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CONSTRUCTABILITY AT DESIGN OFFICES & CONTRACTORS
ANALYSIS AND RECOMMENDATION

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ABSTRACT

A litterateur review was conducted toward the development of comprehensive understanding of the concept "Constructability" and its application in the construction industry. This paper defines and explains constructability, provide some back ground on the extent that constructability as a concept has been used in the past, outlines current practices, discuss some of the elements that have to be considered in the constructability program. It emphasizes the importance of starting the constructability effort at the earliest stages of the project to maximize potential benefits. A questionnaire was generated from the previous researches into two similar parts for the designers and the contractors in the eastern province of Saudi Arabia.

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CHAPTER-1

INTRODUCTION

BACKGROUND

In the ancient times the design was dictated by how the project was going to be built and the design and construction were done by “Master builder”. The construction was based on traditional, general rules, and trial and error.

This situation continued until the Renaissance, when the architectural profession emerged. During this period, some architects valued aesthetics over the mechanics of building. This was the time when design began to separate from building or construction. In addition, it was the beginning of a new system of architectural education as an alternative to apprenticeship, breaking with the long and powerful tradition of craft associations. **(Ref. 1)**

Another important milestone that helped to separate design from construction was the Industrial Revolution, a period of great activity and progress. New materials, systems, and forms of construction were developed. It was during this period that modern engineering emerged, with the establishment of technical universities in which people were trained to deal with these new technologies. However, even though, the design of the projects was ultimately influenced by construction.

By comparison with other industries the separation of the process of design and construction is unique to the construction industry as highlighted in the yearly report such as the Simon Report, The Emmerson Report and the Banwell Report. **(Ref. 3)**

Evaluation results of the studies conducted on American and English Construction Industry showed that the lack of integration between construction and design was found to be one of the roots of the complex problem faced construction industry during 1960s and 1970s in many parts of the world. The declined cost efficiency and quality emphasized the need for constructability to began to be required. **(Ref. 1)**

According to Poh & Chen **(Ref. 2)**, the Singapore construction Industry Development Board is not the first to recognize that buildability is, and should be, a major consideration for construction industry. In spite of the fact that, buildability concepts have existed since humankind acquired the ability to erect simple dwellings and, since then, design has been dictated largely by what is buildable. The building industry realized the importance of buildability in the early 1970s as stated by the paper of Samuels, 1990.

In the early 1980s, the Construction Industry Research and Information Association (CIRIA) UK, identified buildability as a major problem facing the construction industry at that time probably due to the comparative isolation of many designers from the practical construction process. **(Ref. 2)**

Anyone with site experience has certainly heard the words "how am I suppose to build this" or " how is this going to fit". Such on site frustrations can often be traced back to design decisions that lacked knowledge regarding how the object would be built. It would, therefore, seem that design decisions should include constructability input and critiques. However, surprisingly often, little or no explicit constructability input is provided to design decisions leading to the aforementioned frustration in the field and to a slower, more costly construction period. To help overcome this problem and assist engineers from the beginning of a facility design, an experienced contractor who would look over the designer's shoulder and provide constructability feedback on design decisions whenever a designer would want to get constructability input is the right approach. **(Ref. 6)**

DEFINITIONS

As stated by McGeorge and Palmer the terms "constructability" and "buildability" will not be found in any standard dictionary. They are terms, which are specific to the construction industry and have meaning only to those operating within the confines of the industry. **(Ref. 3)**

In the context of this research, the terms are taken to be synonymous and can be used interchangeably. Constructability is preferred and will be used, except when quoting from authors who have chosen buildability.

In 1983, CIRIA defined buildability as '*the extent to which the design of the building facilitates ease of construction, subject to the overall requirements for the completed building'*. The CIRIA definition focused only on the link between design and construction and implied that factors, which are solely within the influence or control of the design team, are those that have a significant impact on the ease of construction of a project. **(Ref. 3)**

About the same time in the USA, the Construction Industry Institute (CII) was founded with specific aim of improving the cost effectiveness, total quality management and international competitiveness of the construction industry in the USA. The CII definition of contractibility is wider in scope than the CIRIA approach and defines constructability as '*a system for achieving optimum integration of construction knowledge and experience in planning, engineering, procurement and field operations in the building process and balancing the various project and environmental constraints to achieve overall project objectives*'. **(Ref. 3)**

According to Robert, 'Constructability the stretch version' is a planning process that requires customer input in every phase of the capital project planning, front-end engineering, detail design, procurement, contracting, construction, checkout, start-up, operation, Maintenance and business management, and communication among all project participants. **(Ref. 4)**

The above definition is called the stretch version of constructability because it takes advantage of the entire project team's experience and knowledge in the definition of success for the project as well as value-added gain and establishing up front the customer/supplier needs for the whole project as well as for each skill interface. It also promotes strong links among all project team members.

Constructability functions as a powerful planning vehicle in drawing all project team members together in a structured approach based on customer requirements and a "right-the first-time" execution strategy. The traditional separation of engineering, construction and non-engineering project contributors early in the project must be integrated such that everyone is focusing on the project success if constructability is to work and provide value to the project.

GOALS OF CONSTRUCTABILITY

The goals of constructability are determined by the scope which constructability is intended to cover. The 1983 CIRIA definition limited the scope of the concept to the relationship between design and construction. The system boundaries of the CIRIA concept are quite narrow, viewing constructability purely as a design oriented activity. As per the writer, a workable concept of constructability needs to recognize that there are many factors in a project environment which impact on the design and construction process, and the link between design and construction and the maintenance of the building as illustrated in figure 1. **(Ref. 3)**

Figure 1 demonstrates the factors influencing the design process, the construction process, and the quality and performance of the finished product. Only when the complex interaction of these factors is acknowledged can the potential of constructability be achieved. In addition, it can be seen that forces such as exogenous factors, endogenous factors and project specific goals influence each stage of the project, from design through to occupancy.

According to Kartam **(Ref. 8)**, constructability goal is to focus on the benefits and necessity of establishing a feedback system for channeling construction

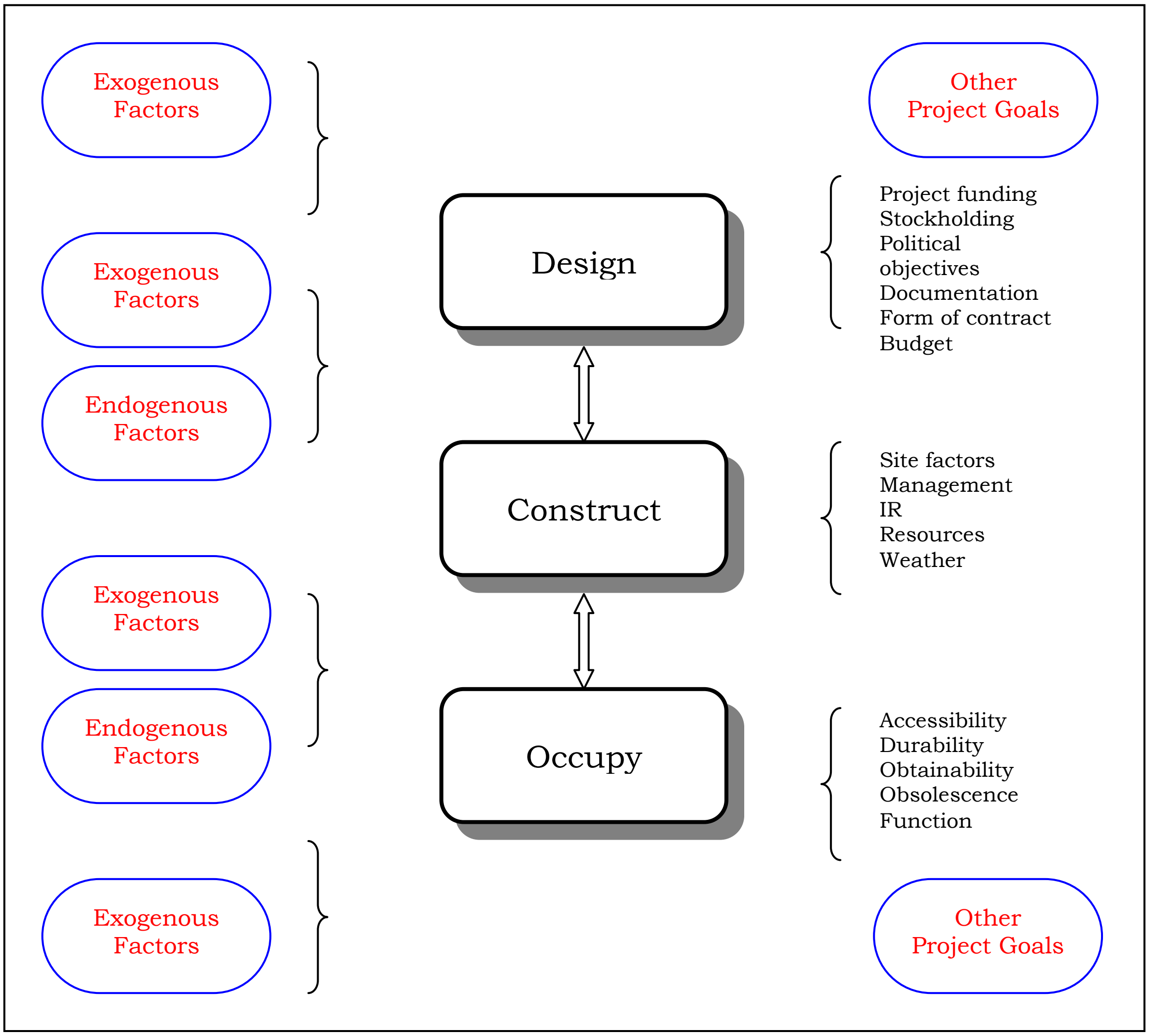

Figure 1. Constructability Framework

knowledge and experience pack into the design stages. The most effective form of feedback system is to bring experienced construction personnel on board in the earliest stage of projects so that constructability is integrated in the planning and design development process.

Constructability is needed to overcome the complexity of design and construction projects due to the following factors: **(Ref. 1)**

- A great selection of materials can be used in design and building construction, each of which has particular characteristics and behaves differently under the same loads.
- Science and technology are moving so fast that it is difficult even for professionals in particular areas of specialization, to stay up to date.

- Regulations, standards, and codes are so diverse and stringent that they limit the design and construction in different ways.
- “There seems to be a demand for the fragmentation of knowledge and for specialization in order to demonstrate expertise”.
- The differences in professional training lead each professional to embrace different things when looking at the same object.

Due to the above factors, it is impossible that one professional can manage the knowledge required to plane, and construct project. Instead, participation of owners, consultants, suppliers, designers, and builders (immediate users of the designer’s product) is required in exchanging knowledge during the pre-construction stage to develop the best design solution.

THE STUDY OBJECT

The aim of the study is to assess constructability practices during design and construction period in the Eastern Province of Saudi Arabia. This will increase the awareness of architecture, Engineers and constructor to the impacts that constructability has on a project’s construction schedule and cost as well as to other possible consequences for the owner.

CHAPTER-2

LITRATURE REVIEW

Modern construction has been characterized as a complex and fragmented process. These characteristics have produced a decrease in the quality and cost efficiency of projects. It has been proven that this problem can be partially overcome by implementing constructability, which is based on the integration of construction knowledge into design as was done in the past. **(Ref. 1)**

The process of integrating constructability information into the early stages of facility planning and design varies significantly. At one end of the spectrum, team members who are construction experts, systematically provide feedback on design and planning alternatives. At the other, owners and designers develop detailed drawings and specifications with little or no consideration for how the facility will be built **(Ref. 7)**. This approach is in sharp contrast to the role of "master builder" assumed by the designers in the past.

According to Fischer & Tatum **(Ref. 6)** construction experts are seldom brought into the design office, and generally too late. We believe that an explicit constructability knowledge base presents opportunities for the delivery of a more constructible project in both fragmented and integrated project delivery processes. In a fragmented process it would enable designers to generate more constructible designs and in an integrated process, e.g. design-built, it would make designers more knowledgeable team members.

In any case, a structured constructability knowledge base that alerts designers to the right knowledge at the right time is necessary. This knowledge should be organized according to variables considered in design and construction planning decisions.

During the construction of any facility, knowledge is gained and lessons are learned. Over time, those involved in construction processes have the opportunity to accumulate a plethora of knowledge, some of which is learned at great human or financial cost. Yet, how much of this hard-earned experience is passed on from project to project and from person to person? Benefits in cost, schedule, quality, and safety could be realized on future projects, if this wealth of constructability knowledge could be effectively harnessed in planning and executing future work. **(Ref. 8)**

This kind of knowledge and lessons learned may have their genesis in any phase of project's life cycle. Similarly, these lessons may be applicable to one or more phase of the project life cycle. Figure 2 shows the three feedback loops from construction life cycle as presented by kartam in his paper. Each loop will be briefly discussed in order to distinguish and highlight the role of constructability from others. **(Ref. 8)**

1. Value Engineering

   Value Engineering has become formalized in the construction industry. It is systematic effort directed at analyzing the functional requirements of system, equipment, facilities, procedure and supplies for the purpose of achieving the essential function at the lowest total cost, consistent with meeting needed performance, reliability, quality, maintainability, aesthetics, safety and fire resistance **(Ref. 5)**. Value Engineering is, traditionally viewed as an intentional reexamination of existing design by the construction contractor or some other designers, usually on an incentive basis. Value engineering is a feed back loop generally confined to the design phase.

2. Constructability

   Constructability loop was defined as the integration of construction knowledge and expertise into all phases of the project. It also recognizes the need to bridge the traditional gab between engineering and construction early in the project if full benefit is to be achieved.

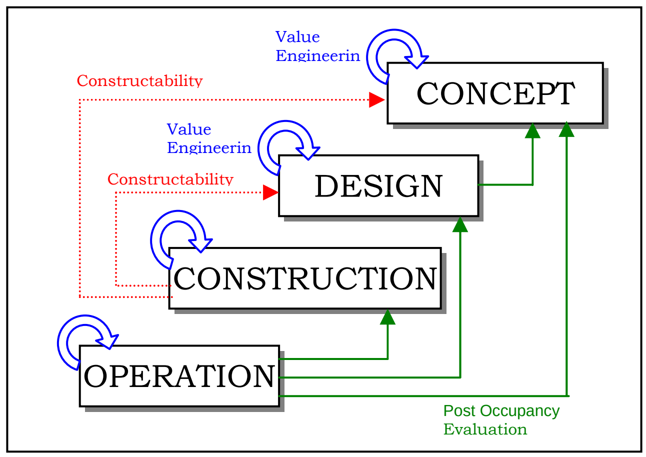

Figure 2. Feedback Channels in Project Life Cycle

3. Post Occupancy Evaluation

   This is another formal feedback loop in the project life cycle in which evaluations occur during the operational and maintenance phase. Many owners to assess the effectiveness of their design and construction programs use this evaluation.

The CII Australia in conjunction with the CII have produced a best practice, how-to-do-it constructability manual. The manual includes (1) Implementation advice on how organizations can establish a constructability program. (2) Flow charting indicating the applicability of the principles of constructability at the various stages of the project life cycle. (3) Executive summaries of the twelve principles of constructability, and (4) Database to record examples of savings from constructability. **(Ref. 3)**

The followings are the *twelve principles* of constructability as per CIIA.

1. Integration – Constructability must be made an integral part of the project plan. The constructability plan has to be included in the overall project's execution plan to provide an integrated, coordinated program **(Ref. 5).** For Geile **(Ref. 4),** constructability planning has become an integral part of capital project management process.

2. Construction knowledge – project planning must actively involve construction knowledge and experience. Ideally, construction expertise would be incorporated from the moment of project inception during the pro-project planning phase of a project, **(Ref. 17).**

3. Team skills – the experience, skills and composition of the project team must be appropriate for the project.

4. Corporate objectives – constructability is enhanced when the project teams gain an understanding of the clients corporate and project objectives.

5. Available resources – the technology of the design solution must be matched with the skills and resources available.

6. External factors – external factors can affect the cost and/or programs of the project.

7. Program – the overall program for the project must be realistic, construction sensitive and have the commitment of the project team.

8. Construction methodology – project design must consider construction methodology.

9. Accessibility – Constructability will be enhanced if the construction accessibility is considered in the design and construction stages of the project.

10. Specifications – project constructability is enhanced when construction efficiency is considered in the specification of the development. On the same token, O'Connor & Hugo **(Ref. 18)**, on their paper "Improving Highway Specification for Constructability" stated that the measure of ease with which a facility can be constructed, is keenly effected by the quality of technical specifications.

11. Construction innovation – the use of innovative techniques during construction will enhance the constructability. Among the publication related to this topic is "Constructability Improvement during Field Operation" by O'Connor & Davis. **(Ref. 15)**

12. Feedback – constructability can be enhanced on similar future project if a post-construction analysis is undertaken by the project team. "Making

Effective Use of Construction Lesson Learned in Project Live Cycle" by Kartam **(Ref. 8)**; and "Constructability Feedback Systems" by Kartam & Flood **(Ref. 19)** are among the publications in this principle.

CONSTRUCTABILITY PROGRAM

Constructability program is the application of a disciplined, systematic optimization of the construction-related aspects of a project during the planning, design, procurement, construction, tests and start-up phases by knowledgeable, experienced construction personnel who are part of a project team. The program's purpose is to enhance the project's overall objectives. These objectives establish the framework for the entire project and must be kept in mind by all projects team members when evaluating each of the various constructability factors. **(Ref. 5)**

An experienced construction personnel need to be involved with the project from the earliest stages to ensure that the construction focus and experience can properly influence the owners, planners and designers, as well as material suppliers. The construction person should be a full-fledged member of the project team, with access to, and participation in, the early decisions that affect the project. This influence includes those considerations that would reduce the overall project schedule, improve overall project quality, operability, maintainability and reliability, and would reduce the overall life-cycle cost.

An effective constructability program beings as early as the conceptual design phase. More savings are realized when implementing such a program in the early phases of project. However, a will designed constructability program should occur throughout all project phases to maximize the overall savings. **(Ref. 9)**

According to Construction Management Committee (CMC) of the ASCE **(Ref. 5)**, Constructability program management who are experienced and knowledgeable construction personnel, can come from the owner staff, a separate construction management firm, or possibly the designer or constructor.

Constructability program *optimizes* the following major project elements from start to finish of the project: **(Ref. 5)**

1. Overall Project Plan
2. Planning and Design
3. Construction-Driven Schedule
4. Costs Estimates
5. Construction and Major Construction Methods

The following paragraphs will discuss each element separately:

1. Overall project plan

A constructability plan has to be included in the overall project execution plan to provide an integrated, coordinated program. The execution plan would cover such things as objectives, schedule, budget, contracting strategy, procurement plan and construction plan.

2. Planning and Design

The plans and specifications describe what is to be built. From conception to final plans and specifications and any subsequent changes, the parts are looked at, probed, compared with alternatives in light of the project objectives by the team, including the knowledgeable, experienced construction persons.

Major considerations include site layout and design configured to enable efficient construction. Within the framework of the project objectives, design factors include simplicity, flexibility, substitutions, labor skill and availability, standardization, specification development construction efficiencies and the effect of adverse weather.

The purpose of constructability is not to cheapen construction or to modify project objectives, nor to dictate designs that are easiest to build, but to ensure that impacts of the design and details on construction is recognized and taken into consideration.

3. Construction-Driven Schedule

Most projects have a fixed completion date. This date might be established by the need to get the facility into operation so it can become a contributing part of the company or to minimize downtime when doing maintenance or retrofit projects. The time available for the project should be divided between the various phases, planning, permitting, design, construction and start-up to optimize the project as a whole rather then considering only one or two phases.

The owner cannot give the designer and the material manufacturer all the time they ask for, then give the remaining time to the construction. This generally result in too little time available at the end that has to be made up by very expensive expediting

The construction Industry Institute (CII) uses the phrase “backward pass” scheduling to characterize the process of starting from the end date and working backward to establish the duration of the various tasks. This is how the date that the design has to be finished by is established. Shortening the construction time is often the most expensive alternative, but even within construction the less skilled trades can be speeded up at lower cost than the more highly skilled ones. In general, it is cheaper to speed up the design process than it is to speed up construction.

So, by having members of the entire project team participate, the time available can be allocated for the best interest of the project.

4. Cost Estimate

Another effort is the development of cost estimates. Establishing cost estimates is the collective responsibility of the project team, i.e., owner designer, or construction manager.

The experienced knowledge construction person needs to participate in developing estimates as the physical facilities to be built are selected. The person can provide special insights with cost impacts of alternatives considering such things as labor, climate, and amount of work in area for contractors.

5. Construction and Major Construction Methods

The construction manager, either the owner, a CM firm, or the general contractor, during the construction phase has to develop a plan to control site-related facilities and operations to facilitates constructability. Included are such things as site facilities (offices, temporary power, water, sewer, security, roads, parking, lay down etc.), a labor plan, materials management, a rigging plan, a construction management organization plan, safety, and a intra-plant access plan to move people, materials and equipment around the site.

These and other considerations listed herein require planning during the early stages of the project.

Major construction methods to be employed have to be identified early, since they may determine how the project must be designed. These methods include the use of construction equipment, labor, effect of weather, and work sequencing.

According to O'Connor **(Ref.15)**, constructability is enhanced when innovative construction methods are utilized. Innovative construction methods refer to methods that are not generally considered common practice across the industry and which are often creative solutions responsive to field challenges.

Having discussed the major project elements above, the following items will introduce some of the *factors that need to be considered* in a constructability program: **(Ref. 5)**

1. Managing the project.
2. Project delivery system.
3. Contracting strategy.
4. Risk management.
5. Labor plan.
6. Access to site.
7. Site layout.
8. Sequence of construction.
9. Availability and procurement of equipment and materials.
10. Prefabrication.
11. Construction management organization plan.
12. Quality management.
13. Material Management.
14. Security.
15. Safety.
16. Operability.
17. Maintainability.

1. Managing the project.

The owner has to recognize the benefits that come from a constructability program and provide the corporate emphasis. The owner's manager of the project has to develop an integrated team that looks at the project as a whole, rather than focusing on each member's functional part. Once the project objectives have been established, each action has to be viewed in light of the overall optimization of these objectives.

A constructability plan should be included as a part of an integrated project execution or implementation plan, which would cover project organization, operating procedures, schedule, budget, overall project strategy, constructing or subcontracting plan, procurement plan, construction plan, and identify potential constraints to successful completion of the project.

2. Project Delivery System.

The method that an owner selects to manage his project has almost an infinite number of variations. However, the main methods, are: construction management, design/build, turnkey, and general constructing. Constructability as a systematic, organized program can be, and is, used in all three methods. The extent to which the owner benefits from and controls the application of good constructability practices depends on the delivery system and the contractual form. The owner has the greatest impact and benefits on constructability under the construction management system, and less under the other systems when lump-sum contracts are used.

3. Contracting Strategy

The selection of the type of contract will affect the way the owner applies a constructability program. For example, on a lump-sum design/build contract, constructability improvements made once the contract is let would ordinarily result in savings to the design/build contractor. If it were a cost plus design/build contract, then it could be structured so that the savings come back to the owner.

Some owners find it useful to separate the construction management from the designer so there is a "second opinion" that can provide insight into the trade-offs and options that might be otherwise hidden or obscured if the designer and the construction manager were the same firm.

The experienced construction person can help formulate a contracting strategy by providing his special knowledge of the contracting climate, i.e. availability of various types and sizes of contractors, suitability of unit price contracts, etc.

4. Risk Management

Risk management refers to the controlling of the many risks associated with building a facility. There is the risk that the windowpanes will fall out, that the facility will not produce the number of megawatts planned or refine oil to the expected quality. There is the risk that the contractor will not be able to obtain the necessary craftsmen or obtain the expected productivity from the craftsmen. There is the risk that the contractor wills not be able to obtain the necessary craftsmen or obtain the expected productivity from the craftsmen. There is the risk that underground conditions are worse than expected. These risks have to be managed.

The responsibility, including financial liability, for these risks should be assigned to and managed by the party best able to control the risk. For example, the construction contractor is in the best position to control the productivity of the craftsmen and to evaluate the availability of craftsmen. The owner or his agent, the designer, is in the best position to evaluate the likelihood of unknown underground conditions that would cost the contractor extra work.

The contracts should be structured to place the risk with the party best able to manage the risk factors. The experienced construction person can contribute to the overall risk management plan through his knowledge of contract construction.

5. Labor Plan

It is important to consider the availability of labor forces of the required skills. In addition, the writer considered whether the project would be built with union or nonunion contractors. Company policy might dictate the use of one type of contractor over another.

During the early stages of the conceptual planning for large projects, the construction member of the team needs to look ahead and project the number of skilled craftsmen that will be needed to build the project. He then needs to determine the amount of other work that will use the same skills during the period to ensure that there will be enough skilled craftsmen for his project. In some cases, it will be necessary to train personnel in the skills that will be needed. In others, it may be necessary to set up camps where personnel from off-site can be brought in. Obviously, these costs have to be considered when establishing the budget for the project.

6. Access to Site

Access to the site, in many cases, fixes the size of equipment that can be brought in. Early study of access routes and possible modes of transportation is needed to determine what modes are available.

The access plan has to consider the availability and limitations of railroads, bridges, and highways. Within cities, traffic patterns can seriously affect access to the project site.

The planner or designer must have this early construction input so he can design the equipment to meet the particular constraints or restrictions. The costs of assembling equipment and facilities are usually less in a manufacturing environment than at a construction site, but transportation costs can be more.

7. Site Layout

The prime concern in sitting a facility is to best accommodate its function and purpose. During conceptual planning, construction input is needed to ensure that construction considerations are fully considered.

In areas where space is limited, the sequence of construction and the layout have to be considered together. Special attention is needed where adjacent facilities and underground lines will affect the construction. Location for heavy cranes can affect the location of high-rise buildings.

In some cases, it might be worthwhile to put in temporary construction rail to position large heavy equipment without double handling. Properly sized laydown and pre-assembly areas must provide optimum access to the final position without crossing other lanes of traffic, Parking for construction craftsmen must be close to the site of their work to minimize inefficiencies. Temporary offices must be located. Roads, water sewer, and power and fire protection are needed during construction. Constructability planning can make possible the construction of temporary facilities that can be incorporated into the permanent one.

8. Sequence of Construction

The experienced construction person on the project team has to provide early input into planning the sequence of construction. It is not always necessary to start at the bottom and build up.

Where tight conditions are critical, the specific order in which parts of the facility have to be built must be established.

- The delivery of complex, engineered owner-purchased equipment often drives the sequences of construction.
- The installation of large, heavy pieces of equipment tends to establish a sequence of construction that permits access of this equipment to its final location.
- The extent that this work has been modularized, preassembled, or prefabricated also controls the sequence of construction.
- The time needed to start test and balance equipment can affect the sequences.

The experienced construction member of the team needs to plan this work to take these types of considerations into account.

9. Availability and Procurement of Equipment and Material.

Some times the owner buy equipment or materials directly, however an experienced construction person has to review the sizes and weights of large, heavy equipment before the owner place the purchase order. This is to ensure that the pieces arrive in the largest packages consistent with access to the site (to minimize expensive field assembly), then access and rig them up to their final position.

The same personnel might be able to provide advice to the project team on alternate materials, so that the materials accomplish the purpose but are more readily available or less expensive.

10. Prefabrication

With the recognition of the advantages of manufacturing components of systems in a controlled environment, prefabricated has become industry standard. Prefabricated buildings account for a large percentage of the one and two story nonresidential buildings built in the United States today. In this case, components, such as the structural steel, wall panels, floor and roof joists, windows, and sometimes the mechanical and electrical portions of the buildings are fabricated under controlled conditions in the shop at high production rates.

11. Construction Management Organization Plan

The constructability program includes a construction management plan outlining the strategy for managing the construction. The source of experienced construction personnel has to be planned. Some companies have an adequate in-house staff they can assign to a particular project. In some cases, it might be necessary to supplement the in-house staff with other individuals to cover areas where a sufficient number of experienced personnel were not available. Many companies will find that they have to bring in outside construction management (CM) organizations.

The plan should outline the organization, responsibilities, procedures, and the type and number of individuals that will be needed, including the supporting staff and facilities. The source of personnel (in-house, temporary hiring or professional construction management firm) for the following functions.

- Constructability planning.
- Construction supervision.
- Contract administration.
- Purchasing and procurement.
- Materials management.
- Accounting.
- Quality and reliability.
- Engineering.
- Schedule-cost.
- Test and start-up.

12. Quality Management

Quality, cost, and scheduling are the three most critical attributes of a construction project, each with its own priority. Quality, in general, is first among these. If the project does not result in facilities that are suitable for the use intended because of a lack of quality, then the project has simply wasted a lot of time and money without accomplishing its objective.

As a part of the initial planning for the project, the project team has to think out those elements of the project that requires special quality control. Although construction personnel routinely require contractors to comply with codes, standards, and good building practices, there are a number of attributes that the owner will consider important enough to receive special quality assurance.

An example of constructability input into quality control is the insistence that the specification for the purchase of the material require the manufacturer to temporarily assemble and match mark large equipment, like metal chimneys or tanks, to give assurance that they will fit when being erected. The project team also has to determine how quality assurance is going to be accomplished, whether through outside laboratories, testing companies, or in-house people or combination thereof.

13. Materials Management

The obtaining of the material and equipment controls the project schedule. This material or equipment must be identified early, with the help of the construction person. Lead times in obtaining equipment must be established and cranked into the schedule.

In addition to tracking the equipment, proper security and maintenance of the material once it is on site and issued to the work crew is considered.

The materials management effort is applicable for materials bought by owners or contractors. The major benefit of proper materials management is the reduced loss in productivity by craft people having the material where it is needed on time. Other benefits include reduction in losses, less warehouse space, reduced surpluses at the end of the project, and less manpower spent in material control.

14. Security

Security for the site has to be thought out during the early stages of the implementation plan. Consideration has to be given to the type and location of materials subject to pilferage, fire protection, the number of workers at the site during construction. The thinking should include such things as the number and location of guard posts, fencing required, the number of people who will work various shifts, and the source and number of guards that will be needed.

15. Safety

The contractors' prior safety performance has to be evaluated. Other indices, like incident rare severity and incident rate frequency, reported as a part of OSHA requirements, also provide guidance to the owner on the likelihood of the contractor performing well in safety. A part of the constructability effort needs to be directed toward obtaining contractors with good safety performance.

As a part of the implementation plan, a safety plan should be developed that takes into account the hazardous aspects of the particular operation. For example, if asbestos removal is considered, or hazardous materials, are to be handled, it is necessary to take into account all the regulatory requirements.

16. Operability

One of the elements of planning for the project is to optimize the functional arrangement and operability of the facility. Instruments, valves and other operating equipment should be situated to facilitate access by the operators. A constructability review will frequently turn up shortcomings as the construction person plans how he will install the equipment. The same analysis of the problems of bringing large pieces of equipment into plants through access ways, hatches, etc., should pieces of equipment into plants through access ways, hatches, etc., should reveal that these same access ways will probably be needed in the further to maintain and replace this equipment.

Constructability planning has to subordinate construction interests with functional requirements in accordance with the overall project objectives. The easiest place to put a piece of heavy equipment into a building from a construction standpoint may be functionally unacceptable to the operator, and it might become necessary to put this equipment in a place where it is very expensive to install.

17. Maintainability

During the course of the constructability program, the importance and priority of maintainability in the scheme of project objectives will dictate trade-offs between costs and quality.

Some elements of maintainability have already been discussed; ensuring there are access aisles left in plants and doorways big enough to accept items that have to be replaced. The person can provide valuable input from his experience in installing this type of equipment.

APPROACHS OF CONSTRUCTABILITY

The recent research conducted by CII concluded that constructability concepts and procedures are not being applied consistently throughout U.S. Construction Industry. The CII investigation found that different approaches are being used by owners to apply construction knowledge and experience to their projects. **(Ref. 10)**

According to Gugel and Russell (Ref. 10), their model will overcome the owners lacked guidance, and will assist them in selecting the appropriate constructability approach to be applied on a given project.

The model shown in the referenced paper presents a rule-based constructability approach selection decision. It is a hierarchy of decision levels has been developed in order to facilitate systematic selection of the constructability approach. Critical variables representing the important characteristics of owner's organization and their projects were used to develop the framework. These data were further analyzed to identify parameters that characterize each variable.

This hierarchy provides a means for subdividing the approach selection problems into a number of sub decisions. Each level contained in the hierarchy (parameter, variable, and characteristic) is explicitly examined and defined as the level represent intermediate decision points in the selection process.

The informal approach: Recognizes the importance of construction inputs, but often limits construction's participation to a more reactive-review role. Procedural guidelines developed for this approach are often limited to design review checklists that focus upon completeness and conformity of contract documents. The lack of procedural guidelines reflects a tendency not to recognize constructability as a unique work process.

The formal project-level approach: Uses procedures designed to ensure effective application of constructability to selected projects. Project-level tracking of lessons learned may be practiced for reference on similar future projects. Benefits and costs of the associated constructability effort may be initially tracked to demonstrate program effectiveness. However, after the benefits of constructability have been demonstrated, benefit/cost data are no longer collected.

Comprehensive tracking approach: Owners use this approach has a database or file of lessons learned. These lessons learned represent ideas implemented on past projects that increased the efficiency of the construction process and, thus, should be replicated on future projects. Additionally, benefit/cost data are routinely collected and used to document the performance of the constructability program.

A detailed explanation of the model can be found in the report (Ref. 10). In addition, the report stated that owners in different projects tested the model, and found the results to be consistent with the constructability approach selected by the owners.

Similarly, Russell, Gugel & Radtke **(ref. 11)** identified three different approaches owners use to implement constructability. The three approaches are using a construction management firm during pre-construction, specialized-formal programming and comprehensive tracking.

The three approaches will be described in the following paragraphs and arranged in increasing formalization, resources required and long-term benefit accrued through documented lessons learned.

1. **Construction management firm during pre-construction:** This approach treat constructability input as a service. Since constructability is viewed as a service rather than a program, benefits and costs attributable to constructability are often considered inseparable from additional services such as value engineering and project planning.

2. **Specialized-formal programming:** It is a project-level program that obtains construction input during the conceptual design phase. Under many circumstances involving this approach, construction personnel assist the owner in establishing the program's philosophy, procedures, and tracking systems. Selected projects are typically limited to application of this approach. Consequentially, formal corporate-level documentation of lessons learned and benefit/cost data are not routinely performed.

3. **Comprehensive tracking:** This approach includes aspects that differentiate it from specialized-formal programming: (1) Corporate commitment, philosophy, and procedures are captured within a corporate implementation manual; (2) lessons learned on each project are documented and entered into a corporate database for future reference and (3) benefit/cost data are recorded. These data are used to document benefits for the purpose of marketing the program and monitor the program's maturity.

The researchers uses the following *six attributes* in order to conduct the comparative analysis of the three approaches: initiation of constructability input, documented benefit/cost data, extent of owner participation formalized procedures, methods to track lessons learned, and designated constructability coordinator(s)

- ***Initiation of constructability input:*** Timing of construction input is a critical consideration. The ability to influence curve presented by CII indicates that the greatest ability to reduce project cost exists during the planning and conceptual design phases of a project. According to CMC **(Ref. 5)**, the maximum benefits to be derived will result when the people with construction knowledge and experience become involved at the very beginning of a project. Figure 3 illustrates how constructability efforts can result in largest payoff during the early stages of a fast track project with overlapping design and construction.

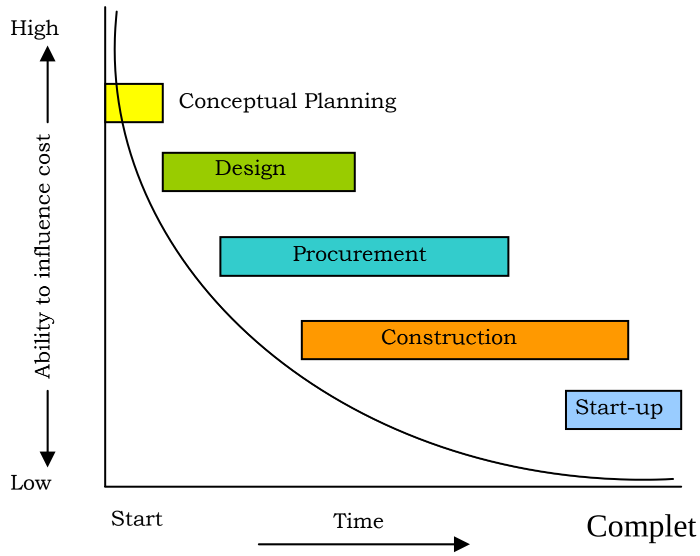

Figure 3. Ability to Influence Final Costs

- ***Documented benefits/cost:*** The benefit/cost data can be an effective means to convince upper management to release funding earlier within the project life cycle. Specific projects have reported 6 – 10% saving of construction costs. **(Ref. 5)**

- ***Extent of owner participation:*** The owner participation varies from one project to another. In one hand, the owner work jointly with the contractor to develop written constructability procedure, developing a formal team-building program and implementing an incentive program that used integrated project goals between the designer and constructor. In the other hand, the owner has only demonstrated low participation in the constructability process by hiring a construction manager to provide constructability input during the pre-detailed design phase.

- ***Formalized Procedures:*** The extent of using documented procedures establishes a formal method of tracking effectiveness. Some may be relay upon experience of CM firm's personnel. Others may use manuals that include description of constructability, identification of roles and responsibilities of team members, an organization chart, and forms for soliciting and tracking ideas and lessons learned.

- ***Method to track lessons learned:*** Beneficial by-products of a constructability program are the lessons learned captured during the process. If lessons learned are not documented, then the benefits are limited for use on future projects. However, a computerized database system that categorized and store lessons learned can facilitate the use of lessons learned for future projects.

- ***Designated Constructability Coordinator:*** Designation of a project constructability coordinator assist in program implementation and monitoring. The number of coordinators and time commitment to a project often depends on project total cost, number of major design consultants involved, and the distance between the project site and participants.

The writers believe that the owner organization and project characteristics are very important to be considered prior selecting a constructability approach. This will enable the owner to determine the most appropriate approach to implement.

CONSTRUCTABILITY PROGRAM IMPLEMENTATION

The key to the successful implementation of constructability is in having effective communications between members of the project team.

While a design and build form of procurement can streamline the lines of communication, the team members themselves must be committed to be constructability concept if a successful outcome is to be achieved. **(Ref. 3)**

According Russell **(Ref. 12)**, the owner commitments toward implementing constructability and developing a project organization structure are the main elements that contribute to the program success.

The challenge in having an effective constructability program is the need to integrate engineering and construction efforts so that the professional skills and experience of both have the forum and procedures that allow them to optimize the planning, design, procurement, construction, and start up phases of a project as whole. **(Ref. 5)**

Constructability implementation benefits can be described as quantitative or qualitative **(Ref. 1), (Ref. 11)**.

- *Quantitative:* Quantifying benefits and costs attributable to constructability requires comparison of the traditional design method to the recommended constructability approach. The economic value depends on numerous factors such as project management capabilities, skill level of craftsman, equipment use, and weather condition.

- *Qualitative:* Safety improvement and zero lost time accidents are an indication of the qualitative benefits of constructability implementation.

The improvements in the schedule, in the quality, in the overall operability, in the maintainability, and in the cost are the real payoffs.
Among the publications related to the benefits of constructability implementation are “Documented Constructability Saving for Petrochemical Facility Expansion” by Russell **(Ref. 12)**; “Constructability For Piping

Automation" by Deborah **(Ref. 13)**; and "Constructability Improvement of Steal Silos During Field Operation" by Elazouni **(Ref. 14)**.

Constructability concepts can be either directed toward owners and designers or constructors. For example, "Construction Improvement During field Operations" by O'Connor & Davis **(Ref. 15)** is directed toward constructor. It states that constructability issues still existing during field operations, thus constructor can still reap constructability benefits from their actions alone.

Whereas "Improving Constructability During Design Phase" by Glavinich **(Ref. 21)** is directed toward designers. The writer stated that, it is the A/E's responsibility to develop a design when implemented by the builder, produces a project that meets the owners needs and expectations. The A/E must be aware of its responsibility for coordinating and integrating all the various systems and components that make up the project. Failure to assume responsibility for project's constructability can result in needless delays and additional cost that eventually have to be absorbed by the owner.

CONSTRUCTABILITY IMPACTS

The effect or impacts of constructability improvements on projects in another way of gaining insight into the constructability improvement process.

According to O'Connor **(Ref. 20)**, constructability improvement impacts are most often modifications in resources utilization and usually involve a trade off between engineering and construction resources. Constructability improvements seldom benefit a project without requiring some additional effort to be expended in some manner.

The impacts from constructability improvement may effect either engineering resources or construction resources or both. The effect on resources is either an increased need or demand or decreased need or demand. The impacts may also be desirable or undesirable based on their cost significance.

According to O'Connor the author, the following five basic construction resources can be used in analyzing the impacts (1) Construction manpower; (2) Materials/temporary requirements; (3) Equipment/tools; (4) information; and (5) time/space. In addition he also considered the following six impacts on engineering: (1) required design effort; (2) required procurement effort; (3) communication needs within engineering; (4) engineer–constructor communication needs; (5) engineer–vendor communication needs; (6) owner–constructor communication needs. **(Ref. 20)**

The following are some of the finding presented by the author in his paper:

1. The likelihood of delays maybe decreased most effectively by increasing engineering information availability and understandability. This will require additional engineering effort and may necessitate additional communication between engineering and construction.

2. The amount of required construction manpower maybe most effectively decreased by simplifying the design, combining design elements, and seeking optimal construction systems, such as modularization. Of course additional engineering effort may be required.

3. Construction activity duration may also be most effectively decreased by seeking the use of optimal construction systems. This will require additional engineering effort. Increased equipment usage and additional field supervision planning efforts should also be expected.

It is interesting to note that these observations all identify a need for some sort of designer-initiated constructability improvement. This reiterates the importance of the designer's role in ensuring economical construction.

BARRIERS TO CONSTRUCTABILITY

A barrier to constructability is any significant inhibitor that prevents effective implementation of the constructability program. Barriers to successful implementation of constructability programs are present in almost all organizations at both corporate and project levels.

According to O'Connor & Miller **(Ref. 22)**, initial efforts should focus on determining the presence and relative significance of constructability barriers. Recognition of barriers to constructability has been identified as one of 15 significant parameters critical for effective constructability implementation. (O'Connor and Miller 1994a).

The following are the seven most common barriers identified by an earlier research:

1. Complacency with status quo.
2. Reluctance to invest additional money and effort in early project stages.
3. Limitations of lump sum competitive contracting.
4. Lack of construction experience in the design organization.
5. Designer's perception that "we do it."
6. Lack of mutual respect between designers and constructors.

7. Construction input is requested too late to be of value.

In addition, Uhlik & Lores in their paper "Assessment of Constructability Practice Among General Contractor" **(Ref. 1)**, listed the most significant barriers identified by the contractors. The barriers were the following: design without construction input is the traditional way of contracting; designers' lack of construction experience and construction technologies knowledge; and the concept is unknown by the owner.

The Construction Management Committee (CMC) in the paper "Constructability and Constructability Program" **(Ref. 5),** also recognized some other barriers to acceptance of constructability efforts include the following.

1. Resistance by the designers, who view such efforts as an intrusion.
2. Shortages of qualified personnel.
3. Training in constructability.
4. Incentives, priorities, costs.

Barriers Breakers

Treatment of constructability barriers should involve a three-phase cycle: identification, mitigation, and review. Once barriers to constructability are identified within an organization or a project team, they must be dealt with in a deliberate and determined manner. **(Ref. 22)**

The authors conclude that such barriers may be mitigated or overcome with certain tactics, known as "barrier breakers." In addressing the problem such breakers should be both effective in combating the barriers and should be implementable or relatively easy to apply.

Researchers proposed a preliminary listing of barrier breakers for each of the seven most common barriers to constructability previously identified. Suggested barrier breakers were based on both the characteristics of the barriers and on the knowledge and experience of the researchers.

Table 1 below summarizes the finding of the researchers, which includes the 15 distinct barrier breakers with at least one for each the seven most common barriers mentioned earlier.

Barrier	Recommended Breakers	Where Effective		Type of Breaker			
		Corporate	Project	Cultural	Procedural	Awareness	Incentive
1. Complacency with status quo	▪ Designate a strong program champion.	X		X		X	
2. Reluctance to invest additional money and effort in early project stages.	▪ Promote the attitude that constructability should be viewed as an incentive 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 constructors who offer constructability input in return for the opportunity to be on the short list of bidders.		X		X		
4. Lack of construction experience in the 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 practice to elevate the visibility of construction issues.	X		X		X	
5. Designer's perception 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 designers 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 project team focused on common objectives and accepted procedures rather than personalities.		X	X	X		
7. Construction input is 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

Table 1. Characteristics of Effective Barriers Breakers

CHAPTER 3

RESEARCH METHODOLOGY

The questionnaires were generated from various literature reviews and will be distributed among design offices and construction companies in the eastern part of Saudi Arabia.

The questionnaire consists of two parts. The first part will be forwarded to the design offices and the second part for the general contractors. In the case of design offices, the questionnaire will be given to the design engineers and managers. Whereas in the contractors case, the questionnaires will be distributed among Foremen, Site Engineers and Project Managers.

QUESTIONNAIRS:

Part 1. Design Offices

1. Information about the person filling the questionnaire:

   Name: ___________________

   Position:

   Company:

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

   - ❑ Private (% of total volume).
   - ❑ Public (% of total volume).

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

   - ❑ General building (Commercial and institutional).
   - ❑ Civil (Heavy and highway)
   - ❑ Industrial
   - ❑ Residential
   - ❑ Other (Explain __________.

4. Please select the range of your annual volume of design work.

- ❑ Less than SR. 5,000,000.
- ❑ Between SR. 5,000,000 and SR. 10,000,000.
- ❑ Between SR. 10,000,000 and SR. 20,000,000.
- ❑ More than SR. 20,000,000.

5. Under what type of contract do you perform design work?

- ❑ Design only (% of total volume).
- ❑ Design and Management (% of total volume).

6. Constructability has been defined as "*the integration of construction knowledge into the planning, design procurement and construction phase of a project in order to increase the success of the execution of the works*". Have you heard this item before?

- ❑ Yes.
- ❑ No.

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

- ❑ Advice owner in the establishment of the project goals and objectives.
- ❑ Execution of feasibility studies and advice in the selection of the site.
- ❑ Advice 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.

8. Please select the activities your organization performs during *design phase* of a project; check all that apply.

- ❑ Analysis of the design to enable efficient construction (ex. 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.
- ❑ Advice design team about sources of materials and engineered equipment.
- ❑ Analysis/revision of the specifications to allow easy construction.
- ❑ No participation.

9. Has your organization participated in 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 works.
- ❑ Innovative use of construction equipment and tools (ex. mobile hydraulic, man-lifts in line of scaffolding).
- ❑ Innovative use of material (ex. fiber reinforced concrete).
- ❑ Capture and transfer of lesson learned to future projects.

10. Considering questions 7 – 10, does your organization implement any of the following actions; 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 savings.
- ❑ Constructability is included in contract documents.
- ❑ None of the above.
- ❑ All of the above (organized, formal constructability program).

11. How often do you participate by obtaining construction knowledge during the design phase of projects?

- ❑ Commonly
- ❑ Seldom
- ❑ Never

12. Based on your experience please select from the following list the barriers to constructability; check all that apply.

- ❑ The concept is unknown by the owner.
- ❑ Owners do not care about constructability in the contracting strategy.
- ❑ Design without construction input-bid construction is the traditional form of contracting.
- ❑ Owners do not choose constructability in their projects.
- ❑ The concept is unknown by designers.
- ❑ Designers lack of construction experience and construction technologies knowledge.
- ❑ The concept is unknown by contractors.
- ❑ Reluctance of field personnel to offer pre-construction advice.
- ❑ There are no proven benefits of constructability.

- ❑ Other (explain).

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

    - ❑ Complex projects.
    - ❑ Small Projects
    - ❑ Large Projects
    - ❑ All Projects.
    - ❑ Certain type of Projects (List ________).

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

    - ❑ Yes
    - ❑ No
    - ❑ Sometimes (Explain ____________)

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

    - ❑ Yes
    - ❑ No
    - ❑ Sometimes (Explain ____________)

Part 2. Contractors

1. Information about the person filling the questionnaire:

   Name: __________________

   Position:

   Company:

2. What best describes your type of organization:

   - ❑ General Contractor
   - ❑ Design Contractor
   - ❑ Subcontractor
   - ❑ Other

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

   - ❑ Private (% of total volume).
   - ❑ Public (% of total volume).

4. Check all that apply.

   - ❑ General building (Commercial and institutional).
   - ❑ Civil (Heavy and highway)
   - ❑ Industrial
   - ❑ Residential
   - ❑ Other (Explain __________.

5. Please select the range of your annual volume of work.

   - ❑ Less than SR. 10,000,000.
   - ❑ Between SR. 10,000,000 and SR. 20,000,000.
   - ❑ Between SR. 20,000,000 and SR. 50,000,000.
   - ❑ More than SR. 50,000,000.

6. Under what type of contract do you perform work?

   - ❑ Traditional (design-bid-construction) (% of total volume).
   - ❑ Design build (% of total volume).
   - ❑ Construction Management (% of total volume).

7. Constructability has been defined as “*the integration of construction knowledge into the planning, design procurement and construction phase of a project in order to increase the success of the execution of the works*”. Have you heard this item before?

- ❑ Yes.
- ❑ No.

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

- ❑ Advice owner in the establishment of the project goals and objectives.
- ❑ Execution of feasibility studies and advice in the selection of the site.
- ❑ Advice 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.

9. 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 (ex. 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.
- ❑ Advice design team about sources of materials and engineered equipment.
- ❑ Analysis/revision of the specifications to allow easy construction.
- ❑ No participation.

10. 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 works.
- ❑ Innovative use of construction equipment and tools (ex. mobile hydraulic, man-lifts in line of scaffolding).
- ❑ Innovative use of material (ex. fiber reinforced concrete).
- ❑ Capture and transfer of lesson learned to future projects.

11. Considering questions 7 – 10, does your organization implement any of the following actions; 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 savings.
- ❑ Constructability is included in contract documents.
- ❑ None of the above.
- ❑ All of the above (organized, formal constructability program).

12. How often do you participate by inserting construction knowledge during the pre-construction phase of projects?

- ❑ Commonly
- ❑ Seldom
- ❑ Never

13. Based on your experience please select from the following list the barriers to constructability; check all that apply.

- ❑ The concept is unknown by the owner.
- ❑ Owners do not care about constructability in the contracting strategy.
- ❑ Design without construction input-bid construction is the traditional form of contracting.
- ❑ Owners do not choose constructability in their projects.
- ❑ The concept is unknown by designers.
- ❑ Designers lack of construction experience and construction technologies knowledge.
- ❑ The concept is unknown by contractors.
- ❑ Reluctance of field personnel to offer pre-construction advice.
- ❑ There are no proven benefits of constructability.
- ❑ Other (explain).

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

- ❑ Complex projects.
- ❑ Small Projects
- ❑ Large Projects
- ❑ All Projects.
- ❑ Certain type of Projects (List ________).

15. Using the traditional process (design without construction input-bid construction), 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 avoid during design phase.
- ❑ Unrealistic schedule.

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

- ❑ Yes
- ❑ No
- ❑ Sometimes (Explain ____________)

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

- ❑ Yes
- ❑ No
- ❑ Sometimes (Explain ____________)

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