School of Management
Blekinge Institute of Technology

DESIGN AND IMPLEMENTATION OF QMS FRAMEWORK IN POWER PLANT PROJECTS
GARRI4 PROJECT AS A MODEL, SUDAN

A THESIS SUBMITTED

BY

MUHANAD FAIZ FAKHRI

ID: 800124-P812

BLEKINGE INSTITUTE OF TECHNOLOGY, SWEDEN

IN PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR THE
DEGREE OF

MASTER OF BUSINESS ADMINISTRATION

SUPERVISOR:

DR. PETER STERVIN

ABSTRACT

School of management

Master of business administration

Design and Implementation of QMS framework in Power Plants Projects, Garri4 project as a model, Sudan

October 2008

114 pages

In recent years, many companies around the world have adopted different forms of quality systems, such as ISO-based quality systems, or BS-based quality systems. It has been perceived that a quality-based company provides higher quality services and products in comparison with non quality-based companies. As a result, quality-based companies have become reputable and attract more customers. In projects construction field, quality has become very essential for both contractors and owners. Contractors tend to provide high quality deliverables to satisfy their clients, and to remain successful in this turbulent business field, while owners want to receive high quality end-products and services, and to ensure that their deliverables matching contractual quality requirements. Therefore owners (whether operating companies or government sectors) have developed different means to measure quality in their projects, such as hiring professional consultants who cooperate with owner's project team. If owners have developed reliable quality management system (QMS) and their staffs are experienced and competent with relevant technical and project management knowledge, then the result will be outstanding.

This study is aimed to design, implement, and examine a QMS in Garri4 power plant project, NEC, Sudan – which has already completed 60% of its activities on the time of QMS implementation. The outcomes of this implementation are intended to be used for future NEC projects. The outlines of the QMS have been prepared from the PMBOK guide, which has been published by PMI (Project Management Institute, USA) as a guide for project management knowledge and practices. In addition to that, the detailed QMS work frame has been designed on the guidance of relevant literature review and joint meetings with NEC project team. The required data before and after the QMS implementation gathered using questionnaires, and a Matrix model has been used to measure QMS objectives and requirements effectiveness based on the collected data. The final results

indicate success on meeting QMS prescribed objectives, while meeting QMS requirements during QMS implementation failed. An extensive analysis based on real observations during QMS implementation and these results has been carried in order to determine driven factors. Finally, a conclusion and recommendations have been drawn.

Keywords: QMS, effectiveness, implementations, objectives, requirements, matrix model, power plant projects, project management, PMBOK, Sudan.

ACKNOWLEDGEMENT

I consider my self as a lucky man for conducting an empirical research in Sudan, which considered being a quite difficult task, especially when it comes to applying and examining a new management system. Therefore, I would like to present my acknowledgements and my gratitude, with great pleasure, to the following respectful gentlemen and women:

- Prof. Peter Stervin, my supervisor, for his valuable support and guidance throughout the whole thesis period. His advices and comments have helped me very much to complete my thesis work successfully.

- Dr. Klaus Solberg Soilen, thesis course instructor, for his helpful comments, and for his great assistance to clarify all unclear thesis matters.

- MBA classmates at BTH, for their endlessness help throughout the whole MBA course. In addition to the valuable information that Mohammad Arshad Sheikh, my classmate, who criticized my work, for its contribution on developing and improving my thesis work to its final phase.

- Eng. Osman A/Karim, general directorate of planning and projects, NEC, Sudan, for his believes on my ability to make a difference, and to contribute in the overall project management improvement activities. I would like to thank him for his permission and approval to the QMS proposal to be implemented and examined in NEC.

- Eng. Elsadig Elkhair, Garri4 project manager in site, for his wonderful response and support to me, and NEC staffs in Garri4 project, for their understanding and contribution to the success of this study.

- My wife Hana and my daughter Lujain, for their patience and scarification while I was working for long hours on this hard thesis.

- I also would like to express my acknowledgement and my gratitude to my parents for their endlessness encouragement.

- And final thanks in the end, the beginning and all times, to my God, for his help, guidance, and support.

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ABBREVIATIONS

Ç Quality Management System

Ν National Electricity Corporation, Sudan

Ι International Standardization Organization

C Circulated Fluidized Bed boiler

C Chinese National Import an Export Company

Ç Quality Control

P Project Management Body Of Knowledge

P Project Management Institute

Ç Quality Assurance

Τ Total quality Management

Ս United States of America

S Statistical Quality Control

Α Acceptable Quality Levels

Β British Standards

, United State Of America

J Japan Standards Association

J Japan standards associations

J Union of Japanese Scientists and Engineers

U United Kingdom

R Research Questions

E European Quality Award

B British Quality Award

Q Quality Assurance Auditing

Q Quality Assurance and Assembly Plans

N Non-Conform Report

C Chief Executive Officer

P Project Management Professional

L Lahmeyer International consultants, Germany

L Limit
F Final Quality Score

F Final Quality Limit

CHAPTER ONE

INTRODUCTION

1. Introduction

This chapter will provide the reader with the appropriate understanding of the research work field. A brief introduction of the concept and the background of QMS (Quality Management System) will be given. After which, the problem under scrutiny will be discussed together with the purpose and motivation of the study. Finally, the thesis scope and arrangements will be presented.

1.1 Motivations

Quality generally refers to the totality of characteristics of a product or service that bears on its ability to (i) efficiently meet the outlined requirements/specifications and (ii) effectively satisfy the stakeholders' needs (Palaneeswaran et al, 2005).

As a client and owner of the Garri4 Project, the Sudanese National Electricity Corporation (NEC) considers quality to be one of the most important factors of success. This can be attributed to the adoption of ISO standards by the company in 1996. In addition to that, NEC has been awarded ISO 9001:2000 certification and is currently ISO-certified.

The project, in which QMS will be applied, is the Garri4 project. The capacity of which is 110 megawatts. The plant is comprised of two CFB (Circulated Fluidized Bed) boilers, two steam turbines, and other auxiliaries. This project is being implemented under the auspices of the National Electricity Corporation of the Republic of Sudan, in conjunction with two other power plant projects which are currently under construction: the Kosti Project (405 megawatts) and the Phase-3 Project (200 megawatts). Although the capacity of Garri4 is less than the two other projects in comparison, it is of more significance due to the fact that it is the first CFB-boiler type power plant in Africa and Arab countries.

The main contractor is Chinese National Machinery Import and Export Company (CMEC), and the consultant is the German, Lahmeyer International Company. The project started on the 26th of December 2006 and is planned to be completed on the 15th of January 2009. At the time of writing this thesis the Garri4 project has reached a point of 60% completion..

Every client plays an important role in achieving the project success and many academics have discussed this point. As Ling stated, clients have a large role to play to ensure project

success (Y.Y.Ling, 2002). Quality also is one of the client's prime concerns in their construction projects (Palaneeswaran et al, 2005). Therefore, the client must be certain that the contractor has implemented the undertaken project according to the contractual standards.

Although NEC is applying the ISO 9001:2000 system, unfortunately there is no pre-defined QMS in its power plant construction projects. The ISO standards are basically implemented in other NEC departments, for example in the Sales and Generation Departments, and to some extent in the Project and Planning Departments, but not in project sites.

All of the parties involved: the client, the consultant, and the contractor are currently applying their respective quality standards however a pre-defined QMS has not been adopted. To this end, a proposal for the designing of a QMS for the Garri4 project has been initiated by the researcher. The proposal has been accepted by the upper-level management of the department, after which the researcher was given the task of designing and implementing a well-structured QMS framework. The result of which, future projects can be modelled after.

1.2 Background Of QMS

It should be mentioned that there are many terminologies related to quality which must be defined according to: dictionaries; international standards; and quality field experts, combined with the historical evolution of quality management as indicated by the relevant literature from Dahlgaard (1999) and Yong et al (2002)

1.2.1 Definitions

1.2.1.1 Quality

According to the internet Encyclopedia dictionary definition (2008): Quality is the totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs. Not to be mistaken for "degree of excellence" or "fitness for use" which meet only part of the definition, (Encyclopedia, 2008)

According to the Business Dictionary, quality in general is a measure of excellence or state of being free from defects, deficiencies, and significant variations, (Business Dictionary, 2008)

The ISO 8402-1986 standard defines quality as "the totality of features and characteristics of a product or service that bears its ability to satisfy stated or implied needs." It has been defined in the Encarta Dictionary as excellence, the higher or finest standards. It also means standard, the general standard or grade of something.

Quality management experts, according to Yong et al (2002) define it in many different ways, such as: quality as a value in terms of costs and prices; quality as being conformance to specification (Garvin); quality as meaning the meeting, exceeding customer's expectations or both (Juran, Deming, Crosby), (Yong et al ,2002).

1.2.1.2 Inspection

The Encarta Dictionary defines inspection as: critical examination; a critical examination of somebody or something aimed at forming a judgment or evaluation; an official examination; an official authoritative examination, such as a motor vehicle inspection. (Encarta Dictionary, 2008).

In addition, British standards and ISO standards define inspection as activities such as: measuring, examining, testing, and gauging one or more characteristics of a product or service and comparing these with specified requirements to determine conformity (BS 4778, 1987; ISO 8402, 1986, cited in Yong et al, 2002).

1.2.1.3 Quality Control (QC)

In the Business Dictionary, quality control is defined as: a subset of quality assurance (QA) processes, it comprises of activities employed in detection and measurement of the variability in the characteristics of output attributable to the production system, and includes corrective responses. (Business dictionary, 2008)

In the field of project management, according to the PMBOK guide (Project Management Body Of Knowledge, which is considered to be the sum of knowledge within the profession of project management, published by PMI, Project Management Institute, the United States of America) Quality Control (QC) is the process of monitoring specific project results to determine whether it complies with relevant quality standards and identifying ways to eliminate unsatisfactory performance. (PMBOK, 2004)

1.2.1.4 Quality Assurance (QA)

The Business Dictionary defines quality assurance as being often used interchangeably with quality control (QC). It is a wider concept that covers all policies and systematic activities implemented within a quality system. QA frameworks include: the determination of adequate technical requirements of inputs and outputs; the certification and rating of suppliers; testing of procured material for its conformance to established quality; performance; safety; reliability standards; proper receipt; storage; issuance of material; auditing of the process quality; evaluation of the process to establish required corrective responses; and auditing of the final output for conformance to (a) technical, (b) reliability, (c) maintainability, and (d) performance requirements. (Business dictionary, 2008)

According to British and ISO standards, Quality Assurance (QA) is defined as: all those planned and systematic actions necessary to provide adequate confidence that a product or service will satisfy given requirements of quality (BS 4778, 1987; ISO 8402, 1986 cited in Yong et al, 2002).

In the project management field, according to the PMBOK guide, Quality Assurance (QA) is defined as: the process of applying planned systematic quality activities to ensure that the project employs all processes needed to meet requirements (PMBOK, 2004).

1.2.1.5 Total Quality Management (TQM)

According to the internet Wikipedia, TQM is a management strategy aimed at embedding awareness of quality in all organizational processes. TQM has been widely used in manufacturing, education, government, and service industries. Total Quality provides an umbrella under which everyone in the organization can strive and create customer satisfaction at continually lower real costs (Wikipedia, 2008).

1.2.1.6 Quality Management System (QMS)

According to The Business Dictionary, the quality management system is a collective of policies, plans, practices, and the supporting infrastructure by which an organization aims to reduce and eventually eliminate non-conformance to specifications, standards, and customer expectations in the most cost effective and efficient manner (business dictionary, 2008).

According to the internet Wikipedia, QMS can be defined as a set of policies, processes and procedures required for quality planning, quality assurance, and quality control. QMS enables the organization to identify, measure, control, and improve the various core processes that will ultimately lead to improved project performance (Wikipedia, 2008).

In the field of project management, according to the PMBOK guide, project quality management includes all the activities of the performing organization that determine quality policies, objectives, and responsibilities so that the project will satisfy the needs for which it was undertaken (PMBOK, 2004).

1.2.2 Evolution Of Quality Management

The majority of quality theoreticians accept Garvin's model (Garvin, 1988, cited in Dahlgaard 1999) of the quality evolution history, which consists of four different stages: inspection; statistical quality control; quality assurance and strategic quality management which are suitable for explaining US and perhaps other western countries' quality practice evolution in general. In contrast, Japan's quality evolution history shows a different picture.

It can be understood from the literature on quality evolution that the history quality evolution can be divided into two different dimensions:

1- The history of quality evolution in relation to implementation, according to Garvin's model in the US and other Western countries

2- The history of quality evolution in relation to TQM's conceptual development, as it can be understood from the Japanese experience in the total quality management field.

1.2.2.1 The Quality Evolution History Of Implementation (US And Western Countries)

1.2.2.1.1 Inspection

According to Yong et al (2002), the inspection work historically found in past time periods such as the middle ages, allowed administrators to have control over production and accountability of work. Similarly, this can said of the Springfield Armoury of America during the 1830s.

From the historical evidence, inspection work was the responsibility of the responsible craftsman, however after the industrial revolution and the mass production, which was dominated by the division and specialization of labour, the quality responsibility became shared amongst the different labors (Yong et al, 2002).

1.2.2.1.2 Quality Control

In addition, according to Yong et al (2002), in 1924, Shewhart developed the statistical quality control chart (SQC). Simple statistical techniques for determining variation limits of the production process and graphic methods for plotting values to assess whether they fell within an acceptable range were developed (Shewhart, 1931, cited in Yong et al, 2002). These graphic results are now known as `process control charts. Shewhart is referred to as the ''father of statistical quality control'', Best (2006a).

In World War II, large volume production required new set of sampling tables based on the concept of acceptable quality levels (AQLs). This concept met with great success as inspections became less time-consuming because they were conducted only when defect rates constantly exceeded AQL (Yong et al, 2002).

1.2.2.1.3 Quality Assurance

Yong et al (2002) also states that the quality assurance era shifted the industry's focus from detecting defect activities to preventing defect activities. The main aim of quality assurance was seen as serving the people who were not directly responsible for the operations, but those who needed to know or to be informed. The evolving of this concept took place during the 1950s and 60s in the defence sector, then, gradually broadened into the private sector. In the 1970s customers of large industrial companies were demanding

their suppliers to assure them of the quality of their purchases, so as to remain in business and continue supplying these customers. Since that time customers' audits have become an inevitable fact in the business sector. However, each customer had different perceptions and expectations of the products' quality which resulted in multiple assessments, eventually leading to the adoption of worldwide standards such as BS standards (British standards) in 1979, and ISO 9000 series standards (International Organization of Standardization) which superseded the BS, they have become widely accepted world-wide by companies as a guarantee of a company's quality practices.

1.2.2.1 The Quality Evolution History Of TQM's Conceptual Development (Japan)

According to Dahlgaard (1999), the quality evolution history in Japan is quite different compared with the US and other Western countries, due to different backgrounds in various areas. Amongst the many areas that have impacted on the quality movement in Japan, is the national situation after World War II in particular and the Japanese cultural tradition has also had a tremendous effect.

An important cultural factor is the Japanese attitude towards foreign elements. The long history of Japan shows that they have had an extraordinary capability to import foreign elements, whether it be in the form of a system, a language, techniques, philosophy, or products.

At the beginning, Japanese adopted Chinese knowledge and techniques which at that time were much more advanced those of the Japanese. In the 19th Century, western countries took over the position of China as a source of ideas, because the western countries showed a more developed technology (Dahlgaard, 1999).

Japan realized that their own technology was inferior to western technologies and for survival it was necessary to acquire western knowledge and technology.

In both reforms (Chinese and western) Japan had showed the same steps in the treatment of `imported' elements from outside. The steps can be divided into the following three phases:

(1) Importing/adoption/learning from the mid-1940s to the early 1960s;

(2) Digesting/implementing/adaptation from the early 1960s to the early 1970s (Japanization: application to the local conditions).

(3) Mastery and further development of those `imported or adopted foreign elements' and eventually exportation to other countries, from the early 1970s to the early 1990s.

1.2.2.1.1 Total Quality Management

After World War II, Japan rebuilt itself into a leading world economy and has become a quality leader for many consumer goods. The loss of the war was perceived by the Japanese to be due to the enormous technological gap between Japan and the USA (Lillrank & Kano, 1989, cited in Yong et al, 2002).

According to Yong et al, 2002, Dr Deming played a key role in instilling the quality philosophy among the Japanese industrialists when he addressed top managers and engineers on the methods and philosophy of W. A. Shewhart. In his lectures, over a period of eight days, to Japanese engineers, Deming covered the use of control charts and acceptance sampling. Participants were encouraged to practise the theory learnt using data from their own factories during the course.

Deming, who returned to Japan in subsequent years for further lectures, was followed to Japan by Joseph M. Juran, another ex-employee of Bell Systems, in the summer of 1954. While Deming concentrated on SQC in his lectures, Juran's emphasis reflected his roots in management. Through his lectures, Juran changed the focus of Japanese industry from a statistical outlook to one that emphasized the responsibility of management to improve quality and productivity. He stated the reasons for his beliefs as such:

. . . there has been some over-emphasis of the importance of the statistical tools, as though they alone are sufficient to solve our quality problems. Such over-emphasis is a mistake. The statistical tools are sometimes necessary, and often useful. But they are never sufficient (Juran, 1954, cited in Yong et al, 2002).

Apart from the prominent contributions of Deming and Juran, three Japanese promotional organizations; the Japan Management Association (JMA), the Japan Standards Association (JSA) and Union of Japanese Scientists and Engineers (JUSE) played a key role in

educating and providing other services to Japanese industries, including training in quality control (Yong et al, 2002). Through such means of mass education, it was ensured that the philosophy of quality control reached the very people who had ultimate control over preventing defects and ensuring quality. If we control the factors in a particular process which cause defective products we can spare a lot of money that is expended for inspections (Ishikawa, 1985, cited in Yong et al, 2002).

As stated by Yong, By the 1960s, the progress of Japan's quality movement was significant, and the image of Japanese products as being cheap and shoddy was no longer a problem in many industries (Kawabe, 1979, cited in Yong et al, 2002). The liberalization policies announced by the Japanese government around this time and the fear of greater foreign competition may have created some of the impetus for the quality-related activities adopted in the early 1960s (Yong et al, 2002).

1.3 Problem under Scrutiny

Certainly it can be stated that, in general, every business owner regardless of the field, would like to receive the final product according to the predefined requirements. Although these requirements may differ according to the product nature, in general, they represent the owner's interests. Therefore, contractors are responsible to do their best to conform to these requirements according to the contractual agreement with the owner. Otherwise, it will be considered as a contract breach and they will be faced with many problems, such as owner's claims to retain the equivalent amount of money that corresponds to the specific mismatch to requirements, and the scheduled project time will be extended as a result of the additional work required to re-match the requirements. A study carried by Bryde on project success criteria in the UK (United Kingdom) found that the lack of contractor's emphasis on meeting stakeholders' needs on cost and time objectives is considered a particular failure (Bryde et al, 2005).

In construction projects, especially power plant projects, in Sudan for example, involve three parties, the owner, the consultant, and the contractor. The contractor is responsible for delivering the final products or services within the contractual time schedule and according to the contractual requirements, and the owner is responsible for supervising all project activities and outcomes with the technical help provided by the consultant to assure that

quality objectives and product/service requirements are met. From the QMS background above, especially (1.2.2.1.2) and (1.2.2.1.3), it can be clearly seen that QA is performed by the customer (the owner) and QC by the contractor.

In standard situations, according to the PMBOK guide, all project processes are aggregated into five process groups, initiating, planning, executing, monitoring and control, and finally closure (PMBOK guide, 2004, pp 38). The project management subject as a whole is not in the scope of this research work, we will focus only on the related processes to the QMS (planning, executing, monitoring and control) as we will see later.

The planning process includes many items such as developing project management planning, scope planning, activity sequencing and time planning, risk management planning, quality planning, and so on (PMBOK guide, 2004, pp 70). We are concerned here with the quality planning process, which is considered to be one part of the Quality Management System of the project combined with quality assurance and quality control (PMBOK guide, 2004, pp 179). These terms and functions will be described and studied in depth in the QMS framework design, Chapter 3. It should be stated that, according to the PMBOK guide, a QMS system should be defined and created because it includes all the activities of the performing organization that determine quality policies, objectives and responsibilities, so that the project will satisfy the needs for which it was undertaken (PMBOK guide, 2004, pp 179).

Unfortunately, in relation to the Garri4 Project, there is no predefined QMS in any of the contract documents; in addition to that, QMS was not implemented in any of the previous power plants projects which belong to NEC. This information was obtained by searching the previous projects' databases and by asking direct questions to the particular project management staffs. The current situation of these projects now which are supplying electricity to the national grid is that they are experiencing many operational and maintenance problems. All the analysis work carried out either by NEC staff or by contractors, states that most of these problems are a result of poor and less than competent construction work. This indicates that the supervision performed by both the owner and the consultant was greatly inadequate. Perhaps it can be said that the consultant is technically competent, but as the PMBOK stated, these technical issues are simply considered to be

tools which are applied within the project management frame as they are understood from quality assurance process (PMBOK guide, 2004, pp 189).

Another important point, as the contract of Garri4 stated, the project is a turnkey project with a fixed price, the contract stated that the owner can ask for commercial claims if the contractor mismatches the requirements, delays the project, or constructed the project to produce less than 110 megawatts, the retained amount of money should be transferred to a contingency budget, which can be used in the future to order spare parts and so forth. So, if there is a deficiency in the area of supervision that means there is a considerable amount of money lost.

So, we can summarize the problems arising from poor supervision (poor quality) into these categories, future problems in operation and maintenance due to unsatisfactory and poor construction, shorter service life for the power plant accordingly, and a considerable loss for money which is paid to the contractor.

1.4 Research Purpose

Based on the research problem above, a need for a proper QMS to be implemented in Garri4 project was highlighted as being quite important. Although the project is 60% completed at this point, this project will not be the last one for NEC. There are many other projects underway, so a proposal has been made to consider implementation of QMS in future projects. The upper - level management of NEC has accepted this proposal, and there after assigned the researcher to organize a committee to develop and implement a QMS for the Garri4 project. After which the proposed QMS will be analyzed and improved. Following this, a final report about the QMS will be presented to decide if it is functioning well or not, whether it helps in performing supervision duties or not. Further work will be done in order to complete and finalize the QMS for NEC in order to be considered for implement in future projects. In actuality this research work is simply a small part of a much larger project to be carried out. With that in mind, the opportunity to design and test a QMS for the Garri4 Project is overwhelming, yet quite exciting. One important fact should be kept in mind is that most of the project phases have been completed. The remaining phases equal about 30% of the construction work in addition to the commissioning phase, which is the trial startup for the power plant before supplying electricity to the national grid. However, the opportunity to apply the QMS to the commissioning phase is not available because the power plant will still be under construction after the research time

period. Therefore, the QMS will focus on the current construction phase in order that it might be implemented.

Based on the above, the following research questions (RQs) are to be answered:

1- Is it possible to design a QMS framework for the Garri4 project during the execution phase considering the fact that it should be done during the earliest stages of the project as the PMBOK guide stated? – RQ1

It is hypothesized that the designing of a detailed QMS framework is possible in the current phase of the project.

This framework will not change the ongoing quality activities, but it will systemize them to facilitate the performance of project quality assurance. The existing standard framework in the PMBOK guide will be used to shape the QMS framework for client use, not for contractor's use. Appropriate information will be taken from relevant literature and the meetings with the project team to consider their points of views.

2- To what extent does the QMS implementation in the Garri4 Project help to achieve the stated quality objectives of the Garri4 Project? – RQ2

It is hypothesized that the QMS implementation can meet the Garri4 Project quality objectives.

The existing situation is that all quality duties are done without a systematic frame. This situation is not standard according to the PMBOK guide. For this reason there is no documentation control. Therefore the researcher's observations as an engineer in Garri4 project will serve as a basis for research. Many engineers in the project do not know how to act systematically when needed in a given situation. Consequently, the quality assurance for the project is extremely deficient, which may negatively affect the final project quality. Therefore, applying a systematic QMS frame will clarify many obscure areas, thereby facilitating the task of supervision and consequently meeting the quality objectives of the project. This hypothesis will be tested in this thesis to determine to what extent it affect is true or false.

1.5 Thesis Scope

As was previously mentioned, the QMS is a part of the project management system; therefore, the research work will be limited to the aspect of QMS. There are other parts of the QMS which will not be covered here extensively, such as the QC (Quality Control). In addition, the coverage of Quality planning will be limited to the current project phase. This research work is concerned with the QA (Quality Assurance), as was explained above in section 1.3. The job of supervision is to assure conformity of project quality to the contractual requirements. In addition to that, the QMS will deal only with the current execution (construction) phase of Garri4 project, as it will not be possible to cover the earliest stages or future stages, because the QMS is designed to be tested within the available thesis work time. Finally, this thesis work will focus on the current situation in the Garri4 project, however the results obtained from this research will assist future efforts to develop and build a concrete QMS for NEC's future projects.

1.6 Outline of the Study

In this section, the scope of this study will be outlined. It consists of five chapters, Chapter 1 has already been presented above, and below are the chapter titles followed by a brief description of each one:

Chapter 1: Introduction
Chapter 2: QMS literature review
Chapter 3: QMS framework design
Chapter 4: Research methodology and Findings
Chapter 5: Analysis and Conclusions

In Chapter 2, the relation of the literature review to the QMS will be highlighted. The outcomes of this literature review will assist in answering the research questions. In Chapter 3 the QMS for the Garri4 project will be designed according to the PMBOK guide, combined with the help and guidance provided by the literature review. In Chapter 4 the second research question will be answered. The research methodology and the findings will be applied in this chapter to measure the QMS effectiveness after implementation in Garri4

project. Finally in Chapter 5 the findings will be examined. This will be done by an analysis to the situations during and after QMS implementation and the final conclusions will be drawn. After which, recommendations will be made accordingly.

CHAPTER TWO

QMS LITERATURE REVIEWS

2.1 Introduction

An attempt was to look for studies covering QMS in construction, or in power plant projects in Sudan, unfortunately none could be found. It is known that, in general, different people attitudes in a specific geographical location towards a system or an idea can be considered to be similar to some extent. There are many unique cultural factors, as we know, that have contributed in shaping those people's behaviors, attitudes, and judgments. As a result, the author of the thesis tried to find previous QMS studies in Sudan, in order to find out these similarities and to use them as basic inputs, as well as to compare them to his findings. This thesis is concerned with the design and implementation of a QMS in a real project. Therefore, it is an alternative to looking for studies relevant to Sudan's experience in QMS field. An international standardized management reference such as the PMBOK guide will be sought after in order to design the general framework of the QMS. Then a detailed design can be achieved by using other relevant factors which have been covered in many international scientific papers and research. The literature review has successfully achieved this task, and many useful and relevant factors have been used in the QMS design accordingly.

This chapter covers the literature that will be reviewed. It consists of 4 sections; the first one summarizes the concept of quality in the project management field, while the second one explains the meaning of a system, its components and its process, and how to understand QMS as a system. The last two sections discuss the QMS design considerations, such as objectives and effectiveness of the system, in addition to the QMS implementation, benchmarking, and the problems facing QMS during design and implementation. As a result, these reviews are relevant to our thesis.

2.2 Quality in Project Management

As we mentioned in the introduction of this chapter, the PMBOK guide has been selected as standardized reference for the general QMS frame. The PMBOK has been described in section 1.3, paragraph 4.

In the PMBOK guide, all project management processes are aggregated into five process groups (PMBOK, 3rd edition, 2004). As shown in Figure (2-1), these process groups are: initiating, planning, executing, monitoring and control, and closure. Whereas QMS is divided into three components: quality planning; quality assurance and quality control. Each

component includes its own inputs, outputs and processing tools. These three components are linked together by way of a feedback loop (more details in Chapter 3).

Project Management Process Groups
Figure (2-1)
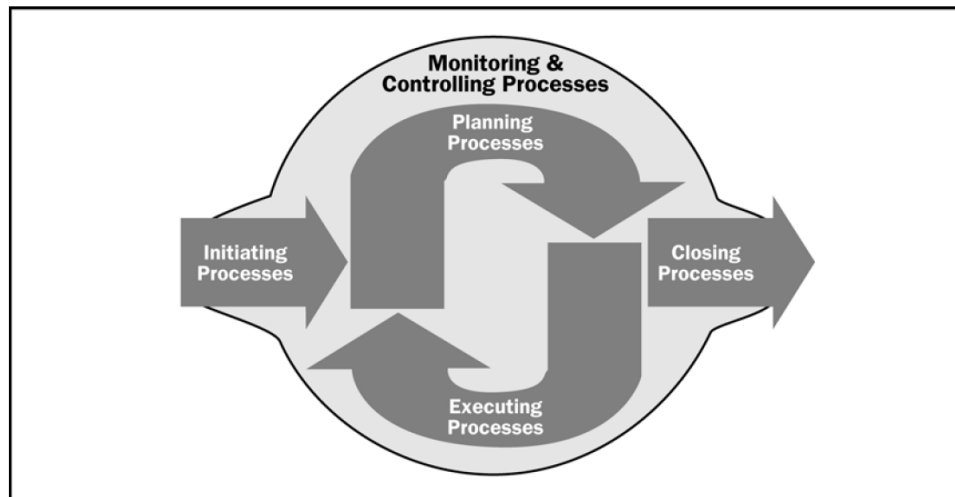
Source: PMBOK (2004), pp. 40

The following table (Table-1) demonstrates the three components of QMS and assigns each of them, according to the PMBOK guide, to the corresponding process group shown in Figure (2-1). This indicates that QMS is an important part of the project life cycle.

Project Quality Management components in Project Management Process Group
Table-1

Project Quality Management Component	Project Management Process Groups
1- Quality Planning	Planning Process Group
2- Quality Assurance	Executing Process Group
3- Quality Control	Monitoring & Controlling Process Group

Source: information taken from Table 3-45, PMBOK (2004), pp.70

Later in Chapter 3, detailed information will be presented, as the QMS design process proceeds.

2.3 Systems theory and Quality

This thesis is dedicated to QMS (Quality Management System), therefore, system theory and the related concepts must be studied in order to understand quality as a system.

There are vast amounts of literature which describe system theory easily and clearly, such as the work of Tito Conti (2006), and Peter Cusins (1994) as will be shown in the following section.

2.3.1 System Definition:

The system is a way of understanding a dynamic process in a system which has its own boundary in an environment, where inputs cross these boundaries from the environment to interact in a transformation process. Then these transformed inputs leave the system as outputs (Figure 2-2); this can be applied to natural systems as well as to man-made systems (Peter Cusins, 1994).

<u>**Basic conceptual framework of a system**</u>
Figure (2-2)
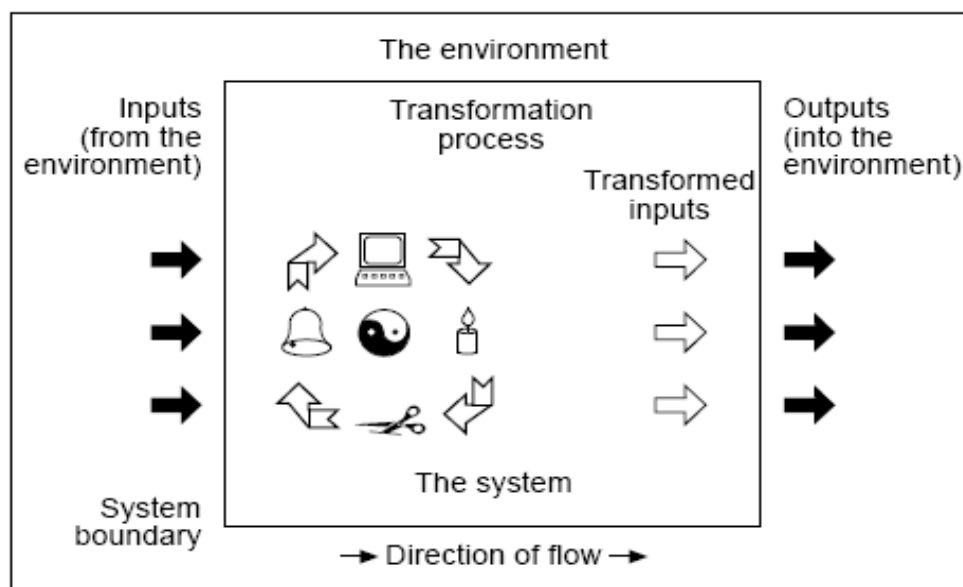
Source: Peter Cusin (1994), pp.20

2.3.2 System Complexity

Peter Cusin states that systems are complex and interacted; any system is always a part of a complex system, such as an organization, which consists of many departments (Systems). Each department consists of many jobs, and each job consists of many tasks. The other statement is that system output can be used as input for other systems, and therefore all system inputs are other systems' outputs. These outputs may be needed by other systems as inputs, if not then they are considered as waste, and as toxic waste if they are damaging the system.

2.3.3 Outputs vs. Outcomes

Peter Cusin also differentiated between outcomes and outputs, outputs are those produced things which cross the system boundary outward, while outcomes are the effects of these outputs on subsequent systems.

2.3.4 Closed and open systems:

According to Peter Cusin, there are closed systems, where there is no feedback loop, and there are open systems, where there is a feedback loop system. An open system is a system that interacts with its environment (Tito Conti, 2006). Peter Cusin explained the feedback process as the following:

''Feedback is thought of as outputs of information about the system which, when fed back into the system as inputs, are able to modify the system while the process is in progress. (In mechanical systems, this is referred to as a "servo-mechanism".) This makes the system more responsive (response-able) and flexible. Feedback can be thought of as two types, internal and external. Internal feedback loops occur entirely within the focus system, i.e. they can be thought of as sub-systems within the system. In external feedback loops, the feedback information is obtained outside the focus system, i.e. they contain information about the outcome(s) which, when fed back into the system, are able to modify the process while in progress'' (Peter Cusin, 1994).

Figure (2-3) shows both of them:

Closed and Open systems
Figure (2-3)
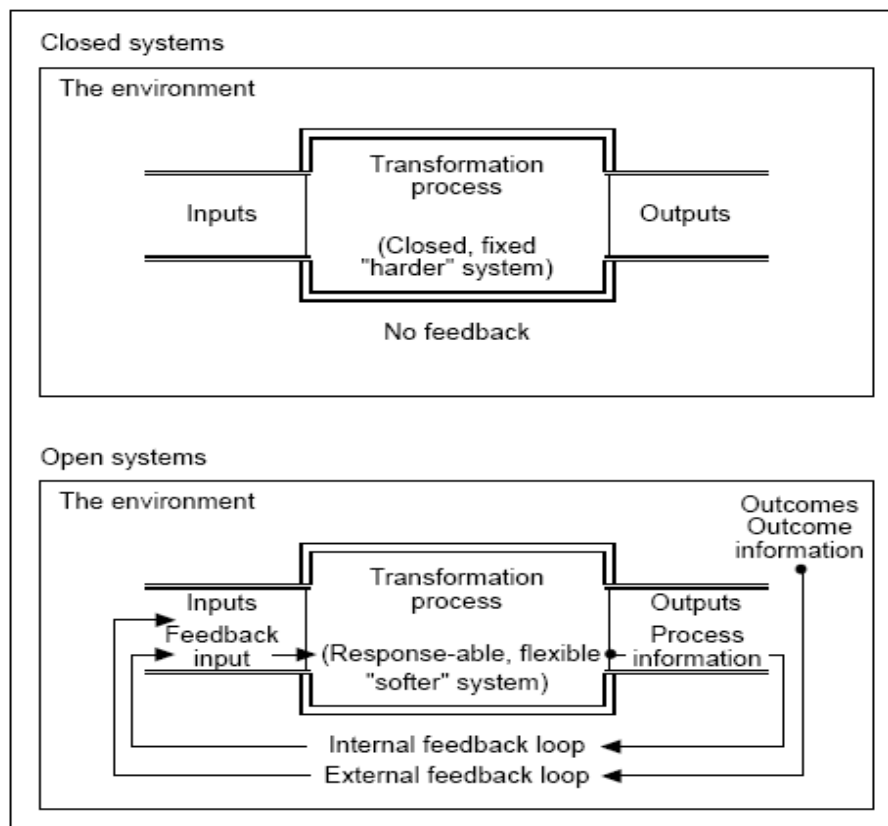
Source: Peter Cusin (1994), pp.22

2.3.5 System thinking and quality management thinking:

Finally, a link between quality management thinking and system thinking can be made in order to understand QMS as a system with similar features and considerations. This idea is summarized accordingly by Peter Cusin (1994):

2.3.5.1 Linking Quality and System thinking:

In order to link quality thinking with system thinking, quality must be regarded as a boundary judgement which is a judgement made between supplier system and the user system boundary about things that crossed it. The supplier outputs are the user's inputs (the user can be another system or sub-system in the organization), so both of them use quality specifications as reference to judge inputs/outputs quality which is means a statement of supplier output (user input) expected by the user. Quality judgement involves: observing

supplier system outputs; comparing them with quality specifications; judging whether they comply with the quality specifications and satisfy user system (inputs) expectations.

2.3.5.2 First Law of Quality

As Cusin stated, the implication of the above information is the first law of quality: Quality can only start when the supplier knows exactly what the user wants.

2.3.5.3 QMS (Quality Management System) as a System

QMS (quality management system) can be considered as the servo-mechanism of an organization (see section 2.3.4), it has four activities:

1- Collecting systems information (user requirements, outputs, and processes) as inputs to QMS.
2- Involving those who can judge this information, this is the transformational process in QMS.
3- Planning with those involved, the modifications to operational processes to improve quality and efficiency of processes, this is the QMS outputs.
4- Ensuring that these modifications are implemented, this is the outcome of QMS.

2.3.5.4 TQM (Total Quality Management) and System thinking:

In the concept of TQM (total quality management) every one has responsibilities towards ensuring the outputs quality of his/her sub-system so as to satisfy the users' requirements (may be other systems or sub-systems) who uses his/her outputs as inputs. That means there is an effective boundary judgement at every system interface in the organization.

2.3.5.5 Quality perception:

Quality perception is a value perception associated with the considered quality (Tito Conti, 2006). As Peter Cusin explained, once clients have received their products, they come into a state of neutral awareness, where neither high quality nor poor quality is noticed. Therefore the following quality factors can be explained poor and high quality perception when they are noticed, these factors are dynamic and static factors:

1- Quality dynamic factors: They might not be noticed if they are not present, but when they are being added they create a high quality image. They are individual, unique, and situation dependent, such as unexpected additional feature or service.

2- Quality static factors: They might not be noticed if they are present, but their absence creates a poor quality image, it is common to all customers, such as sticking to agreed specifications.

2.4 QMS (Quality Management System) design considerations

2.4.1 Introduction

As stated in the (PMBOK guide, 2004), QMS should be built and designed in the earliest project stages, in our current Garri4 project, it is nearly 50% completed, so the likelihood of quality malfunction can be higher in this stage. Feist (Feist et al, 2007) stated that at the earliest stages of the project, quality is cheap and at a later stage a lack of quality costs a lot of time and money. Now we are going to review relevant literature about some important considerations during QMS design, such as QMS objectives, QMS effectiveness, ISO-based QMS, and safety.

2.4.2 QMS Objectives

(1) QMS effectiveness

QMS as any other system must be revised periodically and assessed to check its performance and effectiveness (section 2.3.4). Oztas et al (2005), on their Quality Matrix Model to measure the effectiveness of QMS in Turkey construction industry, stated that the measure of QMS effectiveness depends on what the company defined as its purpose or objectives. If it is not defined for what purpose the QMS is set to achieve, i.e., defining objectives, then it is difficult to measure the effectiveness or the effect of the QMS. They also stated that QMS in the construction industry was implemented slower than other industries, and they gave some reasons such as difficulty in the definition of quality standards and difficulty of feedback process.

As stated by Ostaz et al (2005), effectiveness of QMS is defined as:

''Throughout the research ''effectiveness of QMS'' is defined as ''meeting prescribed quality objectives of the company and specified requirements of ISO 9001:2000''.
For example, if the company has operated a QMS in order to meet customer expectations, then the effectiveness of the system is judged by how well it does this or whether it achieves its goal or not'' (Ostaz et al, 2005).

From the above we can understand that each construction company has its own requirements and expectations for applying QMS. Therefore, in order to measure QMS effectiveness they should state the purpose and objectives that they seek achieve.

(2) Prescribed QMS objectives:

Prescribed QMS objectives are those which represent the company's objectives. They can be determined by the following process: the first step is that a questionnaire should be distributed to the company staff, or the key personnel who are involved in company policy setting. This questionnaire mainly consists of a considerable number of QMS principles that are commonly used in similar organizations. The targeted personnel will normally be requested to tick the most relevant QMS principles. The outcome from this questionnaire is the prescribed QMS for the company. As stated by Ostaz et al (2005) these are:

1- Adoption of employees to the quality policy.
2- Meeting customer expectations.
3- Leadership of top management.
4- Contribution of employees to management.
5- Application of work due to knowledge.
6- And encourage continual improvement.

(3) Methodology:

Ostaz et al used two matrix models, the first one is the matrix of principles, which is used to check effectiveness of whether the firm achieved the quality management system requirements or not. The second one is the matrix of goals, which is used to check the result of a firm as to whether it achieved the prescribed QMS objectives expected by the firm or not. This methodology will be used here in this thesis work with some

modifications, as it deals with QMS within a contractor's organization, and aims to deal with it within an owner's organization. Chapter 4 describes it in depth.

2.4.3 Measuring quality system effectiveness

In the study carried by Nakeeb et al (1998), they discussed the importance of measuring QA and QMS effectiveness, in addition to that, they illustrated many measuring methodologies, and the following is a brief summary of their findings:

(1) Measuring QMS/QA effectiveness:

From Nakeeb's study above, effectiveness of the system is defined as 'meeting the company's specified requirements and prescribed quality objectives'.

Quality system effectiveness can be assessed using specific measurement tools. These measurements are very important as they give indications on how well the QMS met its objectives. This can also help in establishing continuous improvement for the QMS, and allow managers to know how close they are to their targets, and how to make the right decision to improve working processes.

(2) Types of measurements:

According to (Nakeeb et al, 1998), some companies that he interviewed use 'quality costing as a measure to assess their quality effectiveness, but it is misleading. Other companies use 'customer surveys' as a measure, while it is an excellent measure, however, it is not enough because it can also be misleading due to some customers' low experience and others have unreasonable expectations. Some European companies use self-assessment as a measure against a pre-designed model such as European Quality Award (EQA) and British Quality Award (BQA), while some companies develop their own models such as quality measurement matrix used by the US Office of Management and Budget. The matrix methodology used here is similar to the one that we discussed in section (2.4.2), and it will be used in our thesis. More details will be shown later in Chapter 4.

2.4.4 Safety consideration

Safety should be considered as a very important aspect in quality. From experience on construction projects it can clearly be observed the iterative safety hazards arising from human mistakes for the lack of safety knowledge, (T. W. Loushine et al, 2006) While

researching quality and safety management in construction projects in the United States of America, they found that the construction industry alone is responsible for 22% of the occupational fatalities resulted from poor quality and safety compared with other industries. From their conceptual framework, the similarities between quality management, safety management, and their outcomes can be observed.

2.4.5 ISO-based QMS

As we stated in Chapter 1, NEC is adopting ISO 9001:2000. Palaneeswaran et al, (2005) on their study of Hong Kong public sector, found that the implementation of ISO 9000-based QMS could be an effective tool in the construction projects, and that several quality-related problems could be reduced.

(1) Quality related problems:

According to Palaneeswaran et al (2005), project problems that attributed to low quality and poor management of contractors are:

1- Time overrun: which means exceeding the scheduled project time; it results from contractors planning poorly, poor monitoring, and poor controlling processes. It also comes from the reworked and defected items. Therefore, if the contractor committed to the implementation of ISO-based QMS, the following must take place: better planning; reducing rework and defects, which will result in time-overrun reduction.

2- Cost overrun: this results from rework, time overrun, and wastage. Implementing ISO-based QMS by the contractor with high commitment will reduce it; otherwise there will be additional cost from materials required for quality assurance.

3- Rework: these are quality-non-conforming items; ISO-based QMS can help to reduce rework by proper documentation.

4- Wastages: relates to ordering and using of materials. ISO-based QMS helped contractors to build structured procedures for ordering material. This prevents reliance on subjective judgement, and helps contractors to improve their control in using and ordering materials.

5- Defects: ISO-based QMS can help on reducing defect rate by introducing more standard procedures; this can only be achieved by involving site workers who are responsible for carrying out the works.

6- Unjustified claims: ISO-based QMS requires proper recording and documenting for each step such as verbal instructions, which should be confirmed in order to reduce unjustified disputes.

7- Supervision of contractors: ISO-based QMS requires the increase of contractor supervision in order to face the lack of self-discipline which results in fictitious auditing reports without commitments on quality improvement.

8- Quality of materials: the quality of these materials used in construction results in the quality of products and the satisfaction of customers. This can be attributed to the better recording and traceability for materials to avoid future material problems. ISO-based QMS helps in materials control.

9- Quality of workmanship: ISO-based QMS requires the improvement of workers' skills and to offer them good training, which increases their quality.

10- And disputes: the reduction of rework, defects, time and cost overrun. This eventually results in decreasing the disputes in the project.

The previously mentioned ten points summarize the quality related problems, their definitions, and the solutions which an ISO-based QMS provides as found by Palaneeswaran. These problems have been reduced, from client's point of view, after ISO9000 – based QMSs were introduced in contractor's organizations in Hong Kong, and as a result, this increased customer satisfaction.

(2) Performance Evaluation System (PE):

There is a very important point in Palaneeswaran work; he shortlisted 12 contractors for the chosen client, this client applied a PE system (Performance Evaluation system) to assess contractors' performance. It contains three parts (Figure (4-2) explained it clearly):

1- Inputs: it covers six aspects in contractor work such as management and organization of work, resources...etc. it represents 25% of the whole score.

2- Outputs: it covers structural works, architectural works, and other obligations. It represents 75% of the whole score.

3- Maintenance period: there is no score here, it only used for contractor regulations such as penalizing the contractor for any poor performance. It covers outstanding work, execution of works of repair, management response, and documentation.

Figure (4-2) below, which has been reproduced from the original source, explains PE concept and mechanism clearly:

Contractor Performance Evaluation mechanism (PE)

Figure (2-4)
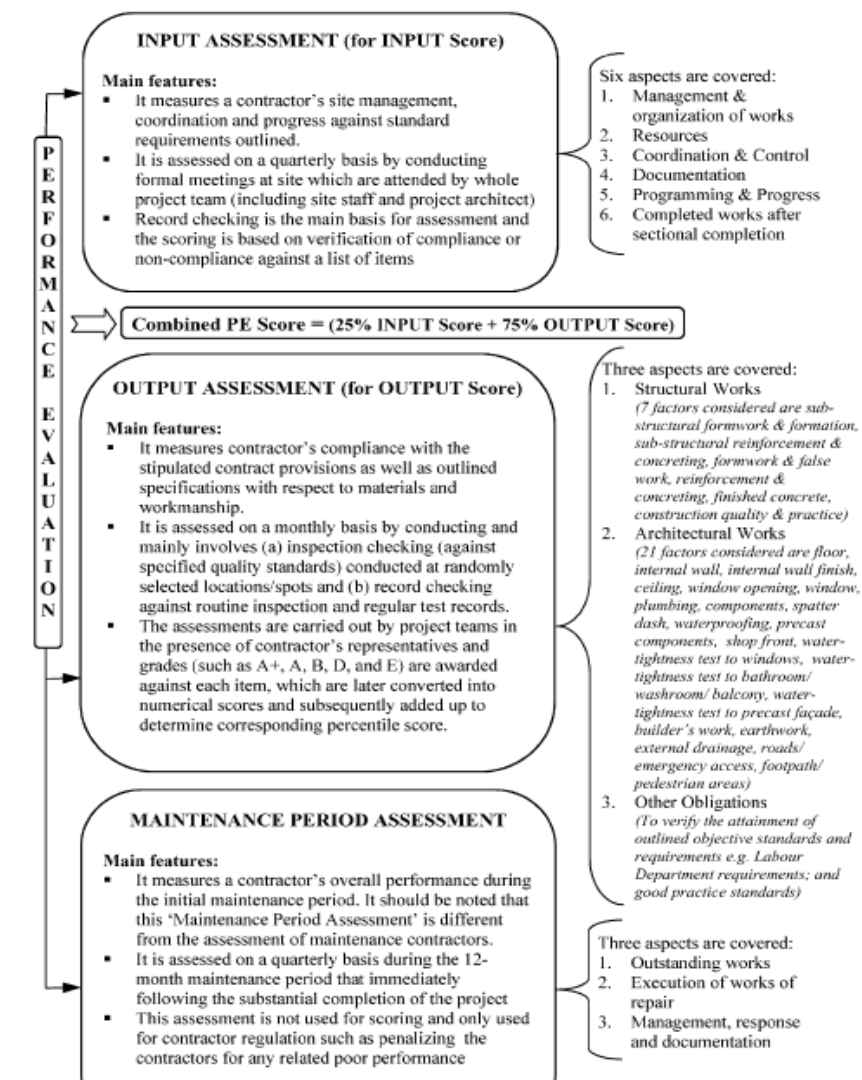
Source: Palaneeswaran et al, (2005), p.1561

2.4.6 QMS in Lithuanian companies

To link the above research result with a real case study, the research done by Ruzevicius et al (2004) on Lithuanian construction companies (quizzing 31 companies in Lithuania) dealt

with many issues, such as finding the reasons that stimulated Lithuanian companies to implement ISO-based QMS, as well as finding the external and internal benefits they gained after implementing QMS. The following is a summary of their findings:

(1) Factors stimulating QMS implementation:

Factors that stimulated Lithuanian companies to implement QMS (in order):

1- Ensure constant quality level.
2- Better customer-needs satisfaction.
3- Competitive improvement.
4- Important for company's image and prestige.
5- Helps to increase current market share.
6- Needed to export goods to foreign countries.
7- Helps to lower production costs.
8- Needed to follow competitors who applied QMS.

(2) Results of QMS implementation:

The results that were achieved after implementing the ISO-based QMS in Lithuanian companies (in order, starts with the most important):

1- Decrease of non-conformity products.
2- More carefully chosen contractors.
3- Fewer complaints from the clients.
4- Successful wins of order tenders.
5- Increase in sales volume.
6- And, increase in labour productivity.

2.5 QMS implementation

2.5.1 Differences between QA and QC

The research paper of Sam et al (2006) discussed the difference between QA and QC. In addition to that it discussed the relationship between cost, time, and quality. The following summary illustrates some parts of their work:

(1) QA vs. QC:

QA are preventive quality measures and checks, it includes establishing that product is delivered according to the required specifications, and it also provides evidence that all quality related activities are being performed effectively. It includes all activities from design up to commissioning and services. QA circle contains QC and the Project Monitoring part that dealing with the project quality, (Figure (5-2)).

QCs are corrective measures, carried out by contractor. However the owner representatives can draw the contractor's attention to carry out QC work, therefore contractors are required to provide owner with documentations that confirming the product/project is complies with agreed specifications.

<u>**QA, QC and Monitoring relationship**</u>
Figure (2-5)
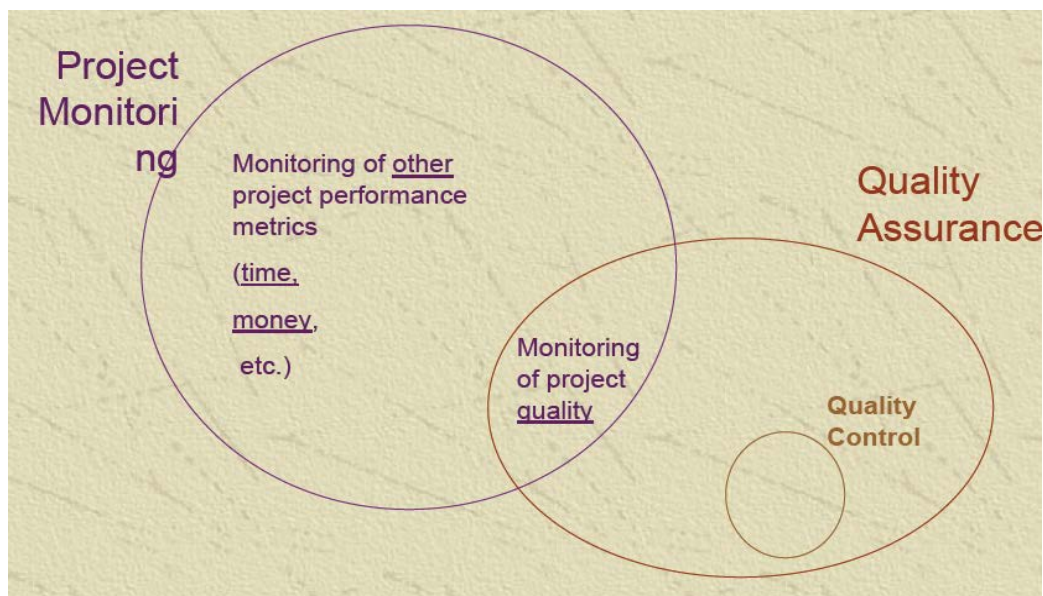
Source: Sam et al (2006), pp.15

(2) Iron Triangle:

The next point they discussed in their paper is the link between quality and key performance metrics (cost, time, and quality), which is also known by The Iron Triangle of project management (Bryde et al, 2005). The linkage between them summarized below, and Figure (6-2) explains it clearly:

1- Cost can be increased by increasing quality. Quality requires rework for non-conforming elements; this cost money, and the high quality requirements can lead to costly miscalculations on labour time.

2- Cost also can be increased by accelerating project time (which needs payment for overtime shift work). Sometimes acceleration results in lower quality, so additional costs will be incurred here to hire better crews and higher-end equipment to avoid this problem. If we slow down progress the cost will be increased as the interest rate on construction loan is increasing over time, and a loss of tenant opportunity cost will occur.

3- Cost can be decreased by trying to save money, however this can lead to substitute lower quality workmanship. Less money in construction means slow work progress, this means there should be a resource reduction and a selection for poor quality workers (the default act of contractor/subcontractors).

4- Quality can be affected by overtime work, shift work, and new hires as well.

It can clearly be understood that cost, time, and quality are inter-related, and quality can be affected dramatically when a change occurs in the other 2 elements.

The following figure illustrates it clearly:

<u>Linkage between quality and key performance metrics</u>
Figure (2-6)
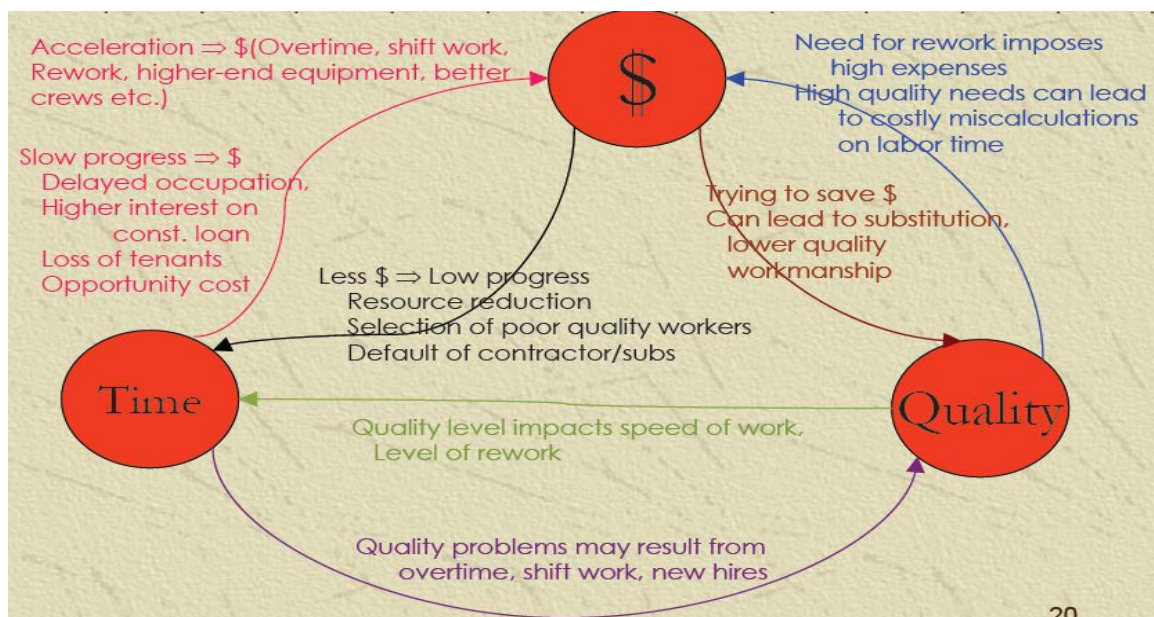
Source: Sam et al (2006), pp.20

(3) What QA can achieve:

QA in the TQM context in construction projects can achieve many things. When these things are achieved successfully, there will be many benefits. The following is a summary of what QA is able to achieve, as presented in the research paper of Pheng et al (1994):

QA is able to:

1- Satisfy customer needs continuously by maintaining a level of product/service quality.
2- Provide the customer with enough confidence that the desired product quality is being achieved.
3- Provide the management with enough confidence that the desired product quality is being achieved and maintained.

(4) Benefits beyond QA implementation:

According to Pheng, once QA is implemented successfully, the following benefits will be gained:

1- Improved client satisfaction, and communication between different project parties.
2- Formalized descriptive framework for responsibilities.
3- Defined lines of authority.
4- Avoidance of costly reworks, errors, and faults by systematic checks.
5- A documented work completion to proof conformity to contractual specifications.
6- Easier implementation and control for changes.
7- Easier identification and quantifications for time and cost claims.

2.5.2 Quality Assurance Auditing (QAA):

According to the research work of Yoram et al (2005) about QAA (Quality assurance Audit); the following is a summary of their paper:

(1) Definition of QAA:

QAA is an inspection process used to assess whether the quality procedures are conforming to the plan or not, to assess QMS implementation effectiveness, and to assess the degree to which QMS objectives are being achieved. Therefore QAA is a system-oriented auditing.

(2) Results of QAA:

The QAA results are used to determine the areas of weakness and non-conformation to standards. In addition to that, corrective actions that follow the audit report to be undertaken will be stated.

2.5.3 Benchmarking

As the (PMBOK guide, 2004) describes the QMS processes generally without details, a need for bench-mark is arising. In the above literature reviews, we discussed many issues that can be considered during the QMS design. It is important to add extra useful practices and guides from well-known cases for benchmarking purposes. Benchmarking with other projects can serve as a very important tool to properly design, implement, and even evaluate the QMS. When we benchmark our system with an existing excellent or successful system, we can be able to determine where we are standing, and how to be better in the light of the benchmarking outcomes. Therefore some relevant research papers have been reviewed on the following pages. These are two studies. The first compares QMS implementation between the USA and Hong Kong, while the other describes QMS procedures as applied in one of the most important research projects in Germany:

(1) QMS implementation between USA and Hong Kong:

On the research paper of Syed et al (2005), which compared QMS implementation between the USA and Hong Kong, the findings can be summarized into three points:

1- The USA firms failed to see the need to obtain ISO-9000 certifications. They are content on using their own QA/QC programs to do their business.

2- On the other hand, the government pressure in Hong Kong forced many companies to obtain ISO-9000 certifications. So they have advantages over others on

international market competition. Both USA and Hong Kong firms ranked management commitment to be the most important element in TQM, followed by customer satisfaction.

3- Finally, QMS effectiveness can be assessed in many ways, such as: benchmarking, statistical process control and defect cost analysis. The output should always be used for continuous improvement purposes.

(2) QMS as applied in a research project:

Feist et al, (2007) on their study of WENDELSTEIN 7-X Stellarator Project QMS, which is considered to be the largest scientific project in Germany. This project covered the QMS of the first ten years of the whole project life, which was planned to be 50 years. The adopted QMS provides guidelines for all processes of the project from the design to the commissioning, and this QMS is tailored to the special needs of the construction of a scientific experiment.

The following are some points which can be used as a bench-marking guides summarized from the above project (Feist et al, 2007):

- Information about instrument and devices used for testing should be provided for quality assurance to ensure the proper testing devices or labs.
- Controlling the flow of material used (certificates of used materials should be listed separately). A report regarding usage and status should be done.
- Organizing a training program on QA techniques and auditing for the whole working staff, to be scheduled.
- QMS tracking path: Project Specifications→General Technical Design→Detailed technical design (drawings) and detailed technical specifications →incoming inspections and detailed component preparation→ assembly and commissioning phase.
- QAAP (Quality Assurance and Assembly Plans)→ a list of all major assembly and test steps, for each step the number of the relevant document is given (work instruction, test procedure, test protocol, non-conformity report...etc) for each step: who is doing it→ who should be informed →after the step carried out, responsible persons have to sign→Each QAAP should be documented.

- Each assembly step in QAAP is supported by work instructions prepared by contractor→checked by QM, Safety, involving the client's department→finally approved by the responsible head.

- Each test's procedure is accompanied by a standard test protocol containing all the parameters which have to be tested with their required values. The Final decision is made to accept/discard the procedures done by the responsible department and the site top manager/consultant.

- QA engineers should use proven and documented procedures only to make sure that all test-equipment has its proper certifications, and to evaluate the result of the test in an independent way without considering the consequences, if a test does not conform to the expected performance, a NCR (Non-Conform Report) must be issued and this NCR must be judged by the Responsible department or head and not by the QA engineers or the inspectors.

2.5.4 Problems facing QMS design and implementation

In the study carried by Krishnan (1993), he stated that during the formulation and implementation of QMS there are many problems. Here are 2 problems related to quality system design and implementation which have been summarized:

1- Confusion among employees regarding which program or system to implement, whether or not they should follow quality experts, use some outperforming companies methodologies such as six sigma, or should they pursue ISO certifications. All this confusion results from the contradictions of goals and definition of quality of different divisions at the same firm. Regardless of the system or method they intend to use, they all must first consider a shared definition of quality and vision, as Krishnan (1993) stated below:

''The initial development of a shared vision presupposes a top-down model of quality improvement: the company begins with a corporate vision which determines its overall quality goals, and articulates them into specific objectives and action programs for individual divisions and departments. Through a cascading process, the initial vision is spread throughout the entire corporation'' Krishnan (1993) .

2- Problems facing QMS implementation such as goals quantification, organizational structure, communication, and training, have been found by Krishnan:

''Implementation problems including an inability to translate broad quality goals into quantitative targets, difficulties over the appropriate organizational structure within which to implement quality programs, communication difficulties, and problems in managing the transition from individual to organizational learning'' Krishnan (1993).

Based on the above statement the following problems and solutions for them are stated as such by Krishnan:

(1) Failure to link programs to results: Articulation of quality goals into quantitative, measurable performance targets linked to specific dates. This leads to a powerful mechanism for revealing and directing attention towards inherent conflicts among goals.

(2) Problems of integration: achieving consistency between goals and performance measures raises the issue of the appropriate organizational structure for managing quality initiatives, because there are many problems can be arise between the quality management and formal functional structure. Many quality decisions in such structural forms taken by other functional departments while ignoring the role of quality management division as the goals are not integrated, therefore, either senior management staff or CEO should be involved and made influence behind quality groups, also, Problems of integrating multiple goals and reconciling conflicts among them can be avoided by setting goals according to priorities and sequence. Once the company attained the first goal, then it can shift to the next one.

(3) Communication problems: this happens between planners and those responsible for the plans work, as well as between departments and functions. Therefore, developing a ''Customer focus'' which can be a very successful approach in encouraging communication

(4) Training problem: this problem comes from the fact that it is easy to achieve individual learning, but it is different when it comes to transit from individual to organizational

learning. This can be done by facilitating a close link between training programs and QMS when one type of QMS aimed at clearly focused objectives is being pursued.

CHAPTER THREE

QMS FRAMEWORK

3.1 Introduction

It has been stated that the purpose of this thesis work is to design, implement, and measure effectiveness of QMS in the Garri4 power plant project in Sudan. In the second chapter, we extensively reviewed relevant literature, which can be used to enhance the QMS work frame design and also to assess its effectiveness.

In this chapter, steps used to design the QMS frame work which will be implemented during the last erection phases will be discussed, as the project has already completed more than 60% of its work.

The above job done after the following activities took place:

- The PMBOK guide was used to make the general QMS work frame, or flow chart.
- An extensive literature review has been done, so as to use its outcomes to design the detailed QMS.
- A general proposal has been made using the combination of the above 2 steps.
- A presentation was given to the Garri4 project staff to show them the QMS concept, benefits, and the general frame.
- Two meetings with Garri4 project staff were held to brainstorm and to set QMS objectives and requirements which will be used to design the QMS and to be a base to measure its effectiveness.
- The QMS was designed accordingly, and then approved by the project site manager after the revision was made by the staff.

On the following pages the previously mentioned steps will be discussed. The completed QMS manual (frame work) is attached in appendix (1).

3.2 The PMBOK guide

The PMBOK guide, or the Project Management Body of Knowledge as introduced in chapter 1, section 1.3, fifth paragraph, is used here to design the general QMS frame work for Garri4 project.

The quality management system in the PMBOK comprises of three linked parts:

1- Quality planning.

2- Quality assurance.

3- Quality control.

As has been stated in the PMBOK, the whole QMS system is considered to be built and implemented within one organization. However, the Garri4 situation is completely different. The Garri4 project is owned by NEC as stated before. Therefore, the owner role is considered to be within the quality assurance, which is the aspect of focus in this thesis work.

A very important point should be considered here, as was stated in chapter 2, section 2.2, the entire project management processes is aggregated into five process groups. These are: initiating, planning, executing, monitoring and control, and closure. As, stated in the PMBOK guide, there are 9 knowledge areas associated with these five process groups. Quality management is one of them as is illustrated in Figure (3-1) below:

PMBOK knowledge areas

Figure (3-1)

Knowledge Area Processes	Project Management Process Groups				
	Initiating Process Group	Planning Process Group	Executing Process Group	Monitoring & Controlling Process Group	Closing Process Group
4. Project Management Integration	Develop Project Charter 3.2.1.1 (4.1) Develop Preliminary Project Scope Statement 3.2.1.2 (4.2)	Develop Project Management Plan 3.2.2.1 (4.3)	Direct and Manage Project Execution 3.2.3.1 (4.4)	Monitor and Control Project Work 3.2.4.1 (4.5) Integrated Change Control 3.2.4.2 (4.6)	Close Project 3.2.5.1 (4.7)
5. Project Scope Management		Scope Planning 3.2.2.2 (5.1) Scope Definition 3.2.2.3 (5.2) Create WBS 3.2.2.4 (5.3)		Scope Verification 3.2.4.3 (5.4) Scope Control 3.2.4.4 (5.5)	
6. Project Time Management		Activity Definition 3.2.2.5 (6.1) Activity Sequencing 3.2.2.6 (6.2) Activity Resource Estimating 3.2.2.7 (6.3) Activity Duration Estimating 3.2.2.8 (6.4) Schedule Development 3.2.2.9 (6.5)		Schedule Control 3.2.4.5 (6.6)	
7. Project Cost Management		Cost Estimating 3.2.2.10 (7.1) Cost Budgeting 3.2.2.11 (7.2)		Cost Control 3.2.4.6 (7.3)	
8. Project Quality Management		Quality Planning 3.2.2.12 (8.1)	Perform Quality Assurance 3.2.3.2 (8.2)	Perform Quality Control 3.2.4.7 (8.3)	
9. Project Human Resource Management		Human Resource Planning 3.2.2.13 (9.1)	Acquire Project Team 3.2.3.3 (9.2) Develop Project Team	Manage Project Team 3.2.4.8 (9.4)	

Source: PMBOK (2004), pp. 70

The following Figure (3-2) shows the relationships between quality components and other relevant activities as a process flow diagram

Project quality management process flow diagram
Figure (3-2)
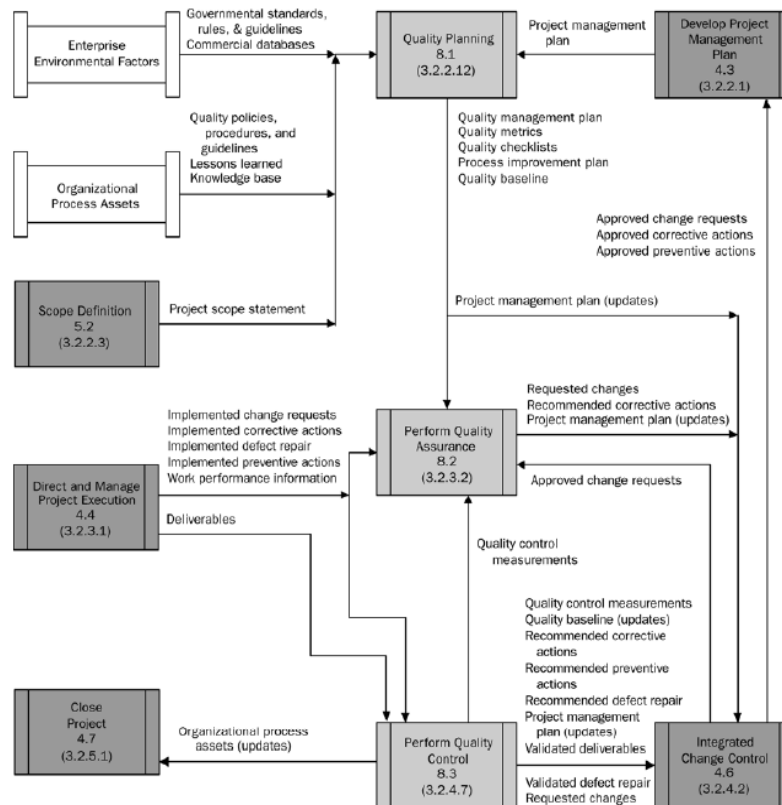
Source: PMBOK (2004), pp.183

Certainly it can be stated that quality planning is a part of the whole project planning. This clearly shows the importance of early quality planning in the earliest project stages. However, being that there is, there is no quality plan or even quality manual for the Garri4 project, and the project to this point in time has completed a bit more than 60% of its work, one can only consider the remaining erection period and the upcoming commissioning (trial operation) phases of the complete power plant. As a result, taking into consideration the limitation of the thesis time (up to fall 2008), the QMS will only cover a maximum period of 3 months of the remaining erection phase, which is divided into two finishing stages, the first one on 15th November 2008, and the second one on 15th January 2009.

As we discussed in chapter 2, section (2.3), quality as a system has inputs, processes and outputs, or outcomes, used by the internal parts of the QMS. There is always feedback

returning to the planning part for continuous improvement purpose. The following figure (3-3) simplifies the QMS as a system:

QMS simple flow chart
Figure (3-3)
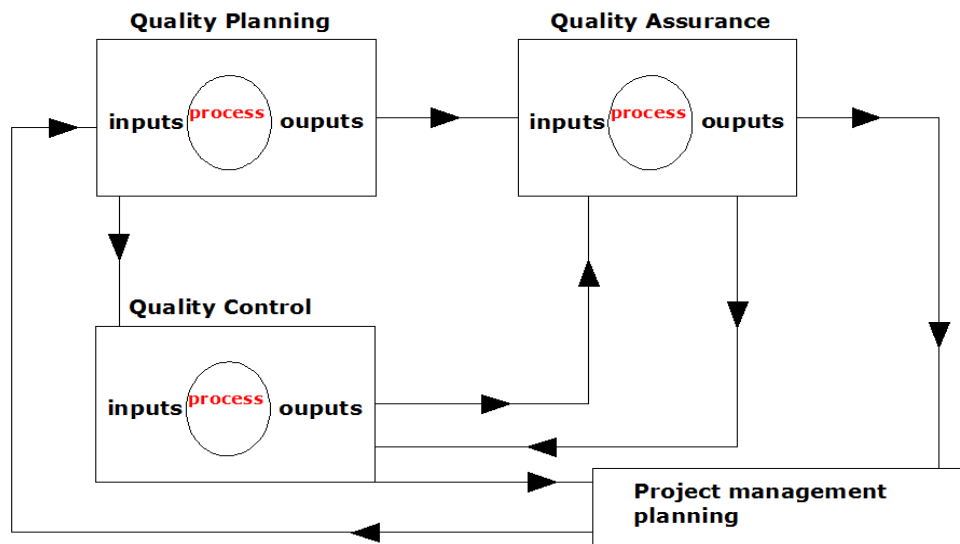
The concept of the above figure is a combination of a thorough and comprehensive understanding of the relationship between various quality components, in addition to the understanding gained from the system theory. As stated previously, quality planning is a part of the project planning, therefore, input is always received from there. Next, quality planning gives required inputs to both quality assurance and quality control. After which, the appropriate processing the outputs from QA and QC exchanged between them as extra input source, which simply means QA gets its inputs from QC and quality planning. The same is true for QC. Finally both QA and QC provide feedback to the whole project planning, and from there new or modified quality plans feed the quality planning accordingly.

Here in table (3-1) are some of the important inputs, processes used, and outputs of the QMS as stated in the PMBOK guide (PMBOK guide, 2004, pp.182)

QMS system data
Table (3-1)

	Quality Planning	Quality assurance	Quality control
Inputs	1- Enterprise environmental factors. 2- Organizational process assets. 3- Project scope statement.	1- Quality management plan. 2- Quality metrics. 3- Quality control measurements	1- Quality management plan. 2- Quality metrics. 3- Work performance information
Processes used	1- Cost-benefit analysis. 2- Benchmarking 3- Cost of quality	1- Quality planning tools and techniques. 2- Quality audits. 3- Process analysis	1- Cause and effect diagram. 2- Statistical sampling. 3- Inspection.
Outputs	1- Quality management plan. 2- Quality metrics. 3- Quality checklists.	1- Requested changes. 2- Recommended corrective actions. 3- Project management plan updates.	1- Quality control measurements. 2- Requested changes. 3- Validated deliverables.

Source: PMBOK (2004), pp.182

It is known that, when a contract is signed to build a power plant, the owner, contractor, and consultant will agree on the quality standards and protocols. While the contractor is responsible for delivering the final project according to the contractual agreement, therefore, he will definitely do all the required actions to fulfil that. This includes erection work, quality control, and so forth. Whereas the owner and consultant are required to assure that the project has been done as the contract specified. Based on these points, considering the different roles of each party, the following general QMS has been designed accordingly. Figure (3-4) illustrates that:
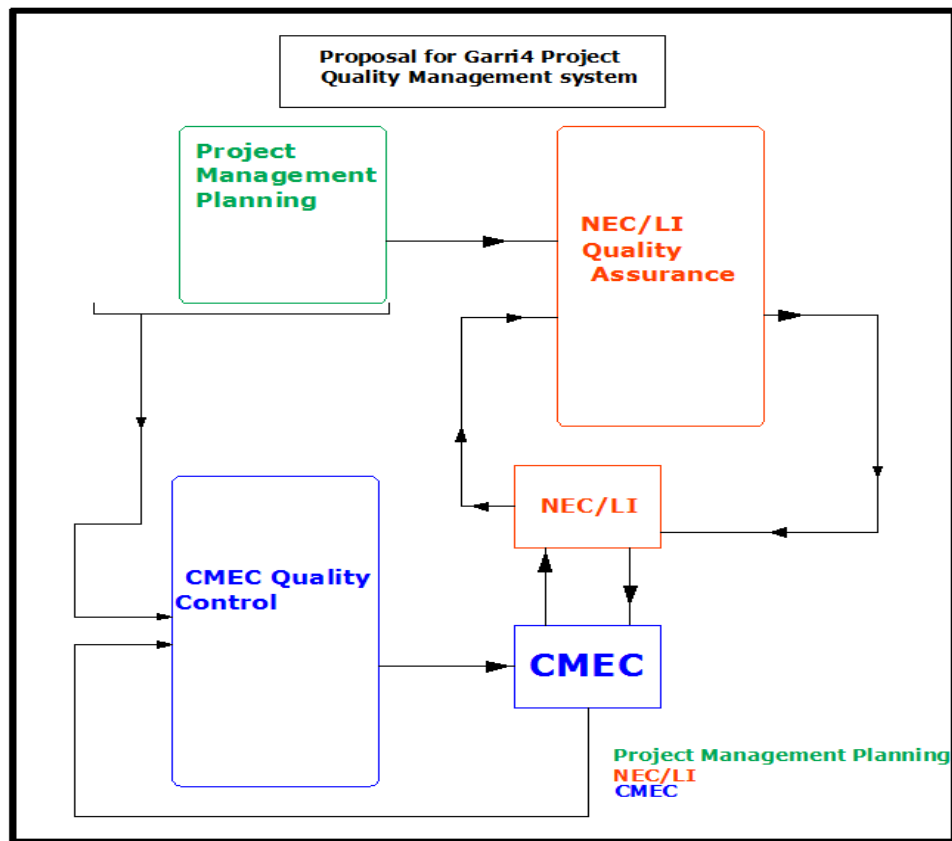
General QMS framework for the Garri4 project
Figure (3-4)

As stated previously, NEC is the owner of the Garri4 project, LI is the consultant, and CMEC is the main contractor (look at list of abbreviations).

In the above figure, the QMS is divided into three parts:

1- Project management planning: which consists of the entire project planning process, including the quality planning as there is no predefined QMS planning in hands, we should consider the inputs and the outputs to be used in our QA work.

2- CMEC QC: as CMEC represents the main project contractor. They are responsible for all QC job, including inspections, corrective actions, defect repair, implementing design change, the whole construction and erection job, and so on; here we are concerned with the QC outputs to be used in our QA work.

3- NEC/LI represent the Client/Consultant part, the main job here is the supervision work and Quality assurance according to the contractual requirements, this includes assuring the completion of the whole project scope and assuring quality that matching the contractual requirements, this can be done using various methods like auditing, and analyzing QC results, and so on

3.3 Setting QMS objectives and requirements:

The general QMS framework which was discussed previously has been shown in a presentation to Garri4 project staffs, accompanied with definitions on the meaning of QMS, differences between QA and QC, and the benefits that the project will gain from applying it.

After this presentation, two meetings were held with the project staffs. They mainly consisted of brainstorming to set QMS objectives and requirements. Many jobs were assigned to staff members, in order to classify all the project jobs into traceable system loops. Finally, the following items came out:

1- QMS objectives
2- QMS requirements
3- Traceable activity loops and the final QMS frame.

The objectives and requirements are listed in chapter 4, here we can talk about traceable activity loops in the final and approved QMS frame work.

3.3.1 Traceable activity loops:

The erection activities in the Garri4 project, for the purpose of applying the QMS, have been divided into 6 loops. Each loop with its documentation system:

1- Inspection work loop and its documentation system
2- Erection Defects loop and its documentation system
3- Design Modifications (Change Requests) loop and its documentation system
4- Inspection Devices Folder
5- Equipments and Materials loop and their documentation system
6- Daily Work follow-up (site notes)

The above loops are discussed in detail on the QMS guide, appendix (A). Least talk Figure (3-5) indicates the first loop:

Inspection loop and its documentation system

Figure (3-5)
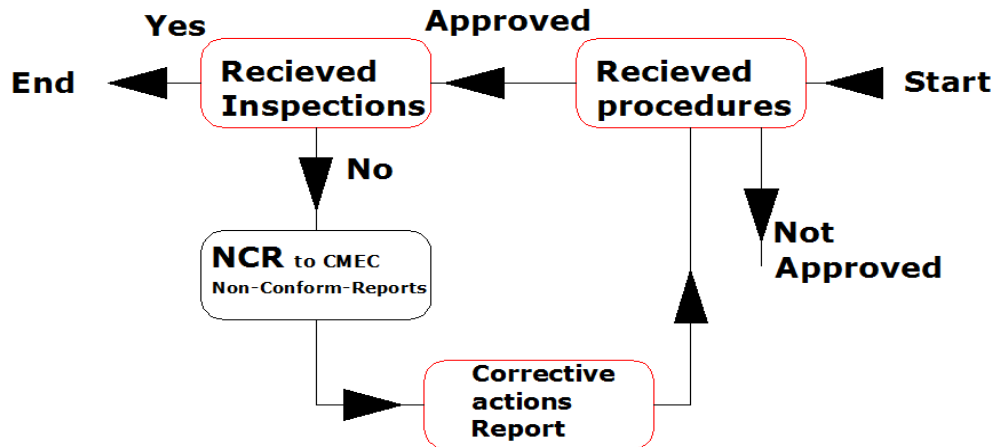
The red colour boxes mean these steps and its documents are to be received from the contractor CMEC, while the blacks are from NEC/LI.

The following text explains this loop:

1- Inspection procedures received from CMEC must be checked for approval, the approved procedures should be kept in (**Approved Procedures**) file, if not approved, then, it should be returned back to CMEC with clarifications.

2- After CMEC runs an inspection, which should be witnessed by NEC/LI, the inspection form/test, result/film should be sent to NEC/LI, after the proper check according to the requirements. If it is consistent, then the job is over and should be kept in (**Received Inspection**) file. The same file can be divided into finished inspection work /pending inspection work.

3- If the inspection result is not consistent with requirements, a NCR (Non-Conform-Report) should be sent to CMEC cited by the inspection form/results. A copy should be kept in (**NCR**) file.

4- The corrective actions which to be done by CMEC accordingly, which should be kept on (**Corrective Actions Report**) file, and then the loop continues again to the procedures and the re-inspection.

Inspection work has the above four files. In addition to that there should be an excel file in a table form to summarize the whole information. Please find these details in the attached QMS guide, appendix (1).

3.3.2 The final QMS frame work:

Finally, the previous general frame work is extended and detailed by the objectives/requirements/ and activity loops outcomes. Figure (3-6) shows it. It is not clear (has been drawn to be seen in an A0 paper) but it will also be shown in separate figures to be clearer:

Final QMS frame work for Garri4 project
Figure (3-6)
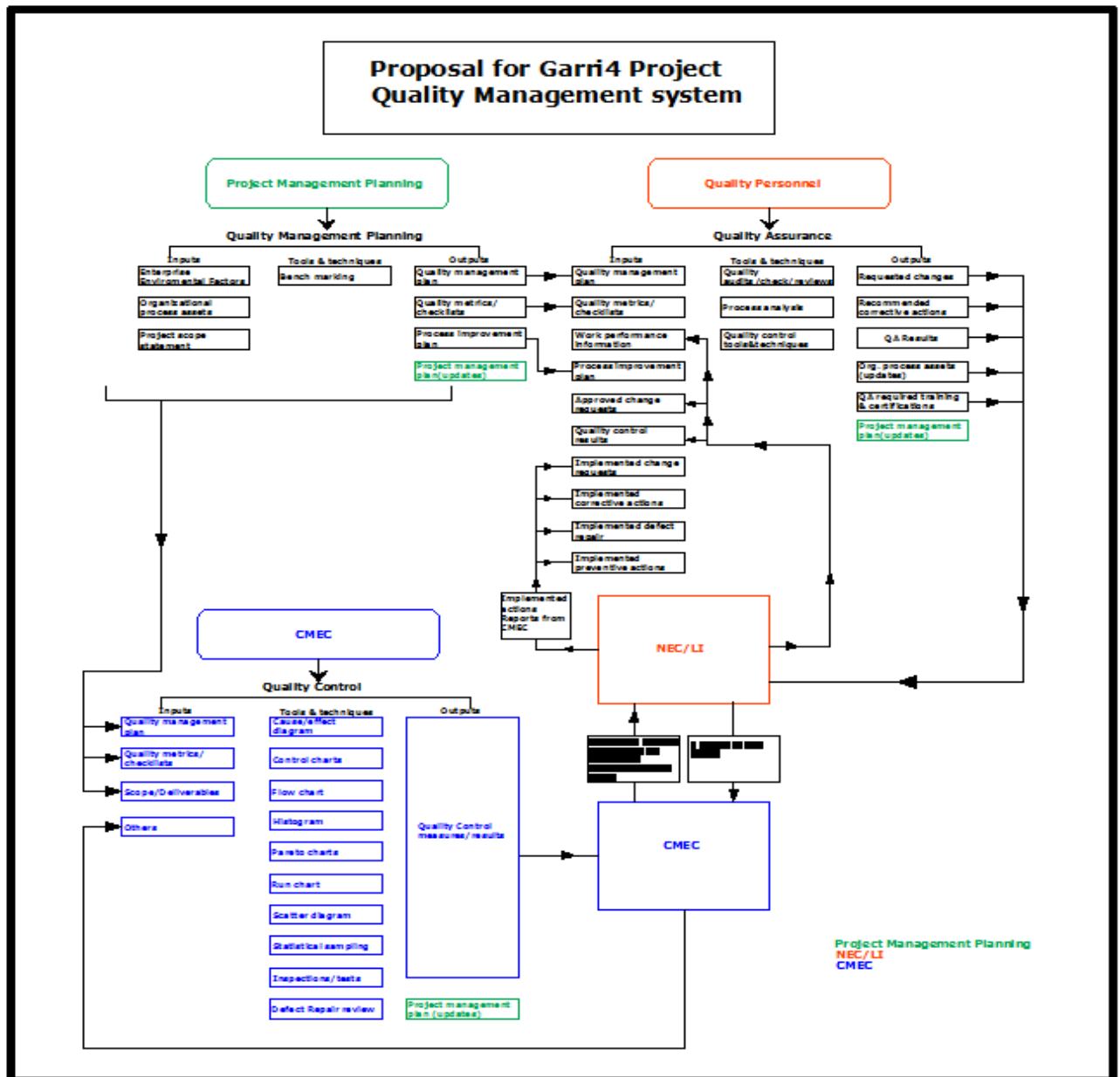
The above figure can be divided into 2 parts for more clarity, A and B:
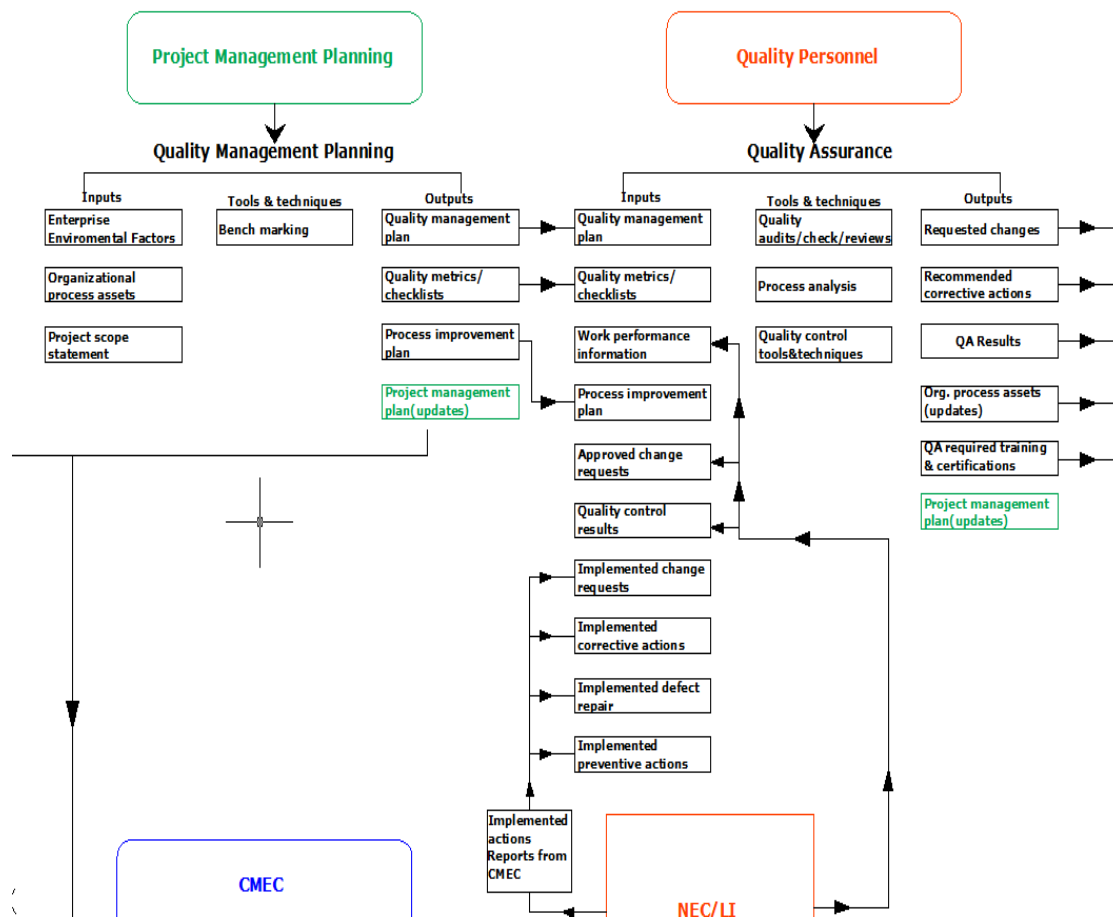
Figure (3-7) part (A)

Below is the summary of the QMS processes flowchart:

- CMEC should send all the QC results, all the requested corrective actions reports, all change requests, all defect repairs reports, procedures, and so on, before reasonable time to NEC/LI.

- NEC/LI should check all these documents received from CMEC and assign each document to the relevant loop, they should check the conformity to standards and contractual requirements, they should inspect the QC results, and they should carry out the appropriate auditing process, this audit and evaluation process is an expert judgement, which includes certified knowledge and experience.

- NEC/LI should report to CMEC any defect detected in project site and state the corrective actions required, also NEC/LI should consider the commercial

issues followed by inconsistencies in contractual requirements by the contractor, or as an impact of design modifications.

- CMEC should send back a report about any requested action from NEC/LI, also CMEC is requested to send their inspection schedule and procedures in advance to allow enough time for NEC/LI preparing for it.

- Every step/loop should be documented.

- QC/QA results should be analyzed periodically.

- NEC staff should be given scheduled certified QA training opportunities, so as to do the auditing/evaluation/supervision job efficiently.

Figure (3-7) part (B)
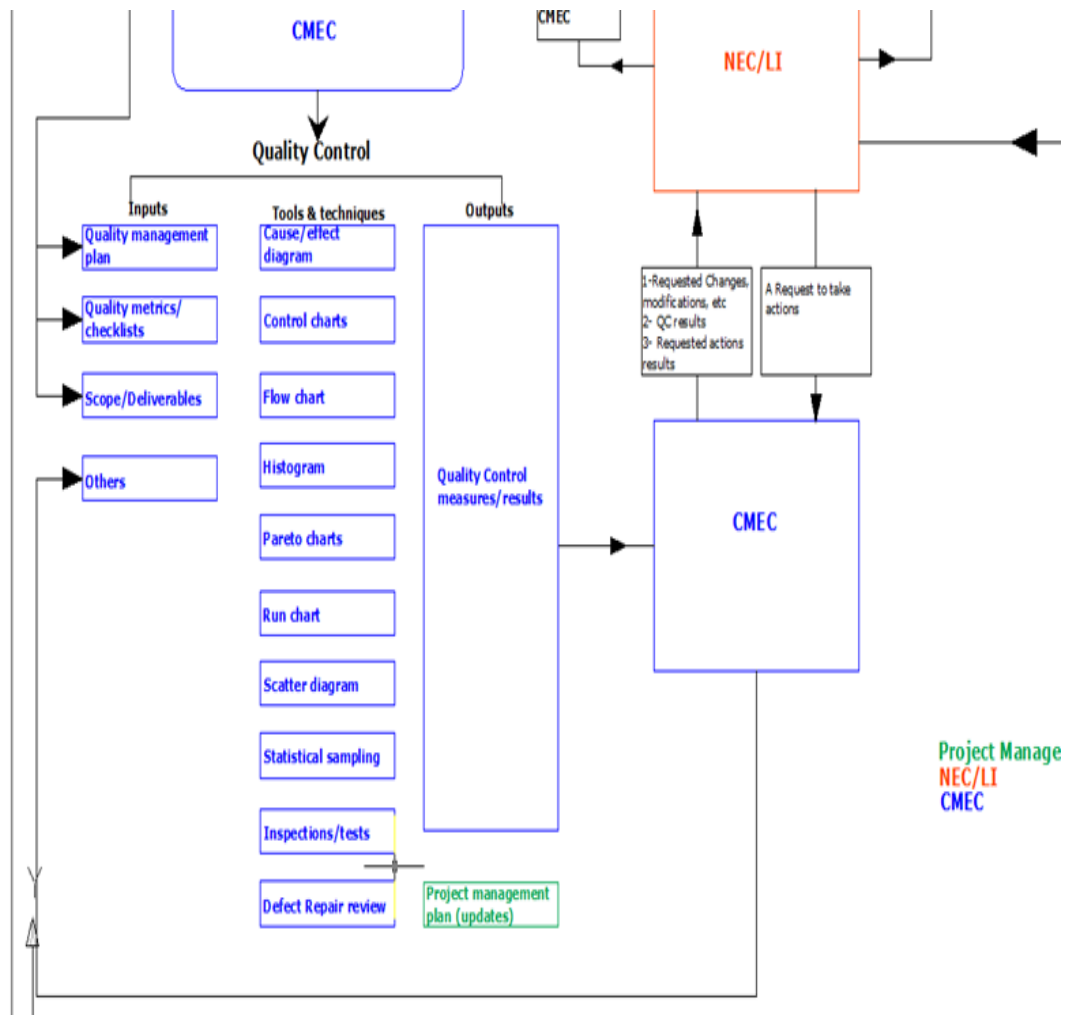
This QMS is scheduled to be implemented in April 2008.

From the above mentioned activities till the QMS formulation and approval, it is obvious that the QMS framework design have been achieved successfully, therefore the first hypothesis has been proved.

CHAPTER FOUR

RESEARCH METHODOLOGY AND FINDINGS

4.1 Introduction

In regards to the research paper of Nakeeb et al (1998) on measuring the QA effectiveness in construction industries, and the research paper of Oztas et al (2005) on measuring QMS effectiveness in Turkish industries, both discussed the matrix model, and it has been used in the second research. Although it has been used in contractors' organizations, it can be used in our study with some modifications. For example the objectives of the QMS in contractors' organizations and clients' organizations are different to some extent. Although Oztas et al (2005) used it once to measure quality system effectiveness; the use of it is intended to be twice, before and after the QMS implementation. The outcome of the first calculation will be used as a base to the second one, if the second calculation is equal to or greater than the first, then the QMS implementation was effective in making a difference and was successfully implemented. This concept can be understood from the following pages.

4.2 Matrix Model Concept

Implement of the matrix model to measure the effectiveness of the QMS in Garri4 project will be made. There are two matrices:

1- Matrix of principles: used to measure the effectiveness of achieving specified QMS requirements stated by Garri4 project management team.

2- Matrix of goals: used to measure the effectiveness of achieving prescribed QMS objectives and goals expected by Garri4 project management team.

Each matrix is comprised of four rows as follows

- **First row**: Quality characteristics which will be defined and determined by the firm.

- **Second row**: Percentage or weight (frequencies) should be assigned to each of the above quality characteristics according to the questionnaire result, given the symbol (W).

- **Third row**: Sequence of importance of these characteristics to the firm. They can be given as a scale from 1 to 10 or to 6 according to the total number of quality characteristics, and can be determined by the management team's priorities in the questionnaire, given the symbol (I).

- **Fourth row**: showing the Score, which equals the sum of W and I multiplied. The score reflects the effectiveness rate of QMS in the company, given the symbol (S).

The following example table illustrates the matrix model for objectives as an example. Only two characteristics are given for illustration purposes:-

Matrix model example
Table (4-1)

Quality Characteristics	1- Meeting Contractual requirements	2- linking activities systematically	others →
Weight(Yes answers percentage) (W)			
Importance (I)			
Score = W×I			

The outcome from the above matrices will be used to produce the following matrix characteristics in order to measure the effectiveness of the QMS:

- **L (limit):** it is the limit of success and effectiveness, the company will make assumptions about it, for example 60% can be the minimum limit of success to meet the QMS objectives (we will add it to the questionnaire, and we will take the higher frequency choice (the Mode), if they become varied, then the Mean can be taken in consideration.

- **FQS (Final Quality Score):** which equals $\sum_{i=1}^{n} S$, where n is the number of scores.

- **FQL (Final Quality Limit):** which equals $L\sum_{i=1}^{n} I$, where I is the importance, and L is the limit. The FQL after applying the QMS will equal the FQS before applying the QMS. Because the FQS before applying the system will be a good indicator of the real situation prior to the QMS implementation. Therefore we equate it to the FQL after QMS implementation to examine whether the QMS implementation would change it or not.

The normal process is to compare FQS with FQL, if FQL $\geq$ FQS, then the project has successfully met the QMS objectives and goals effectively, and if it is less, then the opposite is true; it has failed to meet it.

The following shall be done:

1- Implementation of the matrix model before and after the QMS implementation must be done. A comparative analysis should be made, the resulting FQS from the first measure will be the FQL for the second measure, in order to check whether things will improve after the QMS implementation or not.

2- The above needed data from the questionnaires will be collected.

4.2.1 Matrices Inputs

The quality requirements for the matrix of principles and the QMS objectives for the matrix of goals have been determined, after the literature review and the meetings which were held with the project staff, to be the following:

(1) Quality objectives:

1- Assure that the project as a whole meets contractual quality requirements.

2- Link the whole activities together systematically, so every one will know what to do, when, and how

3- Provide powerful tools for documentation control

4- Provide the upper management of the project with adequate reports.

5- Involvement of every engineer in quality activities

6- Good communication with the contractor

7- Good cooperation between different client's departments

8- Improve qualifications through learning and training

9- An excellent case study for future projects

(2) Quality requirements:

1- Safety guidance implementation

2- Establishing proper documentation system

3- Determining quality objectives

4- Following the loop of each QMS process

5- Following ISO 9001:2000 guidance

6- Availability of activities and tests schedule in advance

7- Proper Computer database for all activities

8- Availability of all standards, scope, contract documents, and all quality related documents

9- Clear job definition

10- Good understanding of the QMS principles

(2) Weight and Ranking procedures:-

The above quality objectives and requirements will be included in the questionnaire. From it the weight and rank of these items can be determined. The weight will be the percentage of (Yes) answers in relation to the total number of (Yes/No) answers. Each individual will be asked to rank these items according to their perceived importance to him/her. Following this, the rank of each item can be statistically determined, by taking the higher frequencies of the given ranks. In addition to that, for sensitivity and validity considerations, other trial calculations will be made for our matrix result using different ranking according to the mean for each of the QMS objectives and requirements.

4.3 The Questionnaire Construction:-

The questionnaire will be as follows:

1- The upper part contains personal information, especially qualifications and experience of the interviewed personnel; this will help in analysing the result as it reflects the staff background and experience in the quality and project management field. The following table illustrates the required information

2-

Required personnel information table

Table (4-2)

Total experience (years)	Power plant projects experience	Qualifications	Professional certifications	Quality training	Project management training
0-2 ( )	0-2 ( )	Bsc ( )	1- technical ( )	Yes( )	Yes( )
2-5 ( )	2-5 ( )	Msc ( )	2- management( )		
5-10 ( )	5-10 ( )	PhD ( )	3- others:-	No ( )	No ( )
More than 10 ( )	More than 10 ( )	MBA ( )			
		Others:-			

3- The entire body of the questionnaire includes a Quality Objectives part, and a Quality Requirements part, each individual is expected to answer by checking (Yes) if he/she believes that certain item is accomplished and met, and to answer by checking (No) if he/she does not think so. The following table illustrates some of the required information:

Questionnaire sample
Table (4-3)

	Quality Objectives:- Do you think the following quality objectives have been achieved?	**Put (√) sign in the preferable answer**		**Rank From 0 to 10**
1-	Supporting the top project management with adequate reports	Yes ( )	No ( )	---------------
2-	involvement of every engineer in quality activities	Yes ( )	No ( )	---------------
	Quality Requirements:- Do you think the following quality requirements have been achieved?			
1-	Safety guidance implementation	Yes ( )	No ( )	---------------
2-	Good understanding of the QMS principles	Yes ( )	No ( )	---------------

The above questionnaire will be used two times. The first time will be before the implementation of the QMS, and the second after four months of the system implementation, but the personal information will be taken once in the first questionnaire.

Every interviewed individual will be asked to put a check (√) sign in front the answer of his/her choice, and to write his/her own statement when he/she chooses (others) as an answer.

The complete questionnaire document is attached to Appendix B.

4.4 Calculations

4.4.1 Prior to QMS implementation

As we discussed on the previous pages, we have to apply the matrix model before and after the QMS implementation. Now, starting from the point which is preceding the QMS implementation, we can use the data which we obtained from the first questionnaire. These raw data re-organized on the following tables, table (4-4) summarized the personnel data of Garri4 site staff, which are at the same time the targeted personnel for our questionnaire. And table (4-5) which shows only the first five results of the questionnaire data for illustration purposes after statistical organization, Mean, Mode, and Percent calculations. The full tables can be found in Appendix C.

The targeted personnel in these questionnaires are the whole NEC Garri4 staffs, the site project manager, sections heads, and the project engineers. The total number of NEC working staff is 19. In table (4-4) we can see all staffs' relevant information in regards to qualifications and experience. As it can be seen from table (4-4), the majority of Garri4 staffs (15 personnel out of 19) have a total experience in the range (2-5) years, and 12 personnel have worked in project management field just for the last 2 years, whereas 6 personnel have more than 2 years in projects field. We can also find that all of the working staffs have completed BSc degree, and those who possessed either MSc or MBA are 2 personnel respectively. It is also obvious that only 2 personnel are certified into management professional certification field, while none of the working staff have been certified in any of the known technical fields. Finally, the personnel who have been trained in both quality and management are only 6 respectively. The importance of these personnel data can be helpful on picturing thesis final results.

NEC targeted personnel data in Garri4 project
Table (4-4)

Total experience (years)	Power plant projects experience	Qualifications	Professional certifications	Quality training	Project management training
0-2 (1)	0-2 (12)	Bsc (19)	1- technical (0)	Yes(6)	Yes(6)
2-5 (15)	2-5 (6)	Msc (2)	2- management(2)		
5-10 (3)	5-10 (1)	PhD (0)	3- others:-	No (11)	No (13)
More than 10 (0)	More than 10 (0)	MBA (2) Others:-			

First five results of questionnaire data of QMS Objectives prior to QMS implementation

Table (4-5)

No.	1	2	3	4	5
Yes	11	8	9	8	8
No	8	11	10	11	11
Mode	7	0	9	6	3
Mean	5.4	4.9	5.4	6.5	5
Percent	58	42	47	42	42

Before going further, the above table calculations are as the following:

- Mode: the statistical element of the higher frequency for each of the questionnaire questions. For example, 7 is the Mode for the first question rank in matrix of objectives, which means targeted personnel for our survey chose 7 as a rank more than any other rank. Therefore 7 is the higher frequent rank, i.e. the Mode.

- Mean: the sum of data divided by its number for each of the questionnaire questions. For example, 5.4 is the Mean for the first question rank in matrix of objectives which equals the sum of all ranks divided by number of responses.

- Percent: yes to (yes+ no) answers percentage for each of the questionnaire questions, it is also the weight (W).

After that, we obtained the limit (L) from the given questionnaire data, we calculated the Mode 70% and the Mean 63% from them.

Then, we created table (4-6) to calculate the Rank (I) by using the Mode on a time (I_1), and the Mean at the second time (I_2), we did that so as to validate our calculations for sensitivity analysis considerations, either by the Mean or the Mode. The score (S $=W \times I$) also calculated, S1 by using (I_1) which has been calculated by the Mode, and S2 by using the (I_2) which has been calculated by the Mean.

Matrix of Objective calculations, prior to QMS implementation

Table (4-6)

No.	Yes	No	W	I_1	I_2	S1	S2
1-	11	8	58	7	5.4	405	313
2-	8	11	42	0	5	0	211
3-	9	10	47	9	5.4	426	256
4-	8	11	42	6	6.5	253	274
5-	8	11	42	3	5	126	211
6-	17	2	89	4	4.6	358	412
7-	11	7	58	7	5.6	405	324
8-	11	7	58	1	3.1	57.9	179
9-	8	10	42	9	4.2	379	177

$$FQS = \sum S \qquad 2411 \quad 2355$$

$$FQL = L \times \sum I \qquad 3220 \quad 2806$$

From the above calculations on table (4-6), we found that:

FQL > FQS for the matrix of Objectives, this result obtained by the Mean and the Mode too.

Now, for the matrix of requirements, the above calculations are identical, therefore, table (4-7) which shows only the first five results of the questionnaire data for illustration purposes after statistical organization, Mean, Mode, and Percent calculations. The full tables can be found in Appendix C. And table (4-8) shows the Rank (I) by using the Mode on a time (I_1), and the Mean at the second time (I_2), we did that so as to validate our calculations for sensitivity considerations, either by the Mean or the Mode. The score ($S = W \times I$) also calculated, S1 by using the (I_1) which has been calculated by the Mode, and S2 by using the (I_2) which has been calculated by the Mean.

First five results of questionnaire data of QMS Requirements prior to QMS implementation

Table (4-7)

No.	1	2	3	4	5
Yes	12	11	9	12	5
No	7	8	10	7	14
Mode	0	6	7	10	2
Mean	5.3	5	5.3	5.4	3.7
Percent	63.2	57.9	47.4	63.2	26.3

Matrix of Requirements calculations, prior to QMS implementation
Table (4-8)

No.	Yes	No	W	I_1	I_2	S1	S2
1-	12	7	63	0	5	0	335
2-	11	8	58	6	5	347	289
3-	9	10	47	7	5	332	251
4-	12	7	63	10	5	632	341
5-	5	14	26	2	4	52.6	97.4
6-	9	10	47	1	4	47.4	166
7-	9	9	47	0	5	0	246
8-	8	11	42	4	4	168	168
9-	13	6	68	0	6	0	376
10-	11	8	58	10	5	579	289
$FQS = \sum S$						2158	2560
$FQL = L \times \sum I$						2800	3000

From the above calculations on table (4-8), we found that:

FQL > FQS for the matrix of Objectives, this result obtained by the Mean and the Mode too.

4.4.2 After QMS implementation

After 4 months of QMS implementation, we made the second questionnaire using the same one which we used prior to QMS implementation. We did so because we need to check whether the QMS implementation would make a difference on the same examined areas or not, and also to facilitate the second hypothesis check. We are not going to repeat the calculations as they are identical to the calculations of the case prior to QMS implementation. As a result, for the Matrix of objectives, on table (4-9) we can see only the first five results of the questionnaire data for illustration purposes after statistical organization, Mean, Mode, and Percent calculations. The full table can be found in Appendix C. And table (4-10) shows the Rank (I) by using the Mode on a time (I_1), and the Mean at the second time (I_2). We did that so as to validate sensitivity of our calculations for sensitivity considerations, either by the Mean or the Mode. The score (S) also calculated, S1 by using the (I_1) which has been calculated by the Mode, and S2 by using the (I_2) which has been calculated by the Mean. This time the targeted personnel for the questionnaire are only 16, as some were in vacations.

First five results of questionnaire data of QMS Objectives after QMS implementation
Table (4-9)

No.	1	2	3	4	5
Yes	7	6	5	5	7
No	8	9	10	10	8
Mode	4	7	9	8	7
Mean	4.1	5.3	6.4	6.125	5.75
Percent	44	38	31	31.25	43.75

Matrix of Objective calculations, after QMS implementation
Table (4-10)

No.	Yes	No	W	I_1	I_2	S1	S2
1-	7	9	44	4	4.13	175	181
2-	6	10	38	7	5.313	263	199
3-	5	11	31	9	6.38	281	199
4-	5	11	31	8	6.1	250	191
5-	7	9	44	7	5.8	306	254
6-	12	4	75	1	5.1	75	383
7-	10	6	63	6	5.2	375	325
8-	9	7	56	1	3.75	56.3	211
9-	5	11	31	6	4.88	188	153
FQS=$\sum S$						1969	2095
FQL=						2411	2355

We should not forget that we do not need to calculate FQL here, as we mentioned in section 4.2. We will use FQS that results from matrix calculations prior to QMS implementation for both objectives and requirements matrices as FQL on the corresponding matrices after QMS implementation. Therefore, it is clear that FQS prior to QMS implementation = FQL after QMS implementation = 2411 when using the Mode, and = 2355 when using the Mean. As a result:

FQL > FQS in both cases, (Mean and Mode) for matrix of objectives.

Now, for the Matrix of requirements after QMS implementation, the above calculations are identical, therefore, table (4-11) which shows only the first five results of the questionnaire data for illustration purposes after statistical organization, Mean, Mode, and Percent calculations. The full table can be found in Appendix C. And table (4-12) shows the Rank (I) by using the Mode on a time (I_1), and the Mean at the second time

(I_2). We did that so as to validate our calculations for sensitivity considerations, either by the Mean or the Mode. The score (S=$W \times I$) also calculated, S1 by using the (I_1) which has been calculated by the Mode, and S2 by using the (I_2) which has been calculated by the Mean.

First five results of questionnaire data of QMS Requirements after QMS implementation
Table (4-11)

No.	1	2	3	4	5
Yes	7	7	9	11	6
No	8	8	6	4	9
Mode	5	6	6	7	4
Mean	4.63	4.75	6.13	6.56	5.69
Percent	43.8	43.8	56.3	68.8	37.5

Matrix of Requirements calculations, after QMS implementation
Table (4-12)

No.	Yes	No	W	I_1	I_2	S1	S2
1-	7	9	44	5	5	219	203
2-	7	9	44	6	5	263	208
3-	9	7	56	6	6	338	345
4-	11	5	69	7	7	481	451
5-	6	10	38	4	6	150	213
6-	4	12	25	1	5	25	128
7-	7	9	44	8	7	350	293
8-	4	12	25	6	5	150	130
9-	10	6	63	6	5	375	321
10-	8	8	50	7	5	350	257
FQS=$\sum S$						2700	2547
FQL=						2157	2560

Again, we should remember that FQL as we mentioned in Chapter (4), section 4.2, we will use FQS that results from Matrix calculations prior to QMS implementation for both objectives and requirements matrices as FQL on the corresponding matrices after QMS implementation. Therefore, it is clear that FQS prior to QMS implementation = FQL after QMS implementation = 2157 when using the Mode, and = 2560 when using the Mean. As a result:

FQL < FQS in the Mode case for matrix of objectives, and:
FQL > FQS in the Mean case for matrix of objectives

4.5 Findings

From the above calculations, the obtained results for QMS implementation in Garri4 project are as the following:

1- QMS objectives have been met during the experiment period, FQL > FQS in both cases, either by using the Mode or the Mean.

2- QMS requirements have not been met, as FQL<FQS by 543 (2157-2700 = - 543) when we calculate by the Mode, and have been met when we used the Mean in our calculations, however, FQL>FQS slightly (2560-2547 = 13). Therefore, for sensitivity considerations, we can assume from these results that the QMS requirements during the experiment period were not satisfied and have not been met accordingly.

Now we can check the validity of the second hypothesis in the following section:

4.6 Validity of the second hypothesis:

We have hypothesized that the QMS implementation can meet Garri4 quality objectives. For those QMS objectives which have been formulated within the joint meetings between the researcher and the Garri4 project staff, section 4.2, they have been met successfully as the Matrix model of objectives after QMS implementation result shows in table (4-10), whereas the quality system requirements which are needed to establish the system successfully have not been met as the Matrix model of requirements after QMS implementation states in table (4-12).

CHAPTER FIVE

ANALYSIS AND CONCLUSION

5.1 Introduction

In this chapter, we will analyze the findings of the thesis in the light of real observations. The analysis will check both QMS objectives and requirements through the matrices models after QMS implementation. Thesis limitations will also be discussed in terms of questionnaire and calculations contribution to this limitation. Finally the thesis conclusion will be drawn and the recommendations will be stated respectively.

5.2 Analysis

5.2.1 Matrix of Objectives after QMS implementation

We used the Mode and also the Mean as trial calculations options to validate calculation sensitivity. The Mode and the mean have the same concept, however, they are completely different numerically especially when the given data are not in the same order. From the result which can be seen from table (4-10), FQL > FQS. Therefore, as we stated in the methodology in Chapter (4) section 4.2 and section 4.5, this result indicates success on meeting the prescribed QMS objectives of the project during the study period. In fact, there are real indications for this success on some of the prescribed QMS objectives in the project after the QMS implementation as the following:

1- Supporting the top project management with adequate reports
After the QMS guide has been signed and approved by the project site manager, he sent a copy to each section for implementation. Each section has been asked to report its relevant activities on monthly basis by using one form for all departments. Before QMS this job was not functioned well, now it has been done routinely.

2- Involvement of every engineer in quality activities
During the earliest stages of the thesis, all NEC project staff in Garri4 contributed on the Seminar, the QMS guide meetings, setting requirements and objectives, and also they have become aware – to some extent - of the quality issues on the site by monitoring and reporting relevant quality data.

3- Good documentation Control
Some sections started to review their documentation system, and re-organize them to some extent using QMS guidance. And also some sections have begun to build computer database for

their sections. Now, the new Archiving office has been completed to organize and store project documents.

4- Good communication with the contractor

After the QMS guide has started to be implemented, the site manager invited the contractor's involved personnel to discuss with them the quality matters, and to tell them about the QMS. He asked them their cooperation on following the indicated quality loops to implement the QMS successfully. Furthermore, the contractor tried to solve some problems, such as safety, translators' availability, and project time schedule.

5- Improve qualifications through learning and training

After the QMS implementation, the guide has been sent to NEC top management. After a while, 3 of NEC engineers have been sent to Korea and South Africa to get technical certifications on vibration analysis and alignment. And they have become certified. These are the only NEC technically certified personnel on Garri4 project for the first time. Furthermore, the NEC projects department scheduled in groups PMP (Project Management Professional) training and certification exams for the whole department staff, together with P3 (Primavera) packages and other relevant professional project management knowledge. We cannot, of course, attribute all these achievements to the QMS implementation; however, it has contributed effectively on raising top management's awareness about these issues, and to find suitable ways to solve them.

5.2.2 Matrix of Requirements after QMS implementation:

From table (4-12), we can see clearly that QMS requirements were not satisfactory. Therefore they have not been met. Although we have different values for FQL and FQS when we use the Mode in a time, and the Mean in the other time, we are tending to assume that FQL<FQS, because the difference is -543 when we use the Mode, and only 13 when we use the Mean.

Another alternative is that we can calculate the Mean for FQL and the Mean for FQS (which had been calculated by using the Mode and the Mean for each):

For FQS:
$$(2700 + 2547) \div 2 = 2623.5$$

For FQL:

$(2157 + 2560) \div 2 = 2358.5$

So, FQL<FQS, 2358.5<2623.5

Therefore, we still can assume that QMS requirements have not been met.

First of all, the above result was not expected. As meeting requirements of every system could contribute to the success of meeting system objectives. What we have right now is the opposite, system objectives have been met while system requirements have not. However, it does not mean that these requirements have not met completely; it means what we have now is less than what was expected. We based our QMS calculations on the FQS which obtained from QMS calculations prior to implementations.

We can analyze these results from some real observations during QMS implementation:

11- Establishing proper documentation system:

Although some sections in Garri4 project have tried to improve the documentation system according to the QMS guide, the job was not complete, and even some sections ignored the QMS guide procedures completely. Some explained this by simply saying it is difficult to re-arrange these documents into the new format, and they believe it is non sense and impractical, as they have more important jobs to do.

12- Following the loop of each QMS process:

Following the QMS loops, especially for activities, have not been met from the researcher's observations. The loops require modifications on the documentation system, as well as modifications on some forms such as inspection forms. There has been a little modification in both of them.

13- Availability of activities and tests schedule in advance

This is the responsibility of the contractor as the contract specified. Although NEC/LI have requested many times to make these items available sufficiently and on time, the contractor response was very slow. Finally, the contractor decided to submit activities'

schedule on monthly basis. Not only this, but also they haven't used the standard and agreed methods (Primavera), they have used an internal scheduling system that depends on the project status and their current capabilities. This act has hindered NEC/LI efforts to better manage and foresee expected delays and unexpected events.

14- Proper Computer database for all activities

There has been very limited work on this item, as some sections started, however some sections stopped completely.

15- Clear job definition

This item can be considered to be one of the most critical factors. The ambiguity of the role definition, and the lack of sufficient responsibilities, together with the lack of sufficient required knowledge to do the job efficiently have all contributed to unclear job definition.

From the above observations, together with the matrix of requirements results, we can diagnose the reasons that have led to this situation:

1- Follow up: there have never been any meetings regarding the QMS progress. The researcher, although is working in Garri4 project, has no authority to call for such meetings, his actions were mainly around notifying responsible personnel about this matter.

2- Resistance to change: This is a very complicated problem. Although it was not expected, as Garri4 staff as a whole was enthusiastic especially on the first QMS formulation stage, this spirit has been declined gradually, and has been translated into some ignorance to the QMS principles.

3- Project management's ignorance and lack of knowledge: This is also a very important failure factor, if the staff and the management lack required knowledge, and ignored the established quality norms, this will eventually results in poor quality as K.N.JHA et al, (2006) stated on their study, which examined the critical factors affecting quality performance in construction projects.

5.3 Thesis limitations:

Although the matrix model methodology has been used successfully in some studies, namely Nakeeb et al (1998) and Oztas et al (2005), it has some limitations which can be explained here. Before that, we have not to forget that we made some modifications on the original matrix model concept and calculations. In the concept part, we changed the matrix utilization from contractor organizations to owners. In addition to that, we used the matrix model to check the situation prior and after QMS implementation. We have also used the calculated FQS from the calculations prior to QMS to be FQL after the QMS implementation. We did that because the FQS (Final Quality Score) prior to QMS implementation indicated the actual situation at that time, the situation which we want to change and improve via applying the QMS.

We can summarize these limitations into two points:

1- The questionnaire.
2- The calculations.

5.3.1 The questionnaire limitations

In the questionnaire which has been prepared by joint meetings between the researcher and the project team, the prescribed objectives were not seems to be enough especially in the project delivery part. This study carried out after 60% of the project completion. That means, in one hand, it would be very difficult to apply new working methodology. This is basically because people are use to doing their jobs from the project earliest stages using specific traditional methods, and they are not pleased to change the way to do their jobs by new means. Furthermore, resistance to change in organizations, even to some extent is a common prevailing culture, and considered to be a common barrier to change that leading to quality improvement, Best (2006b). On the other hand, lack of technical and project management experiences among NEC staffs (see table (5-1)) have hindered their efforts to make professional judgements about the project delivery quality. For this case, NEC has relied very much on the technical support of professional consultants for many years. As a result, it was extremely difficult to set sophisticated objectives to the new born QMS, such as measuring project performance on a technical basis. Therefore, NEC depends mainly on the consultants outcomes.

5.3.2 The calculations limitations

The limitations of which the calculations have contributed to this study are that we have used limited statistical variables, i.e. the Mean and the Mode. Moreover, it is not only the limitations of these variables, but also the reliability of the Mode and the Mean which were not satisfactory. The reasons are that the data which were collected via the questionnaire were not homogeneous, especially the ranking process. In addition to that, there were some indifferent responses to the questionnaire, such as empty spaces. Another important factor is that the targeted personnel can be considered to be very limited, 19 personnel on the first questionnaire, and 16 on the second. That means we have lost about 16% of our questionnaire sample on the second time. Therefore these reasons have contributed to this limitation of our results.

5.4 Conclusions:

This study is an attempt to design and implement a quality management system (QMS) based on the guidance and outlines of the PMBOK guide, so as to be implemented in Garri4 power plant project, Sudan. The study also presents an attempt to examine the effectiveness of the QMS during the erection phase. A matrix model as a measuring tool for the QMS effectiveness, together with the researcher's observation within the QMS implementation period has been used. Based on the calculations, findings, analysis, and observations gathered in this study, the following conclusions are drawn:

- QMS formulation process attracted the attention and the enthusiasm of Garri4 working staffs on its earliest stage. However, during QMS implementation, this enthusiastic spirit has been declined gradually, and some ignorance to the QMS principles has been observed. This behaviour can be explained in terms of organizational behaviour and resistance to change. In addition to that, it is also a direct result of management ignorance to follow up QMS progress periodically to ensure its effectiveness.

- In spite of the above, QMS objectives which have been set in the joint meetings between the researcher and the project team have been met successfully. This result obtained from the matrix model outcomes and supported by real observations. However, these objectives are not satisfactory, especially on project delivery part. To set reliable and sufficient sophisticated objectives it requires certain technical and project management capabilities, which are lacked among Garri4 staffs.

- The QMS pre-requisites and requirements have not been met during QMS implementation. This result obtained from the matrix model outcome and supported by real observations. The main factors which have contributes to these results are the contractor's slow response, in addition to mismatching contractual requirements, such as project time schedule. In addition to that, NEC working staffs' ignorance to the established quality norms, and lack of project management and technical knowledge have contributed to this problem. Finally, QMS has not been applied from the project's earliest stages; this has resulted on the occurrence for resistance to change old working methodology to the new QMS.

5.5 Recommendations:

The following recommendations are drawn to the attention of NEC top management. It is assumed that following these recommendations would enhance QMS success implementation in future NEC power plant projects:

- QMS guide and outlines should be prepared in the earliest project stages. Each stage should have its own QMS to be followed to guarantee satisfactory and standard outcomes. This also can prevent resistance to change, as the earliest adopted working methodology will be prevailing throughout the project life cycle.
- Recruiting and staffing process should be done in the earliest project stages. And the staff as a whole should be involved from the beginning in all project activities. This is very important to ensure staffs' awareness of all project deliverables.
- Technical and project management competence are very crucial success factors. The staffs should undergo extensive training courses, and a considerable number of the working staffs should be certified in project management (such as PMP, and IPMA) in addition to technical certifications. See appendix A, the QMS guide appendix includes some of these technical certifications.
- The QMS effectiveness and the contractor's performance should be examined periodically. This is very important to enable earliest forecasting and immediate remedy for any emerging problems. It is important to note that the successful of QMS effectiveness measuring, and the appropriate remedies, require setting sophisticated project delivery objectives (on technical basis), which depends on the

knowledge and experience of the working staffs. In addition to that, it requires decisive actions to claim the contractor officially for contractual compensations for any contractual mismatch. This would represent a positive pressure on the contractor to provide agreed services.

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<u>APPENDICES</u>

APPENDIX A
QMS guide

National Electricity Corporation
General Directorate of Projects and Planning
Garri4 Project

Quality Management System (QMS) Guide

Prepared By:
Eng: Muhanad Faiz Fakhri

Checked and Edited By: Approved By:
Garri4 Project Team   Eng. Elsadig Elkhair
                                                  Garri4 Project Site Manager

Effective date: 19th of May 2008

Preface

This guide is the QMS (Quality Management System) guide for NEC staff in Garri4 project; it includes the main QMS frame, definitions, process loops, analytical reports and the documentation system.

The need for this QMS guide aroused from the fact that there is no predefined QMS for the project, although all project parties do their quality responsibility, but there is a real need for a well structured QMS frame to accomplish the supervision job successfully and to assure project quality according to the contractual requirements, in addition to document all the processes and their consequences.

This is not a final guide; it should be improved, modified, and changed whenever it needs.

This QMS designed according to the PMBOK guide outlines, and the detailed work done according to the seminar and meetings results, so all the project team participated in this guide.

Chapter 1
Introduction

Chapter Contents:

1-1 Project Management
1-2 Process Groups in Project Management
1-3 Quality Management System (QMS)
1-4 Differences between QA/QC
1-5 The PMBOK Guide
1-6 The standard Processes of formulating QMS
1-7 The current situation in Garri4 project
1-8 The Objectives of QMS for Garri4 Project
1-9 Documents required to carry out the QMS efficiently

Chapter 1
Introduction

1-1 Project Management

Project management is defined as "the application of knowledge, skills, tools and techniques to project activities to meet project requirements"

1-2 Process Groups in Project Management:

The whole processes and activities of a project lifecycle from the earliest stages till completion are aggregated into five process groups:

1- Initiation
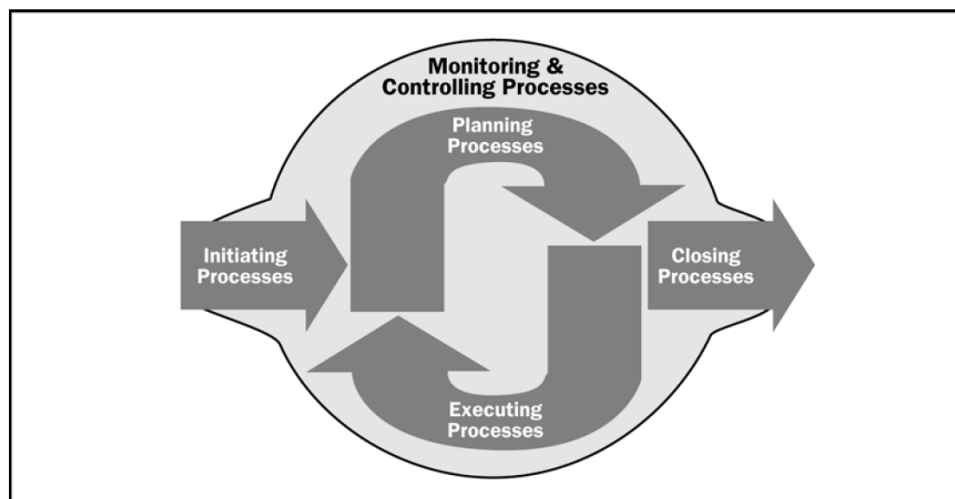2- Planning
3- Execution
4- Monitoring and control.
5- Closure

Figure (1). Project management process groups.

1-3 Quality Management

Quality Management System (QMS):

Quality Management System (QMS) can be defined as a set of policies, processes and procedures required for quality planning, quality assurance, and quality control. QMS enables the organization to identify, measure, control, and improve the various core processes that will ultimately lead to improved project performance.

The following table demonstrates the three components of QMS and assign each of them to the corresponding Process Group:

Project Quality Management Component	Project Management Process Groups
1- Quality Planning	Planning Process Group
2- Quality Assurance	Executing Process Group
3- Quality Control	Monitoring & Controlling Process Group

Table (1). Project Quality Management components in Project Management Process Group

1-4 Differences between QA/QC:

Quality Control

   - The operational techniques and activities that are used to fulfil requirements for quality

Quality Assurance

   - All those planned and systematic activities implemented to provide adequate confidence that an entity will fulfil requirements for quality
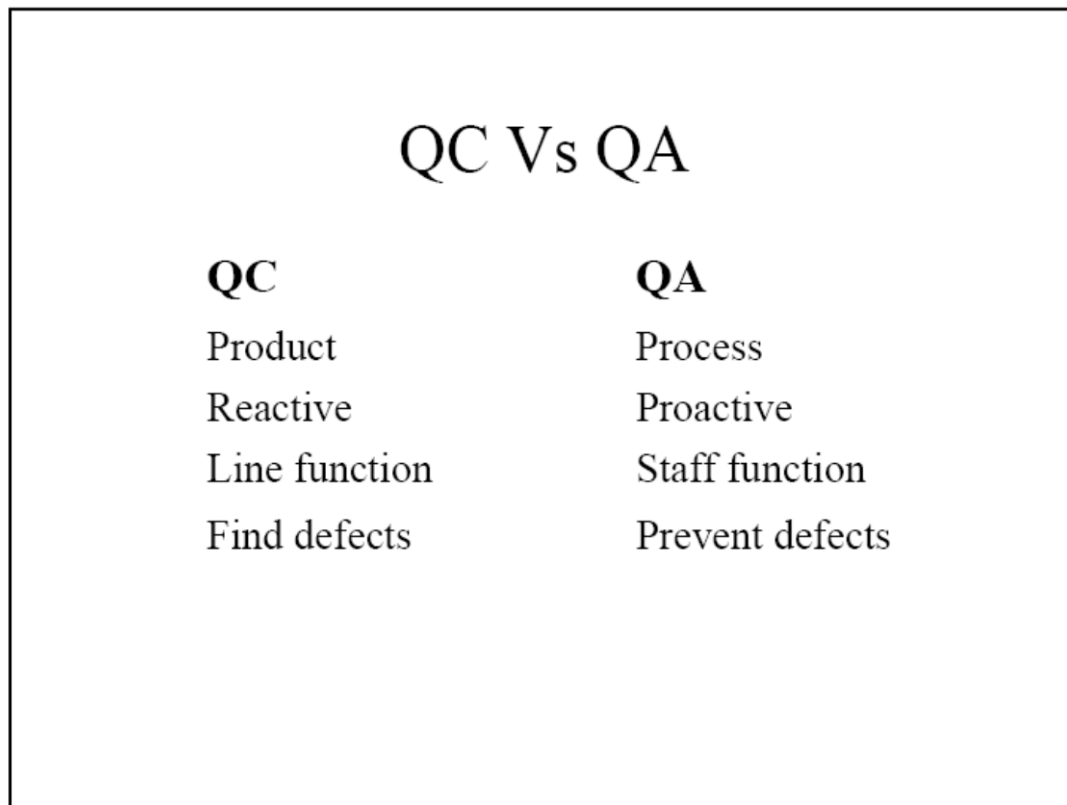
Figure (2). Differences between QA and QC

1-5 The PMBOK Guide

Garri4 Quality Management system designed using the PMBOK guide, 3rd edition-2004, PMI

Project Management Body Of Knowledge is the sum of knowledge within the profession of project management, the body of knowledge rests with the practitioners and academics who apply and advance it.
Published by PMI (Project Management Institute)

1-6 The standard Processes of formulating QMS:

- A Quality plan should be prepared in the earliest stages of the project, covering all project phases to assure quality in each phase.
- It can be submitted by the Contractor, Owner, or as a joint venture.

- The Quality planning provides inputs for both QA and QC, the outputs from QC become inputs for QA and QA outputs become inputs for QC, and also the outputs from both QA and QC update the whole Project Management plan, which in turn feeds the inputs of Quality planning process. In chapter (2) this will be explained in details.
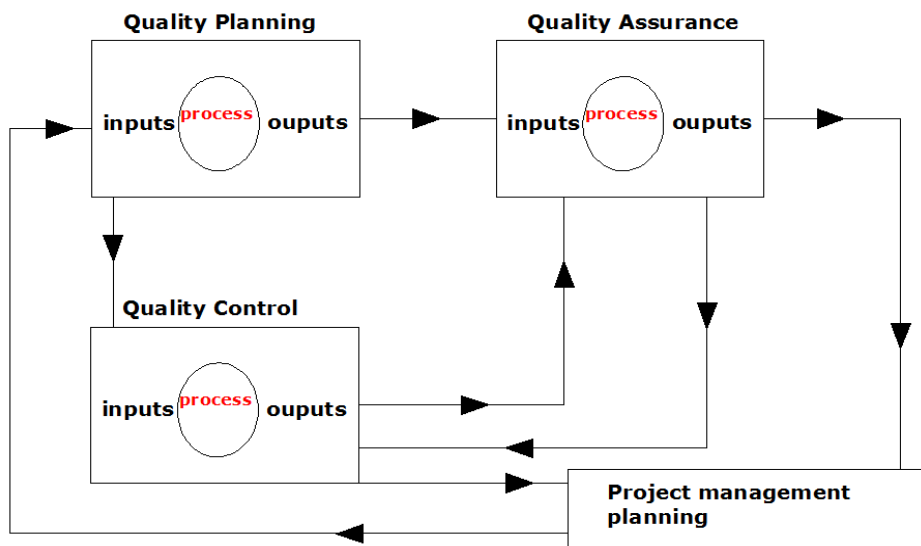
Figure (3). Standard QMS flowchart as summarized from PMBOK

1-7 The current situation in Garri4 project:

- The current situation is that there is no specific Quality Management System.
- No Quality Planning done during the earliest project stages.
- All parties do their quality responsibilities, but there is no predefined QMS.
- The absence of a proper QMS makes supervision job very difficult specially for NEC staff, there are many different loops should be traced separately in order to assure quality according to the contractual requirements and also there is a real need for a system that pressures all project parties to carry out their responsibilities and to be aware about quality issue and the consequent commercial items claims that follow mismatching of contractual requirements.

1- The Objectives of QMS for Garri4 Project:

A QMS frame already designed to:

10- Link the Quality activities flow systematically

11- Provide a powerful tools for documentation control

12- Every one will know what to do, when, and how

13- Supporting the top project management with adequate reports.

14- Improve qualifications through learning and training

15- An excellent case study for future projects

*** An important note should be stated here; the QMS of Garri4 project is designed according to its current situation as an ongoing project, considering that there is no much effort could be done about Quality Planning, but the planning outputs as stated in PMBOK should be generated and used, also as NEC represents the ''Client'', the focus of this QMS will be on QA.

1-9 Documents required to carry out the QMS efficiently:

1- ISO Guidance

2- Relevant standards agreed to be used

3- Safety Guidance

4- Jobs descriptions

5- Time schedule (activities, upcoming tests, inspections, etc)

6- Work Guide includes [change control procedures, defect management procedures, performance measurements criteria, measurement database, lesson learned from previous project, documentation system, final project evaluation criteria, etc]

7- Scope [TTS, drawings, Design meetings, etc]

8- Quality metrics, checklists

9- Any additional documents

Chapter 2

The QMS flowchart for Garri4 Project

Chapter contents:

Chapter 2

The QMS flowchart for Garri4 Project

2-1 The QMS frame:

The QMS frame for Garri4 project designed according to the PMBOK guide, considering NEC role as a client, and considering the current phase of the project (execution phase), this frame and the accompanied guide is not final, but it can be used immediately to control the site job, and it should be modified and updated continuously, the following flowchart representing the summarized Garri4 QMS flowchart, a more detailed flowchart can be viewed in the attached A3 paper size.
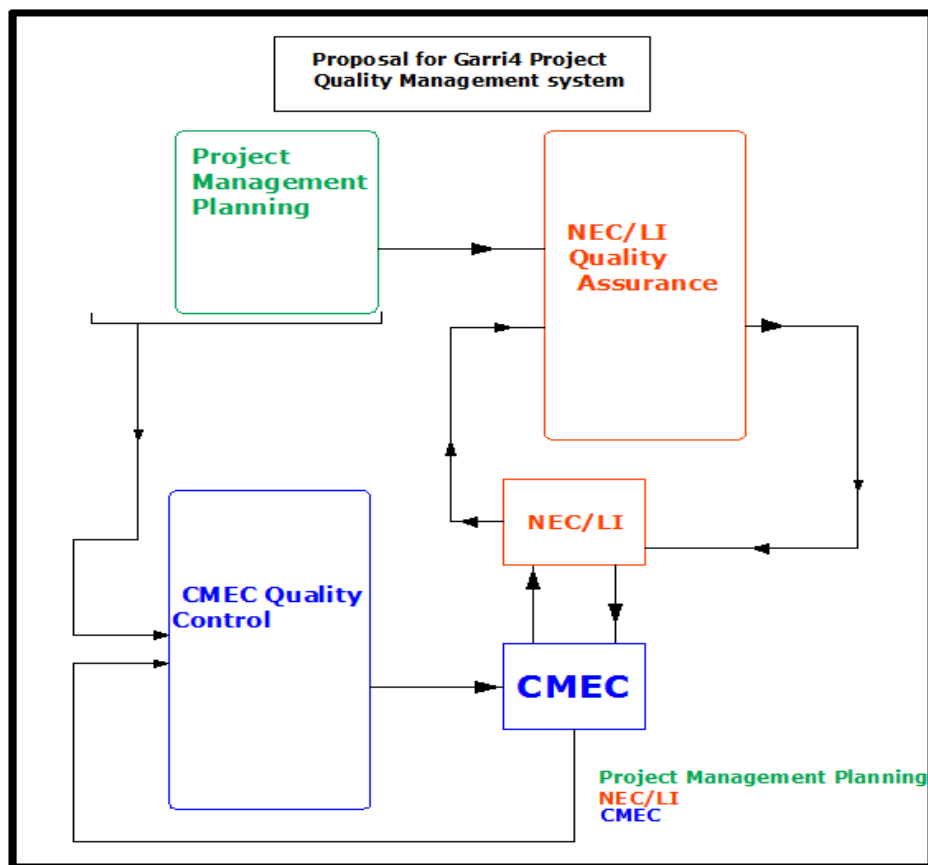

Figure (1). The summarized Garri4 QMS flowchart

In the above figure, the QMS divided into th

4- Project management planning: which consists of the whole project planning process, including the Quality planning, as there is no predefined QMS planning in hands, we should consider the inputs and the outputs to be used in our QA work.

5- CMEC QC: as CMEC represents the main project contractor, they are responsible for all QC job, including inspections, corrective actions, defect repair, implementing design change, the whole construction and erection job, and so on; here we are concerning with the QC outputs to be used in our QA work.

6- NEC/LI represent the Client/Consultant part, the main job here is the supervision work and Quality assurance according to the contractual requirements, this includes assuring the completion of the whole project scope and assuring quality that matching the contractual requirements, this can be done using various methods like auditing, and analyzing QC results, and so on.

2-2 The summarized QMS processes flowchart:

- CMEC should send all the QC results, all the requested corrective actions reports, all change requests, all defect repairs reports, procedures, and so on, before reasonable time to NEC/LI.

- NEC/LI should check all these documents received from CMEC and assign each document to the relevant loop, they should check the conformity to standards and contractual requirements, they should inspect the QC results, and they should carry out the appropriate auditing process, this audit and evaluation process is an expert judgement, which includes certified knowledge and experience.

- NEC/LI should report to CMEC any defect detected in project site and state the corrective actions required, also NEC/LI should consider the commercial issues followed by mismatching contractual requirements by the contractor, or as an impact of design modifications.

- CMEC should send back a report about any requested action from NEC/LI, also CMEC is requested to send their inspection schedule and procedures in advance to allow enough time for NEC/LI preparing for it.

- Every step/loop should be documented; this issue is explained in Chapter 3.

- QC/QA results should be analyzed periodically, an explanation about that is given in Chapter 3.
- NEC staff should be given scheduled certified QA training opportunities, so as to do the auditing/evaluation/supervision job efficiently. Attached a list of certified training required.

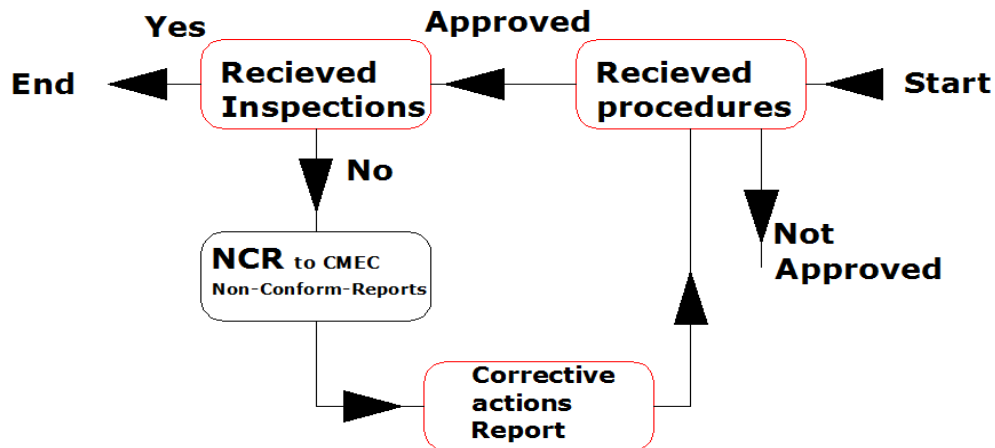# Chapter 3

QMS Work Loops and Documentation Systems

Contents

Chapter 3

QMS Work Loops and Documentation Systems

3-1 Inspection work loop and documentation system (Red files from CMEC):

Fig(1). Inspection Work Loop and Documentation System

5- Inspection procedures received from CMEC must be checked for approval, the approved procedures should be kept in (**Approved Procedures**) file, if not approved, then it should be returned back to CMEC with clarifications.

6- After CMEC ran an inspection which should be witnessed by NEC/LI, the inspection form/test result/film should be sent to NEC/LI, after the proper check according to the requirements if it is matching then the job is over and should be kept in (**Received Inspection**) file, the same file can be divided into finished inspection work /pending inspection work.

7- If the inspection result is not matching requirements, a NCR (Non-Conform-Report) should be sent to CMEC cited by the inspection form/results. A copy should be kept in (**NCR**) file.

8- The corrective actions which would be done by CMEC accordingly should be kept in (**Corrective Actions Report**) file, and then the loop continues again to procedures and re-inspection.

So, Inspection work has the above four files.

The following Excel file should be completed whenever a new action carried out, then it should be printed weekly or as it needs to be discussed in the meetings with CMEC

so as to handle the crucial items, and also this excel file provides analytical tools to evaluate the whole inspection process, how many items re-inspected, and the other relevant information. The excel file should looks like this:

No.	Inspection no.	Description	Result (and why)	No.	Corrective Action report no.	Remark
1-	B23 (an example)	RT-Economizer	conform	-	-	-
2-	B27	UT-CHMNY	NCR, crack 2mm found	NC3	CMEC34	Re-inspect

3-2 Erection Defects loop and documentation system:
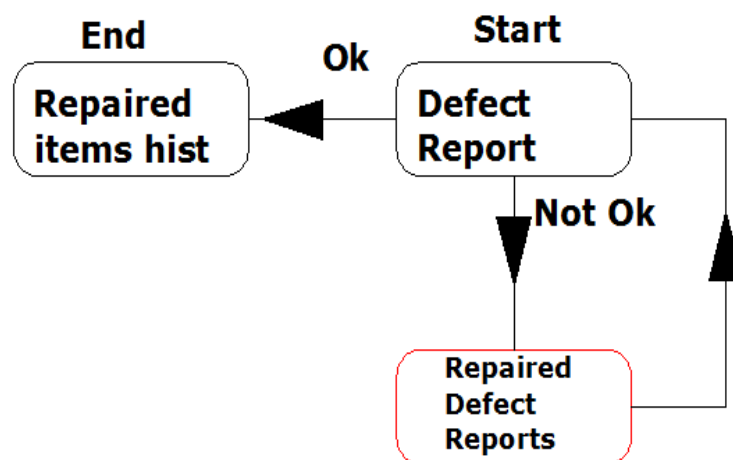
Fig(2). Erection Defects Loop and Documentation System

1- Defects which detected during erection work as site notes should be reported as a defect report including defect type, location, photograph, and the required actions to repair this defect, it should be sent to CMEC and a copy should be kept in (**Defect Report**) file.

2- CMEC should repair this defect accordingly and should send to NEC/LI a report which should be kept into (**Repaired Defect Reports**) file.

3- If NEC/LI accepted the repair work, that Defect Report should be moved from Defect report file to (**Repaired Items history**) file.

4- If NEC/LI do not accept the report, another Defect Report should be sent to CMEC and the loop continues.

So, Erection defects work has the above three files.

The following Excel file should be completed whenever a new action carried out, then it should be printed weekly or as it needs to be discussed in the meetings with CMEC so as to handle the crucial items, and also this excel file provides analytical tools to evaluate the whole erection defects process, how many items repaired, how many defects took place in a specific location, and the other relevant information. The excel file should looks like this:

No.	Defect no.	Description	Repaired defect report no.	Result	Repaired items history no.
1-	B23 (an example)	Economizer tubes, not covered	CMEC45	Tubes are now covered	B23 (the same report moved)
2-	B27	CHMNY, 4mm crack	CMEC 47	Crack still exist	-

The above excel data can be filtered for specific location; a date column should be added.

3-3 Design Modifications (Change Requests) loop and documentation system:
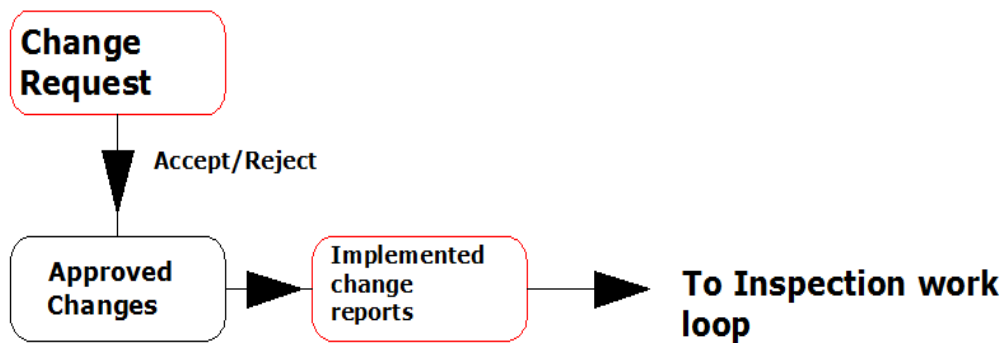
Fig(3).Design modifications Loop and Documentation System

1- When CMEC requests a design change/modification, they should send a change request to NEC/LI, and this request should be kept in (**Change Request**) file.

2- NEC/LI will check the importance, implications, and all financial and technical impacts of this change, and then if they accept it, they would send the Approved Change together with the calculated commercial impact as a notice to CMEC, a copy should be kept in (**Approved Changes**) file.

3- Once CMEC implemented this change, they should send back an Implemented Change Report to NEC/LI, and should be kept in (**Implemented Change Report**) file.

4- After the implementation finished, this loop will interact with Inspection Work loop to inspect and evaluate the change implementation.

So, Design Modification work has three files as mentioned above.

The following Excel file should be completed whenever a new action carried out, then it should be printed whenever a Project Management meeting is held or as it needs to be discussed in the meetings with CMEC so as to handle the crucial items, and also this excel file provides analytical tools to evaluate the whole Design Modification process, commercial items generated, and the other relevant information. The excel file should looks like this:

No.	Change Request no.	Description	Approved Change no.	Remarks	Implemented change report no.
1-	CMEC29 (an example)	Demin hoist	AC23	No commercial	CMEC34
2-	CMEC43	CHM matrial	AC24	COM24	CMEC36

3-4 Inspection Devices Folder:
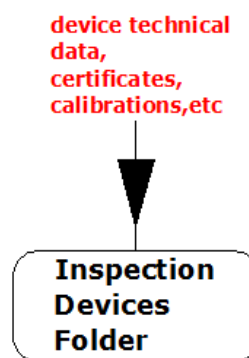
Fig(4).Inspection Devices Folder and Documentation System

For each inspection device used in the project, CMEC requested to submit the relevant technical data together with the proper calibration tests and certifications, all these data should be kept into (**Inspection Devices Folder**).

Also, a suitable excel file should be created for these inspection tools.

3-5 Equipment and Materials loop and documentation system:
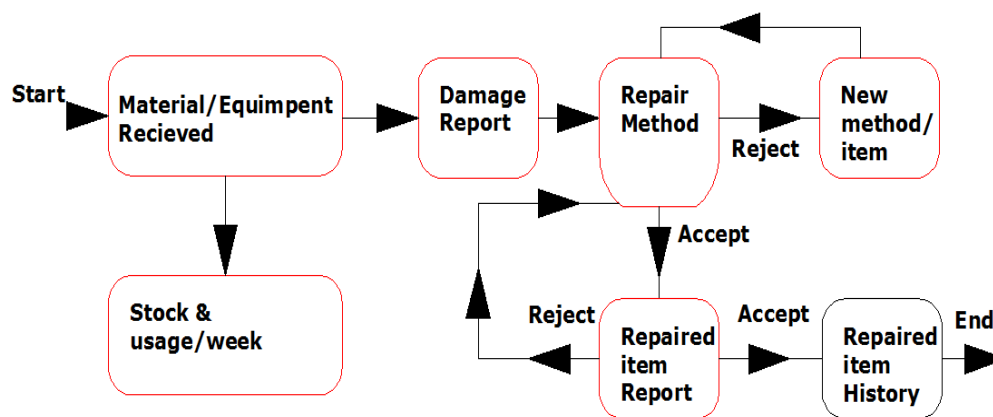
Fig(5). Equipments and Materials Documentation System

Each department should state the critical equipment/material and then each department should ask CMEC to provide a weekly report about the status.

1- All critical material/equipments received together with their relevant certificates and workshop test result should be kept into (**Material/Equipments**) file.

2- A weekly report about these critical material/equipments stock and usage statistics should be provided by CMEC during the weekly meeting, and this statistical report should be kept in (**Stock & Usage**) file, this statistical information needed to have a full awareness about material status and quantity during erection.

3- If any material/equipment damaged during transportation or in site, then a damage report should be submitted by CMEC and NEC/LI could notify CMEC about the damage so they could submit the report, all damage reports should be kept in the (**Damage Report**) file.

4- Next step, CMEC should send the Repair Method from the manufacturer, and it should be kept in (**Repair Method**) file.

5- If NEC/LI accepted the method, then CMEC should perform the repair job, and send NEC/LI Repaired Item Report, and it should be kept in (**Repaired Item Report**) file.

6- If NEC/LI rejected the method, then CMEC should send a new method or a new item as requested by CMEC, these documents should be kept in (**New Method/Item**) file.

7- If the performed repair job according to repaired item report accepted, then the repaired item should be documented into (**Repaired Items History**) file.

8- If the performed repair rejected, then a new method should be submitted.

So, we have the above seven folders in Material/Equipments loop.

The following Excel file should be completed whenever a new action carried out in Damage loop, then it should be printed weekly or as it needs to be discussed in the meetings with CMEC so as to handle the crucial items, and also this excel file provides analytical tools to evaluate the whole Damaged items process, and the other relevant information. The excel file should be looks like this:

No.	Damage Report no.	Description	Repair method no.	status	Repaired item report no.	Remark
1-	D23	2nd boiler Economizer Tubes broken	RM32	accepted	R34	Accepted .Moved to history
2-	D27	Pressure gauge, demin, not working	RM43	Rejected	-	New method/item requested

3-6 Daily Work follow-up:

There should be an excel file for each department about their daily activities, in the site or in the office, and it should be accessible for read only by other departments, it is simply describing the activities of each day and comments about theses activities, so everything done is completely documented, in attachment 3 you can see a sample daily work report form.

3-7 Commissioning loop and documentation system:

This loop should be constructed later and attached to the QMS guide to be implemented.

3-8 Analytical reports samples:

Here is one example for analytical reports, defect repaired:

In defect repaired job, you may need to know the occurrence of defects in a specific location, during a specific time span, you should filter these data in the excel file, then you can do a quick statistics, say the whole defects in the boiler from October 2007 to march 2008 are as the following:
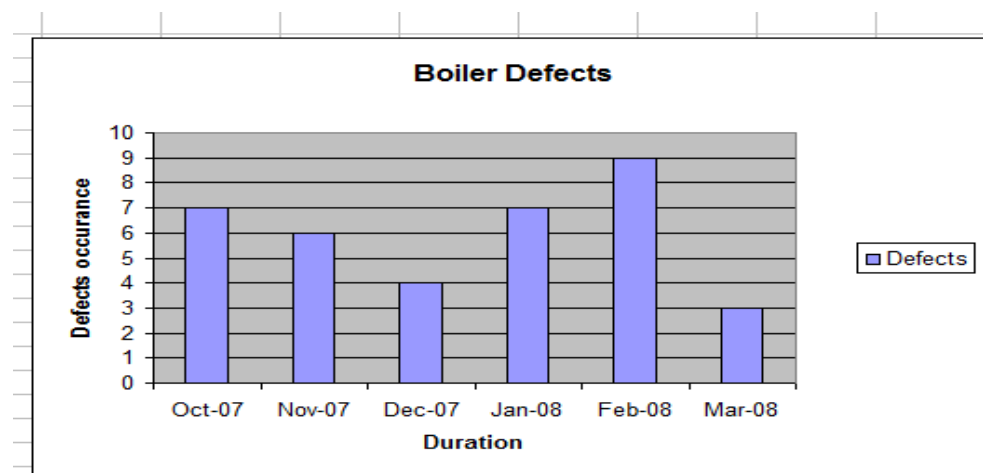
Figure (6). A sample defect graph

According to the above chart, February 08 represent the highest defect occurrence during the last six months, we should find out why that happened, may be you have to revise the details of February 08 defects details, and may be you need to compare with either January 08, then a recommendation for preventive action may be considered, such as welder errors, using the wrong material, and so on.

There are many other forms of reports and methods, and depends on the situation, type of report, and the knowledge and experience of the person carrying out the job. You

may need to know the accumulated defects for the whole project for the last year, or you may need to find out number of re-inspection work, and so on.

Attachment 1

Sample of a daily activity form:

Item No	Date	description	photos	comments	status
Demine water plant					
1	19.03.08	Installation of measuring equipments in demine plant		1. The manufacturer documents for these instruments are missing	
2	19.03.08	Installation of valve control box in demine plant		2. No drawing was submitted for theses cubicles 3. Relays are installed upside down	
3	19.03.08	Instrument air connection to pneumatic valves		4. The material of pipe is??	

Attachment 2

International Training and Certifications Requirements for Project Engineers

(1) Vibration and Alignment training and certifications:
ISO (ISO 18436.2 standard) and ASNT (SNT-TC-1A) Certification

Prerequisites
There are prerequisites for each certification level. It is undesirable for people without practical experience to hold Category II or higher certification levels.

Level	Number of months of practical experience
Category I	2
Category II	12
Category III	36
Category IV	60

Period of Validity: 5 years.
Web page: www.mobiusinstitute.com/

This training and certifications can be requested through these branches:

1- South Korea: InFaith Co. Ltd
Address
673 City of Angel 1st BD.,
161 Kumgogdong, Bundanggu,
Seongnam City, 463-805 Kyonggido
South KOREA

Contact:
+82-(0)31-726-1672
JT Jeong
jt@reliability.co.kr
Mobile: +82-(0)11-9003-1672
Web site URL: www.Reliability.co.kr
Instructors:
Jeong Ju Taek/President
Lee Seung Won /Technical Director

2- Egypt: NATCOM
Contact
Khairy A. Arsanios
Managing Director
NATCOM

Tel: 00 2 (02) 271 8132 / 272 9658 / 272 9659
Fax: 00 2 02 271 8173
Cell: 00 2 012 217 0295
Email: Khairy.Arsanios@NatcomEgypt.com
Website: www.NatcomEgypt.com

(2) NDT training and Certifications:

ACCP and ASNT certifications

ASNT (**A**merican **S**ociety For **N**on-Destructive **T**esting)
ACCP (**A**SNT **C**entral **C**ertification **P**rogram)

Authorized training and examination centres:

(1) South Korea:

The Korean Society for Nondestructive Testing
KSNT
KID Bldg. 1473-10, Seocho-3dong, Seocho-ku,
Seoul, 137-868, Korea

Contact: Hong Joo Chung
Phone: +82-2-583-7564
Fax: +82-2-582-2743
E-mail: ksnt@unitel.co.kr

(2) Egypt:
Quality Control Co.

QCCO
3 Nablous St.
Mohandsein, Cairo
Egypt

Contact: Mohsen Hassanein
Phone: +202 33456809
Fax: +202 33456037
Cell phone: +(2) 010 900 60 40
E-mail: info@qualitycontrol-egypt.com or
mohsen.hassanein@qualitycontrol-egypt.com
Web: www.qualitycontrol-egypt.com

(3) UAE United Arab Emirates:

United Arab Emirates Section, an ASNT Local Section
Manager / Plant Integrity
TUV Middle East
P.O. Box 46030
Abu Dhabi, UAE

Contact: S. Madhavan
Phones: +971 50 6682184   or
+971 2 4478500
Fax: +971 2 4478600
Emails: smadhavan@tuvme.com or
smadhavan@tuv.ae

APPENDIX B

The questionnaire

Blekinge Tekniska Hogskola (BTH)
School of Management
MBA Program
Sweden

This is a questionnaire to Garri4 power plant project staff, National Electricity Corporation, Sudan. The purpose is to assess their (QMS) Quality Management System effectiveness, as a requirement for the researcher's thesis completion purpose.

Please complete the questionnaire by the following:

1- Put sign (√) in front of your answer, selecting the suitable option to you on the **Personal Information** Part
2- When your answer is (**others**), then please specify in the given space
3- Put sign (√) in front of your answer, whether (**Yes**) or (**No**)
4- Rank the **QMS Objectives** according to your preference, giving the most important one to you highest rank, and so on. Use the range (0-9).
5- Rank the **QMS Requirements** according to your preference, giving the most important one to you highest rank, and so on. Use the range (0-10).
6- Please specify the **Successful QMS implementation target percentage** as you believe. You will find it at the end of the questionnaire

Part-1: Personal Information

Total experience (years)	Power plant projects experience	Qualifications	Professional certifications	Quality training	Project management training
0-2 ( )	0-2 ( )	Bsc ( )	1- technical ( )	Yes( )	Yes( )
2-5 ( )	2-5 ( )	Msc ( )	2- management( )		
5-10 ( )	5-10 ( )	PhD ( )	3- others:-	No ( )	No ( )
More than 10 ( )	More than 10 ( )	MBA ( )			
		Others:-			

Part-2: QMS Objectives and Requirements

Quality Objectives:- **Do you think the following quality objectives have been achieved?**	**Put (√) sign in the preferable answer**	**Rank** **From 0 to 9**
1- Supporting the top project management with adequate reports	Yes ( ) No ( )	---------------
2- involvement of every engineer in quality activities	Yes ( ) No ( )	---------------
3- The Project meets it's contractual quality requirements	Yes ( ) No ( )	---------------

4-	Good documentation control	Yes ( )	No ( )	--------------
5-	Good communication with the contractor	Yes ( )	No ( )	--------------
6-	Good cooperation between different client's departments	Yes ( )	No ( )	--------------
7-	Improve qualifications through learning and training	Yes ( )	No ( )	--------------
8-	This Project can be an excellent case study (Benchmark) for future projects	Yes ( )	No ( )	--------------
9-	Linking project activities systematically to be understood (the sequences to do every job are clear and understood)	Yes ( )	No ( )	--------------

Quality Requirements:-
Do you think the following quality requirements have been achieved?

1-	Safety guidance implementation	Yes ( )	No ( )	--------------
2-	Good understanding of the QMS principles	Yes ( )	No ( )	--------------
3-	Establishing proper documentation system	Yes ( )	No ( )	--------------
4-	Determining quality objectives	Yes ( )	No ( )	--------------
5-	Following the loop of each QMS process	Yes ( )	No ( )	--------------
6-	Following ISO 9001:2000 guidance	Yes ( )	No ( )	--------------
7-	Availability of activities and tests schedule in advance	Yes ( )	No ( )	--------------
8-	Proper Computer database for all activities	Yes ( )	No ( )	--------------
9-	Availability of all quality related documents (Scope, Standards, contract documents…etc)	Yes ( )	No ( )	--------------
10-	Clear job definition	Yes ( )	No ( )	--------------

Part-3: Please specify in percentage (for example 60%), to what extent do you think the QMS should be effective on meeting its requirements and objectives?

Please Specify: -------------

Thank You Very Much For Your Valuable Participation

APPENDIX C

Questionnaire data and Matrix model results

1- Questionnaire data before QMS implementation

No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Yes	11	8	9	8	8	17	11	11	8	12	11	9	12	5	9	9	8	13	11
No	8	11	10	11	11	2	7	7	10	7	8	10	7	14	10	9	11	6	8
Mode	7	0	9	6	3	4	7	1	9	0	6	7	10	2	1	0	4	0	10
Mean	5.4	5	5	6.5	5	4.6	5.6	3.1	4.2	5	5	5.3	5.4	4	4	5.2	4	5.5	5
Percent	58	42	47	42	42	89.5	57.9	58	42	63	58	47	63	26	47	47.4	42.1	68	58

L values from the questionnaire

85	50	70	80	70	70	60	65	50	80	70	50	60	70	50	35	80	60	35

Mode 62.6
Mean 70

Matrix of objectives

No.	Yes	No	W	i1	i2	S1	S2
1-	11	8	58	7	5.4	405	313
2-	8	11	42	0	5	0	211
3-	9	10	47	9	5.4	426	256
4-	8	11	42	6	6.5	253	274
5-	8	11	42	3	5	126	211
6-	17	2	89	4	4.6	358	412
7-	11	7	58	7	5.6	405	324
8-	11	7	58	1	3.1	57.9	179
9-	8	10	42	9	4.2	379	177
FQS=						2411	2355
FQL=						3220	2806

so, FQL>FQS

Matrix of requirements

No.	Yes	No	W	i1	i2	S1	S2
1-	12	7	63		5	0	335
2-	11	8	58	6	5	347	289
3-	9	10	47	7	5	332	251
4-	12	7	63	10	5	632	341
5-	5	14	26	2	4	52.6	97.4
6-	9	10	47	1	4	47.4	166
7-	9	9	47	0	5	0	246
8-	8	11	42	4	4	168	168
9-	13	6	68	0	6	0	376
10-	11	8	58	10	5	579	289
FQS=						2158	2560
FQL=						2800	3000

FQL>FQS

No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
yes	7	6	5	5	7	12	10	9	5	7	7	9	11	6	4	7	4	10	8
no	8	9	10	10	8	3	5	6	10	8	8	6	4	9	11	8	11	5	7
manual	4	7	9	8	7	1	6	1	6	5	6	6	7	4	1	8	6	6	7
mutawas	4.1	5	6	6.1	5.8	5.13	5.19	3.8	4.9	5	4.8	6.1	6.6	6	5	6.69	5.19	5.1	5.1
percent	44	38	31	31	44	75	62.5	56	31	44	44	56	69	38	25	43.8	25	63	50

Matrix of objectives

No.	Yes	No	W	i1	i2	S1	S2
1-	7	9	44	4	4.1	175	181
2-	6	10	38	7	5.3	263	199
3-	5	11	31	9	6.4	281	199
4-	5	11	31	8	6.1	250	191
5-	7	9	44	7	5.8	306	254
6-	12	4	75	1	5.1	75	383
7-	10	6	63	6	5.2	375	325
8-	9	7	56	1	3.8	56.3	211
9-	5	11	31	6	4.9	188	153
FQS=						1969	2095
FQL=						2411	2355

so, FQL>FQS

Matrix of requirements

No.	Yes	No	W	i1	i2	S1	S2
1-	7	9	44	5	5	219	203
2-	7	9	44	6	5	263	208
3-	9	7	56	6	6	338	345
4-	11	5	69	7	7	481	451
5-	6	10	38	4	6	150	213
6-	4	12	25	1	5	25	128
7-	7	9	44	8	7	350	293
8-	4	12	25	6	5	150	130
9-	10	6	63	6	5	375	321
10-	8	8	50	7	5	350	257
FQS						2700	2547
FQL=						2157	2560

FQL<FQS