Cost analysis in the implementation of ISO quality system in a petroleum refinery

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Abstract: The substantial amounts of financial and non-financial resources invested annually on petroleum refinery operations justify the need for documentation on the cost of implementing ISO quality systems in refineries. The experience of ISO quality system implementation cost analysis in a petroleum refinery in a developing country is reported with a combination of mathematical model and application. The concept of strain as a function of growth in the physical sciences is adopted to conceptualise the growth phenomenon in the ISO organisation. Practically, developing a quantitative approach in evaluating cost of ISO implementation would help the manager in relying on scientific fact instead of intuition. The approach is new and has the potential for helping the top management in planning the strategy and allocating necessary funds for effective implementation of ISO quality systems.

Keywords: ISO implementation; quality system; cost element; quantitative approach; petroleum refineries; cost analysis.

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1 Introduction

There are strong evidences that the ISO quality system is one of the most widely implemented initiatives worldwide (Bhuiyan and Alam, 2004; Capman et al., 2000; Lekkas et al., 2002; Ashok and Santhakuma, 2002; Yeung et al., 2003). It has been applied in web-based electronic document management (Yao and Trappey, 2003), small, medium and large size enterprises (Gotzamani, 2004), education institutions, banking sectors and postal services (Singh and Sareen, 2006), software development process improvement (Lee and Chang, 2006), turning operations (Petropoulos et al., 2007), and information security management (Lee and Chang, 2007).

Yao and Trappey (2003) derived the data requirements for ISO 9000-based document management and presented a scenario for quality-related document management for ISO 9000 compliance. Singh and Sareen (2006) stated the wide application of ISO 9000 in banking sectors, postal services, and educational institutions, and focused on the survey to find out the contribution of ISO 9000 standards in Indian educational institutions. Lee and Chang (2006) applied ISO 9000 in quality oriented knowledge management for software development process improvement. In the study by Petropoulos et al. (2007), the selection of subsets of mutually unrelated ISO 13565-21997 surface roughness parameters in turning operations was made. In Gotzamani (2004), a thorough analysis of ISO 9000 contribution to small and medium size enterprises in comparison with large enterprises was made. Lee and Chang (2007) discussed ISO 17799: 2005 control, process, and security organisation structure. Oke and Charles-Owaba (2007) presented a review of the literature on the implementation of ISO-based quality management systems.

Viadiu and Fransi (2006) analyse the way the specialised consultants implementing the ISO 9000:2000 standard enable their customers to assume the principles. Sakthivel et al. (2007) report the development of an information system for the fifth clause of ISO 9001:2000 standard, which enumerates the management responsibility towards enhancing the effectiveness of ISO 9001:2000 based quality management system. After designing the information system of this clause, an implementation study was conducted in an Indian high technology oriented small size company. Lin and Wu (2007) describe organisational innovation by way of the ISO 9000 knowledge creation process. A process model that integrates ISO 9001:2000 clauses is proposed to explore knowledge creation opportunities within the ISO 9000 system. In addition, a comprehensive ISO 9000-based knowledge creation system framework in which the Socialisation, Externalisation, Combination and Internalisation (SECI) modes, and various 'ba' proposed by Nonaka and Konno are introduced for organisational innovation toward customer satisfaction, is proposed.

The ISO quality management system is a family of standards and guidelines for quality in industries, including the petrochemical industry (Awan and Bhatti, 2003; China et al., 2001; Stevensona and Barnesb, 2002; Yacout et al., 1998). It ensures that the processes that developed petroleum products are documented and performed in a quality manner. In the petroleum industry, ISO quality system is widening in acceptance and scope on the premise that getting the ISO certificate is not a once-and-for-all award, but must be renewed at regular intervals based on the recommendation of the certification body (Beirao and Cabral, 2002; Nicolau and Selters, 2001; Benezech et al., 2001). Bearing in mind the huge benefit of product's international acceptance, the implementation of ISO quality system is believed to be of significant benefit to oil refineries (Poksinska et al., 2003; Geraedts et al., 2000; Yahya and Goh, W., 2001). This would then be transformed into profit and goodwill to petroleum refineries (Chang and Rao, 1998).

A refinery is a plant where crude oil is transformed into finished product such as liquefied petroleum gas (LPG), petrol, diesel, etc. Despite a vast number of available studies on ISO quality system, no significant documentation has been made on the cost implication of the implementation of ISO quality systems in petroleum refineries. Information on this study would be relevant to managers in petroleum refineries that seek scientific approaches in the management of plants (Wright and Geroy, 2003). The study is much more important than before in view of the stiff competition that exists among oil refineries worldwide. Apart from the benefit of increased customer patronage of ISO certification to organisation, the immediate community also benefit from the implementation of community friendly ISO quality management system. This ISO program also protects the lives of inhabitant in oil refinery environment by forcing oil refineries to document their procedure in dispensing waste products (Poksinska et al., 2003).

From the above literature review, it could be inferred that research documentation on ISO quality systems, although extensive, seems to have provided only partial solutions to problems in petroleum refineries. Many of the studies have not fully explored the cost analysis of ISO implementation, particularly in the petroleum refineries. Thus, a strong need arises to assist managers with a practical tool that is easy to understand and apply in solving cost-related problems in ISO implementation. The focus of this study is to present the experience of ISO quality system implementation cost analysis in a petroleum refinery using a combination of mathematical model and applications. The following is a summary of the succeeding sections. Section 2 presents some details on petroleum refinery. Section 3 discusses the mathematical framework for the work based on a number of cost elements. The necessary notations are also described here. In Section 4, a case study is considered in order to verify the working of the model. Section 5 concludes on the study.

2 The petroleum refinery

The USA Environmental Protection Agency (EPA, 2007) stated that the petroleum refining industry converts crude oil into more than 2500 refined products. Some of the numerous products include LPG, gasoline, kerosene, aviation fuel, diesel fuel, fuel oils, lubricating oils, and feedstocks for the petrochemical industry. The oil refinery whose case is considered is a commercial, integrated international oil company with various subsidiaries. The organisation is in the down streamed sector, comprising of all activities involving the delivery of crude oil to the processing plants. In particular, the company has two – old and new refinery. The old refinery was commissioned in 1965 with the current capacity of 60,000 barrels per stream day. The refinery has its own utilities, which consist of water boreholes, water treatment, cooling water towel, instrument air, and stream boilers. The utilities supplied from the new refineries are power and nitrogen by air. The old refineries are designed to generate their own gas as processed fuel. However, the new refinery was commissioned in 1989 with an installed capacity of 150,000 barrels per stream day. It was originally intended to serve as an export refinery. Subsequently, it has been dedicated to domestic market service given frequent interruptions in supply from the other three refineries in the country. The new refinery is made up of areas 1–4. Area 1 is made up of the crude distillation unit (CDU) and vacuum distillation unit (VDU). This is where crude oil first passes when it comes freshly from the storage tank. Area 2 is made up of Naptha hydro-treating unit (NHU), where Naptha is hydro disulphurised. The catalytic reforming unit (CRU) is responsible for upgrading naptha to reformate. This has a higher octane value. The kero hydro-treating unit (KHU) is where kero is treated to make it acceptable for aviation use i.e. Aviation Turbine Kerosene (ATK).

Area 3 is made up of fluid catalytic cracking unit (FCCU), where vacuum gas oil (VGO) and heavy diesel oil are cracked to obtain more valuable product such as premium motor spint (PMS) and liquidified petroleum gas (LPG). Other unit area 3 include gas concentration, gas treating and oxidation unit. The addition of mercapton to our local cooking gas is a safety measure that gives the odourless butane gas a smell so that it will be noticed whenever there is a link. Area 4 has three process units namely dimersol, Butane, Isomerisation and Alkylation units. The units are designed to produce high octane gasoline blend component. The major finished fuel products of the refinery are: LPG, premium motor spirit (PMS), dual purpose kerosene (DPK), ATK, automotive gas oil (AGO), low pour fuel oil (LPFO) and high pour fuel oil (HPFO).

3 Mathematical model

In formulating the model, the following notations are used and the assumptions made are also stated in the next sub-section. These notations relate to the quantity, density, mass, volume, and other parameters of the products. It also concerns the number of employees, and cost-related issue on procurement, certification, maintenance and others.

3.1 Notations and model assumptions

3.1.1 Notations

In the current sub-section, we define the specific notations used in the current work. These are defined as follows:

Nomenclature

Symbol	*Description*
Q	quantity of products per unit time
N	number of employees in the company
T	turnover of the organisation per unit time
P	density of product i.e. petroleum product
M	mass of product i.e. petroleum product
V	volume of product i.e. petroleum product
S	size of company
N	number of products i.e. petroleum products
F	residue of products transferred to other companies
X	number of employees working on day shift
Y	number of employees working on night shift
C	capital per unit time
P	profit per unit time
E	education and training cost
P_s	procurement of standards cost
M_s	maintenance of standards cost
C_c	certification cost
S	supplier cost
I	internal audit cost
T	Time
c_i	cost elements
X'(t)	number of staff that are from the quality management department, at time t
X(t)	number of staff participating in the inspection/assessment exercise from the quality management department at time t
Y(t)	number of staff that are aware of ISO certification/programme from other departments at a particular time t [i.e. all other staff apart from z(t))
Z(t)	number of staff that were formerly in the quality management department but have been transferred to other departments at time t
N(t)	total number of staff at time t, $N(t) = N(0) \times e^{kt}$
X(0)	number of staff participating in the inspection/assessment exercise at time t=0 from the quality management department
Y(0)	number of staff that are aware of ISO certification/programme from other departments at time t=0
Z(0)	number of staff that were formerly in the quality management department but have been transferred to other departments at time t = 0
N(0)	total number of staff at time t=0, i.e. initial number of staff at the start time
K	rate of growth of staff in the company
A(t')	number of general inspections made for a specified time frame t'
B(t')	number of impromptu inspections made for a specified time frame t'

Nomenclature (continued)

Symbol	*Description*
C(t')	number of either general or impromptu inspections made for a specific reason in a specified time frame t'
F(t')	total number of inspections made for a specified time frame t'
D(t')	number of times the personnel in the quality management department assess the facility"
L(t'')	number of facilities being inspected at a particular time t''
M(t'')	number of staff inspecting a certain number of facilities l(t'') at a particular time t''
N(t'')	number of facilities that are not being inspected at a particular time t''
P(t'')	total number of facilities at time t'' either being inspected or not depending on the time
J(t'')	number of staff that are not inspecting at time t''
D(t'')	number of facilities at time t'' that are being assessed not inspected by the quality management staff
Q_m	Number of staff in the quality management department
O_D	Number of staff in other departments
₦	Naira, Nigerian currency (₦ 127 = $1)

3.1.2 Model assumptions

The assumptions stated below are necessary in order to define the conditions under which the model proposed in the current work becomes applicable. The conditions relate to the system design and implementation and well as the systems controllers.

1. All ISO-related exercises in the refinery are carried out solely by the quality management department.
2. Every Staff hired is assumed to have no initial knowledge about ISO certification, but have the privilege of being educated on it.
3. An ISO-awareness programme is done for the new Staff by the quality management department.
4. When a Staff in the quality management department reaches a particular level, he/she is transferred to another department to oversee ISO-related activities excluding ISO-related exercise.
5. The total number of Staff working in the quality department at a particular period of time is assumed fixed or constant.
6. The organisation is growing every year with the intake of new employees.
7. The rate of which employees are taken is far greater than the rate of which employees are sacked or retired and the rate at which employees resigned. This makes the later negligible.
8. The practice of ISO exercise starts at time t=0.

9 The number of staff that undertakes the inspection exercise determines how long the exercise will run.

10 The number of staff in the quality management department determines how frequent the inspections are made.

11 Before an inspection is done, there is a brief for the quality management personnel to determine what kind of inspection should be carried out.

12 There are two types of inspections, they are:
   a general inspection – where the area to be inspected is informed on the exercise
   b impromptu inspection – this is carried out without any prior agreement with any staff working in the area to be inspected.

13 A time frame is chosen to study the number of inspections in that time frame.

14 When there is no inspection going on, the workers in the quality management department go around, assessing the company for standards.

15 The number of facilities affects how long it will take in inspecting the area.

16 The number of facilities affects the number of staff to inspect the area.

17 The number of facilities affects the types of facilities present.

18 The types of facilities determine the type of inspection being made.

19 At time, t" = 0, inspection just began on some facilities.

3.2 Cost elements contained in the mathematical model

The cost elements described here include education and training cost, procurement of standards cost, and maintenance of standards cost (Sun et al., 2004).

1 Education and training cost

In the employment of both technical and non-technical personnel, the oil refinery that is used as a case study attaches much importance to the basic educational qualifications and experience of candidates applying for a position. For example, a supervisor of technicians who repair pumps, turbines, reciprocating compressors, heat exchangers, valves, oil purifiers, condensers, etc. is expected to have at least a national diploma (ND) certificate in Mechanical Engineering. Based on his experience in previous places of work, the amount of training required to make him suited for the job will then be determined. The training offered to the technical personnel in a refinery helps in attaining a state of competence on the job since it would afford the personnel the opportunity of acquiring skills relevant to the production of PMS, DPK, AGO, ATK, LPG, LPFO and HPFO. These products require highly specialised training in order to produce them in top quality.

The training offered to refinery workers aims at speeding up the completion time through proper skill acquisition in order to maintain the ISO quality management system in the refinery, the management understands that supporting employees in higher educational attainment would assist. Thus, employees with long period of service to the refinery are given grants to pursue further education. This helps employees who are skilled on a higher level job but without supporting educational background to attain their goals and get promoted. Primarily, this helps the ISO quality implementation programme since new educational exposure enhances candidates understanding of how to properly document activities and its implementation. Usually, in an effort to improve the ISO implementation environment, some training are done outside the refinery. The aim is to improve interaction among employees.

2 Procurement of standards cost

In the procurement of standards, certain costs are incurred before the applicant company is certified. This includes fees paid to the certification and accreditation bodies and other associated costs. The certification body is the international organisation for standardisation (Lee, 1998; Poksinska et al., 2003). The fees paid to this organisation relates to the amount charged for the particular family of standards applied for. For instance, an organisation may require only the ISO 9000 family of standards while another outfit may apply for both ISO 9000 family of standards and ISO 14000 family of standards (Pun et al., 1999, Poksinska et al., 2003; Coleman and Douglas, 2003). In the first instance, the fees charged for the first company would be less than that of the later. However, after standards must have been procured and implemented, an accreditation agency belonging to the government would then be responsible for the regular check and accreditation of the petroleum oil refinery. In particular the oil refinery whose case is studied here is ISO 9002 certified. In performing its duty, the accreditation body assesses the oil refinery based on an extended sample of its size, functions, products, services and processes.

The accreditation body therefore provides a list of problems to be made known to the management before the certification exercise is done. If the preliminary survey indicates that there is much gap to be filled before certification is done, a discussion is made with the management on what charges or fees will be paid on this extra consultancy work. Since ISO certification is not a once-and-for-all affair, the accreditation body will need to visit the organisation many times in order to gradually put a company representatives on ISO steering committee to monitor ISO activities (Quazim and Padibjo, 1998; Sun, 2000; Sun and Cheng, 2002; Terziovski et al., 2003; Withers and Ebrahimpour, 2000). While this is done, regular updating of standards will require revision of some procedures earlier developed. Thus, the accreditation body will charge for this service.

3 Maintenance of standards cost

Usually, organisations that are ISO certified strive to maintain such standards for a continued benefit derived both within the organisation and outside. The internal benefits could be in form of:

a better documentation which makes enquiries for information easy and fast

b improved departmental corporation where the relationship among the various sub-group members in the organisation become more cordial with less friction among staff c apart from the healthy nature of relationship within groups, it enhanced inter company communication between similar departments of the company in the conglomerate

d greater quality awareness and the struggle for quality competitiveness.

For the external benefits to the organisation include:

a Competitive edge: Here, an ISO certified company is believed to have a competitive edge over others in the international market since the products are certified.

b Reduced quality audits: The need to audit quality of the ISO certified organisation is reduced since guidelines and procedures that are followed for ISO implementation would have prevented quality procedural loopholes (Schroder and McEachern, 2002).

c It bring honour to the company: It is prestigious for a company to be ISO certified. Top management of such companies take pride in managing an ISO certified company. Employees also like to associate with companies that are ISO certified.

Possibility of producing higher quality products in ISO certified companies is heightened. From the foregoing, all the costs associated with the maintenance of standards must be estimated before implementing ISO certification in organisations. Much of this cost relates to purchase of stationeries and the apportioned cost of personnel to maintain standards.

3.3 *The mathematical model*

The mathematical model discussed here are of two categories. The first concerns the deviation of expressions that establish the rate of implementation of ISO in the refinery. The second shows the relationship among the various costs. Such costs include education and training cost, procurement of standards cost, maintenance of standards cost, certification cost, supplier cost, and internal audit cost.

3.3.1 *Rate of implementation of ISO in the refinery*

The benefits of ISO implementation are probably the main reason why a refinery may opt for certification. There are certain factors, which affect the rate of implementing ISO, they are:

1 number of staff

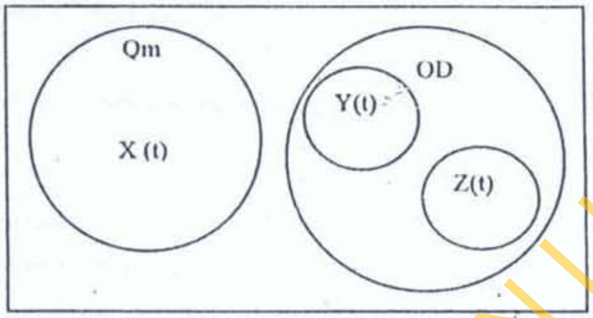
2 number of inspectors made

3 number of facilities to be inspected.

In determining the quality of an organisation's product, there are certain factors that could be assessed. These factors vary from product testing to technical, administrative and human factors. In organisations implementing ISO, there are guidelines that must be followed and verified by auditors. Consider the whole staff of the refinery treated as a Venn diagram as represented below in Figure 1.

By the principles governing summation of components of the Venn diagram, it could be stated that X(t) + y(t) + z(t) = N(t). However, the number of refinery staff may not be constant since the organisation is dynamic, expands, and engages new skilled personnel every year. Thus, this growth in the staff strength of the refinery staff may be likened to the strain, which represents the growth in material.

Figure 1 Venn diagram representing the staff of the refinery



Thus,

$$\text{Strain} = \frac{\text{change in length}}{\text{original length}} \tag{1}$$

Strain is a growth concept in physical services that represents an extension in size in relations to its original size. This concept would be useful if applied to the current problem investigated. Now, let us look at a population growth in the refinery (i.e. change in population size in relation to the population size).

$$\text{Relative rate of growth} = \frac{\text{rate of growth}}{\text{size of population}} \tag{2}$$

Rate of growth is a differential of the size of the population of refinery staff, expressed as dN/dt. Therefore,

$$\text{Relative rate of growth} = \frac{dN/dt}{N} \tag{3}$$

If the relative rate of growth is a constant given by K, then,

$$KN = \frac{dN}{dt} \tag{4}$$

Equation (4) is a first order differential equation. In order to progress with the formulation, let us multiply both sides by e^{-kt}, we then have

$$KNe^{-kt} = \frac{dN}{dt}e^{-kt} \tag{5}$$

By now comparing equations (4) and (5), we have

$$\frac{dN}{dt} e\text{-}kt = e^{-kt} \frac{dN}{dt} + N(-ke^{-kt}) \quad (6)$$

From the combination of equations (5) and (6), we have

$$\frac{d}{dt} Ne^{-kt} = 0 \quad (7)$$

Since the derivative of $Ne^{-kt} = 0$ then

$$N = ce^{kt} \quad (8)$$

Equation (8) is the solution to the differential equation (4). Thus, we have

$$N(t) = ce^{kt} \quad (9)$$

and

$$x(t) = y(t) + z(t) = ce^{kt} \quad (10)$$

From equation (9), at time $t = 0$, we have:

$$N(0) = ce^{o} = c. \text{ Therefore } c = N(0)$$

But

$$N(t) = N(0)\, e^{kt} \quad (11)$$

$$x(t) + y(t) + z(t) = [x(0) + y(0) + z(0)]e^{kt}$$

$$x(t) + y(t) + z(t) = [x(0) + y(0)]\, e^{kt} \quad (12)$$

The equations (9) and (10) can be used to calculate the rate of growth of the employees in the refinery. This calculation also covers the number of employees in the quality management department. The presence of more trained staff in the quality management department makes it better for the refinery to get or stay ISO certified.

3.3.2 Relationship among costs

The petroleum refinery in the case study aims to maximise profit while keeping all the cost elements to the minimum. Thus, it is necessary to develop a mathematical model that reflects profit quantification. The following cost elements are then discussed in the model:

- education and training cost (e)
- procurement of standards cost (P_s)
- maintenance of standards cost (M_s)
- certification cost (C_c)
- supplier cost (S)
- internal audit cost (I).

It is noted that for a quantity of crude oil (Q_c) to be refined, it has to produce a certain amount of profit (P) to make it worthwhile. We also know that the revenue (C) for a certain quantity of crude oil is constant if inflation in the environment is held constant. From the general equation, we have that Revenue (C) minus the Cost incurred (C_i) gives profit (P). Thus, mathematically,

$$C - C_i = P \tag{13}$$

However, a strong relationship between the cost elements and profits could be established. Thus, the cost elements may be related to profits mathematically as:

$$c_i \alpha P \tag{14}$$

Now, the education and training cost is expressed in an equation as:

$$c_i = ae^2 + be + c \tag{15}$$

Also, if the cost of procurement of standards and maintenance of standards are related by the expression

$$P_s + M_s^2 = X$$

$$c_i = aX^3 + bX^2 + cX$$

For certification cost, internal audit cost and supplier development cost, we also have a relationship. For example,

$$c_i + I + S = D$$

Therefore,

$$c_i = aD^3 + b$$

Our equations are thus:

$$c_i = ae^2 + be + c \tag{16}$$

$$c_i = aX^3 + bX^2 + cX \tag{17}$$

$$c_i = aD^3 + b \tag{18}$$

a, b, c are constants.

Let us find out how all the quantities are related. From 3, $b = c_i - aD^3$ put this in (16) and (17)

$$c_i = ae^2 + (c_i - aD^3)e + c \tag{19}$$

$$c_i = aX^3 + (c_i - aD^3)X^2 + cX \tag{20}$$

From 19,

$$c = ci - ae^2 - (ci - aD^3)e$$

Put this in (20)

$$c_i = aX^3 + (c_i - aD^3)e + [c_i - ae^2 - (c_i - aD^3)e]X$$

$$c_i = a[X^3 - D^3X^2 + e^2X + D^3eX] + c_iX^2 + c_iX - c_ieX \tag{21}$$

By making a the subject of the formula

$$a = \frac{c_l}{X}\left[\frac{1 - X^2 - X - eX}{X^2 - D^3X - e^2 + D^3e}\right] \tag{22}$$

From $b = c_l - aD^3$, we have:

$$b = c_l\left[1 - \frac{D^3\left(1 - X^2 - X - eX\right)}{X\left(X^2 - D^3X - e^2 + eD^3\right)}\right] \tag{23}$$

From $c = c_l - ae^2 - (c_l - aD^3)e$, we have:

$$c - c_l\,(1 - e) - a(e^2 - D^3e)$$

Putting a into the equation, we have:

$$c = c_l[1 - e] - \frac{c_l}{X}\left[\frac{1 - X^2 - X - eX}{X^2 - D^3X - e^2 + eD^3}\right]\left(e^2 - D^3e\right) \tag{24}$$

Remember $C_e + I + S = D$ and $P_s + M_s^2 = X$. Put these two equations for (22), (23) and (24),

$$a = \frac{c_l}{Ps + M_s^2}\left[\frac{1 - \left(P_s + M_s^2\right)^2 - \left(P_s + M_s^2\right) - e\left(P_s + M_s^2\right)^2}{\left(P_s + M_s^2\right)^2 - \left(P_s + M_s^2\right)(Cc + I + S)^3 - e^2 + e(Cc + I + S)^3 e}\right] \tag{25}$$

$$b = c_l\left[\frac{1 - (Cc + I + S)^3\left(1 - \left(P_s + M_s^2\right)^2 - \left(P_s + M_s^2\right) - e\left(P_s + M_s^2\right)^2\right)}{\left(P_s + M_s^2\right)^2 - \left(P_s + M_s^2\right)(Cc + I + S)^3\left(P_s + M_s^2\right) - e^2 + e(Cc + I + S)^3}\right] \tag{26}$$

$$c = c_l(1 - e) - \frac{c_l}{\left(P_s + M_s^2\right)}\left[\frac{1 - \left(P_s + M_s^2\right)^2 - \left(P_s + M_s^2\right) - e\left(P_s + M_s^2\right)}{\left(P_s + M_s^2\right)^2 - (Cc + I + S)^3\left(P_s + M_s^2\right) - e^2 + e(Cc + I + S)^3}\right] \tag{27}$$

From our first three equation, let $c_1 = ae^2 + be + c$; $c_2 = aX^3 + bX^2 + cX$; and $c_3 = aD^3 + b$. Then,

$$c_1 = ae^2 + be + c$$

$$c_2 = a\left(P_s + M_s^2\right)^3 + b\left(P_s + M_s^2\right)^2 + c\left(P_s + M_s^2\right)$$

$$c_3 = a(Cc + I + S) + b$$

and let $c_1 + c_2 + c_3 = c_l$; c_l will be the total cost incurred from the cost elements.

Since $c_l \propto P$; $c_l = KP$ (profit here is the estimated profit given that the products sell). Where K = constant.

$$c_l = c_1 + c_2 + c_3 = ae^2 + be + c + a\left(P_s + M_s^2\right)^3 + b\left(P_s + M_s^2\right)^2 + c\left(P_s + M_s^2\right)$$

$$+ a(Cc + I + S)^3 + b$$

c_l = From $b = c_l - aD^3$, we have

$$= a\left[e^2 + \left(P_s + M_s^2\right)^3 + \left(Cc + I + S\right)^3\right] +$$
$$b\left[e\left(P_s + M_s^2\right)^2 + 1\right] + c\left[1 + Ps + M_s^2\right]$$

Therefore, the relationship between our cost incurred from our cost elements and our profit gained is:

$$a\left[e^3 + \left(P_s + M_s^2\right)^3 + \left(Cc + I + S\right)^3\right] + b\left[e\left(P_s + M_s^2\right)^2 + 1\right] + c\left[1 + Ps + M_s^2\right] = KP.$$

i.e.

$$KP = a\left[e^2 + \left(P_s + M_s^2\right)^3 + \left(Cc + I + S\right)^3\right] + b\left[e\left(P_s + M_s^2\right)^2 + 1\right] + c\left[1 + Ps + M_s^2\right]$$

The profit (P) above is the profit that should be gained if everything goes on well i.e. if the products are sold at a reasonable price. If there is profit, there could be loss too. What if the products are not selling, say we produce goods of a high standard and they are too expensive, and consumers going for products that are cheaper with far lower standard. The profit or loss will be calculated from: Capital (c) – total cost incurred (c_{it}) = profit or loss i.e. $c - c_{it} = P$. Note that c_{it} = cost incurred from the cost elements + miscellaneous cost.

4 Case applications

The case applications discuss studies based on a number of cases labelled Case 1 to 3, with detailed discussions following.

4.1 Case study 1

In a certain production company, there is 5,000 staff, 5% of the total number of staff work in the QM department. 10% of the staff in the QM department are transferred to other departments. The rate of growth in the company is 0.00002. Only 50 staff in the QM department are allowed to participate in any assessment or inspecting exercise. In six months of operation, eight general inspections, four impromptu inspections and two special inspections were made. The table below shows the distribution of the inspection. The inspection/assessment exercise usually centres on the production areas and the mechanical engineering workshop. The table shows the equipment and their numbers in both the production areas and the mechanical engineering workshop respectively.

Table 1 shows a total number of 39 equipments suitably distributed in the production area of the organisation.

Table 2 shows a total number of 15 equipments in the mechanical engineering workshop. The Table 3 below gives a relationship between the type of equipment and the total number of hours used to inspect/assess the total number of each equipment available.

Total inspection exercise does not exceed four hours, while work is done for ten hours a day, five days a week, four week a month and 40 weeks a year.

From the case study, x' (t) = when t =0, number of staff working in the QM department = 5% x N (t) = 5% x 5,000 = 250 people.

N (t) = Number of staff in the company at time t 10% of $n^1(t) = z(t)$, but when t = 0, z(t) =0 z(t)=0 (t=0). Note that $n^1(t) + y(t) + z(t) = N(t)$.

Then $N(0) = x^1(0) + y(0) + z(0)$, and $y(0) = N(0) - n^1(0) - z(0) = 5{,}000 - 250 - 0 = 4750$.

But k = 0.00002, therefore $N(t) = N(0)\, e^{kt}$.

This equation is used to get the number of staff in the company [N(t)] at any time t. Note: n(t) = number of staff that participate in the inspection/assessment exercise at time t.

Six months in this company = 24 hours = 120days 1200hours

When t' =0; $a(t^1) = a(0) = 1$ = number of general inspections; $b(t^1) = b(0) = 0$ = number of impromptu inspections; $c(t^1) = c(0) = 0$ = number of general/impromptu done for a specific reason; $f(t^1) = f(0) = 1$ = total number of inspection; $d(t^1) = f(t^1) \times n(0)$ = number of assessment exercise done in time t^1.

The equation above gives us the number of assessment done for a specific time frame. Similarly, when t^1 = 1200hours; $a(t^1) = a(1200) = 8$; $b(t^1) = b(1200) = 4$; $c(t^1) = c(1200) = 2$; $f(t^1) = f(1200) = 14$

Table 1 Equipment in production area

Production area	
Equipment	*Number*
Stem boiler	4
Turbo generators	4
Oil purifiers	4
Air compressors	3
Steam turbines	8
Pump A	4
Pump B	12
Total	39

Table 2 Equipment in mechanical engineering workshop

Mechanical engineering workshop	
Equipment	*Number*
Lathe machine	6
Drilling machine	2
Welding machine	2
Shaft alignment m/c	1
Grinding machine	2
Milling machine	2
Total	15

Table 3 Types and quantity of equipment and hours used for inspection

Type of equipment	*Number of hours used to inspect each machine*	*Number of equipment staff*	*Total number of equipment*	*Total number of hours used to inspect total number of equipment*	*Total number of equivalent staff*
Steam boiler	4	1	4	16	4
Turbo generators	4	1	4	16	4
Oil purifiers	3	1	4	12	3
Air compressors	3	1	3	9	3
Steam turbines	3	1	8	24	6
Pump A	3	1	4	12	3
Pump B	1	1	12	12	3
Lathe machine	3	1	6	18	5
Drilling machine	1	1	2	2	1
Welding machine	1	1	2	2	1
Shaft alignment m/c	4	1	1	4	1
Grinding machine	3	1	2	6	2
Milling machine	3	1	2	6	2
Total	36	13	54	139	38

From Table 3, the last column shows the total number of equivalent staff that can be used to inspect a total number of equipment in just four hours. We can add the staff number to make sure it does not exceed 50 staff, because only 50 staffs are available for inspection. Since the total number of staff is less than 50, we can inspect all the equipment. When $t^{11} = 0$, Number of facilities inspected $(t^{11}) = 54$; Number of staff that inspected the equipment $m(t^{11})$ 38; Number of equipment that were not being inspected $n(t^{11}) = 0$; Total number of facilities $p(t^{11}) = 54$; Number of staff that did not inspect $j(t^{11}) = 50 - m(t^{11}) = 50 - 38 = 12$ staff; $d(t^{11}) = \dfrac{p(t^{11}) \times n(0)}{n^1(t)}$. The formula is used to set the number of equipment that can be assessed.

4.2 Case study 2

A production company has a 500 staff working capacity, 2% of the total number of staff work in the QM department. 40% of the staff in the QM department are transferred to other departments. The rate of growth in the company is 0.000015. 50% of the staff in the QM department are allowed to participate in any assessment/inspection exercise. In 12 months of operation, 14 general inspections were made and eight impromptu inspections were made for special reasons. The table below shows the distribution of inspections. The inspection/assessment exercise usually centres on the production areas and the mechanical engineering workshop. The tables below show the equipment and their numbers in both the production areas and the mechanical engineering workshop respectively.

Table 4 Equipment in production area (Case 2)

Production area	
Equipment	*Number*
Stem boiler	1
Turbo generators	1
Oil purifiers	1
Air compressors	1
Steam turbines	3
Pump A	2
Pump B	6

The total number of equipment shown for Case 2 in the production area is six.

Table 5 Equipment in production area (Case 2)

Mechanical engineering workshop	
Equipment	*Number*
Lathe machine	2
Drilling machine	2
Welding machine	1
Shaft alignment m/c	1
Grinding machine	1
Milling machine	1
Total	8

The total number of equipment for Case 2 in the Mechanical engineering workshop is eight. Table 6 shows the data that represents the situation.

Table 6 Data on general, impromptu, and special cases for Cases 1, 2, and 3

		General (Cases 1,2,3)	*Impromptu (Cases 1,2,3)*	*Special (Cases 1,2,3)*
Month 1	Day 1	1,1,1	–,–,–	–,–,–
	Special	–,–,–	–,1,–	–,–,–
	Day 2	1,–,1	–,–,–	–,–,–
Month 2	Day 1	–,1,1	1,–,–	–,–,–
	Special	–,1,1	–,–,–	1,1,–
	Day 2	1,1,–	–,–,1	–,–,–
Month 3	Day 1	–,–,1	1,1,–	–,–,–
	Special	–,–,–	–,–,–	–,–,–
	Day 2	1,1,1	–,–,–	–,–,–
Month 4	Day 1	1,1,1	–,–,–	–,–,–
	Special	–,–,–	–,–,–	–,–,–
	Day 2	1,1,1	–,–,–	–,–,–

Table 6 Data on general, impromptu, and special cases for Cases 1, 2, and 3 (continued)

		General (Cases 1,2,3)	*Impromptu (Cases 1,2,3)*	*Special (Cases 1,2,3)*
Month 5	Day 1	–,1,–	1,–,1	–,–,–
	Special	–,–,–	–,–,–	–,–,–
	Day 2	1,–,1	–,1,–	–,–,–
Month 6	Day 1	1,1,–	–,–,1	–,–,–
	Special	–,–,–	–,–,–	1,–,–
	Day 2	–,1,1	1,–,–	–,–,–
Month 7	Day 1	–,1	1,1	–,–
	Special	–,–	–,–	–,1
	Day 2	1,–	–,1	–,–
Month 8	Day 1	1,–	–,–	–,–
	Special	–,–	–,–	–,–
	Day 2	–,–	1,1	–,–
Month 9	Day 1	1,1	–,–	–,–
	Special	–,–	–,–	–,1
	Day 2	1,1	–,–	–,–
Month 10	Day 1	–,–	1,1	–,–
	Special	–,–	–,–	–,–
	Day 2	–,1	–,–	–,–
Month 11	Day 1	–,1	–,–	–,–
	Special	–,–	–,–	–,–
	Day 2	–,–	1,1	–,–
Month 12	Day 1	1,–	–,–	–,–
	Special	–,–	–,–	–,1
	Day 2			

The Table 7 below gives a relationship between the type of equipment and the total number of hours used to inspect/assess the total number of each equipment available.

Total inspection exercise should not exceed four hours. Work is done for only ten hours a day, five days a week, four weeks a month, 40 weeks a year.

From the case study, $n^1(t)$ = when t =0, number of staff working in the QM department = 2% x N (t) = 2% x 5,000 = 10 people; N (t) = Number of staff in the company = 500 people; x (0) = number of people allowed to inspect = 5; 40% of x'(t) + Z(t), when t =0, Z (t) =0

$x'(t) + y(t) + Z(t) = N(t)$; $N(0) = x'(0) + y(0) - Z(0)$; $Y(0) = x'(0) - Z(0) = 5{,}000 - 10 - 0 = 490$. But $k = 0.000015$, $N(t) = N(0)e^{kt}$

This equation is used to get the number of staff in the company at time t. 12 months in this company = 44 weeks = 240days 2400hours

When t' =0; a (t') = a (0) = 1 = number of general inspections; b (t') = b (0) = 0 = number of Impromptu inspections; c (t') = c (0) = 0 = number of general/impromptu done for a specific reason; f (t') = f (0) = 1 = total number of inspection; d(t') = $\frac{f(t^{1}) \times x(0)}{x^{1}(t)}$ = number of assessment exercise done in time t'.

When t' =2400hrs; a (t') = a (2400) = 14; b (t') = b (2400) = 8; c (t') = c (2200) = 2 f (t') = f (1200) = 24. From Table 8, the last column shows the total number of equivalent staff that can be used to inspect a total number of equipment in just four hours. Since only five staff can inspect, we would choose a number of equipment to be inspected on the first day of inspection, then the rest that could not be inspected would be done on a later day. A staff could inspect the steam boiler, the turbo generator, the shaft alignment machine, and the air compressors making it four staff. The milling machine and the welding machine can be inspected by just one staff since the total of the hours need to inspect both equipment is four hours. When t''= 0; Number of facilities inspected (t'') = 6; Number of staff that inspected the equipment m(t'') = 5; Number of equipment that were not being inspected x (t'') = 23 – 6 = 17; Total number of facilities p (t'') = 23; Number of staff that did not inspect j (t'') = 0

$$d(t'') = \text{Number of equipment that can be assessed } \frac{p(t^{11}) \times x(0)}{x^{1}(t)}$$

Table 7 Equipment, number of staff, and inspection hours

Type of equipment	*Number of hours used to inspect each machine*	*Number of equipment staff*	*Total number of equipment*	*Total number of hours used to inspect total number of equipment*	*Total number of equivalent staff*
Steam boiler	4	1	1	4	1
Turbo generators	4	1	1	4	1
Oil purifiers	3	1	1	3	1
Air compressors	3	1	1	3	1
Steam turbine	3	1	3	9	3
Pump A	3	1	2	6	2
Pump B	1	1	6	6	2
Lathe machine	3	1	2	6	2
Drilling machine	1	1	2	2	1
Welding machine	1	1	1	1	1
Shaft alignment m/c	4	1	1	4	1
Grinding machine	3	1	1	3	1
Milling machine	3	1	1	3	1
Total	36	13	23	54	18

4.3 Case study 3

A production company in the south-south part of an African country has 3,000 staff working there. The company has a well founded QM department, which handles all assessment, and inspection exercise in the company. The distribution of staff in the company is as follows:

- Number of staff in the company: 3,000
- Number of staff in the QM department: 8% of 3,000
- Number of staff transferred from the QM department to other department: 10% of number in QM department
- Number of staff that handle the assessment/inspection exercise: 20% of number in QM department
- k = 0.00002.

With its over 12 years of operation, the company decided to look at the inspection/assessment exercise over the last 12 months.

They are as follows: General inspections: 16; General inspections (specified): three; Impromptu inspections: seven; Impromptu inspections (specified): two

The days in which the inspections were done is listed below: The inspection/assessment exercise usually centres on the production and mechanical workshop area in the company. Tables 8 and 9 below show the type of equipment, their number and the manufacturers' specification on how many types of inspections should be carried out on the equipment in the production area and mechanical workshop respectively.

Table 8 Equipment in production area

No.	*Equipment*	*Number*	*Manufacturers opinion inspections per month*
1	Steam boiler	4	1
2	Turbo generator	4	0.5 (i.e. once in two months)
3	Oil purifiers	4	2
4	Air compressors	4	2
5	Steam turbines	8	1
6	Pump A	3	1
7	Pump B	12	2
	Total	39	9.5

Table 8 shows manufacturers opinion inspections per month.

The Table 10 below gives a relationship between the type of equipment and the total number of hours used to inspect/assess the total number of each equipment available.

Table 9 Mechanical engineering workshop

No.	Equipment	Number	Manufacturers opinion inspections per month
1	Lathe machine	5	0.5 (i.e. once in two months)
2	Drilling machine	4	0.5 (i.e. once in two months)
3	Welding machine	2	1
4	Grinding machine	2	0.5 (i.e. once in four months)
5	Milling machine	2	2
6	Shaft alignment machine	1	0.5 (i.e. once in four months)
	Total	16	5

Table 10 Equipment, number of staff, and inspection hours

Type of equipment	Hours for inspecting each machine	Number of equipment staff	Total number of equipment	Total hours for inspecting equipment	Total number of equivalent staff
Steam boiler	4	1	4	16	4
Turbo generators	4	1	4	16	4
Oil purifiers	3	1	4	12	3
Air compressors	3	1	4	12	3
Steam turbine	3	1	8	24	6
Pump A	3	1	3	9	3
Pump B	1	1	12	12	3
Lathe machine	3	1	5	15	4
Drilling machine	1	1	4	4	1
Welding machine	1	1	2	2	1
Shaft alignment m/c	3	1	2	6	2
Grinding machine	3	1	2	6	2
Milling machine	4	1	1	4	1
Total	36	13	55	138	37

Total inspection exercise should not exceed four hours. Work is done ten hours a day, five days a week, four weeks a month, 40 weeks a year.

Note that all equipment can be assessed at the specified time without the manufacturer's opinion.

From the case study, When $t = 0$, $x'(t)$ = Number of staff working in the QM department = 8% of 3,000 = 240 people.

$N(t)$ = Number of staff in the company = 3,000

$z(t)$ = Number of staff transferred to other departments

At $t = 0$, $z(0) = 0$, $x'(t) + y(t) + z(t) = N(t)$

$$N(0) = x'(0) + z(0) + y(0)$$

$y(0) = N(0) - x'(0) - z(0)$

$y(0) = 3,000 - 240 - 0 = 2760$

$k = 0.00002$

$N(t) = N(0)\, e^{kt}$

This equation is used to get the number of staff in the company at any time t.

$x(t)$ = Number of staff that participate in inspection/assessment exercise at time t

$x(0) = 48$

12 months in the company = 48 weeks = 240 days = 2400hrs.

When t' = 0, looking at Table 1.

$a(t') = a(0) = 1$ = number of general inspections

$b(t') = b(0) = 0$ = number of impromptu inspections

$c(t') = c(0) = 0$ = number of general/impromptu inspections done for a specific reason (special)

$f(t') = f(0) = 1$, total number of inspections.

$d(t') = \dfrac{F(t'') \times x(0)}{x'(t)}$ = number of assessment exercise done in time t'.

Note that after the first week of operation, t' = 0.

Three weeks later, for t' = 150hrs.

$a(t') = a(150) = 2$; $b(t') = b(150) = 0$; $c(t') = c(150) = 0$; $F(t') = F(150) = 2$

t' = 200hrs

$a(t') = a(200) = 3$; $b(t') = b(200) = 0$; $c(t') = c(200) = 0$; $F(t') = F(200) = 3$

t' = 350hrs

$a(t') = a(350) = 3$; $b(t') = b(350) = 1$; $c(t') = c(350) = 1$; $F(t') = F(350) = 5$.

Let us consider the first and second months of operation of the company.

- Month 1, Day 1: In the first day of inspection in the first month of operation, all the equipment was inspected. Only 37 out of 48 staff did the inspection.
- Month 1, Day 2: The dashes indicate that no inspections should be done on the equipment due to manufacturer's opinion.
- Month 2, Day 1: 25 out of 48 staff were needed to inspect just 39 equipment in the first day of inspection in the second month of operation within the timeframe (t') of 12 months.
- Month 2, special inspection: During special inspections, all equipments are inspected irrespective of the manufacturer's opinion.
- Month 2, Day 2: Once again, we have 11 staff inspecting out of 48 available. .

Table 11 Number of equipment inspected

Equipment	*M1D1*	*M1D2*	*M2D1*	*M2D2*
Steam boiler	4	–	4	–
Turbo generator	4	–	–	–
Oil purifiers	4	12	4	4
Air compressors	4	12	4	4
Steam turbines	8	–	8	–
Pump A	3	–	3	–
Pump B	12	12	12	12
Lathe machine	5	–	–	–
Drilling machine	4	–	–	–
Welding machine	2	–	2	–
Grinding machine	2	–	–	–
Milling machine	2	2	2	2
Shaft alignment machine	1	–	–	–
Total	55	22	39	22

Note: M1D1: Month 1, Day 1; M1D2: Month 1, Day 2; M2D1: Month 2, Day 1; M2D2: Month 2, Day 2.

When t'' = 0, Table 5 i.e. Month 1, Day 1

Number of facilities inspected l(t'') = 55

Number of staff that inspected the equipment m(t'') = 37

Number of equipment that were not being inspected n(t'') = 0

Total number of facilities = P(t'') = 55

Number of staff that did not inspect j(t'') = x(t) – m(t'') = 48 – 37 = 11 staff.

When t'' = 150, Table 6 i.e. Month 1, Day 2

l(t'') = 22; m(t'') = 11; n(t'') = p(t'') – l(t'') = 55 – 22 = 33 equipment

p(t'') = 55; j(t'') = x(t) – m(t'') = 48 – 11 = 37 staff.

When t'' = 200, Table 7 i.e. Month 2, Day 1

l(t'') = 39; m(t'') = 25; n(t'') = p(t'') – l(t'') = 55 – 39 = 16

p(t'') = 55; j(t'') = x(t) = m(t'') = 48 – 25 = 23 staff.

When t'' = 350, Table 8 i.e. Month 2, Day 2

l(t'') = 22; m(t'') = 11; n(t'') = p(t'') – l(t'') = 55 – 22 = 33 equipment

p(t'') = 55, j(t'') = x(t) = m(t'') = 48 – 11 = 37 staff

$$d(t'') = \text{Number of equipment that can be assessed} = \frac{P(t'') \times x(0)}{x'(t)}.$$

4.4 Cost implications

Table 12 Cases 1 and 2: Statistics showing number of staff, time, total inspection hours, and cost of implementation of ISO

Equipment	*Number of staff*		*Total inspection hours*		*Cost of implementation (₦'000)*	
	Case 1	*Case 2*	*Case 1*	*Case 2*	*Case 1*	*Case 2*
Steam boiler	4	1	16	4	160	40
Turbo generator	4	1	16	4	160	40
Oil purifiers	3	1	12	3	120	30
Air compressors	3	1	9	3	90	30
Steam turbines	6	1	24	9	240	90
Pump A	3	1	12	6	120	60
Pump B	3	1	12	6	120	60
Lathe machine	5	1	18	6	180	60
Drilling machine	1	1	2	2	20	20
Welding machine	1	1	2	1	20	10
Grinding machine	1	1	4	4	40	40
Milling machine	2	1	6	3	60	30
Shaft alignment machine	2	1	6	3	20	30
Total	38	13	139	54	1390	540

Case 1 For Cases 1 and 2, if a quality management staff inspects equipment for one hour, he would be paid ₦10,000. For Case 1, there are 139 hours used for inspection for a day. Thus, we have 139 X 10,000 = ₦1,390,000 was spent for inspection in one day. Therefore, total cost spent for ISO implementation for its six months of operation will be ₦1,390,000 X 14 inspections = ₦19,460,000. For Case 2, there are 54 hours used for inspection for a day. Therefore 54 X 10,000 = ₦540,000 was spent for inspection for a day. Thus, total cost spent for ISO implementation for the whole year of operation is 540,000 x 24 inspections = ₦12,960,000.

Case 3 For each of Month 1, Day 1, Month 1, Day 2, Month 2, Day 1, Month 2, Day 2, a quality management staff who inspects earns ₦10,000 per hour. However, total cost for ISO implementation for Months 1 and 2 is ₦1,380,000 + ₦ 420,000 + ₦ 930,000 + ₦ 42,000 = ₦ 3,150,000.

Table 13 Case 3: Statistics showing number of staff, time, total inspection hours, and cost of implementation of ISO for two months

Equipment	*Number of staff*				*Total inspection hours*				*Cost of implementation (₦'000)*			
	M1D1	*M1D2*	*M2D1*	*M2D2*	*M1D1*	*M1D2*	*M2D1*	*M2D2*	*M1D1*	*M1D2*	*M2D1*	*M2D2*
Steam boiler	4	–	4	–	16	–	16	–	160	–	160	–
Turbo generator	4	–	–	–	16	–	–	–	160	–	–	–
Oil purifiers	3	3	3	3	12	12	12	12	120	120	120	120
Air compressors	3	3	3	3	12	12	12	12	120	120	120	120
Steam turbines	6	–	6	–	24	–	24	–	240	–	240	–
Pump A	3	–	3	–	9	–	9	–	90	–	90	–
Pump B	3	3	3	3	12	12	12	12	120	120	120	120
Lathe machine	4	–	–	–	15	–	–	–	150	–	–	–
Drilling machine	1	–	–	–	4	–	–	–	40	–	–	–
Welding machine	1	–	1	–	2	–	2	–	20	–	20	–
Grinding machine	2	–	–	–	6	–	–	–	60	–	–	–
Milling machine	2	2	2	2	6	6	6	6	60	60	60	60
Shaft alignment machine	1	–	–	–	4	–	–	–	40	–	–	–
Total	37	11	25	11	138	42	93	42	1380	420	930	420

4.5 Discussion

A case study analysis of a petroleum refinery is considered here. The data used is simulated in view of the difficulty of obtaining actual data from the source. However, the data generated strongly reflects what obtains in practice, hence could guide decision makers in similar industry to making useful decisions. Three scenarios where generated in order to understand the effects of the implementation process in the organisation. The first concerns a situation where the total number of staff reaches 5,000 in value. Out of this, 5% work in the quality department. However, 10% of these staff members in the quality departments are seconded to other departments. In addition, the rate of growth in the company is 0.00002. Also, only 50 staff in the quality management department are allowed to participate in any assessment or inspection exercise. In six months of operation, eight general inspections, four impromptu inspections and two special inspections were made.

The second scenario concerns a situation where there are 500 staff working in the petroleum refinery. 2% of the total number of staff works in the Quality Management Department. However, 41% of the staff in the Quality Management Department are transferred to other departments. The rate of growth in the company is 0.000015. 50% of the staff in the Quality Management Department are allowed to participate in any assessment or inspection exercise. In 12 months of operation, 14 general inspections were made and eight impromptu inspections were made. Two out of 14 general inspections were made for special reasons.

The third case concerns a situation where there are 3,000 staff working in the company. 8% of the 3,000 staff that work in the company works in the Quality Management Department. About 10% of those that work in the Quality Management Department are transferred to other department. However, 20% of the number of staff that work in the Quality Management Department handle the assessment or inspection exercise. The growth rate is 0.00002. In 12 months of operation, 16 general inspections were made, three general inspections were specified, seven impromptu inspections were made, two impromptu inspections were specified. The inspection exercise was based on the manufacturer's opinion.

5 Conclusion

The paper links application of a theoretical model to a practical world of management in a developing country. Mathematical models were developed for calculation of the total cost of implementation. Three case studies were developed for different types of petrol refineries to get the total cost used for ISO implementation for specific time period. Case 1 considers a scenario where the company has a staff of 5,000. It had 14 inspections over six months of operation of which eight were general, four were impromptu and two were special. The workers are paid ₦ 10,000 per hour for any inspections made. There was a total of 139 hours used for inspection. For an inspection, ₦ 1,390,000 was used. Therefore for 14 inspections, ₦ 19,460,000 was used for inspection for a period of six months. Case 2 discusses a scenario where the company has a staff of 500 staff. It had 24 inspections in one year. The inspections were comprised of 14 general, eight impromptu and two special. Inspectors are paid ₦ 10,000 per hour during inspection time. A total of

54 hours were used for inspection. For one inspection, ₦ 540,000 was used. For 24 inspections, ₦ 12,960,000 was used for a period of one year.

For Case 3, the company has 3,000 staffs. It was studied for over a two-month period. There were three general inspections, one impromptu and one special inspection. Here, staffs were also paid ₦ 10,000 per hour spent for inspection. For the first day of the first month, there was a total of 138 hours used. Therefore the cost for that day is ₦ 1,380,000. For the second day of the first month, there was a total of 42 hours used. Therefore the cost for that day is ₦ 420,000. For the first day of the second month, there was a total of 93 hours used. Therefore the cost for that day is ₦ 930,000. For the first day of the first month, there was a total of 42 hours used. The cost for that day is ₦ 420,000. The total cost for two months is ₦3,150,000.

Due to the difficulty in getting the real values for the case study, hypothetical values were used. However, in order to obtain more realistic values, we need to get more precise values for the case studies to calculate implementation cost. This is a limitation of the study. A possible future extension of the research is to calculate the turnover and then compare with the implementation cost.

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