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ASSESSMENT OF CONSTRUCTABILITY PRACTICES AMONG GENERAL CONTRACTORS IN THE EASTERN PROVINCE OF SAUDI ARABIA

BY

FAWZI A. AL-YOUSIF

A Thesis Presented to the
DEANSHIP OF GRADUATE STUDIES

KING FAHD UNIVERSITY OF PETROLEUM & MINERALS
DHAHRAN, SAUDI ARABIA

In Partial Fulfillment of the
Requirements for the Degree of

MASTER OF SCIENCE

In

CONSTRUCTION ENGINEERING AND MANAGEMENT

JUNE, 2001

KNG FAHD UNIVERSITY OF PETROLEUM & MINERALS
DHAHRAN, SAUDI ARABIA

DEANSHIP OF GRADUATE STUDIES

This thesis, written by **FAWZI A. AL-YOUSIF** under the direction of his thesis advisor and approved by his thesis committee, has been presented and accepted by the Dean of Graduate Studies, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN CONSTRUCTION ENGINEERING & MANAGEMENT**

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DEDICATION

To the soul of Mohammed Adorra, who was brutally and inhumanly killed by the Zionist regime in Palestine.

To my parents, who instilled in me the values of life and saw me grow to this stage and made me what I am.

To my wife, my two lovely daughters and my wonderful son, whose presence beside me is a great strength, and in whose well-being lies my happiness.

ACKNOWLEDGEMENTS

Any accomplishment requires the support of many people and this research work is no different. I could not have successfully completed this research without a great deal of help and encouragement. I would therefore like to express my sincere thanks to all those who contributed in this research process.

Firstly, I'd like to thank Dr. Sadi Assaf, Committee Chairman for his encouragement, inspiration and ideas. Also, thanks to Dr. Osama Jannadi, Committee Member, and Prof. Elahi Ishteeaque, Committee Member, for their valuable suggestions and support.

I would like to pay my due respects and thanks to all those organisations who shared their valuable moments in filling up the questionnaire and sending on time their helpful comments and suggestions. Their contribution gave new perspective and fresh ideas that have been a tremendous source of inspiration in completing my research. Without their effective participation this research would not have been complete. And thanks to my friend L. Shantharam, who has been a good supporter in making this research.

Finally, significantly I wish to acknowledge KFUPM for providing the various facilities utilized in the preparation of this thesis.

مـــلخـــص الـــرســـالـــة

الاســـم : فـــوزي عبد الله آل يـــوسف

عنوان الرسالة : تقدير استخدام " منهج البناء المخطط " من قبل المقاولين في المنطقة الشرقية بالمملكة.

التخصص : هنـدســة وإدارة التشييـد .

تاريخ التخرج : ربيع الأول ١٤٢٢ هـ

تطورت صناعة التشييد في المملكة العربية السعودية بصورة سريعة جداً ، وقد أظهرت الدراسات أنه بتطبيق التخطيط والتنظيم المناسبين ، فإن كل مشروع إنشائي يمكن أن يشهد زيادة في تخفيض التكلفة وتحسّن عام في النوعية . ويعتقد الباحث أن الحل يكمن في " منهج البناء المخطط (Constructabiliy)" ، حيث أنه مبني على الجمع بين العلم والخبرة في مجال التشييد ، بجميع مراحل المشروع : كالتخطيط ، والتصميم ، وتدبير المواد ، والإنشاء . وبناءً على فهم الدور المهم الذي يلعبه المقاولون في مجال إنشاء المشاريع ، فقد قام الباحث بتطوير استبيان ليستخدم كأداة لقياس مدى استخدام منهج البناء المخطط لدى المقاولين في المنطقة لشرقية من المملكة . وقد لوحظ ، بعد الحصول على المعلومات القيمة ، أن المقاولين في المنطقة الشرقية أكثر اهتماماً بتنفيذ " منهج البناء المخطط " ، وذلك راجع لوجود أرامكو السعودية في المنطقة والتي تصر على هذا المنهج كجزء من عملية تقييم كفاءة المقاولين . وقد فُهم أن تطبيق منهج البناء المخطط قد مارسه المقاولون خلال مراحل الإنشاء وكذلك فإن تحقيق منهج البناء المخطط والتطبيقات المتعلقة به يختلف باختلاف حجم المشروع ، نـــوعـــه أو مـــدى تعقيده .

THESIS - ABSTRACT

FULL NAME OF STUDENT	:	**FAWZI A. AL-YOUSIF**
TITLE OF STUDY	:	**ASSESSMENT OF CONSTRUCTABILITY PRACTICES AMONG GENERAL CONTRACTORS IN THE EASTERN PROVINCE OF SAUDI ARABIA**
MAJOR FIELD	:	**CONSTRUCTION ENGINEERING AND MANAGEMENT**
DATE OF DEGREE	:	**JUNE, 2001**

The construction industry in the Kingdom of Saudi Arabia has developed very rapidly, and studies have indicated that by applying proper planning and systems, every construction project could witness an increase in cost efficiency and overall project quality. The researcher believes that constructability or buildability is the solution, as it is based on the integration of construction knowledge and experience during planning, design, procurement and construction phases of a project. Understanding the key role played by general contractors in the construction project, the researcher developed a questionnaire as a measuring tool to assess constructability implementation among general contractors in the Eastern Province of Saudi Arabia. Upon obtaining valuable data, it was found that General Contractors in the Eastern Province have a good awareness of constructability implementation, and this is due to the existence of Saudi Aramco, which insists on the constructability program as part of its Contractor Qualification process. It was understood that constructability is being practised commonly during the preconstruction phase by the general contractors. Also, the implementation of constructability and other practises related to it differs according to the project size, type and complexity.

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CHAPTER 1

INTRODUCTION

1.1 General

The construction industry in the Kingdom of Saudi Arabia experienced tremendous growth during the early 1970s and continued to grow until the late 1980s. Today, it is still growing, but far less in comparison. This construction boom period helped in gaining an ocean of knowledge and mastering many valuable lessons. But of course, this was in return for many human lives and huge financial losses. Still, how much of this knowledge and experience is passed on from one project to another? The answer to such huge irrepairable loss is in constructability.

Constructability, or Buildability, as a term is not well known, in fact these two terms are not found in most dictionaries, but in practice the concept has been known since the beginning of the construction industry. "In ancient times the design was dictated, about how the project should be built, and the construction was done by the master builder." (Uhlik and Lores 1998).

Involving people with construction knowledge and experience at the very beginning of the project results in maximizing benefits. "It has been shown that the integration of construction knowledge during the planning, design and procurement phases of a project bring extraordinary benefits into the delivery of the project. This is due to the fact that these are the phases in which one is able to influence the overall project the most." (Lores 1997).

To receive the design after completion is not a constructability program. It has to start from the beginning, because it is very difficult to make substantial changes in the design once you are through with it. Constructability considerations have to be started at the same time as the initial project planning and should continue during the entire life of the project.

In short, constructability optimizes the following project elements from start to finish.

- *Overall project plan*
- *Planning and designing*
- *Construction - driver schedule*
- *Cost and estimates*
- *Construction methods*

(Russell et al., 1992)

Highlights of constructability effectiveness

The Construction Industry Institute (CII) made many case studies to highlight the importance and the effectiveness of constructability. In one case study (Residence Community in San Antonio, Texas) the resulting savings reduced project costs by approximately 10 percent ($3.5 Million) and enabled the project to be completed on schedule. In another case study (Refinery Expansion), the project was completed 14 months ahead of schedule with a 23 percent ($253 million) saving from the original estimate. A third one (Arctic Oil Production Facility in Alaska) had a project cost reduction from $3.8 billion to $ 1.4 billion.

The benefits attained on these projects clearly demonstrate that an effective constructability program was a major factor in achieving completion ahead of schedule and reducing costs. However, studies indicate that, overall, constructability is not being implemented to its full potential (Construction, 1986).

1.2 Definition of Constructability

Constructability, as defined by the Construction Industry Institute (CII), is the "Optimum integration of construction knowledge and experience in planning, engineering, procurement and field operations to achieve overall project objectives" (Construction, 1986). Along the same lines, O'Connor and Tucker in their study 'Industrial Project Constructability Improvement' give a slightly different definition: "Constructability is seen as the ability of project conditions to enable the optimal utilization of construction resources."

Fisher and Rajan, 1996 defined constructability as "A measure of the ease or expediency with which a facility can be constructed." Also, constructability is often described as integrating construction knowledge, resources, technology and experience into the engineering and design of a project.

The construction management committee of the ASCE construction division has defined constructability as "The capability of being constructed." It has also defined a constructability program as "The application of a disciplined, systematic optimization of the construction-related aspects of a project during the planning, design, procurement, construction, test and start up phases by knowledgeable, experienced

construction personnel who are part of a project team, to enhance the project's overall objectives." (ASCE, 1991).

Constructability, in simple words, is the ability to construct effectively.

1.3 Why Constructability is Needed

"We can have all the computers in the world to help us, and we can draw like angels; but if we don't really know what the materials are like and how they are made and the way they are handled by people actually building the thing, then we really can not be very creative. We cannot innovate unless we know so much about building that we can suggest how to change things." LeMessurier, 1989:99-100).

In the past, the so-called "master builder professional" used to manage all the knowledge required to plan, design and construct a project. Nowadays, it is no longer possible to do the same, due to the complexity of projects and the variety of materials that can be used in design and construction. Materials have particular characteristics and behave differently under the same loads. Another reason is that "science and technology are moving so fast that it is difficult, even for professionals in particular areas of specialization, to stay up to date." (Lores, 1997). In addition to all of the above, there are the regulations, standards, and codes, which are so diverse that it needs a professional to be specialized in this area.

What is really required, as stated by Lores, (1997) is the participation of owners, consultants, suppliers, designers, and builders (immediate users of the designer's

product) in exchanging knowledge during the pre-construction stage to develop the best design solution. Both construction and design can influence each other to achieve the overall project objectives.

The CII task force is convinced that constructability offers one of the greatest opportunities for improvement in our industry. The pressures of global competition leave no alternative but to adopt the changes that will make the construction industry as effective as possible. Constructability is one of those necessary and vital changes.

1.4 Research Objectives

The purpose of the present piece of research is to:

1. Determine current implementation practices for constructability in the Eastern Province of Saudi Arabia.
2. Assess the existence of common barriers to constructability implementation.

1.5 Methodology

The major steps in this research study can be summarized as follows:

- A review of previous research on constructability was conducted, in order to become familiar with the topic and to facilitate the analysis of the data obtained from the survey.
- A survey was used for the purpose of collecting data as well as identifying the participants.
- A Questionnaire was developed and sent by either mail, e-mail or carried to the participants.

- Finally, the collected data and the findings were analyzed.

1.6 Scope and Limitation

The objective of this study was to determine whether or not the general contractors in the Eastern Province of Saudi Arabia were applying the constructability concept, and if they were, to what extent. If they were not, what were the common barriers?

1.7 Significance of this Study

Construction projects usually involve heavy total cost. Therefore, time and resources play a vital and critical role in deciding the cost factor of every project. Hence, by doing the job right the very first time, total project cost can be reduced substantially by identifying mistakes, analyzing the situation and solving any problem.

One study conducted earlier on industrial projects showed the direct cost for construction rework at greater than 12% of the total project cost (Ledbetter, Davis & Burati, 1989).

The Construction industry in Saudi Arabia is one of the biggest industries and any extra cost means huge losses to the contractors and higher expenses to the clients. To avoid such loss on construction rework, extensive research needs to be conducted to improve the construction process.

Of course, constructability is the answer to such loss.

Constructability in Saudi Arabia is a new concept. In fact, not many research projects, may be none at all, have been done on this subject. To bring this subject of constructability to light will benefit the owners, constructors & designers, and therefore to consider constructability in their projects could prove highly beneficial in this industry.

The need for constructability was not given much importance in the past, in spite of a major development plan in the region. The Government of Saudi Arabia aimed more on developing the basic structural foundation of the country within a short span of time and the cost factor was not of prime importance, where as now, as the oil prices are fluctuating, the country needs more construction projects, but with the least possible cost within a reasonable time. Constructability implementation in the region could be of great importance to achieve overall project cost benefit, as this concept has already been tested and used in many countries around the world and proved to be very effective at optimizing the total cost throughout the project life cycle.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

2.1.1 Historical Overview of Construction

There is no doubt that historical evidence and facts have always been very supportive in the development and innovation of almost every field of study.

The construction field is no exception. An old story talks about the time of building the pyramids. Hamid, a superintendent in the pyramid building project, faced certain difficulties during the phase of construction and decided to bring his problems to his project manager's attention. He complained that the stones delivered to the site were too large to be installed in their position properly. It required excessive manpower, was unsafe for the workers and time consuming. He added a few complaints about the quality too, the stones cut were not of true shape and required additional effort to make them fit. Also the stones were arriving late to the site.

On hearing Hamid's complaints, the project manager called for a meeting with the designers, stone suppliers, and Mr. Hamid. He insisted on an aggressive constructability program. The designers were forced to reduce the size of the stones and the supplier had to improve the quality and delivery of the stones.

The end result was 13.5% faster in the installation and an overall cost saving of 23.8%.

The above story tells us that constructability has been used since the beginning of construction and it is not new. People may not have known the term "Constructability" but they used the basic concept of constructability. "In ancient times, the design was dictated by how the project was going to be built, and the design and construction were done by the "master builder". The construction was based on traditions, general rules, and the trial and error method." (Uhlik and Lores, 1998).

Only when the architectural profession came into the picture and started to value the beauty of art over the mechanics of building, design started to be separate from building or construction.

Another reason why design separated from construction was the Industrial Revolution. Major development occurred in materials, such as cast iron, reinforced concrete and steel. Overall construction systems and varied forms of construction in the industry made it very difficult to master design and construction as one profession.

"In modern practice, with rare exceptions, the work of designing and the work of construction are separated. There is schism or separation among architecture, engineering and construction practice and the limitations in built form which arise as consequence of these separations." (LeMessurier, 1989).

2.1.2 Current Practice

We are aware that the facts and figures of the past have clearly highlighted the importance of the constructability concept and its major benefits in the construction industry. But still, certain questions remain:

- Are people fully aware of the term constructability?
- How far is this concept being really implemented?
- Are they utilizing the benefits of constructability?
- Are experiences based on constructability being shared among construction companies for better utilization of this concept?

An overall survey shows that the existence of a constructability program in various corporations ranges from sophisticated programs in some cases to none at all in others. In many cases, companies are practicing some elements of a constructability program without giving it the name. For example, people are reviewing the plans and specifications to make sure that the equipment is the right size to get into the building, that there is access to the building, or they are thinking of the access for operations, maintenance or replacement, but without giving the term "constructability".

Many owners, engineers and contractors are not fully aware of the benefits of constractability, such as reducing the scheduled time, functional improvements and total project cost reduction.

Overall, the Construction Industry Institute (CII) Task Force believed that industry-wide constructability implementation is progressing slowly and lacks structure. For example, based on an assessment of 62 companies that had a constructability program, only two companies (three percent) ware found to have comprehensive formal programs, while 46 companies (75 percent) had formal, yet non-comprehensive programs. Fourteen of the 62 companies (22 percent) had either no program or practiced only limited application of selected concepts. Thus, considerable opportunity exists to exploit a more structured approach to constructability implementation.

2.1.3 Development of Constructability

Historical facts prove the existence of a constructability concept since long ago. But the need for and development of the concept began to be felt seriously in the construction industry due to great number of problems and difficulties it faced during the 1960s and 1970s. During this period, the construction industry in many parts of the world declined in efficiency and quality.

Analyzing the cause of the setback, the CII Task Force identified the lack of integration between construction and design as the root of the complex problem faced by the construction industry. Hence, the only answer to solve all the major problems faced in the industry was CONSTRUCTABILITY.

A short extract from Integrating Construction Resources and Technology into Engineering says: "All too often chances to cut schedule time and costs are lost because construction operates as a production process separated by a chasm from financial planning, scheduling, and engineering or architectural design. To close that gap, some owners and contractors mesh their expertise with that of engineers in a planned constructability program. A seasoned project manager or construction manager sits with engineers as they labor at their drawing boards and help them avoid cost-boosting gaffes. Too many engineers separated from field experience are not up to date about how to build what they design, or how to design so structures and equipment can be erected most efficiently." (Business Roundtable, 1982).

In the late 1970s, a few authors started to write papers indicating the importance of constructability and inserting the knowledge of construction into design, and the greater benefits obtained from it. For example, Boyd Paulson said that "Understanding the level of influence concept can be helpful informing contractual arrangements that minimize the sub optimization of cost for one project at the expense of overall project cost and benefits. Contractual arrangements should be drawn so as to assure that current construction and even operations knowledge will be injected in the design process" (Paulson, 1976).

In 1983, the Construction Industry Institute (CII) was officially established at the University of Texas at Austin. It was an association of owners, contractors, academic institutions, and other construction professionals. The mission of the CII is to improve construction industry cost-effectiveness, and to provide continuing research

in construction. "One area of research funded by the CII is the interface between design and construction practices, for which it has designated a Constructability Task Force. Two primary objectives of the constructability Task Force are to promote the benefits of constructability improvement to industry professionals, and to provide a package of concepts for improving constructability." (Kartam, 1996).

The CII has also sponsored research, and distributed publications and source documents providing suggestions for constructability improvements. The work performed by the CII is highly useful, as it has promoted the concept of constructability improvement. The CII has also developed a constructability implementation roadmap (Figure 2.1) to provide guidance in the planning, development, and implementation of a constructability program. This roadmap is the most significant tool presented in the constructability implementation guide. It provides an overview of the constructability process by emphasizing six milestones:

1. Commit to implementing constructability.
2. Establish constructability program.
3. Obtain constructability capabilities.
4. Plan constructability implementation.
5. Implement constructability
6. Update corporate program.

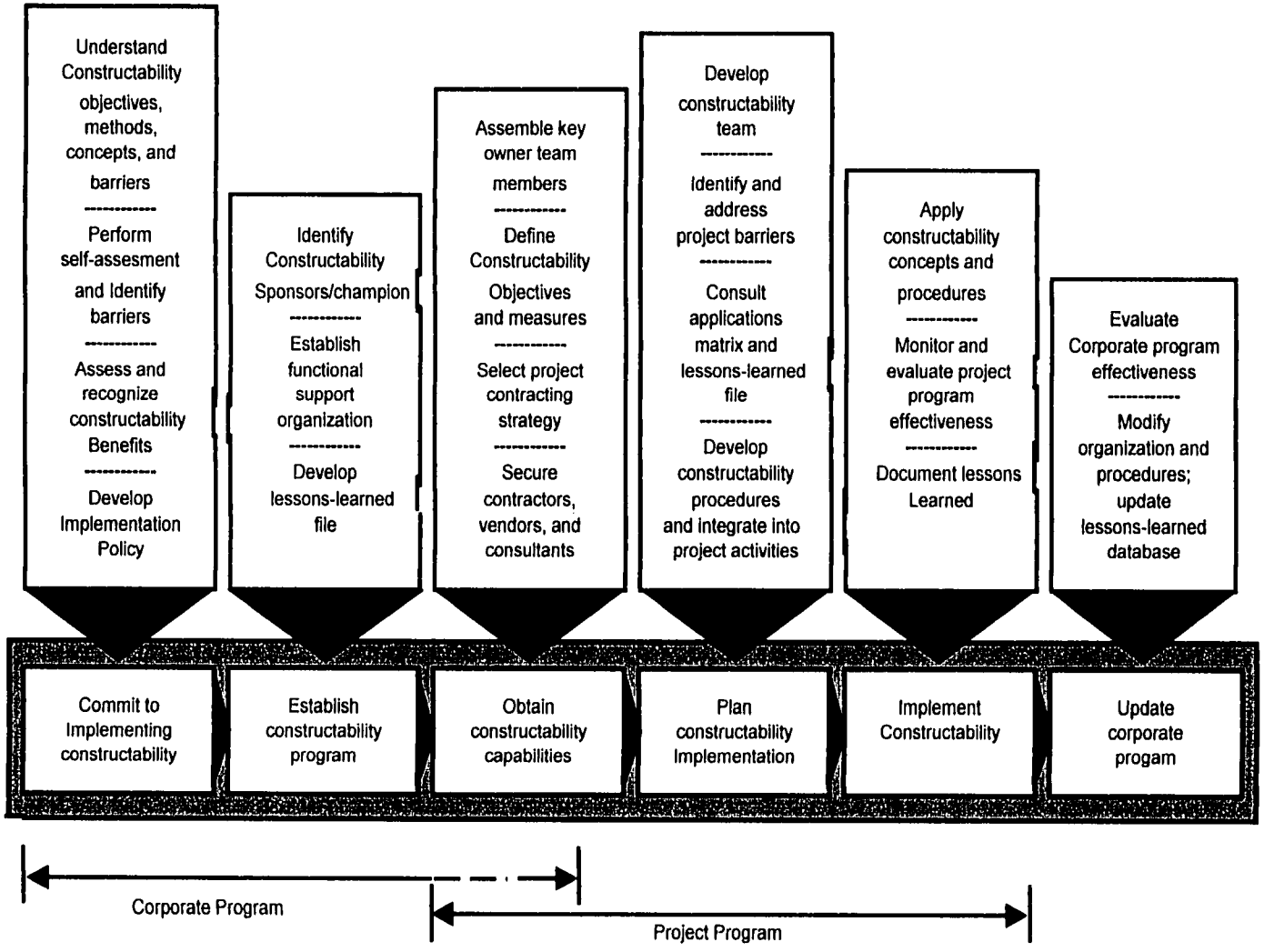


Figure 2.1 Constructability Implementation Roadmap

(Source: Constructability Implementation Guide, 1983)

2.1.4. The Constructability Concept

The Construction Industry Institute (CII) has developed and formalized fourteen generic concepts of constructability published in the constructability concepts file. The concepts are the following:

1. A Constructability program is an integral part of a project execution plan.
2. Project planning involves construction knowledge and experience.
3. Early construction involvement is considered in development of contracting strategy.
4. Project schedules are construction-sensitive.
5. Basic design approaches consider major construction methods.
6. Site layouts should promote efficient construction.
7. Project team participants responsible for constructability are identified early.
8. Advanced information technologies are applied throughout project.
9. Design and procurement schedules are construction-sensitive.
10. Designs are configured to enable efficient construction.
11. Design elements are standardized.
12. Construction efficiency is considered in specification development.
13. Module/preassembly designs are prepared to facilitate fabrication, transport, and installation.
14. Designs promote construction accessibility of personnel, material, and equipment.

Also the Construction Industry Institute (CII) Task Force has developed application matrices to assist in applying the constractability concepts. These matrices are the tools to link specific activities within each phase of the process to constructability concepts. The matrix is based on the fifteen significant parameters shown in the Corporate Constructability Program Evaluation Matrix in Figure 2.2 and 2.3 and is very useful when developing a project execution plan. The constructability implementation roadmap shown in Figure 2.1 includes these matrices in the step "Consult application matrix and lessons-learned file" within the "Plan Constructability Implementation" milestone. Therefore, application of constructability concepts in a project can contribute substantially to the success of the project, as proven by many case study.

2.2 Constructability and Value Engineering

"The design of construction projects in general is a complicated process. It requires investment, experience and talented people. But regardless of how capable or how overwhelmingly able a designer is, there will be unnecessary cost hidden in his design. In other words, opportunities exist for value improvement in every construction project regardless of how excellent the original design is." (Mitchell, and Hood, 1986). In an effort to utilize the existing opportunity for improving value, more focus is given to value engineering. Value engineering focuses on the initial construction cost of a project as well as taking into consideration all associated costs during the projected life of the project. It is a tool to optimize the total ownership cost of the project. In simple terms, "value engineering is an organized, creative approach to

Figure 2.2: Corporate Constructability Program Evaluation Matrix

Program Classification:

1 No Programs	2 **Application of** Selected Supports	3 Informal Program	4 Formal Program	5 Comprehensive Formal Program

I. Corporate Culture

A. Program Designation	No designation	Part of standard construction management activities	Part of another program, such as Quality, or only identified on a project level	Recognize on a corporate level, but may be part of another program	Stand alone program on same level as Quality or Safety.
B. Corporate Constructability Policy Statement	None exists; no need seen for such	No corporate policy, may have on project level	Statement exists, but may be part of other policies	Widely distributed corporate policy	Widely distributed corporate policy
C. Management Attitude Toward Constructability	No recognition of need for or benefits of Constructability	Limited support within company, some recognition of benefits	Support varies within company, support on a project-by-project basis	Management supports programs. Constructability understood as a corporate policy	Total management support; active participants in improving programs
D. Recognition of Constructability Barriers/Problems	Many barriers exist, no recognition of barriers or problems encountered	Many barriers exist; aware of external limiters; May deny internal factors	Recognize presence of barriers/problems, accept as part of the job	Actively identify, work to document and correct	Most barriers gone; problems caught and corrected quickly
E. Constructability Training of Personnel	None	If any occurs, done as part of on-the-job training	Awareness seminars for specific projects	Part of standard recognition	Part of standard orientation; deeply ingrained in corporate culture

II. Personnel

A. Executive Sponsor for Constructability	No sponsor	No sponsor	Sponsor identified, role of sponsor may be ambiguous or weak	Yes, sponsor actively supports program	Yes, sponsor actively supports program
B. Assignment of Corporate Constructability Duties	None	No corporate personnel dedicated to constructability	May have corporate duties as part of other responsibilities	Full or part-time corporate coordinator; corporate support organization for program implementation	Full-time, high-level corporate coordinator, support organization well developed

III. Documentation / Tracking

A. Constructability Program documentation	None; CII documents may be available	Limited reference in any manuals; CII documents may be distributed or referenced	Project-level program documents exist; may be included in other corporate documents	Corporate constructability manual is available	Corporate constructability manual is thoroughly widely distributed, and periodically updated
B. Tracking of Constructability Lessons Learned	None	Believe that ideas are adequately conveyed via word of mouth, personnel interaction	Some individual documentation; primarily post-project reviews and reports	Systems exist for capture and communication of lessons learned	Database on lessons learned involves input from all levels
C. Sharing Advanced Construction Technologies	Not done	New information routed occasionally - journals, word-of-mouth	Library may exist; Information routinely routed or seminars held	Formalized routing system, R&D department identifies and promotes	Formalized system with company seminars and prior applications
D. Constructability Referenced in Contract Documents	No reference	Limited reference, on specific projects, often only at request of other project participants	Level of reference varies by project type, role, or participants	Standard item in all contracts	Standard item in all contracts, actively promoted to other organizations
E. Tracking Constructability Savings/Effects	Not Applicable	No tracking or recognition of program results	No tracking, limited recognition of program results on project	Track for particular projects or selected items; may track major ideas across projects	Data kept on all projects; widespread confidence in savings beyond those measured

(Source: Constructability Implementation Guide, May 1983)

Figure 2.3: Project Constructability Program Evaluation Matrix

Program Classification:

1 No Programs	2 Application of Selected Supports	3 Informal Program	4 Formal Program	5 Comprehensive Formal Program

I. Corporate Culture

A. Program Designation	No designation	Part of standard construction management activities	Part of another program, such as Quality, or only identified on a project level	Recognize on a corporate level, but may be part of another program	Stand alone program on same level as Quality or Safety
D. Recognition of Constructability Barriers/Problems	Many barriers exist, no recognition of barriers or problems encountered	Many barriers exist; aware of external limiters; may deny internal factors	Recognize presence of barriers/problems, accept as part of the job	Actively identify, work to document and correct	Most barriers gone; problems caught and corrected quickly
E. Constructability Training of Personnel	None	If any occurs, done as part of on-the-job training	Awareness seminars for specific projects	Part of standard recognition	Part of standard orientation; deeply ingrained in corporate culture

II. Personnel

C. Role of Project Constructability Coordinator	Not identified	Part-time if identified; very limited responsibility	Full or part-time position; responsibilities vary by project size, type, participants	Full or part-time position; responsibilities vary by project size, type, participants	Full-time position, plays major project role

III. Documentation / Tracking

A. Constructability Program documentation	None; CII documents may be available	Limited reference in any manuals; CII documents may be distributed or referenced	Project-level program documents exist; may be included in other corporate documents	Corporate constructability manual is available	Corporate constructability manual is thoroughly widely distributed, and periodically updated
C. Sharing Advanced Construction Technologies	Not done	New information routed occasionally - journals, word-of-mouth	Library may exist; information routinely routed or seminars held	Formalized routing system, R&D department identifies and promotes	Formalized system with company seminars and prior applications
D. Constructability Referenced in Contract Documents	No reference	Limited reference, on specific projects, often only at request of other project participants	Level of reference varies by project type, role, or participants	Standard item in all contracts	Standard item in all contracts, actively promoted to other organizations
E. Tracking Constructability Savings/Effects	Not Applicable	No tracking or recognition of program results	No tracking, limited recognition of program results on project	Track for particular projects or selected items; may track major ideas across projects	Data kept on all projects; widespread confidence in savings beyond those measured

IV. Implementation

A. Name of the Project-level Efforts & Inputs	None	Reactive approach, constrained by review mentality, lack of understanding of proactive benefits	Aware of major benefits; proactive approach; efforts vary project by project	Proactive effort on all projects, routinely consult lessons learned	Aggressive, proactive efforts from beginning of project; routinely consult lessons learned
B. Implementation of Constructability Concepts	None	Some concepts used periodically, often considered too late to be use	Selected concepts applied regularly; full use. Timeliness of input varies across projects	All concepts consistently considered, timely implementation of feasible concepts	All concepts consistently considered, continuously evaluated, aggressively implemented

(Source: Constructability Implementation Guide, May 1983)

isolate unnecessary costs which do not contribute to the quality, use, life and appearance of a project." (Clawson, 1970). As defined by the U.S. Government Department of Defense, "Value Engineering is an organized effort directed at analyzing the function system, products, specifications/standards, practices, and procedures, for the purpose of satisfying the required function at the lowest cost of ownership without reducing the needed quality." (Value Management Briefing, 1994). It differs from a traditional cost reduction approach in that it is function oriented rather than item oriented. "Function oriented cost reduction leads to more creative alternatives that perform the required function at a lower cost, while item oriented cost reduction is done by modifying the item itself." (Van Nostrand, 1982).

Constructability and value engineering are very similar and overlap with each other. The ultimate goal of both is similar, that is to achieve the essential functions at the lowest cost. Both value engineering and constructability consider the life cost of a project. "Value Engineering (VE) is an important operation in life-cycle analysis. VE examines functional requirements over the facility life-cycle with an ultimate goal of providing the required functions of a facility at the lowest total cost. Constructability and VE are often confused. The two are generally similar in effect, but differ markedly in scope and methodology. While VE analyzes the entire life cycle from a functional viewpoint, constructability is focused on maximizing the efficient operations of the construction phase by exploiting construction expertise in the early project phase. VE often challenges and changes project form and function; constructability de-emphasizes these issues and works for optimization of construction

within functional bounds. Constructability and VE may easily coexist, and often complement each other." (Hugo et al., 1990).

Constructability and value engineering represent formal feedback loops in the project life cycle. Evaluation occurs throughout the project's phases, which start from conceptual planning and feasibility studies and move to construction and operation and maintenance. Figure 2.4 shows the feedback channels in Project Lifecycle.

2.3 Constructability and TQM

Constructability may be well accepted as a continuous improvement program within a Total Quality Management Program. The need for a shift in operational practices, and modification of standard policies for effective constructability implementation are best met within the comprehensive efforts of Total Quality Management (TQM) implementation.

TQM is a business philosophy requiring company-wide effort involving team work at all levels working towards continuous improvement of products, processes and services to enhance quality and overall performance.

TQM and constructability, being a part of TQM, both face stiff resistance, as recognition and mitigation of barriers is an integral part of efforts to implement constructability and all other innovative methods within TQM.

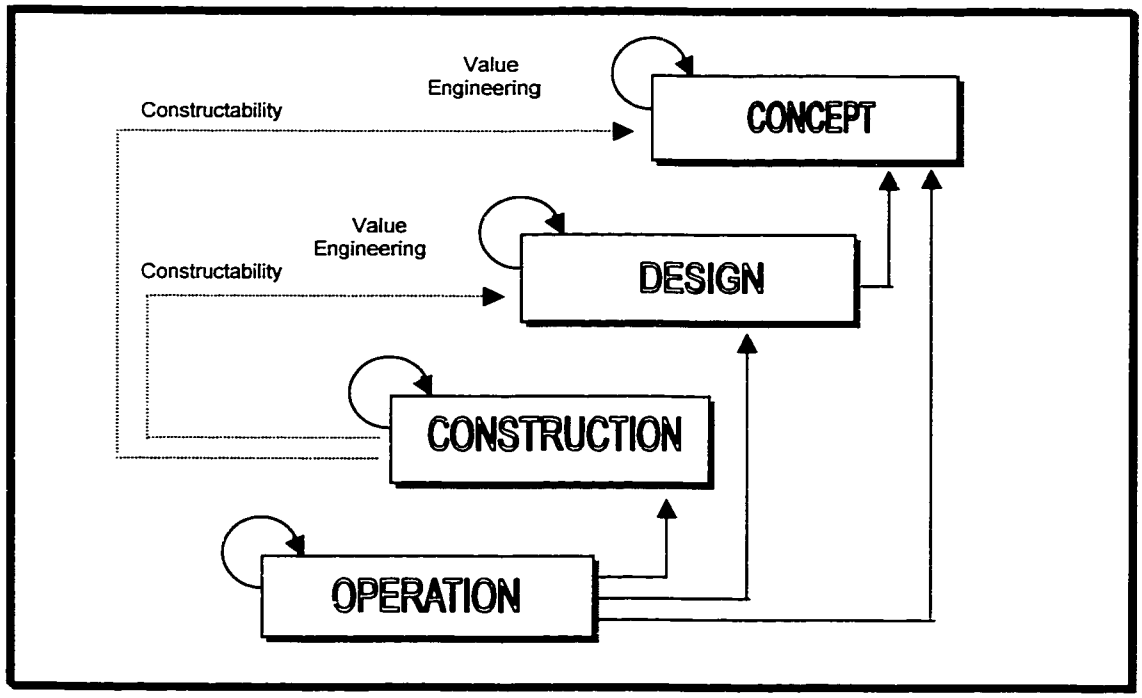


Figure 2.4 Feedback Channels in Project Life Cycle

(Source: Implementing Constructability, Participant Handbook, Construction Industry Institute.)

2.4 Constructability and the ability to influence final cost over project life

The benefits of constructability can occur at all stages of a project, although the Pareto principle (Figure 2.5) dictates that the earlier in the process that constructability is implemented, the greater will be the potential of time and cost savings and quality improvements. Chen, Mc George, and Varnam (1991) claim that "the implementation of constructability management can lead to significant quantifiable improvements in project performance in terms of time, cost and quality. In addition to the quantifiable measures, constructability management can also lead to qualitative improvements in the project process as well as the building project."

Figure 2.6 presents the curve of ability to influence cost over a project's life cycle. The curve suggests that the largest potential to generate constructability saving is early in the project life cycle, and the opportunity to gain benefits drops off quickly once into the design and procurement phases. There is a relatively small potential for gaining these benefits during field operations. The maximum benefits occur when people with construction knowledge and experience are involved at the very beginning of a project.

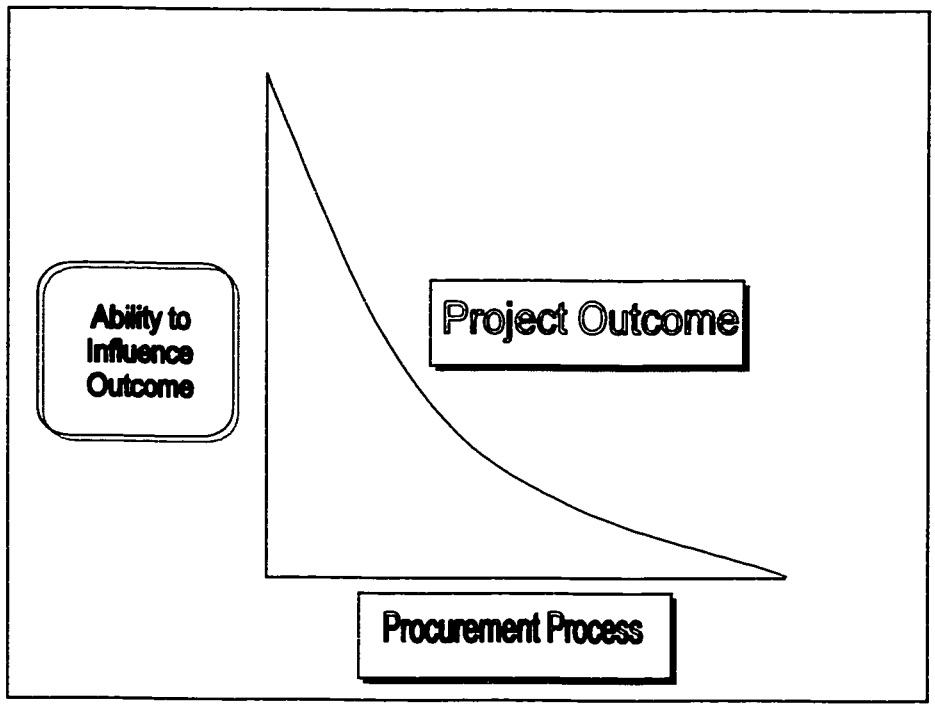


Figure 2.5 - Cost Influence / Pareto Curve

(Source: Constructability Implementation, 1993)

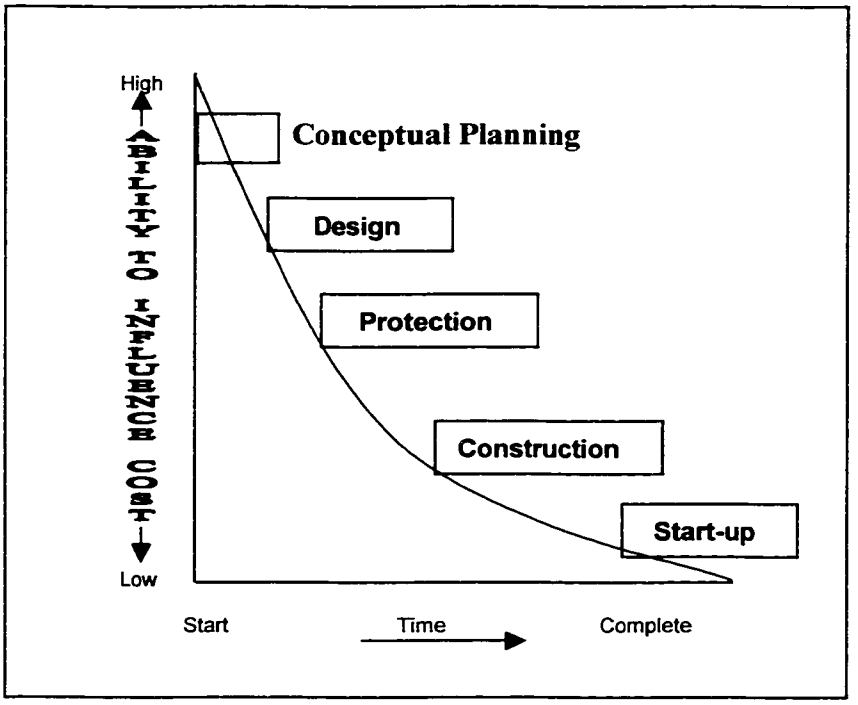


Figure 2.6 - Ability to Influence Final Cost over Project Life.

(Source: Constructability, A Primer, July 1986)

2.5 A Constructability Program

2.5.1 What is a Constructability Program?

Constructability and a constructability program are two different terms with only a minor change in the meaning. We have earlier seen constructability or buildability being defined in the most-simple words as "the ability to construct effectively".

In order to effectively construct, integration of construction knowledge, resources, technology and experience into the engineering and design of a project becomes very essential. To make this process of integration more effective and achievable, a constructability program is applied.

"A constructability program is the application of a disciplined, systematic optimization of the construction-related aspects of a project during the planning, designing, procurement, construction, test and start-up phases by knowledgeable and experienced construction personnel who are part of a project team. The program's purpose is to enhance the project's overall objective." (ASCE, 1991).

A constructability program cannot be viewed as a work process supported by a set of checklists used by construction personnel to review design documents for completeness and errors. This is called an informal constructability program and is less effective than pro-active formal programs. "A formal constructability program consists of a designated corporate coordinator, written procedure, project-level

coordinators, a computerized lessons learned database, and tracking systems to monitor the program's effectiveness." (Russell and Gugel, 1993).

This pro-active constructability program is viewed as a means to increase competitiveness, and competitiveness is enhanced through the re-use of documented lessons learned.

Developing a constructability program for a project results in lower costs, better productivity, earlier project completion and earlier start-up: in short a totally better project.

In order to effectively apply a constructability program, the involvement of experienced construction personnel with the project right from the earliest stage is necessary to ensure the construction focus and experience to properly influence the owners, planners, designers and material suppliers. Such experienced and knowledgeable construction personnel to manage the constructability program could possibly be staff members of the project owner, a separate construction management firm, the designer, or the constructor. If the owner's capability is insufficient to have in-house personnel, a construction management firm can provide constructability input all the way from conceptual planning to completion.

The initial task of the constructability program is to develop project objectives. Firstly, the owner has to set his requirements such as square footage, number of rooms in a hotel or capacity of the place, etc. He has to make a decision as to whether his

project is to be completed with least capital cost or least life-cycle cost. Secondly, he has to establish the cost of the project, and finally to schedule the project and determine the time of completion of project.

When evaluating any of the various other constructability considerations, these objectives must be kept in the mind of the project team members. Each and every action has to be viewed in light of the overall optimization of these objectives.

The constructability program on a large size project should be part of the project execution plan to provide guidance to all the constructability elements. A project execution plan includes the constructability plan to provide an integrated, coordinated program and it covers the objectives, schedules, budget, contracting strategy, procurement plan and construction plan.

2.5.2 Attributes of a Constructability Program

A constructability program consists of 6 major attributes and their corresponding sub-attributes. The 6 major attributes are:

1) Corporate commitment
2) Program support
3) Contractual relationships between participants
4) Constructability planning
5) Constructability implementation
6) Program updating (see table 2.1)

Table 2.1. Attributes of a Corporate Constructability Program

Program Attributes	Program Sub-Attributes
Corporate Commitment	Policy Statement Executive Sponsor (Champion)
Program Support	Designated constructability personnel Corporate level Project level Written program procedures Definition of constructability Constructability roles and responsibilities Constructability organization chart Constructability idea approval procedure Constructability activity scheduling Sample lessons-learned forms Program reporting forms Lessons-learned file Program process tracking Cost saving Future application of ideas Analysis tools Orientation program
Contractual Relationships Between Participants	Reimbursable construction contract type Partnering program Incentives program
Constructability Planning	Organization chart Preliminary review of lessons-learned Activity planning
Constructability Implementation	Weekly constructability meetings
Program Updating	Process measurement Updating lessons learned Integration of new technology

(Source: Russell and Gugel, 1993)

1) Corporate commitment:

Corporate commitment consists of two sub-attributes. The management of an organization must show its commitment towards constructability to provide necessary support to the individuals in the implementation level. Therefore, the two sub-attributes become very necessary. They are: the policy statement and executive sponsor.

A policy statement should include:

a) The organization's commitment to constructability

b) A constructability definition, and

c) The role of Constructability in enhancing the organization's competitiveness.

The executive sponsor must hold a position in the upper management level to show the organization's commitment.

2) Program support:

This attribute consists of six sub-attributes, each of which gives support and continued growth to the program.

The first is designated constructability personnel to manage and update the program by directing the project coordinators, maintaining the lessons-learned file and reporting the program's progress to the executive sponsor.

The Second is a written program procedures, which ensure consistent implementation. The procedures should include the definition of constructability, roles and responsibilities of project team members, constructability activity scheduling, lessons learned and copies of program-reporting forms.

The third attribute is the lessons-learned file, which is considered to be the most valuable part of the constructability program. This should be maintained in a central file or database for future use. The next sub-attribute is the program progress tracking for collecting constructability ideas and determining the cost and schedule savings estimates for each idea. The fifth consists of the analysis tools to enable comparative analysis of multiple design alternatives and construction methods.

The sixth sub-attribute of the program support attribute is the orientation program. Each member of the constructability team must be aware of the philosophy of constructability. Orientation programs may address the following:

1. Definition of constructability.
2. Establishment of a project-level constructability policy statement.
3. Importance of teamwork and communication.
4. Discussion of project objectives.
5. Discussion of the project's critical success factors.
6. Identification of roles and responsibilities of constructability team members.
7. Review of general constructability procedures for the project.

(Radtke, 1992).

3) Contractual relationships between participants:

The contractual relationships between project participants can largely affect the implementation of constructability. "The construction contract type often impacts the timing of constructors' input." (Gugel, 1992).

While in a reimbursable construction contract the constructor can be selected prior to the completion of the project's plan to enable the constructor to provide input into the design process, on the other hand a fixed price contract may limit the contractor's ability to participate in the design process.

Partnering programs can be used between owners, designers and contractors to have a positive impact on constructability. The CII Task Force defined Partnering Programs as: "A long term commitment between two or more organizations for the purpose of achieving specific business objectives by maximizing the effectiveness of each participant's resources." (Construction Industry Institute, 1991). "The relationship is based on trust, dedication to common goals, and an understanding of each other's individual expectations and values." (Cook and Hancher, 1990).

4) Constructability planning:

As much as possible, involvement of major project participants in constructability planning is essential and contributes largely for the benefit of overall planning.

The following are the 3 important factors to be considered in constructability planning:

- It is essential to have an organization chart indicating the constructability team participants and delineating their specific roles in the project.

- A review of the lessons-learned documents must be conducted by the constructability team prior to the start-up of the detailed design.
- Activity planning can be done to schedule the constructability activities by using a bar-chart schedule.

5) Constructability implementation:

In order to ensure proper implementation of constructability in any project, a weekly constructability meeting is essential. This will enable constructability ideas to be evaluated on time without any delay.

6) Program updating:

Constructability is a continuous improvement process. Therefore, program performance should be monitored and updated regularly through progress measurement, updating lessons-learned, and integration of advanced technology.

Progress measurement can be achieved by having a quarterly report submission system to give any recommendation of changes in specs, standards or procedures, if any, to enhance construction efficiency.

Updating of lessons-learned can be made possible by a constructability team who can identify additional lessons learned to be evaluated and finally added to the corporate file.

Integration of advanced technologies is essential to foster continuous improvements in a successful constructability program. New technology can be either in construction methods and techniques or in information systems.

2.6 Barriers and Barrier Breakers to Constructability

2.6.1 Barriers to Constructability Implementation

For successful implementation of a constructability program, identification and removal of its barriers becomes essential in any construction project. "A barrier to constructability is any significant inhibitor that prevents effective implementation of a constructability program." (O'Connor and Miller 1995). The presence of such barriers affects most of the construction organization at both corporate and project level and therefore as a step to the implementation of the constructability program, efforts should be made to determine the presence and relative significance of constructability barriers, and finally the barriers should be removed in order to achieve successful constructability implementation.

"Recognition of barriers to constructability has been identified as one of the 15 significant parameters critical for effective constructability implementation." (O'Connor & Miller, 1994). Also, the Construction Industry Institute (CII) Task Force has issued a list of 41 barriers to constructability which are considered to be potentially significant as inhibitors to effective implementation. Based on the above, O'Connor and Miller in 1994 conducted research which indicated that, of the 41 barriers, 18 were identified as potentially and most significant.

Table 2.2 shows these 18 barriers and their frequency of occurrence.

Table 2.2: Most Common Barriers to Constructability

Barriers		Frequency (percent n = 62)
Rank (1)	Description (2)	(3)
1	Complacency with the status quo	35
2	Reluctance to invest additional money and effort in early project stages	35
3	Limitations of lump-sum competitive contracting	31
4	Lack of construction experience in design organization	23
5	Designer's perception that "we do it"	19
6	Lack of mutual respect between designers and contructors	19
7	Construction input is requested too late to be of value	19
8	Belief that there are no proven benefits to constructability	18
9	Owner's lack of awareness/understanding of the concepts of constructability	16
10	Misdirected design objectives and designer performance measures	15
11	Owner's perception that "we do it"	15
12	Lack of genuine commitment to constructability	15
13	Designer's lack of awareness / understanding of the concepts of constructability	15
14	Poor communication skills of constructors	15
15	Lack of documentation and retrieval of "lessons learned"	13
16	Lack of team building or partnering	13
17	Poor timeliness of constructor input	13
18	The right people were / are not available	11

(Source: O'Connor and Miller, 1994b.)

2.6.2 Characteristics of Common Barriers

The barriers are described by three main characteristics:

1. The Primary Organization Affected,
2. Where Encountered? and
3. The Type of Barrier (Table 2.3)

The first characteristic, "The Primary Organization Affected," provides an indicator for each organization about the significance of a barrier which they should be more aware of.

The second characteristic, "Where Encountered?" highlights the area of the barrier's occurrence: whether the barriers occurred at either the corporate level, project level or both together. This characteristic will help the management in determining the expectation of those common barriers.

The third characteristic is "The Type of Barrier." These are in some cases cultural barriers, which are caused by company tradition or inflexible attitude. Procedural barriers, the second type are some kind of established methods or practices not easily changed, or may be the lack of interest in change, which results in deviation from the current procedures. The third type of barrier, awareness barriers, includes the lack of understanding of the concept, methods and benefits of constructability; and the fourth type, incentive barriers, are caused by lack of motivation or attraction to constructability implementation.

Table 2.3: Characteristics of Common Barriers to Constructability

Rank (1)	Barrier (2)	Primary Organization Affected			Where Encountered		Type of Barrier			
		Owner (3)	Designer (4)	Construction (5)	Corporate (6)	Project (7)	Cultural (8)	Procedural (9)	Awareness (10)	Incentive (11)
1	Complacency with the status quo	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2	Reluctance to invest additional money and effort in early project stages	Yes	No	No	Yes	Yes	No	No	Yes	Yes
3	Limitations of lump-sum competitive contracting	Yes	No	No	No	Yes	No	Yes	Yes	No
4	Lack of construction experience in design organization	No	Yes	No	Yes	Yes	Yes	No	No	No
5	Designer's perception that "we do it"	No	Yes	No	Yes	Yes	No	No	Yes	
6	Lack of mutual respect between designers and constructors	No	Yes	Yes	Yes	Yes	Yes	No	No	No
7	Construction input is requested too late to be of value	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No
8	Belief that there are no proven benefits to constructability	Yes	Yes	Yes	Yes	No	No	No	Yes	No
9	Owner's lack of awareness/understanding of the concepts of constructability	Yes	No	No	Yes	Yes	No	No	Yes	No
10	Misdirected design objectives and designer performance measures	No	Yes	No	No	Yes	Yes	Yes	Yes	No
11	Owner's perception that "we do it"	Yes	No	No	Yes	Yes	No	No	Yes	No
12	Lack of genuine commitment to constructability	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
13	Designer's lack of awareness understanding of the concepts of constructability	No	Yes	No	Yes	Yes	No	No	Yes	No
14	Poor communication skills of constructors	No	No	Yes	Yes	Yes	Yes	No	No	No
15	lack of documentation and retrieval of "lessons learned"	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes
16	Lack of team building or partnering	Yes	Yes	Yes	No	Yes	Yes	No	No	No
17	Poor timeliness of constructor input	No	No	Yes	No	Yes	Yes	No	Yes	Yes
18	The right people were/are not available	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
		11	12	9	13	15	9	7	14	6

(Source: O'Connor and Miller, 1994b.)

Views and opinions on the importance of barriers are not on the same level in every organization. Different organizations hold different views on barriers, due to the change in the level of awareness of constructability, differing levels of expectations from implementation efforts, and varying perceptions of constructability requirements. For example, low-level companies have more difficulty in justifying additional cost and effort to implement constructability, but this barrier is less likely to occur in high-level companies. Also, some barriers are more significant than others to different organizations or even to different departments in the same organization.

2.6.3 Barrier Breakers

It is now known that implementation of constructability programs will have certain barriers. Therefore, for successful and effective implementation of constructability, it is essential to identify these barriers. On identifying these barriers, the work should be directed to overcome or mitigate these barriers by using certain tactics called barrier breakers.

A study was done by O'Connor and Miller (1995) on "Overcoming barriers to successful constructability implementation efforts" and proposed barrier breakers for the seven most common barriers to constructability. The list of potential barrier breakers was critiqued by the constructability implementation task force for completeness and applicability prior to industry evaluation.

The final listing of proposed barrier breakers is shown in Table 2.4, following the seven (enumerated) most common barriers to constructability (O'Connor & Miller, 1993).

2.6.4 Evaluation and Analysis of Barrier Breakers

For evaluating and analyzing the barrier breakers, O'Connor and Miller in 1995 developed a questionnaire to be used to assess:

1. The significance of the barrier breakers to overcome the barriers in question.
2. The do-ability or level of difficulty, or the level of effort required in implementing the barrier breakers.

The assessment was then based on a three-point scale method that was used to evaluate such tactics for low, medium or high significance and level of effort respectively.

The results of the questionnaire were analyzed and tabulated in Figures 2.7 - 2.13 for each barrier. Preferable barrier breakers are those that are plotted on the upper left quadrant of each chart. This shows that these barrier breakers are more significant and require less effort for implementation. On the other hand, on the lower right quadrant of each chart shows the barrier breakers that are less significant and need more effort for implementation.

Table 2.4: Barrier Breakers Identified For Assessment

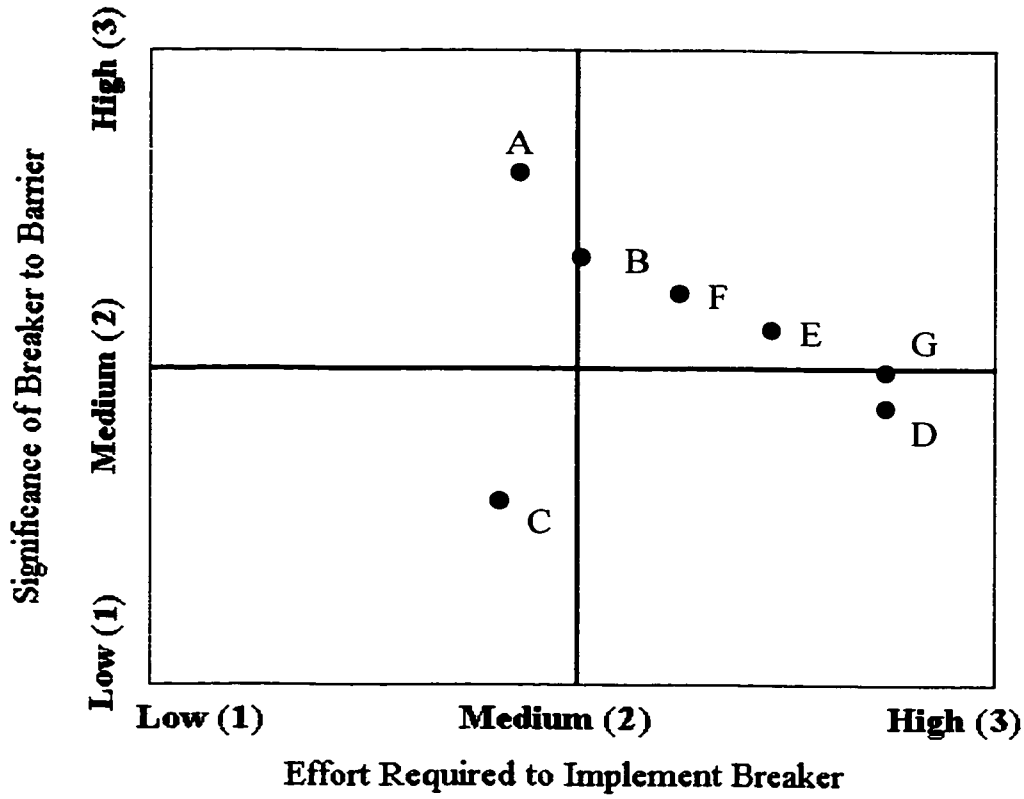
1. Complacency With the Status Quo A. Designate a strong program champion. B. Report constructability program benefits regularly. C. Make constructability the responsibility of younger, energetic individuals who regularly confront the status quo. D. Establish funded programs that promote creativity and intelligent risk-taking. E. Establish monetary awards for rewarding innovation and intelligent risk-taking, F. Conduct training programs in shifting paradigms, promoting creativity, and promoting critical thinking. G. Screen out personnel who regularly support the status quo.
2. Reluctance to Invest Additional Money & Effort in Early Project Stages A. Shift traditional construction budget dollars to protect planning and design; key additional design funding to constructability studies. B. Document success stories and use to sell the program to owners; tabulate concrete, defensible cost-savings data to prove the benefits of early involvement. C. Promote the attitude that constructability should be viewed as an investment opportunity with a corresponding downstream payoff. D. Get CII or others to create promotional tools to sell the program to owners. E. Include constructability as part of a standard bid response and in cost tracking/control efforts. F. Establish formal commitment to the idea of constructability, then convince owners that constructability must start very early in the project process.
3. Limitations of Lump-Sum Competitive Contracting A. Owner/designer acquire in-house construction expertise as input during design. B. Owner/designer procure out-of-house construction expertise as input during design. C. Use only A/E's with strong constructability capabilities. D. Document/disseminate cost-benefit data to disprove the low-bid economy mentality. E. Understand the benefits and flexibility of negotiated contracts and acquire skills to manage same; include constructability as a reimbursable service. F. Develop a short list of contractors who offer constructability input in return for the opportunity to be on the short list of bidders. G. Focus on optimizing the project rather than optimizing the design phase.
4. Lack of Construction Experience in Design Organization A. Conduct in-house training on construction (constructability methods, field problems, lessons-learned, etc.) B. Send employees to constructability short courses. C. Communicate construction issues from field engineers to office engineers and designers.

(Source: O'Connor and Miller, 1995).

Table 2.4: Barrier Breakers Identified For Assessment – Contd.

4. Lack of Construction Experience in Design Organization (cont.) D. In design budget, include adequate travel allowance for field visits by design office personnel. E. Modify hiring practices; establish construction experience as a criterion for hiring; look for good communication skills; look for team skills. F. Close the "project loop" by getting feedback from the field and by tracking lessons learned. G. Modify design management practices to elevate the visibility of constructability issues (e.g., make constructability a routine meeting agenda item from the start of the project) H. Change attitudes; get designers to start viewing the field as a good source of information. I. Establish a new in-house position: Constructability Specialist.
5. Designer's Perception that "We Do It" A. Involve outside experts in conducting a thorough self-assessment: is constructability really being done? B. Conduct and be receptive to constructor end-of-project assessments on actual degree of constructability. C. Periodically question or quiz design personnel on timely, relevant constructability issues; ascertain the breadth & depth of their knowledge on constructability. D. Convince yourself that conventional Value Engineering analyses do not address the breadth of constructability opportunities or issues. E. Find out what constructability is before assessing whether or not you are doing it.
6. Lack of Mutual Respect Between Designers & Constructors A. Aggressively promote effective team-building among project personnel; expose the roles and contributions of each individual; conduct role-playing and objectivity exercises. B. Establish constructor presence in design process before pride of authorship develops. C. Keep the project team focused on common objectives and accepted procedures rather than personalities. D. Cross-pollinate knowledge and experience between design and construction personnel. E. Conduct sensitivity training for selected individuals who have difficulty working with different types of people.
7. Construction Input Is Requested Too Late To Be Of Value A. Increase awareness of the necessity for early construction involvement; recognize the benefits of the pro-active (vs. reactive) approach. B. Include constructability as an early activity in a formal project activity flow plan or "roadmap" C. Automate a lessons-learned database to make it available whenever needed. D. Include individuals with significant construction experience in the project team from the outset; expect active participation from these individuals.

(Source: O'Connor and Miller, 1995).

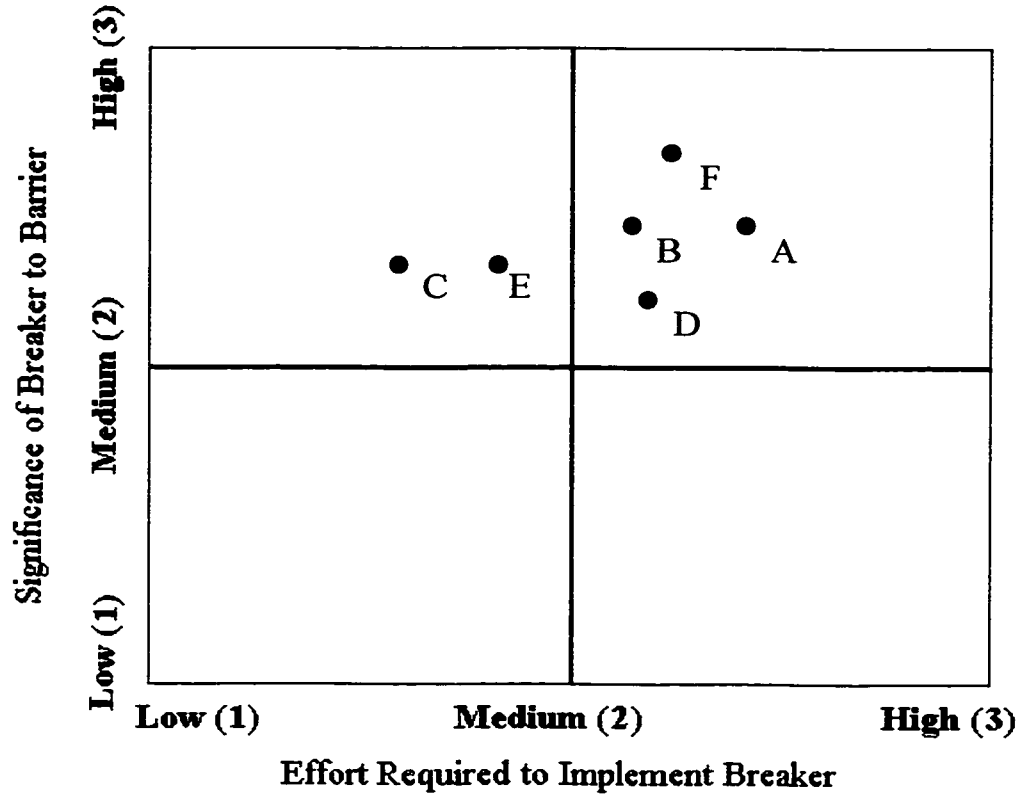


Legend: Barrier Breakers

A: Designate a strong program. (1.95, 2.73)
B: Report constructability program benefits regularly. (2.01, 2.38)
C: Make constructability the responsibility of younger, energetic, individuals who regularly confront the status quo. (1.73, 1.54)
D: Establish funded programs that promote creativity and intelligent risk-taking. (2.65, 1.92)
E: Establish monetary awards for rewarding innovation and intelligent risk taking. (2.49, 2.03)
F: Conduct training programs in shifting paradigms, promoting creativity, and promoting critical thinking. (2.26, 2.31)
G: Screen out personnel who regularly support the status quo. (2.65, 1.97)

Figure 2.7
Barrier Breakers For 1: Complacency With The Status Quo

(Source: O'Connor and Miller, 1995).



Legend: Barrier Breakers

A: Shift traditional construction budget dollars to project planning and design; key additional design funding to constructability studies (2.35, 2.65)

B: Document success stories and use to sell program to owners; tabulate concrete, defensible cost-savings data to prove the benefits of early involvement. (2.16, 2.57)

C: Promote the attitude that constructability should be viewed as an investment opportunity with corresponding downstream payoff. (1.68, 2.43)

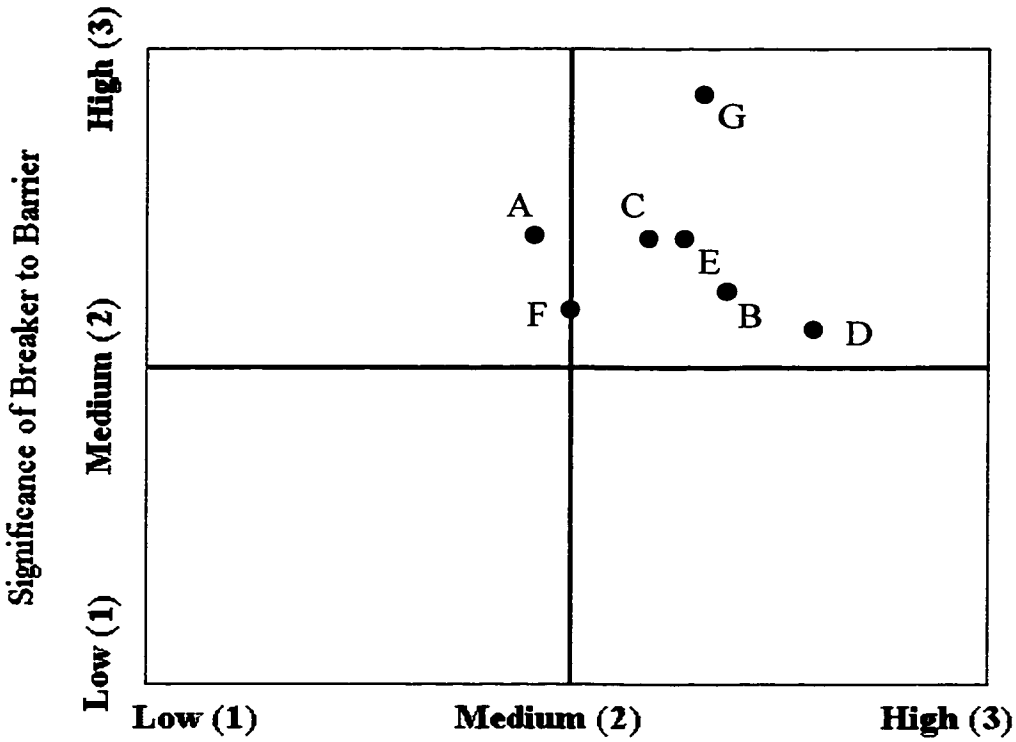
D: Get CII or others to create promotional tools to sell the program to owners. (2.14, 2.14)

E: Include constructability as a part of a standard bid response and in cost tracking / control efforts. (1.86, 2.38)

F: Establish formal commitment to the idea of constructability, then convince owners that constructability must start very early in the process. (2.22, 2.76)

Figure 2.8
Barrier Breakers For 2: Reluctance To Invest Additional Money & Effort In Early Project Stages

(Source: O'Connor and Miller, 1995.)



Legend: Barrier Breakers

A: Owner / designer acquire in-house construction expertise as input during design. (1.92, 2.38)

B: Owner / designer procure out-of-house construction expertise as input during design. (2.35, 2.14)

C: Use only A/E's with strong constructability capabilities. (2.08, 2.38)

D: Document / disseminate cost-benefit data to disprove the low-bid economy mentality. (2.49, 2.11)

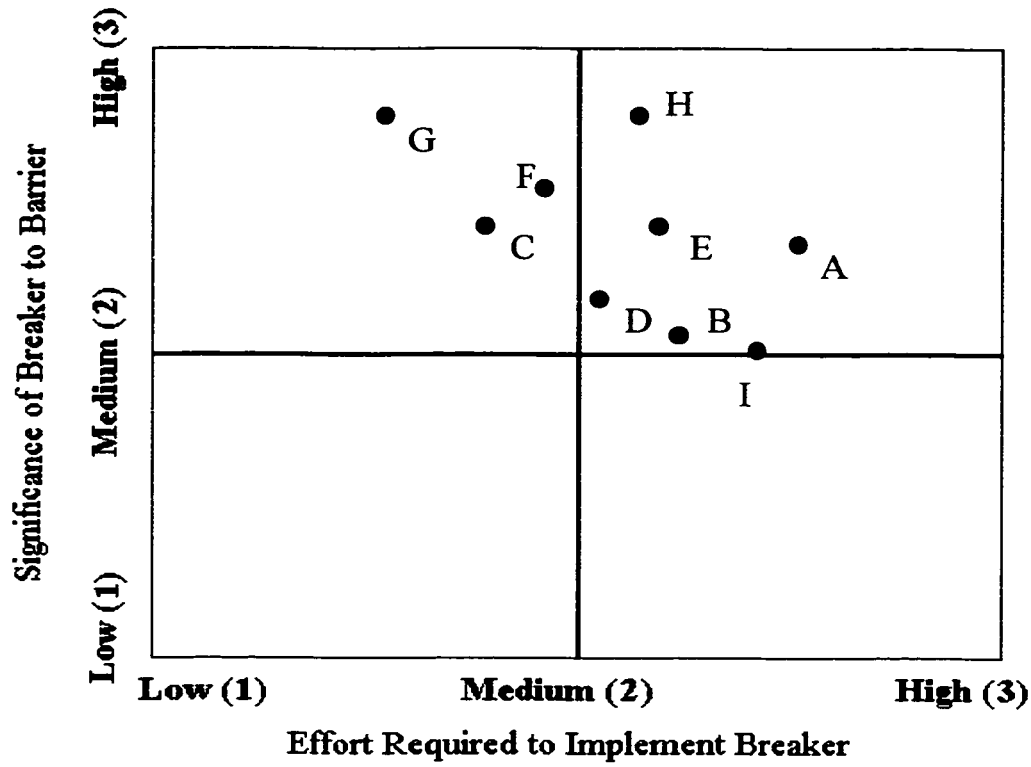
E: Understand the benefits and flexibility of negotiated contracts and acquire the skills to manage same; include constructability as a reimbursable service. (2.14, 2.39)

F: Develop a short list of contractors who offer constructability input in return for the opportunity to be on the short list of bidders. (1.97, 2.08)

G: Focus on optimizing the project rather than optimizing the design phase. (2.23, 2.80)

Figure 2.9
Barrier Breakers For 3: Limitations of Lump-sum Competitive Contracting

(Source: O'Connor and Miller, 1995.)

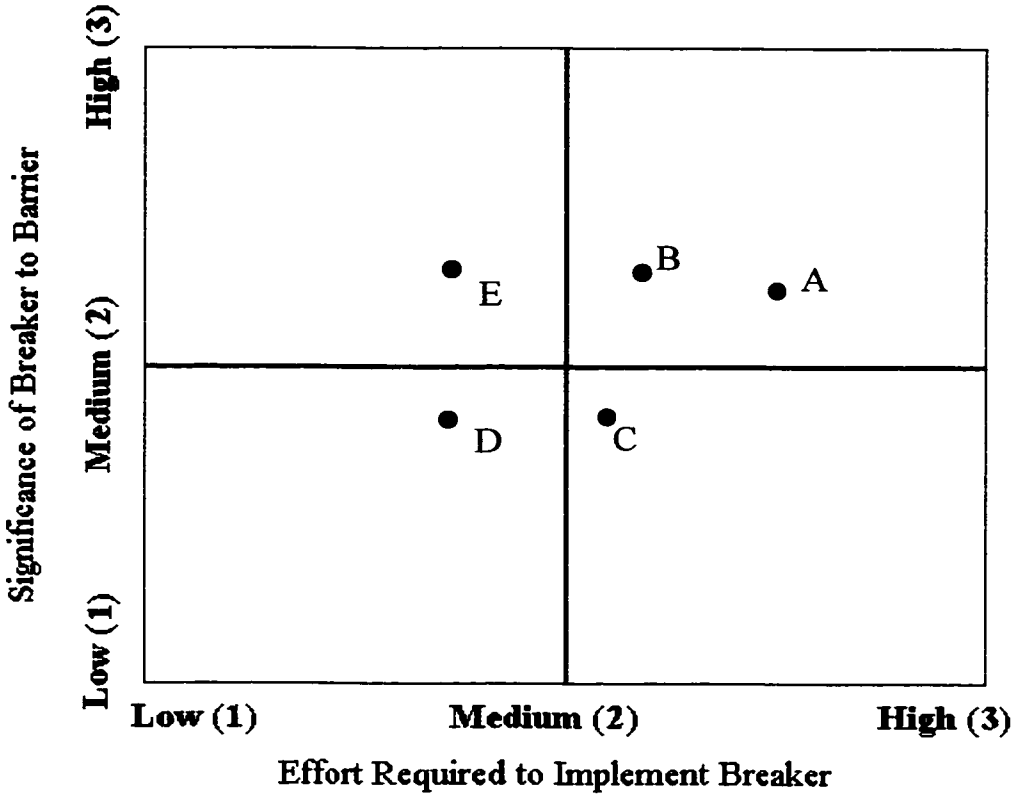


Legend: Barrier Breakers

A: Conduct in-house training on construction. (2.36, 2.36)
B: Send employees to constructability short courses. (2.22, 2.06)
C: Communicate construction issues from field engineers to office engineers / designers. (1.86, 2.40)
D: In design budget, include adequate travel allowance for field visits by design office personnel. (2.06, 2.17)
E: Modify hiring practices; establish construction experience as a criterion for hiring; look for good communication skills; look for team skills, (2.14, 2.37)
F: Close the "project loop" by getting feedback from the field and tracking lessons-learned. (1.92, 2.47)
G: Modify design management practices to elevate the visibility of constructability issues. (1.63, 2.66)
H: Change attitudes; get designers to start viewing the field as a good source of information. (2.12, 2.71)
I: Establish a new in-house position: Constructability Specialist. (2.39, 2.00)

Figure 2.10
Barrier Breakers For 4: Lack of Construction Experience in Design Organization

(Source: O'Connor and Miller, 1995.)



Legend: Barrier Breakers

A: Involve outside experts in conducting a thorough self-assessment: is constructability really being done? (2.50, 2.17)

B: Conduct and be receptive to constructor end-of-project assessments on actual degree of constructability. (2.14, 2.33)

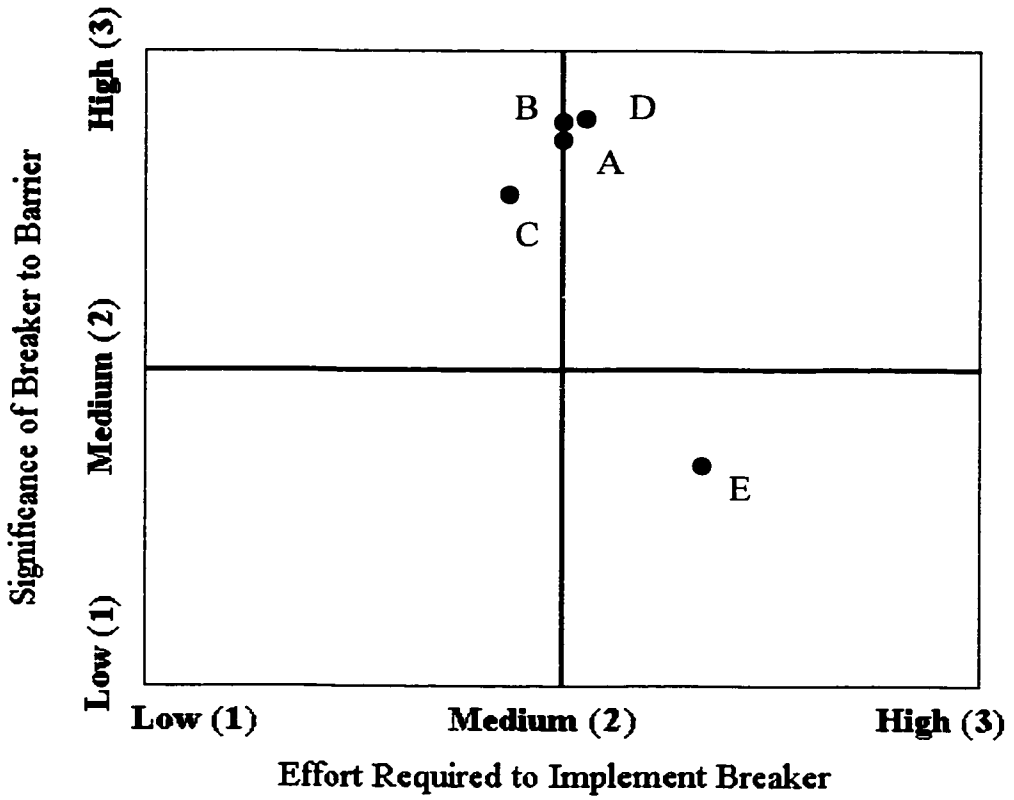
C: Periodically question or quiz design personnel on timely, relevant constructability issues; ascertain the breadth & depth of their knowledge on constructability. (2.08, 1.83)

D: Convince yourself that conventional Value Engineering analyses do not address the breadth of constructability opportunities or issues. (1.83, 1.86)

E: Find out what constructability is before you assess whether or not you are doing it. (1.69, 2.31)

Figure 2.11
Barrier Breakers For 5: Designer's Perception That "We Do It"

(Source: O' Connor and Miller, 1995.)



Legend: Barrier Breakers

A: Aggressively promote effective team-building among project personnel; expose the roles and contributions of each individual; conduct role-playing and objectivity exercises. (1.97,2.79)

B: Establish constructor presence in design process before pride of authorship develops. (2.00, 2.83)

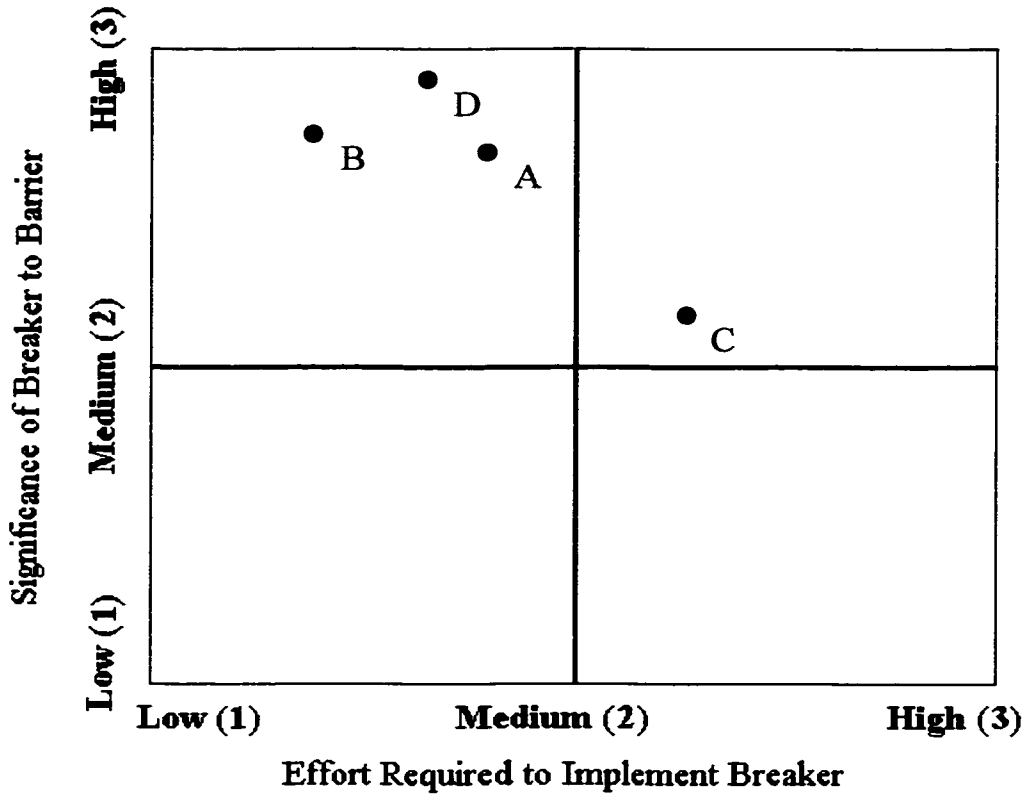
C: Keep the team focused on common objectives and accepted procedures rather than personalities. (1.86, 2.66)

D: Cross-pollinate knowledge and experience between design and construction personnel. (2.06, 2.86)

E: Conduct sensitivity training for selected individuals who have difficulty working with different types of people. (2.33, 1.64)

Figure 2.12
Barrier Breakers For 6: Lack of Mutual Respect Between Designers & Constructors

(Source: O' Connor and Miller, 1995.)



Legend: Barrier Breakers

A: Increase awareness of the necessity for early construction involvement; recognize the benefits of pro-active (vs. reactive) approach. (1.88, 2.91)

B: Include constructability as an early activity in a formal project activity flow plan or "roadmap." (1.61, 2.78)

C: Automate a lessons-learned database to make it available whenever needed. (2.18, 2.12)

D: Include individuals with significant construction experience in the project team from outset; expect active participation from these individuals. (1.72, 2.86)

Figure 2.13
Barrier Breakers For 7: Construction Input Is Requested Too Late To Be Of Value

(Source: O' Connor and Miller, 1995.)

2.6.5 Characteristics of Barrier Breakers

The preferable barrier breakers, those that are found to be more significant and require less effort for implementation, are summarized in Table 2.5.

This list of 15 barrier breakers in the preference level does not include some which are recognized as significant for overcoming barriers in constructability due to implementation difficulties.

In Table 2.5, two characteristics for each barrier breakers are indicated:

1. Whether the 15 barrier breakers are more effective at the corporate level or at the project level.

2. Whether the type of barrier breakers are cultural, procedural, awareness oriented or incentive oriented.

Table 2.5: Characteristics of Effective Barrier Breakers Identified

Barrier	Recommended Breakers	Where Effective		Type of Breaker			
		Corporate	Project	Cultural	Procedural	Awareness	Incentive
1: Complacency with the status quo	* Designate a strong program champion.	X		X		X	
2: Reluctance to invest additional money & effort in early project stages	* Promote the attitude that constructability should be viewed as an investment opportunity with corresponding downstream payoff.	X	X				X
	* Include constructability as part of a standard bid response and in cost tracking/control efforts.		X		X	X	
3: Limitations of lump-sum competitive contracting	* Owner/designer acquire in-house construction expertise for input during design.		X		X	X	
	* Develop a short list of contractors who offer constructability input in return for the oportunity to be on the short list of bidders.		X		X		
4: Lack of construction experience in design organization	* Communicate construction issues from field engineers to office engineers/designers.		X	X	X		
	* Close the "project loop" by getting feedback from the field and by tracking lessons learned.		X	X	X		
	* Modify design management practices to elevate the visibility of constructability issues.	X		X		X	
5: Designer's perceprion that "We do it"	* Find out what constructability is before you assess whether or not you are doing it.	X				X	
6: Lack of mutual respect between design and constructors	* Aggressively promote effective team-building among project personnel.		X	X			
	* Establish constructor presence in design process before pride of authorship develops		X	X			
	* Keep the project team focused on common objectives and accepted procedures rather than personalities.		X	X	X		
7: Construction input requested too late to be of value	* Increase awareness of the necessity for early construction involvement.	X				X	
	* Include constructability as an early activity in a formal project activity flow plan or roadmap.	X	X		X		
	* Include individuals with significant construction experience in the project team from the outset.	X	X		X		
Sum of effective breakers in each category		7	11	7	8	6	1

(Source: O' Connor and Miller, 1995.)

CHAPTER 3

RESEARCH METHODOLOGY

3.1 The Research Process

The entire research process was broken down into the following 4 stages.

(i) Literature Review.

(ii) Research Method Plan.

(iii) Implementation of Research Method Plan.

(iv) Data Management & Analysis.

The highlights of the above 4 stages of this research process are summarized as detailed below.

(i) Literature Review

A comprehensive understanding of the subject "Constructability" is required before conducting a new piece of research, and this necessitates a review of the major literature associated with the field, in order to become more familiar with the subject by studying and closely observing previous studies conducted in this field.

(ii) Research Method Plan

Immediately after the literature review stage, a detailed plan of the research method was drafted and it was decided that a survey would be used for collecting the required data.

(iii) Implementation of Research Method Plan

In this period, the questionnaire was designed, sent to many personnel for participation, and feedback was received from participants.

(iv) Data Management and Analysis

The final stage, as the heading signifies, involves managing of received data, studying and analyzing various related issues.

3.2 The Questionnaire

Initially, it had been decided to have face-to-face interviews with the participants. But, considering various contingencies like fixing appointments, traveling long distances, participants' minimum acceptance level for personal interviews, keeping of appointments etc., many of the participants suggested receiving questionnaires by fax for effective participation. As a result, the plan was changed to e-mail and fax the questionnaire and closely follow up by telephone.

The questionnaire was taken from research done by Lores (1997) and was modified slightly in order to suit the region and to make it more objective, as follows:

1. Question 2 was added.
2. Question 6 – Currency was changed from US$ to SR.
3. Question 11 – One choice was added: **"No Participation"**.
4. Question 14 – The basic concept of the question is the same, but the format was changed. Instead of selecting the barriers to constructability from the list, the question was changed to "Rate the barriers on the list" as Always / Sometimes / Never.

The questionnaire was designed in three parts. A copy of the questionnaire is presented in Appendix A.

The first part includes questions one through seven, to obtain information about the characteristics of the organization, such as:

- Name and position of the person, company name, address, phone and fax. All are optional.
- Organization's nationality.
- In what sector the organization is performing work.
- What type of work the organization is involved with.
- What range of annual volume of work.
- What type of contract.

Questions two through seven were considered to be independent variables of the research, because it was believed that the characteristics of the organization might influence the answers to the rest of the questionnaire.

The second part of the questionnaire contains the definition of the term "constructability" in order to assess the participants' awareness of the term. Even if the respondent is not fully aware of the term "constructability", the definition helps him to understand constructability enough to complete the questionnaire, as many organizations may be unknowingly practicing the concept of constructability.

In questions nine to twelve, the participants were asked to check all the activities that their organization performed during the conceptual, design and construction phases of the project and the implementation of the constructability program.

The third part of the questionnaire was designed to determine the opinions of the general contractors on the following issues:

- Their participation during the pre-construction phase by inserting construction knowledge.
- Rating a list of barriers to constructability by choosing – "Always / Sometimes / Never".
- Indicating the type of projects that constructability should be implemented with.
- The difficulties that they encountered by using a traditional method (design without construction input).
- Whether the participation of construction contractors during the design phase can improve the drawing and specifications.
- If constructability should be included during the design phase as another specialty.

3.3 Sampling

At this stage, selection of the type of organization for survey plays a key role in making the research more effective. By looking at the subject from various different angles, and to avoid any potential conflicts and discrepancies in the collected data bank General Contractors were the only type of organization selected for use in this survey.

Small General Contractors were not included in this survey. Only contractors who were rated as grade 2 and more, as classified by the Chamber of Commerce and Industry were chosen. A count of 49 such CCI rated contractors, and another count of 43 contractors approved and listed by Saudi Aramco were selected and used in this survey. A copy of the contractors lists is presented in Appendix D.

3.4 Sample Size

The sample size required for this survey was determined using the following formula (Kish, 1995):

$$n_o = (p * q) / v^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

$$n = n_o / [1 + (n_o / N)] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Where n_o : First estimate of sample size

p : The proportion of the characteristic being measured in the target population.

q : 1 - p

v : The maximum percentage of standard error allowed

N : The Population size

n : The sample size.

For the purpose of getting the maximum sample size, the value of "p" and "q" are taken as 0.5 for both. The maximum standard error allowed in this research was taken as v = 10% (0.1), and the total population consisted of 92 contractors (Appendix D).

$$n_o = 25$$

$$n = 19.67$$

3.5 Sampling Method

It is quite common that the response rating for the questionnaire mailed is never 100% for any research except for rare cases. So a decision was made to mail, fax or e-mail all the contractors on the two lists. From the list of questionnaires mailed, the response in the beginning was way below expectation. Of the 92 posted questionnaires, only 2 replies were received. This poor performance led to the alternative approach of faxing the questionnaire and following it up by phone. Many participants responded and valuable data was collected. In some cases, the researcher conducted personal interviews with the contractors' representatives.

Over a period of 3 ½ months, about 37 questionnaires were received. This means a response rate of 40%. The received data was carefully read and in some cases the respondents were contacted for certain clarifications.

3.6 Statistical Analysis

In this research, two methods of data analysis were used: descriptive analysis and statistical analysis.

The descriptive analysis was to count the frequencies of the Yes and No responses, calculate the proportion and present the results in tables and graphs for all the questions in the survey.

The statistical analysis was to determine the independence between two variables by statistical significance. The statistical technique used to provide answers to such questions are based on the chi-square distribution. This technique is called the chi-square test of independence.

The term statistical significance is used to show that the differences between the variables are statistically meaningful and not by chance (Fink, 1995).

The statistical analysis was used to determine the existence of a relationship between the independent variables, which are the characteristics of the organization, and the dependant variables, which are the implementation of constructability during the conceptual, design and construction phases.

Statistical software called SPSS 9.05 was used to analyze the data, and the following formula was used to determine the Chi-square value:

$$X^2 = \sum \sum (Oij - Eij)^2 / Eij$$

Where

Oij = Observed number of observations.

Eij = Estimated number of observations.

Level of significance was chosen as $\alpha = 0.05$. The α value will be compared with the P value (observed significance) obtained from the output of the SPSS software. If the P value is smaller than $\alpha = 0.05$, then the null hypothesis (the independence between variables) is rejected and the variable is said to be dependant. Computer output of results is presented in Appendix C.

CHAPTER 4

DISCUSSION OF THE RESULTS

4.1 Response Rate

The response rated against the total number of questionnaires sent to various participants is summarized below.

The list obtained from the Chamber of Commerce and Industry containing 49 contractors in the Grade 2 and above category were expected to respond to the questionnaire faxed by the researcher. Of the above 49 contractors only 12 (25%) responded. Out of these 12, 2 of them were not under the General Contractors type and therefore excluded from the list.

A second list containing 43 contractors, obtained from Aramco Contracting Dept., was sent to those concerned. Of this list, 25 contractors responded to the questionnaire, making the rate of response 58%. Out of these 25 respondents, 4 were not under the General Contractors type and therefore excluded from the list.

Therefore, of the total 92 questionnaires sent to different contractors, 37 (40%) responded. From this 37, 6 did not fit under the General Contractors category and

therefore remained excluded, which means that only 31 questionnaires were used and included in the database.

In this exercise of data collection through the questionnaire survey method, sixty percent (60%) of the contractors did not care to reciprocate or show any form of interest in the constructability issue in spite of continuous follow-up efforts.

4.2 Description of the Results

The presentation of the results will be in four major parts.

The **first part** will discuss the characteristics of the organization, such as: nationality, type of work, the sector where work is performed, type of contract and volume of work. The results of this part were acquired from questions 2 to 7 in the survey questionnaire.

The **second part**, that is questions 8, 13,15,16,17 and 18, indicates the respondents' opinions with respect to the constructability issues.

The **third part** covered under question 14 presents the results regarding the barriers to constructability.

The **fourth part** contributes the answer on how the participants are using the concept of constructability in their different project stages. These results were obtained from questions 9,10,11 and 12 in the survey questionnaire.

To summarize the results, Fig 4.1 gives cummulative percentages of positive responses for each category for the entire survey. For example, in question 6, 32% of the respondents have an annual volume of work ranging between SR.50,000,000 and SR.100,000,000.

4.2.1 Part 1: Characteristics of the Organization

The majority of the participating organizations were of Saudi nationality (i.e. about 87%) and had an annual project volume of up to SR.100 million.

Of the participating organizations, the majority of the General Contractors worked in General Building Construction projects (77%) and Industrial projects (55%) under the Construction Management and Design-Build method of contract. Many of them performed work in both private and public sectors.

Table 4.1 and Figures 4.2, 4.3, 4.4, 4.5 and 4.6 summarize the general characteristics in terms of nationality, sector of work performed, type of work, volume of work and type of contract for all the organizations that participated in the survey.

4.2.2 Part 2 Contractors' Opinions on Constructability

A detailed summary of the participants' opinions about the constructability issue is shown in Table 4.2 and Figures 4.7 to 4.12.

Question 8 defines Constructability and judges the participants' awareness of the definition.

Eighty-four percent (84%) of the participants were aware of the term constructability. This indicates that constructability is very common in this part of Saudi Arabia among the General Contractors.

One main reason for this high percentage (84%) of constructability awareness could possibly be the result of Saudi Aramco's existence in the province that stipulates the need for constructability for all General Contractors as a key requirement for qualification.

Two remarks from 2 respondents who answered to not having heard of the constructability term before were:

" No, but I am practicing it."

" We know the concept."

Question 13 asked "How often do you participate by inserting constructability knowledge during the pre-construction phase of projects?"

Seventy seven percent (77%) of the General Contractors were commonly participating during this stage of the project and only three percent (3%) expressed that they never participated during this stage of the project. This result shows that General Contractors are participating in the earlier phase of the projects.

1. Information about the person filling the questionnaire:

Name: (Optional)_____

Position: _____

Company:_____

Address:_____

_____

Phone: _____ Fax: _____

Email: _____

2. Organization Nationality.

☐	Saudi.	87%
☐	Joint Venture.	3%
☐	Other	10%

3. What best describes your organization type:

☐	General Contractor.	100%	☐	Design Build Contractor.	0%
☐	Subcontractor.	0%	☐	Other	0%

4. In what sector does your organization perform work? Check all that apply.

☐	Private (% of total volume). 79%	☐	Public (% of total volume). 72%

5. What type of work is your organization typically involved with? Check all that apply.

☐	General Building.	77%	☐	Industrial.	55%
☐	Civil (Heavy and Highway).	26%	☐	Other	23%

6. Please indicate the range of annual volume of work.

☐	Less than SR50,000,000	35%
☐	Between SR50,000,000 and SR100,000,000	32%
☐	Between SR100,000,000 and SR500,000,000	23%
☐	More than SR500,000,000	10%

7. Under what type of contract do you perform work? Check all that apply

☐	Traditional (design without construction input) (____% of total volume).	39%
☐	Design-build (____% of total volume).	58%
☐	Construction Management (____% of total volume).	71%

8. Constructability has been defined as: "The optimum integration of construction knowledge and experience in planning, engineering, procurement and field operations to achieve overall project objectives". Have you heard this term before?

☐	Yes.	84%	☐	No.	16%

Figure 4.1 Cumulative percentages of Positive Responses for the Entire survey.

9. Has your organization participated in the conceptual phase of a project by doing any of the following activities: Check all that apply.

☐ Advise owner in the establishment of the project goals and objectives.	52%
☐ Execution of feasibility studies and advice in the selection of the site.	39%
☐ Advise owner in the contracting strategy.	58%
☐ Suggest structural systems.	55%
☐ Selection of the major construction methods and materials.	71%
☐ Preparation of the schedule, estimates and budget.	81%
☐ No participation.	10%

10. Has your organization participated in the design-procurement phase of a project by doing any of the following activities: Check all that apply.

☐ Analysis of the design to enable efficient construction (e.g. Ensure workmen can get tools to areas to make connections).	52%
☐ Insert into the design the concern of accessibility of personnel, materials and equipment.	58%
☐ Promote designs that facilitate construction under adverse weather conditions.	29%
☐ Preparation of the schedule, estimates and budget.	77%
☐ Advise design team about sources of materials and engineering equipment.	65%
☐ Analysis/revision of the specifications to allow easy construction.	68%
☐ No participation.	10%

11. Please select the activities your organization performs during the construction phase: Check all that apply.

☐ Careful analysis of layout, access, and temporary facilities to improve productivity.	97%
☐ Planning the sequence of field task to improve productivity.	90%
☐ Use of preassembly or prefabrication for the execution of the works.	77%
☐ Innovative use of construction equipment and tools (e.g. Mobile hydraulic man-lifts in lieu of scaffolding).	68%
☐ Innovative use of material (e.g. Fiber reinforced concrete).	58%
☐ Capture and transfer of lessons-learned to future projects.	81%
☐ No participation.	3%

12. Considering questions 8 – 11, does your organization implement any of the following? Check all that apply.

☐ There is an organizational policy statement toward the implementation of constructability.	55%
☐ The management of the organization supports constructability.	81%
☐ Assignment of constructability coordinator in the organization level and in the project level.	68%
☐ Constructability is included in contract documents.	58%
☐ None of the above.	16%
☐ All of the above (organized, formal constructability program).	39%

13. How often do you participate by inserting construction knowledge during the preconstruction phase of projects?

☐ Commonly.	77%
☐ Seldom.	20%
☐ Never.	3%

Figure 4.1 Cumulative percentages of Positive Responses for the Entire survey.

14. Based on your experience, please rate the following list of barriers to constructability.

	ALWAYS	SOMETIMES	NEVER
a. The concept is unknown by the owner.	☐ 19%	☐ 71%	☐ 10%
b. Owners do not care about constructability in the contracting strategy.	☐ 29%	☐ 52%	☐ 19%
c. Design without construction input is the traditional form of contracting.	☐ 33%	☐ 44%	☐ 23%
d. Owners do not choose constructability in their projects.	☐ 29%	☐ 55%	☐ 16%
e. The concept is unknown by designers.	☐ 10%	☐ 60%	☐ 30%
f. Designers lack of construction experience and knowledge of construction technologies.	☐ 10%	☐ 77%	☐ 13%
g. The concept is unknown by contractors.	☐ 13%	☐ 52%	☐ 35%
h. Reluctance of field personnel to offer preconstruction advise.	☐ 13%	☐ 64%	☐ 23%
i. There are no proven benefits of Constructability.	☐ 3%	☐ 30%	☐ 67%
Other (explain)			
j. _____	☐	☐	☐
k _____	☐	☐	☐
l. _____).	☐	☐	☐

15. Where do you think constructability should be implemented? Check all that apply.

☐ Complex Projects.	16%	☐ Small Projects.	3%
☐ Large Projects.	26%	☐ All Projects.	71%
☐ Certain types of Projects.	10%		

16. Using the traditional process (design without construction input), have you encountered any of the following difficulties? Check all that apply.

☐ Specifications problems.	90%
☐ Tolerance problems.	53%
☐ Problems with physical interference.	70%
☐ Weather related problems that could be avoided during design phase.	30%
☐ Unrealistic schedule.	77%

17. Do you agree that the participation of construction contractors during the design of a project can help to produce better drawings, specifications, and buildable projects?

☐ Yes.	90%	☐ No. 0%	
☐ Sometimes.	10%		

18. Do you think constructability should be included as another specialty during the design phase of the project
such as: architectural, mechanical, electrical, etc.?.

☐ Yes.	74%	☐ No.	13%
☐ Sometimes.	13%		

Thank you for your time, this concludes your participation in this survey.

Figure 4.1 Cumulative percentages of Positive Responses for the Entire survey.

Table 4.1: Characteristics of Respondents

	Characteristics of the Organization	% of Frequency n=31
Nationality		
	Saudi	**87%**
	Other	**10%**
	Joint Venture	**3%**
Sector		
	Private	**79%**
	Public	**72%**
Type of Work		
	General Building	**77%**
	Industrial	**55%**
	Civil (Heavy & Highway)	**26%**
	Other	**23%**
Volume of Work		
	Less than SR 50M	**35%**
	Between SR 50M & 100M	**32%**
	Between SR 100M & 500M	**23%**
	More than SR 500M	**10%**
Type of Contract		
	Construction Management	**71%**
	Design-Build	**58%**
	Traditional	**39%**

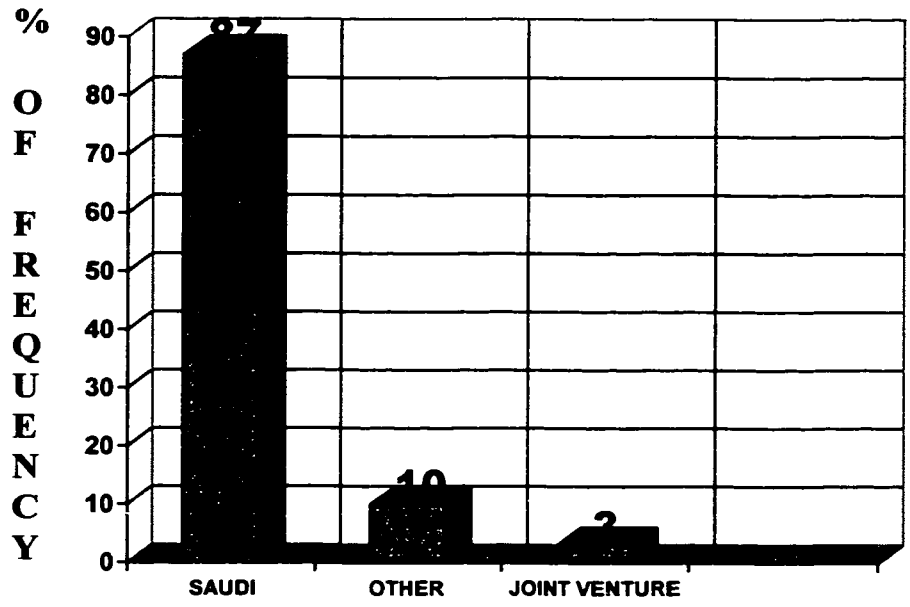


Figure 4.2: Nationality of the Organization

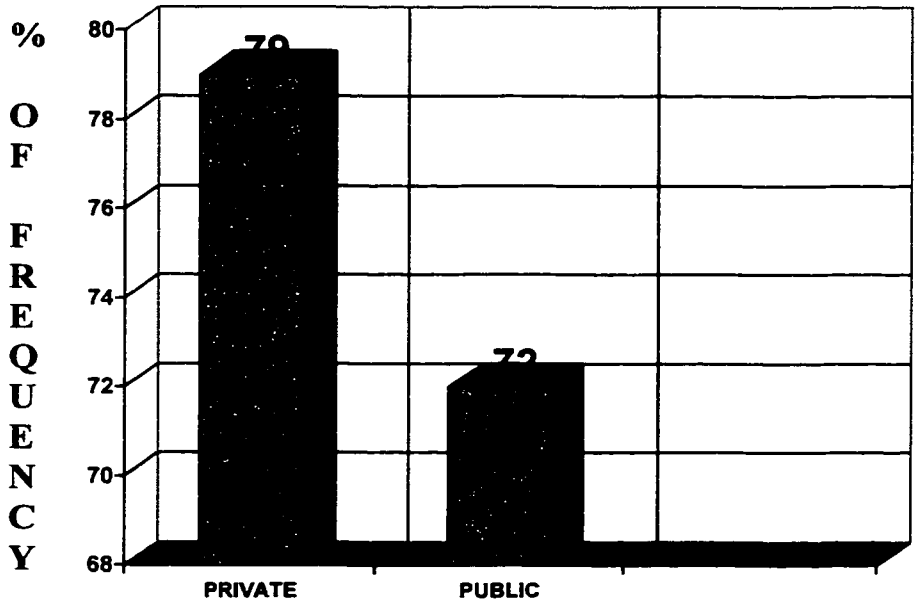
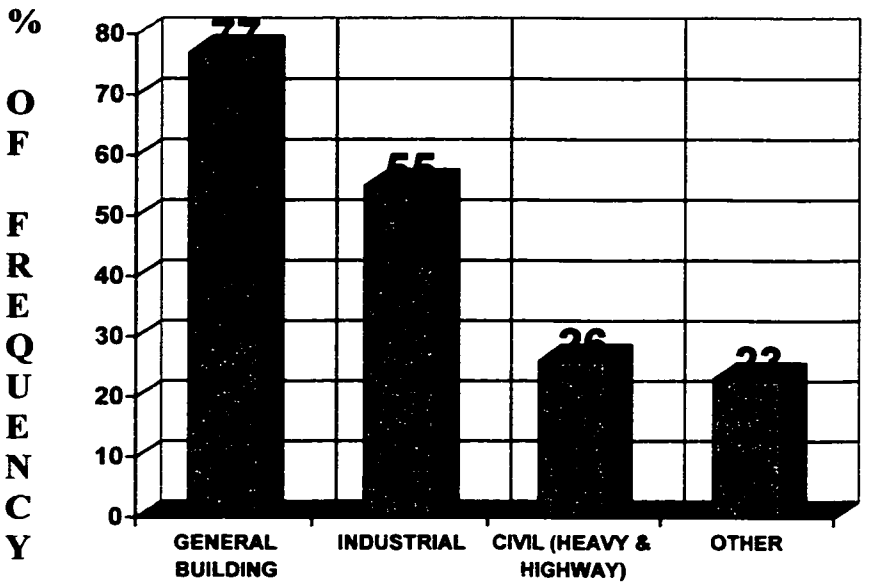
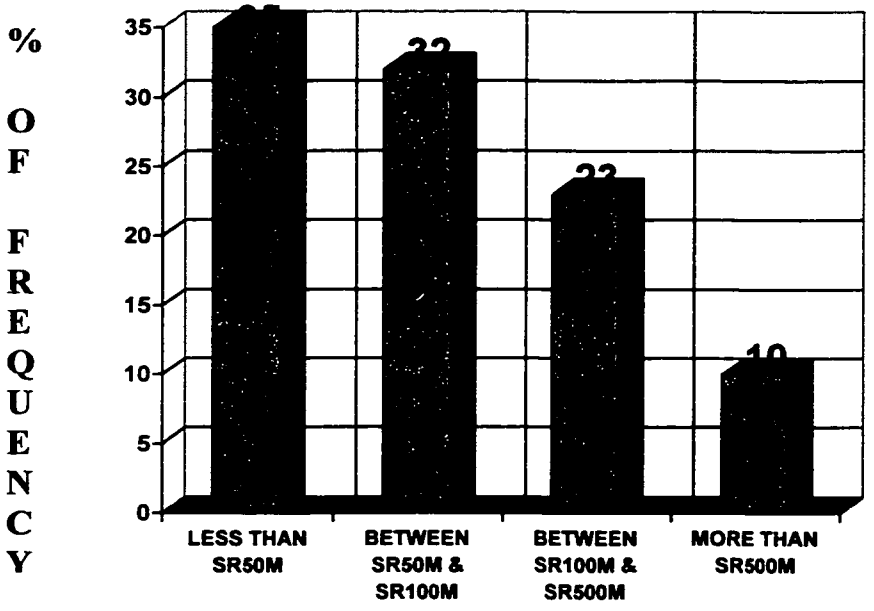


Figure 4.3: Sector where Organization Perform Work



TYPE OF WORK
Figure 4.4: Type of Work



VOLUME OF WORK
Figure 4.5: Range of Annual Volume of Work

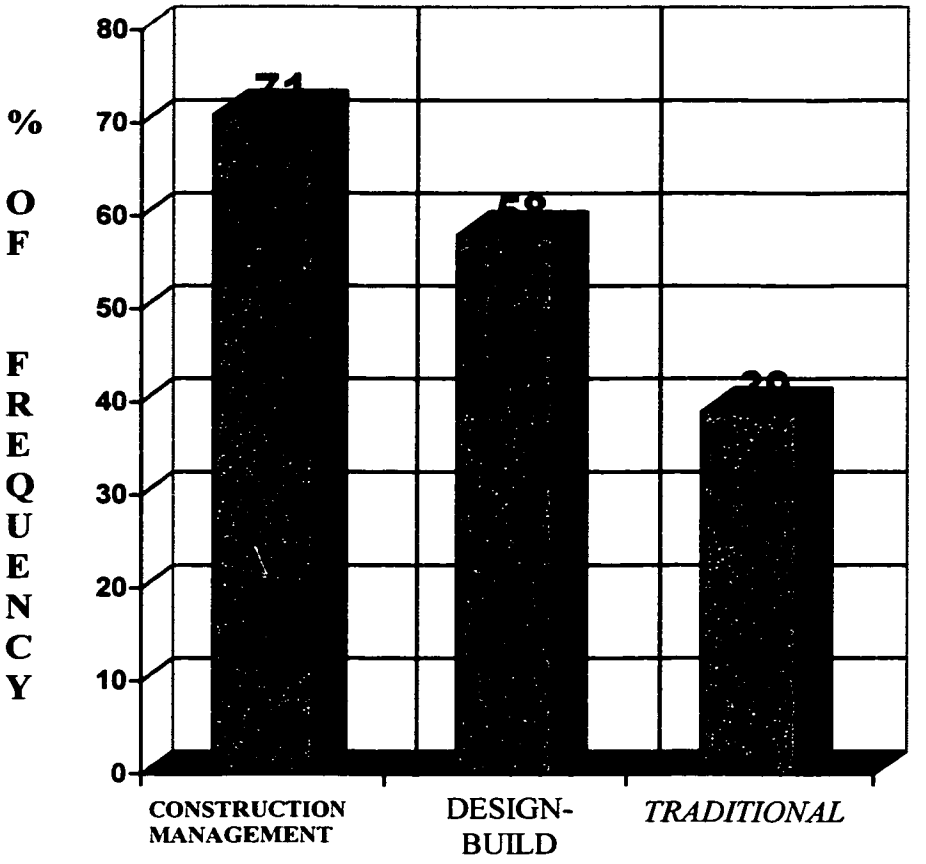
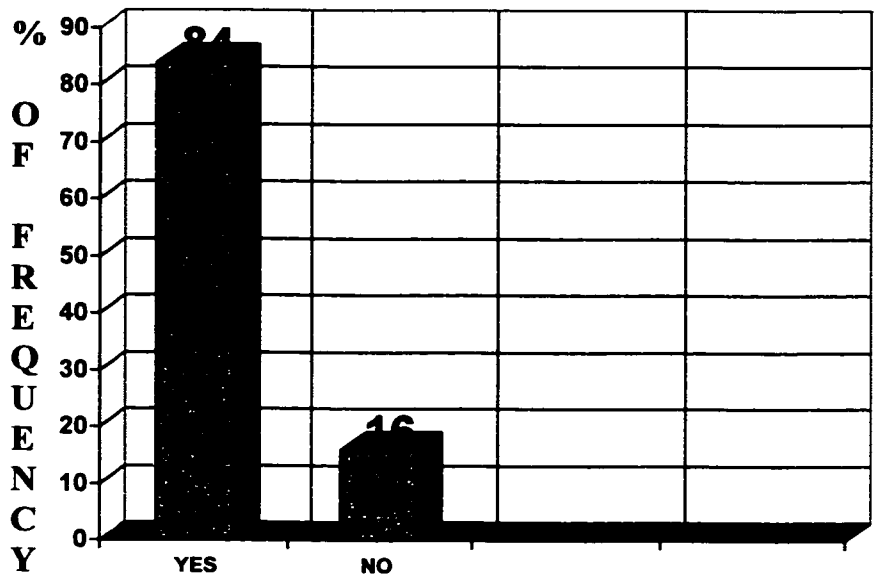


Figure 4.6: Type of Contract

Table 4.2: Respondent's Opinions about Constructability Issues

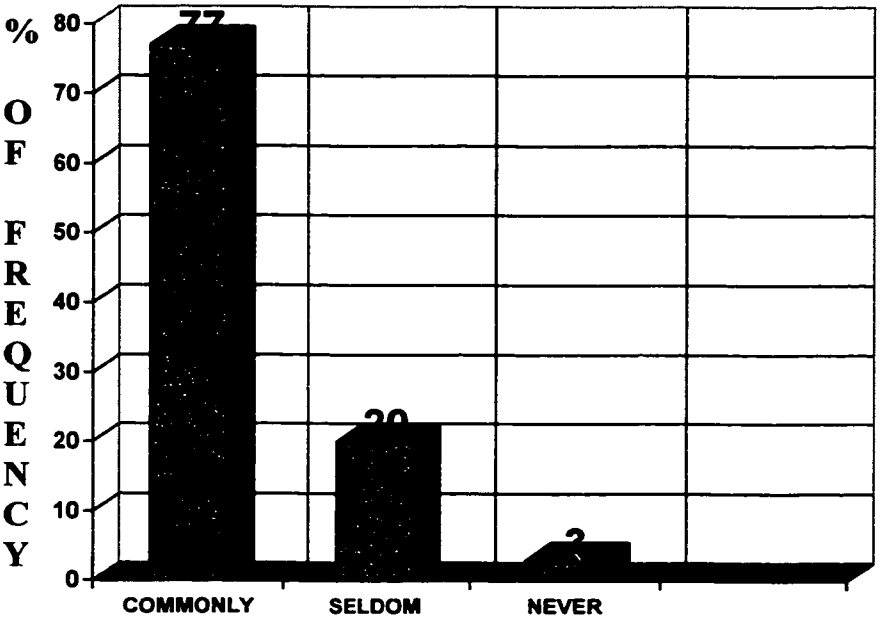
Q	Opinion of Respondents	% Frequency n=31
8	Have you heard of the term constractability before?	
8a	Yes	84%
8b	No	16%
13	How often do you participate by inserting construction knowledge during the preconstruction phase of projects?	
13a	Commonly	77%
13b	Seldom	20%
13c	Never	3%
15	Where do you think constructability should be implemented? *	
15d	All Projects	71%
15c	Large Projects	26%
15a	Complex Projects	16%
15e	Certain type of Projects	10%
15b	Small Projects	3%
16	Using the traditional process (design without construction input), have you encountered any of the following difficulties? *	
16a	Specification problems	90%
16e	Unrealistic schedule	77%
16c	Problems with physical interference	70%
16b	Tolerance problems	53%
16d	Weather related problems that could be avoided during design phase	30%
17	Do you agree that the participation of construction contractors during the design of a project can help to produce better drawings, specification, and buildable projects?	
17a	Yes	90%
17c	Sometimes	10%
17b	No	0%
18	Do you think constructability should be included as another specialty during the design phase of the project such as: architectural, mechanical, electrical, etc.?	
18a	Yes	74%
18b	No	13%
18c	Sometimes	13%

Note: * Not an exclusive question



Have you heard of the term Constructability before?

Figure 4.7: How often had you heard of the term Constructability before.



How often do you participate by inserting Construction knowledge during the preconstruction phase of projects?

Figure 4.8: How often participants participate during pre-construction phase.

Question 15: "Where do you think constructability should be implemented?"

Seventy one percent (71%) thought that constructability should be implemented in all projects. Twenty six percent (26%) thought that constructability should be implemented in large projects, and sixteen percent (16%) in complex projects. One respondent thought that it should be implemented in small projects and this seem to be odd.

One remark from a participant about where constructability should be implemented was: "Certain type of projects : Schedule driven, technically challenging".

Question 16: "Using the traditional process, have you encountered any of the following difficulties?"

Most of the respondents (90%) face a specification problem when using the traditional process. Also, unrealistic schedules, physical interference and tolerance were common difficulties encountered by General Contractors.

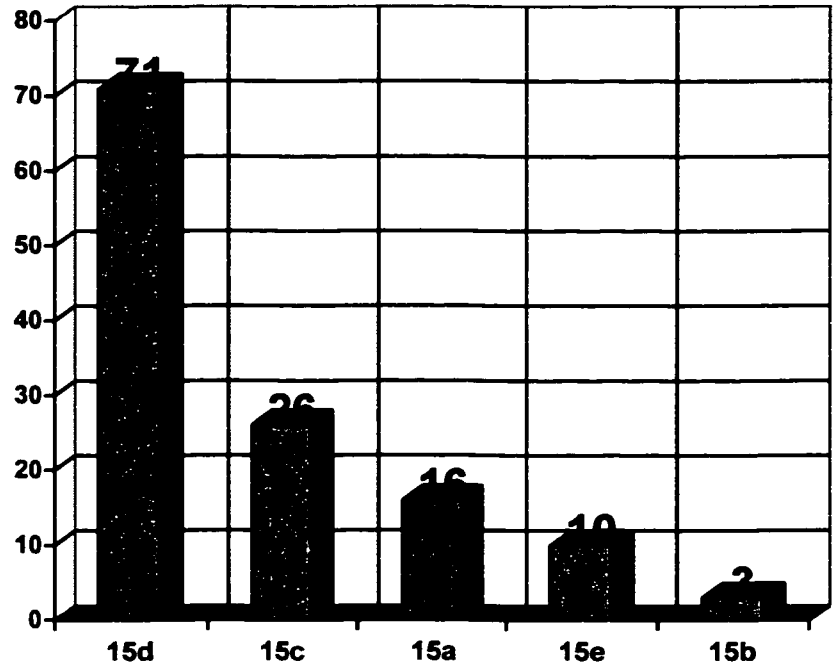
Question 17: "Do you agree that the participation of construction contractors during the design of a project can help to produce better drawings, specifications and buildable projects?"

The majority of the participants (90%) agreed that the participation of General Contractors during the design could help to produce better specifications and drawings. Some remarks made by the participants are as follows:

" Sometimes : Only input".

" Sometimes : When they understand what they are talking about".

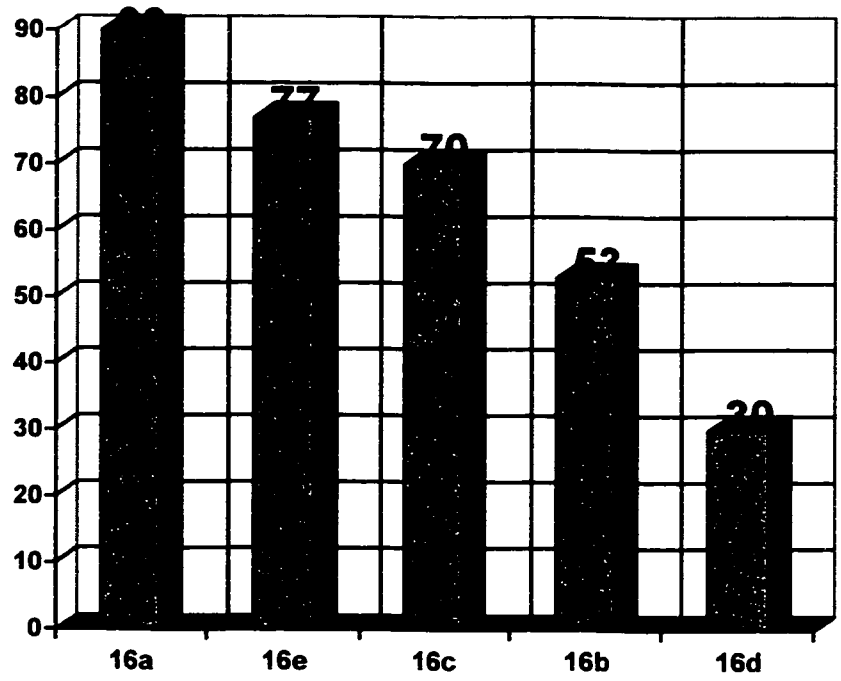
" Yes : He will advise some practical experience" .



Where do you think constructability should be implemented?

15d = All Projects
15c = Large Projects
15a = Complex Projects
15c = Certain Types of Projects
15b = Small Projects

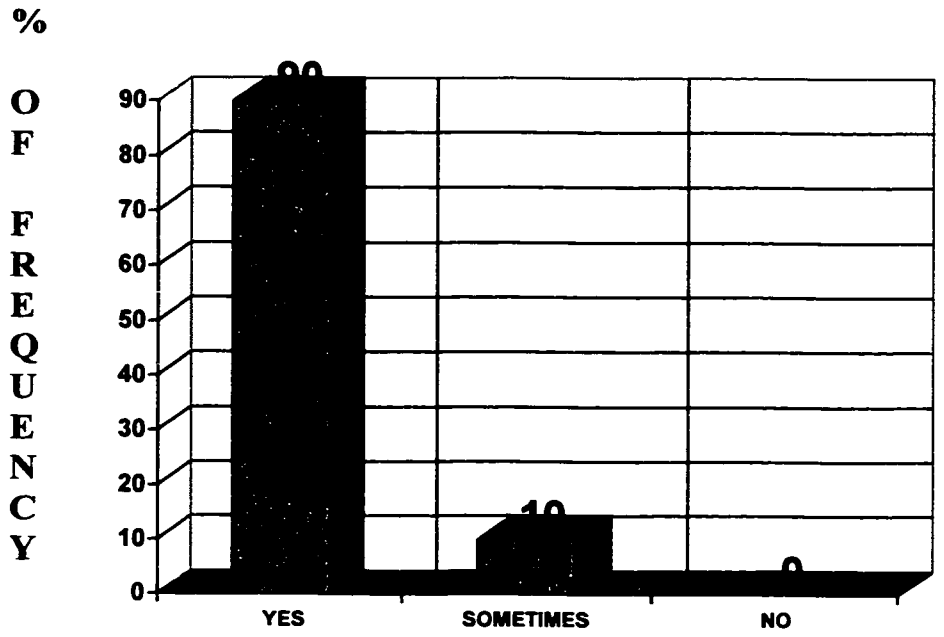
Figure 4.9: Where Constructability Should be Implemented.



Using the traditional process (design without construction input), have you encountered any of the following difficulties?

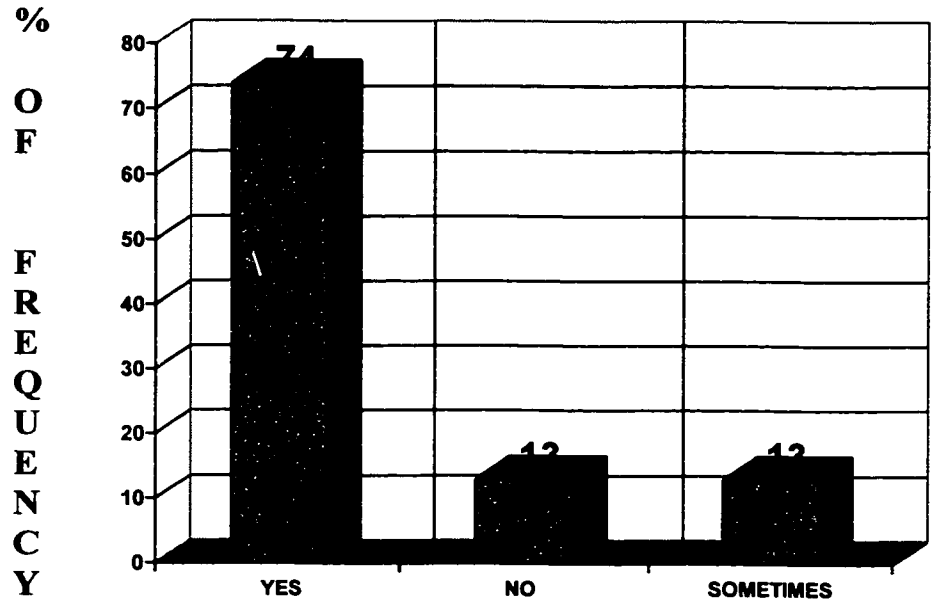
16a = Specification problems
16e = Unrealistic Schedule
16c = Problems with physical interference
16b = Tolerance problems
16d = Weather related problems that could be avoided during design phase

Figure 4.10: Difficulties Encountered Under Traditional Methods of Construction.



Do you agree that the participation of construction contractors during the design of a project can help to produce better drawings, specification , and buildable projects?

Figure 4.11: Participation of Construction Contractors During the Design of Work.



Do you think constructability should be included as another specialty during the design phase of the project such as: architectural, mechanical , electrical, etc.?

Figure 4.12: Should Constructability be Included as Another Specialty During Design Phase?

Question 18: "Do you think constructability should be included as another specialty during the design phase of the project?"

Seventy four percent (74%) of the General Contractors agreed that constructability should be included as another specialty. Among the participants that answered "sometimes", some stated the following:

" Sometimes : Input by the Construction Manager after 60% detail design is very helpful."

" Sometimes : In projects that are special or where cost and time of completion are critical."

" Sometimes : Not specialty but requirements, it applies to all ....."

4.2.3 Part 3: Barriers to Constructability

Table 4.3 summarizes how General Contractors identify the barriers to constructability.

As explained earlier, the rating of the barrier is derived from the selection of "Always / Sometimes / Never" against every respective barrier mentioned.

"Always" equals "Yes"

"Never" equals "No", and

" Sometimes" means to show that the barriers exist, but not in all cases.

The most significant barriers encountered were:

- Design without construction inputs in the traditional form of contracting.
- Owners do not care about constructability in the contracting strategy, and
- Owners do not choose constructability in their projects.

Table 4.3 General Contractors Identify Barriers to Constructability

Barrier	Description	% Frequency n = 31		
		Yes	Some times	No
14c	**Design without construction input is the traditional form of contracting**	**33**	**44**	**23**
14b	**Owners do not care about Constructability in the Contracting Strategy**	**29**	**52**	**19**
14d	**Owners do not choose Constructability in their projects**	**29**	**55**	**16**
14a	**The concept is unknown by the owner**	**19**	**71**	**10**
14h	**Reluctance of field personnel to offer pre-construction advise**	**13**	**64**	**23**
14g	**The concept is unknown by Contractors**	**13**	**52**	**35**
14e	**The concept is unknown by Designer**	**10**	**60**	**30**
14f	**Designer's lack of construction experience and knowledge of construction technologies**	**10**	**77**	**13**
14i	**There are no proven benefits of Constructability**	**3**	**30**	**67**

The last selected barrier was:

- There are no proven benefits of constructability.

This means that General Contractors are very well aware of the benefits of constructability.

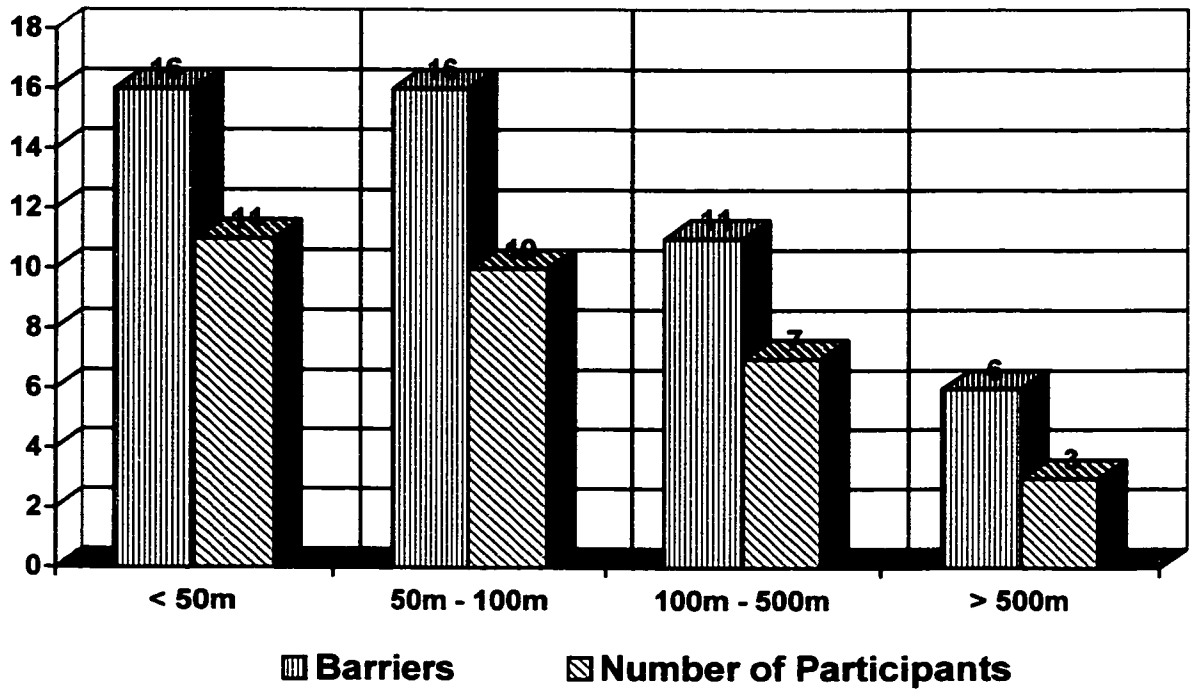
Upon analyzing the response, it appears that the "Sometimes" rating frequency is too high, and it may be that General Contractors are uncertain of their answers or may be these barriers exist, but not regularly.

One barrier was stated by a participant as "The lack of general awareness for quality services by Contractors in the community in general"

Figure 4.13 cross-tabulates the nine barriers with the annual volume of work of participants and shows that all the organizations with different annual volumes were having the same number of barriers. Only the organizations with an annual volume of more than SR.500,000,000 were having less barriers because the number of participants was less.

Figure 4.14 shows the type of work versus the barriers and number of participants. Although the number of barriers against each type of work varies by considering the number of participants in each type of work it clearly shows that the percentage level of the number of barriers against the participants is almost equally distributed.

Even in the type of contract, the same result is seen when the method of cross tabulation is used. From Figure 4.15, it is obvious that the percentage level of the number of barriers in comparison to the number of participants in each type of contract was almost equally distributed.



`Figure 4.13 Volume of Work versus Barriers & Number of Participants.

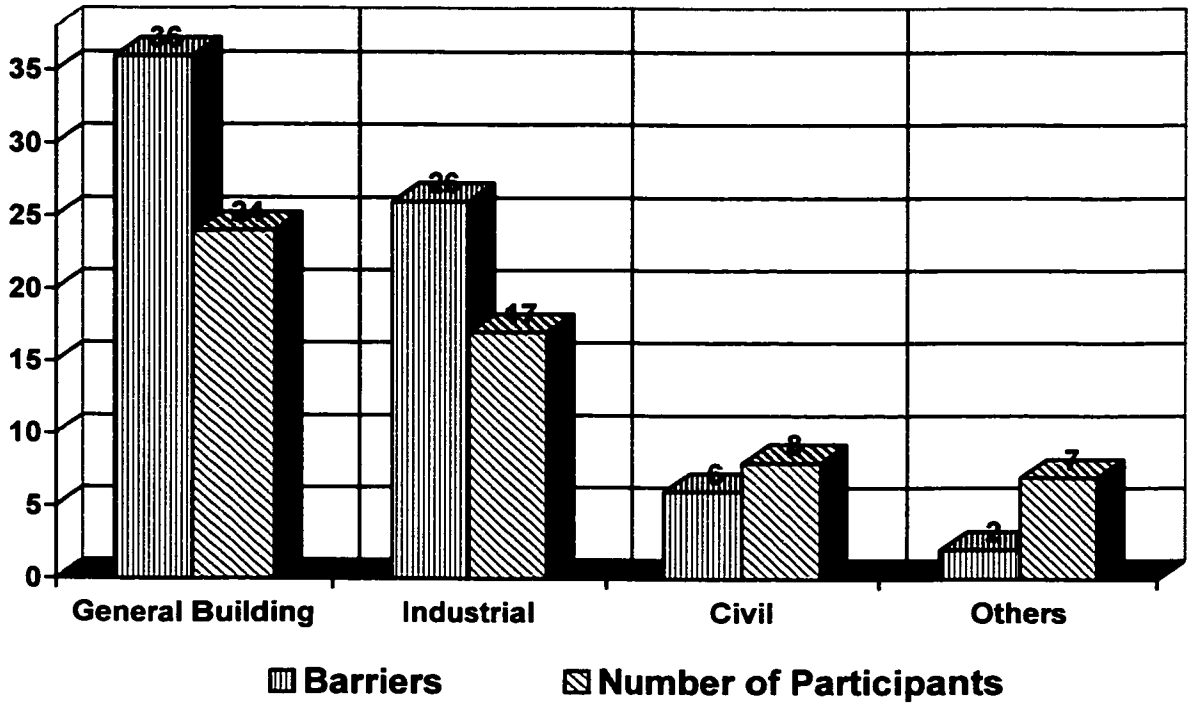


Figure 4.14 Type of Work versus Barriers & Number of Participants.

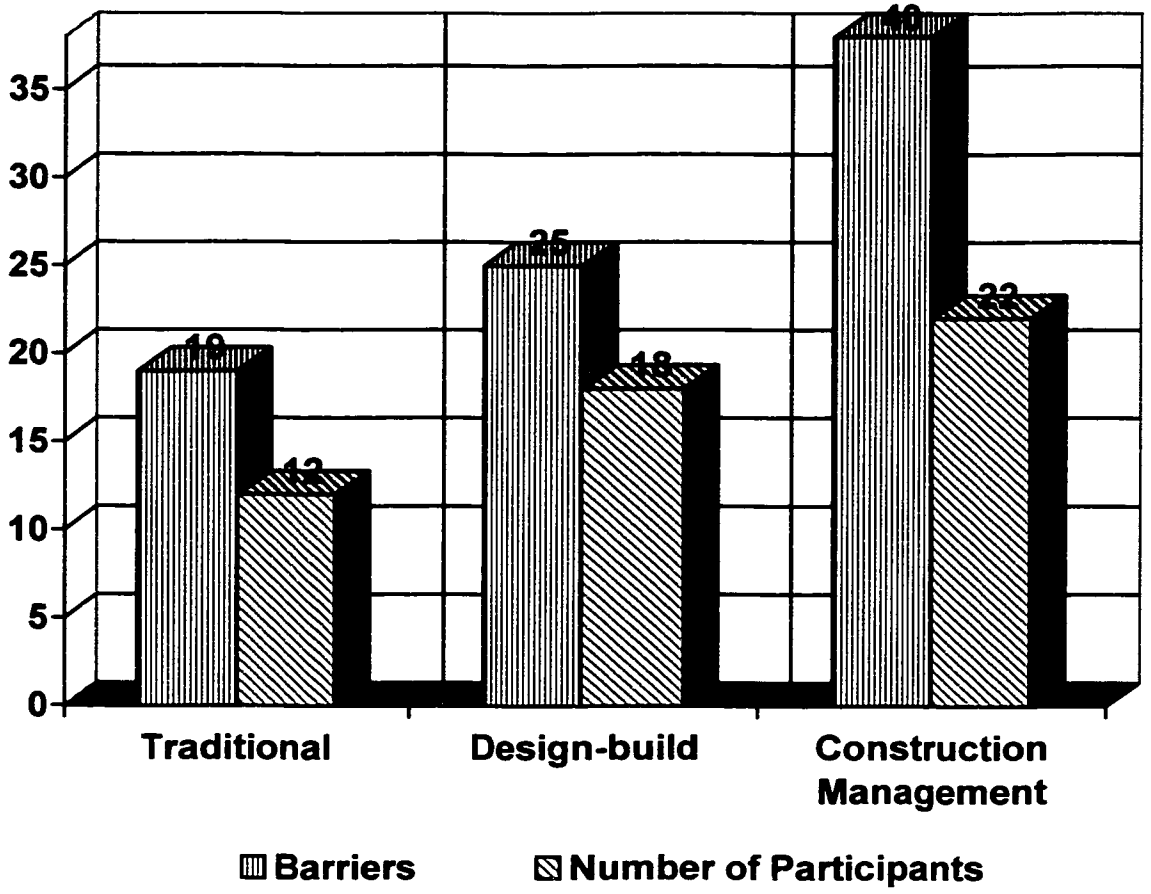


Figure 4.15 Type of Contract versus Barriers & Number of Participants.

4.2.4 Part 4: The Constructability Concept

Part 4a: Descriptive Analysis

Questions nine to twelve discuss "How the organizations participate during various stages of a project". By this, the researcher understood how the concept of constructability was implemented during the conceptual phase, design-procurement phase and construction phase.

Table 4.4 and Figures 4.18 to 4.21 support the above.

Question nine (Figure 4.18): shows the implementation of the constructability concept during the conceptual phase. The most common activities by the General Contractors were the preparation of the schedule, estimates and budget, the selection of the major construction methods, and advising the owner of the contracting strategy. These activities were very much expected from the General Contractors.

Execution of feasibility studies and advice in the selection of the site was the least common activity performed by the General Contractors during the conceptual phase. The reason is that owners in most cases choose to make the feasibility study with another consultant.

Question ten (Figure 4.19): looks at the implementation of the constructability concept during the design-procurement phase. From the questionnaire, preparation of the schedule, estimates and budget, analysis / revision of specifications to allow easy construction, and advising the design team about sources of materials and engineering equipment, were the most common activities performed by the General Contractors

Table 4.4 How General Contractors Implement the Constructability Concept.

Stage	Activities Performed	Q	% Frequency n = 31
Conceptual Phase	Preparation of the schedule, estimates and budget.	9f	81
	Selection of the major construction methods and materials.	9e	71
	Advise owner on the contracting strategy.	9c	58
	Suggest structural systems.	9d	55
	Advise owner on the establishment of the project goals and objectives.	9a	52
	Execution of feasibility studies and advice in the selection of the site.	9b	39
	No participation.	9g	10
Design-Procurement Phase	Preparation of the schedule, estimates and budget.	10d	77
	Analysis/revision of the specifications to allow easy construction.	10f	68
	Advise design team about sources of materials and engineering equipment.	10e	65
	Insert into design the concern of accessibility of personnel, materials and equipment.	10b	58
	Analysis of the design to enable efficient construction (e.g. Ensure workmen can get tools to areas to make connections).	10a	52
	Promote designs that facilitate construction under adverse weather conditions.	10c	29
	No participation.	10g	10
Construction Phase	Careful analysis of layout, access, and temporary facilities to improve productivity.	11a	97
	Planning the sequence of field tasks to improve productivity.	11b	90
	Capture and transfer of lessons-learned to future projects.	11f	81
	Use of preassembly or prefabrication for the execution of the works.	11c	77
	Innovative use of construction equipment and tools (e.g. mobile hydraulic man-lifts in lieu of scaffolding).	11d	68
	Innovative use of material (e.g. fiber reinforced concrete).	11e	58
	No participation.	11g	3
Constructability Program	The management of the organization supports constructability.	12b	81
	Assignment of constructability coordinator in the organization level and in the project level.	12c	68
	Tracking of constructability is included in contract documents.	12d	58
	There is an organizational policy statement toward the implementation of constructability.	12a	55
	All of the above (organized, formal constructability program).	12f	6
	None of the above.	12e	5

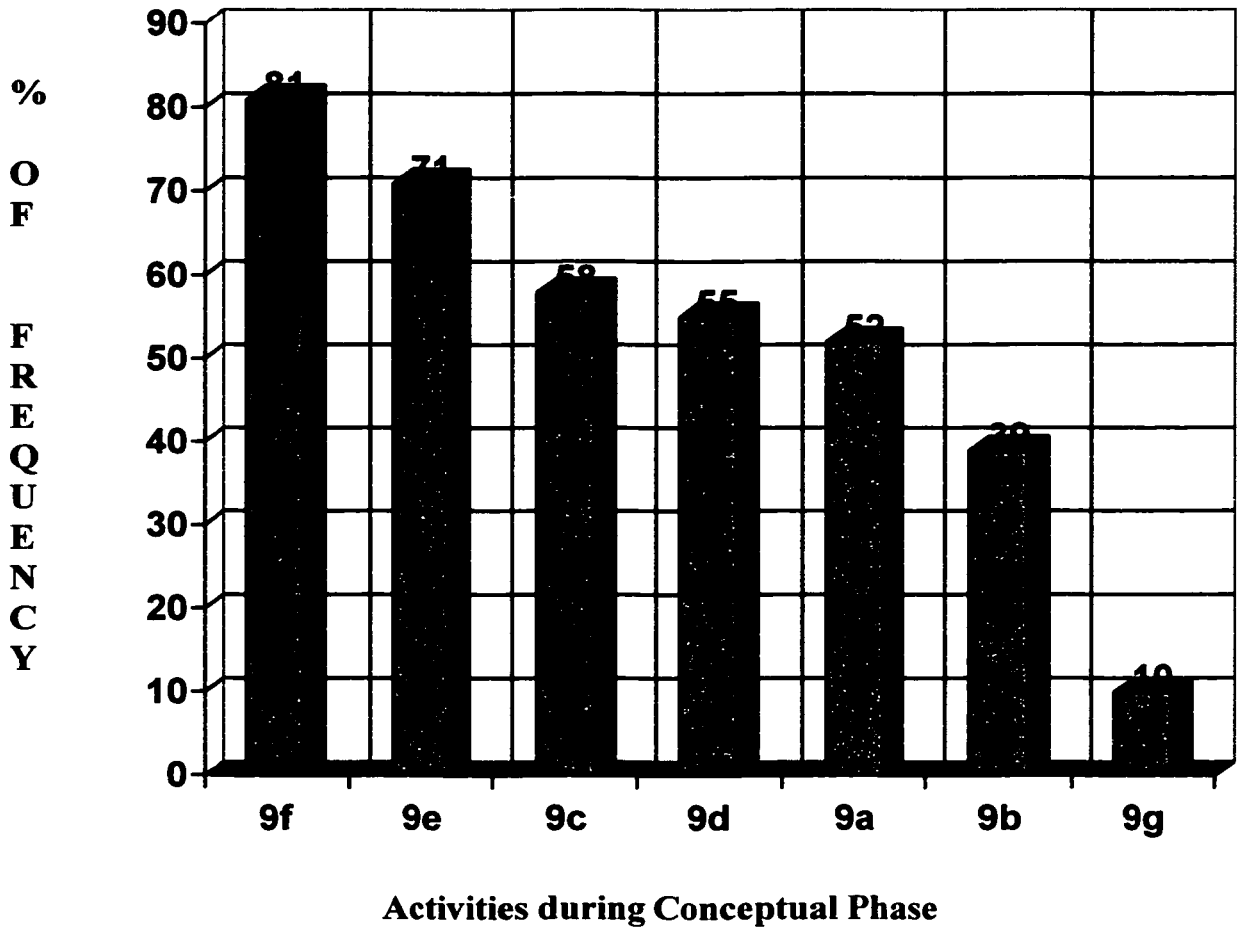


Figure 4.18 Implementation of the Constructibility Concept During the Conceptual Phase.

Activities:
9a. Advise owner in the establishment of the project goals and objectives.
9b. Execution of feasibility studies and advice in the selection of the site.
9c. Advise owner on the contracting strategy.
9d. Suggest structural system.
9e. Selection of the major construction methods and materials.
9f. Preparation of the schedule, estimates and budget.
9g. No participation.

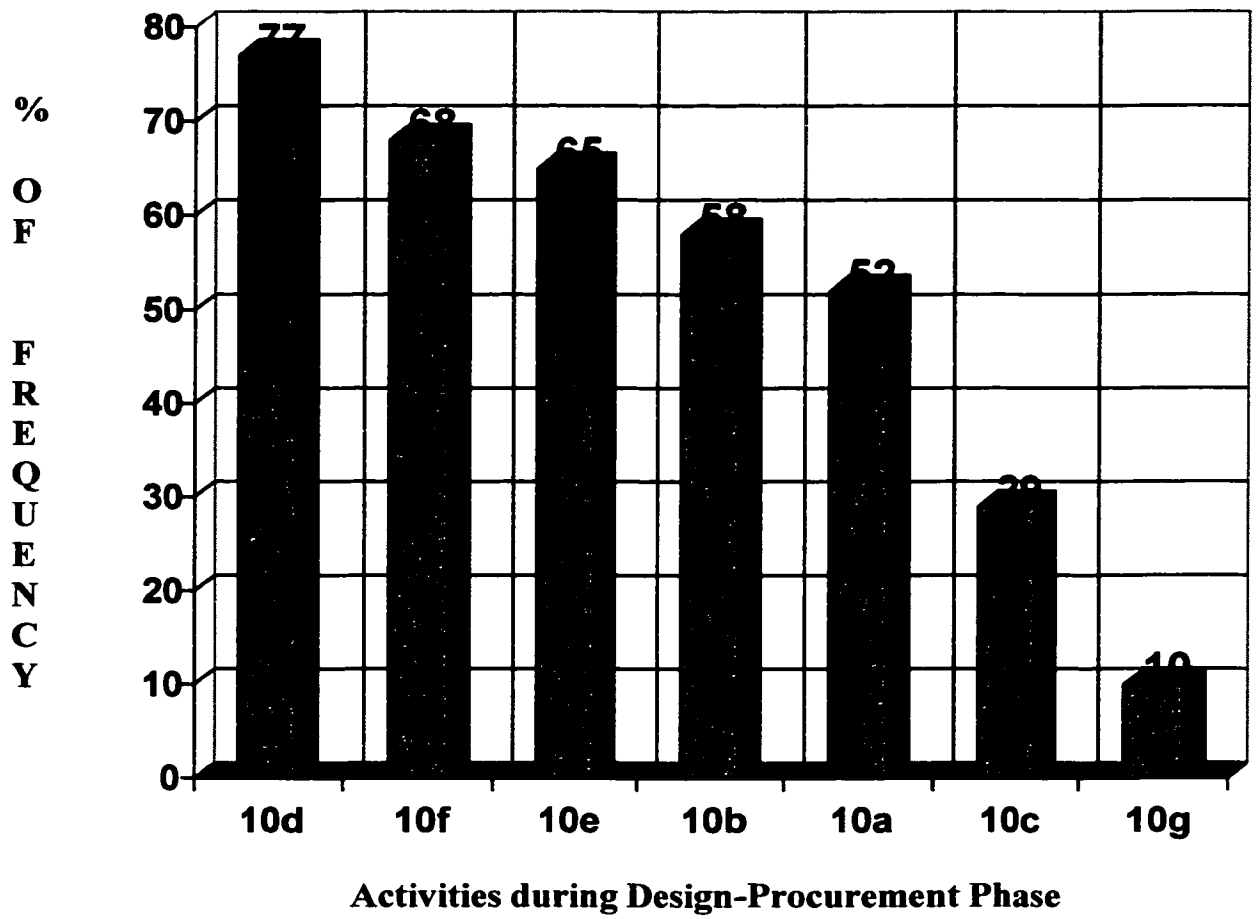


Figure 4.19 Implementation of Constructibility Concept during Design-Procurement Phase.

Activities:

10a. Analysis of the design to enable efficient construction (ex. Ensure workmen can get tools to areas to make connections).
10b. Insert into the design the concern of accessibility of personnel, materials and equipment.
10c. Promote designs that facilitate construction under adverse weather conditions.
10d. Preparation of the schedule, estimates and budget.
10e. Advise design team about sources of materials and engineered equipment.
10f. Analysis/revision of the specifications to allow easy construction.
10g. No participation.

during the design-procurement phase. These activities were again very much expected from General Contractors, because they have the experience and the information to perform these services. Also, it is very common that a General Contractor reviews specifications and drawings before starting the construction phase.

Question eleven (Figure 4.20): considers the implementation of the constructability concept during the construction phase. The questionnaire response shows that careful analysis of layout, access and temporary facilities to improve productivity, capture and transfer of lessons-learned to future projects, were the most common activities performed by the General Contractors. In fact, Table 4.4 "Construction Phase" and Figure 4.20 clearly indicate that all activities were performed by the General Contractors with almost equal share which indicates again that they are practicing constructability in the construction phase.

Question twelve (Figure 4.21): looks at the implementation of the constructability concept towards a constructability program. Eighty one percent (81%) of the participants said that the management supported constructability. Sixty eight percent (68%) of the participants responded that they assigned a constructability coordinator in the organization level and in the project level. Fifty eight percent (58%) of the participants have responded that constructability is included in contract documents and fifty five percent (55%) responded saying that there is an organizational policy statement towards the implementation of constructability. Only five percent (5%) of the respondents do not take any action to implement a constructability program.

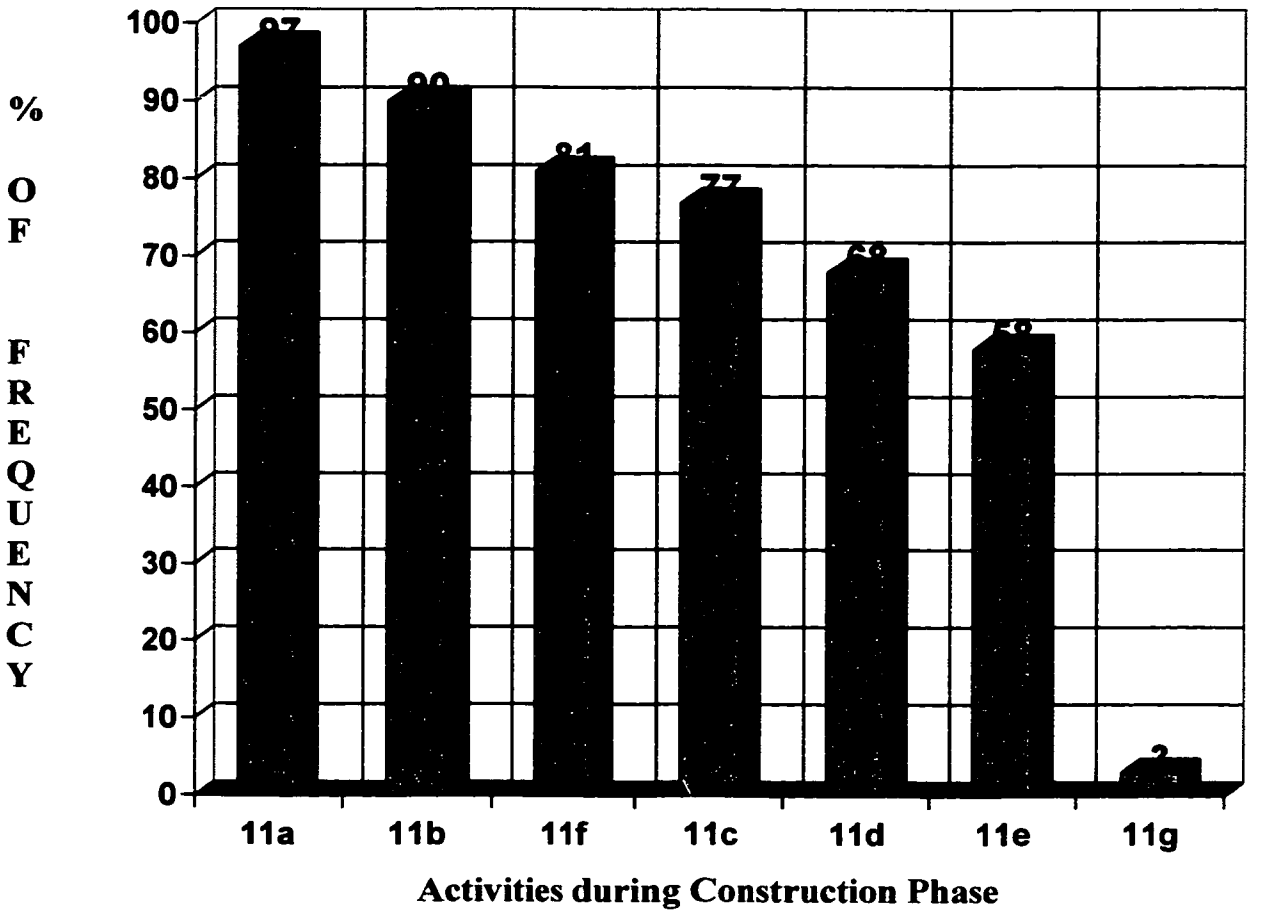


Figure 4.20 Implementation of the Constructibility Concept During the Construction Phase.

Activities:

11a. Careful analysis of layout, access, and temporary facilities to improve productivity.
11b. Planning the sequence of field tasks to improve productivity.
11c. Use of pre-assembly or prefabrication for the execution of the works.
11d. Innovative use of construction equipment and tools (e.g. mobile hydraulic man-lifts in lieu of scaffoldings).
11e. Innovative use of material (e.g. fiber reinforced concrete).
11f. Capture and transfer of lessons-learned to future projects.
11g. No participation.

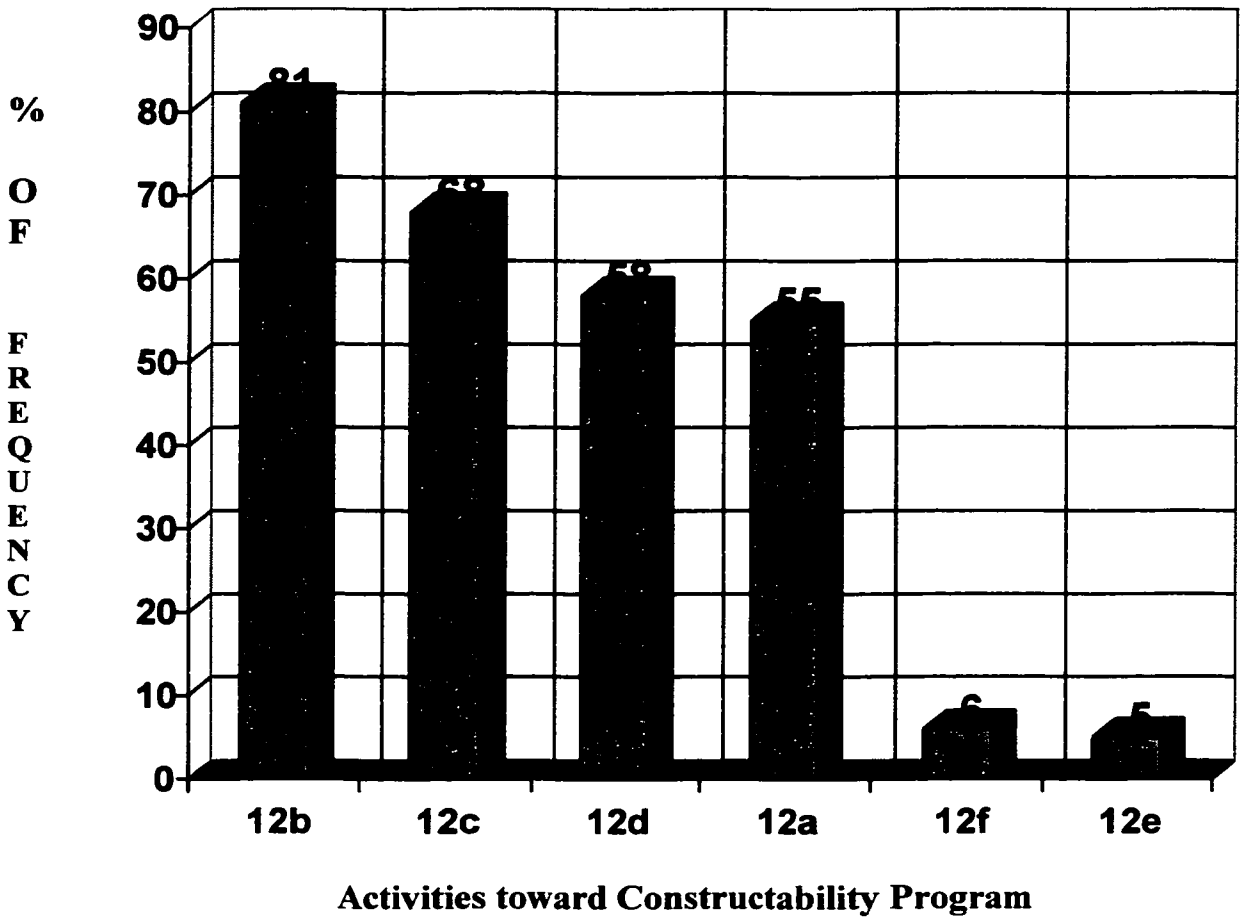


Figure 4.21 Implementation of Constructibility Concept towards a Constructability Program.

Activities:

12a. There is an organizational policy statement towards the implementation of constructability.
12b. The management of the organization supports constructability.
12c. Assignment of constructability coordinator in the organization level and in the project level.
12d. Tracking of constructability is included in contract documents.
12e. None of the above.
12f. All of the above (organized, formal constructability program).

The above results prove that constructability programs are most commonly implemented by the General Contractors. One of the reasons for this high percentage of implementation of the constructability concept in this part of the Kingdom is the stipulation of Saudi Aramco for constructability in construction projects.

In addition to making the constructability concept compulsory, Saudi Aramco also educates in the need for it and helps contractors in their implementation.

Part 4b: Statistical Analysis

In this part of the study, relationships, between the characteristics of the organization and the implementation of the constructability concept are to be found. In order to test for a relationship, a Chi-square test was used to determine the independence between these characteristics, such as: the organization's nationality, type of work etc. and the application of the constructability concept in different stages of a project.

One of the most frequent uses of Chi-square is for testing a null hypothesis that two criteria of classification are independent. "Two criteria of classification are said to be independent if the distribution of one criterion in no way depends on the distribution of the other" (Daniel & Terrell, 1995).

In order to carry out the Chi-square test for independence, a statistics package called SPSS 9.05 was used.

The level of significance α was selected before collecting the data to equal 0.05. This choice of α, which is the most common value, was based on tradition. If the value obtained for P (observed significance) was less than $\alpha = 0.05$, the null hypothesis Ho which stated independence between variables was rejected and the variables were said to be dependent. Appendix C shows examples of the computer output for the Chi-square tests.

1. The relationship between the organization's nationality and the application of the constructability concept.

It was found that none of the constructability activities were influenced by the nationality of the organization except for the preparation of the schedule, estimates and budget in the conceptual phase. Results indicate that Saudi General Contractors participate in preparation of the schedule, estimates and budget more than joint venture or others. See Table 4.5.

2. Application of the constructability concept related to sector where work is performed. It was found that there is a relationship between the private sector and the following activities: selection of major construction methods and materials; insertion into design the concern of accessibility of personnel, materials and equipment; analysis of specifications to allow easy construction and careful analysis of layout; access and temporary facilities to improve productivity.

Also, a relationship was found between the public sector and the following activities: use of pre-assembly or pre-fabrication for the execution of works; innovative use of

Table 4.5 Chi-square Results: Organization Nationality versus Concept

Does Organization Nationality influence the constructability activities and actions that the General Contractors implement?

Independent variable: Organization Nationality.

Null hypothesis: The implementation of Constructability activities is independent of the Organization Nationality.

Stage	Q	Survey Measures	Chi-square	df	P-Value
	8	Have you heard of the term constructability before?	1.146	2	0.564
Activities Performed during Conceptual Phase	9a	Advise owner on the establishment of the project goals and objectives.	2.919	2	0.232
	9b	Execution of feasibility studies and the selection of the site.	0.145	2	0.930
	9c	Advise owner on the contracting strategy.	0.936	2	0.626
	9d	Suggest structural systems.	4.133	2	0.127
	9e	Selection of the major construction methods and materials.	2.937	2	0.230
	9f	Preparation of the schedule, estimates and budget.	6.523	2	* 0.038
	9g	No participation.	17.653	2	0.000
Activities Performed during Design Phase	10a	Analysis of the design to enable efficient construction.	3.125	2	0.210
	10b	Insert into the design the concern of accessibility of personnel, materials and equipment.	0.146	2	0.930
	10c	Promote designs that facilitate construction under adverse weather conditions.	2.937	2	0.230
	10d	Preparation of the schedule, estimate and budget.	1.739	2	0.419
	10e	Advise design team about sources of materials and engineered equipment.	1.207	2	0.547
	10f	Analysis/revision of the specifications to allow easy construction.	1.020	2	0.600
	10g	No participation.	0.639	2	0.727
Activities Performed during Construction Phase	11a	Careful analysis of layout, access, and temporary facilities to improve productivity.	0.199	2	0.905
	11b	Planning the sequence of field tasks to improve productivity.	0.639	2	0.727
	11c	Use of preassembly or prefabrication for the execution of the works.	1.739	2	0.419
	11d	Innovative use of construction equipment and tools.	5.655	2	0.059
	11e	Innovative use of materials (e.g. fiber reinforced concrete).	2.410	2	0.300
	11f	Capture and transfer of lesson learned to future projects.	1.924	2	0.382
	11g	No participation.	0.199	2	0.905
Other Action	12a	There is an organizational policy statement toward the implementation of constructability.	4.910	2	0.086
	12b	The management of the organization supports constructability.	1.431	2	0.489
	12c	Assignment of constructability coordinator in the organization level and in the project level.	0.316	2	0.854
	12d	Constructability is included in contract documents.	2.989	2	0.224
	12e	None of the above	1.146	2	0.564
	12f	All of the above (organized, formal constructability program).	2.252	2	0.324

Note: * Statistically Significant $P < 0.05$

construction equipment and tools, capture and transfer of lessons-learned to future projects, and the management of the organization supporting constructability.

The survey results indicate that the General Contractors in the public sector, participate more in the construction phase and they have very good management support for practicing constructability. See Tables 4.6 and 4.7.

3. Application of the constructability concept related to type of work performed.
There was no relationship found between the constructability concept and the building general contractors. See Table 4.8.

In the case of Industrial General Contractors (Table 4.9) a relationship was found with the following activities: advising owner of the project's goals and objectives; execution of feasibility studies and selection of site; advice in contracting strategy; selection of major construction method and materials; planning the sequence of field tasks to improve production; use of pre-assembly or pre-fabrication for the execution of work; and capture and transfer of lessons-learned to future projects. These results show that Industrial General Contractors participate more during the conceptual phase and are also concerned with the use of pre-assembly and transfer of lessons-learned to future projects. This may be due to the fact that Industrial General Contractors were dealing with bigger projects which require more preparation, especially in the conceptual phase.

It was found that a relationship did not exist between General Contractors in Heavy Construction and the implementation of the constructability concepts. (See Table 4.10).

Table 4.6 Chi-square Results: Sector where Work is Performed versus Concept.

Does the private sector where the organization works influence constructability activities and actions that the General Contractors implement?

Independent variable: Private sector where work is performed.

Null hypothesis: The implementation of constructability activities is independent of the sector where the organization performs work.

Stage	Q	Survey Measures	Chi-square	df	P-Value
	8	Have you heard of the term constructability before?	0.002	1	0.967
Activities Performed during Conceptual Phase	9a	Advise owner on the establishment of the project goals and objectives.	0.009	1	0.924
	9b	Execution of feasibility studies and the selection of the site.	0.068	1	0.794
	9c	Advise owner on the contracting strategy.	0.232	1	0.630
	9d	Suggest structural systems.	0.232	1	0.630
	9e	Selection of the major construction methods and materials.	5.784	1	* 0.016
	9f	Preparation of the schedule, estimates and budget.	0.002	1	0.967
	9g	No participation	1.125	1	0.289
Activities Performed during Design Phase	10a	Analysis of the design to enable efficient construction.	0.676	1	0.411
	10b	Insert into the design the concern of accessibility of personnel, materials and equipment.	4.535	1	* 0.033
	10c	Promote designs that facilitate construction under adverse weather conditions.	0.452	1	0.502
	10d	Preparation of the schedule, estimate and budget.	2.763	1	0.096
	10e	Advise design team about sources of materials and engineered equipment.	0.004	1	0.947
	10f	Analysis/revision of the specifications to allow easy construction.	4.488	1	* 0.034
	10g	No participation	0.326	1	0.568
Activities Performed during Construction Phase	11a	Careful analysis of layout, access, and temporary facilities to improve productivity.	3.976	1	* 0.046
	11b	Planning the sequence of field tasks to improve productivity.	0.326	1	0.568
	11c	Use of preassembly or prefabrication for the execution of the works.	0.349	1	0.554
	11d	Innovative use of construction equipment and tools.	0.004	1	0.947
	11e	Innovative use of materials (e.g. fiber reinforced concrete).	1.459	1	0.227
	11f	Capture and transfer of lesson learned to future projects.	0.737	1	0.391
	11g	No participation.	3.970	1	* 0.046
Other Action	12a	There is an organizational policy statement toward the implementation of constructability.	0.009	1	0.924
	12b	The management of the organization supports constructability.	1.974	1	0.160
	12c	Assignment of constructability coordinator in the organization level and in the project level.	0.730	1	0.393
	12d	Constructability is included in contract documents.	0.232	1	0.630
	12e	None of the above	0.002	1	0.967
	12f	All of the above (organized, formal constructability program).	0.068	1	0.794

Note: * Statistically Significant: $P < 0.05$

Table 4.7 Chi-square Results: Sector where Work is Performed versus Concept.

Does the public sector influence constructability activities and actions that General Contractors implement?

Independent variable: Public sector where work is performed.

Null hypothesis: The implementation of constructability activities is independent of the sector where the organization performs work.

Stage	Q	Survey Measures	Chi-square	df	P-Value
	8	Have you heard of the term constructability before?	3.178	1	0.075
Activities Performed during Conceptual Phase	9a	Advise owner on the establishment of the project goals and objectives.	0.895	1	0.344
	9b	Execution of feasibility studies and the selection of the site.	0.785	1	0.376
	9c	Advise owner on the contracting strategy.	2.032	1	0.154
	9d	Suggest structural systems.	0.338	1	0.561
	9e	Selection of the major construction methods and materials.	2.778	1	0.096
	9f	Preparation of the schedule, estimates and budget.	0.466	1	0.495
	9g	No participation	0.540	1	0.462
Activities Performed during Design Phase	10a	Analysis of the design to enable efficient construction.	0.514	1	0.474
	10b	Insert into the design the concern of accessibility of personnel, materials and equipment.	0.120	1	0.730
	10c	Promote designs that facilitate construction under adverse weather conditions.	0.037	1	0.847
	10d	Preparation of the schedule, estimate and budget.	1.077	1	0.299
	10e	Advise design team about sources of materials and engineered equipment.	0.045	1	0.833
	10f	Analysis/revision of the specifications to allow easy construction.	0.216	1	0.642
	10g	No participation	0.055	1	0.814
Activities Performed during Construction Phase	11a	Careful analysis of layout, access, and temporary facilities to improve productivity.	0.395	1	0.530
	11b	Planning the sequence of field tasks to improve productivity.	2.558	1	0.110
	11c	Use of preassembly or prefabrication for the execution of the works.	4.035	1	* 0.045
	11d	Innovative use of construction equipment and tools.	8.028	1	* 0.005
	11e	Innovative use of materials (e.g. fiber reinforced concrete).	1.395	1	0.238
	11f	Capture and transfer of lesson learned to future projects.	5.784	1	* 0.016
	11g	No participation.	0.395	1	0.530
Other Action	12a	There is an organizational policy statement toward the implementation of constructability.	0.895	1	0.344
	12b	The management of the organization supports constructability.	11.769	1	* 0.001
	12c	Assignment of constructability coordinator in the organization level and in the project level.	1.857	1	0.173
	12d	Constructability is included in contract documents.	0.338	1	0.561
	12e	None of the above	3.178	1	0.075
	12f	All of the above (organized, formal constructability program).	0.001	1	0.976

Note: * Statistically Significant: $P < 0.05$

Table 4.8 Chi-square Results: General Building versus Concept.

Does the type of work that the organization is involved with influence the constructability activities and actions that the General Contractors implement?

Independent variable: General Building

Null hypothesis: The implementation of constructability activities is independent of Working on general building Projects.

Stage	Q	Survey Measures	Chi-square	df	P-Value
	8	Have you heard of the term constructability before?	0.023	1	0.880
Activities Performed during Conceptual Phase	9a	Advise owner on the establishment of the project goals and objectives.	1.422	1	0.233
	9b	Execution of feasibility studies and the selection of the site.	0.329	1	0.531
	9c	Advise owner on the contracting strategy.	0.859	1	0.354
	9d	Suggest structural systems.	0.524	1	0.469
	9e	Selection of the major construction methods and materials.	3.468	1	0.063
	9f	Preparation of the schedule, estimates and budget.	0.149	1	0.700
	9g	No participation	0.220	1	0.639
Activities Performed during Design Phase	10a	Analysis of the design to enable efficient construction.	0.111	1	0.739
	10b	Insert into the design the concern of accessibility of personnel, materials and equipment.	0.003	1	0.955
	10c	Promote designs that facilitate construction under adverse weather conditions.	0.001	1	0.976
	10d	Preparation of the schedule, estimate and budget.	2.637	1	0.104
	10e	Advise design team about sources of materials and engineered equipment.	0.215	1	0.643
	10f	Analysis/revision of the specifications to allow easy construction.	0.465	1	0.495
	10g	No participation	0.969	1	0.325
Activities Performed during Construction Phase	11a	Careful analysis of layout, access, and temporary facilities to improve productivity.	3.543	1	0.060
	11b	Planning the sequence of field tasks to improve productivity.	0.220	1	0.639
	11c	Use of preassembly or prefabrication for the execution of the works.	0.186	1	0.667
	11d	Innovative use of construction equipment and tools.	0.056	1	0.813
	11e	Innovative use of materials (e.g. fiber reinforced concrete).	0.663	1	0.415
	11f	Capture and transfer of lesson learned to future projects.	0.492	1	0.483
	11g	No participation.	3.543	1	0.060
Other Action	12a	There is an organizational policy statement toward the implementation of constructability.	1.005	1	0.316
	12b	The management of the organization supports constructability.	0.149	1	0.700
	12c	Assignment of constructability coordinator in the organization level and in the project level.	1.336	1	0.248
	12d	Constructability is included in contract documents.	0.663	1	0.415
	12e	None of the above	1.739	1	0.187
	12f	All of the above (organized, formal constructability program).	0.066	1	0.798

Table 4.9 Chi-square Results: Industrial versus Concept.

Does the type of work that the organization is involved with influence the Constructability activities and actions that the General Contractors implement?

Independent variable: Industrial work.

Null hypothesis: The implementation of constructability activities is independent of working on Industrial Projects.

Stage	Q	Survey Measures	Chi-square	df	P-Value
	8	Have you heard of the term constructability before?	0.530	1	0.467
Activities Performed during Conceptual Phase	9a	Advise owner on the establishment of the project goals and objectives.	5.427	1	* 0.020
	9b	Execution of feasibility studies and the selection of the site.	6.419	1	* 0.011
	9c	Advise owner on the contracting strategy.	5.237	1	* 0.022
	9d	Suggest structural systems.	0.241	1	0.623
	9e	Selection of the major construction methods and materials.	5.448	1	* 0.020
	9f	Preparation of the schedule, estimates and budget.	0.070	1	0.791
	9g	No participation.	0.620	1	0.431
Activities Performed during Design Phase	10a	Analysis of the design to enable efficient construction.	0.027	1	0.870
	10b	Insert into the design the concern of accessibility of personnel, materials and equipment.	0.682	1	0.409
	10c	Promote designs that facilitate construction under adverse weather conditions.	0.003	1	0.959
	10d	Preparation of the schedule, estimate and budget.	0.524	1	0.469
	10e	Advise design team about sources of materials and engineered equipment.	0.001	1	0.981
	10f	Analysis/revision of the specifications to allow easy construction.	1.312	1	0.252
	10g	No participation.	0.188	1	0.665
Activities Performed during Construction Phase	11a	Careful analysis of layout, access, and temporary facilities to improve productivity.	1.255	1	0.263
	11b	Planning the sequence of field tasks to improve productivity.	4.033	1	* 0.043
	11c	Use of preassembly or prefabrication for the execution of the works.	6.004	1	* 0.014
	11d	Innovative use of construction equipment and tools.	1.312	1	0.252
	11e	Innovative use of materials (e.g. fiber reinforced concrete).	0.682	1	0.409
	11f	Capture and transfer of lesson learned to future projects.	4.377	1	* 0.036
	11g	No participation.	1.255	1	0.263
Other Action	12a	There is an organizational policy statement toward the implementation of constructability.	1.480	1	0.224
	12b	The management of the organization supports constructability.	4.337	1	* 0.036
	12c	Assignment of constructability coordinator in the organization level and in the project level.	1.312	1	0.252
	12d	Constructability is included in contract documents.	2.425	1	0.119
	12e	None of the above	2.922	1	0.087
	12f	All of the above (organized, formal constructability program).	1.106	1	0.293

Note: * Statistically Significant: $P < 0.05$

Table 4.10 Chi-square Results: Heavy Construction Work versus Concept.

Does the type of work that the organization is involved with influence the Constructability activities and actions that the General Contractors implement?

Independent variable: Heavy Construction work.

Null hypothesis: The implementation of constructability activities is independent of working on Heavy Construction Work.

Stage	Q	Survey Measures	Chi-square	df	P-Value
	8	Have you heard of the term constructability before?	0.105	1	0.746
Activities Performed during Conceptual Phase	9a	Advise owner on the establishment of the project goals and objectives.	0.512	1	0.474
	9b	Execution of feasibility studies and the selection of the site.	0.579	1	0.447
	9c	Advise owner on the contracting strategy.	1.270	1	0.260
	9d	Suggest structural systems.	0.102	1	0.750
	9e	Selection of the major construction methods and materials.	0.085	1	0.771
	9f	Preparation of the schedule, estimates and budget.	0.325	1	0.569
	9g	No participation.	0.098	1	0.754
Activities Performed during Design Phase	10a	Analysis of the design to enable efficient construction.	2.362	1	0.124
	10b	Insert into the design the concern of accessibility of personnel, materials and equipment.	0.288	1	0.592
	10c	Promote designs that facilitate construction under adverse weather conditions.	0.375	1	0.540
	10d	Preparation of the schedule, estimate and budget.	0.627	1	0.429
	10e	Advise design team about sources of materials and engineered equipment.	2.488	1	0.115
	10f	Analysis/revision of the specifications to allow easy construction.	1.926	1	0.165
	10g	No participation.	1.155	1	0.282
Activities Performed during Construction Phase	11a	Careful analysis of layout, access, and temporary facilities to improve productivity.	2.971	1	0.085
	11b	Planning the sequence of field tasks to improve productivity.	0.980	1	0.754
	11c	Use of preassembly or prefabrication for the execution of the works.	0.036	1	0.849
	11d	Innovative use of construction equipment and tools.	1.926	1	0.165
	11e	Innovative use of materials (e.g. fiber reinforced concrete).	1.270	1	0.260
	11f	Capture and transfer of lesson learned to future projects.	0.325	1	0.569
	11g	No participation.	2.971	1	0.085
Other Action	12a	There is an organizational policy statement toward the implementation of constructability.	1.770	1	0.183
	12b	The management of the organization supports constructability.	2.588	1	0.108
	12c	Assignment of constructability coordinator in the organization level and in the project level.	0.260	1	0.610
	12d	Constructability is included in contract documents.	3.837	1	0.050
	12e	None of the above	2.074	1	0.150
	12f	All of the above (organized, formal constructability program).	0.579	1	0.447

4. Application of the constructability concept related to range of annual volume of work.

It was found (as shown in Table 4.11) that there was a relationship between the volume of work and the following activities: execution of feasibility studies and selection of the site; advising the owner on the contracting strategy; selection of major construction methods and materials; and inserting into the design the concern of accessibility of personnel, materials and equipment.

It was also found that organizations with a larger volume of work had a greater relationship with the above activities (Table 4.12). This is a very logical result because organizations with a large volume of work tend to spend more on the implementation of a constructability program to reduce loss and increase profitability.

5. Application of the constructability concept related to type of contract used.

In Tables 4.13 and 4.14, it was found that there was a relationship between both traditional and design-build contracts and some of the constructability concept activities. They are as follows: advising the owner on the establishment of the project goals and objectives; advising the owner on the contracting strategy; selection of major construction methods and materials; analysis of the design to enable efficient construction; inserting into the design the concern of accessibility of personnel, materials and equipment; innovative use of construction equipment and tools; and capture and transfer of lessons learned to future projects.

Table 4.11 Chi-square Results: Range of Annual Volume of Work versus Concept.

Does the gross volume of annual work influence the participation of Constructability activities and actions that the General Contractors implement?

Independent variable: Range of Annual Volume of Work.

Null hypothesis: The implementation of constructability activities is independent of the Annual Volume of Work of the organization.

Stage	Q	Survey Measures	Chi-square	Df	P-Value
	8	Have you heard of the term constructability before?	1.882	3	0.597
Activities Performed during Conceptual Phase	9a	Advise owner on the establishment of the project goals and objectives.	4.807	3	0.187
	9b	Execution of feasibility studies and the selection of the site.	14.250	3	* 0.003
	9c	Advise owner on the contracting strategy.	10.668	3	* 0.014
	9d	Suggest structural systems.	5.251	3	0.154
	9e	Selection of the major construction methods and materials.	8.006	3	* 0.046
	9f	Preparation of the schedule, estimates and budget.	2.569	3	0.463
	9g	No participation.	2.889	3	0.409
Activities Performed during Design Phase	10a	Analysis of the design to enable efficient construction.	7.571	3	0.056
	10b	Insert into the design the concern of accessibility of personnel, materials and equipment.	9.211	3	* 0.027
	10c	Promote designs that facilitate construction under adverse weather conditions.	4.108	3	0.250
	10d	Preparation of the schedule, estimate and budget.	2.384	3	0.497
	10e	Advise design team about sources of materials and engineered equipment.	5.653	3	0.130
	10f	Analysis/revision of the specifications to allow easy construction.	1.831	3	0.608
	10g	No participation.	1.983	3	0.576
Activities Performed during Construction Phase	11a	Careful analysis of layout, access, and temporary facilities to improve productivity.	3.543	3	0.315
	11b	Planning the sequence of field tasks to improve productivity.	2.473	3	0.480
	11c	Use of preassembly or prefabrication for the execution of the works.	0.651	3	0.885
	11d	Innovative use of construction equipment and tools.	3.614	3	0.306
	11e	Innovative use of materials (e.g. fiber reinforced concrete).	2.492	3	0.477
	11f	Capture and transfer of lesson learned to future projects.	1.280	3	0.734
	11g	No participation.	3.543	3	0.315
Other Action	12a	There is an organizational policy statement toward the implementation of constructability.	0.279	3	0.964
	12b	The management of the organization supports constructability.	3.568	3	0.312
	12c	Assignment of constructability coordinator in the organization level and in the project level.	3.353	3	0.340
	12d	Constructability is included in contract documents.	2.492	3	0.477
	12e	None of the above	3.380	3	0.337
	12f	All of the above (organized, formal constructability program).	2.966	3	0.397

Note: * Statistically Significant: $P < 0.05$

Table 4.12 Range of Annual Volume of Work versus Dependent Constructability Concept.

Phase	Activities Performed	<SR50m % Frequency n=11	SR50m – SR100m % Frequency n=10	SR100m – SR500m % of Frequency n=7	>SR50m % Frequency n=3
Conceptual Phase	• Execution of feasibility studies and selection of the site.	63.6	0	28.6	100
	• Advise owner on the contracting strategy.	81.8	20.0	57.1	100
	• Selection of major construction methods and materials	90.9	40.0	71.4	100
Design Phase	• Insert into the design the concern of accessibility of personnel, materials and equipment	72.7	20.0	85.7	66.7

Table 4.13 Chi-square Results: Type of Contract versus Concept.

Does the Traditional Contract influence participation in Constructability activities and actions that the General Contractors implement?

Independent variable: Traditional Contract.

Null hypothesis: The implementation of constructability activities is independent of the Traditional Contract.

Stage	Q	Survey Measures	Chi-square	Df	P-Value
	8	Have you heard of the term constructability before?	4.284	1	0.038
Activities Performed during Conceptual Phase	9a	Advise owner on the establishment of the project goals and objectives.	1.777	1	0.183
	9b	Execution of feasibility studies and the selection of the site.	3.178	1	0.075
	9c	Advise owner on the contracting strategy.	9.079	1	* 0.003
	9d	Suggest structural systems.	1.106	1	0.293
	9e	Selection of the major construction methods and materials.	1.453	1	0.228
	9f	Preparation of the schedule, estimates and budget.	0.091	1	0.763
	9g	No participation.	0.040	1	0.841
Activities Performed during Design Phase	10a	Analysis of the design to enable efficient construction.	12.577	1	* 0.000
	10b	Insert into the design the concern of accessibility of personnel, materials and equipment.	5.134	1	* 0.023
	10c	Promote designs that facilitate construction under adverse weather conditions.	1.517	1	0.218
	10d	Preparation of the schedule, estimate and budget.	2.273	1	0.132
	10e	Advise design team about sources of materials and engineered equipment.	0.940	1	0.332
	10f	Analysis/revision of the specifications to allow easy construction.	0.010	1	0.919
	10g	No participation.	2.098	1	0.148
Activities Performed during Construction Phase	11a	Careful analysis of layout, access, and temporary facilities to improve productivity.	1.636	1	0.201
	11b	Planning the sequence of field tasks to improve productivity.	1.094	1	0.296
	11c	Use of preassembly or prefabrication for the execution of the works.	2.273	1	0.132
	11d	Innovative use of construction equipment and tools.	0.793	1	0.373
	11e	Innovative use of materials (e.g. fiber reinforced concrete).	0.001	1	0.981
	11f	Capture and transfer of lesson learned to future projects.	0.091	1	0.763
	11g	No participation.	1.636	1	0.201
Other Action	12a	There is an organizational policy statement toward the implementation of constructability.	1.106	1	0.293
	12b	The management of the organization supports constructability.	0.091	1	0.763
	12c	Assignment of constructability coordinator in the organization level and in the project level.	2.820	1	0.093
	12d	Constructability is included in contract documents.	0.001	1	0.981
	12e	None of the above	0.004	1	0.948
	12f	All of the above (organized, formal constructability program).	0.239	1	0.625

Note: * Statistical Significant $P < 0.05$

Table 4.14 Chi-square Results: Type of Contract versus Concept.

Does the Design-build Contract influence participation in Constructability activities and actions that the General Contractors implement?

Independent variable: Design-build Contract.

Null hypothesis: The implementation of constructability activities is independent of the Design-build Contract.

Stage	Q	Survey Measures	Chi-square	Df	P-Value
	8	Have you heard of the term constructability before?	0.799	1	0.371
Activities Performed during Conceptual Phase	9a	Advise owner on the establishment of the project goals and objectives.	3.895	1	* 0.048
	9b	Execution of feasibility studies and the selection of the site.	0.595	1	0.440
	9c	Advise owner on the contracting strategy.	1.304	1	0.253
	9d	Suggest structural systems.	0.009	1	0.925
	9e	Selection of the major construction methods and materials.	6.691	1	* 0.010
	9f	Preparation of the schedule, estimates and budget.	0.199	1	0.656
	9g	No participation.	0.834	1	0.361
Activities Performed during Design Phase	10a	Analysis of the design to enable efficient construction.	0.267	1	0.605
	10b	Insert into the design the concern of accessibility of personnel, materials and equipment.	3.533	1	0.060
	10c	Promote designs that facilitate construction under adverse weather conditions.	0.385	1	0.535
	10d	Preparation of the schedule, estimate and budget.	0.003	1	0.955
	10e	Advise design team about sources of materials and engineered equipment.	1.505	1	0.220
	10f	Analysis/revision of the specifications to allow easy construction.	0.394	1	0.530
	10g	No participation.	0.101	1	0.751
Activities Performed during Construction Phase	11a	Careful analysis of layout, access, and temporary facilities to improve productivity.	1.431	1	0.232
	11b	Planning the sequence of field tasks to improve productivity.	0.834	1	0.361
	11c	Use of preassembly or prefabrication for the execution of the works.	3.230	1	0.072
	11d	Innovative use of construction equipment and tools.	4.775	1	* 0.029
	11e	Innovative use of materials (e.g. fiber reinforced concrete).	0.164	1	0.686
	11f	Capture and transfer of lesson learned to future projects.	5.236	1	* 0.022
	11g	No participation.	1.431	1	0.232
Other Action	12a	There is an organizational policy statement toward the implementation of constructability.	2.425	1	0.119
	12b	The management of the organization supports constructability.	1.869	1	0.172
	12c	Assignment of constructability coordinator in the organization level and in the project level.	0.023	1	0.880
	12d	Constructability is included in contract documents.	0.164	1	0.686
	12e	None of the above	3.547	1	0.060
	12f	All of the above (organized, formal constructability program).	2.306	1	0.129

Note: * Statistically Significant: $P < 0.05$

Table 4.15 Chi-square Results: Type of Contract versus Concept.

Does the Construction Management Contract influence participation in Constructability activities and actions that the General Contractors implement?

Independent variable: Construction Management Contract.

Null hypothesis: The implementation of constructability activities is independent of the Construction Management Contract.

Stage	Q	Survey Measures	Chi-square	Df	P-Value
	8	Have you heard of the term constructability before?	2.775	1	0.096
Activities Performed during Conceptual Phase	9a	Advise owner on the establishment of the project goals and objectives.	1.697	1	0.193
	9b	Execution of feasibility studies and the selection of the site.	1.453	1	0.228
	9c	Advise owner on the contracting strategy.	0.033	1	0.856
	9d	Suggest structural systems.	2.368	1	0.124
	9e	Selection of the major construction methods and materials.	0.285	1	0.593
	9f	Preparation of the schedule, estimates and budget.	0.067	1	0.796
	9g	No participation.	0.030	1	0.863
Activities Performed during Design Phase	10a	Analysis of the design to enable efficient construction.	0.079	1	0.779
	10b	Insert into the design the concern of accessibility of personnel, materials and equipment.	2.024	1	0.155
	10c	Promote designs that facilitate construction under adverse weather conditions.	0.285	1	0.593
	10d	Preparation of the schedule, estimate and budget.	0.001	1	0.976
	10e	Advise design team about sources of materials and engineered equipment.	2.232	1	0.135
	10f	Analysis/revision of the specifications to allow easy construction.	0.862	1	0.350
	10g	No participation.	1.359	1	0.244
Activities Performed during Construction Phase	11a	Careful analysis of layout, access, and temporary facilities to improve productivity.	0.423	1	0.516
	11b	Planning the sequence of field tasks to improve productivity.	2.283	1	0.531
	11c	Use of preassembly or prefabrication for the execution of the works.	0.954	1	0.329
	11d	Innovative use of construction equipment and tools.	0.862	1	0.353
	11e	Innovative use of materials (e.g. fiber reinforced concrete).	0.966	1	0.326
	11f	Capture and transfer of lesson learned to future projects.	0.067	1	0.796
	11g	No participation.	0.423	1	0.516
Other Action	12a	There is an organizational policy statement toward the implementation of constructability.	0.003	1	0.959
	12b	The management of the organization supports constructability.	1.588	1	0.208
	12c	Assignment of constructability coordinator in the organization level and in the project level.	3.150	1	0.076
	12d	Constructability is included in contract documents.	3.186	1	0.074
	12e	None of the above	0.348	1	0.555
	12f	All of the above (organized, formal constructability program).	0.176	1	0.675

In the case of the Construction Management Contract (Table 4.15), no relationship was found with the constructability concept activities. By studying the results, Table 4.16 shows that constructability concepts are implemented more in Design-Build and Traditional types of contract. Since the General Contractors were responsible for both design and construction, it is understandable why the constructability concepts were used in Design-Build contracts while under the Traditional type it is not clear. It may be due to the fact that the concept is misunderstood. Although Construction Management Contracts are used by 50% of the participants, they are showing less interest in implementing the constructability concepts.

Table 4.16 Type of Contract versus Dependent Constructability Concept.

Phase	Activities Performed	Traditional % Frequency n=12	Design-build % Frequency n=18	Construction Management % of Frequency n=22
Conceptual Phase	• Advise owner in the establishment of the project goals and objectives.	66.7	66.7	59.1
	• Advice owner in the contracting strategy.	91.7	66.7	59.1
	• Selection of major construction methods and materials	83.3	88.9	68.2
Design Phase	• Analysis of the design to enable efficient construction	91.7	55.6	50.0
	• Insert into the design the concern of accessibility of personnel, materials and equipment.	83.3	72.2	50.0
Construction Phase	• Innovative use of construction equipment and tools.	58.3	83.3	72.7
	• Capture and transfer of lesson learned to future projects.	83.3	74.4	81.8

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Upon carefully studying the facts of historical evidence, understanding current construction methodology and implementation practices in construction projects in this region, and analysing the overall growth of the construction industry and the various barriers that affect the optimisation of project objectives, the researcher puts forward hereunder his conclusions and suggestions.

5.1.1 General Issues of Constructability

a) The term "constructability" is very well known to the General Contractors in this part of Saudi Arabia. This high level of awareness among General Contractors in this region may be due to Saudi Aramco, which insists on a constructability program as part of its contractor qualification process.

b) General Contractors are commonly participating during the pre-construction phase of the project by inserting their construction knowledge.

c) Most of the General Contractors think that constructability should be implemented in all projects regardless of the project size, type or complexity.

d) Specification problem and unrealistic schedules are the most significant difficulties encountered by the General Contractors under the Traditional method of contracting.

e) General Contractors feel that constructability should be included as another specialty requirement during the design phase of a project. This practice can help them to produce better drawings and specifications by participating during the design phase.

5.1.2 Barriers

a) General Contractors in common were having the same opinion about the barriers to constructability, irrespective of the volume of work, type of work or type of contract. As an exception, only organizations with an annual volume of more than SR 500 Million were found to have less barriers.

b) The most significant barriers to constructability highlighted by General Contractors were as follows:

- Design without construction input is the traditional form of contracting.
- Owners do not care about constructability in the contracting strategy.
- Owners do not choose constructability in their projects.

c) The least mentioned barriers to constructability by General Contractors were:
"There are no proven benefits of constructability" By this, it is obvious that General Contractors are very well aware of the benefits of constructability.

d) General Contractors believe that the following barriers to constructability exist sometimes, but not always:

- Designers' lack of construction experience and knowledge of construction technology.
- The concept is unknown to the owners

e) A new barrier to constructability witnessed during the research process was the lack of general awareness of quality services by contractors in the community in general.

5.1.3 The Constructability Concept

a) The application of the constructability concept by General Contractors was found most in the construction phase.

b) Constructability programs are commonly implemented by General Contractors.

c) It was found that, in the implementation of constructability concepts by General Contractors in the industrial type of work and the design-build contract, there is a dependent relationship between them. Table 5.1 summarizes the dependence between them.

5.1.4 General Findings

a) The majority of General Contractors agreed that the management of their organization supported constructability.

b) Organizations with a larger volume of work tend to have a formal constructability program.

Table 5.1 Constructability Concepts Related with Industrial Type of Work and Design-build Contract.

Phase	Q	Constructability Concepts	Industrial Construction	Design-build Contract
Activities Performed during Conceptual Phase	9a	Advise owner on the establishment of the project goals and objectives.	[redacted]	[redacted]
	9b	Execution of feasibility studies and the selection of the site.		
	9c	Advise owner on the contracting strategy.		
	9e	Selection of the major construction methods and materials.		[redacted]
Activities Performed during Construction Phase	11b	Planning the sequence of field tasks to improve productivity.	[redacted]	[redacted]
	11c	Use of pre-assembly or prefabrication for the execution of the work.		
	11d	Innovative use of construction equipment and tools..		[redacted]
	11f	Capture and transfer of lessons learned to future projects.	[redacted]	
Other Action	12b	The management of the organization supports constructability.	[redacted]	

5.2 Recommendations

a) General Contractors should practice constructability and educate their clients in its implementation, thereby developing in them an awareness of the various benefits that could result from constructability implementation.

b) General Contractors, owners and designers should form an association for Constructability. This will enable them to be fully aware of constructability and its related benefits. This association will give them a chance to share banks of related information and best practices, thereby benefiting construction projects as a whole. Also, it will help them create special clauses in contracts in order to improve teamwork and integration among participants.

c) As part of promoting constructability programs, owners should insist on involving the General Contractors in the conceptual phase and design-procurement phase. Design-build is one way to deliver a project that can bring many benefits based on the successful integration of design and construction.

d) Designers and General Contractors should practice insertion of concern for accessibility of personnel, materials and equipment in the design phase of any project. This could result in huge savings for the contractors.

e) Constructability should be implemented in all projects, regardless of their size or complexity.

f) Constructability should be included as another specialty during the pre-construction phase of a project.

g) General Building and Heavy Construction contractors should practice successful implementation of constructability concepts in their projects. The same benefit obtained by implementing constructability in Industrial Projects can be obtained in General Building and Heavy Constructors too.

h) General Contractors should put more effort into making use of the lessons learned. This can be made possible by creating a database of the various facts and figures witnessed during all construction projects and should be used for the benefit of future projects.

i) Construction engineering and construction management colleges need to add constructability to their curriculum. It will have a great effect in applying constructability in the future.

5.3 Areas for Further Studies

The researcher feels that there should be more studies to identify various barriers to Constructability, and to plan tactics and techniques to overcome or mitigate each individual barrier.

APPENDIX A

Questionnaire Form

Constructability Questionnaire

This questionnaire will be sent to a representative sample of General Contractors in Saudi Arabia. Certain questions may have more than one answer and are indicated by the words check all that apply. Otherwise, please check only one answer. Individual responses to questions and Company and Project identifications will remain anonymous.

1. Information about the person filling the questionnaire:

   Name: (Optional) _____

   Position: _____

   Company: _____

   Address: _____

   _____

   Phone: _____ Fax: _____

   Email: _____

2. Organization Nationality.

   ☐ Saudi.
   ☐ Joint Venture.
   ☐ Other (Specify: _____).

3. What best describes your organization type:

   ☐ General Contractor. ☐ Design Build Contractor.
   ☐ Subcontractor. ☐ Other (Please list: _____).

4. In what sector does your organization perform work? Check all that apply.

   ☐ Private (____% of total volume). ☐ Public (____% of total volume).

5. What type of work is your organization typically involved with? Check all that apply.

   ☐ General Building. ☐ Industrial.
   ☐ Civil (Heavy and Highway). ☐ Other (List: _____).

6. Please indicate the range of annual volume of work.

   ☐ Less than SR50,000,000
   ☐ Between SR50,000,000 and SR100,000,000
   ☐ Between SR100,000,000 and SR500,000,000
   ☐ More than SR500,000,000

7. Under what type of contract do you perform work? Check all that apply?

   ☐ Traditional (design without construction input) (____% of total volume).
   ☐ Design-build (____% of total volume).
   ☐ Construction Management (____% of total volume).

8. Constructability has been defined as: "The optimum integration of construction knowledge and experience in planning, engineering, procurement and field operations to achieve overall project objectives". Have you heard this term before?

☐ Yes. ☐ No.

9. Has your organization participated in the conceptual phase of a project by doing any of the following activities: Check all that apply.

☐ Advise owner in the establishment of the project goals and objectives.
☐ Execution of feasibility studies and advice in the selection of the site.
☐ Advise owner in the contracting strategy.
☐ Suggest structural systems.
☐ Selection of the major construction methods and materials.
☐ Preparation of the schedule, estimates and budget.
☐ No participation.

10. Has your organization participated in the design-procurement phase of a project by doing any of the following activities: Check all that apply.

☐ Analysis of the design to enable efficient construction (e.g. Ensure workmen can get tools to areas to make connections).
☐ Insert into the design the concern of accessibility of personnel, materials and equipment.
☐ Promote designs that facilitate construction under adverse weather conditions.
☐ Preparation of the schedule, estimates and budget.
☐ Advise design team about sources of materials and engineering equipment.
☐ Analysis/revision of the specifications to allow easy construction.
☐ No participation.

11. Please select the activities your organization performs during the construction phase: Check all that apply.

☐ Careful analysis of layout, access, and temporary facilities to improve productivity.
☐ Planning the sequence of field task to improve productivity.
☐ Use of preassembly or prefabrication for the execution of the works.
☐ Innovative use of construction equipment and tools (e.g. Mobile hydraulic man-lifts in lieu of scaffolding).
☐ Innovative use of material (e.g. Fiber reinforced concrete).
☐ Capture and transfer of lessons learned to future projects.
☐ No participation.

12. Considering questions 8 – 11, does your organization implement any of the following? Check all that apply.

☐ There is an organizational policy statement toward the implementation of constructability.
☐ The management of the organization supports constructability.
☐ Assignment of constructability coordinator in the organization level and in the project level.
☐ Tracking of constructability is included in contract documents.
☐ None of the above.
☐ All of the above (organized, formal constructability program).

13. How often do you participate by inserting construction knowledge during the preconstruction phase of projects?

☐ Commonly.
☐ Seldom.
☐ Never.

14. Based on your experience, please rate the following list of barriers to constructability.

	ALWAYS	SOMETIMES	NEVER
a. The concept is unknown by the owner.	☐	☐	☐
b. Owners do not care about constructability in the contracting strategy.	☐	☐	☐
c. Design without construction input is the traditional form of contracting.	☐	☐	☐
d. Owners do not choose constructability in their projects.	☐	☐	☐
e. The concept is unknown by designers.	☐	☐	☐
f. Designers lack construction experience and knowledge of construction technologies.	☐	☐	☐
g. The concept is unknown by contractors.	☐	☐	☐
h. Reluctance of field personnel to offer preconstruction advise.	☐	☐	☐
i. There are no proven benefits of Constructability.	☐	☐	☐
Other (explain)			
j. _____	☐	☐	☐
k _____	☐	☐	☐
l. _____).	☐	☐	☐

15. Where do you think constructability should be implemented? Check all that apply.

☐ Complex Projects. ☐ Small Projects.
☐ Large Projects. ☐ All Projects.
☐ Certain types of Projects. (List: _____).

16. Using the traditional process (design without construction input), have you encountered any of the following difficulties? Check all that apply.

☐ Specifications problems.
☐ Tolerance problems.
☐ Problems with physical interference.
☐ Weather related problems that could be avoided during design phase.
☐ Unrealistic schedule.

17. Do you agree that the participation of construction contractors during the design of a project can help to produce better drawings, specifications, and buildable projects?

☐ Yes. ☐ No.
☐ Sometimes. (Explain: _____).

18. Do you think constructability should be included as another specialty during the design phase of the project such as: architectural, mechanical, electrical, etc.?.

☐ Yes. ☐ No.
☐ Sometimes. (Explain: _____).

Thank you for your time, this concludes your participation in this survey.

APPENDIX B

Data

	Q2	Q3	Q4A	Q4B	Q5A	Q5B	Q5C	Q5D	Q6	Q7A	Q7B	Q7C	Q8	Q9A	Q9B	Q9C	Q9D	Q9E	Q9F	Q9G	Q10A	Q10B	Q10C	Q10D	Q10E	Q10F	Q10G	Q11A	Q11B	Q11C	Q11D	Q11E	Q11F
1	2	GC	2	1	1	1	2	2	2	2	2	1	1	2	2	2	2	2	2	1	2	2	2	1	1	1	2	1	1	1	2	2	2
2	1	GC	1	2	1	1	1	2	4	2	1	1	1	1	1	1	2	1	1	2	2	2	2	1	1	1	2	1	1	2	1	1	1
3	1	GC	2	1	1	1	2	2	1	2	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	1	1	1	1	1	1	1
4	1	GC	2	1	2	2	1	2	3	1	2	1	2	1	2	1	1	2	1	2	1	2	2	1	1	2	2	2	2	2	2	2	2
5	1	GC	1	1	1	1	1	2	2	1	1	2	1	2	2	1	1	1	1	2	1	2	2	1	2	1	2	1	1	1	1	1	1
6	1	GC	1	1	2	1	2	2	2	2	1	1	1	1	2	2	2	1	1	2	2	2	2	1	2	1	2	1	1	1	1	2	1
7	3	GC			2	1	1	1	4	1	1	1	1	1	1	1	2	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	1
8	1	GC	1	2	1	1	2	2	1	1	1	2	2	1	1	1	1	1	1	2	1	1	1	1	1	1	2	1	1	1	2	2	1
9	1	GC	1	1	1	1	1	2	3	1	1	1	1	1	1	1	1	1	1	2	1	1	2	1	1	1	2	1	1	1	1	1	1
10	1	GC	2	1	2	1	2	2	2	2	2	1	1	2	2	2	2	2	1	2	2	2	2	1	2	2	2	1	1	1	1	1	1
11	3	GC	1	2	1	2	1	2	2	2	2	1	1	2	2	2	2	2	2	1	1	2	1	1	1	1	2	1	1	1	1	1	1
12	1	GC	1	1	1	2	2	2	3	2	1	1	1	2	2	2	1	1	1	2	1	1	1	1	1	1	2	1	1	1	1	1	1
13	1	GC	1	1	1	2	2	2	2	2	1	2	1	2	2	2	2	1	1	2	2	2	2	1	2	1	2	1	1	1	1	1	1
14	1	GC	1	1	1	2	2	2	1	2	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	2	1	1	1	1	2	1
15	3	GC			2	2	2	1	3	1	1	2	1	2	2	2	2	2	2	1	1	1	2	1	2	2	2	1	1	1	1	1	1
16	1	GC	1	1	1	1	2	2	1	1	2	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	2	1	1	1	1	1	1
17	1	GC	1	2	1	2	2	2	1	1	2	2	2	2	2	1	2	1	1	2	1	1	2	1	1	2	2	1	2	1	2	2	2
18	1	GC	2	1	1	1	1	1	3	1	1	2	1	1	1	1	1	1	1	2	1	1	1	2	1	1	2	1	1	1	1	2	1
19	1	GC	1	2	1	2	2	2	2	2	2	1	1	2	2	2	1	2	1	2	2	2	2	2	2	2	1	1	1	1	2	2	1
20	1	GC	1	1	1	1	2	1	3	2	1	1	1	1	2	1	1	1	2	2	1	1	2	1	1	1	2	1	1	1	1	2	1
21	1	GC	1	1	1	1	2	2	1	2	1	1	1	1	1	1	1	1	1	2	2	1	2	2	2	2	1	1	1	1	1	1	1
22	2	GC	1	1	1	1	2	2	1	1	2	1	1	2	1	1	1	1	1	2	1	1	2	1	1	1	2	1	1	1	2	1	1
23	1	GC	1	1	2	1	2	2	4	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	2	1	1	1	1	1	1
24	1	GC	1	2	2	2	2	1	2	2	2	1	1	1	2	2	1	2	1	2	2	1	2	1	1	1	2	1	1	2	2	1	2
25	1	GC	1	1	1	2	2	1	1	2	2	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	2	1	1	2	1	1	1
26	1	GC	2	1	1	2	2	2	2	2	2	1	1	2	2	2	2	2	1	2	2	2	2	2	1	2	2	1	1	2	1	2	1
27	1	GC	1	1	1	2	2	2	1	2	2	1	1	2	1	1	2	1	1	2	2	2	2	1	1	1	2	1	1	1	1	1	1
28	1	GC	1	2	1	2	2	2	1	2	2	1	2	2	2	2	1	1	2	2	2	2	2	2	2	1	2	1	1	2	2	2	2
29	1	GC	1	1	1	1	1	1	3	2	1	2	1	2	2	2	2	1	1	2	2	1	2	1	1	1	2	1	1	1	1	1	1
30	1	GC	1	2	1	2	2	2	1	2	1	2	1	2	2	2	2	2	1	2	2	1	2	2	2	2	2	1	2	2	2	2	2
31	1	GC	1	1	1	1	2	2	2	1	1	2	2	1	2	1	2	1	2	2	2	1	2	1	2	2	2	1	1	1	2	2	1

1 = Yes, 2 = No, GC = General Contractor

Question 6: 1 = Less than SR50M, 2 = 50M to 100M

3 = 100M to 1500M, 4 = more than 500M

	Q11G	Q12A	Q12B	Q12C	Q12D	Q12E	Q12F	Q13	Q14A	Q14B	Q14C	Q14D	Q14E	Q14F	Q14G	Q14H	Q14I	Q15A	Q15B	Q15C	Q15D	Q15E	Q16A	Q16B	Q16C	Q16D	Q16E	Q17A	Q17B	Q17C	Q18A	Q18B	Q18C
1	2	2	1	1	2	2	2	3	3	3	2	2	3	3	3	2	3	2	2	2	1	2	1	2	1	2	1	1	2	2	1	2	2
2	2	2	1	1	1	2	2	1	2	2	1	2	3	2	3	2	2	2	2	1	2	1	1	2	1	2	1	1	2	2	1	2	2
3	2	1	1	1	1	2	1	1	2	3	2	2	2	2	3	2	3	2	2	2	1	2	1	2	1	1	1	1	2	2	1	2	2
4	1	2	1	1	1	2	2	1	1	2	2	2		2	2	2		2	2	1	2	2	1	2	2	2	2	1	2	2	1	2	2
5	2	1	1	1	1	2	1	1	2	2	1	2	2	2	2	2	3	2	2	2	1	2	1	1	1	2	1	1	2	2	1	2	2
6	2	1	1	1	1	2	1	1	2	2	2	2	2	2	2	2	3	2	2	2	1	2	1	1	1	1	1	1	2	2	1	2	2
7	2	1	1	1	1	2	1	1	3	3	3	3	3	2	3	3	3	2	2	2	1	2						1	2	2	2	2	1
8	2	1	1	1	1	2	1	1	1	1	2	2	2	2	2	3	3	2	2	2	1	2	1	2	2	2	1	1	2	2	2	2	1
9	2	1	1	2	1	2	2	1	2	1	1	1	2	2	2	2	2	2	2	2	1	2	1	2	1	2	1	1	2	2	1	2	2
10	2	2	1	1	2	2	2	2	1	1	1	1	2	2	1	1	1	2	2	2	1	2	2	2	2	2	2	2	2	1	1	2	2
11	2	1	1	1	1	2	1	1	2	2	2	3	2	2	2	2	3	2	2	2	1	2	1	1	1	2	1	2	2	1	1	2	2
12	2	2	1	1	2	2	2	1	2	1	1	2	1	1	1	2	2	2	2	2	1	2	1	2	1	2	1	1	2	2	1	2	2
13	2	2	1	1	2	2	2	1	2	2	3	2	3	3	2	2	3	2	2	2	1	2	1	1	1	2	1	1	2	2	2	1	2
14	2	1	1	2	2	2	2	1	1	1	2	2	2	2	2	2	3	2	2	2	1	2	1	1	1	2	1	1	2	2	1	2	2
15	2	1	1	2	2	2	2	1	2	2	2	2	2	2	2	2	3	2	2	2	1	2	1	1	1	2	1	1	2	2	1	2	2
16	2	1	1	1	1	2	2	1	2	2	2	1	2	2	2	3	2	2	2	2	1	2	1	1	1	2	1	1	2	2	1	2	2
17	2	2	2	2	2	1	2	2	1	1	1	1	2	2	2	3	2	1	2	1	2	2	1	1	1	2	1	1	2	2	2	1	2
18	2	1	1	2	2	2	2	2	2	2	2	2	2	2	2		2	2	2	2	1	2	1	1	1	1	1	1	2	2	1	2	2
19	2	2	2	2	2	1	2	2	2	1	1	1	2	2	2	1	3	1	2	1	2	2	1	1	1	2	1	2	2	1	2	1	2
20	2	2	1	1	1	2	2	1	2	2		2	2	1	2	1	2	2	1	2	2	2	1	1	2	1	1	1	2	2	1	2	2
21	2	1	1	1	1	2	1	1	2	3	2	2	1		3	1	2	2	2	2	1	2	2	2	1	2	1	1	2	2	1	2	2
22	2	2	1	2	2	2	2	1	2	2	3	2	2	2	2	2	3	2	2	2	1	2	1	2	2	2	1	1	2	2	1	2	2
23	2	1	1	1	1	2	1	1	2	2	1	1	1	1	1	3	2	1	2	1	2	1	1	1	1	2	2	1	2	2	2	2	1
24	2	1	2	1	1	2	2	1	3	2	3	2	3	2	3	2	3	2	2	2	1	2	1	1	1	1	1	1	2	2	1	2	2
25	2	1	1	1	1	2	1	1	2	3	3	3	3	3	3	3	3	2	2	2	1	2	2	2	2	1	2	1	2	2	1	2	2
26	2	1	1	1	1	1	1	1	2	1	2	1	2	2	2	2	3	2	2	2	1	2	1	1	2	1	1	1	2	2	1	2	2
27	2	2	1	1	1	2	2	1	2	3	3	3	3	3	3	3	3	1	2	1	2	1	1	1	1	1	1	2	1	2	2	2	1	2
28	2	2	2	2	2	1	2	2	1	1	1	1	2	2	1	2	3	2	2	1	2	2	1	2	2	2	2	1	2	2	1	2	2
29	2	1	1	1	1	2	1	1	2	2	2	2	3	2	3	2	3	2	2	2	1	2	1	1	1	1	1	1	2	2	1	2	2
30	2	2	2	2	2	2	1	1	2	2	3	3	3	2	3	2	3	2	2	2	1	2	1	2	2	2	2	1	2	2	1	2	2
31	2	2	2	2	2	1	2	2	2	2	1	1	2	2	3	2	3	1	2	1	2	2	1	2	1	2	1	1	2	2	2	2	1

Question 13: 1 = Commonly, 2 = Seldom, 3 = Never
14: 1 = Always 2 = Sometimes 3 = Never

APPENDIX C

Examples of statistical computer printout

Crosstabs

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Q8 * Q4B	29	93.5%	2	6.5%	31	100.0%
Q9A * Q4B	29	93.5%	2	6.5%	31	100.0%
Q9B * Q4B	29	93.5%	2	6.5%	31	100.0%
Q9C * Q4B	29	93.5%	2	6.5%	31	100.0%
Q9D * Q4B	29	93.5%	2	6.5%	31	100.0%
Q9E * Q4B	29	93.5%	2	6.5%	31	100.0%
Q9F * Q4B	29	93.5%	2	6.5%	31	100.0%
Q9G * Q4B	29	93.5%	2	6.5%	31	100.0%

Q8 * Q4B

Crosstab

			Q4B		
			yes	no	Total
Q8	yes	Count	19	5	24
		Expected Count	17.4	6.6	24.0
		% within Q8	79.2%	20.8%	100.0%
		% within Q4B	90.5%	62.5%	82.8%
		% of Total	65.5%	17.2%	82.8%
	No	Count	2	3	5
		Expected Count	3.6	1.4	5.0
		% within Q8	40.0%	60.0%	100.0%
		% within Q4B	9.5%	37.5%	17.2%
		% of Total	6.9%	10.3%	17.2%
Total		Count	21	8	29
		Expected Count	21.0	8.0	29.0
		% within Q8	72.4%	27.6%	100.0%
		% within Q4B	100.0%	100.0%	100.0%
		% of Total	72.4%	27.6%	100.0%

Chi-Square Tests

	Value	Df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	3.178[b]	1	.075		
Continuity Correction	1.519	1	.218		
Likelihood Ratio	2.869	1	.090		
Fisher's Exact Test				.112	.112
Linear-by-Linear Association	3.068	1	.080		
N of Valid Cases	29				

a. Computed only for a 2x2 table

b. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 1.38.

Q9A * Q4B

Crosstab

			Q4B		
			Yes	No	Total
Q9A	yes	Count	12	3	15
		Expected Count	10.9	4.1	15.0
		% within Q9A	80.0%	20.0%	100.0%
		% within Q4B	57.1%	37.5%	51.7%
		% of Total	41.4%	10.3%	51.7%
	No	Count	9	5	14
		Expected Count	10.1	3.9	14.0
		% within Q9A	64.3%	35.7%	100.0%
		% within Q4B	42.9%	62.5%	48.3%
		% of Total	31.0%	17.2%	48.3%
Total		Count	21	8	29
		Expected Count	21.0	8.0	29.0
		% within Q9A	72.4%	27.6%	100.0%
		% within Q4B	100.0%	100.0%	100.0%
		% of Total	72.4%	27.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.895[b]	1	.344		
Continuity Correction	.281	1	.596		
Likelihood Ratio	.901	1	.343		
Fisher's Exact Test				.427	.298
Linear-by-Linear Association	.864	1	.353		
N of Valid Cases	29				

a. Computed only for a 2x2 table

b. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 3.86.

Q9B * Q4B

Crosstab

			Q4B		Total
			yes	no	
Q9B	Yes	Count	9	2	11
		Expected Count	8.0	3.0	11.0
		% within Q9B	81.8%	18.2%	100.0%
		% within Q4B	42.9%	25.0%	37.9%
		% of Total	31.0%	6.9%	37.9%
	No	Count	12	6	18
		Expected Count	13.0	5.0	18.0
		% within Q9B	66.7%	33.3%	100.0%
		% within Q4B	57.1%	75.0%	62.1%
		% of Total	41.4%	20.7%	62.1%
Total		Count	21	8	29
		Expected Count	21.0	8.0	29.0
		% within Q9B	72.4%	27.6%	100.0%
		% within Q4B	100.0%	100.0%	100.0%
		% of Total	72.4%	27.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.785[b]	1	.376		
Continuity Correction	.209	1	.647		
Likelihood Ratio	.817	1	.366		
Fisher's Exact Test				.671	.330
Linear-by-Linear Association	.758	1	.384		
N of Valid Cases	29				

a. Computed only for a 2x2 table

b. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 3.03.

Q9C * Q4B

Crosstab

			Q4B		
			Yes	no	Total
Q9C	yes	Count	14	3	17
		Expected Count	12.3	4.7	17.0
		% within Q9C	82.4%	17.6%	100.0%
		% within Q4B	66.7%	37.5%	58.6%
		% of Total	48.3%	10.3%	58.6%
	No	Count	7	5	12
		Expected Count	8.7	3.3	12.0
		% within Q9C	58.3%	41.7%	100.0%
		% within Q4B	33.3%	62.5%	41.4%
		% of Total	24.1%	17.2%	41.4%
Total		Count	21	8	29
		Expected Count	21.0	8.0	29.0
		% within Q9C	72.4%	27.6%	100.0%
		% within Q4B	100.0%	100.0%	100.0%
		% of Total	72.4%	27.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	2.032[b]	1	.154		
Continuity Correction	1.007	1	.316		
Likelihood Ratio	2.018	1	.155		
Fisher's Exact Test				.218	.158
Linear-by-Linear Association	1.962	1	.161		
N of Valid Cases	29				

a. Computed only for a 2x2 table

b. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 3.31.

Q9D * Q4B

Crosstab

			Q4B		
			yes	no	Total
Q9D	yes	Count	13	4	17
		Expected Count	12.3	4.7	17.0
		% within Q9D	76.5%	23.5%	100.0%
		% within Q4B	61.9%	50.0%	58.6%
		% of Total	44.8%	13.8%	58.6%
	No	Count	8	4	12
		Expected Count	8.7	3.3	12.0
		% within Q9D	66.7%	33.3%	100.0%
		% within Q4B	38.1%	50.0%	41.4%
		% of Total	27.6%	13.8%	41.4%
Total		Count	21	8	29
		Expected Count	21.0	8.0	29.0
		% within Q9D	72.4%	27.6%	100.0%
		% within Q4B	100.0%	100.0%	100.0%
		% of Total	72.4%	27.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.338[b]	1	.561		
Continuity Correction	.026	1	.873		
Likelihood Ratio	.336	1	.562		
Fisher's Exact Test				.683	.432
Linear-by-Linear Association	.327	1	.568		
N of Valid Cases	29				

a. Computed only for a 2x2 table

b. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 3.31.

Q9E * Q4B

Crosstab

			Q4B		
			yes	no	Total
Q9E	yes	Count	17	4	21
		Expected Count	15.2	5.8	21.0
		% within Q9E	81.0%	19.0%	100.0%
		% within Q4B	81.0%	50.0%	72.4%
		% of Total	58.6%	13.8%	72.4%
	No	Count	4	4	8
		Expected Count	5.8	2.2	8.0
		% within Q9E	50.0%	50.0%	100.0%
		% within Q4B	19.0%	50.0%	27.6%
		% of Total	13.8%	13.8%	27.6%
Total		Count	21	8	29
		Expected Count	21.0	8.0	29.0
		% within Q9E	72.4%	27.6%	100.0%
		% within Q4B	100.0%	100.0%	100.0%
		% of Total	72.4%	27.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	2.778[b]	1	.096		
Continuity Correction	1.445	1	.229		
Likelihood Ratio	2.621	1	.105		
Fisher's Exact Test				.164	.116
Linear-by-Linear Association	2.683	1	.101		
N of Valid Cases	29				

a. Computed only for a 2x2 table

b. 1 cells (25.0%) have expected count less than 5. The minimum expected count is 2.21.

Q9F * Q4B

Crosstab

			Q4B		
			yes	no	Total
Q9F	yes	Count	18	6	24
		Expected Count	17.4	6.6	24.0
		% within Q9F	75.0%	25.0%	100.0%
		% within Q4B	85.7%	75.0%	82.8%
		% of Total	62.1%	20.7%	82.8%
	No	Count	3	2	5
		Expected Count	3.6	1.4	5.0
		% within Q9F	60.0%	40.0%	100.0%
		% within Q4B	14.3%	25.0%	17.2%
		% of Total	10.3%	6.9%	17.2%
Total		Count	21	8	29
		Expected Count	21.0	8.0	29.0
		% within Q9F	72.4%	27.6%	100.0%
		% within Q4B	100.0%	100.0%	100.0%
		% of Total	72.4%	27.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.466[b]	1	.495		
Continuity Correction	.018	1	.894		
Likelihood Ratio	.440	1	.507		
Fisher's Exact Test				.597	.425
Linear-by-Linear Association	.450	1	.502		
N of Valid Cases	29				

a. Computed only for a 2x2 table

b. 1 cells (25.0%) have expected count less than 5. The minimum expected count is 1.36.

Q9G* Q4B

Crosstab

			Q4B		
			yes	no	Total
Q9G	Yes	Count	1	1	2
		Expected Count	1.4	.6	2.0
		% within Q9G	50.0%	50.0%	100.0%
		% within Q4B	4.8%	12.5%	6.9%
		% of Total	3.4%	3.4%	6.9%
	No	Count	20	7	27
		Expected Count	19.6	7.4	27.0
		% within Q9G	74.1%	25.9%	100.0%
		% within Q4B	95.2%	87.5%	93.1%
		% of Total	69.0%	24.1%	93.1%
Total		Count	21	8	29
		Expected Count	21.0	8.0	29.0
		% within Q9G	72.4%	27.6%	100.0%
		% within Q4B	100.0%	100.0%	100.0%
		% of Total	72.4%	27.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.540[b]	1	.462		
Continuity Correction	.000	1	1.000		
Likelihood Ratio	.486	1	.486		
Fisher's Exact Test				.483	.483
Linear-by-Linear Association	.522	1	.470		
N of Valid Cases	29				

a. Computed only for a 2x2 table

b. 2 cells (50.0%) have expected count less than 5. The minimum expected count is .55.

APPENDIX D

List of Contractors

LIST OF CONTRACTORS

List of Contractors in the Eastern Province as classified by the Chamber of Commerce as Grade 2 or better:

SN	COMPANY NAME	ADDRESS	TEL./FAX #
1	A. A. AL-QAHTANI & SONS	P.O. BOX 20, DAMMAM 31411	
2	SAUDI ARABIAN PONGLEM FOR CONSTRUCTION	P.O. BOX 2578, DAMMAM 31461	
3	AL-NAHDA FOR ENGINEERING AND CONTRACTING	P.O. BOX 121, DAMMAM 31411	
4	AL-FOZAN COMPANY	P.O. BOX 38, AL-KHOBAR 31952	
5	A. A. AL-DOSSARY FOR TRADING	P.O. BOX 973, AL-KHOBAR 31952	
6	N. AL-SEBAIE COMPANY	P.O. BOX 12, AL-KHOBAR 31952	8575588 / 8576279
7	AL-MADAR COMPANY FOR CONTRACTING	P.O. BOX 120, DHAHRAN AIRPORT 31932	
8	A & S AL-MOJIL COMPANY	P.O. BOX 53, DAMMAM 31411	
9	SAUDI TAISI LIMITED	P.O. BOX 90, ALKHOBAR 31952	
10	AL-MIRA CENTER FOR TRADING	P.O. BOX 2120, DAMMAM 31451	
11	IKHWAN COMPANY	P.O. BOX 7999, DAMMAM 31472	
12	AL-QAHTANI AND COMPANY	P.O. BOX 2224, DAMMAM 31451	
13	SAUDI CONDRICO LIMITED	P.O. BOX 693, DAMMAM 31421	
14	EASTERN ESTABLISHMENT	P.O. BOX 204, AL-KHOBAR 31952	
15	SAUDI ARABIAN MAROBINI	P.O. BOX 3203, AL-KHOBAR 31952	
16	REZAYAT COMPANY	P.O. BOX 90, AL-KHOBAR 31952	
17	AL-ERAIFI COMPANY	P.O. BOX 345, DAMMAM 31411	
18	AL-SARAN & AL-HAJRI CONTRACTING	P.O. BOX 214, DHAHRAN AIRPORT 31952	
19	SAUDI DANISH COMPANY FOR CONTRACTING	P.O. BOX 718, DAMMAM 31421	
20	AL-MAHA FOR CONTRACTING	P.O. BOX 2118, DAMMAM 31451	
21	AL-OTAISHAN AND SONS COMPANY	P.O. BOX 2178, DAMMAM 31451	
22	AL-HAIDER COMPANY FOR CONTRACTING	P.O. BOX 18, RAHIMA 31941	
23	LINA COMPANY FOR CONTRACTING	P.O. BOX 4379, DAMMAM 31491	
24	AL-JOUL FOR CONTRACTING	P.O. BOX 86, AL-KHOBAR 31952	
25	AL-AJINA FOR CONTRACTING	P.O. BOX 344, AL-KHOBAR 31952	
26	SAUDI GROUP FOR CONSTRUCTION MATERIAL	P.O. BOX 857, DHAHRAN AIRPORT 31932	
27	MASTORA FOR CONTRACTING AND TRADE	P.O. BOX 24, RASTANURA 31941	
28	AL-HALA FOR CONTRACTING	P.O. BOX 341, DHAHRAN AIRPORT 31932	
29	AL-ZAYER COMPANY	P.O. BOX 679, QATIF 31911	
30	ASIAD INTERNATIONAL FOR CONTRACTING	P.O. BOX 50, RAHIMA 31941	
31	COMMUNICATION SYSTEMS COMPANY LTD.	P.O. BOX 30248, AL-KHOBAR 31952	8948068 / 8948068
32	F.D. AL-DOSSARY FOR CONTRACTING	P.O. BOX 1945, DAMMAM 31491	
33	AL-MOHANA CONTRACTING	P.O. BOX 1945, DAMMAM 31411	8422754 / 8423221
34	SHAFI BINJABER & BROS FOR CONTRACTING	P.O. BOX 285, DHAHRAN AIRPORT 31932	8947262 / 8952519
35	SAMRY COMPANY LTD	P.O. BOX 257, DAMMAM 31411	8578098 / 8345722
36	SAUDI NATIONAL ESTABLISHMENT	P.O. BOX 54, HAFR ALBATIN 31991	
37	M. AL-SAEED COMPANY	P.O. BOX 120, AL-KHOBAR 31952	
38	AL-YAMAMA FOR CONTRACTING AND TRADE	P.O. BOX 2110, DAMMAM 31451	8270174 / 8270089
39	AL-MASHAREG FOR CONTRACTING	P.O. BOX 2540, DAMMAM 31461	8421660 / 8421658
40	AL-JORAN FOR CONTRACTING	P.O. BOX 20760, AL-THOGBA 31952	8649959 / 8942279
41	AL-TADAMON NATIONAL COMPANY	P.O. BOX 2072, DAMMAM 31491	8464556 / 8418412
42	AL-YOSSR CONTRACTING	P.O. BOX 293, AL-JUBAIL 31951	3621676 / 3622923
43	INTERNATIONAL CENTER FOR COMMERCE &	P.O. BOX 360, AL-KHOBAR 31952	8578577 / 8572253
44	SAUDI SONS CO. FOR CONTRACTING & TRADING	P.O. BOX 79316, AL-KHOBAR 31952	5961312
45	SNAS CONTRACTING EST.	P.O. BOX 756, AL-KHOBAR 31952	8827777 / 8826732
46	MOHAMMAD ALSHAFAI CONTRACTING EST.	P.O. BOX 42, SAIHAT 31952	8562417 / 8560976
47	AL-MOHSIN CONTRACTING EST.	P.O. BOX 529, SAIHAT 31972	8380474 / 8380870
48	AL NASSAR TRADING & CONTRACTING EST.	P.O. BOX 1802, AL-KHOBAR 31952	8985808 / 8987076
49	OSAIS CONTRACTING EST.	P.O. BOX 1083, DAMMAM 31431	8262861 / 8263098

LIST OF CONTRACTORS

List of Contractors approved by ARAMCO

SN	COMPANY NAME	ADDRESS	TEL / FAX #
1	NOJAIDI, MOHAMMED A. EST. FOR TRDG. & CONTR.	P.O. BOX 20651, AL-KHOBAR 31952	8422442 / 8417734
2	WABRAN, NASIR MANEA CO. & PARTNERS	P.O. BOX 20651 AL-KHOBAR 31952	8641293 / 8952240
3	SAUDI TECHNICAL FOR CONTRACTING COMPANY	P.O BOX 93719, RIYADH 11683	4620434 / 4627564
4	FLOUR ARABIA LTD.	P.O. BOX 360, DHAHRAN AIRPORT 31952	8829292 / 8826448
5	KING WILKINSON (S.A.) LTD.	P.O. BOX 1110, AL-KHOBAR 31952	8591111 / 8595093
6	OMRANIA & ASSOCIATES ARCH. ENGINEERING	OLAYA ST. P.O. BOX 2600, RIYADH 11451	4622886 / 4620354
7	PETROCON ARABIA LTD.	P.O. BOX 212, DHAHRAN AIRPORT 31952	8948700 / 8987116
8	PETRO-INFRASTRUCTURE ENGG. CONSULTANTS	DHAHRAN ROAD, AL-KHOBAR 31932	8982967 / 8952138
9	RADICON CONSULTING & DESIGN OFFICE	P.O. BOX 684, AL-KHOBAR 31952	8955036 / 8944468
10	SAUDI ENGINEERING GROUP INTERNATIONAL	P.O. BOX 1835, AL-KHOBAR 31952	8972221 / 8961397
11	SAUDI CONSULTING & DESIGN OFFICE	P.O. BOX 2017, AL-KHOBAR 31952	8949001 / 8947593
12	SAUDI CONSOLIDATED ENGINEERING COMPANY	P.O. BOX 1713, AL-KHOBAR 31952	8946816 / 8942341
13	SAUDI ARABIAN BECHTEL CO.	P.O. BOX 88, DHAHRAN AIRPORT 31932	8825288 / 8825369
14	IMAD CO. FOR TRADING & CONT.		8647562 / 8643887
15	HAMMAM CO. FOR CONSTRUCTION		6672715 / 6672719
16	ALMABANI GENERAL CONTRACTORS CO. LTD	P.O. BOX 2781, JEDDAH 21461	6516532 / 6519180
17	SUWAIDI, M.S. EST. FOR CONTRACTING	P.O. BOX 12, RASTANURA 31941	6671270 / 8419625
18	NATIONAL ENGG SVCS & MARKETING C. LTD.	P.O. BOX 1498, AL-KHOBAR 31952	8971050 / 8643121
19	FOUAD ABDULLA FOUAD CO. LTD.	P.O. BOX 806, DAMMAM 31421	8173000 / 8173300
20	TURKI A.A. CORPORATION	P.O. BOX 718, DAMMAM 31421	8332339 / 8347331
21	SAUDI OGER LTD.	P.O. BOX 1449, DAMMAM 31421	4770079 / 4783081
22	REDWAN HOLDING COMPANY	P.O. BOX 4061, AL-KHOBAR 31952	6600505 / 6652615
23	KETTANEH BROS SAUDI ARABIA	P.O. BOX 383, AL-KHOBAR 31952	8645452 / 8944301
24	HAMOOD, JAFFAR MOHAMMED EST. FOR TRD & CONT.	P.O. BOX 2547, DAMMAM 31541	8260451 / 8260693
25	BINALI, AHMAD N. & SONS CO. FOR TRD & CONT	P.O. BOX 2, DAMMAM 31411	8263654 / 8265245
26	HAJRI, MADI M. & PARTNERS COMPANY	P.O. BOX 1968 AL-KHOBAR 31952	8946650 / 8984204
27	ARNAOUT, OMAR KHALIL ST. FOR CONTRACTING	P.O. BOX 3001, AL-KHOBAR 31952	8940336 / 8647185
28	ALI, HUSSEIN CONTRACTING EST.	P.O. BOX 4866, AL-KHOBAR 31952	8649524 / 8954673
29	HARETH, SALEM SALEH EST.	P.O. BOX 1324, AL-KHOBAR 31952	8645361 / 8990241
30	GHAMDI, ALI HASSIN EST. FOR CONTRACTING	P.O. BOX 75, RAHIMA 31941	6670174 / 6673932
31	YAMI, AHMED YAHYA EST.	P.O. BOX 98 ABQAIQ 31992	5728892 / 5724856
32	BADER, ABDULRAHMAN EST. FOR TRDG & CONTG.	P.O. BOX 10, ABQAIQ 31992	5660884 / 5663824
33	ISSAM KABBANI & PARTNERS CO. FOR CONST. MAINT.	P.O. BOX 6897, DAMMAM 31452	8570034 / 8578177
34	ALLIED ENGINEERING ENTERPRISES S.A. LTD.	P.O. BOX 31276, JEDDAH 21497	6532515 / 6524027
35	FAST CONTRACTING COMPANY	P.O. BOX 5180 AL-TAHLIA ST. JEDDAH	6634675 / 6673348
36	ARABIAN GULF CONSTRUCTION CO, LTD.	P.O. BOX 1633, DAMMAM 31441	8570985 / 8572193
37	HAMMA, HADI HAMAD EST FOR CONTRACTING	P.O. BOX 3 RAHIMA 31941	6671258 / 6672359
38	SADIQ, HUSSEIN KADHAM EST.	P.O. BOX 164, RASTANURA 31941	6670701 / 6673140
39	AL-SUWAIDI EST. FOR CONTRACTING		6670304 / 6671270
40	CONTRACTING & TRADING CO. SAUDI BINLADIN		8955075 / 8950427
41	NATIONAL ENGG SVCS & MARK COMPANY		8971050 / 8947825
42	M. R. AL-KATHLAN		6672996 / 6670820
43	HAMOOD JAFFAR MOHAMMED EST.		8260451 / 8260693

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