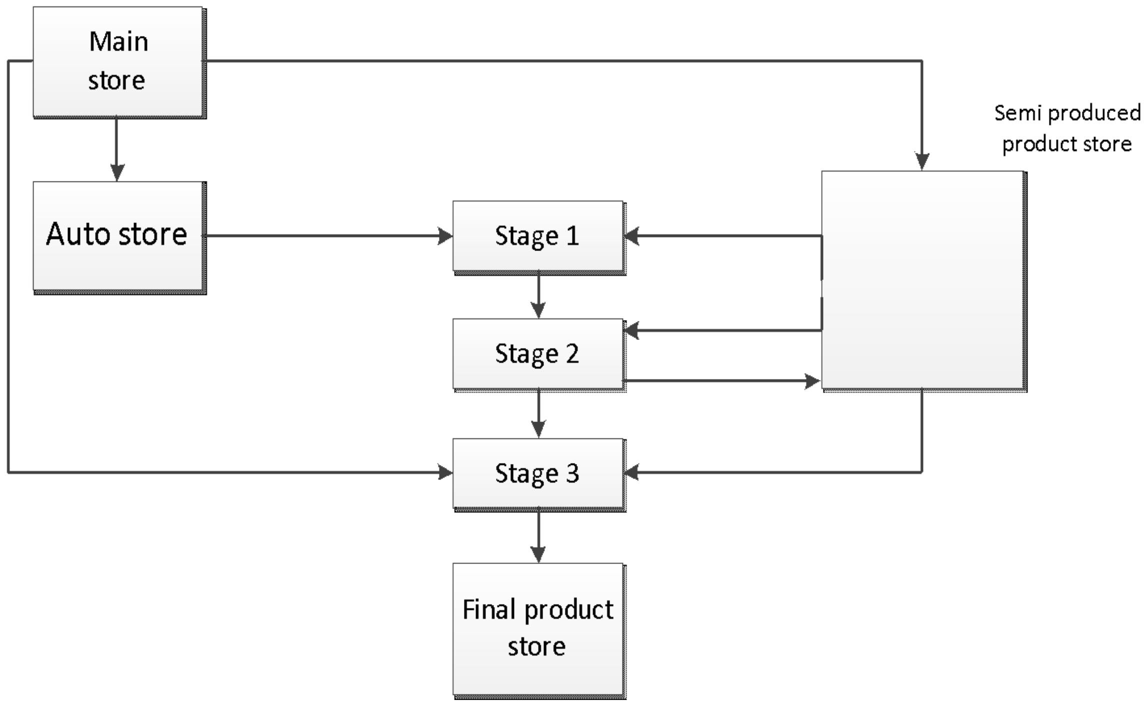


Figure 8 Material Flow in Production System

4-7 quality cost study at the factory

The factory has done some quality costing study to determine the quality issues in terms in money however, the following facts have raise:

- The study does not represent the real value of total quality costing to the top management; therefore, a corrective action could not be taken.
- It does not explore the opportunities for improvements which may be gained by identifying the high costs and the attempt to reduce it.

The following is an example of the quality costing system applied in the factory.

Table 4 Value and quantity of losses for 1st quarter of year 2009

NO.	**CODE NO.**	**DESCRIPTION**	**QUANTITY**	**PRICE**	**TOTAL**
1	14-26-	Screen	12	39.37	472.44 L.D
2	Main-1426	Main board	87	33.25	2892.75L.D
3	Speaker	Speakers	29	0.27	7.83 L.D
					3373.02L.D

Table 5 Model 2126

NO.	**CODE NO.**	**DESCRIPTION**	**QUANTITY**	**PRICE**	**TOTAL**
1	21-26-	Screen	2	33.25	66.50 L.D
2	Main-2126	Main board	26	27.78	722.28L.D
					788.78

Table 6 Value and quantity of losses due to after sales maintenance

NO.	**DESCRIPTION**	**QUANTITY**	**PRICE**	**TOTAL**
1	Screen 2850	2	62.59	125.18 L.D
2	Screen 1471	1	18.32	18.32 L.D
3	Screen 4500	1	49.58	49.58 L.D
4	Screen 2070	1	14.18	14.18 L.D
5	Deviation coil	46	0.22	10.12 L.D
6	Font frame 1471	1	9	9.00 L.D
7	Screen 2126	2	55.56	111.12 L.D
Total				337.50 L.D

Table 7 Summary of the losses quantity for the 1st Quarter of year 2009

NO.	MODEL	LOSSES	NOTES
1	1426	3372.43 L.D	
2	2126	788.77 L.D	
3	After sale maintenance	337.50 L.D	
Total losses		4498.70 D.L.	

Table 8 The quantity of used material maintenance during 1st Quarter of year 2009

NO.	CODE NO.	QUANTITY	UNIT PRICE	TOTAL
1	14-1204-001191	100	4.6061	460.61L.D
2	14-aa13-30017D	100	1.9268	192.68L.D
3	14-1203-000644	70	0.0487	3.409L.D
4	14-AA13-200002H	70	0.267	18.69L.D
5	14-1204-000441	40	0.7661	30.644L.D
6	14-1103-000156	30	0.0528	1.584L.D
7	14-2008-000277	30	0.0437	1.311L.D
8	RH-IX1148CE22	25	2.0968	52.42L.D
				761.348L.D

The cost of rework = number of workers* average salaries *total period + cost of material

= 15* 250 * 3 + 761.348

=12011 L.D

4-8 Data collection and calculation and analysis:

The process of the assembly lines were followed to determine the actual quality cost during the period of one year from January 2010 to December 2010. The collection cost started by monitoring different manufacturing and assembly processes as follows:

- Select the model 2931 as the target product to calculate quality cost. The production line has been chosen for the following reasons. This product has stable demand and the production rate is almost constant.
- Study the assembly process and understand the task at each work stations**.** The production line for this model has three stages:

a- (Auto insertion) stage**:** It starts with receiving materials from sub-store and it ends by handing out the PCBS to semi-completed product store. In this process the electronic components are inserted automatically like (capacitors, transformers...etc.) which go through the following procedures:

1. Eye-let rings are inserted using the eye-let machine.
2. Vertical assembly process for components such as transistors, capacitors ... etc.
3. Horizontal assembly process for components such as resistors, diodes ... etc.
4. The final inspection process where the inserted PCBs are inspected using computer program.

b- The manual insertion stage: It starts by receiving PCB from auto insertion line. In this process electronic components which require special technician are installed. Three processes are made in this stage which are:

1. Assembly electronic components.
2. Soldering process.
3. Inspection and alignments pre adjustments to the complete PCBs.

c- Final assembly stage: At this stage, the TV set takes its final shape. The final assembly stage consists of:

1. Hosting the screen into the front plastic cabinet.
2. Installing the electronic PCBs “main board – sub boards” into the cabinet.
3. Pre-trials of the assembled TV set are carried out to check the power supply and the overall picture and sound.
4. Final adjustments to the power supply voltages and adjustments to picture characteristics such as color – brightness –sound levels are provided at this stage.
5. Final inspection and packing and move to complete product store.

- Preparing Flowchart for all manufacturing process and identify input, out and control. In this step we use the process flowchart to point out the production, inspection and testing operation at each stage of the production line as shown in the flowchart. Auto insertion stage – Figure 9 Manual insertion stage – Figure 10 Final assembly stage – Figure 11

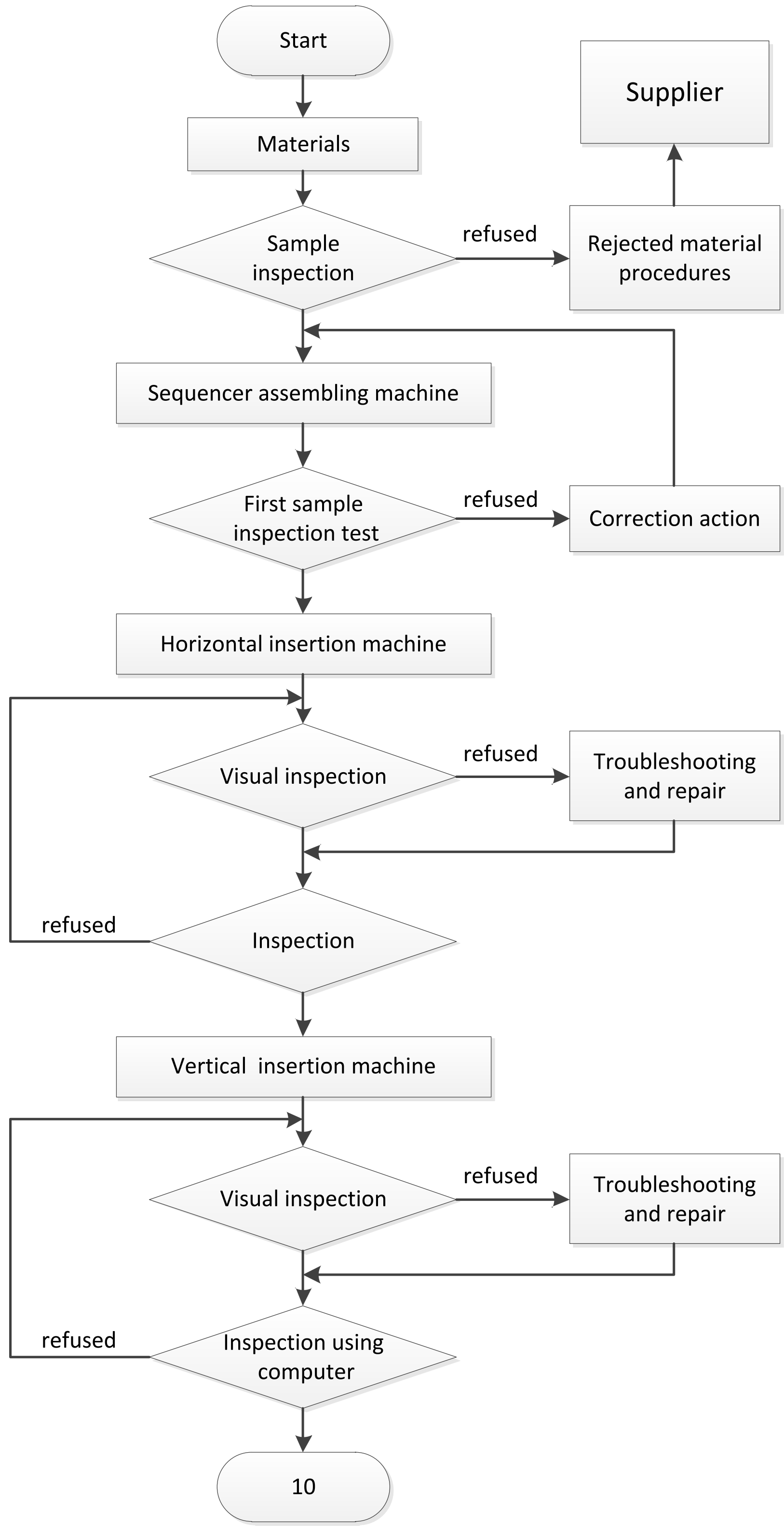


Figure 9 Auto insertion stage flow chart

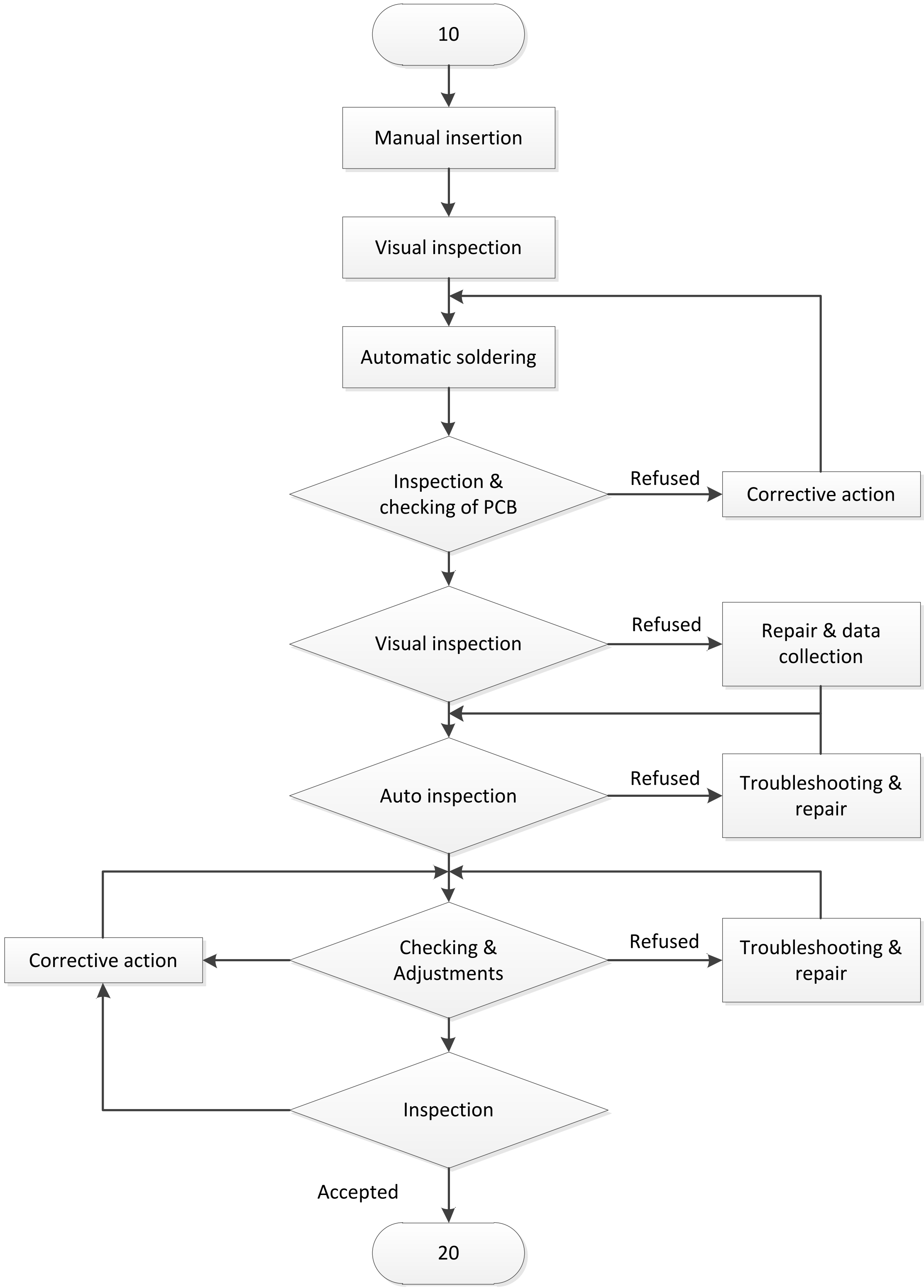


Figure 10 Manual assembly stage flowchart

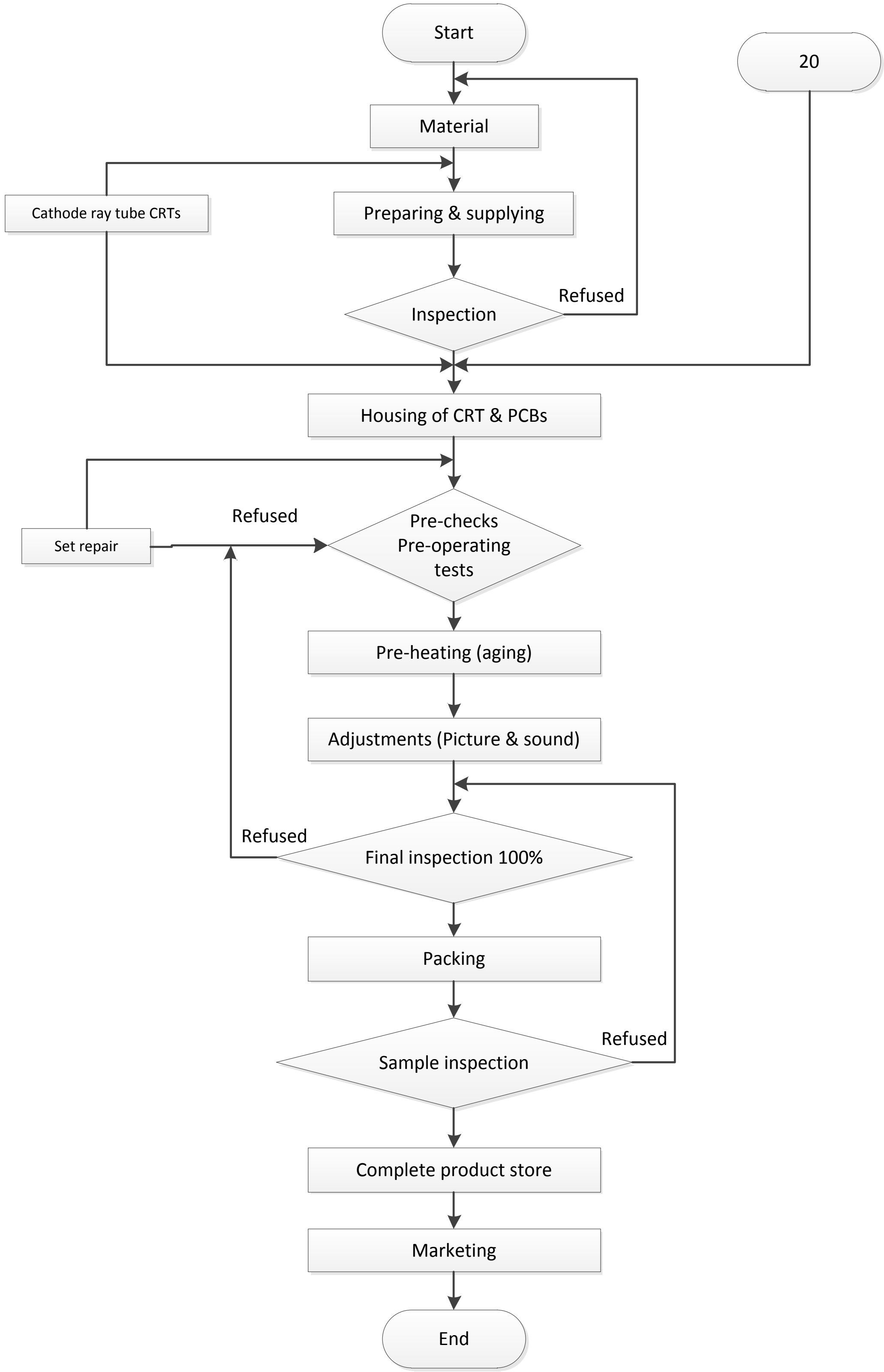


Figure 11 Final assembly stage flowchart

4-9 Cost Collecting

The quality cost data is collected from the following sources.

1. Financial department reports.
2. Production department reports.
3. Quality control department reports.
4. Accounting department reports.
5. Statistics and information reports.

The following figure shows source information for quality costing and process of collection cost:

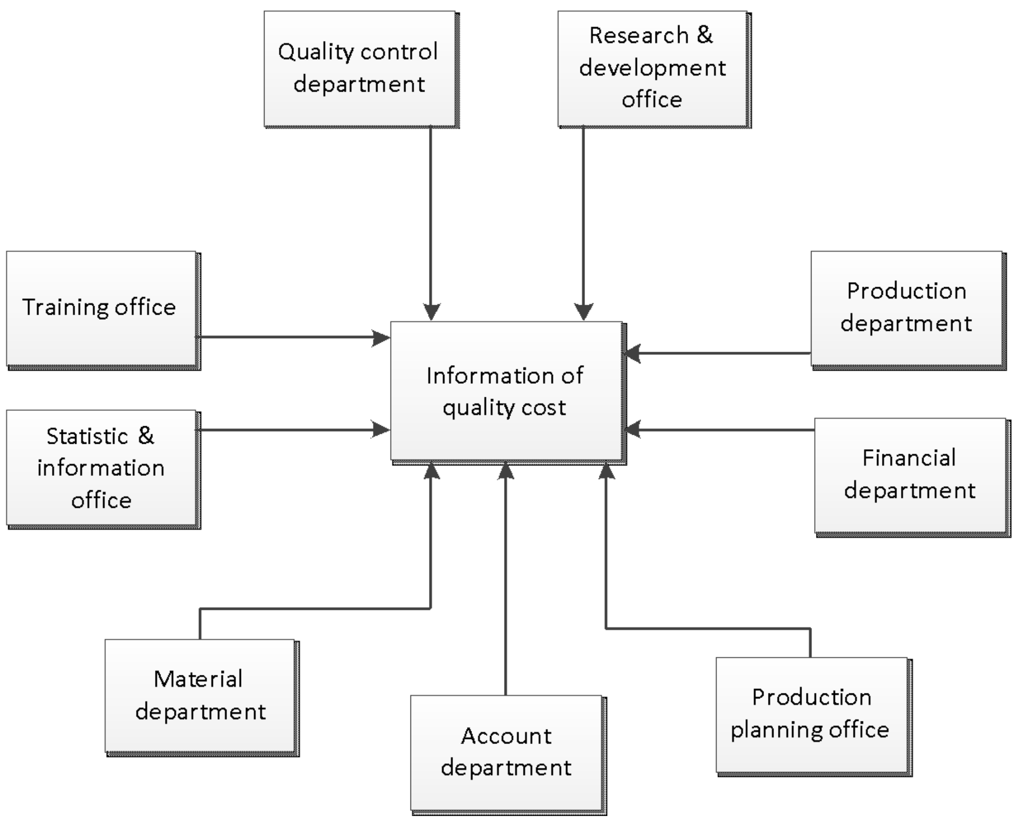


Figure 12 Source information for quality costing

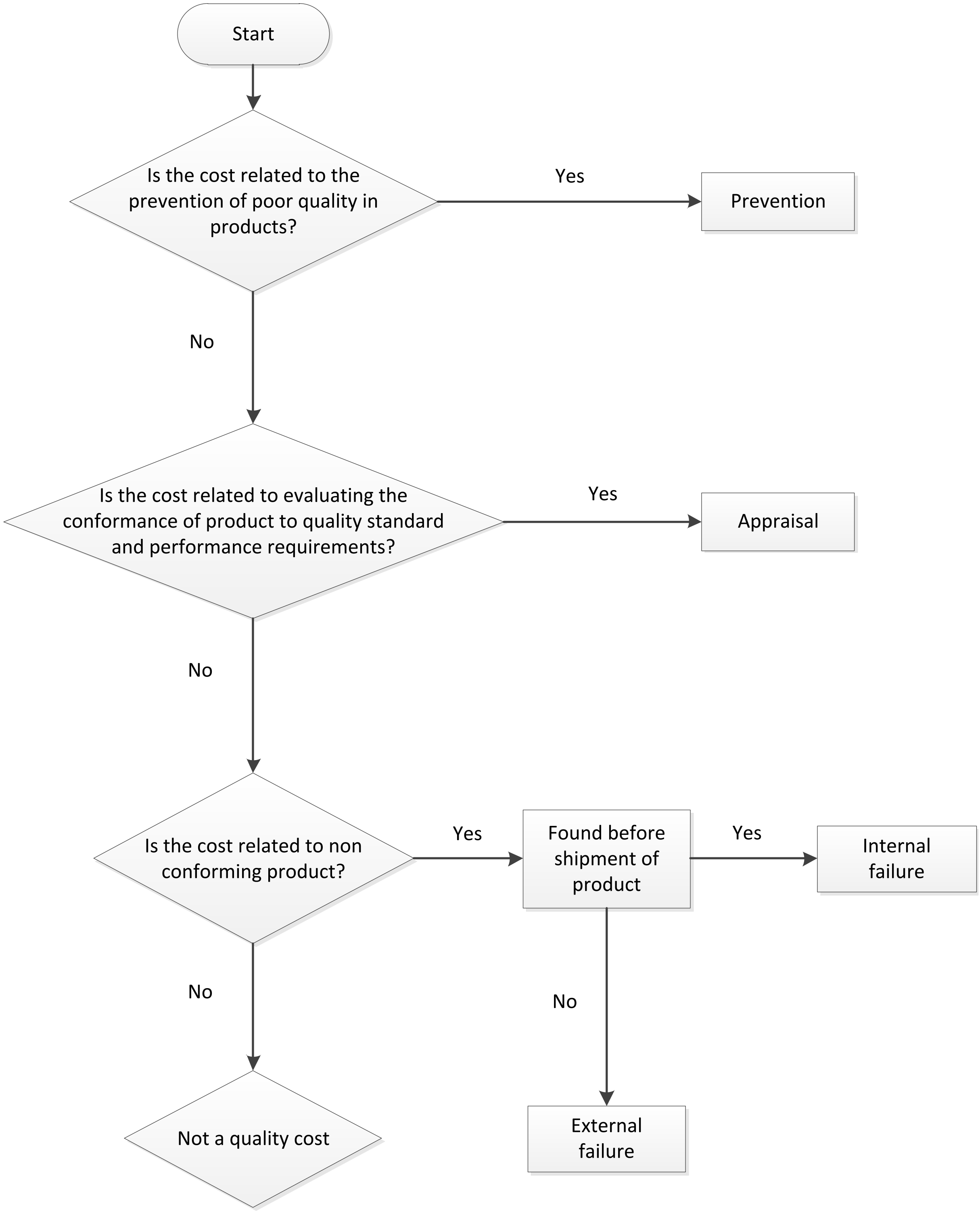


Figure 13 The collection costs flow chart

4-10 Elements of Cost of quality calculation and reporting

When the list of cost elements has been identified the collection of cost date can begin.

The BS 6143 has been used as a cost guidance

Table 9 BS 6143 Quality costs elements

BS 6143	Elements
A1	Quality control and process control engineering.
A2	Test and inspection equipment – maintenance and calibration.
A3	Supplier quality assurance.
A4	Training.
A5	Audit.
B1	Laboratory acceptance testing.
B2	Inspection and test.
B3	In – process inspection (non-inspectors).
B4	Review of test and inspection data.
C1	Scrap.
C2	Rework and repair.
D1	Complaints.
D2	Warranty replacement.

4-11 Prevention Costs

These costs are associated with personnel in planning, implementing and maintaining the quality system. Prevention costs are incurred to reduce failure and appraisal costs to minimum. It's the most difficult of categories the cost. This is because prevention activities are made up of a number of disparate elements carried out on part – time basis by personnel from different departments. This cost depends heavily on estimates of apportionment of time.

- A1 Quality Engineering. These costs include the activities associated with the creation of the overall quality plan, the inspection plan. It also includes the implementation and maintenance of the plans. This work is carried out by quality team who meet once a month and cumulative effort input is estimated to be equivalent to 3 per cent of the time of each member.
- A2 Calibration and maintenance of production equipment used to evaluate quality The cost of calibration and maintenance of templates, jigs, fixtures and similar measurement and evaluating devices should be included but not the cost of equipment used to manufacture TV's. This work is carried out by external companies who calibrate production equipment used to evaluate quality once a year.
- A3 Supplier Assurance. The cost of evaluating supplier quality activities, auditing the activities during the contract, and associated effort with suppliers. The cost of three full time employees audit the supplier's activities have been counted.
- A4 Quality training. The costs incurred in the development and implementation of formal training programs for the purpose of preventing errors, includes the total cost (course preparation, instruction and necessary materials) of quality improvement programs, new employee quality orientations, and other programs designed to provide:

1. Inspector and operator training in new manufacturing methods.

2. Tester training in new product design and testing procedures.

   This cost covers the training of all employees in production lines which takes a week at the beginning of production plus the training expenses and external training for some employees.

- A5 Auditing. The cost of evaluating the execution of activities in the overall quality plan used in the plant. This work is done by internal auditor who visits the plant twice a year; each visit takes a week. The prevention costs and findings at the various stages are summarized in tables 10, 11, and 12.

Table 10 Prevention costs at auto insertion stage

PREVENTION COSTS

Data / *31.12.2010* Prepared by /

Report months / year 2010 Stage / Auto insertion

		Recorded costs (L.D)						
Coding	Cost elements	1st qtr	2nd qtr	3rd qtr	4th qtr	Quality annual cost	Source	Notes
A1	Quality control and process control engineering	3300	3300	3300	3300	13200	Estimated time	The quality team consist of Q.C., Prod. Mat. Dept.
A2	Calibration and maintenance of production equipment used to evaluate quality	Nil	Nil	Nil	Nil	Nil	-	Not applicable in this stage
A3	Supplier assurance	500	500	500	500	2000	Q.C. Dept.	
A4	Quality training	1226	-	-	-	1226	Training office	Internal and external training
A5	Audit	600	-	-	-	600	Estimated time	Internal audit
Total						17026 L.D		

Table 11 Prevention costs at manual insertion stage

PREVENTION COSTS

Data / 31.12.2010 Prepared by /

Report months / year 2010 Stage / Manual insertion

		Recorded costs (L.D)						
Coding	Cost elements	1^{st} qtr	2^{nd} qtr	3^{rd} qtr	4^{th} qtr	Project annual cost	Source	Notes
A1	Quality control and process control engineering	33	33	33	33	13200	Estimated time from Q.C. Dept.	The quality team consist of Q.C., Prod. Mat. Dept.
A2	Calibration and maintenance of production equipment used to evaluate quality	6000	-	-	-	6000	Q.C. Dept. Main Dept.	Calibration once a year.
A3	Supplier assurance	500	500	500	500	2000	Q.C. Dept.	
A4	Quality training	1126	-	-	-	1126	Training office	Internal and external training
A5	Audit	60	-	-	-	6000	Estimated time	Internal audit
Total						28326L.D		

Table 12 Prevention costs at final assembly stage

PREVENTION COSTS

Data / 31.12.2010 — Prepared by /

Report months / year 2010 — Stage / Final assembly

		Recorded costs (L.D)						
Coding	Cost elements	1st qtr	2nd qtr	3rd qtr	4th qtr	Quality t annual cost	Source	Notes
A1	Quality control and process control engineering	3300	3300	3300	3300	13200	Estimated time	The quality team consist of Q.C., Prod. Mat. dep.
A2	Calibration and maintenance of production equipment used to evaluate quality	3200	-	-	-	3200	Q.C. dep. Main dep.	Calibration once a year.
A3	Supplier assurance	500	500	500	500	2000	Training office	
A4	Quality training	1126	-	-	-	1126	Training office	Internal and external training
A5	Audit	600	-	-	-	600	Estimated time	Internal audit
Total						20126L.D		

4-12 Appraisal costs

Appraisal costs are associated with measuring, evaluating or auditing products to assure conformance with quality standards and performance requirements. These costs are easy to collect since it comes from the salary of full time or part time employees whom involved in these activities.

- B1 Laboratory acceptance testing. These are costs of tests to evaluate the quality of purchased materials (semi-finished or finished) which become part of the final product. This work is carried out by a special company (international inspection company) which inspects and assures that the components are made as specified in the contract.
- B2 Inspection and testing. This is the activity of inspection and testing first during the process of manufacture, and then as a final check to establish the quality of finished product and its packaging. This element covers the inspection activity from within the quality control department (but does not include testing, work carried out by production operators) It's the cost of full time inspectors, plus 20 percent of the time of supervising.
- B3 In- process inspection. The cost of in-process evaluation of conformance to requirement. The quality control department estimated 15 percent of the time of all operators is used in inspection activities.
- B4 Review of test and inspection date. This is the work of running production lines control unit to acquire continuing data on quality performance. It includes the analysis of these data to identify the quality troubles. It's considered that 10 percent of time two senior staff and a full time employee are counted as a cost element. The

results of the examination of the appraisal costs at various stages are shown in tables 13, 14 and 15.

Table 13 Appraisal costs at auto insertion stage

APPRAISAL COSTS

Data / 31.12.2010 Prepared by /

Report months / year 2010 Stage / Auto insertion

		Recorded costs (L.D)						
Coding	Cost elements	1st qtr	2nd qtr	3rd qtr	4th qtr	Project annual cost	Source	Notes
B1	Laboratory acceptance testing	36402	36402	36402	36402	145608	Accounts Dept.	0.06 of the lot price
B2	Inspection and test	702	702	702	702	2808	Q.C. Dept.	Full Time
B3	In-process inspection (non-inspector)	750	750	750	750	3000	Estimated time from production Dept.	
B4	Review of testing and inspection data	230	230	230	230	920	Estimated time	
Total						152336 L.D		

Table 14 Appraisal costs at manual insertion stage

APPRAISAL COSTS

Data / 31.12.2010 | Prepared by /

Report months / year 2010 | Stage / Manual insertion

		Recorded costs (L.D)						
Coding	Cost elements	1st qtr	2nd qtr	3rd qtr	4th qtr	Project annual cost	Source	Notes
B1	Laboratory acceptance testing	36402	36402	36402	36402	145608	Accounts Dept.	0.06 of the lot price
B2	Inspection and test	2622	2622	2622	2622	10488	Q.C. Dept.	Full Time
B3	In-process inspection (non-inspector)	3750	3750	3750	3750	15000	Estimated time from production Dept.	
B4	Review of testing and inspection data	230	230	230	230	920	Estimated time	
Total						172016 L.D		

Table 15 Appraisal costs at final assembly stage

APPRAISAL COSTS

Data / 31.12.2010 — Prepared by /

Report months / year 2010 — Stage / Final assembly

		Recorded costs (L.D)						
Coding	Cost elements	1st qtr	2nd qtr	3rd qtr	4th qtr	Project annual cost	Source	Notes
B1	Laboratory acceptance testing	36402	36402	36402	36402	145608	Accounts Dept.	0.06 of the lot price
B2	Inspection and test	2622	2622	2622	2622	10482	Q.C. Dept.	Full Time
B3	In-process inspection (non-inspector)	2250	2250	2250	2250	9000	Estimated time from production Dept.	
B7	Review of testing and inspection data	230	230	230	230	920	Estimated time	
Total						166010L.D		

4-13 Internal failure costs

These are defined as the costs occur when product, components, material fail to meet quality requirements prior to transfer of ownership to the customer. The major items of cost are scrap and rework. The cost elements comprising internal failure costs, according to B56143 are as follows:

C1 Scrap, rework and repair. All scrap losses incurred in the course of meeting quality requirement. This element includes only that scrap arising through the fault of the manufacturer. Costs are generated from inspection / rejection reports. They comprise the cost of material, parts, components assemblies and product end items which cannot economically rework. Included is the labor and labor overhead content of the scrapped items. This cost element is collected from accounting department, which specifies the price of each scrap part. The quality control department will add to that 16 percent of price to cover labor and overhead cost

Table 16 Internal failure costs at auto insertion stage

INTERNAL FAILURE COSTS

Data / 31.12.2010 — Prepared by /

Report months / year 2010 — Stage / Auto insertion

		Recorded costs (L.D)						
Coding	Cost elements	1st qtr	2nd qtr	3rd qtr	4th qtr	Project annual cost	Source	Notes
C1	Scrap	500	-	200	78	778	Accounts and Q.C. Dept.	
C2	Rework and repair	1000	1000	1000	1000	4000	Q.C. Dept.	Components are negligible
Total						4778 L.D		

Table 17 Internal failure costs at manual insertion stage

INTERNAL FAILURE COSTS

Data / 31.12.2010 Prepared by /

Report months / year 2010 Stage / Manual insertion

		Recorded costs (L.D)						
Coding	Cost elements	1st qtr	2nd qtr	3rd qtr	4th qtr	Project annual cost	Source	Notes
C1	Scrap	500	-	200	78	778	Accounts and Q.C. Dept.	
C2	Rework and repair	1980	1980	1980	1980	7920	Q.C. Dept.	Components are negligible
Total						8698L.D		

Table 18 Internal failure costs at final assembly stage

INTERNAL FAILURE COSTS

Data / 31.12.2010 Prepared by /

Report months / year 2010 Stage / Final assembly

		Recorded costs (L.D)						
Coding	Cost elements	1^{st} qtr	2^{nd} qtr	3^{rd} qtr	4^{th} qtr	Project annual cost	Source	Notes
C1	Scrap	500	-	200	78	778	Accounts and Q.C. Dept.	
C2	Rework and repair	2500	2500	2500	2500	10000	Q.C. Dept.	Included Material, overhead, labor
Total						10778 LD		

4-14 External failure cost.

These are costs associated with defects that are found after product is shipped to the customer. These costs also would disappear if there are no defect.

- D1 Complaints administration. The costs of administration of these complaints which are due to quality defects. The quality control department analyze the reports which come from after-sales services department. The report which contains customer's complaints. It's estimated that the cost of such actions is 20 percent of time of the head of the department and two engineers.
- D2 Warranty replacement. It's the expenses of repairing the product free of charge during the period of warranty. The external failure costs are summarized in table19.

Table 19 External failure costs

EXTERNAL FAILURE COSTS

Data / 31.12.2010

Report months / year 2010

		Recorded costs (L.D)						
Coding	Cost elements	1st qtr	2nd qtr	3rd qtr	4th qtr	Project annual cost	Source	Notes
D1	Complaints administration	657	657	657	657	2628	Estimated time	
D2	Warranty replacement	-	-	2350	1565	3915	Accounts Dept.	
Total						6543 L.D		

Chapter 5 Cost analysis and Recommendations

5-1 Introduction

Introducing quality cost study to any organization can help them to know how much they spend to keep the quality system work in good status. To achieve the best results from studying quality cost, it is necessary to discuss the results and analyze the costs in order to determine the causes of high costs and to know clearly how they affected the quality system. Table 20 shows the real quality costs that the factory spends during the year 2010.

Table 20 The Percentage of each actual category of quality cost

Quality cost category	Total Quality Cost	Personage of Total Quality cost
Prevention Cost	65478L.D	11.3%
Appraisal Cost	490362 L.D	83.5%
Internal Failure Cost	24254L.D	4.1%
External Failure Cost	6543L.D	1.1%
Total cost	586637 L.D	100%

The ratios of each cost category to the total cost is very widely among industries and even among companies is the same industry. Dobbins (2011) stated that appraisal cost usually range in neighborhood of 25% and the typical prevention costs do not exceed 5% of the total cost. However, many references exhibit ratio which falls within the following range as showed in table 21.

Table 21 Percentage of each category of quality cost

Quality Cost Category	Percentage of total
Prevention cost	.05% - 5%
Appraisal Cost	10 % - 50%
Internal Failure Cost	10 % - 25%
External Failure Cost	5 % - 15%

It appears that the cost of conformance is 94 % of the total quality cost which included the prevention cost (11.3%) and the appraisal cost (83.5%). This means that the factory is putting more effort and investing more money in the prevention and appraisal activities to reduce the internal and external failure cost. However, high quality should be achieved at the lowest cost and without understanding the reasons of having high prevention and appraisal cost, it is very difficult to achieve continuous improvement. Figure 14 shows a pie chart for the quality cost category and figure 15 shows a bar chart of total cost category. The analysis of quality cost reveals potential for saving while improving quality over a period of time. Grantham (1995) stated that documenting the dollar wasted by not doing the right thing first time will capture the attention of top management for immediate implementation of quality improvement program. The first step toward continuous improvement activities and to achieve the goal of applying cost of quality program is understanding the cost analysis.

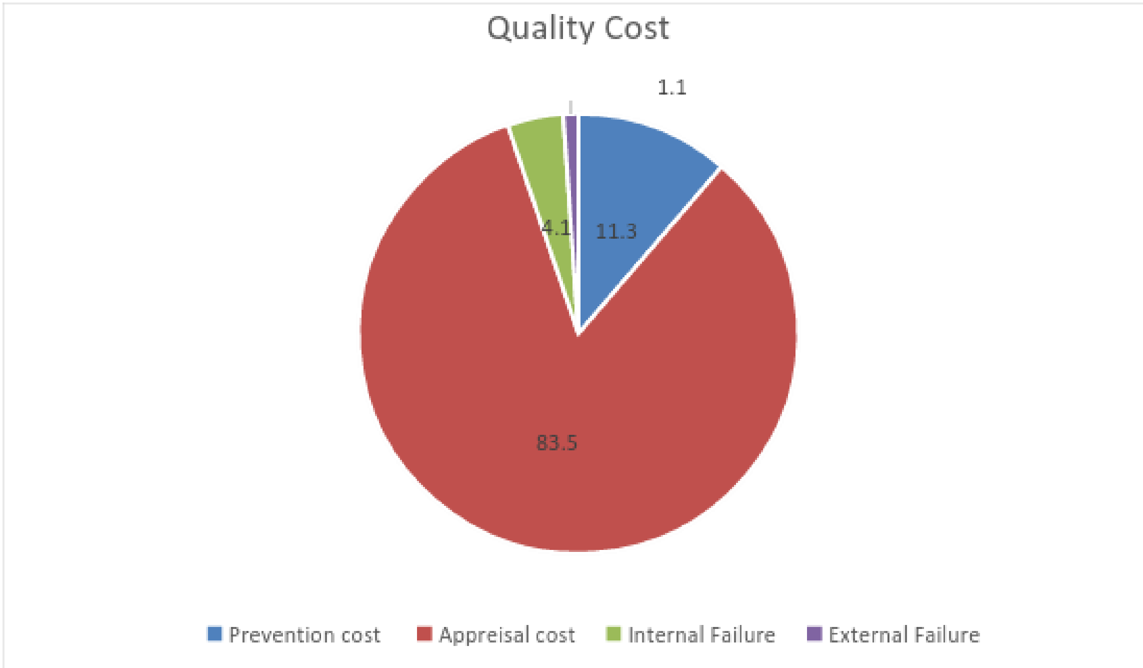


Figure 14 Cost of quality

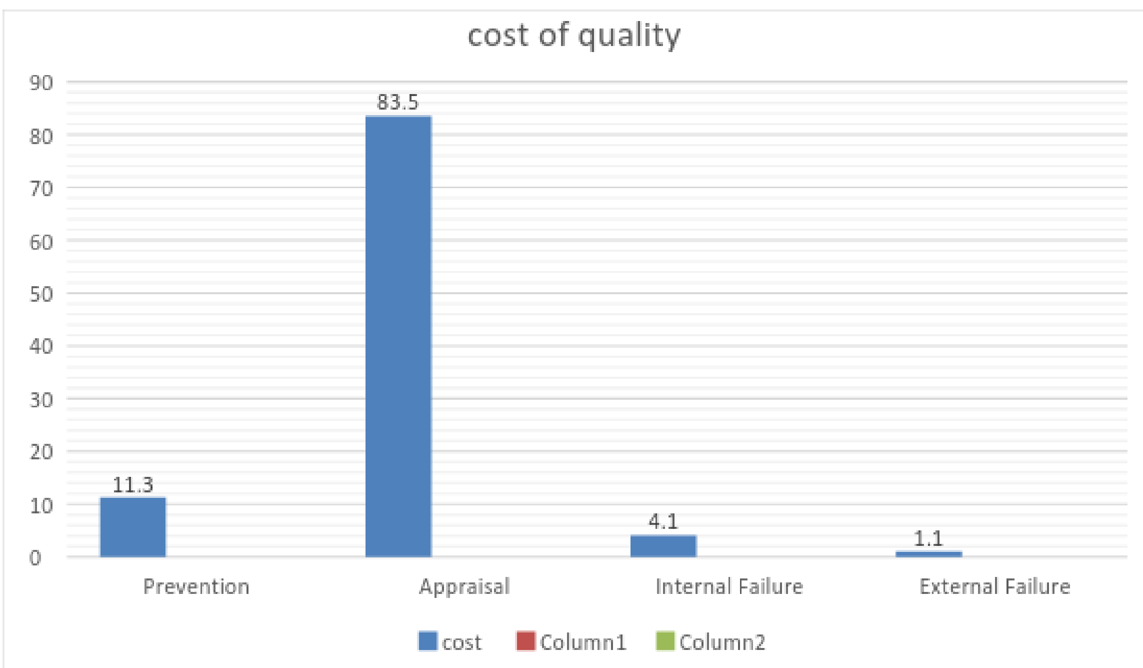


Figure 15 Bar chart for cost of quality

5-2 Analyzing prevention cost.

The quality cost report showed that the prevention cost is 11.3% of the total cost. This percentage is higher than the standard percentage which is around 5% of the total cost. Corcoran (1987) stated that prevention costs are difficult to estimate. These costs are considered to be normal costs of doing business. It notes that measuring prevention costs in quality department and engineering is relatively easy to estimate, but difficult in other functional areas. Table 22 and figure 16 present the summary of the prevention cost.

Table 22 Summary of prevention cost

Cost element	Code	Cost L.D
Quality control and engineering cost	A1	39600 L.D
Calibration cost	A2	9200 L.D
Supplier assurance cost	A3	6000 L.D
Quality training cost	A4	3378 L.D
Audit cost	A5	72200L.D

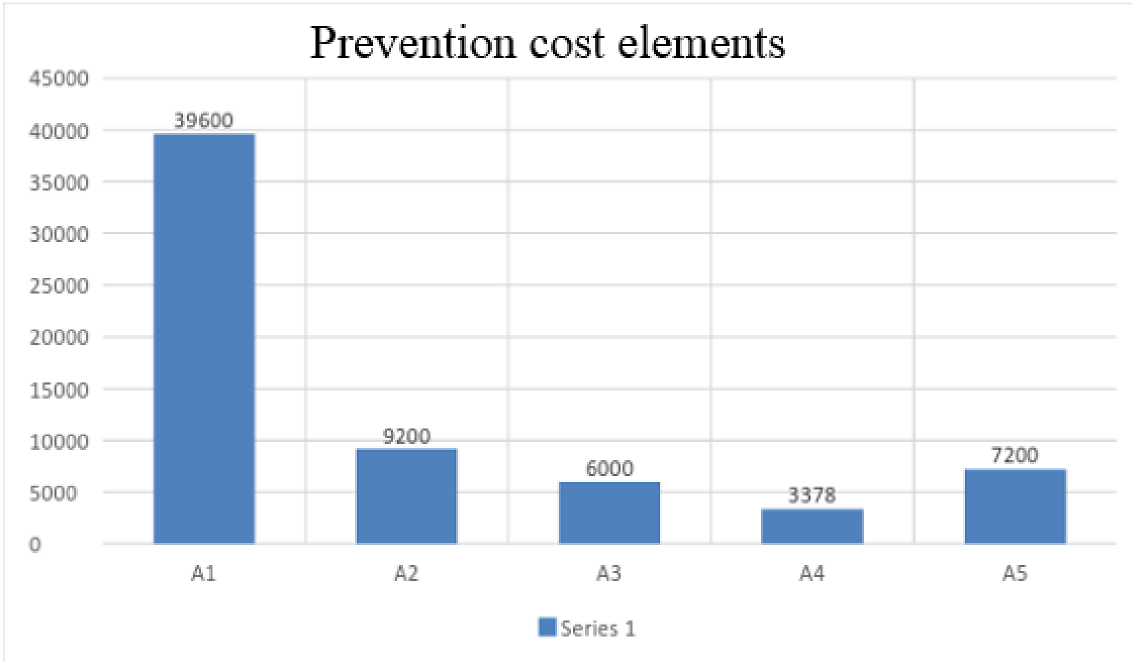


Figure 16 Summary of prevention cost

Referring to the previous table and figure, it is clear that there is a potential opportunity for the factory to measure the value of the quality effort in terms of money and to explore and to identify strong and weak point of the quality system. It is immediately obvious from Figure 16 that there is an opportunity to reduce the quality control and process control activities A1 by investigating the causes of increasing this cost element. The largest prevention element also was identified and measured.

5-3 Analyzing Appraisal cost.

The quality cost report showed that the appraisal cost is 83.5 % of the total cost. This percentage is higher than the standard percentage which is around 25% of the total cost. These costs included the cost associated with measuring, evaluating or auditing to ensure conformance to the standards that have been imposed. Normally, the factory used 100% inspection plan to make sure no defective product can pass. These costs distributed among the shown elements which represent appraisal element costs. Table 23and figure 17 present the summary of the Appraisal cost.

Table 23 Summary of Appraisal cost

Cost element	Code	Cost L.D
Laboratory acceptance testing	B1	436824 L.D
Inspection and test cost	B2	23778
In- process inspection cost	B3	27000 L.D
Review of testing and inspection date cost	B4	2760 L.D

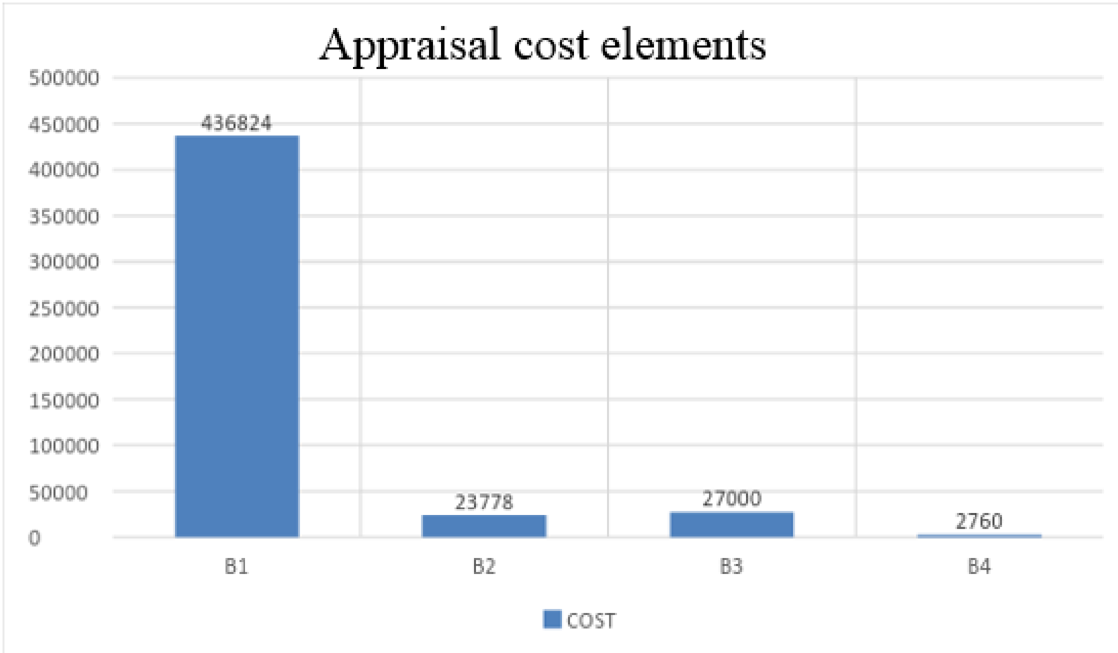


Figure 17 Summary of Appraisal cost

Referring to table 22 and figure 17, it is obvious that the laboratory acceptance test cost is the greatest cost in this category. It is about 90% of the total appraisal cost. This cost is caused by external international company who performs laboratory material test for all the parts. This cost could be reduced if this task done internally.

5-4 Analyzing the internal failure cost.

The quality cost report showed that the internal failure cost is 4.1 % of the total cost. This percentage is very good. The standard percentage in this category is around 10 % of the total cost. These costs are mainly the cost of material used to fix any defective product or the cost of overtime and labor cost. The largest element of the failure is scrap and rework. Management should examine the root cause for components being scrapped .Table 24 and figure 18 are presented the summary of the internal failure cost.

Table 24 Summary of Internal Failure cost

Cost element	Code	Cost L.D
Scrap cost	C1	2334 L.D
Rework and repair cost	C2	21920L.D

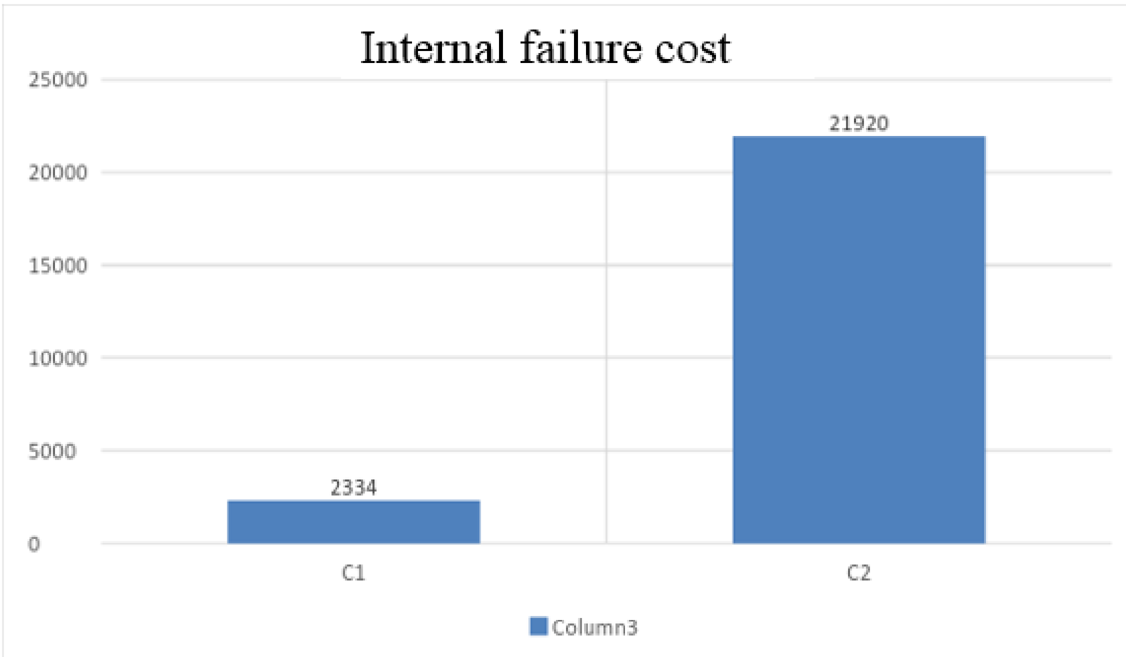


Figure 18 Summary of Internal Failure cost

5-5 Analyzing the External failure cost.

The quality cost report showed that the external failure cost is 1.1 % of the total cost. This percentage is very good. The standard percentage in this category is around 10 % of the total cost. These costs are mainly the cost of warranty and managing the customer complaints .Table 25 and figure 18 are present the summary of the internal failure cost.

Table 25 Summary of external Failure cost

Cost element	Code	Cost L.D
Complaints administration	D1	2628 L.D
Warranty replacement cost	D2	3915L.D

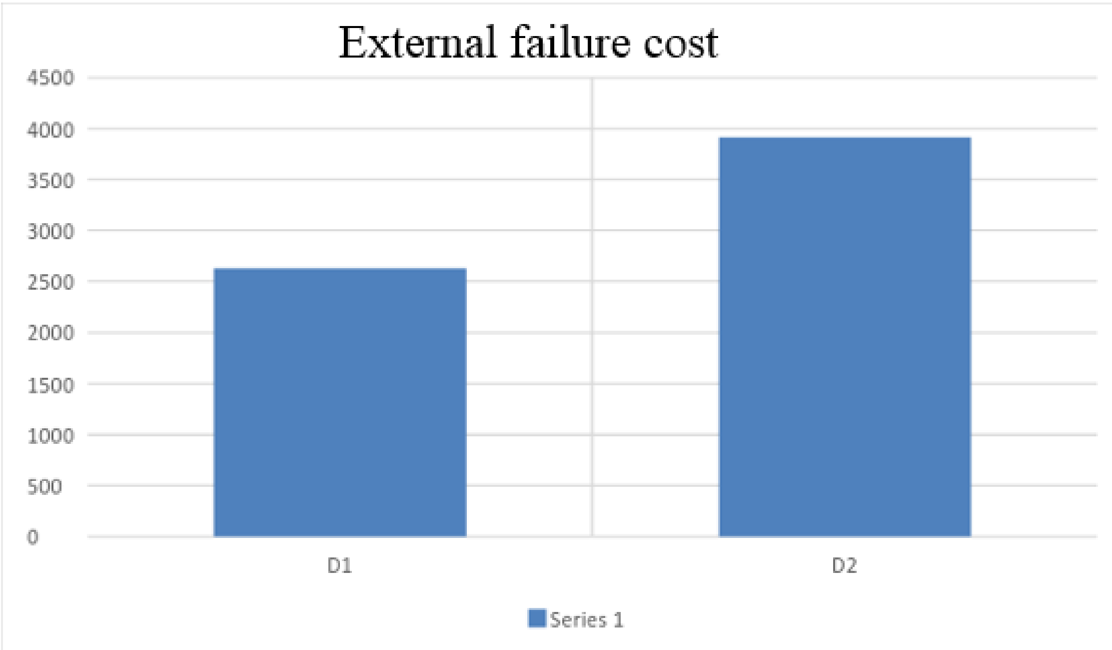


Figure 19 Summary of external Failure cost

5-6 Performance Measurement

Quality costs indices are a useful tool for determining and analyzing quality expenditures in a company, and help in performance evaluation .The most useful indices are total quality cost as a percentage of sales turnover, total material costs, total manufacturing costs and labor hours. The following two measurement comparison indices are used to compare cost of quality results.

1- Total sales revenue to quality cost

2- Production related to quality cost

5-6-1 Internal comparison

After all costs have been collected they should be analyzed to represent the quality issues and effort from different viewpoint.

Total produced units study period = 6000 unit a year

Total sales revenue during study period = 2,550,000 L.D

Unit price = 425 L.D

The cost of quality to total sales revenue = ∑ of quality cost ÷ total sales revenue

= (586637/ 2,550,000) x 100

= 23 %

Cost of quality to total produced units = 586637 / 6000

= 97.8 L.D/ Unit

Unit quality cost to unit price = 97.8 / 425

= 23 %

The following table 24 present outcomes classified according to each category and figure 20 present the internal comparison

Table 26 Internal compassion result

Cost Category	Cost Value L.D	Total quality cost to total revenue %	Quality cost to production
Prevention cost	65478 LD	2.56 %	11 L.D/unit
Appraisal cost	490362 L.D	19.24 %	81 L.D/Unit
Internal failure cost	24254L.D	.95 %	4.0 L.D L.D
External failure cost	6543LD	.25 %	2 L.D/Unit
Total cost of quality	586637LD	23%	98 L.D /Unit

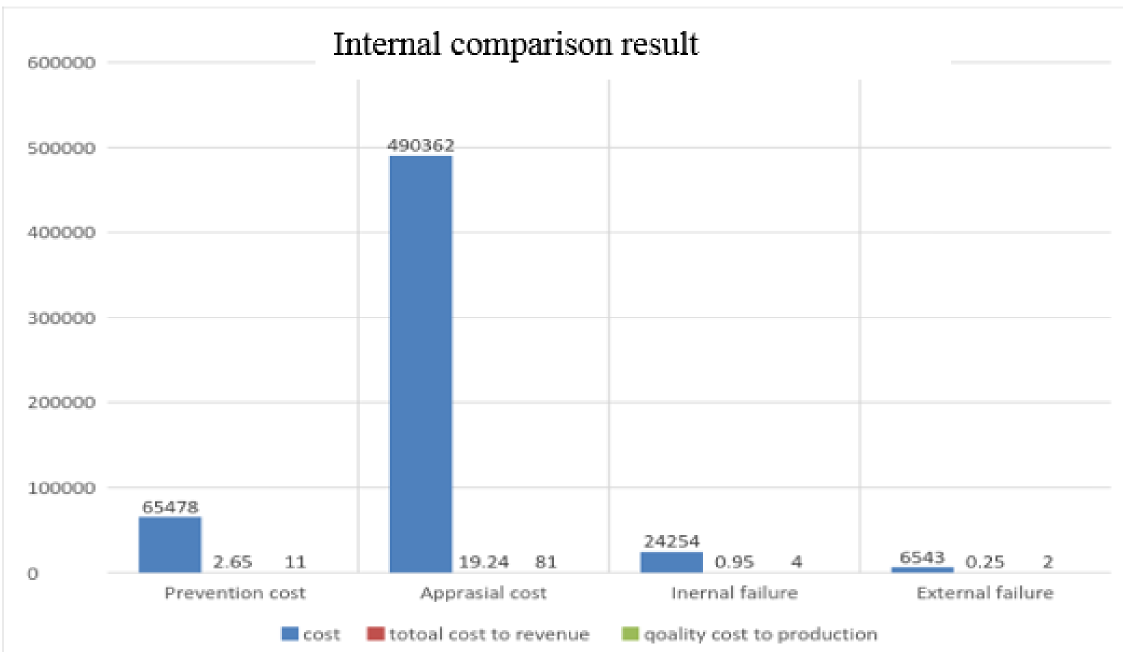


Figure 20 Internal comparison result

5-6-2 External comparison result

The other measurement index is comparing quality cost to the number of sold products.

In other competitive companies in the same sector as shown in Table 27.

Table 27 Percentage of cost / number of sold products

Type of industry	Quality cost relative to sales
Simple mechanical industry	.02 % - 2%
Ordinary mechanical industry	1 % - 5%
Accurate mechanical industry	2 % - 10%
Electronic industry and high technology and high complicated industries	5 % - 25%

Referring to table 27 it appears that the quality cost in the factory falls within the competitive range and showed that the quality system in the factory works in a good status. Even though, there is still room for improvement by focusing more on the area that has high quality cost. Crosaby (1979) popularized the idea that all methods of combatting poor quality pay for themselves many times over. He estimates direct increase in profitability of 5% to 10 % of sales possible through quality improvement. From the previous analysis, the following results can be concluded:

1- Prevention costs ratio is out of standard limit. The ratio 11.3% compared to 5% is high and the continues improvement time with the assistant from the top management should investigate this category and propose a solution that could lead to reduce this cost by at least 40 %.
2- Appraisal cost is very high. It exceeds the standard range. The ratio 83.5% is far away from the reasonable percentage cost. It is important for the management to discuss and bring this issue with other departments for cost reduction
3- Internal and external failure. The failure rate is within the standard limit. However, the factory should adopt a zero defect philosophy.

4- The strategy for using quality costs should be followed to improve the cost of the quality system and they should start by the following :

5- Take direct attack on the appraisal and failure activities and reduce failure.

6- Invest in the right prevention activities to bring the improvement very quickly and this based on the fact that for each failure there is a root cause and causes are preventable and prevention is always cheaper

Chapter 6 Conclusions and Future Research

6-1 Conclusions

The quality cost study is a helpful tool to the organization top management as a performance measurement system and future planning strategy. The objective of this dissertation is to develop a quality cost model that includes the all quality cost elements using the BS 6143 as a guide to provide assistance in cost categorization. This model aimed to assist industrial and business organizations to determine the investment and return of their quality improvement programs, also this model will support the accounting system to track the quality issues and translate this data in terms of money. A Generic mathematical model has been developed with series of steps to describe the cost collection method. Cost data has been collected from the study of labor and machine and shop floor inspection reports, sales reports and customer's satisfaction .This information has been used to calculate and estimate the quality cost. To achieve the best result from studying quality cost, cost analysis has been applied to evaluate the effectiveness of quality management system, as well as to identify the quality issues within the factory and creation of opportunities for improvement.

In chapter three, various quality cost models have been studied and, based on reviewing and analyzing these models a generic quality cost model is developed. In chapter four, a case study has been applied to validate the model. Cost analysis and recommendation for improvement has been implemented in chapter five. Conclusions and recommendations presented in chapter six.

6-2 Recommendations for future work

Based on the knowledge obtained in the research, the following points would be recommended for an extra research for the future work:

1- Developing and implementing a quality cost model in service sector**.** It has been noted that there is insufficient research regarding calculating cost of quality in the service sector

2- Studying the influence of using different tools such as statistical quality control SPC, just in time JIT and quality education and training on the total quality cost.

3- Developing quality cost model to determine the effect of the customer dissatisfaction or loss of customer on the external failure cost.

4- Developing a method to study the influence of warranty cost on the quality system.

5- Studying the impact of the loss of capital investment optimization though downtime and other quality cost elements which were not listed in the international quality cost standard

6- Developing a quality cost model using ASQ cost standard and compare the result to BS standard.

7- Studying the different quality cost indexes and compare the result to the accounting system to adjust the quality and to better understand the cost trend

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Appendix

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