Quality Management Activities in Design And Construction Phases in Saudi Arabia

by

Ahmad Abdulaziz Al-Abdulrazzak

A Thesis Presented to the

FACULTY OF THE COLLEGE OF GRADUATE STUDIES

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This thesis, written by **AHMAD ABDULAZIZ AL-ABDUL RAZZAK**, under the direction of his Thesis Committee, and approved by all the membrs, has been presented to and accepted by the Dean, College of Graduate Studies, in partial fulfillment of the requirements for the Degree of **MASTER OF SCIENCE IN CONSTRUCTION ENGINEERING AND MANAGEMENT.**

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I dedicate this work to my beloved parents

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خلاصة الرسالة

اسم الطالب الكامل : احمد عبد العزيز احمد العبد الرزاق

عنوان الدراسة : نشاطات الادارة لضمان الجودة فى مراحل التصميم و الانشاء فى المملكة العربية السعودية
التخصص : هندسة و ادارة التشييد
تاريخ الشهادة : ٣٠ ذو الحجة ١٤١٣ هجرى

ان صناعة التشييد فى المملكة العربية السعودية تواجة تحديا خطيرا لتطوير الاداء, و ان ضمان الجودة فى مراحل التصميم و الانشاء هو من الامور الهامة فى صناعة التشييد .

ما هى نشاطات الادارة و التى يمكن استخدامها فى مراحل التصميم و الانشاء لضمان الجودة فى تلك المراحل? ان الهدف الرئيسى من هذة الدراسة هو تحديد نشاطات الادارة المستخدمة فى مراحل التصميم والانشاء فى المملكة العربية السعودية .

تم تحديد نشاطات الادارة من خلال الاستبيان الذى ارسل للمكاتب الاستشارية و المقاولين . و قد حللت المعلومات احصائيا ببرنامج ساس (SAS) .

و تبين من خلال البحث بان مراجعة المخططات و التدقيق على المواصفات هو من اهم النشاطات المستخدمة من قبل المكاتب الاستشارية, بينما الاهتمام بتدريب عناصر المكتب كان من اقل هذة النشاطات اهمية. و تبين كذلك بان تقييم مقاولى الباطن و فحص المواد من اهم النشاطات المستخدمة من قبل المقاولين و ان الاهتمام بتدريب و تعليم عناصر المقاول هو من اقلها اهمية.

تمت التوصية بضرورة استخدام نشاطات الادارة فى مجال مراقبة الجودة و ضمانها و ذلك من قبل المكاتب الاستشارية و المقاولين لضمان جودة المشاريع المنفذة.

درجة الماجستير فى العلوم
هندسة و ادارة التشييد
جامعة الملك فهد للبترول و المعادن
الظهران / المملكة العربية السعودية

THESIS ABSTRACT

NAME OF STUDENT: AHMAD ABDULAZIZ AHMAD AL-ABDUL RAZZAK

TITLE OF STUDY: QUALITY MANAGEMENT ACTIVITIES IN DESIGN AND CONSTRUCTION PHASES IN SAUDI ARABIA

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The construction industry in the Kingdom of Saudi Arabia, like that in any other country, faces the serious challenge of improving its performance. Quality of design and construction are primary objectives in the construction industry.

What are the Quality Management (QM) activities in the design and construction phases? The main objective of this study is to determine QM activities used in the design and construction phases of constructed projects in Saudi Arabia.

Questionnaires were mailed to consulting offices and contractors. Their responses were analyzed and ranking of QM activities, frequencies, step-wise regression, and Regression Analysis were presented.

The results show that QM activities such as drawing checks and provision of clear, concise and uniform plans and specifications are the most important for consulting offices, while education of employees is the least important. Subcontractor evaluation and lab tests of materials are the most important for contractors, while education of employees is the least important.

It is recommended that consulting offices and contractors consider the quality management activities to assure quality in the constructed projects.

MASTER OF SCIENCE DEGREE

KING FAHD UNIVERSITY OF PETROLEUM & MINERALS

DHAHRAN, SAUDI ARABIA

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CHAPTER I

INTRODUCTION

Quality of design and construction are primary considerations in construction industry. Quality is defined as conformance to requirements, and it can be characterized as meeting the requirements of the owner, design professional, contractor, and regulatory agencies (ASCE 1990). Fisher (1986) summarizes the opinions of the world quality leaders about the concept of quality costs. Crossby (1979) stated: "quality is free - lack of quality costs money". Deming (1986) stated: "quality control eventually leads to substantial cost cuts. However, short term cost cuts can allow quality and reliability to be diminished"(Davis 1987). Juran(1974) stated: "quality of conformance costs money but is repaid through improved market standing." Quality costs do not include the cost of doing things correctly. They consist of quality management costs and deviation costs. Deviation costs are those costs associated with departures from the requirements, and include rework, impact, litigation and warranty costs. Quality management and deviation costs are additive and the goal is to minimize the total (Davis 1987).

The problem of the quality of design and construction is a topic of current concern, but it is not a new topic. Nearly two decades ago, Abdun-Nur stated (Davis 1987): "compared with industrial operations, quality is most crudely controlled in construction, production is less predictable, waste is very high (some of it inherent, but not all), labor costs have advanced more, and productivity has increased very little since the

initial mechanization of two or three decades ago."

Fundamental problems are the reliable determination of the costs associated with poor quality as well as the proper evaluation of the efficiency of construction quality management efforts. In the National Conference "Quality Assurance in the Building Community" (Trainor 1983), the costs due to poor quality in engineered construction have been estimated to be at least 7.5% of total costs.

Quality costs consist of quality management costs and deviation costs. To track the cost of quality, quality management activities and deviations must be first defined and then arranged and coded in such a way as to track the quality costs. This study will define the involvement of design professionals and contractors in quality management activities in design and construction phases in Saudi Arabia.

1.1 Significance of the Study

The development and acceptability of quality management programs can be greatly enhanced by a standard system to evaluate them. The determination of the actual cost of poor quality of construction is also of great interest.

Quality costs consist of quality management costs and deviation costs. Determining the quality management activities of the design and construction phases of the Saudi construction industry is very important. These activities can be rearranged and coded in such a way as to track quality management costs which are a part of the total costs of quality. These costs are additive and the goal is to minimize the total. A quality performance tracking system (QPTS) can be used to track quality costs in the design and construction phases of a project.

1.2 Statement of the Problem

The construction industry in the Kingdom of Saudi Arabia like that of any other country faces the serious challenge of improving its performance. Though there are many construction projects, the current level of performance is not encouraging. There are several indications of problems within the industry. Delays in construction are expensive. There has been no precise definition of the cost of poor quality and no attempt to measure it as it occurs. Delay costs and quality related costs are two major factors contributing to the high costs in construction industry. Several studies addressed the delay problems in Saudi Arabia (Al-Sultan 1989).In addition,there are several clauses in government regulations which

address the penalties of delays.However,the cost of quality in Saudi Arabia is very high. This is evident from the rapid deterioration of the newly built construction projects, and the amount of money allocated for maintenance.There has been no study which quantify the cost of quality in construction in Saudi Arabia.

Numerous writers in the United States have promoted the benefits of measuring quality related costs in manufacturing design and production (Schrder 1986), but there is no indication that the concept has been applied intensively to the construction industry.

Construction and its support industries are extremely important. Their vitality has a major effect on the Saudi economy. Quality commitment by top management is essential for success. It is obvious that the firm characteristics contribute to the level of quality. Improved quality management of design and construction has the potential to reduce the life cycle costs of construction projects.

1.3 Objectives

The main objectives of this study can be summarized as follows:

1. Determination of quality management activities in the design phase of the Saudi construction industry.
2. Determination of quality management activities in the construction phase of the Saudi construction industry.
3. Correlation between the firm's characteristics and quality management activities used by the firm.

1.4 Scope and Limitations

This study is limited to large building contractors and consulting offices in Saudi Arabia . Grade 1, 2, and 3 contractors are in the study. The Ministry of Housing and Public Work (MOH & PW) classification is used in this regard. The consulting offices are as classified by the Chamber of Commerce.

Large contractors are more likely to be concerned about the issues of quality and more likely to establish quality improvement programs. There are other reasons for dealing with large contractors. For example, large contractors mean larger projects, which means higher potential for quality improvement. Considering the above mentioned fact, this study is limited to defining quality management activities in the design and construction phases for large contractors and consulting offices in Saudi Arabia.

CHAPTER 2

LITERATURE REVIEW

An overview of the literature can lead to the conclusion that there is little written about quality management activities in the design and construction phases of construction projects. This chapter summarizes the literature related to the quality management activities in the design and construction phases of construction projects.

2.1 Quality of Design and Construction

Regarding the definition of quality, four meanings are given in Webster's New World Dictionary (Guralnik 1984). Two of these meanings consider quality as a synonym for characteristic or basic nature. The other two meanings refer to the degree of goodness. Quality may be used in all of the above meanings in reference to design and construction by public and practitioners also. The American Society for Quality Control (ASQC) has presented a more technical meaning for quality (Freund 1985): "The totality of features and characteristics of a product or service that bears on its ability to satisfy a given need."

It is a common complaint that quality in a service industry is much harder to define and control than in a manufacturing industry (Saarinen 1990). In manufacturing, the final products are tangible, with measurable specifications, and they are produced through the same production process. Crossby (1979) stated that quality in service industries is the same as in manufacturing, "conformance to requirements." In his view, there is no

room for non-conformance. The performance standard is zero defects, and this standard is achieved by "doing it right the first time." The latest Manual of Professional Practice for Quality in the Constructed Project, published by the American Society of Civil Engineers (ASCE 1990), has adopted the definition of quality as "conformance to predetermined requirements."

Davis (1987) stated that defining quality as "conformance to requirements" has two major effects. First, it requires the establishment and communication of the requirements. For design, functional requirements are set by the owner. Formulation and communication of these requirements at this stage is not easily done and can be a source of problems as Tatum (1985) stated. Emphasis in this definition is on communication between the design office and the owner. In construction , the requirements must be clearly stated in the contract documents , like the drawings and specifications, and that is done by the design team. The other effect of using the above definition is that the presence or absence of quality becomes measurable provided that all the requirements are completely specified. If the requirements are met, quality has been achieved; otherwise, it has not. According to Davis (1987), the advantage of making the achievement of quality measurable is that it can be studied in terms of costs.

Even among quality professionals, the definition of quality is not static. There is a strong tendency to broaden its meaning beyond quality of design and conformance. The term "quality of maintenance," an application of quality to life cycle costs, has been introduced (Stalcup 1985). Mayo (1986) wrote: "Quality is more than a set of procedures. It is

also an attitude - a broad positive way of approaching tasks." According to Sullivan (1986), this concept goes beyond the concepts of quality of products and services to include such things as the quality of human behavior and the quality of the national economy.

For the purposes of this thesis, the definition of quality for the design and construction is that adopted by the "Construction Industry Institute" (CII 1989) : "Quality is conformance to the established requirements."

2.2 Definition of Quality Related Terms

In the literature, there are at least five expressions which appear to be used interchangeably. These are: quality assurance, quality control , quality program, quality management, and quality system. Quality assurance is sometimes used to refer to the overall set of quality activities (ACI Committee 1985). Quality control has been used as a comprehensive term encompassing the whole range of quality activities dealing with design (ACI Committee 1985). This use is also clear in the titles of books (Juran 1974), which deal with a broad range of quality activities, not just quality control . According to Johnstone (1985), quality assurance and quality control may be considered separate sub-elements of quality management . One distinction that may be made between quality assurance and quality control is that quality assurance is a function of the owner, while quality control is a function of the contractor (Ledbetter 1985). A quality program may refer to a set of documents (Ledbetter 1985).

2.3 Design Quality Management Activities

Designers have a responsibility to the public and to their clients as well as to the contractor. The public and the owner impose requirements to be met. The contractor relies on the designer to communicate the requirements through the contract documents. The minimum requirements for the public are found in codes and standards adopted as statutes by governing authorities. Failure to meet such requirements can result in various penalties imposed through the legal system (Davis 1987). Establishment of the written requirements is a critical step in the design process. A good design must satisfy the requirements set by the owner and the public. Problems in design quality can be seen in design related failures like reducing the life span of a project and increasing the cost of maintenance, etc. Other evidence of design quality problems occurs during construction when errors, omissions and ambiguities in plans and specifications become evident. According to Diekmann (1985), the control and documentation of changes are major undertakings which cause expensive delays in project completion. Such delays may lead to claims between the owner and contractor. Diekmann (1985) stated that poor quality design may expose the designer to suit by a wide variety of claimants including the contractor and the public also.

Design firms use quality management techniques of varying sophistication. Many of them, however, do not call such practices quality management. They consider them as integral part of design. Saarinen (1990) says that in consulting engineering, quality management is an on-going process of:

- Establishing requirements (e.g., the project's scope of work,

policies and procedures for billing and accounting, performance standards for business development).

- Communicating those requirements to all members of the project team.

- Providing the proper leadership, staff, tools, and environment for meeting the requirements.

- Checking to see that the requirements are met.

In fact, these activities are considered as part of Total Quality Management (TQM) (Burati 1991).

According to Muller (1984), there has been some resistance to the application of quality management programs to the design phase.

This section discusses the quality management activities, searched from the literature, which can be used to assure quality in the design phase of a constructed project. Appendix (IX) shows the arrangement of quality management activities as discussed in the following paragraphs of this section.

2.3.1 Establishment of Quality Program Management

Definition of the interrelationship and responsibilities of the quality program management, and personnel qualification are important issues in assuring quality in the design phase. The design firm should clearly define management policies, objectives, and responsibilities for each unit of the organization. The responsibility and authority for quality of those involved in the design (managing and directing the design) should be

defined and their interrelationship shown on organization charts. According to ASCE Quality Manual (1990), the consultant's management should periodically review the status and adequacy of the quality program and should appoint a representative to ensure that quality program requirements are complied with. The management should define quality program representatives authority to resolve quality matters. According to the quality system of VBB Viak's consulting firm (1991), every employee is responsible for his part of the overall quality. The head of each division is responsible for the division's quality management. Within every division, there is a quality group consisting of the division's representative on the quality advice panel, and the quality manager and with one person responsible for quality in each region and within the division. The task leader bears the ultimate responsibility for planning, conducting and documenting quality assurance within the task. The chairman of VBB Viak's quality advice panel is responsible for assuring that a satisfactory quality system is fully maintained. He is also responsible for assuring that the quality managers carry out quality audits within their respective divisions. At least once a year, the quality manager shall arrange a review of how the company's quality assurance system has functioned within the division during the past year. The result of the reviews shall be documented and made known to those responsible within the area subject to review and the quality advice panel. The management responsible for the area subject to review shall take suitable measures to correct those deficiencies exposed by the review. According to their quality system, quality is a concept that depends upon each individual consultant's ability to identify and discuss the client's requirements and at the same time to act professionally both as a technical specialist and in his role as a

consultant. It is, therefore, the duty of every staff member to see that the guidelines in the quality system are followed in the daily work.

2.3.2 Documentation

Control of documents is very important to the design offices since it is concerned with precision and accuracy of review as well as issuance and revision of all documents related to the design. Documents should be approved by personnel having high experience in the affected work activity. He should make sure that all essential documents affecting quality are reviewed for adequacy and approved for release by authorized personnel. Changes to documents should be subject to the same degree of control used in performing the original documents. According to the ASCE Quality Manual (1990), the authorized personnel for documentation should maintain a record of changes as they are made and that documents should be revised after a practical number of changes have been issued.

2.3.3 Education of Firm's Employees

Training for a firm's employees is an important step in assuring quality in the design. Training might be through short courses, seminars or on-the-job training. The VBB VIAK consulting firm has established policy for staff training. Annual planning dialogues are carried out to survey the individual need for training. A budget and program for carrying out staff training is fixed every year.

2.3.4 Initiation of Communication Program

Saarinen (1990) stated that meeting quality requirements must extend through all levels of the organization because each individual can

have an impact on quality. According to Burgess (1988), the emphasis on assuring the quality of design comes from engineering or project management. Communication among the design team members is a vital element in achieving quality in the design phase. Insufficient communication can lead to project failures and problems and to the dissatisfaction of all team members. According to ACI Committee (1985), at least 25 percent of design failures resulted from poor communication or lack of communication between the team members.

2.3.5 Control of Drawings and Specifications

Proper control of drawings and specifications is very important to any project. Burgess (1984) stated that experience shows that the preparation, review, approval and distribution of drawings is generally well controlled, while this is not always the case with specifications since specifications, for unknown reasons, are frequently allowed to become out-dated and do not reflect current practices. Drawing and specifications are the two sets of documents given to the contractor that provide necessary technical information. So, it is critical that drawings and specifications be clear, concise and uniform.

2.3.6 Provision of Technically Qualified Design Team Members

Assuring quality in the design comes also through having a well qualified staff. According to the Manual of Professional Practice, Quality in the Constructed Project (1990), design personnel should be encouraged to participate in continuing education programs and professional groups, since such participation will keep employees current with the latest information on changing aspects of design and analysis methods.

2.3.7 Design Review

Design review is a vital element in assuring quality in the design phase of a construction project. Design might be reviewed by checking of its calculations, space allocation, aesthetics, functionality, capacity, review of client's comments,and by reviewing the standards and regulations used to come up with the design. Burgess (1988) stated that design review is simply a critical but objective review of the design before it is released for construction . It is a good step in assuring quality to expose the design to your experienced personnel to avoid errors and omissions. Studies by Kirby (1983) and Morgren (1986) found that 56% of all contract modifications are to correct design deficiencies like errors, omissions and ambiguities (Davis 1987).

2.3.8 Standardization of Office Procedures and Provision of Office Library Facilities

In order to assure quality in the design phase, office procedures and policies should be standardized in order to establish a common basis for all projects and improve concentration on the owner's requirements for the design and production of the contract documents. A library with available current reference material including codes, standards, catalogues and design manuals is necessary in a design office.

2.3.9 Arrangement for Organizational/Project Peer Reviews

The ASCE Manual "Quality in the Constructed Project" defines peer review as a technique that promotes quality in design organizations and their services. A peer review is the highest level of action to improve quality in design of constructed projects. According to the Manual, peer

reviews can be grouped in several ways. The two most important categories are organizational peer reviews and project peer reviews. Organizational peer reviews consider a design organization as a whole, focussing on its policies, procedures and practices and not on any single project, while project peer reviews consider particular projects, not the organization's practice in general.

2.3.10 Monitoring and Controlling Design, Cost and Schedules

In order to assure quality in the design phase of a project, the design team leader should monitor progress reports, which reflect budgeted versus actual expenditures. The expenditures should represent the work performed. If more time is being spent in developing a certain portion of a project than was budgeted, an explanation must be obtained and corrective action taken. If additional services not contained in the contract are required to meet the overall project requirements, this information should be communicated to the owner immediately. An amendment for the additional work should be negotiated and added to the contract.

A project schedule has a series of milestones and delivery dates for submittals or reports identified in the contract. Adherence to these key dates keeps the project on schedule and provides the owner a means of monitoring progress. It also allows the owner to comment on various aspects of the project as work progresses.

2.3.11 Establishment of an Incentive System

Establishment of an incentive system to motivate persons whose activities affect the quality of work is very important. According to the ASCE Quality Manual (1990), the establishment of an incentive system

will promote quality and increase productivity also.

2.4 Quality Management for the Construction Phase

There are several reasons why quality is not easily achieved during the construction process. In the first place, the requirements of quality as defined are not always adequately described. In fact, designers disclaim the possibility of anticipating and detailing everything in the construction documents. Second, the environment for construction is unstable. The size and complexity of projects vary. Working conditions are somewhat uncontrollable. The labor force is variable; its size, composition, and motivation change. Cooperation between subcontractors is problematic (Davis 1987).

The need to apply special efforts to obtain quality in the construction process is well recognized. Part of the designer's traditional role has been to see that the construction requirements are fulfilled, as means to guarantee quality. This is accomplished through, for example, requiring samples of workmanship, periodic inspections, and materials testing. One of the reasons offered for using a construction management firm is to obtain quality for the owner. While problems associated with quality are not new in the construction industry, formalized approaches to construction quality management are. According to Hartstern (1982), quality control programs evolved out of inspection programs and became formalized in the 1960's as legally imposed requirements by government work.

Quality management is more comprehensive than quality control . According to Crossby (1979): "Quality management is a systematic way of

guaranteeing that organized activities happen the way they are planned. It is a management discipline concerned with preventing problems from occurring by creating the attitudes and controls that make prevention possible." Quality cannot be attained through quality control inspection methods alone. According to Deming, quality comes not from inspection, but from improvement of the process. Saarinen (1990) stated: "Whereas quality control is designed to catch defects, quality management is designed to prevent them." Quality management can be seen as based on four basic principles (Saarinen 1990):

- Total involvement: every level of the firm, from senior management on down, must be involved in quality improvement activities.

- Customer orientation: every one in the firm must understand the requirements of his customers and be conscious of how well he is meeting their needs. Quality may not be the same for every customer, but each customer expects his specifications to be met.

- Systematic support: structures, policies, and procedures must be implemented to encourage quality. Quality must be part of the strategic plan, budget process, and performance appraisal system." If you are not willing to reward those who make your processes work better (as distinct from those who rush in at the last minute to put out the fires), you will never achieve quality," Arnold cautions.

- Continuous improvement: even when customers are satisfied,

the firm must keep looking for ways to improve, because customer needs change and the competition may be improving too.

2.5 Commitment to Quality

Patterson (1983) stated: "The attitudes of management toward quality, performance, and cost effectiveness are reflected down through the ranks from general management to the newest engineer in training." Support, endorsement and participation of management personnel are required for the success of a project. According to Farrington (1987), applying a well planned quality management program incorporates communication between design and construction to promote an opportunity to improve constructability and to prevent problems that were encountered in the past, and also to avoid foreseeable problems of the future. As management accepts responsibility for quality and strives to optimize the quality program, owners will begin to recognize benefits such as reduction of errors, improved productivity and opportunities for reduced cost of deviations.

2.6 Activities Involved in Quality Management of Construction

This section discusses the quality management activities, searched from the literature, which can be used to assure quality in the construction phase of a constructed project. Appendix (X) shows the arrangement of quality management activities as discussed in the following paragraphs of this section.

2.6.1 Quality Program Management/Verification Actions

It is the responsibility of a contractor to define clearly his management policies, objectives, and responsibilities for each unit of his organization. The responsibility and authority for the quality of personnel managing and directing the project should be defined and their interrelationship should be shown on organization charts. According to the American Society for Quality Control (ASQC 1987), the contractor's management should periodically review the status and adequacy of the quality program and should appoint a representative to ensure that quality program requirements are complied with. It is also the responsibility of the management to define the quality program representative's authority to resolve quality matters. It is the contractor's responsibility to define the responsibilities and authority of individuals who perform the work and to verify conformance to quality requirements. Saarinen (1990) stated that commitment to meeting quality requirements must extend through all levels of the organization, because each individual can have an impact on quality. According to him, senior management is responsible for communicating and emphasizing the firm's commitment to quality and for establishing the firm - wide quality management procedures and requirements. Saarinen (1990) stated: "If we provide the requirements without the system or conditions conducive to success, we cannot expect quality."

It is the responsibility of the contractor to define the responsibility and authority of personnel responsible for performing quality verification actions.

2.6.2 Inspection and Testing

Almost all construction professionals agree that inspection is an essential part of the construction process. Inspection is one of the principal mechanisms used in quality management systems. Ellis (1990) stated that inspection is a fundamental part of the construction process and that it is through inspection that we assure the conformance of the predetermined requirements. Inspection and performance testing are an essential element in all quality management programs. According to Ellis (1990), the inspection process assists the construction managers in producing a construction process. In this way, problems can be detected early and corrected, which will result in reducing replacement costs.

2.6.3 Documentation

Control of documents is important to a contractor since it is concerned with precision and accuracy of review as well as issuance and revision of all project documents related to quality. Documents should be developed and approved by personnel having experience in the affected work activity. The contractor should make sure that all essential documents affecting quality are reviewed for adequacy and approved for release by authorized personnel. Changes to documents should be subject to the same degree of control used in performing the original document. According to ASQC (1987), all changes should be processed in writing so they can be acted on promptly at the specified locations. The contractor should maintain a record of changes as they are made. Documents should be revised after a practical number of changes have been issued.

2.6.4 Control of Procurement Documents

Control of procurement documents is very important to the contractor. The procedure on purchasing control according to ASQC (1987), should include instructions for the preparation of purchase and indicate who is responsible for their review and approval.

2.6.5 Material/Equipment Identification/Verification of Procedures

A contractor must verify that the materials and equipment meet prescribed quality and contractual requirements and that they are properly received and handled to ensure that the quality is not degraded because of inappropriate methods. According to ASQC (1987) the contractor should ensure that materials and equipment are positively identifiable and traceable directly to a specified origin point. The materials and equipment should be appropriately cleaned, preserved and stored to prevent damage or deterioration. The materials storage areas should be arranged for ease of retrieval or installation of material without damage or adverse contact with neighboring materials or equipment.

2.6.6 Maintenance of Quality Records/Training and Qualification of Surveillance Personnel

It is the responsibility of the contractor to maintain quality records as evidence that all of his activities comply with the requirements of his quality program. It is his responsibility to maintain training and qualification for surveillance personnel to assure their competence for performing quality.

2.6.7 Establishment of Communication Program

Clearly communicating information such as requirements, costs, schedules and technical data is a very important element in having quality in the constructed projects. A coordinated effort among the various members is required to achieve an integrated program that is necessary to complete a quality project. According to the manual of Professional Practice (ASCE 1990), it is the responsibility of the contractor to maintain proper communications during the construction phase of a project.

2.6.8 Planning for Construction

Planning for construction is necessary to meet most of the project objectives. When planning in construction operations is effective, adequate lead time to mobilize certain critical resources is secured and the responsibility for quality performance is clearly assigned. According to the ASCE (1990) manual, the contractor should prepare plans and procedures, plan to provide the resources necessary for quality construction and make construction contributions to key decisions by the owners and design professional.

2.6.9 Qualification of Subcontractors

Most projects have a substantial number of subcontractors involved, and each is responsible for only certain activities. On a typical project, these activities include plumbing, heating, and air conditioning electrical, elevators, glass, roofing, wall covering and asphalt. On some projects, the

general contractor will only provide management and supervisory personnel, and virtually all trade and craft work is done by subcontracted firms.

Regardless of the business relationship established among the general contractor and the various subcontractors, the contractor is responsible for the quality of the work and meeting quality control specifications in the contract documents.

2.6.10 Safety Program

Each job site should have a well-planned safety and first aid program with participation by all contractors, testing agencies, and related personnel. Some services like first aid facility and nursing may be shared and financially supported by all contractors. In most cases, the owner furnishes these services without charge through a contractual arrangement with the contractor. According to the ASCE (1990), each job site should deploy plans for emergencies. Emergency telephone numbers for ambulance, fire and police should be posted, and first aid and fire-fighting training should be implemented.

2.6.11 Coordination and Communications

A successful construction phase requires coordination between design, construction and start-up of the facility. According to the ASCE (1990), the owner is responsible for providing this coordination in the contractual arrangement selected.

Coordination and communication are enhanced if clear communication is established. Some basics are (ASCE 1990):

- Only the contractor should direct labor.
- Only the contractor should coordinate subcontractors.
- The contractor should receive direction only from the owner.
- Manufacturers should receive direction only from the project manager.

Coordination among project team members is based on a realistic plan and schedule developed in the preconstruction phase. Decisions on procurement, permits, and construction durations are required before construction begins. Specific lines of communication must be clearly established for each project.

2.6.12 Design Revisions/Checks

During a construction phase evaluation, the design professional should review the number and magnitude of changes to determine the following questions: Are there too many? Does the revised schedule allow enough time, or is it causing too much confusion among the subcontractors? Does feedback from the contractor indicate that a problem exists with the design team? What programs exist to control quality? Are functions and responsibilities clearly defined? Is quality an agenda item? Request for clarifications of drawings and specifications is an indication of problems which may require immediate action.(ASQC 1987)

The owner and contractor should participate in, and lead the evaluation. Reviews should be considered in two phases. One phase is determination of the work performed was initially correct. The second phase is executing the inspections or tests that verify compliance.(ASCE

1990)

2.6.13 Insurance Needs of Contractors

The contractor must provide insurance for his own acts, those of the subcontractors, or any one for whom the contractor may be held liable. Specifically, the contractor must provide worker's compensation and other employee benefits. With respect to property damage, the property (except for the work itself) must be insured. A specific provision usually requires the contractor to protect work and materials stored off site or in transit. The exposure from vehicles used in the construction processes is addressed by requiring coverage for liability resulting from the use of such vehicles. (ASCE 1990)

Because the contractor supervises the job site and the construction process puts both life and property at risk, the contractor usually is required to hold harmless and indemnify other parties not in control at the job site. The contract stipulates that the contractor supports that commitment with insurance. Coverage limits are usually tailored to the size and nature of the project, and specified in the contracts between the parties.(ASCE 1990)

To assure that the financial protection requirements are met, certificates of insurance are required, with the further provision that the insurers must notify the certificated holders if coverage is canceled for any reason.

2.6.14 Education of Contractor's Employees

Training for contractor's employees through short courses, seminars, or on-the-job training is an important step in assuring quality in the construction phase of a project in an indirect way and in the long run. The revenue from these quality management activities affects the contractor positively both technically and financially (ASCE 1990). Contractors may develop their own training, qualification and certification program in accordance with recognized standards and guidelines. This concept is supported by the ASQC Construction Technical Committee, "Quality Management for the Constructed Project" (1987) because it provides for tailoring specific needs that may be necessary to satisfy unique organizational considerations.

2.6.15 Provision of Technically Qualified Team Members

Assuring quality in the construction phase comes also through having a well qualified staff. Contractor's personnel should be encouraged to participate in continuing education programs through short courses, seminars and on-the-job training, since such participation will keep employees current with the state-of-the-art information about construction methods, etc.(ASCE 1990)

2.6.16 Establishment of an Incentive System

Motivating contractor's personnel is a very important step to promote quality and increase productivity (ASCE 1990).

CHAPTER 3

RESEARCH DESIGN

This chapter presents all the steps that were performed to achieve the objectives set for this study. The procedures include all information relevant to where and how these data were secured, and the method whereby samples were selected.

3.1 Data Collection

This study is an exploratory type of research to define the quality management activities in the Saudi building design and construction industry.

Questionnaires were mailed to a randomly selected sample. Mail survey was used due to several reasons. Mail surveys are typically lower in cost than personal interviews. It is often a one-person job. Another value in using mail is that respondents who might otherwise be inaccessible can be contacted. Persons such as major corporate executives are difficult to reach in any other way. In a mail survey, the respondents can take more time to collect facts, talk with others, or consider replies at length than is possible with other ways of data collection. Mail surveys are typically perceived as being more impersonal, providing more anonymity than the other communication modes (Dillman 1978). Finally, questionnaires were used due to the unwillingness of firms especially contractors to spare some time for interviews. This has been experienced by several researchers (Zamel 1991) and (Abu-Asbah, in progress). Therefore, it was decided to

use mailed questionnaires for data collection. Follow up letters were sent to the contractors and the consulting offices with a copy of the questionnaire after one month from mailing the first copy.

See Appendices I and II for the questionnaire for design offices and contractor firms.

3.2 Population and Sample Size

The population of this study is the large building contractors (Grades 1, 2 and 3) and consulting offices. Large contractors are defined to be those contractors who can take projects of more than 50 million Saudi riyals each.

In this study, the size of the samples was determined using the following formula (Cochran 1977):

$$n = n_o / (1 + n_o/N)$$

$$n_o = t^2 Pq/d^2$$

where:

n = Sample size

n_o = First estimate of the sample size

N = Total population

t = value of the standard normal variant (if 95% confidence level t = 1.96)

p = The proportion of the characteristic being measured in the target population (P = 0.5)

q = 1-P = 1 - 0.5 = 0.5

d = The precision = 0.15

Substituting the pre-defined variables for the consulting offices, the following sample size was obtained.

$$n = 38, \quad \text{for total population of } N = 358.$$

Also, substituting the pre-defined variables for the contractors, the following sample size was obtained.

$$n = 36, \quad \text{for total population of } N = 258.$$

It is usually the case in such a study that the response rate will not be high. In this study a response rate of 30% was predicted. 175 questionnaires were mailed to the consulting offices and 150 questionnaires were mailed to the building contractors all over the Kingdom. 38 answers were received from the consulting offices and 30 answers were also received from the building contractors.

3.3 Data Analysis

The analysis of the data was through the use of SAS, the Statistical Analysis System, which is a package available on the mainframe of King Fahd University of Petroleum & Minerals.

The data collected from the survey was coded and entered into the system which provided the following:

1. A measurement of the firms involvement in quality activities, ranking of quality management activities and calculating frequencies.

2. Step wise Regression Analysis was used to select the variables

for the design phase which are:

- Annual business volume of the consulting firm.
- Years in business of the consulting firm.
- Average contract duration of the consulting firm.

The other variables were not significant.

Step wise Regression Analysis was used also to select the variables for the construction phase which are:

- Annual business volume of the contractor.
- Average contract size of the contractor.
- Average contract duration.
- Years in business.

The other variables were not significant.

(See Appendices VII and VIII for the step wise regression analysis of the design and construction phases)

Simple Linear Regression and Multiple Regression were performed for the selected significant variables.

CHAPTER 4

QUALITY MANAGEMENT ACTIVITIES

Quality Management activities in the design and construction phases of Saudi construction projects are discussed in this chapter. Determination of quality management activities in the design and construction phases of Saudi construction industry , and the correlation between the firm's characteristics and quality management activities used by the firm are introduced in this chapter.

4.1 Quality Management of the Design Phase

Table 1 introduces the Quality Management (QM) activities which can be used by consulting firms to assure quality in the design phase of a construction project.

4.1.1 Overall Ranking of Quality Management Activities

The SAS computer program shown in Appendix (III) was developed to rank the overall design quality management activities according to their importance. The ranking was based on the total score for each activity or factor. For example, factor number 1 received six "No" answers which counts for a zero score and 30 "yes" answers which counts for a score of 30 (one point for each yes answer). The summation of the two will yield the total score. Rank No.1

Table No:1 Quality Management Activities Analysis for the Design Phase.

Factor	QM Activity	No Answer		Yes Answer	
		Frequency	Percentage	Frequency	Percentage
1	Definition of the interrelationship and responsibilities of the quality program management and direction	6	16.67	30	83.33
2	Establishment of qualification parameters for persons whose activities affect the quality of work	2	5.26	36	94.74
3	Establishment of an incentive system to motivate persons to produce quality work	10	26.32	28	73.68
4	On the job training for employees	5	13.16	33	86.84
5	Short courses for employees	19	51.35	18	48.65
6	Seminars for employees	19	51.35	18	48.65
7	Calculation checks of the design	2	5.26	36	94.74
8	Drawing checks/Review	0	0	38	100
9	Specification checks/Review	1	2.63	37	97.37
10	Formal drafting check/Review	2	5.26	36	94.74
11	Review of client's comments	1	2.63	37	97.37
12	Review/check of standards	1	2.63	37	97.37
13	Review/check of regulations	1	2.70	36	97.30
14	Review/check of space allocation	1	2.63	37	97.37

Contd...

Table No:1 ; Quality Management Activities Analysis for the Design Phase

Factor	QM Activity	No Answer		Yes Answer	
		Frequency	Percentage	Frequency	Percentage
15	Review/check of aesthetics	2	5.26	36	94.74
16	Functionality Review	0	0	38	100
17	Capacity Review	1	2.63	37	97.37
18	Documentation of any documents related to the design of the project	4	10.53	34	89.47
19	Frequent contacts between the project parties	2	5.26	36	94.74
20	Communication program	8	21.62	29	78.38
21	Communication to resolve conflicts	2	5.41	35	94.59
22	Provision of technically qualified team members	1	2.63	37	97.37
23	Provision of cost estimate of the project	1	2.63	37	97.37
24	Submission of progress reports to the owner	2	5.26	36	94.74
25	Standardization of office procedures	3	7.89	35	92.11
26	Office library facilities	5	13.16	33	86.84
27	Provision of clear, concise, and uniform plans and specifications	0	0	38	100
28	Arrangements for organizational peer review	20	52.63	18	47.37
29	Arrangements for project peer review	18	47.37	20	52.63

will be for the activity which got the highest score and rank No.2 will be for the activity which got the second highest score, etc. The outcome of this analysis is shown in Table 2 and discussed in the following paragraphs.

4.1.1.1 Drawing Checks/Review

Drawings are very important documents for consulting offices. They must be checked thoroughly, especially in the local design offices, since what is happening is that the Architectural Engineer provides the architectural drawings which are sent to the structural engineer to produce the structural drawings. After that, both types of drawings are released for construction without reviewing and matching them. The significance of communication between the team members appears. Due to lack of communication during construction, a lot of mistakes and errors like mismatching between the architectural drawings and structural drawings start to come to the surface. So, it is very important to review the drawings carefully before releasing them for construction in order to avoid the weak link between the architectural engineer and the structural engineer.

Even though it can be seen in Table 2 that this quality management activity is ranked as No.1 which indicates the importance of this QM activity for the consulting offices, the above mentioned is still a problem in the local design offices.

Table:2: Overall Quality Management Ranking

Factor	Quality Management Activity	Overall Ranking
8	Drawing checks/Review	
16	Functionality Review	1
27	Provision of clear, concise and uniform plans and specifications	
9	Specification checks/Review	
11	Review of client's comments	
12	Review/check of standards	
14	Review/check of space allocation	2
17	Capacity review	
22	Provision of technically qualified design team members	
23	Provision of cost estimate of the project	
2	Establishment of qualification parameters for persons whose activities affect the quality of work	
7	Calculation checks of the design	
10	Formal drafting check/Review	
13	Review/check of regulations	3
15	Review/check of aesthetics	
19	Frequent contacts between the project parties	
24	Submission of progress reports to the owner	

Contd....

Table:2: Overall Quality Management Ranking

Factor	Quality Management Activity	Overall Ranking
21	Communication to resolve conflicts	4
25	Standardization of office procedures	
18	Documentation of any documents related to the design team members	5
4	On the job training for employees	6
26	Office library facilities	
1	Definition of the interrelationship and responsibilities of the quality program management and direction	7
20	Communication program	8
3	Establishment of an incentive system to motivate persons to produce quality work	9
29	Arrangements for project peer review	10
5	Short courses for employees	11
6	Seminars for employees	
28	Arrangements for organizational peer review	

Errors, omissions, and ambiguities are some of the main proplems which might appear in drawings. Major effects will arise during the construction phase of a project if these drawings are not checked carefully during the design phase by the consulting firms. These inadequacies in drawings are a main cause of changes. The control of changes are major undertakings which cause expensive delays in project completion time. Such delays may lead to a variety of claims between the owner and contractor. Another proplem which might appear from not checking the drawings is a bad reputation for the consulting office which will affect its future career.

4.1.1.2 Provision of Clear, Concise and Uniform Plans & Specifications /Specification Checks (Review)

Plans are the only documents given to the contractor which show the design concept, size and scope of the job, the number and size of materials or items, and how they are assembled into a final project. So, it is critical that drawings be clear, concise and uniform.

Drawings and specifications are the two sets of documents given to the contractor that provide necessary technical information. So, it is critical that drawings and specifications be clear, concise and uniform. Inadequacies like errors and omissions in plans and specifications are a main cause of change, which as discussed earlier in this section, cause expensive delays in project completion and lead to claims between the owner and contractor.

Despite the fact that these two quality management activities are ranked as No.1 and No. 2 respectively as shown in Table 2, some of the

consulting offices nonetheless provide unclear specifications. Unclear specifications will have a bad effect later during the construction phase. It is harmless to use government or certain standard specifications for the general specification of a project. On the other hand, it is necessary to use modified and suitable specifications for the special specifications of a project and review these specifications to make sure that the items inside them suit the project they are going to be used for.

4.1.1.3 Calculation Checks of the Design

Checking the calculations of design is a very important step in assuring quality in the design phase. Many problems can be avoided, like failure of the structure. The reputation of the consulting office will suffer if they provide a wrong design.

Although calculation checks are ranked as No.3 as shown in Table 2, they are still considered an important quality management activity since they obtained a score of 36 points compared to rank No.1 which obtained the score of 38 points.

4.1.1.4 Training for Employees

Despite the fact that training for firm's employees through short courses or seminars is an important step in assuring quality in the design phase of a project in an indirect way and in the long run, these quality management activities are ranked at the lowest due possibly to the fact that some of the consulting firms are not willing to pay for short courses or attendance at seminars by their employees thinking that this will affect the budget of the firm. The revenue from these quality management activities affects the firm positively both technically and financially.

4.1.1.5 Arrangements for Organizational Peer Review/ Arrangements for Project Peer Review

Despite the fact that peer review is one of the best ways to improve quality in the design of constructed projects, these quality management activities in fact scored very low and ranked at the end as is shown in Table 2. The main reason for that might be that the concept of peer review is still new and not well known for most of the consulting offices in Saudi Arabia . However, peer reviews must be requested as added safeguards for the public, the owner, and the design professional. Another benefit from these quality management activities might be that the overall time to complete a constructed project can be reduced by a peer review. Another main reason for not using this quality management activity might be that the consulting offices are trying to avoid being reviewed by another party who might detect their mistakes.

4.1.2 Ranking of Design Quality Management Activities Based on Annual Business Volume

The total population was divided based on annual business volume into five categories:

Category 1 = Up to 5 million.

Category 2 = 5 to 10 million.

Category 3 = 10 to 100 million.

Category 4 = 100 to 500 million.

Category 5 = Over 500 million.

The ranking of the quality management activities was based on the total score as discussed in the previous section 4.1.1.

The outcome of this analysis is shown in Tables 3 to 7 and Figures 1 to 5.

Table:3: Ranking of Design Quality Management Activities Based on Annual Business Volume up to SR 5 Million

Factor	Quality Management Activity	Overall Ranking
2	Establishment of qualification parameters for persons whose activities affect the quality of work	
8	Drawing checks/Review	
11	Review of client's comments	
12	Review/check of standards	
13	Review/check of regulations	
16	Functionality Review	1
17	Capacity review	
22	Provision of technically qualified design team members	
23	Provision of cost estimate of the project	
24	Submission of progress reports to the owner	
27	Provision of clear, concise and uniform plans and specifications	
7	Calculation checks of the design	
9	Specification checks/Review	
10	Formal drafting check/Review	
14	Review/check of space allocation	2
15	Review/check of aesthetics	
19	Frequent contacts between the project parties	
25	Standardization of office procedures	
26	Office library facilities	

Contd...

Table:3: Ranking of Design Quality Management Activities Based on Annual Business Volume up to SR 5 Million

Factor	Quality Management Activity	Overall Ranking
18	Documentation of any documents related to the design team members	3
20	Communication program	
21	Communication to resolve conflicts	
4	On the job training for employees	4
1	Definition of the interrelationship and responsibilities of the quality program management and direction	5
28	Arrangements for organizational peer review	
29	Arrangements for project peer review	
3	Establishment of an incentive system to motivate persons to produce quality work	6
5	Short courses for employees	7
6	Seminars for employees	

DESIGN PHASE

1 11
2 10
3 9
4 8
5 6
6 5
7 4

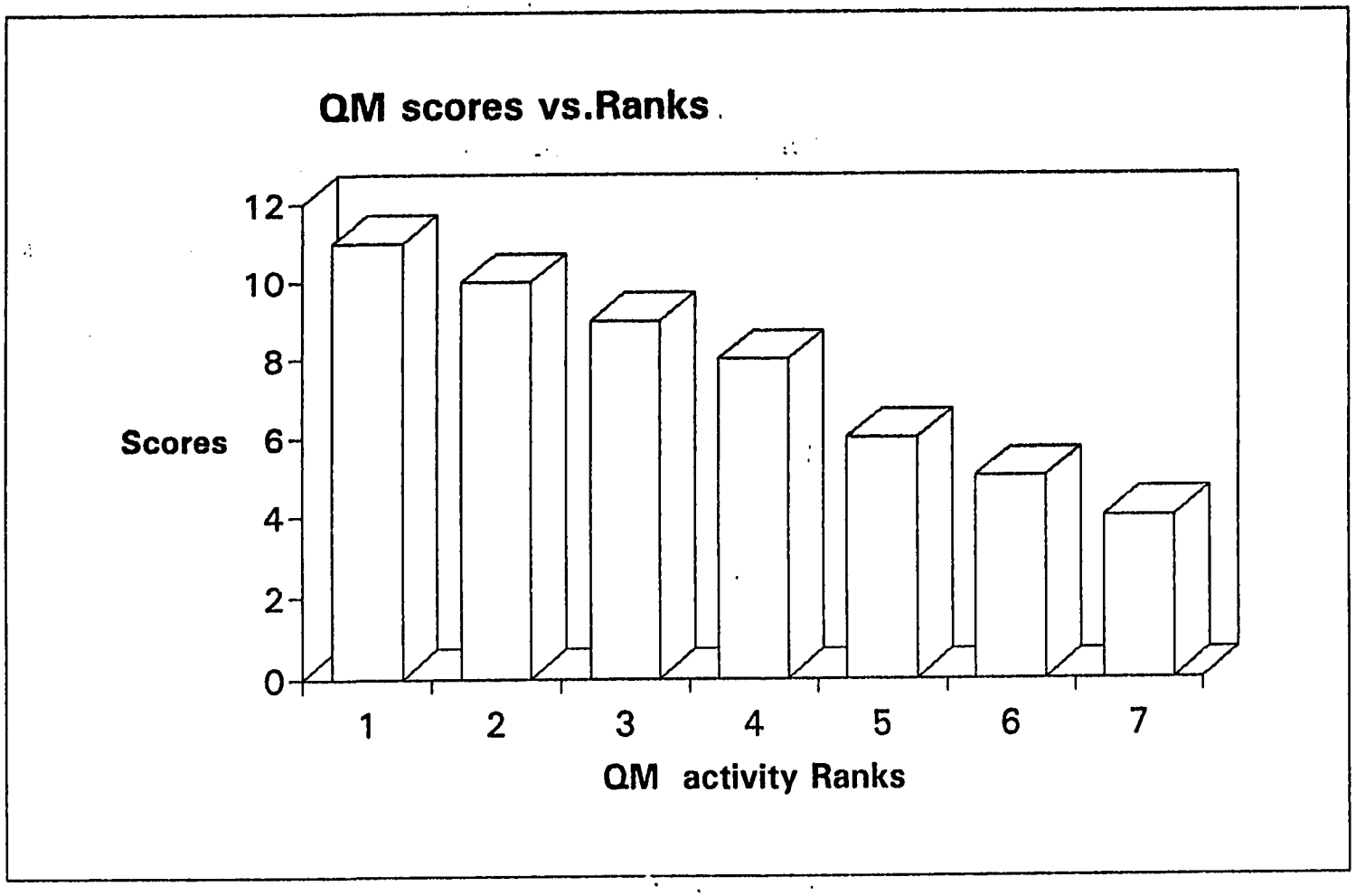

Figure # 1;Quality Manaement Scores Vs. Ranks, Design Phase
(Annual Business Volume up to SR. 5 Million)

Table:4: Ranking of Design Quality Management Activities Based on Annual Business Volume from SR 5 to 10 Million.

Factor	Quality Management Activity	Overall Ranking
3	Establishment of an incentive system to motivate persons to produce quality work	
4	On the job training for employees	
7	Calculation checks of the design	
8	Drawing checks/Review	
9	Specification checks/Review	
10	Formal drafting check/Review	
14	Review/check of space allocation	
15	Review/check of aesthetics	
16	Functionality Review	1
18	Documentation of any documents related to the design team members	
19	Frequent contacts between the project parties	
21	Communication to resolve conflicts	
22	Provision of technically qualified design team members	
23	Provision of cost estimate of the project	
27	Provision of clear, concise and uniform plans and specifications	

Contd.....

Table:4; Ranking of Design Quality Management Acitivities Based on Annual Business Volume from SR 5 to 10 Million

Factor	Quality Management Activity	Overall Ranking
2	Establishment of qualification parameters for persons whose activities affect the quality of work	2
11	Review of client's comments	
12	Review/check of standards	
13	Review/check of regulations	
17	Capacity review	
24	Submission of progress reports to the owner	
25	Standardization of office procedures	
26	Office library facilities	
1	Definition of the interrelationship and responsibilities of the quality program management and direction	3
20	Communication program	4
5	Short courses for employees	5
6	Seminars for employees	6
28	Arrangements for organizational peer review	
29	Arrangements for project peer review	

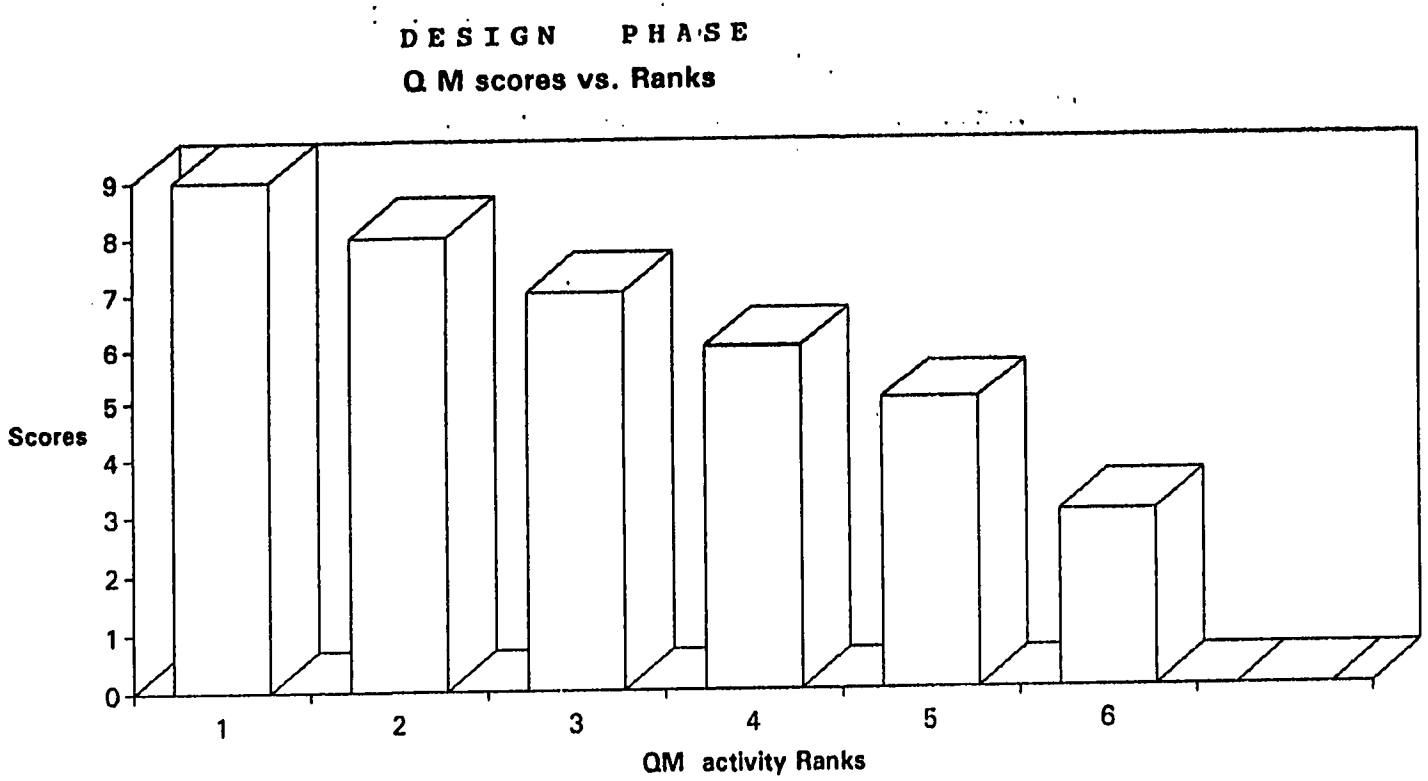

Figure # 2: Quality Management Scores Vs. Ranks, Design Phase (Annual Business Volume from SR 5 to SR 10 Million)

Table:5: Ranking of Design Quality Management Activities Based on Annual Business Volume from SR. 10 to SR.100 Million

Factor	Quality Management Activity	Overall Ranking
7	Calculation checks of the design	
8	Drawing checks/Review	
9	Specification checks/Review	
10	Formal drafting check/Review	
11	Review of client's comments	
12	Review/check of standards	
14	Review/check of space allocation	1
15	Review/check of aesthetics	
16	Functionality Review	
17	Capacity review	
27	Provision of clear, concise and uniform plans and specifications	
1	Definition of the interrelationship and responsibilities of the quality program management and direction	
2	Establishment of qualification parameters for persons whose activities affect the quality of work	
3	Establishment of an incentive system to motivate persons to produce quality work	2
13	Review/check of regulations	

Contd...

Table: 5; Ranking of Design Quality Management Acitivities Based on Annual Business Volume from SR 10 to SR 100 Million

Factor	Quality Management Activity	Overall Ranking
19	Frequent contacts between the project parties	
21	Communication to resolve conflicts	
22	Provision of technically qualified design team members	
23	Provision of cost estimate of the project	2
24	Submission of progress reports to the owner	
25	Standardization of office procedures	
4	On the job training for employees	
18	Documentation of any documents related to the design team members	3
26	Office library facilities	4
20	Communication program	5
29	Arrangements for project peer review	6
6	Seminars for employees	7
5	Short courses for employees	
28	Arrangements for organizational peer review	8

DESIGN PHASE

1 14
2 13
3 12
4 11
5 10
6 8
7 7
8 5

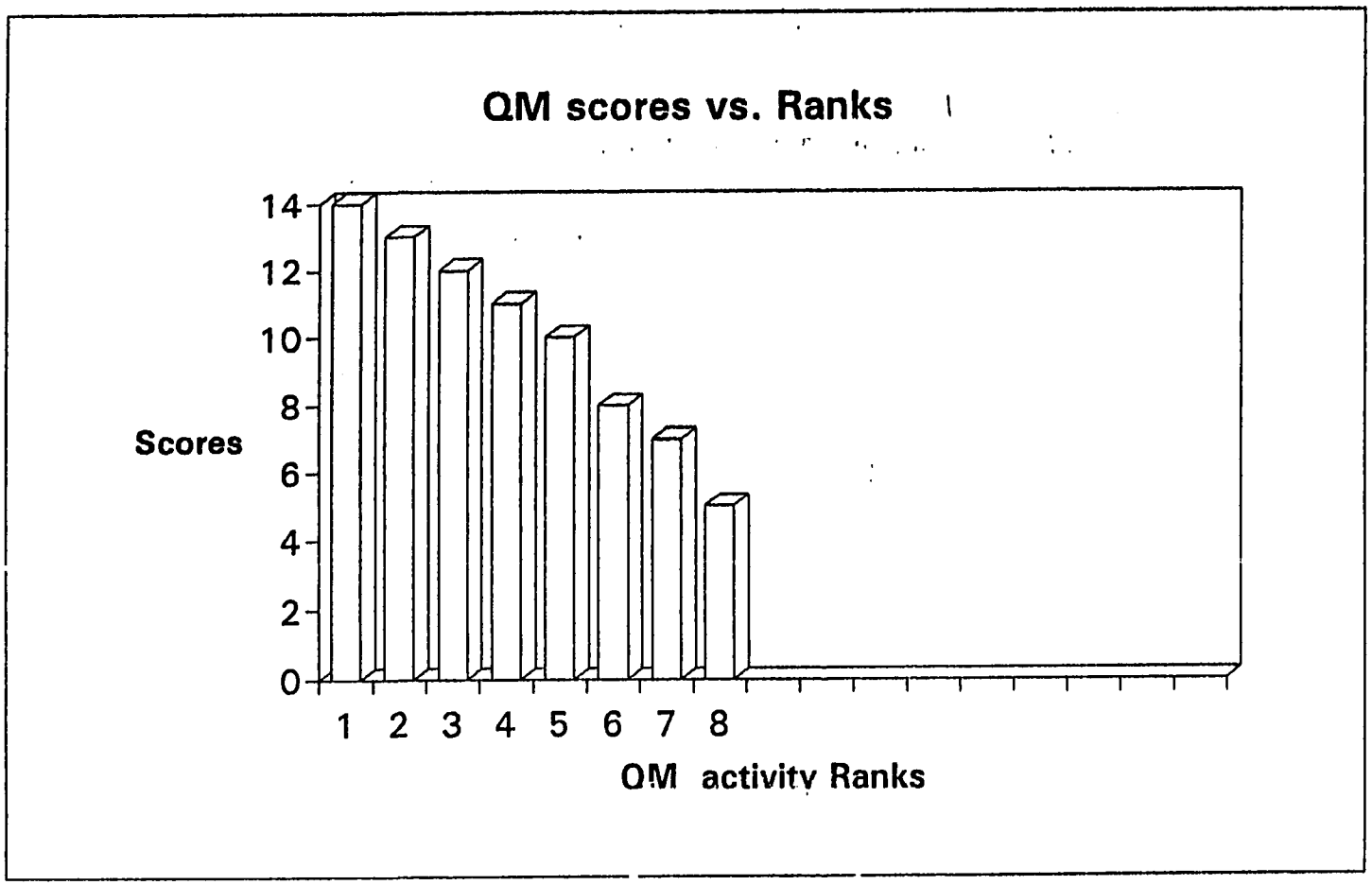

Figure # 3: Quality management Scores Vs. Ranks, Design Phase (Annual Business Volume from SR 10 to SR 100 Million)

Table:6: Ranking of Design Quality Management Activities Based on Annual Business Volume from SR 100 to SR 500 Million

Factor	Quality Management Activity	Overall Ranking
1	Definition of the interrelationship and responsibilities of the quality program management and direction	
2	Establishment of qualification parameters for persons whose activities affect the quality of work	
4	On the job training for employees	
5	Short courses for employees	
6	Seminars for employees	
8	Drawing checks/Review	
9	Specification checks/Review	
11	Review of client's comments	
12	Review/check of standards	
13	Review/check of regulations	
14	Review/check of space allocation	
16	Functionality Review	
17	Capacity review	1
18	Documentation of any documents related to the design team members	
19	Frequent contacts between the project parties	
20	Communication program	

Contd...

Table:6; Ranking of Design Quality Management Acitivities Based on Annual Business Volume from SR 100 to SR 500 Million

Factor	Quality Management Activity	Overall Ranking
21	Communication to resolve conflicts	
22	Provision of technically qualified design team members	
23	Provision of cost estimate of the project	
24	Submission of progress reports to the owner	1
25	Standardization of office procedures	
26	Office library facilities	
27	Provision of clear, concise and uniform plans and specifications	
28	Arrangements for organizational peer review	
3	Establishment of an incentive system to motivate persons to produce quality work	
7	Calculation checks of the design	
10	Formal drafting check/Review	2
15	Review/check of aesthetics	
29	Arrangements for project peer review	

DESGIN PHASE

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2	1
3	0
4	0
5	0
6	0
7	0
8	0

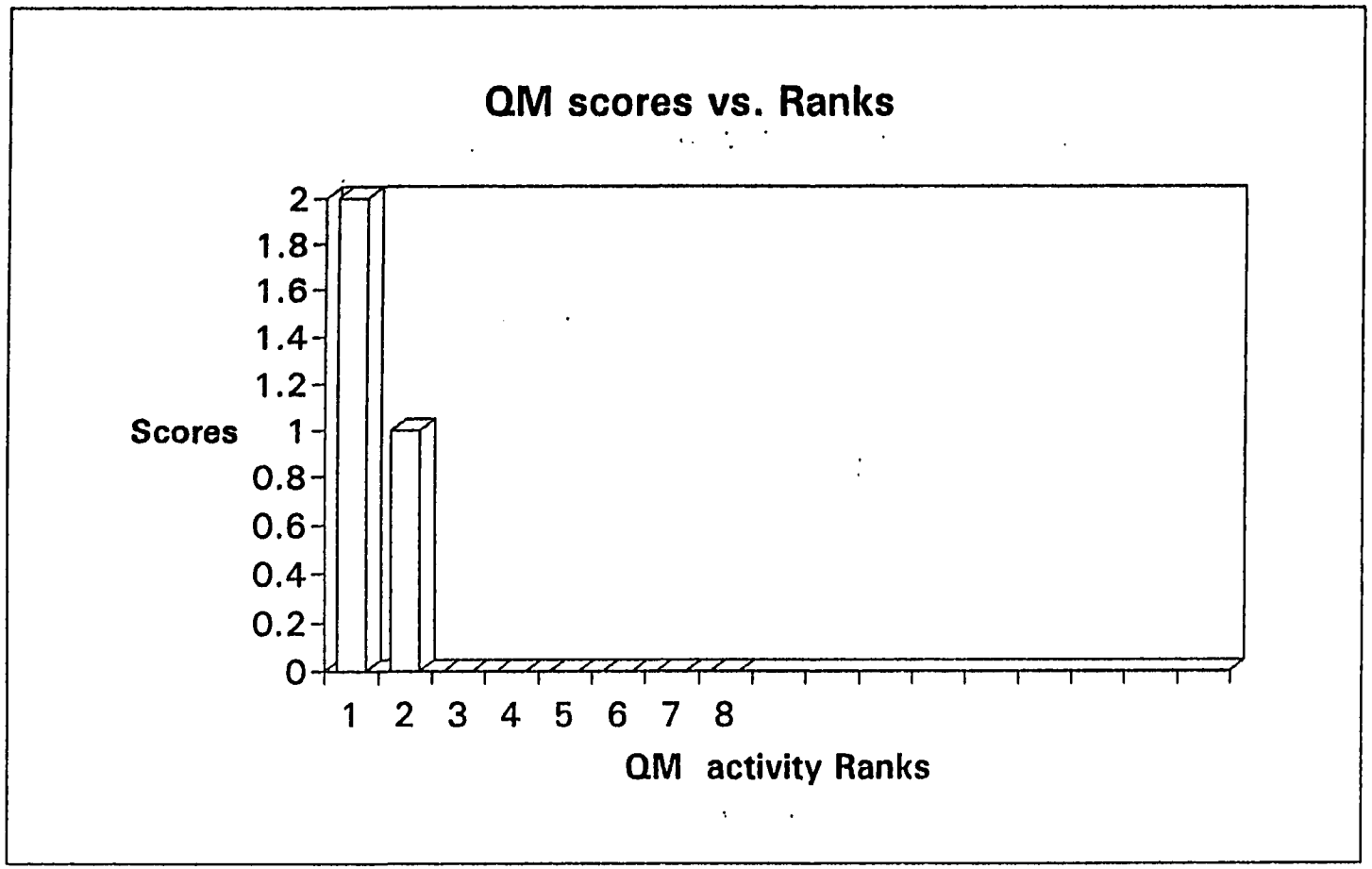

Figure # 4: Quality Management Scores Vs. Ranks, Design Phase
(Annual Business Volume from SR 100 to SR 500 Million)

Table:7: Ranking of Design Quality Management Activities Based on Annual Business Volume Over SR 500 Million.

Factor	Quality Management Activity	Overall Ranking
1	Definition of the interrelationship and responsibilities of the quality program management and direction	
2	Establishment of qualification parameters for persons whose activities affect the quality of work	
4	On the job training for employees	
5	Short courses for employees	
6	Seminars for employees	
7	Calculation checks of the design	
8	Drawing checks/Review	
9	Specification checks/Review	
10	Formal drafting check/Review	
11	Review of client's comments	
12	Review/check of standards	
13	Review/check of regulations	
14	Review/check of space allocation	
15	Review/check of aesthetics	
16	Functionality Review	
17	Capacity review	1
18	Documentation of any documents related to the design team members	

Contd...

Table:7; Ranking of Design Quality Management Activities Based on Annual Business Volume Over SR 500 Million

Factor	Quality Management Activity	Overall Ranking
19	Frequent contacts between the project parties	1
20	Communication program	
21	Communication to resolve conflicts	
22	Provision of technically qualified design team members	
23	Provision of cost estimate of the project	
24	Submission of progress reports to the owner	
25	Standardization of office procedures	
26	Office library facilities	
27	Provision of clear, concise and uniform plans and specifications	
28	Arrangements for organizational peer review	
29	Arrangements for project peer review	
3	Establishment of an incentive system to motivate persons to produce quality work	2

DESIGN PHASE

1	2
2	1
3	0
4	0
5	0
6	0
7	0
8	0

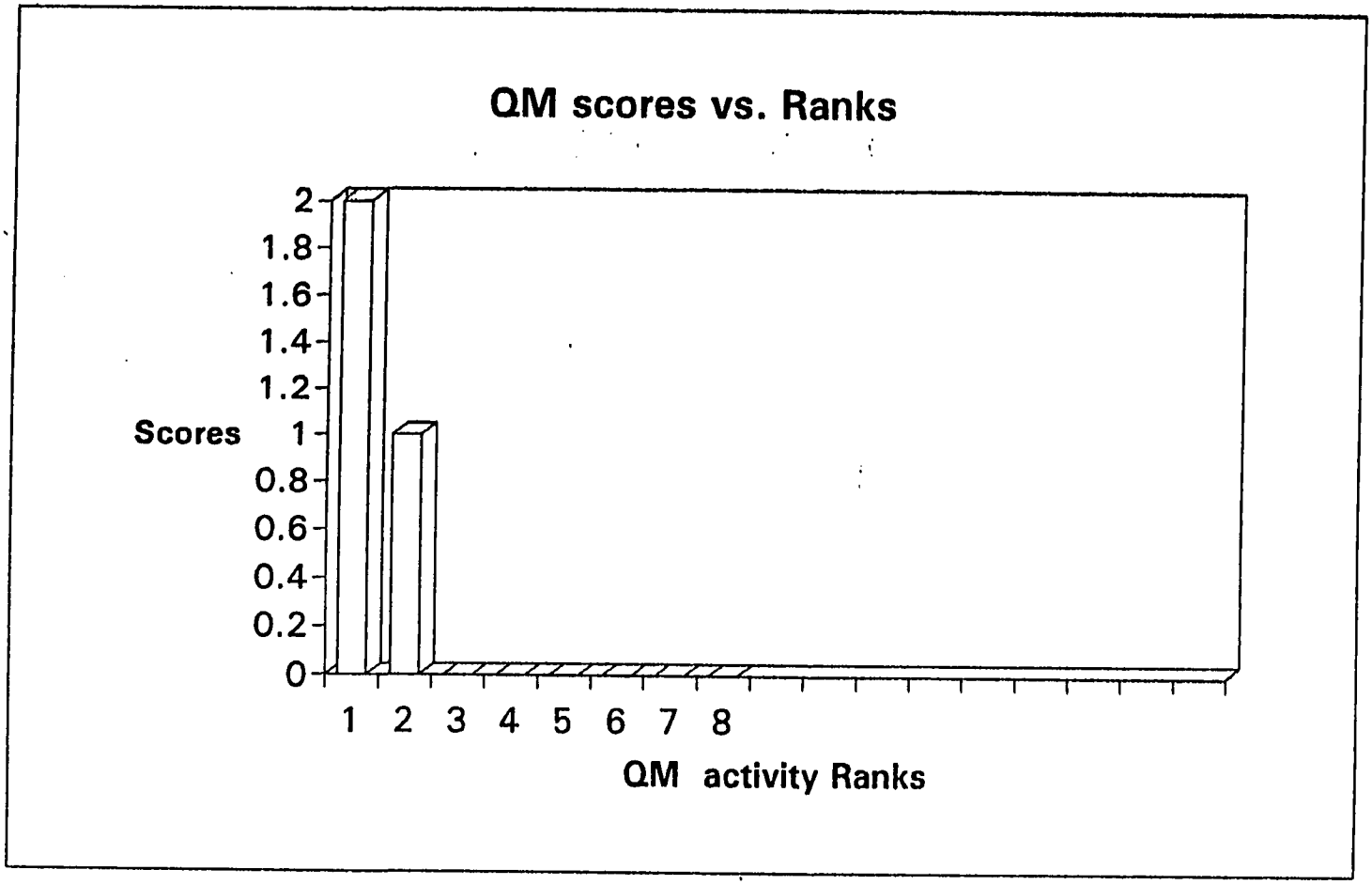

Figure # 5: Quality Management Scores Vs. Ranks, Design Phase (Annual Business Volume over SR 500 Million)

From the previous Annual Business Volumes tables, it is apparent that quality management activities No.8 and No.17, drawing checks and capacity review, are ranked as No.1 among all of the categories or ranges, which means that these two activities are important for consulting offices with different annual business volumes. Capacity review is ranked as No.2 in the overall quality design ranking and commonly as No.1 in rankings of quality management activities based on annual business volume, which emphasizes the importance of this quality management activity.

4.1.3 Ranking of quality management activities based on Years in Business

Based on the experience of the consulting firms, the population was divided into two groups, below ten years and above or equal to ten years in business. The ones below ten years were considered as having a short experience while those above or equal to ten years were considered as having a long experience. The activities were ranked for each of the mentioned two groups. The results are shown in Tables 8 and 9 and also in Figures No.6 and No.7.

Table:8: Ranking of Design Quality Management Activities Based on Years in Business (Long Experience)

Factor	Quality Management Activity	Overall Ranking
8	Drawing checks/Review	1
11	Review of client's comments	
14	Review/check of space allocation	
16	Functionality Review	
17	Capacity review	
22	Provision of technically qualified design team members	
27	Provision of clear, concise and uniform plans and specifications	
2	Establishment of qualification parameters for persons whose activities affect the quality of work	2
9	Specification checks/Review	
12	Review/check of standards	
15	Review/check of aesthetics	
23	Provision of cost estimate of the project	
25	Standardization of office procedures	
26	Office library facilities	

Contd...

Table:8; Ranking of Design Quality Management Acitivities Based on Years in Business (Long Experience)

Factor	Quality Management Activity	Overall Ranking
7	Calculation checks of the design	3
10	Formal drafting check/Review	
13	Review/check of regulations	
19	Frequent contacts between the project parties	
21	Communication to resolve conflicts	
24	Submission of progress reports to the owner	
4	On the job training for employees	4
18	Documentation of any documents related to the design team members	
1	Definition of the interrelationship and responsibilities of the quality program management and direction	5
20	Communication program	
3	Establishment of an incentive system to motivate persons to produce quality work	6
5	Short courses for employees	7
6	Seminars for employees to the owner	8
28	Arrangements for organizational peer review	
29	Arrangements for project peer review	

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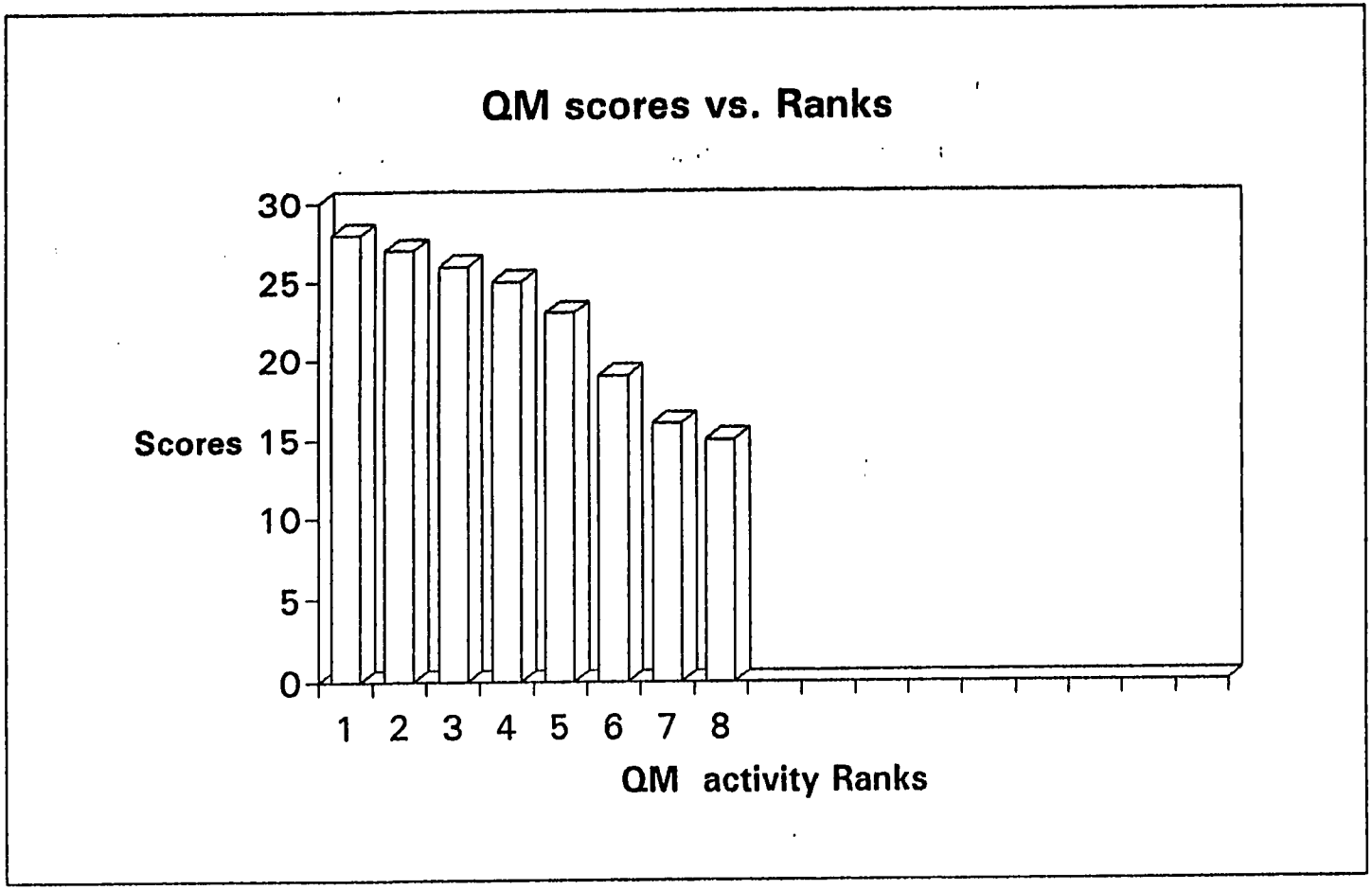

Figure # 6: Quality Management Scores Vs. Ranks, Design Phase
(Experience above or equal to 10 years)

Table:9: Ranking of Design Quality Management Activities Based on Years in Business (Short Experience)

Factor	Quality Management Activity	Overall Ranking
7	Calculation checks of the design	
8	Drawing checks/Review	
9	Specification checks/Review	
10	Formal drafting check/Review	
12	Review/check of standards	
13	Review/check of regulations	
16	Functionality Review	1
19	Frequent contacts between the project parties	
23	Provision of cost estimate of the project	
24	Submission of progress reports to the owner	
27	Provision of clear, concise and uniform plans and specifications	
2	Establishment of qualification parameters for persons whose activities affect the quality of work	
3	Establishment of an incentive system to motivate persons to produce quality work	
11	Review of client's comments	
14	Review/check of space allocation	
15	Review/check of aesthetics	
17	Capacity review	2
18	Documentation of any documents related to the design team members	
21	Communication to resolve conflicts	
22	Provision of technically qualified design team members	

Contd....

Table:9; Ranking of Design Quality Management Acitivities Based on Years in Business (Short Experience)

Factor	Quality Management Activity	Overall Ranking
4	On the job training for employees	
25	Standardization of office procedures	3
1	Definition of the interrelationship and responsibilities of the quality program management and direction	4
20	Communication program	
26	Office library facilities	5
29	Arrangements for project peer review	6
6	Seminars for employees to the owner	
28	Arrangements for organizational peer review	7
5	Short courses for employees	8

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6 5
7 3
8 2

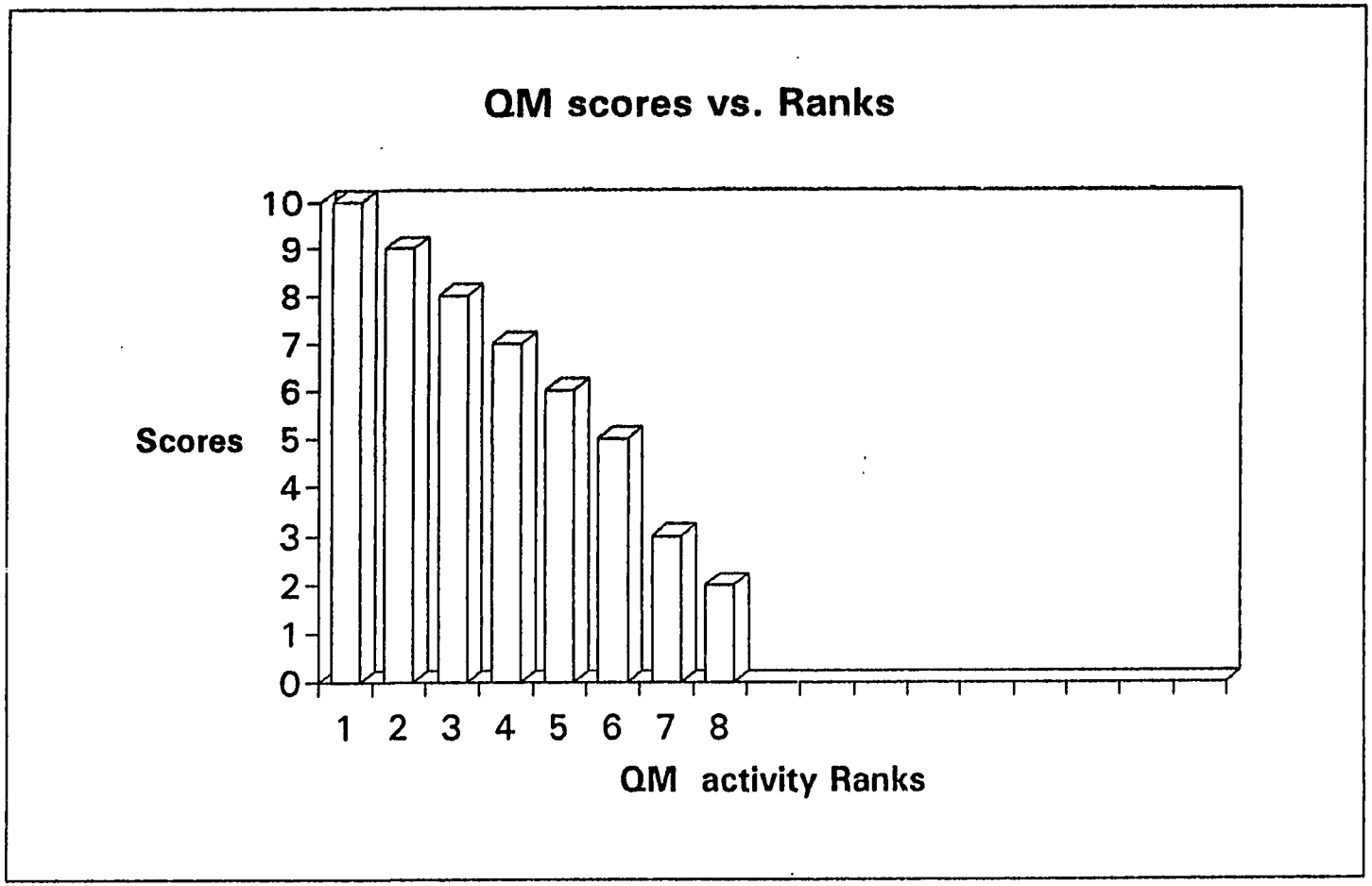

Figure # 7: Quality Management Scores Vs. Ranks, Design Phase (Experience less than 10 years)

From Tables 8 and 9, it is apparent that the consulting offices with long experience tend to provide more technically qualified design team members than those which have shorter experience. Design team members should be encouraged to participate in continuing education programs and professional groups, since such participation will keep the design team current with the latest information concerning design and analysis methods and techniques. It is also clear that consulting offices with long experience tend to check the design more thoroughly and carefully before releasing it for construction more than those offices with shorter experience. Another point is that more experienced consulting offices are more concerned about the training of the firm's employees than those of less experience. A convincing reason might be that consulting offices with long experience are more concerned about their reputation and future carreer than those of shorter experience.

4.1.4 The Relationship between offices characteristic and QM activities

To find the relationship between the annual business volume of the consulting firms and their quality management activities , the consulting firms' years in business and their quality management activities and between the average contract duration of the consulting firms and their quality management activities, simple and multiple regression analyses were performed. Table 10 presents the input data which were used for the analysis.

Table:10: Data for Regression Analysis, Design Phase.

Annual Business Volume (Millions of SR) X1	Years in Business X2	Average Contract Duration (Months) X4	Overall Design Quality Criteria Y
3.5	11	5	0.758
0.1	7	5	0.896
14	10	84	0.827
1.5	10	12	0.793
4.0	15	12	0.758
2.0	16	-	0.931
40	9	18	1.0
6	14	6	0.827
6	12	24	1.0
25	7	12	0.793
34	20	-	0.965
3	16	1	0.931
40	22	24	1.0
20	15	12	0.896
3	7	3	0.758
8	11	10	0.793
6	7	8	0.862

Contd...

Table:10; Data for Regression Analysis, Design Phase

Annual Business Volume (Millions of SR) X1	Years in Business X2	Average Contract Duration (Months) X4	Overall Design Quality Criteria Y
7	12	-	0.896
32	15	12	0.965
10	15	10	0.827
23	12	6	0.862
5	10	5	0.862
8	8	12	0.686
10	8	10	0.965
12	13	10	0.827
15	18	12	0.897
9	12	8	1.0
10	14	7	0.758
12	11	3	0.827
8	9	5	0.862

4.1.4.1 Simple Linear Regression

General Linear Models (GLM) were used between the annual business volume and overall design quality criteria, which yielded the following equation:

$$Y = 0.824 + 0.004 \quad X_1 \qquad (1)$$

Coefficient of determination, $R^2 = 21\%$

Coefficient of variation, C.V. = 9.0%

Correlation coefficient, r = 0.455

t value = 0.0115

where:

X_1 = Annual business volume of consulting firm

Y = Overall design quality criteria of consulting firm (Y is a dimensionless factor varying between 0 and 1, the closer of Y value from 1, the more number of usage of QM activities).

The importance of the Y value for a consulting office can be seen through calculating the Y value for an office as to evaluate and compare its overall design quality criteria with other consulting offices.

In Table No.10, Y values were calculated as follows:

Example: Consulting firm No.1 has a quality criteria of 22/29 = 0.758

where: 22 is the number of yes answers, while 29 is the total number of design quality management activities.

The GLM was used also between years in business and overall design quality criteria yielding the following equation:

$$Y = 0.768 + 0.0082 \quad X_2 \qquad (2)$$

$R^2 = 13.6\%$

C.V. = 9.4%

r = 0.368

t = 0.045

where:

X_2 = Years in business of the consulting firm.

Graphical presentations of Y versus X_1 and Y versus X_2 are shown in Figures 8 and 9.

The GLM was used also between average contract duration and overall design criteria yielding the following equation:

$$Y = 0.854 + 0.00047 \quad X_4 \qquad (3)$$

$R^2 = 21\%$

C.V. = 10.4%

where:

X_4 = Average contract duration of the consulting firm.

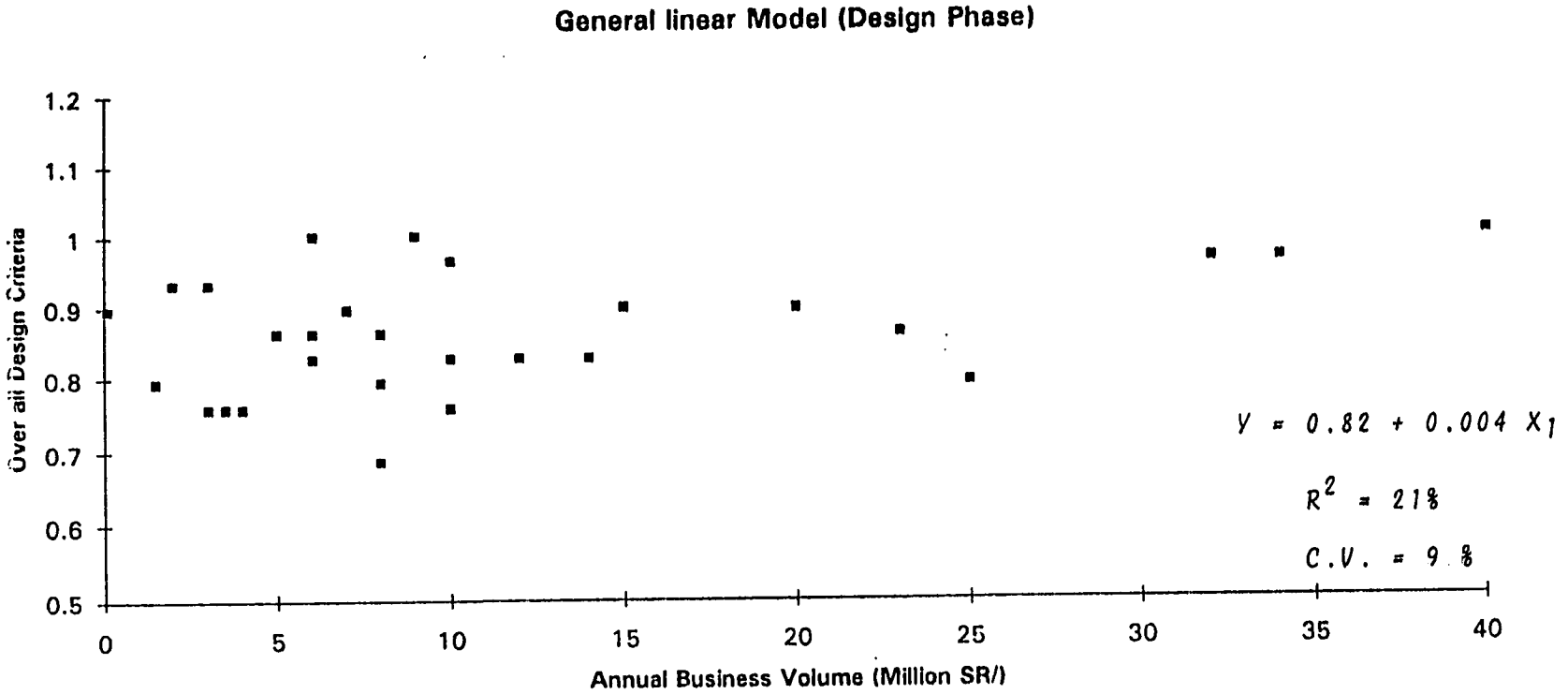

Figure # 8: General Linear Model for Design Phase
(Overall Design Criteria Vs. Annual Business Volume)

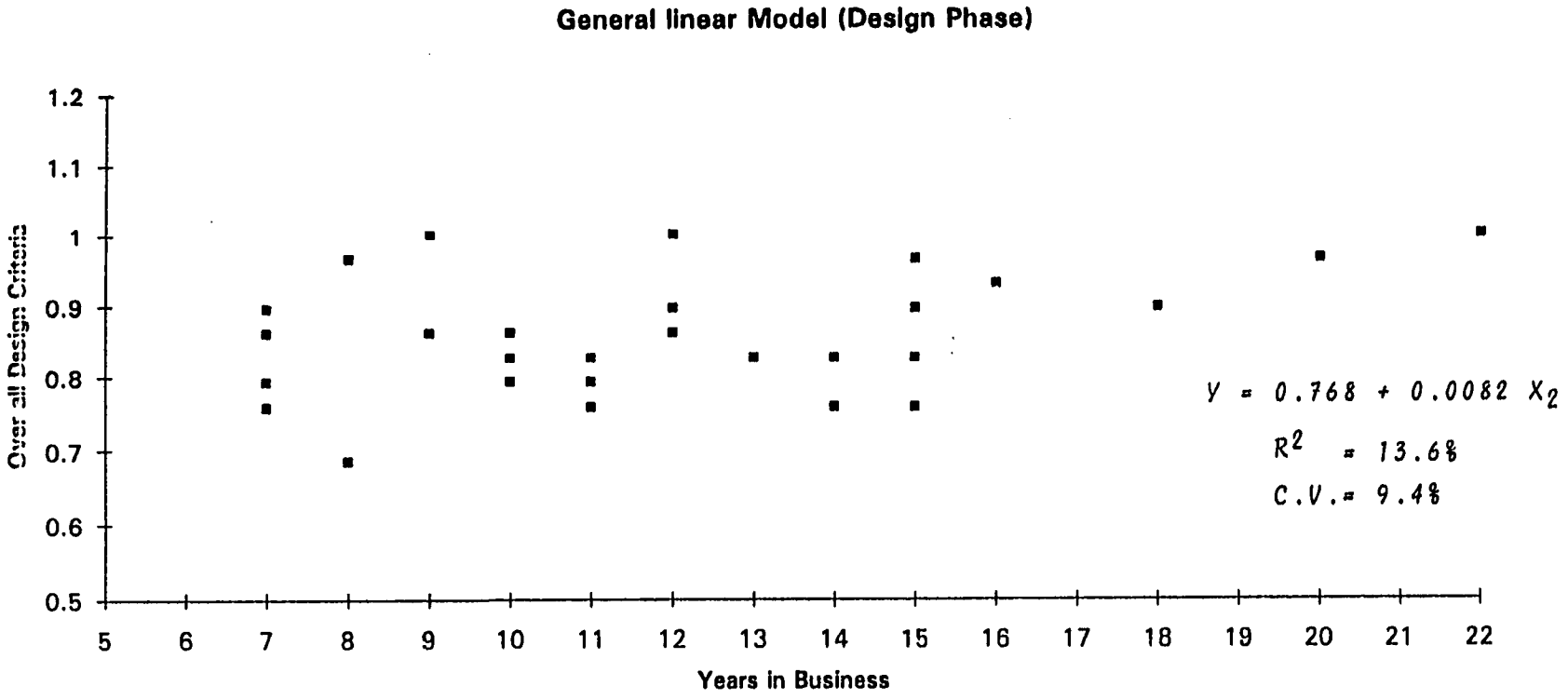

Figure # 9: General Linear Model for Design Phase
(Overall Design Criteria Vs. Years in Business)

4.1.4.2 Multiple Regression

Regressions were performed between annual business volume, years in business, average contract duration and overall design quality criteria yielding the following equations:

$$Y = 0.859 - 0.0032 X_1 + 0.00017 X_1^2 \quad (4)$$

where:

$R^2 = 26\%$

C.V. = 8.85%

$$Y = 0.8862 - 0.0113 X_2 + 0.00073 X_2^2 \quad (5)$$

where:

$R^2 = 16\%$

C.V. = 9.5%

$$Y = 0.771 - 0.0028 X_1 + 0.005 X_2 \quad (6)$$

where:

$R^2 = 25\%$

C.V. = 8.9%

$$Y = 0.778 + 0.0033 X_1 + 0.0036 X_2 - 0.0001 X_4 \quad (7)$$

where:

$R^2 = 23.7\%$

C.V. = 9.47%

4.2 Quality Management of the Construction Phase

Table 11 introduces the quality management (QM) activities which can be used by contractors to assure quality in the construction phase of a construction project. Frequencies and percentages are shown for each QM activity.

4.2.1 Overall Ranking of Quality Management Activities

The computer program shown in Appendix V was developed to rank the overall construction quality management activities according to their importance. The ranking was based on the total score for each activity or factor, in the same way discussed in Section 4.1.1. The outcome of this analysis is shown in Table 12.

4.2.1.1 Data Presentation

The results of the survey show that a majority of the contractors give top priority to documentary and procedural papers, including distribution of correspondence, change orders, claims and planning schedules, etc. Similarly, client's comments, and change orders are met with changing of specifications and drawings by the contractor. In-situ and laboratory tests for quality control of material and workmanship are also on top of the list of the tasks contractors seem to care about the most.

Table:11: Quality Management Activities Analysis for the Construction Phase.

Factor	QM Activity	No Answer		Yes Answer	
		Frequency	Percentage	Frequency	Percentage
1	Definition of the interrelationship and responsibilities of the quality program management and direction	15	51.7	14	48.3
2	Responsibilities of personnel accountable for performing quality verification actions	9	30.0	21	70.0
3	Instructions and procedures related to inspection and testing	1	3.3	29	96.7
4	Instructions and procedures related to compliance with the accepted criteria	8	27.6	21	72.4
5	Control and distribution of documents	1	3.4	28	96.6
6	Review and approval of documents	0	0	29	100.0
7	Control of changes to documents	1	3.4	28	96.6
8	Control of procurement documents	2	6.7	28	93.3
9	Inspection of purchased items on receipt	0	0	30	100
10	Control of cleaning, preservation and storage	0	0	30	100

Contd...

Table:11; Quality Management Acitivities Analysis for the Construction Phase

Factor	QM Activity	No Answer		Yes Answer	
		Frequency	Percentage	Frequency	Percentage
11	Positive material identification	6	20.0	24	80
12	Materials and/or equipment retrieval	10	34.5	19	65.5
13	Qualifications of welding personnel	20	69.0	9	31.0
14	Qualifications of heat treatment personnel	21	72.4	8	27.6
15	Qualifications of personnel engaged in work with concrete	5	17.2	24	82.8
16	Verification of welding procedures	12	42.9	16	57.1
17	Verification of heat treatment procedures	16	57.1	12	42.9
18	Verification of concrete work procedures	4	14.3	24	85.7
19	Verification of equipment	6	21.4	22	78.6
20	Program for issuance, collection and return of measuring and testing equipment	8	27.6	21	72.4

Contd....

Table:11; Quality Management Activities Analysis for the Construction Phase -

		No Answer		Yes Answer	
Factor	QM Activity	Frequency	Percentage	Frequency	Percentage
21	Establishment of a list of measuring and testing equipment requiring calibration	7	23.3	23	76.7
22	Maintenance of quality records	7	23.3	23	76.7
23	Training and qualifications of surveillance personnel on the project	12	41.4	17	58.6
24	Documentation and reporting of the results of the surveillance	11	37.9	18	62.1
25	Establishment of a system of incentives to motivate project personnel to produce quality work	9	31.0	20	69.0
26	Subcontractor evaluation depending on reputation, past experience, financial position, etc.	0	0	30	100
27	Qualifications and testing of your employees	16	53.3	14	46.7
28	Qualifications and testing of new employees	9	30	21	70
29	On job training for employees	17	56.7	13	43.3
30	Seminars for employees	27	90	3	10.0

Contd....

Table:11; Quality Management Activities Analysis for the Construction Phase

		No Answer		Yes Answer	
Factor	QM Activity	Frequency	Percentage	Frequency	Percentage
31	Short courses for employees	28	93.3	2	6.7
32	Calculation checks of the design	10	33.3	20	66.7
33	Review/checks of design drawings	5	16.7	25	83.3
34	Specification checks	4	13.3	26	86.7
35	Review of clients' and designers' comments	4	13.3	26	86.7
36	Review of work regulations	4	13.3	26	86.7
37	Constructability review	6	20	24	80
38	In-situ tests of materials	1	3.3	29	96.7
39	Lab. tests of materials	0	0	30	100
40	Inspection of results related to material tests	6	20	24	80
41	Inspection of physical structure of the project	9	30	21	70
42	Documentation of any records related to the project	7	23.3	23	76.7

Contd...

Table:11; Quality Management Activities Analysis for the Construction Phase

Factor	QM Activity	No Answer		Yes Answer	
		Frequency	Percentage	Frequency	Percentage
43	Documentation of construction methods	10	33.3	20	66.7
44	Planning for construction	0	0	30	100
45	Provision of technically qualified team members for the project	6	20	24	80
46	Evaluation of materials/equipment suppliers	1	3.3	29	96.7
47	Establishment of a communication program between the staff on the project	8	26.7	22	73.3
48	Initiation of a reporting system	5	16.7	25	83.3
49	Establishment of checklists	5	16.7	25	83.3
50	Initiation of a safety program	11	36.7	19	63.3
51	Compliance with insurance requirements	1	3.3	29	96.7

Table:12: Overall Construction Quality Management Ranking

Factor	Quality Management Activity	Overall Ranking
9	Inspection of purchased items on receipt	1
10	Control of cleaning, preservation and storage	
26	Subcontractor evaluation depending on reputation, past experience, financial position, etc.	
39	Lab. tests of materials	
44	Planning for construction	
3	Instructions and procedures related to inspection and testing	2
6	Review and approval of documents	
38	In-situ tests of materials	
46	Evaluation of materials/equipment suppliers	
51	Compliance with insurance requirements	
5	Control and distribution of documents	3
7	Control of changes to documents	
8	Control of procurement documents	
34	Specification checks	4
35	Review of clients' and designers' comments	
36	Review of work regulations	

Contd...

Table:12; Overall Construction Quality Management Ranking

Factor	Quality Management Activity	Overall Ranking
33	Review/checks of design drawings	
48	Initiation of a reporting system	5
49	Establishment of checklists	
11	Positive material identification	
15	Qualifications of heat treatment personnel	
18	Verification of concrete work procedures	
37	Constructability review	6
40	Inspection of results related to material tests	
45	Provision of technically qualified team members for the project	
21	Establishment of a list of measuring and testing equipment requiring calibration	
22	Maintenance of quality records	7
42	Documentation of any record related to the project	
19	Verification of equipment	
47	Establishment of a communication program between the staff on the project	8

Contd...

Table:12; Overall Construction Quality Management Ranking

Factor	Quality Management Activity	Overall Ranking
2	Responsibilities of personnel accountable for performing quality verification actions	9
4	Instructions and procedures related to compliance with the accepted criteria	
20	Program for issuance, collection and return of measuring and testing equipment	
28	Qualifications and testing of new employees	
41	Inspection of physical structure of the project	
25	Establishment of a system of incentives to motivate project personnel to produce quality work	10
32	Calculation checks of the design	
43	Documentation of construction methods	
12	Materials and/or equipment retrieval	11
50	Initiation of a safety program	
24	Documentation and reporting of the results of the surveillance	12
23	Training and qualifications of surveillance personnel on the project	13
16	Verification of welding procedures personnel on the project	14

Contd....

Table:12; Overall Construction Quality Management Ranking

Factor	Quality Management Activity	Overall Ranking
1 27	Definition of the interrelationship and responsibilities of the quality program management and direction Qualifications and testing of your employees	15
29	On job training for employees	16
17	Verification of heat treatment procedures	17
13	Qualifications of welding personnel	18
14	Qualifications of heat treatment personnel	19
30	Seminars for employees	20
31	Short courses for employees	21

The survey further shows that selection of materials for the project and subcontracting part of the work are also well taken care off by the contractors. A majority of the contractors responded positively when asked about whether they keep their stores clean and organized.

On the other hand, the lowest among their concerns was providing continuing education and training to their employees. The survey showed that they were not concerned about modern techniques whic would make project management through cost control, material retrieval, resources based planning, etc., basic tools to enhance performance. A majority of contractors responded negatively to questions about quality control on welding procedures and the concern for qualified welders.

Along the same lines, a majority of contractors were not interested in re-checking whether their employees were maintaining the quality of their know-how. In between, it seemed that most did in fact make calculation checks on designs, initiate and maintain programs for testing equipment, preserve of quality records, seriously scrutinize qualification of new employees, site safety, material identification and care for a system of employees incentives to improve productivity.

4.2.1.2 Discussion of Data

The survey results present a familiar picture of an average contractor working in Saudi Arabia . With few exceptions, most of the contracting firms in Saudi Arabia consist of a dominance of foreign elements, from ordinary labor, to foreman, engineers and technical staff. A majority of contractors even have foreign management with an inactive,

or semi-active, Saudi partnership. On the contrary, most of the clients in Saudi Arabia are governmental organizations, such as ministries or semi government bodies These organizations employ predominantly Saudi engineers and technical supervisors. This staff is highly trained and vigilant. Knowing very well the set up of the Saudi contracting market, the government bodies have laid down stringent regulations for quality control of the projects. Reports on material approval and on job quality control are mandatory in contract documents. The clients frequently employ in addition to their own supervisory staff, highly qualified consultants.

Before discussing the results of the survey, it would seem a natural trend suiting the Saudi environment that all contractors in order to win the contract should agree to stringent quality control procedures that are mentioned in contract documents. Since there is no escape from these controls, the survey shows that most of the contractors carry out in-situ and lab tests on materials routinely. Secondly when a client issues a change order or makes comments on contractor drawings or documents, the contractor has to take it seriously in order to get approval, as otherwise contract clauses forbid payments for non-approved work, and this is what the survey confirmed. The survey further showed that most of the contractors prepare a time schedules (planning) for their work. This is also an obligatory requirement of most of the clients and secondly any profit oriented contractors would do it to avoid over-running costs and delay penalties.

The other priority of the surveyed contractor was their vigilance in the inspection of purchased materials and their strict sub-contractor

evaluation. These two items have direct impact on the contractor's profit. Any material purchased which does not meet the client's approval or project specifications is likely to be rejected, and the subcontractor if he is unable to do the work will be the cause of further loss to the main contractor. Thus, these items are very well taken care of by the contractors.

On the other hand, their lowest priorities are issues which are related to long term strategies and/or to long term unforeseen profits such as the continuing education of their employees. They had to finish the project at a certain time and they were not sure of the next project. As a result, they did not waste their money on improving know-how which would not bring any quick profit to them, according to their "earn and away" motto. The qualification of their staff is unimportant as long as things continue along and ministries keep on accepting projects. There are several instances when an engineer was approved for civil projects, only to perform the duties of a mechanical engineer or vice versa. A draftsman becomes a foreman and a laborer becomes a supervisor, etc. care much for the qualification of their employees.

The survey further showed that contractors have little interest in welding work quality and the qualification of welders. This attitude is less due to disregard for good welding procedures than to contractors who had not done serious welding projects in their fields. Welding terms were simply unknown to them.

In between the "yes" and "no" answers, there are issues to which contractors give only half-hearted attention. Some are required by clients but not pushed too hard by them and others are required by contractors

themselves but not on an urgent or must basis. A check on design calculation is done sometimes to reduce costs on turn-key projects, for example to reduce the thickness of a retaining wall to save the cost of concrete, etc. The system of incentives for employees to improve productivity is not a top priority with many contractors, as it is difficult to establish an exact straight line relationship between the cost of incentives and extra profit. Site safety is also not their top priority due to the existence of work insurance, workman compensation insurance and due to the absence of penalties for poor safety at the site.

4.2.2 *Ranking of Construction Quality Management Activities Based on Annual Business Volume*

The total population was divided based on the annual business volume, into three categories as follows:

Category 1 = Less than SR 50 million.

Category 2 = From SR 50 million to SR 100 million.

Category 3 = Greater than SR 100 million.

Ranking of the quality management activities according to their importance and within each category was done with the help of the SAS package, and a computer program was developed for this purpose (see Appendix VI). The ranking of QM activities was based on the total points the activity got, the same method applied in the calculation of the design phase. The outcome of this analysis is shown in Tables 13, 14 and 15 and Figures 10, 11, and 12.

Table:13: Ranking of Construction Quality Management Activities Based on Annual Business Volume (Less than SR 50 Million)

Factor	Quality Management Activity	Overall Ranking
6	Review and approval of documents	1
9	Inspection of purchased items on receipt	
10	Control of cleaning, preservation and storage	
26	Subcontractor evaluation depending on reputation, past experience, financial position, etc.	
38	In-situ tests of materials	
39	Lab. tests of materials	
44	Planning for construction	
46	Evaluation of materials/equipment suppliers	
51	Compliance with insurance requirements	
3	Instructions and procedures related to inspection and testing	2
5	Control and distribution of documents	
7	Control of changes to documents	
8	Control of procurement documents	3
49	Establishment of checklists	4

Contd....

Table:13; Ranking of Construction Quality Management Activities Based on Annual Business Volume (Less than SR 50 Million)

Factor	Quality Management Activity	Overall Ranking
18	Verification of concrete work procedures	
33	Review/check of design drawings	
34	Specification checks	
35	Review of clients' and designers' comments	5
36	Review of work regulations	
48	Initiation of a reporting system	
11	Positive material identification	
12	Materials and/or equipment retrieval	
15	Qualifications of heat treatment personnel	6
19	Verification of equipment	
37	Constructability review	
4	Instructions and procedures related to compliance with the accepted criteria	
20	Program for issuance, collection and return of measuring and testing equipment	
40	Inspection of results related to material tests	7
42	Documentation of any record related to the project	
45	Provision of technically qualified team members for the project	

Contd...

Table:13; Ranking of Construction Quality Management Activities Based on Annual Business Volume (Less than SR 50 Million)

Factor	Quality Management Activity	Overall Ranking
21	Establishment of a list of the measures and testing equipment	
22	Maintenance of quality records	
41	Inspection of physical structure of the project	8
47	Establishment of a communication program between the staff on the project	
2	Responsibilities of personnel accountable for performing quality verification actions	
28	Qualifications and testing of new employees	
32	Calculation checks of the design	9
43	Documentation of construction methods	
50	Initiation of a safety program	
16	Verification of welding procedures personnel on the project	
23	Training and qualifications of surveillance personnel on the project	10
25	Establishment of a system of incentives to motivate project personnel to produce quality work	
24	Documentation and reporting of the results of the surveillance	11
27	Qualifications and testing of your employees	

Contd....

Table:13; Tanking of Construction Quality Management Activities Based on Annual Business Volume (Less than SR 50 Million)

Factor	Quality Management Activity	Overall Ranking
1	Definition of the interrelationship and responsibilities of the quality program management and direction	12
13	Qualifications of welding personnel	13
17	Verification of heat treatment procedures	
29	On job training for employees	
14	Qualifications of heat treatment personnel	14
30	Seminars for employees	15
31	Short courses for employees	

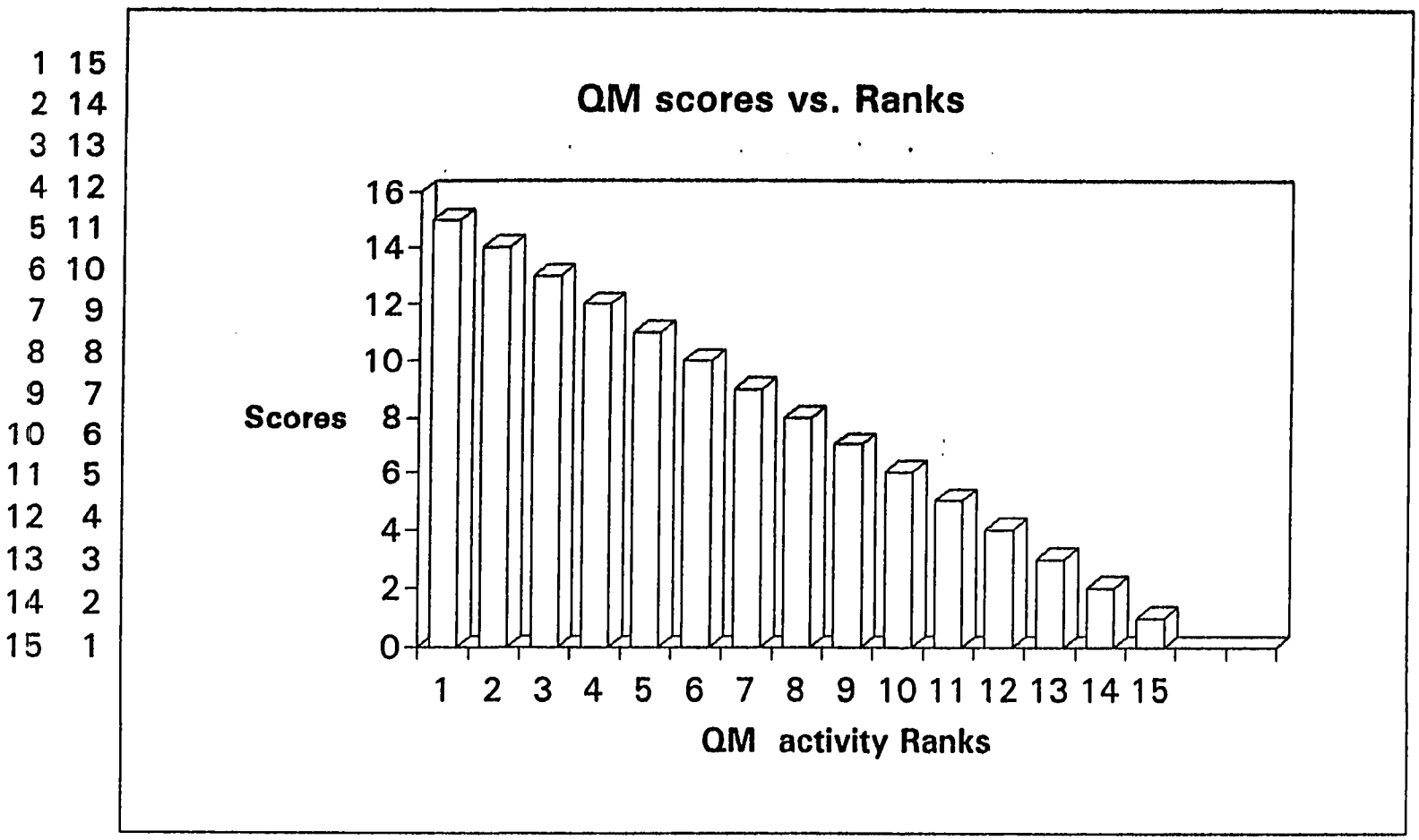

Figure # 10: Quality Management Scores Vs. Ranks, Construction Phase (Annual Business Volume less than SR 50 Million)

Table: 14: Ranking of Construction Quality Management Activities Based on Annual Business Volume (SR 50 to SR 100 Million)

Factor	Quality Management Activity	Overall Ranking
3	Instructions and procedures related to inspection and testing	
4	Instructions and procedures related to compliance with the accepted criteria	
8	Control of procurement documents	
9	Inspection of purchased items on receipt	
10	Control of cleaning, preservation and storage	
21	Establishment of a list of the measuring and testing equipment	
22	Maintenance of quality records	
24	Documentation and reporting of the results of the surveillance	
25	Establishment of a system of incentives to motivate project personnel to produce quality work	
26	Subcontractor evaluation depending on reputation, past experience, financial position, etc.	1
34	Specification checks	
35	Review of clients' and designers' comments	
36	Review of work regulations	
38	In-situ tests of materials	

Contd...

Table:14; Ranking of Construction Quality Management Activities Based on Annual Business Volume (SR 50 to SR 100 Million)

Factor	Quality Management Activity	Overall Ranking
39	Lab. tests of materials	
40	Inspection of results related to material tests	
44	Planning for construction	1
45	Provision of technically qualified team members for the project	
47	Establishment of a communication program between the staff on the project	
2	Responsibilities of personnel accountable for performing quality verification actions	
5	Control and distribution of documents	
6	Review and approval of documents	
7	Control of changes to documents	2
11	Positive material identification	
15	Qualifications of heat treatment personnel	
18	Verification of concrete work procedures	
20	Program for issuance, collection and return of measuring and testing equipment	
23	Training and qualifications of surveillance personnel on the project	
28	Qualifications and testing of new employees	

Contd...

Table:14 ; Ranking of Construction Quality management Activities Based on Annual Business Volume (SR 50 to SR 100 Million)

Factor	Quality Management Activity	Overall Ranking
33	Review/check of design drawings	2
37	Constructability review	
41	Inspection of physical structure of the project	
42	Documentation of any record related to the project	
46	Evaluation of materials/equipment suppliers	
48	Initiation of a reporting system	
51	Compliance with insurance requirements	
19	Verification of equipment	3
32	Calculation checks of the design	
43	Documentation of construction methods	
49	Establishment of checklists	
50	Initiation of a safety program	
1	Definition of the interrelationship and responsibilities of the quality program management and direction	4
16	Verification of welding procedures personnel on the project	

Contd...

Table: 14; Ranking of Construction Quality Management Activities. Based on Annual Business Volume (SR 50 to SR 100 Million)

Factor	Quality Management Activity	Overall Ranking
12	Materials and/or equipment retrieval	
17	Verification of heat treatment procedures	5
29	On job training for employees	
27	Qualifications and testing of your employees	6
13	Qualifications of welding personnel	
14	Qualifications of heat treatment personnel	7
30	Seminars for employees	
31	Short courses for employees	8

CONSTRUCTION PHASE

1	7
2	6
3	5
4	4
5	3
6	2
7	1
8	0
9	0
10	0
11	0
12	0
13	0
14	0
15	0

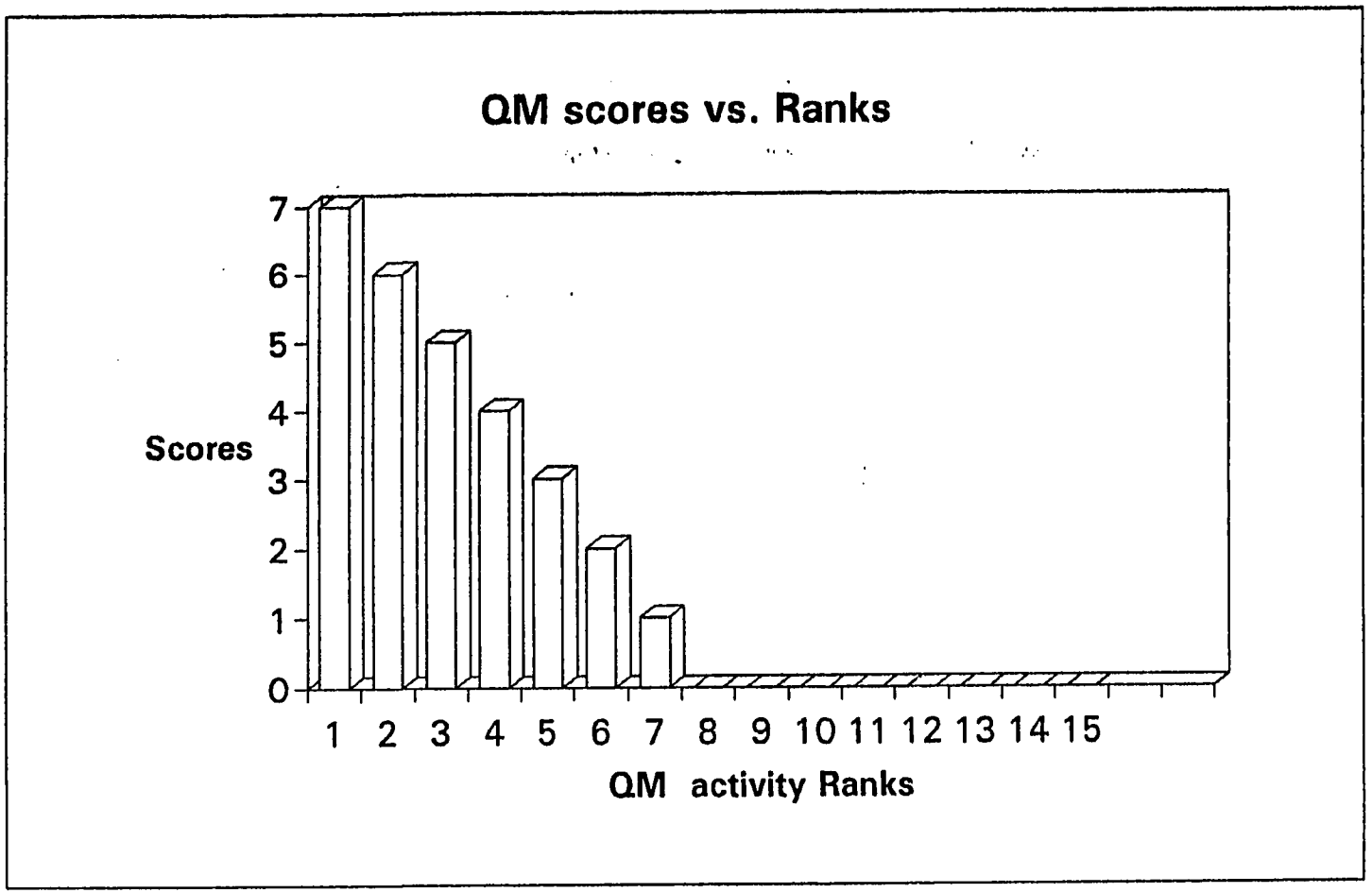

Figure # 11: Quality Management Scores Vs. Ranks, Construction Phase (Annual Business Volume from SR 50 to SR 100 Million)

Table: 15: Ranking of Construction Quality Management Activities Based on Annual Business Volume (Over SR 100 Million)

Factor	Quality Management Activity	Overall Ranking
2	Responsibilities of personnel accountable for performing quality verification actions	
3	Instructions and procedures related to inspection and testing	
5	Control and distribution of documents	
6	Review and approval of documents	
7	Control of changes to documents	
8	Control of procurement documents	
9	Inspection of purchased items on receipt	
10	Control of cleaning, preservation and storage	
11	Positive material identification	
15	Qualifications of heat treatment personnel	
21	Establishment of a list of the measuring and testing equipment	1
22	Maintenance of quality records	
26	Subcontractor evaluation depending on reputation, past experience, financial position, etc.	
28	Qualifications and testing of new employees	
32	Calculation checks of the design	
33	Review/check of design drawings	

Contd...

Table:15; Ranking of Construction Quality management Activities Based on Annual Business Volume 97 (Over SR 100 Million)

Factor	Quality Management Activity	Overall Ranking
34	Specification checks	
35	Review of clients' and designers' comments	
36	Review of work regulations	
37	Constructability review	
39	Lab. tests of materials	
40	Inspection of results related to material tests	1
42	Documentation of any record related to the project	
43	Documentation of construction methods	
44	Planning for construction	
45	Provision of technically qualified team members for the project	
46	Evaluation of materials/equipment suppliers	
48	Initiation of a reporting system	
49	Establishment of checklists	
51	Compliance with insurance requirements	
18	Verification of concrete work procedures	
19	Verification of equipment	
25	Establishment of a system of incentives to motivate project personnel to produce quality work	
27	Qualifications and testing of your employees	
29	On job training for employees	2
38	In-situ tests of materials	
41	Inspection of physical structure of the project	
47	Establishment of a communication program between the staff on the project	
50	Initiation of a safety program	

Contd....

Table:15; Ranking of Construction Quality Management Activities Based on Annual Business Volume (Over SR 100 Million).

Factor	Quality Management Activity	Overall Ranking
1	Definition of the interrelationship and responsibilities of the quality program management and direction	
12	Materials and/or equipment retrieval	
16	Verification of welding procedures personnel on the project	
17	Verification of heat treatment procedures	3
20	Program for issuance, collection and return of measuring and testing equipment	
24	Documentation and reporting of the results of the surveillance	
4	Instructions and procedures related to compliance with the accepted criteria	
13	Qualifications of welding personnel	
14	Qualifications of heat treatment personnel	4
23	Training and qualifications of surveillance personnel on the project	
30	Seminars for employees	
31	Short courses for employees	5

1	8
2	7
3	6
4	5
5	1
6	0
7	0
8	0
9	0
10	0
11	0
12	0
13	0
14	0
15	0

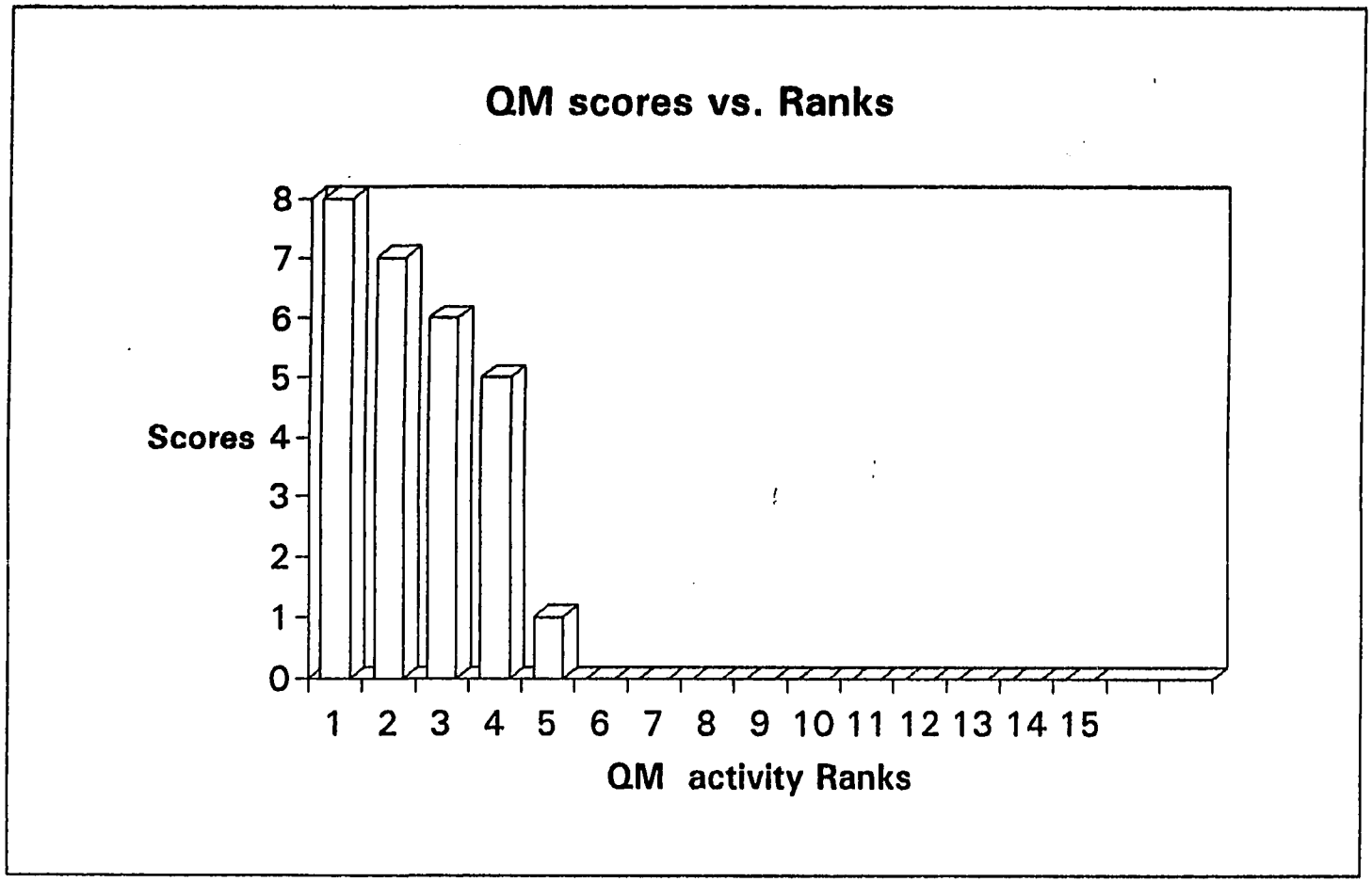

Figure # 12: Quality Management Scores Vs. Ranks, Construction Phase (Annual Business Volume greater than SR 100 Million)

4.2.3 *Ranking of Construction Quality Management Activities Based on Years in Business*

Based on the experience of the contractors, the population was divided into two groups, one below and one at or above twenty years in business. The one below twenty years was considered as having a short experience while the one at or above twenty years was considered as having long experience. The activities were ranked for each of the above mentioned groups. The outcomes are shown in Tables 16 and 17 and also in Figures 13 and 14.

4.2.4 *Ranking of Construction Quality Management Activities Based on Contract Size*

Based on the average contract sizes of contractors, the population was divided into two sizes. Size number one is for contractors whose average contract is less than SR 50 million, while size number two is for contractors whose average contract is greater than or equal to SR 50 million. The activities were ranked for each of these two sizes. The results are shown in Tables 18 and 19 and Figures 15 and 16.

Table:16: Ranking of Construction Quality Management Activities Based on Years in Business (Long experience; More than or Equal to 20 Years)

Factor	Quality Management Activity	Overall Ranking
9	Inspection of purchased items on receipt	
10	Control of cleaning, preservation and storage	
26	Subcontractor evaluation depending on reputation, past experience, financial position, etc.	1
39	Lab. tests of materials	
44	Planning for construction	
46	Evaluation of materials/equipment suppliers	
3	Instructions and procedures related to inspection and testing	
6	Review and approval of documents	
20	Program for issuance, collection and return of measuring and testing equipment	
34	Specification checks	
35	Review of clients' and designers' comments	2
36	Review of work regulations	
38	In-situ tests of materials	
40	Inspection of results related to material tests	
45	Provision of technically qualified team members for the project	
51	Compliance with insurance requirements	

Contd....

Table:16; Ranking of Construction Quality Management Activities Based on Years in Business (Long Experience; More than or Equal to 20 Years)

Factor	Quality Management Activity	Overall Ranking
2	Responsibilities of personnel accountable for performing quality verification actions	
5	Control and distribution of documents	
7	Control of changes to documents	
8	Control of procurement documents	
11	Positive material identification	3
15	Qualifications of heat treatment personnel	
18	Verification of concrete work procedures	
19	Verification of equipment	
21	Establishment of a list of the measuring and testing equipment	
22	Maintenance of quality records	
33	Review/check of design drawings	
37	Constructability review	
47	Establishment of a communication program between the staff on the project	
48	Initiation of a reporting system	
49	Establishment of checklists	
4	Instructions and procedures related to compliance with the accepted criteria	
24	Documentation and reporting of the results of the surveillance	
25	Establishment of a system of incentives to motivate project personnel to produce quality work	4
42	Documentation of any record related to the project	

Contd...

Table:16; Ranking of Construction Quality Management[103] Activities based on Years in Business (Long Experience; More than or Equal to 20 Years)

Factor	Quality Management Activity	Overall Ranking
23	Training and qualifications of surveillance personnel on the project	
28	Qualifications and testing of new employees	
32	Calculation checks of the design	5
41	Inspection of physical structure of the project	
43	Documentation of construction methods	6
50	Initiation of a safety program	
1	Definition of the interrelationship and responsibilities of the quality program management and direction	
12	Materials and/or equipment retrieval	7
16	Verification of welding procedures personnel on the project	
29	On job training for employees	8
17	Verification of heat treatment procedures	
27	Qualifications and testing of your employees	9
13	Qualifications of welding personnel	
14	Qualifications of heat treatment personnel	10
30	Seminars for employees	
31	Short courses for employees	11

CONSTRUCTION PHASE

1	15
2	14
3	13
4	12
5	11
6	10
7	9
8	8
9	7
10	4
11	1
12	0
13	0
14	0
15	0

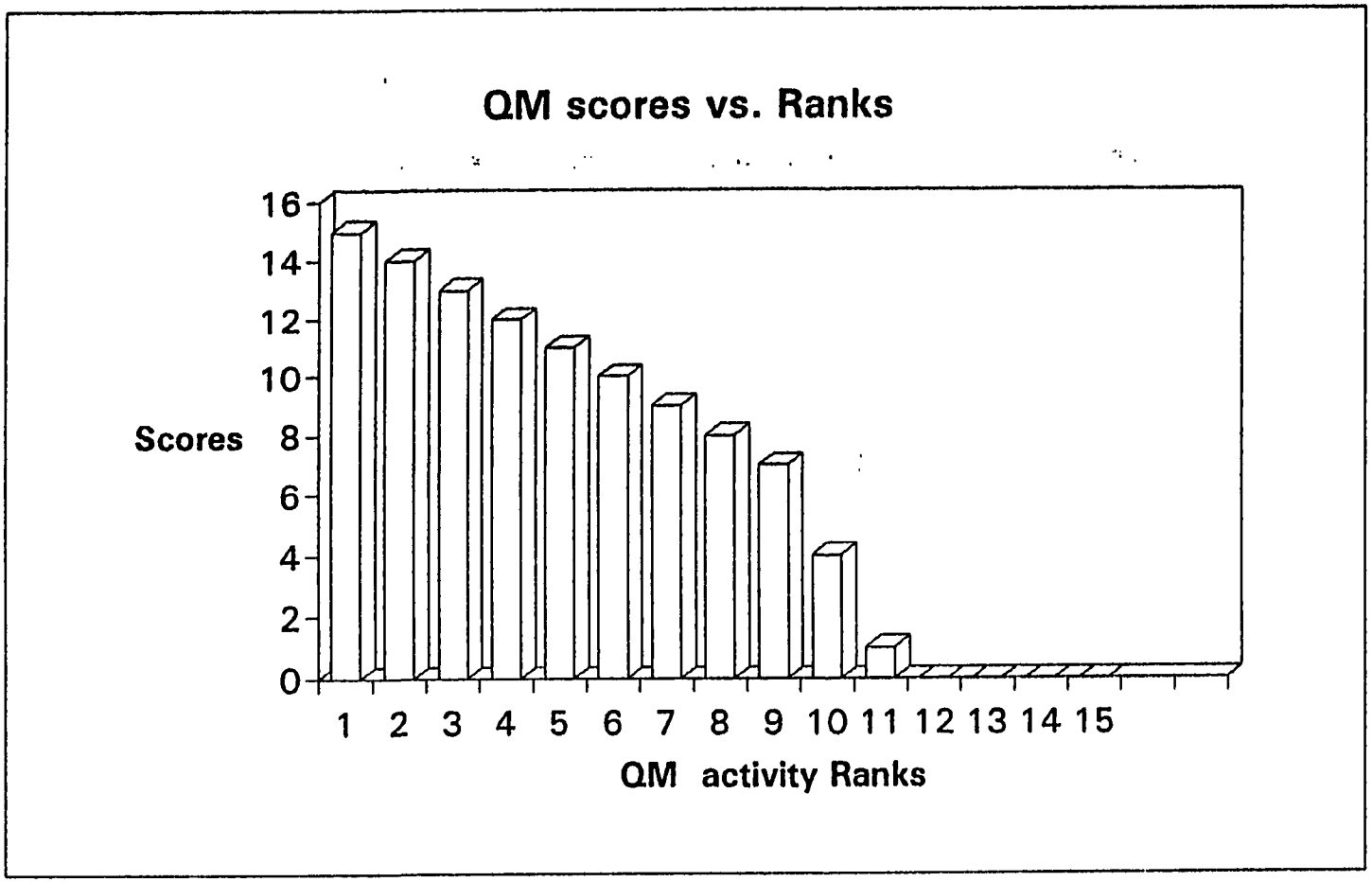

Figure # 13: Quality Management Scores Vs. Ranks, Construction Phase (Experience greater than or equal to 20 years)

Table:17: Ranking of Construction Quality Management Activities Based on Years in Business (Short Experience < 20 Years)

Factor	Quality Management Activity	Overall Ranking
3	Instructions and procedures related to inspection and testing	
5	Control and distribution of documents	
6	Review and approval of documents	
7	Control of changes to documents	
8	Control of procurement documents	
9	Inspection of purchased items on receipt	
10	Control of cleaning, preservation and storage	1
26	Subcontractor evaluation depending on reputation, past experience, financial position, etc.	
38	In-situ tests of materials	
39	Lab. tests of materials	
44	Planning for construction	
51	Compliance with insurance requirements	
46	Evaluation of materials/equipment suppliers	2
33	Review/check of design drawings	
34	Specification checks	
35	Review of clients' and designers' comments	3
36	Review of work regulations	

Contd....

Table:17; Ranking of Construction Quality Management Activities Based on Years in Business (Short Experience < 20 Years)

Factor	Quality Management Activity	Overall Ranking
48	Initiation of a reporting system	3
49	Establishment of checklists	
11	Positive material identification	4
15	Qualifications of heat treatment personnel	
18	Verification of concrete work procedures	
37	Constructability review	
42	Documentation of any record related to the project	
12	Materials and/or equipment retrieval	5
21	Establishment of a list of the measuring and testing equipment	
22	Maintenance of quality records	
28	Qualifications and testing of new employees	
40	Inspection of results related to material tests	
41	Inspection of physical structure of the project	
43	Documentation of construction methods	
45	Provision of technically qualified team members for the project	
4	Instructions and procedures related to compliance with the accepted criteria	6
19	Verification of equipment	
32	Calculation checks of the design	
47	Establishment of a communication program between the staff on the project	
50	Initiation of a safety program	

Contd...

Table:17; Ranking of Construction Quality Management Activities Based on Years in Business (Short Experience < 20 years)

Factor	Quality Management Activity	Overall Ranking
2	Responsibilities of personnel accountable for performing quality verification actions	
25	Establishment of a system of incentives to motivate project personnel to produce quality work	7
16	Verification of welding procedures personnel on the project	
20	Program for issuance, collection and return of measuring and testing equipment	8
27	Qualifications and testing of your employees	
23	Training and qualifications of surveillance personnel on the project	
24	Documentation and reporting of the results of the surveillance	9
1	Definition of the interrelationship and responsibilities of the quality program management and direction	
13	Qualifications of welding personnel	10
17	Verification of heat treatment procedures	
29	On job training for employees	
14	Qualifications of heat treatment personnel	11
30	Seminars for employees	12
31	Short courses for employees	13

CONSTRUCTION PHASE

1	15
2	14
3	12
4	11
5	10
6	9
7	8
8	7
9	6
10	5
11	4
12	2
13	1
14	0
15	0

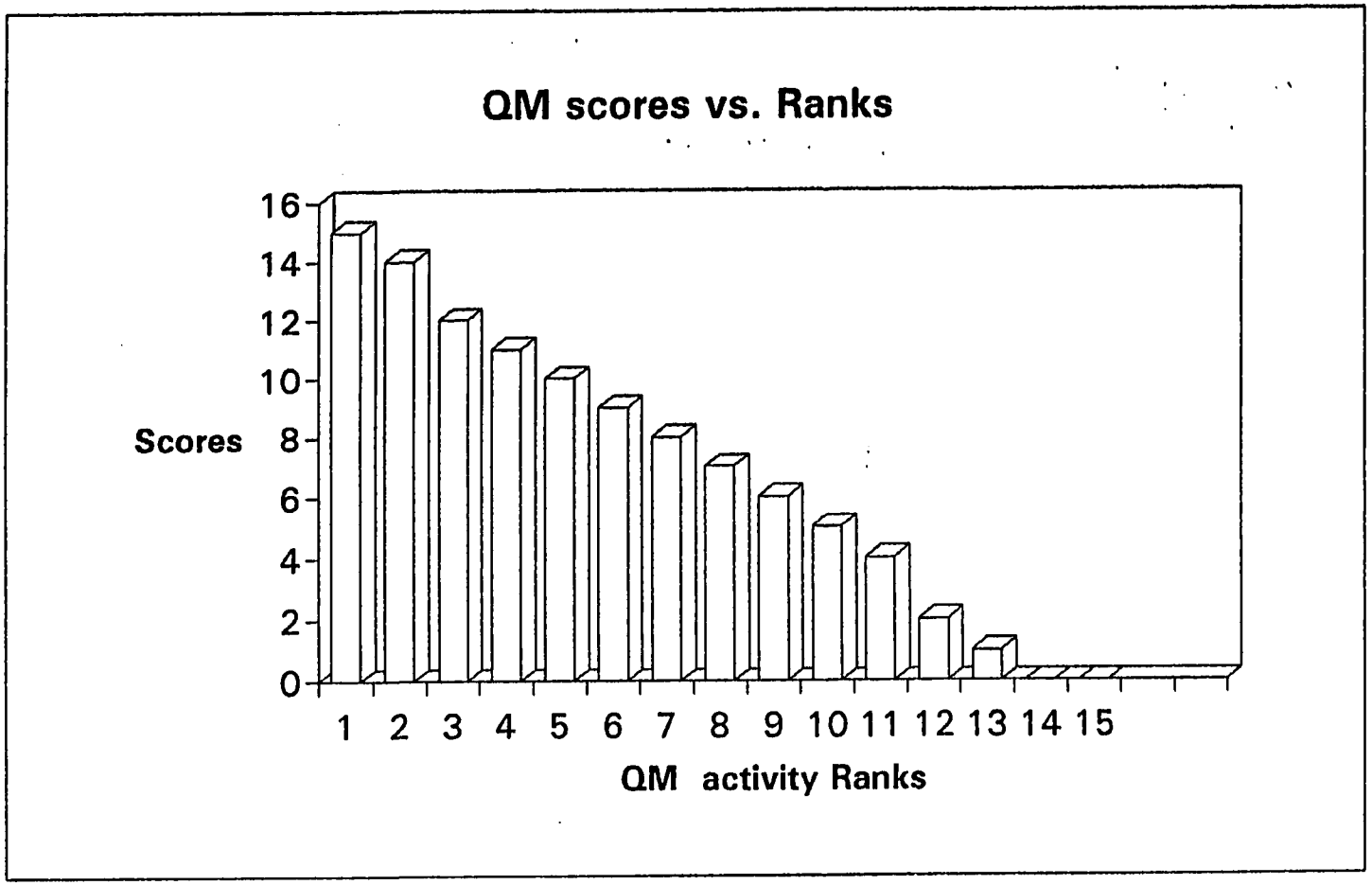

Figure # 14: Quality Management Scores Vs. Ranks, Construction Phase (Experience less than 20 years)

Table: 18: Ranking of Construction Quality Management Activities Based on Contract Size (See #1 < SR 50 Million)

Factor	Quality Management Activity	Overall Ranking
9	Inspection of purchased items on receipt	
10	Control of cleaning, preservation and storage	
26	Subcontractor evaluation depending on reputation, past experience, financial position, etc.	1
38	In-situ tests of materials	
39	Lab. tests of materials	
44	Planning for construction	
46	Evaluation of materials/equipment suppliers	
3	Instructions and procedures related to inspection and testing	
6	Review and approval of documents	2
51	Compliance with insurance requirements	
5	Control and distribution of documents	
7	Control of changes to documents	3
8	Control of procurement documents	

Contd....

Table:18; Ranking of Construction Quality Management Activities Based on Contract Size (Size #1 < SR 50 Million)

Factor	Quality Management Activity	Overall Ranking
34	Specification checks	4
35	Review of clients' and designers' comments	
36	Review of work regulations	
49	Establishment of checklists	
33	Review/check of design drawings	5
48	Initiation of a reporting system	
11	Positive material identification	6
15	Qualifications of heat treatment personnel	
18	Verification of concrete work procedures	
37	Constructability review	
40	Inspection of results related to material tests	
45	Provision of technically qualified team members for the project	
4	Instructions and procedures related to compliance with the accepted criteria	7
20	Program for issuance, collection and return of measuring and testing equipment	
21	Establishment of a list of the measuring and testing equipment	
22	Maintenance of quality records	
42	Documentation of any record related to the project	
47	Establishment of a communication program between the staff on the project	
12	Materials and/or equipment retrieval	8
19	Verification of equipment	
41	Inspection of physical structure of the project	

Contd...

Table:18; Ranking of Construction Quality Management Activities Based on Contract Size (Size #1 < SR 50 Million)

Factor	Quality Management Activity	Overall Ranking
2	Responsibilities of personnel accountable for performing quality verification actions	9
28	Qualifications and testing of new employees	
25	Establishment of a system of incentives to motivate project personnel to produce quality work	
32	Calculation checks of the design	
43	Documentation of construction methods	10
50	Initiation of a safety program	
23	Training and qualifications of surveillance personnel on the project	
24	Documentation and reporting of the results of the surveillance	11
16	Verification of welding procedures personnel on the project	12
1	Definition of the interrelationship and responsibilities of the quality program management and direction	
27	Qualifications and testing of your employees	13
29	On job training for employees	
13	Qualifications of welding personnel	
17	Verification of heat treatment procedures	14
14	Qualifications of heat treatment personnel	15
30	Seminars for employees	16
31	Short courses for employees	17

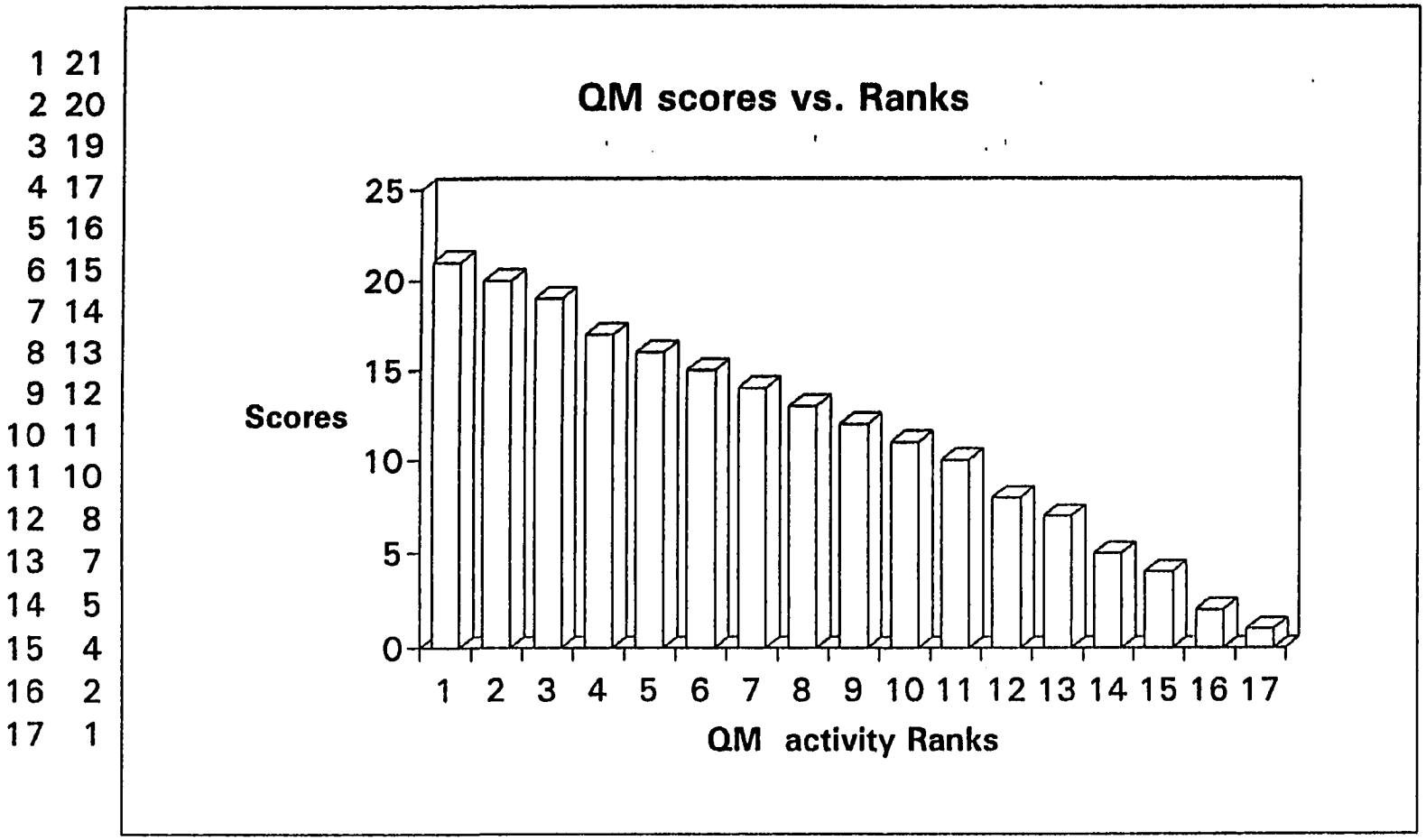

Figure # 15: Quality Management Scores Vs. Ranks, Construction Phase (Contract size less than SR.50 Million)

Table:19: Ranking of Construction Quality Management Activities Based on Contract Size (See #2 More than or Equal to SR 50 Million)

Factor	Quality Management Activity	Overall Ranking
2	Responsibilities of personnel accountable for performing quality verification actions	
3	Instructions and procedures related to inspection and testing	
5	Control and distribution of documents	
6	Review and approval of documents	
7	Control of changes to documents	
8	Control of procurement documents	
9	Inspection of purchased items on receipt	
10	Control of cleaning, preservation and storage	
11	Positive material identification	
15	Qualifications of heat treatment personnel	
18	Verification of concrete work procedures	
19	Verification of equipment	
21	Establishment of a list of the measuring and testing equipment	1
22	Maintenance of quality records	
25	Establishment of a system of incentives to motivate project personnel to produce quality work	
26	Subcontractor evaluation depending on reputation, past experience, financial position, etc.	
28	Qualifications and testing of new employees	

Contd....

Table:19; Ranking of Construction Quality Management Activities Based on Contract Size (Size # 2 More than or Equal to SR 50 Million)

Factor	Quality Management Activity	Overall Ranking
32	Calculation checks of the design	
33	Review/check of design drawings	
34	Specification checks	
35	Review of clients' and designers' comments	
36	Review of work regulations	
37	Constructability review	
39	Lab. tests of materials	1
40	Inspection of results related to material tests	
42	Documentation of any record related to the project	
43	Documentation of construction methods	
44	Planning for construction	
45	Provision of technically qualified team members for the project	
48	Initiation of a reporting system	
51	Compliance with insurance requirements	
16	Verification of welding procedures personnel on the project	
24	Documentation and reporting of the results of the surveillance	
38	In-situ tests of materials	
41	Inspection of physical structure of the project	
46	Evaluation of materials/equipment suppliers	2
47	Establishment of a communication program between the staff on the project	
49	Establishment of checklists	
50	Initiation of a safety program	

Contd...

Table:19; Ranking of Construction Quality Management Activities Based on Contract Size (Size #2 More than or Equal to SR 50 Million)

Factor	Quality Management Activity	Overall Ranking
1	Definition of the interrelationship and responsibilities of the quality program management and direction	
4	Instructions and procedures related to compliance with the accepted criteria	
17	Verification of heat treatment procedures	
20	Program for issuance, collection and return of measuring and testing equipment	3
23	Training and qualifications of surveillance personnel on the project	
27	Qualifications and testing of your employees	
12	Materials and/or equipment retrieval	
29	On job training for employees	4
13	Qualifications of welding personnel	
14	Qualifications of heat treatment personnel	5
30	Seminars for employees	
31	Short courses for employees	6

CONSTRUCTION PHASE

1	9
2	8
3	7
4	6
5	4
6	1
7	0
8	0
9	0
10	0
11	0
12	0
13	0
14	0
15	0
16	0
17	0

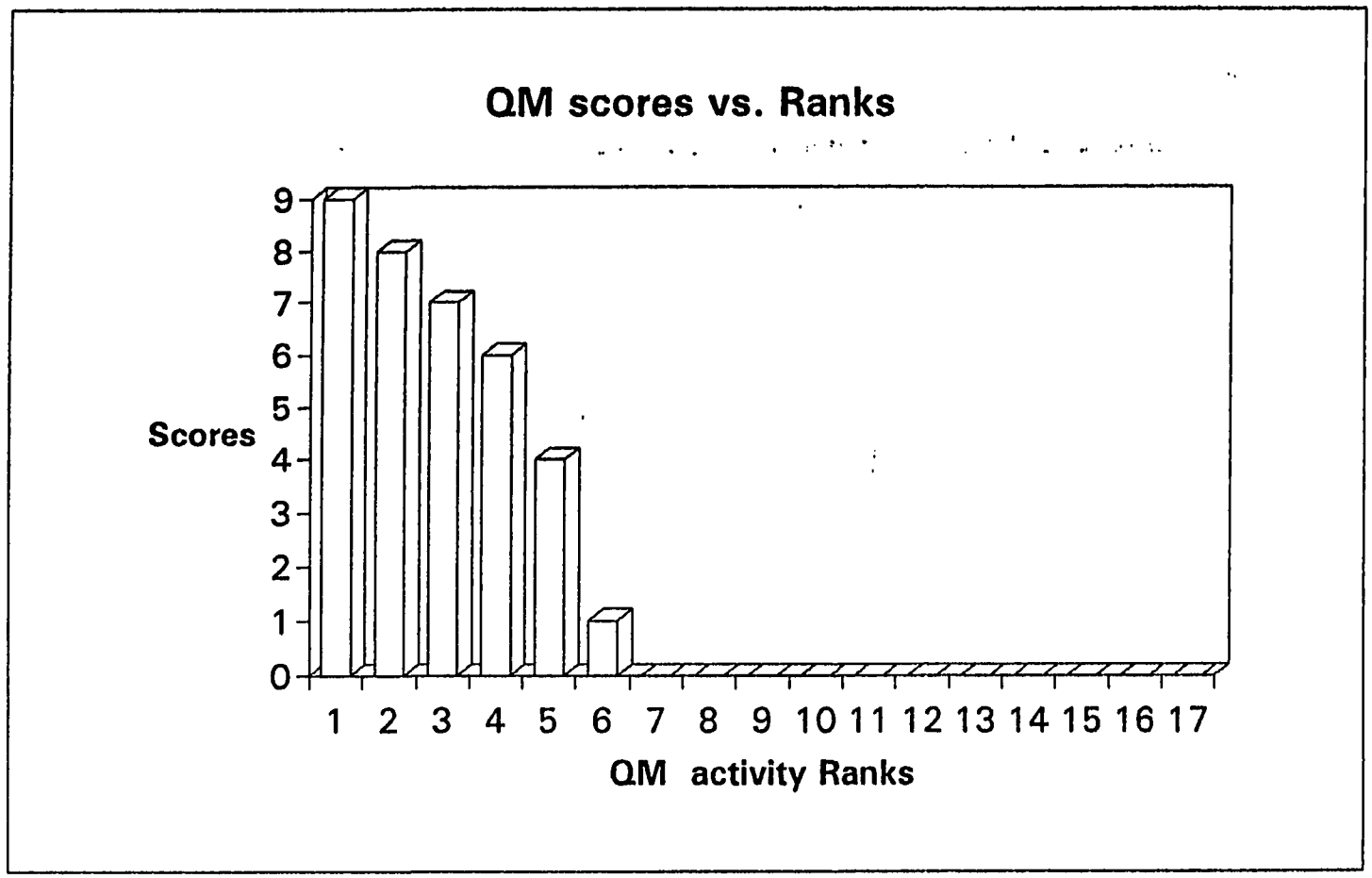

Figure # 16: Quality Management Scores Vs. Ranks, Construction Phase (Contract size greater than or equal to SR 50 Million)

4.2.5 *Ranking of Construction Quality Management Activities Based on Contract Duration*

Based on the average contract duration, the population was divided into two groups. Group number one is for contractors whose average contract duration is of less than one year, while group number two is for contractors whose average contract duration is greater than or equal to one year. The activities were ranked for each of these two groups. The results are shown in Tables 20 and 21 and Figures #17 and 18.

4.2.6 The Relationship between contractors characteristic & QM activities

To find the relation between contractor characteristics and quality management activities, General Linear Models (GLM) were used. Data used for this analysis are shown in Table 22 and the outcome of this analysis is summarized by the following equations:

$$Y' = 0.657 + 0.00096 \quad X'_1 \qquad (8)$$

where:

Y′ = Overall construction quality criteria of a contractor (Y′ is a dimensionless factor with value varying between zero and 1.0, the closer of the Y′ value to 1.0, the more usage of QM activities).

The importance of the Y′ value for a building contractor can be

seen through calculating the Y′ value for this contractor as to evaluate and compare its overall construction criteria with other building contractors.

X'_1 = Annual business volume of a contractor.

$$Y' = 0.693 + 0.001\ X'_2 \qquad (9)$$

where:

X'_2 = Average contract size of a contractor.

$$Y' = 0.689 + 0.035\ X'_3 \qquad (10)$$

where:

X'_3 = Average contract duration of a contractor.

$$Y' = 0.670 + 0.0038\ X'_4 \qquad (11)$$

where:

X'_4 = Years in business of a contractor.

Table:20: Ranking of Construction Quality Management Activities Based on Contract Duration (Group # 1, < 1 year)

Factor	Quality Management Activity	Overall Ranking
3	Instructions and procedures related to inspection and testing	
6	Review and approval of documents	
7	Control of changes to documents	
9	Inspection of purchased items on receipt	
10	Control of cleaning, preservation and storage	
26	Subcontractor evaluation depending on reputation, past experience, financial position, etc.	1
38	In-situ tests of materials	
39	Lab. tests of materials	
44	Planning for construction	
46	Evaluation of materials/equipment suppliers	
51	Compliance with insurance requirements	
5	Control and distribution of documents	
8	Control of procurement documents	
11	Positive material identification	
19	Verification of equipment	
22	Maintenance of quality records	
34	Specification checks	2
35	Review of clients' and designers' comments	
36	Review of work regulations	
45	Provision of technically qualified team members for the project	
48	Initiation of a reporting system	
49	Establishment of checklists	

Contd...

Table:20; Ranking of Construction Quality Management Activities Based on Contract Duration (Group # 1, < 1 year)

Factor	Quality Management Activity	Overall Ranking
2	Responsibilities of personnel accountable for performing quality verification actions	
4	Instructions and procedures related to compliance with the accepted criteria	
15	Qualifications of heat treatment personnel	
20	Program for issuance, collection and return of measuring and testing equipment	
21	Establishment of a list of measuring and testing equipment requiring calibration	3
33	Review/checks of design drawings	
37	Constructability review	
40	Inspection of results related to material tests	
42	Documentation of any record related to the project	
12	Materials and/or equipment retrieval	
23	Training and qualifications of surveillance personnel on the project	
24	Documentation and reporting of the results of the surveillance	4
25	Establishment of a system of incentives to motivate project personnel to produce quality work	
41	Inspection of physical structure of the project	
47	Establishment of a communication program between the staff on the project	

Contd...

Table:20; Ranking of Construction Quality Management Activities Based on Contract Duration (Group # 1, < 1 year)

Factor	Quality Management Activity	Overall Ranking
28	Qualifications and testing of new employees	
43	Documentation of construction methods	5
16	Verification of welding procedures	
27	Qualifications and testing of your employees	
32	Calculation checks of the design	6
50	Initiation of a safety program	
1	Definition of the interrelationship and responsibilities of the quality program management and direction	
13	Qualifications of welding personnel	
17	Verification of heat treatment procedures	7
29	On job training for employees	
14	Qualifications of heat treatment personnel	8
30	Seminars for employees	
31	Short courses for employees	9

CONSTRUCTION PHASE

1	8
2	7
3	6
4	5
5	4
6	3
7	2
8	1
9	0
10	0
11	0
12	0
13	0
14	0
15	0
16	0
17	0

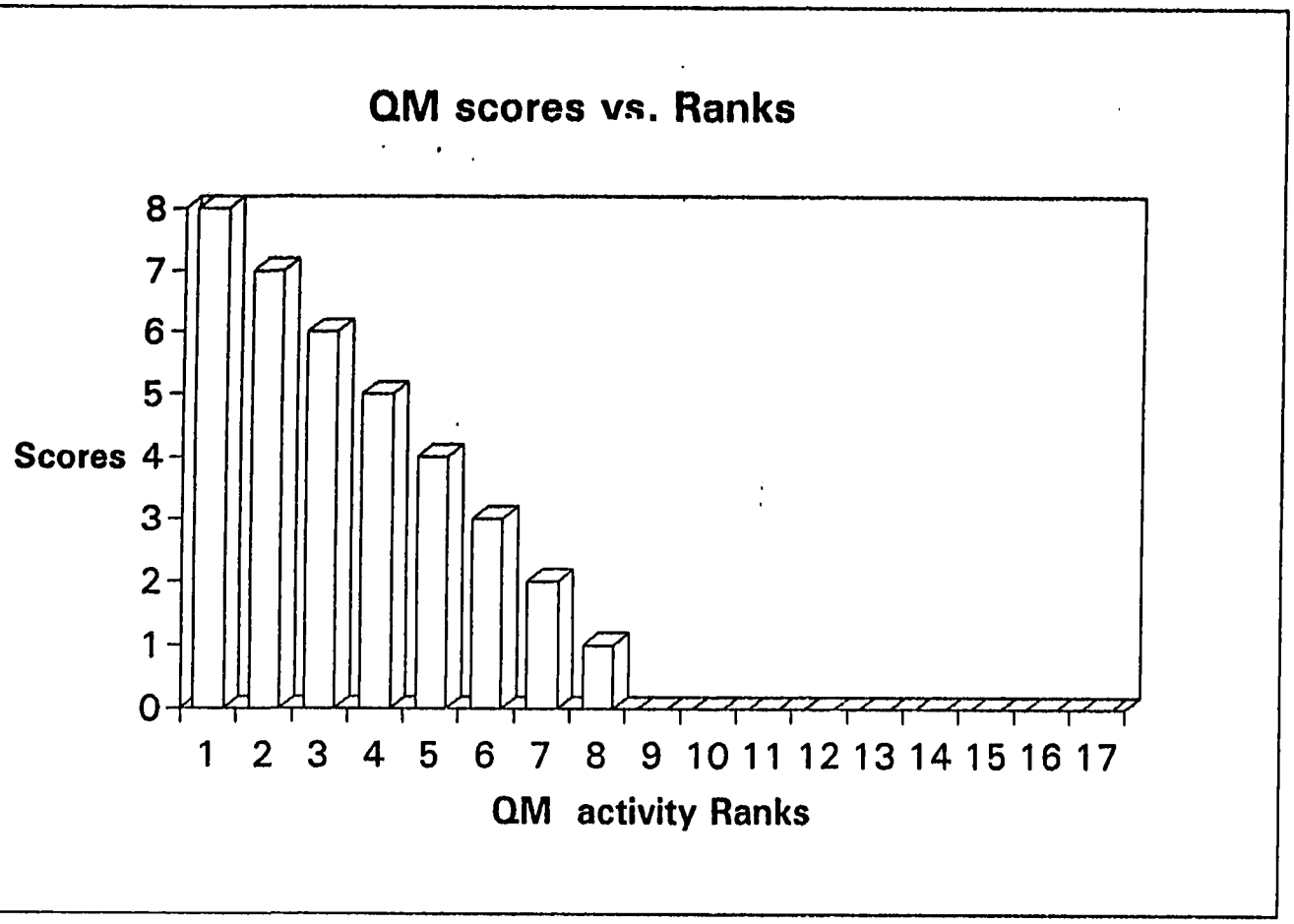

Figure # 17: Quality Management Scores Vs. Ranks, Construction Phase (Contract duration less than 1 year)

Table:21: Ranking of Construction Quality Management Activities Based on Contract Duration (Group # 2, More than or Equal to 1 Year)

Factor	Quality Management Activity	Overall Ranking
9	Inspection of purchased items on receipt	1
10	Control of cleaning, preservation and storage	
26	Subcontractor evaluation depending on reputation, past experience, financial position, etc.	
39	Lab. tests of materials	
44	Planning for construction	
3	Instructions and procedures related to inspection and testing	2
5	Control and distribution of documents	
6	Review and approval of documents	
8	Control of procurement documents	
38	In-situ tests of materials	
46	Evaluation of materials/equipment suppliers	
51	Compliance with insurance requirements	
7	Control of changes to documents	3
33	Review/checks of design drawings	4
34	Specification checks	
35	Review of clients' and designers' comments	
36	Review of work regulations	

Contd...

Table:21; Ranking of Construction Quality Management Activities Based on Contract Duration (Group #2, More than or Equal to 1 year)

Factor	Quality Management Activity	Overall Ranking
15	Qualifications of heat treatment personnel	
37	Constructability review	
40	Inspection of results related to material tests	5
48	Initiation of a reporting system	
49	Establishment of checklists	
11	Positive material identification	
18	Verification of concrete work procedures	
21	Establishment of a list of measuring and testing equipment requiring calibration	
28	Qualifications and testing of new employees	
32	Calculation checks of the design	6
42	Documentation of any record related to the project	
45	Provision of technically qualified team members for the project	
47	Establishment of a communication program between the staff on the project	
22	Maintenance of quality records	
41	Inspection of physical structure of the project	
43	Documentation of construction methods	7
50	Initiation of a safety program	

Contd...

Table:21; Ranking of Construction Quality Management Activities Based on Contract Duration (Group #2 ; More than or Equal to 1 Year)

Factor	Quality Management Activity	Overall Ranking
2	Responsibilities of personnel accountable for performing quality verification actions	
4	Instructions and procedures related to compliance with the accepted criteria	
19	Verification of equipment	8
20	Program for issuance, collection and return of measuring and testing equipment	
25	Establishment of a system of incentives to motivate project personnel to produce quality work	
12	Materials and/or equipment retrieval	9
16	Verification of welding procedures	
24	Documentation and reporting of the results of the surveillance	10
1	Definition of the interrelationship and responsibilities of the quality program management and direction	11
23	Training and qualifications of surveillance personnel on the project	
27 29	Qualifications and testing of your employees On job training for employees	12
17	Verification of heat treatment procedures	13
13	Qualifications of welding personnel	
14	Qualifications of heat treatment personnel	14
30	Seminars for employees	15
31	Short courses for employees	16

CONSTRUCTION PHASE

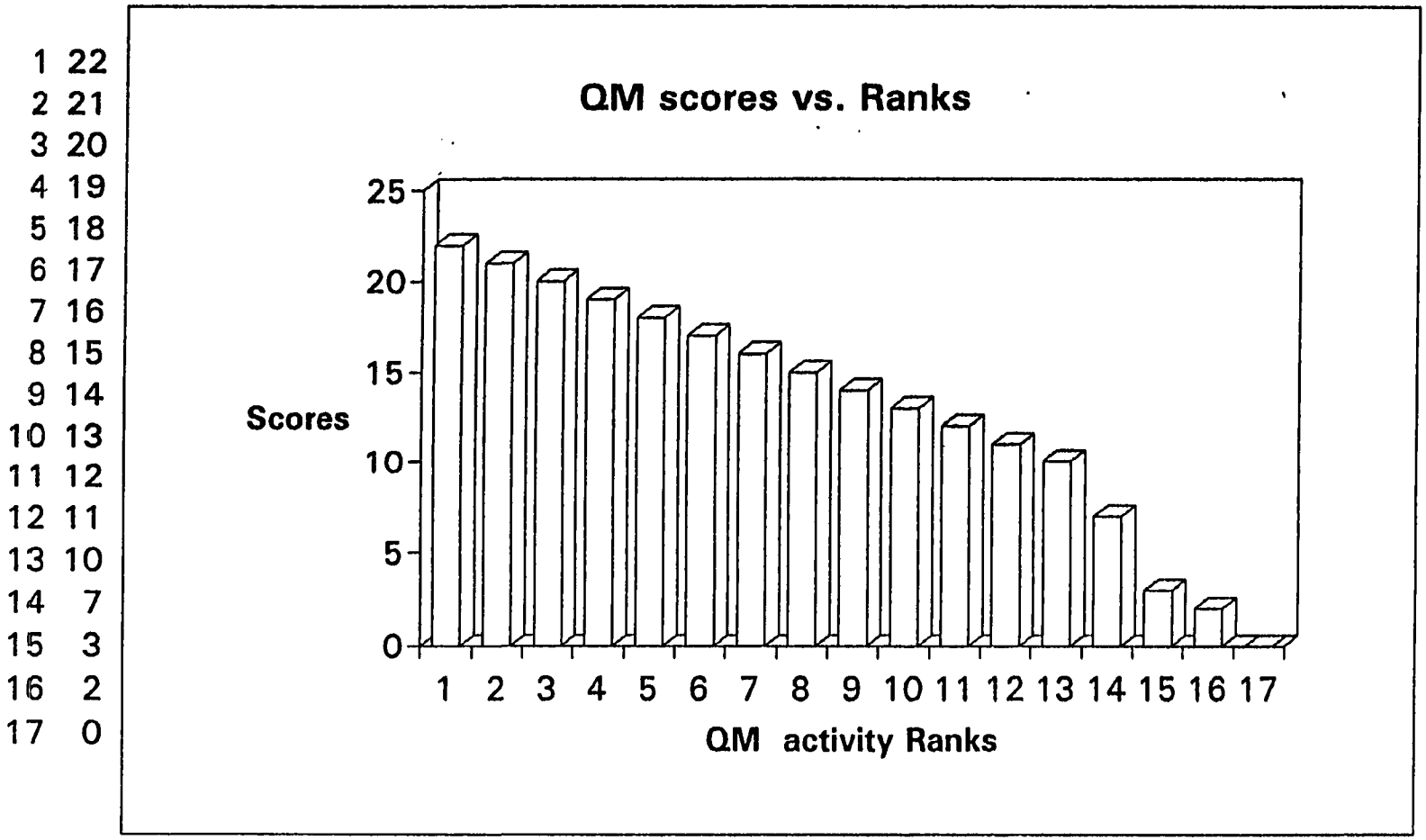

Figure # 18: Quality management Scores Vs. Ranks, Construction Phase (Contract duration greater than or equal to 1 year)

Table:22: Date for Regression Analysis, Construction Phase

Annual Business Volume (Millions of SR) X'1	Average Contract Size (Millions of SR) X'2	Average Contract Duration (Years) X'3	Years in Business X'4	Overall Construction Quality Criteria Y'
14	6	1	19	0.412
300	100	2	18	0.843
70	12	1	50	0.921
400	350	3	23	0.942
110	80	1.5	21	0.902
100	100	2	10	0.921
250	40	1.5	20	1.0
52	36	2	23	0.588
45	11	2	26	0.568
50	25	1	20	0.745
10	4.5	2	16	0.353
140	100	2	14	0.843
60	40	2	18	0.725
50	30	1.5	21	0.745
15	6	1	24	0.647
80	50	2	14	0.863

Contd....

Table:22; Date for Regression Analysis, Construction Phase

Annual Business Volume (Millions of SR) X'1	Average Contract Size (Millions of SR) X'2	Average Contract Duration (Years) X'3	Years in Business X'4	Overall Construction Quality Criteria Y'
20	4	2	22	0.843
120	100	2	23	0.902
40	10	1	30	0.921
70	50	2	17	0.804
70	8	1	23	0.725
70	25	2	26	0.902
40	5	1	21	0.745
10	5	2	18	0.333
420	300	3	21	0.942
100	25	1.5	20	0.823
21	10	2	15	0.745
15	7	2	24	0.333

CHAPTER 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.1 SUMMARY

The construction industry in the Kingdom of Saudi Arabia , like that in any other country, faces the serious challenge of improving its performance. Quality of design and construction are primary objectives in the construction industry .

A review of the literature revealed that there are many important quality management activities which can be used in the design and construction phases of a constructed project. This study tried to determine quality management activities used in the design and construction phases of constructed projects in Saudi Arabia .

A total of 175 questionnaires were mailed to consulting offices and 160 questionnaires were mailed to the building contractors all over the Kingdom. The main part of both types of questionnaires was devoted to the determination of used quality management activities in the design and construction phases of constructed projects.

Upon receiving back the questionnaires , the needed anaylsis were performed:

5.1.1 Quality Management of the Design Phase

5.1.1.1 Overall Ranking of Quality Management Activities

Drawing checks, functionality review, and provision of clear, concise and uniform plans and specifications were ranked as No.1 and got the highest total scores in the overall ranking of Design Quality Management (QM) activities. On the other hand, education of firm's employees through short courses and seminars, and arrangement for organizational and project peer reviews were ranked as No.11 and got the lowest total scores. Calculation of frequencies were also introduced.

5.1.1.2 Ranking of Design Quality Management Activities Based on Annual Business Volume

The total population was divided into five categories:

Category 1 = Up to 5 million

Category 2 = 5 to 10 million

Category 3 = 10 to 100 million

Category 4 = 100 to 500 million

Category 5 = Over 500 million

5.1.1.3 Ranking of QM Activities Based on Years in Business

Based on the experience of the consulting firms, the population was divided into two groups, below ten years and above or equal to ten years in business. The activities were ranked for each of the mentioned two groups.

5.1.1.4 The Relationship between firm's characteristic and QM activities

Step-wise regression analysis was used to select the significant variables

for the design phase which were:

- Annual business volume of the consulting firm.
- Years in business of the consulting firm.
- Average contract duration of the consulting firm.

After that, simple linear regression and multiple regression were performed for the selected significant variables.

5.1.2 Quality Management of the Construction Phase

5.1.2.1 Overall Ranking of Quality Management Activities

Inspection of purchased items on receipt, control of cleaning, preservation and storage, subcontractor evaluation, lab tests of materials, and planning for construction were the QM activities ranked as No.1 and got the highest total points, while education of firm's employees through short courses and seminars were the QM activities ranked as No. 20 and No.21 and got the lowest total points.

Calculation of frequencies were also introduced.

5.1.2.2 Ranking of Construction Quality Management Activities Based on Annual Business Volume

The total population was divided into three categories:

Category 1 = Less than SR 50 million

Category 2 = From SR 50 million to SR 100 million

Category 3 = Greater than SR 100 million.

5.1.2.3 Ranking of Construction QM Activities Based on Years in Busines

Based on the experience of the contractors, the population was divided into two groups, one below and one at or above 20 years in business.

5.1.2.4 Ranking of Construction QM Activities Based on Contract Size

The population was divided into two sizes. Size number one is for contractors whose average contract is less than SR 50 million, while size number two is for contractors whose average contract is greater than or equal to SR 50 million.

5.1.2.5 Ranking of Construction QM Activities Based on Contract Duration

The population was divided into groups. Group number one is for contractors whose average contract duration is of less than one year, while group number two is for contractors whose average contract duration is greater than or equal to one year.

5.1.2.6 The relationship between contractor's characteristic & QM activities

Step-wise regression analysis was used to select the significant variables for the construction phase which were:

- Annual business volume of the contractor.
- Average contract size of the contractor.
- Average contract duration.
- Years in business.

Simple linear regression was performed for the selected significant variables.

The last chapter of the thesis contains the summary, conclusions, recommendations, and recommendations for further studies.

5.2 CONCLUSIONS

The survey analysis indicates and reveals the following conclusions:

A. Design Phase

1. The highest affirmative response from consulting offices was in their usage of quality management activities drawing checks, functionality review, and provision of clear, concise, and uniform plans and specifications. The survey further showed that continued education of their employees and arrangement for peer reviews were among their lowest priorities.

2. The highest affirmative response from consulting offices with annual business volume up to SR 5 million was in their usage of QM activities, establishment of qualification parameters for persons whose activities affect the quality of work, drawing checks, review of client's comments, review of standards and regulations, functionality review, capacity review, provision of technically qualified design team members, provision of cost estimate of the project, submission of progress reports to the owner, and provision of clear, concise and uniform plans and specifications. Establishment of an incentive system and education of their employees were their lowest priorities.

3. The highest affirmative response from consulting offices with annual business volume from SR 5 to SR 10 million was in their usage of QM activities, establishment of an incentive system, on the job training for employees, calculation checks of the design, drawing

checks, specification checks, drafting checks, space allocation checks and aesthetics, functionality review, documentation, frequent contacts between the project parties, communication, provision of technically qualified design team members, provision of cost estimate of the project, and provision of clear, concise and uniform plans and specifications. Education of their employees and arrangement for peer reviews were their lowest priorities.

4. The highest affirmative response from consulting offices with annual business volume from SR 10 to SR 100 million was in their usage of QM activities, calculation checks of the design, drawing checks, specification checks, drafting checks, review of client's comments, check of standards, check of space allocation, check of aesthetics, functionality review, capacity review, and provision of clear, concise and uniform plans and specifications. Education of their employees and arrangement for peer reviews were their lowest priorities.

5. The affirmative response from consulting offices with annual business volume from SR 100 to SR 500 million was in their usage of all QM activities, except establishment of an incentive system, calculation checks of the design, formal drafting check, check of aesthetics, and arrangement for project peer review which were in their lowest priorities.

6. The affirmative response from consulting offices with annual business volume over SR 500 million was in their usage of all QM activities, except establishment of an incentive system which came in their second priority.

7. The affirmative response from consulting offices with long life was in their usage of drawing checks, review of client's comments, check of space allocation, functionality review, capacity review, provision of technically qualified design team members and provision of clear, concise and uniform plants and specifications. The survey showed that education of firm's employees and arrangement for organizational and project peer reviews were among their lowest priorities.

8. The affirmative response from consulting offices with short life in business was in their usages of calculation checks of the design, drawing checks, specification checks, drafting checks, check of standards and regulations, functionality review, frequent contact between the project parties, provision of cost estimate of the project, submission of progress reports to the owner and provision of clear, concise and uniform plans and specifications. Education of firm's employees and arrangement for peer reviews were their lowest priorities.

B. Construction Phase

1. The survey showed that building contractors carry out in-situ and lab tests on materials, since these quality control procedures are mentioned in the contract documents.

2. The survey showed that building contractors prepare time schedules for (i.e., plan) their work.

3. The highest affirmative response from contractors was in their usage of QM activities inspection of purchased items on receipt, control of

cleaning, preservation and storage, subcontractor evaluation, lab tests of materials and planning for construction . The survey showed that education of firm's employees and qualifications of heat treatment personnel were among their lowest priorities.

4. The highest affirmative response from contractors with annual business volume less than SR 50 million was in their usage of QM activities, review and approval of documents, inspection of purchased items, control of cleaning, preservation and storage, subcontractor evaluation, in-situ tests of materials, lab tests of materials, planning for construction , evaluation of materials/equipment suppliers, and compliance with insurance requirements. Qualifications of heat treatment personnel and education of firm's employees were among their lowest priorities.

5. The highest affirmative response from contractors with annual business volume from SR 50 million to SR 100 million was in their usage of QM activities, instructions related to inspection, testing, and compliance with accepted criteria, documentation, maintenance of quality records, incentive systems, subcontractor evaluation, specification checks, in-situ and lab tests of materials, planning for construction , communication program, and provision of technically qualified team members. The survey further showed that education of firm's employees was among their lowest priorities.

6. The highest affirmative response from contractors with annual business volume over SR 100 million was in their usage of QM activities, quality verification actions, instructions related to inspection and testing, dcumentation, control of purchased items,

quality records, subcontractor evaluation, checks of the design and specifications and regulations, constructability review, planning for construction, reporting system, using of checklists. Education of firm's employees was among their lowest priorities.

7. The highest affirmative response from contractors with long life in business more than or equal to 20 years was in their usage of QM activities, inspection of purchased items, subcontractor evaluation, lab test of materials, planning for construction , and evaluation of materials/equipment suppliers. Education of firm's employees was among their lowest priorities.

8. The highest affirmative response from contractors with short life in business less than 20 years was in their usage of QM activities, instruction related to inspection and testing, documentation, subcontractor evaluation, in-situ lab tests of materials, planning for construction , and compliance with insurance requirements. The survey showed that education of firm's employees was in their lowest priorities.

9. The highest affirmative response from contractors with contract sizes of less than SR 50 million was in their usage of QM activities, inspection of purchased items on receipt, control of cleaning, preservation and storage, subcontractor evaluation, in-situ and lab tests of materials, planning for construction , and evaluation of materials/equipment suppliers. The survey showed that education of firm's employees and qualifications of heat treatment personnel were their lowest priorities.

10. The affirmative response from contractors with contract sizes of more than or equal to SR 50 million was in their usage of all QM activities except the education of firm's employees, qualification of heat, welding personnel, instruction and procedures related to compliance with the accepted criteria, training of surveillance personnel on the project, definition of interrelationship and responsibilities of quality program management and direction, which were their second priorities.

11. The highest affirmative response from contractors taking contracts of less than 1 year was in their usage of QM activities, instruction related to inspection and testing, documentation, subcontractor evaluation, in-situ and lab tests of materials, planning for construction , evaluation of materials/equipment suppliers, and compliance with insurance requirements. The survey showed that education of firm's employees was their lowest priority.

12. The highest affirmative response from contractors taking contracts of more than or equal to 1 year was in their usage of QM activities, control of cleaning, preservation and storage, inspection of purchased items, subcontractor evaluation, lab tests of materials and planning for construction . The survey showed that qualification of heat treatment personnel and education of firm's employees were their lowest priorities.

5.3 RECOMMENDATIONS

1. In order for consulting firms to assure quality in the design phase of constructed projects, they are advised to consider the following factors:

   Education of the firm's employees, calculation checks of the design, drawing checks, documentation of any documents related to the design of the project, communication programs, provision of a technically qualified design team, provision of a cost estimate of the project, submission of progress reports, provision of clear, concise and uniform plans and specifications, office library facilities, and arrangement for organizational and project peer reviews.

2. In order for contractors to assure quality in the construction phase of constructed projects, they are advised to consider the following factors:

   Documentation, inspection of purchased items, materials and equipment retrieval, qualifications of work personnel, verification of procedures and equipment, maintenance of quality records, establishment of a system for incentives, continuing education of employees, subcontractor evaluation, in-situ tests of materials, lab tests of materials, planning for construction , communication programs, reporting systems, safety programs, and the establishment of checklists.

5.4 RECOMMENDATIONS FOR FUTURE STUDIES

Future studies could pursue the following:

1. Codes can be assigned to quality management activities and deviation rework categories, and integrated into work breakdown structure cost coding systems.

2. A cost tracking system for design and construction phases can be developed in which a work breakdown structure (WBS) coding system may be used to track costs of particular work packages.

3. Quality cost tracking during other phases of the construction process (preplanning, procurement, start-up, operations) can be considered.

"APPENDICES"

APPENDIX I

QUALITY QUESTIONNAIRE FOR

DESIGN PHASE

بسم الله الرحمن الرحيم

Ministry of Higher Education
King Fahd University of Petroleum & Minerals
DHAHRAN 31261, SAUDI ARABIA

وزارة التعليم العالي
جامعة الملك فهد للبترول والمعادن
الظهران ٣١٢٦١ المملكة العربية السعودية

سعاده الأخ /

السلام عليكم ورحمه الله وبركاته :::

يقوم قسم الهندسه وإداره التشييد في كليه تصاميم البيئة بجامعه الملك فهد للبترول والمعادن بدراسة النشاطات الإدارية المستخدمة من قبل المكاتب الإستشارية في المملكه العربية السعودية لضمان الجوده في مرحله تصميم المشاريع الهندسية .

الهدف من الدراسه هوالتعرف على النشاطات الإدارية المستخدمة من قبل المكاتب الإستشارية في المملكه .

أرجو منك التفضل بتزويدنا بالمعلومات الضرورية المتعلقة بدور شركتكم خلال مرحله التصميم . وللمعلوميه فإن كل الردود ستبقى سرية للغاية وسوف تستعمل لغرض الأبحاث فقط.نحن نقدر حاجتكم الماسة للوقت ، ولكن مشاركتكم في هذا البحث ضرورية للغاية .
إذا كنت ترغب في الحصول على نتائج هذا البحث فما عليك إلا أن تزودنا بعنوانك . .
شاكرين تعاونك معنا على تعبئه هذا الإستبيان .

د . عبد العزيز بوبشيت
مدير برنامج هندسةإدارة التشييد

أحمد العبد الرزاق
مساعد باحث

Telephone : 860-0000
Telex : 801060 KFUPM SJ
Cable. : AL-JAMAAH

تلفون : ٨٦٠ - ٠٠٠٠ (٠٣)
تلكس : ٨٠١٩٥٠ حافهد

بسم الله الرحمن الرحيم

Ministry of Higher Education
King Fahd University of Petroleum & Minerals

وزارة التعليم العالي
جامعة الملك فهد للبترول والمعادن

Dear Respondent:

The Construction Engineering and Management Department of the College of Environmental Design at King Fahd University of Petroleum and Minerals is presently engaged in a study that will try to find out the quality management activities used by the consulting offices in Saudi Arabia to assure quality in the design phase of a project.

The objective of the study is to define the quality management activities used by the consulting officers in Saudi Arabia.

We are asking you to participate by providing needed information related to your organization's involvement during design phase. The answers of the questionnaire will be used only for the purpose of study, without mentioning the name of the organization. We know that there are numerous demands on your time. But your involvement is really important for this study.

If you are interest in the outcome of this survey, you may provide us with a P.O. Box number so that we can send you the results of the study. Your assistance in filling out this questionnaire will be very much appreciated.

Sincerely yours

Abdul Aziz Bubshait, Ph.D.
Director of CEM - Graduate Program

Ahmad Al-Abdul Razzak
Graduate Student

Quality Questionnaire

For Design Phase

Title of the Respondent: _____

I. General questions about the firm

(a) Type of firm
(please indicate the percentage of work) % of work

a) Building _____

b) Engineering (highways, ... others) _____

c) Industrial (power plants, refinery) _____

d) Others (please specify) _____

Total = 100 %

(b) Annual business volume
(Millions of Saudi Riyals) _____

(c) Number of permanent employees _____

(d) Number of temporary employees _____

(e) Average contract duration (months) _____

(f) Number of years in business _____

(g) Annual profit ratio _____

II. Questions about the Quality Management Activities: which of the following activities are used by your company to assure quality in the design phase? Please respond by putting a tick next to the appropriate answer.

	Quality Management Activities	Yes	No
1	Definition of the interrelationship and responsibilities of the quality program management and direction		
2.	Establishment of qualification parameters for persons whose activities affect the quality of work.		
3.	Establishment of an incentive system to motivate persons to produce quality work.		
4.	On the job training for employees.		
5.	Short courses for employees.		
6.	Seminars for employees.		
7.	Calculation checks of the design.		
8.	Drawing checks / review.		
9.	Specification checks / review.		
10.	Formal drafting check / review.		
11.	Review of clients' comments.		
12.	Review / check of standards.		

	Quality Management Activities	Yes	No
13.	Review / check of regulations.		
14.	Review / check of space allocation.		
15.	Review / check of aesthetics.		
16.	Functionality review		
17.	Capacity review.		
18.	Documentation of any documents related to the design of the project. . .		
19.	Frequent contacts between the project parties		
20.	Communication program.		
21.	Communication to resolve conflicts.		
22.	Provision of technically qualified design team members.		
23.	Provision of cost estimate of the project.		
24.	Submission of progress reports to the owner.		
25.	Standardization of office procedures.		
26.	Office library facilities.		
27.	Provision of clear, concise and uniform plans and specifications.		

	Quality Management Activities	Yes	No
28.	Arrangements for organizational peer review		
29.	Arrangements for project peer review		
30.	Other (please specify)		

III. If you have any additional comments that may help us to understand your firm's method of assuring quality in the design phase, please feel free to add them below:

_____

_____

_____

_____

_____

Thank you very much for your cooperation.

Definitions

Communication: Communicating information such as requirements, expectations, scope, costs, schedules and technical data, in order to assure quality in the constructed project.

Documentation: Any record or pictorial information describing, defining, specifying, reporting or certifying activities, requirements, procedures or results.

Organizational Peer Review: Consider a design organization as a whole, focusing on its policies, procedures, and practices and not on any single project.

Peer Review: A technique that promotes a company's quality in both design and services.

Personnel Qualifications: The characteristics or abilities gained through training or experience, or both, that enable an individual to perform a required function.

Project Peer Review: Consider particular projects, not the organization's practice is general.

Quality Program: All those planned activities or programs necessary to provide adequate confidence that design will conform to established requirements.

بسم الله الرحمن الرحيم

وزارة التعليم العالي
جامعة الملك فهد للبترول والمعادن
كلية تصاميم البيئة
برنامج هندسة وإدارة التشييد

Ministry of Higher Education
King Fahd University of Petroleum & Minerals
COLLEGE OF ENVIRONMENTAL DESIGN
Construction Engineering & Management Program

التاريخ : ١٥ / ١ / ١٩٩٢م

سعاده الأخ /
السلام عليكم ورحمه الله وبركاته

إلحاقا لخطابنا المرفق به الإستبيان الخاص بدراسة النشاطات الإدارية المستخدمة من قبل المكاتب الإستشارية في المملكة العربية السعودية لضمان الجودة في مرحلة تصميم المشاريع الهندسية .

ونظرا لأنه لم يصلنا الإستبيان المذكور حتى تاريخة ، وحيث أن مشاركتكم في تعبئه هذا الإستبيان تشكل عنصرا رئيسيا في نجاح هذا البحث وتطبيقة .

لذا نأمل التكرم بالتعاون معنا في تعبئة الإستبيان ومن ثم إعادته الى العنوان التالي في موعد أقصاه ٢٠ / ٢ / ١٩٩٢م .

جامعة الملك فهد للبترول والمعادن
الظهران ٣١٢٦١
ص . ب ٧٠٨٦
أحمد العبد الرزاق

د . عبد العزيز بوبشيت
مدير برنامج هندسة وإدارة التشييد

أحمد العبد الرزاق
مساعد باحث

APPENDIX II

QUALITY QUESTIONNAIRE FOR

CONSTRUCTION PHASE

بسم الله الرحمن الرحيم

Ministry of Higher Education
King Fahd University of Petroleum & Minerals
DHAHRAN 31261, SAUDI ARABIA

وزارة التعليم العالي
جامعة الملك فهد للبترول والمعادن
الظهران ٣١٢٦١ المملكة العربية السعودية

سعاده الأخ /

السلام عليكم ورحمه الله وبركاته :::

يقوم قسم الهندسه وإداره التشييد في كليه تصاميم البيئة بجامعه الملك فهد للبترول والمعادن بدراسة النشاطات الإدارية المستخدمة من قبل مقاولي البناء في المملكه العربية السعودية لضمان الجوده في مرحله تنفيذ المشاريع الهندسية .

الهدف من الدراسه هوالتعرف على النشاطات الإدارية المستخدمة من قبل مقاولي البناء في المملكه .

أرجو منك التفضل بتزويدنا بالمعلومات الضرورية المتعلقة بدور شركتكم خلال مرحله التنفيذ . وللمعلوميه فإن كل الردود ستبقى سرية للغاية وسوف تستعمل لغرض الأبحاث فقط.نحن نقدر حاجتكم الماسة للوقت ، ولكن مشاركتكم في هذا البحث ضرورية للغاية .
إذا كنت ترغب في الحصول على نتائج هذا البحث فما عليك إلا أن تزودنا بعنوانك .
شاكرين تعاونك معنا على تعبئه هذا الإستبيان .

د . عبد العزيز بوبشيت
مدير برنامج هندسة إدارة التشييد

أحمد العبد الرزاق
مساعد باحث

بسم الله الرحمن الرحيم

Ministry of Higher Education
King Fahd University of Petroleum & Minerals

وزارة التعليم العالي
جامعة الملك فهد للبترول والمعادن

Dear Respondent:

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The objective of the study is to define the quality management activities used by the building contractors in Saudi Arabia.

We are asking you to participate by providing needed information related to your organization's involvement during construction phase. The answers of the questionnaire will be used only for the purpose of study, without mentioning the name of the organization. We know that there are numerous demands on your time. But your involvement is really important for this study.

If you are interest in the outcome of this survey, you may provide us with a P.O. Box number so that we can send you the results of the study. Your assistance in filling out this questionnaire will be very much appreciated.

Sincerely yours

Abdul Aziz Bubshait, Ph.D.
Director of CEM - Graduate Program

Ahmad Al-Abdul Razzak
Graduate Student

Quality Questionnaire

For Construction Phase

Title of the Respondent: _____

I. General questions about the firm

(a) Grade of the contractor
(According to the Ministry of Housing and Public work) _____

(b) Annual business volume
(Millions of Saudi Riyals) _____

(c) Number of permanent employees _____

(d) Amount of work in (SR) subcontracted on average job:

(1) None _____ (2) Less than 25% _____ (3) 26-50% _____
(4) 51% - 75% _____ (5) 76-100% _____

(e) Average contract size
(Millions of SR) _____

(f) Average contract duration (years) _____

(g) Number of years in Business _____

(h) Annual profit ratio _____

II. Questions about the Quality Management Activities: which of the following activities are used by your company to assure quality in the construction phase? Please respond by putting a tick next to the appropriate answer.

	Quality Management Activities	Yes	No
1	Definition of the interrelationship and responsibilities of the quality program management and direction.		
2.	Responsibilities of personnel accountable for performing quality verification actions.		
3.	Instructions and procedures related to inspection and testing.		
4.	Instructions and procedures related to compliance with accepted criteria.		
5.	Control and distribution of documents.		
6.	Review and approval of documents.		
7.	Control of changes to documents.		
8.	Control of procurement documents.		
9.	Inspection of purchased items on receipt.		
10.	Control of cleaning, preservation and storage.		
11.	Positive material identification.		
12.	Materials and/or equipment retrieval.		

	Quality Management Activities	Yes	No
13.	Qualifications of welding personnel.		
14.	Qualifications of heat treatment personnel.		
15.	Qualifications of personnel engaged in work with concrete.		
16.	Verification of welding procedures.		
17.	Verification of heat treatment procedures.		
18.	Verification of concrete work procedures.		
19.	Verification of equipment.		
20.	Program for issuance, collection and return of measuring and testing equipment.		
21.	Establishment of a list of the measuring and testing equipment requiring calibration.		
22.	Maintenance of quality records.		
23.	Training and qualifications of surveillance personnel on the project.		
24.	Documentation and reporting of the results of the surveillance.		
25.	Establishment of a system of incentives to motivate project personnel to produce quality work.		

	Quality Management Activities	Yes	No
26.	Subcontractor evaluation depending on reputation, past experience, financial position, ...etc.		
27.	Qualifications and testing of your employees.		
28.	Qualifications and testing of new employees.		
29.	On job training for employees.		
30.	Seminars for employees. .		
31.	Short courses for employees		
32.	Calculation checks of the design		
33.	Review / checks of design drawings		
34.	Specification checks		
35.	Review of clients' and designers' comments		
36.	Review of work regulations		
37.	Constructability review		
38.	In-situ tests of materials		
39.	Lab. tests of materials.		
40.	Inspection of results related to material tests.		

	Quality Management Activities	Yes	No
41.	Inspection of physical structure of the project.		
42.	Documentation of any records related to the project.		
43.	Documentation of construction methods.		
44.	Planning for construction.		
45.	Provision of technically qualified team members for the project.		
46.	Evaluation of materials / equipment suppliers.		
47.	Establishment of a communication program between the staff on the project.		
48.	Initiation of a reporting system.		
49.	Establishment of checklists.		
50.	Initiation of a safety program.		
51.	Compliance with insurance requirements.		
52.	Other (please specify)		

III. If you have any additional comments that may help us understand your firm's method of assuring quality in the construction phase, please feel free to add them below:

_____

_____

_____

_____

_____

Thank you very much for your cooperation.

Definitions

Communications: Communicating information such as requirements, expectations, scope, costs, schedules and technical data, in order to assure quality in both construction processes, and the final product.

Constructability: The optimum use of construction knowledge and experience in planning, procurement, and field operations to achieve overall project objectives.

Documentation: Any recorded or pictorial information describing, defining, specifying, reporting or certifying activities, requirements, procedures or results.

Inspection: The actual act of verifying the conformity of a material, structure, component or system to its requirements.

Material tests: The determination or verification of the capability of materials to meet specified requirements by subjecting the materials to a set of physical, chemical, environmental or operating conditions.

Personnel Qualifications: The characteristics or abilities gained through training or experience or both that enable an individual to perform a required function.

Quality Program: All those planned activities or programs necessary to provide adequate confidence that construction will conform to established requirements.

Subcontractor Evaluation: An appraisal to determine whether or not subcontractors are capable of producing a quality product, and generating evidence that support decisions of acceptability.

بسم الله الرحمن الرحيم

وزارة التعليم العالي
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COLLEGE OF ENVIRONMENTAL DESIGN
Construction Engineering & Management Program

التاريخ : ١٥ / ١ / ١٩٩٢م

سعادة الأخ /
السلام عليكم ورحمه الله وبركاته

إلحاقا لخطابنا المرفق به الأستبيان الخاص بدراسة النشاطات الإدارية المستخدمه من قبل مقاولي البناء في المملكة العربية السعودية لضمان الجوده في مرحلة تنفيذ المشاريع الهندسية .

ونظرا لأنه لم يصلنا الإستبيان المذكور حتى تاريخه ، وحيث أن مشاركتكم في تعبئه هذا الإستبيان تشكل عنصرا رئيسيا في نجاح البحث وتطبيقه .

لذا نأمل التكرم بالتعاون معنا في تعبئه الإستبيان ومن ثم إعادته الى العنوان التالي في موعد أقصاه ١٠ / ٢ / ١٩٩٢م .

جامعة الملك فهد للبترول والمعادن
الظهران ٣١٢٦١
ص . ب ٧٠٨٦
أحمد العبد الرزاق

د . عبد العزيز بوبشيت
مدير برنامج هندسة و إدارة التشييد

١٩٩٢/١/١٩م
أحمد العبد الرزاق
مساعد باحث

APPENDIX III

SAS COMPUTER PROGRAM FOR OVERALL QUALITY DESIGN ANALYSIS

FILE: DESIGN4 SAS A1 KING FAHD UNIVERSITY OF PETROLEUM AND MINERAL

```
CMS FI DD DISK DESIGN DATA A;
OPTIONS NOCENTER NODATE;TITLE;
TITLE 'OVERALL DESIGN QUALITY ANALYSIS';
;
;
DATA ALL (KEEP=VOLUME LIFE F1-F29);
   INFILE DD;
   INPUT ID 1-2
    I_AA 4-6  I_AB 7-9  I_AC 10-12  I_AD 13-15
    I_B 17-21  I_C 23-25  I_D 27-29  I_E 31-33  I_F 35-36  I_G 38-39
    @41 (F1-F29) (1.);
  IF          I_B<5    THEN VOLUME=1;
  ELSE IF   5<=I_B<10   THEN VOLUME=2;
  ELSE IF  10<=I_B<50   THEN VOLUME=3;
  ELSE IF  50<=I_B<100  THEN VOLUME=4;
  ELSE IF 100<=I_B<500  THEN VOLUME=5;
  ELSE IF      I_B=>500 THEN VOLUME=6;
  IF I_F=<10 THEN LIFE='SHORT';ELSE LIFE='LONG ';
;
;
PROC FORMAT;
  VALUE BVF 1='UPTO 5 M.'
            2='5 TO 10 M.'
            3='10 TO 50 M.'
            4='50 TO 100 M.'
            5='100 TO 500 M.'
            6='OVER 500 M.';
  VALUE YNF 1=YES   0=NO;
;
;
DATA ALL2 (KEEP=VOLUME LIFE FACTOR RESPONSE);
   SET ALL;
   FACTOR=' 1';RESPONSE=F1;OUTPUT;
   FACTOR=' 2';RESPONSE=F2;OUTPUT;
   FACTOR=' 3';RESPONSE=F3;OUTPUT;
   FACTOR=' 4';RESPONSE=F4;OUTPUT;
   FACTOR=' 5';RESPONSE=F5;OUTPUT;
   FACTOR=' 6';RESPONSE=F6;OUTPUT;
   FACTOR=' 7';RESPONSE=F7;OUTPUT;
   FACTOR=' 8';RESPONSE=F8;OUTPUT;
   FACTOR=' 9';RESPONSE=F9;OUTPUT;
   FACTOR='10';RESPONSE=F10;OUTPUT;
   FACTOR='11';RESPONSE=F11;OUTPUT;
   FACTOR='12';RESPONSE=F12;OUTPUT;
   FACTOR='13';RESPONSE=F13;OUTPUT;
   FACTOR='14';RESPONSE=F14;OUTPUT;
   FACTOR='15';RESPONSE=F15;OUTPUT;
   FACTOR='16';RESPONSE=F16;OUTPUT;
   FACTOR='17';RESPONSE=F17;OUTPUT;
   FACTOR='18';RESPONSE=F18;OUTPUT;
   FACTOR='19';RESPONSE=F19;OUTPUT;
   FACTOR='20';RESPONSE=F20;OUTPUT;
   FACTOR='21';RESPONSE=F21;OUTPUT;
   FACTOR='22';RESPONSE=F22;OUTPUT;
   FACTOR='23';RESPONSE=F23;OUTPUT;
```

FILE: DESIGN4 SAS A1 KING FAHD UNIVERSITY OF PETROLEUM AND MINERALS,

```
   FACTOR='24';RESPONSE=F24;OUTPUT;
   FACTOR='25';RESPONSE=F25;OUTPUT;
   FACTOR='26';RESPONSE=F26;OUTPUT;
   FACTOR='27';RESPONSE=F27;OUTPUT;
   FACTOR='28';RESPONSE=F28;OUTPUT;
   FACTOR='29';RESPONSE=F29;OUTPUT;
;
DATA ALL3;SET ALL2;IF RESPONSE=. THEN DELETE;
;
PROC SORT DATA=ALL3;BY FACTOR;
PROC FREQ;TABLES RESPONSE/NOPRINT OUT=VOLUME;BY FACTOR;
DATA VOLUME1;SET VOLUME;POINTS=RESPONSE*COUNT;
PROC PRINT;ID FACTOR;VAR RESPONSE COUNT POINTS;
PROC MEANS DATA=VOLUME1 MAXDEC=3 SUM NOPRINT;VAR POINTS;
BY FACTOR;OUTPUT OUT=VOLUME2 SUM=POINTS;
PROC SORT;BY DESCENDING POINTS;
PROC PRINT;ID FACTOR;VAR POINTS;
```

APPENDIX IV

SAS COMPUTER PROGRAM FOR RANKING OF DESIGN QUALITY MANAGEMENT ACTIVITIES BASED ON ANNUAL BUSINESS VOLUME AND YEARS IN BUSINESS

FILE: DESIGN3 SAS A1 KING FAHD UNIVERSITY OF PETROLEUM AND MINERAL

```
CMS FI CD DISK DESIGN DATA A;
OPTIONS NOCENTER NODATE;TITLE;
TITLE 'DESIGN ANALYSIS';
;
;
DATA ALL (KEEP=VOLUME LIFE F1-F29);
   INFILE DD;
   INPUT ID 1-2
    I_AA 4-6  I_AB 7-9  I_AC 10-12  I_AD 13-15
    I_B 17-21  I_C 23-25  I_D 27-29  I_E 31-33  I_F 35-36  I_G 38-39
    @41 (F1-F29) (1.);
  IF           I_B<5    THEN VOLUME=1;
  ELSE IF   5<=I_B<10   THEN VOLUME=2;
  ELSE IF  10<=I_B<100  THEN VOLUME=3;
  ELSE IF 100<=I_B<500  THEN VOLUME=4;
  ELSE IF      I_B=>500 THEN VOLUME=5;
  IF I_F=<10 THEN LIFE='SHORT';ELSE LIFE='LONG ';
;
;
PROC FORMAT;
  VALUE BVF 1='UPTO 5 M.'
            2='5 TO 10 M.'
            3='10 TO 100 M.'
            4='100 TO 500 M.'
            5='OVER 500 M.';
  VALUE YNF 1=YES   0=NO;
;
;
DATA ALL2 (KEEP=VOLUME LIFE FACTOR RESPONSE);
   SET ALL;
   FACTOR=' 1';RESPONSE=F1;OUTPUT;
   FACTOR=' 2';RESPONSE=F2;OUTPUT;
   FACTOR=' 3';RESPONSE=F3;OUTPUT;
   FACTOR=' 4';RESPONSE=F4;OUTPUT;
   FACTOR=' 5';RESPONSE=F5;OUTPUT;
   FACTOR=' 6';RESPONSE=F6;OUTPUT;
   FACTOR=' 7';RESPONSE=F7;OUTPUT;
   FACTOR=' 8';RESPONSE=F8;OUTPUT;
   FACTOR=' 9';RESPONSE=F9;OUTPUT;
   FACTOR='10';RESPONSE=F10;OUTPUT;
   FACTOR='11';RESPONSE=F11;OUTPUT;
   FACTOR='12';RESPONSE=F12;OUTPUT;
   FACTOR='13';RESPONSE=F13;OUTPUT;
   FACTOR='14';RESPONSE=F14;OUTPUT;
   FACTOR='15';RESPONSE=F15;OUTPUT;
   FACTOR='16';RESPONSE=F16;OUTPUT;
   FACTOR='17';RESPONSE=F17;OUTPUT;
   FACTOR='18';RESPONSE=F18;OUTPUT;
   FACTOR='19';RESPONSE=F19;OUTPUT;
   FACTOR='20';RESPONSE=F20;OUTPUT;
   FACTOR='21';RESPONSE=F21;OUTPUT;
   FACTOR='22';RESPONSE=F22;OUTPUT;
   FACTOR='23';RESPONSE=F23;OUTPUT;
   FACTOR='24';RESPONSE=F24;OUTPUT;
   FACTOR='25';RESPONSE=F25;OUTPUT;
```

FILE: DESIGN3 SAS A1 KING FAHD UNIVERSITY OF PETROLEUM AND MI

```
   FACTOR='26';RESPONSE=F26;OUTPUT;
   FACTOR='27';RESPONSE=F27;OUTPUT;
   FACTOR='28';RESPONSE=F28;OUTPUT;
   FACTOR='29';RESPONSE=F29;OUTPUT;
;
DATA ALL3;SET ALL2;IF RESPONSE=. THEN DELETE;
;
PROC SORT DATA=ALL3;BY VOLUME FACTOR;
PROC FREQ;TABLES RESPONSE/NOPRINT OUT=VOLUME;BY VOLUME FACTOR;
DATA VOLUME1;SET VOLUME;POINTS=RESPONSE*COUNT;
PROC PRINT;ID FACTOR VOLUME;VAR RESPONSE COUNT POINTS;
PROC MEANS DATA=VOLUME1 MAXDEC=3 SUM NOPRINT;VAR POINTS;
BY VOLUME FACTOR;OUTPUT OUT=VOLUME2 SUM=POINTS;
PROC SORT;BY VOLUME DESCENDING POINTS;
PROC PRINT;ID FACTOR;BY VOLUME;VAR POINTS;FORMAT VOLUME BVF.;
;
;
PROC SORT DATA=ALL3;BY LIFE FACTOR;
PROC FREQ;TABLES RESPONSE/NOPRINT OUT=LIFE;BY LIFE FACTOR;
DATA LIFE1;SET LIFE;POINTS=RESPONSE*COUNT;
PROC PRINT;ID FACTOR LIFE;VAR RESPONSE COUNT POINTS;
PROC MEANS DATA=LIFE1 MAXDEC=3 SUM NOPRINT;VAR POINTS;
BY LIFE FACTOR;OUTPUT OUT=LIFE2 SUM=POINTS;
PROC SORT;BY LIFE DESCENDING POINTS;
PROC PRINT;ID FACTOR;BY LIFE;VAR POINTS;
;
```

APPENDIX V

OVERALL QUALITY CONSTRUCTION ANALYSIS

```
FILE: CONSTR4  SAS      A1  KING FAHD UNIVERSITY OF PETROLEUM AND MINERALS,

CMS FI DD DISK CONSTR DATA A;
OPTIONS NOCENTER NODATE;TITLE;
TITLE 'OVERALL CONSTRUCTION QUALITY ANALYSIS';
DATA ALL;
  INFILE DD;
  INPUT ID 1-2
     I_A 4  I_B 6-10  I_C 12-15  I_D 17  I_E 19-21  I_F 23-24
     I_G 26-27  I_H 29-30
     @32 (F1-F51) (1.);
;
DATA ALL2 (KEEP= FACTOR RESPONSE);
   SET ALL;
   FACTOR=' 1';RESPONSE=F1;OUTPUT;
   FACTOR=' 2';RESPONSE=F2;OUTPUT;
   FACTOR=' 3';RESPONSE=F3;OUTPUT;
   FACTOR=' 4';RESPONSE=F4;OUTPUT;
   FACTOR=' 5';RESPONSE=F5;OUTPUT;
   FACTOR=' 6';RESPONSE=F6;OUTPUT;
   FACTOR=' 7';RESPONSE=F7;OUTPUT;
   FACTOR=' 8';RESPONSE=F8;OUTPUT;
   FACTOR=' 9';RESPONSE=F9;OUTPUT;
   FACTOR='10';RESPONSE=F10;OUTPUT;
   FACTOR='11';RESPONSE=F11;OUTPUT;
   FACTOR='12';RESPONSE=F12;OUTPUT;
   FACTOR='13';RESPONSE=F13;OUTPUT;
   FACTOR='14';RESPONSE=F14;OUTPUT;
   FACTOR='15';RESPONSE=F15;OUTPUT;
   FACTOR='16';RESPONSE=F16;OUTPUT;
   FACTOR='17';RESPONSE=F17;OUTPUT;
   FACTOR='18';RESPONSE=F18;OUTPUT;
   FACTOR='19';RESPONSE=F19;OUTPUT;
   FACTOR='20';RESPONSE=F20;OUTPUT;
   FACTOR='21';RESPONSE=F21;OUTPUT;
   FACTOR='22';RESPONSE=F22;OUTPUT;
   FACTOR='23';RESPONSE=F23;OUTPUT;
   FACTOR='24';RESPONSE=F24;OUTPUT;
   FACTOR='25';RESPONSE=F25;OUTPUT;
   FACTOR='26';RESPONSE=F26;OUTPUT;
   FACTOR='27';RESPONSE=F27;OUTPUT;
   FACTOR='28';RESPONSE=F28;OUTPUT;
   FACTOR='29';RESPONSE=F29;OUTPUT;
   FACTOR='30';RESPONSE=F30;OUTPUT;
   FACTOR='31';RESPONSE=F31;OUTPUT;
   FACTOR='32';RESPONSE=F32;OUTPUT;
   FACTOR='33';RESPONSE=F33;OUTPUT;
   FACTOR='34';RESPONSE=F34;OUTPUT;
   FACTOR='35';RESPONSE=F35;OUTPUT;
   FACTOR='36';RESPONSE=F36;OUTPUT;
   FACTOR='37';RESPONSE=F37;OUTPUT;
   FACTOR='38';RESPONSE=F38;OUTPUT;
   FACTOR='39';RESPONSE=F39;OUTPUT;
   FACTOR='40';RESPONSE=F40;OUTPUT;
   FACTOR='41';RESPONSE=F41;OUTPUT;
   FACTOR='42';RESPONSE=F42;OUTPUT;
   FACTOR='43';RESPONSE=F43;OUTPUT;
```

FILE: CONSTR4 SAS A1 KING FAHD UNIVERSITY OF PETROLEUM AND MINERALS,

```
   FACTOR='44';RESPONSE=F44;OUTPUT;
   FACTOR='45';RESPONSE=F45;OUTPUT;
   FACTOR='46';RESPONSE=F46;OUTPUT;
   FACTOR='47';RESPONSE=F47;OUTPUT;
   FACTOR='48';RESPONSE=F48;OUTPUT;
   FACTOR='49';RESPONSE=F49;OUTPUT;
   FACTOR='50';RESPONSE=F50;OUTPUT;
   FACTOR='51';RESPONSE=F51;OUTPUT;
;
DATA ALL3;SET ALL2;IF RESPONSE=. THEN DELETE;
;
PROC SORT DATA=ALL3;BY FACTOR;
PROC FREQ;TABLES RESPONSE/NOPRINT OUT=VOLUME;BY FACTOR;
DATA VOLUME1;SET VOLUME;POINTS=RESPONSE*COUNT;
PROC PRINT;ID FACTOR ;VAR RESPONSE COUNT POINTS;
PROC MEANS DATA=VOLUME1 MAXDEC=3 SUM NOPRINT;VAR POINTS;
BY FACTOR;OUTPUT OUT=VOLUME2 SUM=POINTS;
PROC SORT;BY DESCENDING POINTS;
PROC PRINT;ID FACTOR;VAR POINTS;
```

APPENDIX VI

SAS COMPUTER PROGRAM FOR RANKING OF CONSTRUCTION QUALITY MANAGEMENT ACTIVITIES BASED ON FIRM'S CHARACTERISTICS

```
FILE: CONSTR3  SAS      AT  KING FAHD UNIVERSITY OF PETROLEUM AND MINERALS,

CMS FI DD DISK CONSTR DATA A;
OPTIONS NOCENTER NODATE;TITLE;
TITLE 'CONSTRUCTION ANALYSIS';
DATA ALL;
  INFILE DD;
  INPUT ID 1-2
     I_A 4  I_B 6-10  I_C 12-15  I_D 17  I_E 19-21  I_F 23-24
     I_G 26-27  I_H 29-30
     @32 (F1-F51) (1.);
;
  IF           I_B<50   THEN VOLUME=1;
  ELSE IF  50<=I_B<100  THEN VOLUME=2;
  ELSE IF      I_B=>100 THEN VOLUME=3;
;
  IF I_E<50 THEN SIZE=1;ELSE SIZE=2;
;
;
  IF I_F=<1 THEN YEARS=1;ELSE YEARS=2;
;
  IF I_G=<20 THEN LIFE='SHORT';ELSE LIFE='LONG ';
;
;
PROC FORMAT;
  VALUE BVF 1='UPTO 50 M.'
            2='50 TO 100 M.'
            3='OVER 100 M';
;
;
DATA ALL2 (KEEP=VOLUME LIFE SIZE YEARS FACTOR RESPONSE);
   SET ALL;
   FACTOR=' 1';RESPONSE=F1;OUTPUT;
   FACTOR=' 2';RESPONSE=F2;OUTPUT;
   FACTOR=' 3';RESPONSE=F3;OUTPUT;
   FACTOR=' 4';RESPONSE=F4;OUTPUT;
   FACTOR=' 5';RESPONSE=F5;OUTPUT;
   FACTOR=' 6';RESPONSE=F6;OUTPUT;
   FACTOR=' 7';RESPONSE=F7;OUTPUT;
   FACTOR=' 8';RESPONSE=F8;OUTPUT;
   FACTOR=' 9';RESPONSE=F9;OUTPUT;
   FACTOR='10';RESPONSE=F10;OUTPUT;
   FACTOR='11';RESPONSE=F11;OUTPUT;
   FACTOR='12';RESPONSE=F12;OUTPUT;
   FACTOR='13';RESPONSE=F13;OUTPUT;
   FACTOR='14';RESPONSE=F14;OUTPUT;
   FACTOR='15';RESPONSE=F15;OUTPUT;
   FACTOR='16';RESPONSE=F16;OUTPUT;
   FACTOR='17';RESPONSE=F17;OUTPUT;
   FACTOR='18';RESPONSE=F18;OUTPUT;
   FACTOR='19';RESPONSE=F19;OUTPUT;
   FACTOR='20';RESPONSE=F20;OUTPUT;
   FACTOR='21';RESPONSE=F21;OUTPUT;
   FACTOR='22';RESPONSE=F22;OUTPUT;
   FACTOR='23';RESPONSE=F23;OUTPUT;
   FACTOR='24';RESPONSE=F24;OUTPUT;
   FACTOR='25';RESPONSE=F25;OUTPUT;
```

FILE: CONSTR3 SAS A1 KING FAHD UNIVERSITY OF PETROLEUM AND MINERALS,

```
   FACTOR='26';RESPONSE=F26;OUTPUT;
   FACTOR='27';RESPONSE=F27;OUTPUT;
   FACTOR='28';RESPONSE=F28;OUTPUT;
   FACTOR='29';RESPONSE=F29;OUTPUT;
   FACTOR='30';RESPONSE=F30;OUTPUT;
   FACTOR='31';RESPONSE=F31;OUTPUT;
   FACTOR='32';RESPONSE=F32;OUTPUT;
   FACTOR='33';RESPONSE=F33;OUTPUT;
   FACTOR='34';RESPONSE=F34;OUTPUT;
   FACTOR='35';RESPONSE=F35;OUTPUT;
   FACTOR='36';RESPONSE=F36;OUTPUT;
   FACTOR='37';RESPONSE=F37;OUTPUT;
   FACTOR='38';RESPONSE=F38;OUTPUT;
   FACTOR='39';RESPONSE=F39;OUTPUT;
   FACTOR='40';RESPONSE=F40;OUTPUT;
   FACTOR='41';RESPONSE=F41;OUTPUT;
   FACTOR='42';RESPONSE=F42;OUTPUT;
   FACTOR='43';RESPONSE=F43;OUTPUT;
   FACTOR='44';RESPONSE=F44;OUTPUT;
   FACTOR='45';RESPONSE=F45;OUTPUT;
   FACTOR='46';RESPONSE=F46;OUTPUT;
   FACTOR='47';RESPONSE=F47;OUTPUT;
   FACTOR='48';RESPONSE=F48;OUTPUT;
   FACTOR='49';RESPONSE=F49;OUTPUT;
   FACTOR='50';RESPONSE=F50;OUTPUT;
   FACTOR='51';RESPONSE=F51;OUTPUT;
;
DATA ALL3;SET ALL2;IF RESPONSE=. THEN DELETE;
;
PROC SORT DATA=ALL3;BY VOLUME FACTOR;
PROC FREQ;TABLES RESPONSE/NOPRINT OUT=VOLUME;BY VOLUME FACTOR;
DATA VOLUME1;SET VOLUME;POINTS=RESPONSE*COUNT;
PROC PRINT;ID FACTOR VOLUME;VAR RESPONSE COUNT POINTS;
PROC MEANS DATA=VOLUME1 MAXDEC=3 SUM NOPRINT;VAR POINTS;
BY VOLUME FACTOR;OUTPUT OUT=VOLUME2 SUM=POINTS;
PROC SORT;BY VOLUME DESCENDING POINTS;
PROC PRINT;ID FACTOR;BY VOLUME;VAR POINTS;FORMAT VOLUME BVF.;
;
;
PROC SORT DATA=ALL3;BY LIFE FACTOR;
PROC FREQ;TABLES RESPONSE/NOPRINT OUT=LIFE;BY LIFE FACTOR;
DATA LIFE1;SET LIFE;POINTS=RESPONSE*COUNT;
PROC PRINT;ID FACTOR LIFE;VAR RESPONSE COUNT POINTS;
PROC MEANS DATA=LIFE1 MAXDEC=3 SUM NOPRINT;VAR POINTS;
BY LIFE FACTOR;OUTPUT OUT=LIFE2 SUM=POINTS;
PROC SORT;BY LIFE DESCENDING POINTS;
PROC PRINT;ID FACTOR;BY LIFE;VAR POINTS;
;
;
PROC SORT DATA=ALL3;BY SIZE FACTOR;
PROC FREQ;TABLES RESPONSE/NOPRINT OUT=SIZE;BY SIZE FACTOR;
DATA SIZE1;SET SIZE;POINTS=RESPONSE*COUNT;
PROC PRINT;ID FACTOR SIZE;VAR RESPONSE COUNT POINTS;
PROC MEANS DATA=SIZE1 MAXDEC=3 SUM NOPRINT;VAR POINTS;
BY SIZE FACTOR;OUTPUT OUT=SIZE2 SUM=POINTS;
```

FILE: CONSTR3 SAS A1 KING FAHD UNIVERSITY OF PETROLEUM AND MINERAL

```
PROC SORT;BY SIZE DESCENDING POINTS;
PROC PRINT;ID FACTOR;BY SIZE;VAR POINTS;
;
;
;
PROC SORT DATA=ALL3;BY YEARS FACTOR;
PROC FREQ;TABLES RESPONSE/NOPRINT OUT=YEARS;BY YEARS FACTOR;
DATA YEARS1;SET YEARS;POINTS=RESPONSE*COUNT;
PROC PRINT;ID FACTOR YEARS;VAR RESPONSE COUNT POINTS;
PROC MEANS DATA=YEARS1 MAXDEC=3 SUM NOPRINT;VAR POINTS;
BY YEARS FACTOR;OUTPUT OUT=YEARS2 SUM=POINTS;
PROC SORT;BY YEARS DESCENDING POINTS;
PROC PRINT;ID FACTOR;BY YEARS;VAR POINTS;
;
```

APPENDIX VII

STEP WISE REGRESSION FOR THE

DESIGN PHASE

OBS	X1	X2	Y	X3	X4	X5
1	3.5	11	0.758	72	5	12
2	0.1	7	0.896	333	5	.
3	14.0	10	0.827	403	84	.
4	1.5	10	0.793	34	12	15
5	4.0	15	0.758	30	12	10
6	2.0	16	0.931	16	.	.
7	40.0	9	1.000	.	18	.
8	6.0	14	0.827	45	6	30
9	6.0	12	1.000	62	24	.
10	25.0	7	0.793	233	12	10
11	34.0	20	0.965	.	.	4
12	3.0	16	0.931	25	1	.
13	40.0	22	1.000	215	24	7
14	20.0	15	0.896	60	12	13
15	3.0	7	0.758	5	3	.
16	8.0	11	0.793	30	10	15
17	6.0	7	0.862	12	8	5
18	7.0	12	0.896	30	.	.
19	32.0	15	0.965	25	12	12
20	10.0	15	0.827	40	10	15
21	23.0	12	0.862	21	6	.
22	5.0	10	0.862	20	5	.
23	8.0	8	0.686	.	12	.
24	10.0	8	0.965	12	10	.
25	12.0	13	0.827	.	10	.
26	15.0	18	0.896	20	12	.
27	9.0	12	1.000	10	8	8
28	10.0	14	0.758	20	7	.
29	12.0	11	0.827	6	3	.
30	8.0	9	0.862	12	5	.

N = 12 REGRESSION MODELS FOR DEPENDENT VARIABLE: Y

NUMBER IN MODEL	R-SQUARE	VARIABLES IN MODEL
1	0.42275401	X1
1	0.24767966	X2
1	0.21081240	X4
1	0.09871446	X5
1	0.00751045	X3
2	0.62726681	X1 X3
2	0.45495389	X1 X2
2	0.43898562	X1 X5
2	0.42529109	X1 X4
2	0.37151502	X2 X5
2	0.27979430	X2 X4
2	0.27181882	X3 X4
2	0.24771713	X2 X3
2	0.23386033	X4 X5
2	0.09923511	X3 X5
3	0.64516176	X1 X3 X5
3	0.63154278	X1 X2 X3
3	0.63060583	X1 X3 X4
3	0.48962159	X1 X2 X5
3	0.47588250	X1 X2 X4
3	0.44611545	X1 X4 X5
3	0.37904564	X2 X3 X5
3	0.37200416	X2 X4 X5
3	0.30705068	X2 X3 X4
3	0.29217948	X3 X4 X5
4	0.65710112	X1 X2 X3 X5
4	0.64578541	X1 X3 X4 X5
4	0.63226483	X1 X2 X3 X4
4	0.55278379	X1 X2 X4 X5
4	0.38126000	X2 X3 X4 X5
5	0.66100435	X1 X2 X3 X4 X5

FORWARD SELECTION PROCEDURE FOR DEPENDENT VARIABLE Y

STEP 1 VARIABLE X1 ENTERED R-SQUARE = 0.42275401 C(P) = 2.21687444

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	1	0.03711188	0.03711188	7.32	0.0221
ERROR	10	0.05067412	0.00506741		
TOTAL	11	0.08778600			

VARIABLE	PARAMETER ESTIMATE	STANDARD ERROR	TYPE II SUM OF SQUARES	F	PROB>F
INTERCEP	0.79227369	0.03125374	3.25636294	642.61	0.0001
X1	0.00463464	0.00171259	0.03711188	7.32	0.0221

BOUNDS ON CONDITION NUMBER: 1, 1

STEP 2 VARIABLE X3 ENTERED R-SQUARE = 0.62726681 C(P) = 0.59713234

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	2	0.05506524	0.02753262	7.57	0.0118
ERROR	9	0.03272076	0.00363564		
TOTAL	11	0.08778600			

VARIABLE	PARAMETER ESTIMATE	STANDARD ERROR	TYPE II SUM OF SQUARES	F	PROB>F
INTERCEP	0.80133524	0.02678498	3.25406852	895.05	0.0001
X1	0.00744689	0.00192505	0.05440593	14.96	0.0038
X3	-0.00071062	0.00031978	0.01795336	4.94	0.0534

BOUNDS ON CONDITION NUMBER: 1.761102, 7.04441

NO OTHER VARIABLE MET THE 0.5000 SIGNIFICANCE LEVEL FOR ENTRY INTO THE MODEL.

SUMMARY OF FORWARD SELECTION PROCEDURE FOR DEPENDENT VARIABLE Y

STEP	VARIABLE ENTERED	NUMBER IN	PARTIAL R**2	MODEL R**2	C(P)	F	PROB>F
1	X1	1	0.4228	0.4228	2.2169	7.3236	0.0221
2	X3	2	0.2045	0.6273	0.5971	4.9382	0.0534

MODEL: MODEL1
DEPENDENT VARIABLE: Y

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	0.00135	0.00135	0.169	0.6843
ERROR	25	0.19885	0.00795		
C TOTAL	26	0.20020			

ROOT MSE	0.08919	R-SQUARE	0.0067
DEP MEAN	0.86033	ADJ R-SQ	-0.0330
C.V.	10.36635		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR HO: PARAMETER=0	PROB > |T|
INTERCEP	1	0.854500	0.02226310	38.382	0.0001
X4	1	0.000469	0.00113941	0.411	0.6843

MODEL: MODEL1
DEPENDENT VARIABLE: Y

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	3	0.04742	0.01581	2.379	0.0959
ERROR	23	0.15278	0.00664		
C TOTAL	26	0.20020			

ROOT MSE	0.08150	R-SQUARE	0.2368
DEP MEAN	0.86033	ADJ R-SQ	0.1373
C.V.	9.47333		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR HO: PARAMETER=0	PROB > |T|
INTERCEP	1	0.777918	0.05416602	14.362	0.0001
X1	1	0.003336	0.00160319	2.081	0.0488
X2	1	0.003605	0.00458198	0.787	0.4395
X4	1	-0.000106	0.00107139	-0.098	0.9224

APPENDIX VIII

STEP WISE REGRESSION FOR THE

CONSTRUCTION PHASE

OBS	X1	X2	X3	X4	Y	X5	X6
1	14	6.0	1.0	19	0.412	250	.
2	300	100.0	2.0	18	0.843	965	.
3	70	12.0	1.0	50	0.921	600	.
4	400	350.0	3.0	23	0.942	2000	8
5	110	80.0	1.5	21	0.902	400	15
6	100	100.0	2.0	10	0.921	321	3
7	250	40.0	1.5	20	1.000	.	2
8	52	36.0	2.0	23	0.588	74	18
9	45	11.0	2.0	26	0.568	.	5
10	50	25.0	1.0	20	0.745	8	.
11	10	4.5	2.0	16	0.353	30	.
12	140	100.0	2.0	14	0.843	1500	.
13	60	40.0	2.0	18	0.725	.	2
14	50	30.0	1.5	21	0.745	70	.
15	15	6.0	1.0	24	0.647	270	.
16	80	50.0	2.0	14	0.863	100	.
17	20	4.0	2.0	22	0.843	80	.
18	120	100.0	2.0	23	0.902	310	.
19	40	10.0	1.0	30	0.921	300	.
20	70	50.0	2.0	17	0.804	4	.
21	70	8.0	1.0	23	0.725	.	10
22	70	25.0	2.0	26	0.902	500	.
23	40	5.0	1.0	21	0.745	90	.
24	10	5.0	2.0	18	0.333	250	15
25	420	300.0	3.0	21	0.942	100	.
26	100	25.0	1.5	20	0.823	300	.
27	21	10.0	2.0	15	0.745	1200	10
28	15	7.0	2.0	24	0.333	50	.

N = 6 REGRESSION MODELS FOR DEPENDENT VARIABLE: Y

NUMBER IN MODEL	R-SQUARE	VARIABLES IN MODEL
1	0.37921460	X6
1	0.37341441	X2
1	0.36899013	X1
1	0.22750886	X5
1	0.04251036	X3
1	0.01383075	X4
2	0.64075381	X2 X3
2	0.59679073	X1 X3
2	0.55972349	X4 X6
2	0.54262626	X1 X6
2	0.52530362	X1 X4
2	0.52490683	X2 X6
2	0.49585404	X2 X4
2	0.43560587	X5 X6
2	0.38035832	X3 X6
2	0.37411210	X1 X2
2	0.37363421	X2 X5
2	0.36912541	X1 X5
2	0.30560944	X3 X5
2	0.27691C98	X4 X5
2	0.07438106	X3 X4
3	0.93447374	X3 X4 X6
3	0.83874023	X1 X3 X6
3	0.81667080	X2 X3 X6
3	0.79950490	X1 X3 X4
3	0.77620455	X2 X3 X4
3	0.76031571	X1 X2 X6
3	0.73498486	X1 X2 X4
3	0.71476637	X2 X3 X5
3	0.68007148	X1 X2 X3
3	0.66022213	X1 X3 X5
3	0.62394773	X2 X4 X6
3	0.57896046	X4 X5 X6
3	0.57629387	X1 X4 X6
3	0.54990604	X1 X5 X6
3	0.53864349	X3 X5 X6
3	0.52874099	X1 X4 X5
3	0.52727644	X2 X5 X6
3	0.49614137	X2 X4 X5
3	0.37455280	X1 X2 X5
3	0.33743695	X3 X4 X5
4	0.99995950	X1 X3 X4 X6
4	0.99730139	X2 X3 X4 X6
4	0.94224221	X3 X4 X5 X6
4	0.93289083	X1 X2 X5 X6
4	0.88971320	X1 X2 X3 X6
4	0.86608849	X1 X3 X5 X6
4	0.86105355	X2 X3 X5 X6
4	0.84383695	X1 X2 X4 X5

NUMBER IN MODEL	R-SQUARE	VARIABLES IN MODEL
4	0.83856265	X1 X2 X3 X4
4	0.33549817	X1 X3 X4 X5
4	0.83476254	X2 X3 X4 X5
4	0.83186451	X1 X2 X3 X5
4	0.76388898	X1 X2 X4 X6
4	0.71502905	X2 X4 X5 X6
4	0.61608737	X1 X4 X5 X6
5	1.00000000	X1 X2 X3 X4 X5
5	1.00000000	X1 X2 X3 X5 X6
5	1.00000000	X1 X2 X4 X5 X6
5	1.00000000	X2 X3 X4 X5 X6
5	1.00000000	X1 X2 X3 X4 X6
5	1.00000000	X1 X3 X4 X5 X6

NOTE: MODELS OF NOT FULL RANK ARE NOT INCLUDED.

FORWARD SELECTION PROCEDURE FOR DEPENDENT VARIABLE Y

STEP 1 VARIABLE X6 ENTERED R-SQUARE = 0.37921460 C(P) = .

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	1	0.10943129	0.10943129	2.44	0.1931
ERROR	4	0.17914221	0.04478555		
TOTAL	5	0.28857350			

VARIABLE	PARAMETER ESTIMATE	STANDARD ERROR	TYPE II SUM OF SQUARES	F	PROB>F
INTERCEP	1.04555375	0.21459231	1.06316917	23.74	0.0082
X6	-0.02670033	0.01708106	0.10943129	2.44	0.1931

BOUNDS ON CONDITION NUMBER: 1, 1

STEP 2 VARIABLE X4 ENTERED R-SQUARE = 0.55972349 C(P) = .

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	2	0.16152137	0.08076068	1.91	0.2921
ERROR	3	0.12705213	0.04235071		
TOTAL	5	0.28857350			

VARIABLE	PARAMETER ESTIMATE	STANDARD ERROR	TYPE II SUM OF SQUARES	F	PROB>F
INTERCEP	0.74304462	0.34343550	0.19824404	4.68	0.1192
X4	0.02752256	0.02481657	0.05209008	1.23	0.3483
X6	-0.04427173	0.02295488	0.15753016	3.72	0.1494

BOUNDS ON CONDITION NUMBER: 1.909843, 7.639372

STEP 3 VARIABLE X3 ENTERED R-SQUARE = 0.93447374 C(P) = .

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	3	0.26966436	0.08988812	9.51	0.0967
ERROR	2	0.01890914	0.00945457		
TOTAL	5	0.28857350			

VARIABLE	PARAMETER ESTIMATE	STANDARD ERROR	TYPE II SUM OF SQUARES	F	PROB>F
INTERCEP	1.49534864	0.27533853	0.27886419	29.50	0.0323
X3	-0.53425454	0.15796830	0.10814299	11.44	0.0774
X4	0.07945999	0.01932151	0.15990303	16.91	0.0544
X6	-0.09570303	0.01867866	0.24819996	26.25	0.0360

BOUNDS ON CONDITION NUMBER: 5.664454, 42.11842

STEP 4 VARIABLE X1 ENTERED R-SQUARE = 0.99995950 C(P) = .

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	4	0.28856181	0.07214045	6172.03	0.0095
ERROR	1	0.00001169	0.00001169		
TOTAL	5	0.28857350			

VARIABLE	PARAMETER ESTIMATE	STANDARD ERROR	TYPE II SUM OF SQUARES	F	PROB>F
INTERCEP	0.97350138	0.01618999	0.04225331	3615.60	0.0106
X1	-0.00355175	0.00008832	0.01889746	1617.05	0.0158
X3	-0.57968899	0.00566755	0.12225867	10461.6	0.0062
X4	0.21138152	0.00335020	0.04652361	3981.00	0.0101
X6	-0.21673190	0.00308054	0.05784589	4949.85	0.0090

BOUNDS ON CONDITION NUMBER: 126.135, 1297.592

NO OTHER VARIABLE MET THE 0.5000 SIGNIFICANCE LEVEL FOR ENTRY INTO THE MODEL.

SUMMARY OF FORWARD SELECTION PROCEDURE FOR DEPENDENT VARIABLE Y

STEP	VARIABLE ENTERED	NUMBER IN	PARTIAL R**2	MODEL R**2	C(P)	F	PROB>F
1	X6	1	0.3792	0.3792	.	2.4435	0.1931
2	X4	2	0.1805	0.5597	.	1.2300	0.3483
3	X3	3	0.3748	0.9345	.	11.4382	0.0774
4	X1	4	0.0655	1.0000	.	1617.0469	0.0158

APPENDIX IX

ARRANGEMENT OF DESIGN QUALITY

MANAGEMENT ACTIVITIES

DESIGN QUALITY MANAGEMENT ACTIVITIES

ESTABLISHMENT OF QUALITY PROGRAM MANAGEMENT

- Definition of the interrelationship and responsibilities of quality program management and direction.
- Establishment of qualification parameters for persons whose activities affect the quality of work.

DOCUMENTATION

- Documentation of any documents related to the design of the project.

EDUCATION OF FIRM'S EMPLOYEES

- On the job training for employees.
- Short courses for employees.
- Seminars for employees.

INITIATION OF COMMUNICATION PROGRAM

- Frequent contacts between the project parties.
- Communication program.
- Communication to resolve conflicts.

CONTROL OF DRAWINGS AND SPECIFICATIONS

- Drawings checks/review.
- Specification checks/review.
- Formal drafting check/reivew.
- Provision of clear, concise and uniform plans and specifications.

PROVISION OF TECHNICALLY QUALIFIED TEAM MEMBERS

- Provision of technically qualified design team members

DESIGN REVIEW

- Calculation checks of the design.
- Review/checks of standards.
- Review/check of regulations.
- Review/check of space allocation.
- Review/check of aesthetics.
- Functionality review.
- Capacity review.
- Review of clients' comments.

STANDARDIZATION OF OFFICE PROCEDURES/ OFFICE LIBRARY FACILITIES

- Standardization of office procedures.
- Office library facilities.

ARRANGEMENT FOR ORGANIZATIONAL/PROJECT PEER REVIEWS

- Arrangements for organizational peer review.
- Arrangements for project peer review.

MONITORING AND CONTROLLING DESIGN, COSTS AND SCHEDULES

- Provision of cost estimate of the project
- Submission of progress reports to the owner.

ESTABLISHMENT OF AN INCENTIVE SYSTEM

- Establishment of an incentive system to motivate persons to produce quality work.

APPENDIX X

ARRANGEMENT OF CONSTRUCTION QUALITY MANAGEMENT ACTIVITIES

CONSTRUCTION QUALITY MANAGEMENT ACTIVITIES

QUALITY PROGRAM MANAGEMENT/VERIFICATION ACTIONS

- Definition of the interrelationship and responsibilities of the quality program management and direction.
- Responsibilities of personnel accountable for performing quality verification actions.

INSPECTION AND TESTING

- Inspection of purchased items on receipt.
- Instructions and procedures related to inspection and testing.
- Instructions and procedures related to compliance with accepted criteria.
- In-situ test of materials.
- Lab test of materials.
- Inspection of results related to material tests.
- Inspection of physical structure of the project.

DOCUMENTATION

- Control and distribution of documents
- Review and approval of documents
- Control of changes to documents
- Documentation and reporting of the results of the surveillance
- Documentation of any records related to the project
- Documentation of construction methods

CONTROL OF PROCUREMENT DOCUMENTS

- Control of procurement documents.

MATERIAL/EQUIPMENT IDENTIFICATION/VERIFICATION OF PROCEDURES

- Establishment of a list of the measuring and testing equipment requiring calibration.
- Control of cleaning, preservation and storage.
- Positive material identification.
- Materials and/or equipment retrieval.
- Verification of equipment.
- Program for issuance, collection and return of measuring and testing equipment.
- Verification of welding procedures.
- Verification of heat treatment procedures.
- Verification of concrete work procedures.
- Evaluation of materials/equipment suppliers.

MAINTENANCE OF QUALITY RECORDS/TRAINING AND QUALIFICATION OF PERSONNEL

- Maintenance of quality records.
- Training and qualifications of surveillance personnel on the project
- Qualifications of welding personnel.
- Qualifications of heat treatment personnel.
- Qualifications of personnel engaged in work with concrete.
- Qualifications and testing of your employees.
- Qualifications and testing of new employees.

ESTABLISHMENT OF COMMUNICATION PROGRAM

- Establishment of a communication program between the staff on the project.

PLANNING FOR CONSTRUCTION

- Planning for construction

QUALIFICATION OF SUBCONTRACTORS

- Subcontractor evaluation depending on reputation, past experience, financial position, etc.

SAFETY PROGRAM

- Initiation of a safety program.

COORDINATION AND COMMUNICATION

- Establishment of a communication program between the staff on the project.
- Initiation of a reporting system.
- Establishment of checklists.

DESIGN CHECKS

- Calculation checks of the design.
- Review/checks of design drawings.
- Specification checks.
- Review of work regulations.
- Review of clients' and designers' comments.
- Constructability review.

INSURANCE NEEDS OF CONTRACTORS

- Compliance with insurance requirements.

EDUCATION OF CONTRACTOR'S EMPLOYEES

- On-job training for employees.
- Seminars for employees.
- Short courses for employees.

PROVISION OF TECHNICALLY QUALIFIED TEAM MEMBERS

- Provision of technically qualified team members for the project.

ESTABLISHMENT OF AN INCENTIVE SYSTEM

- Establishment of a system of incentives to motivate project personnel to produce quality work.

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