# Evaluation of Design Construction Interface in Construction Industry

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## Abstract

*The study focuses on the causes of discrepancies at the design and construction interface. The subject is treated in two parts. The first part covers a review of literature discussing the subject of design construction interface issues. The review which includes major periodicals, research reports, and some text books, is summarized into four parts; definition of interface, construction, the cost and pricing aspects, and the management and administration of change orders. The information and recommendations made in this part were used to develop and establish direction for the second part of the study. Initially pilot study was carried out based on survey questionnaire developed through literature review. Pilot study encircles three large building projects, eventually the validity of tentative questionnaire was evaluated and final questionnaire for survey at macro perspective was organized. Responses from (31) thirty one consultants and thirty contractors were analyzed through statistical analysis tool, the results indicate that lack of coordination, insufficient working drawing details, involvement of designer as consultant, involvement of contractor as consultant and participants' honest wrong beliefs are considered as most important origins of professional dissonances on project design and construction interfaces. Whereas, the project management as individual professional service, nationality of professional firms and involvement of contractor in design phases are interestingly revealed as least important origins of dissonances between professionals on project design and construction interfaces in large building projects. The cause and effect diagram which is represented as part of research work helps to pin point the root cause of the problem of design construction interface issues.*

## 1. Introduction

Transforming an idea into reality, whether a building, a heavy civil or an industrial project, requires input from a wide range of members of the project team. This team is normally composed of different organizations, each with a wide range of administrative units, with their own organisational culture, individual project objectives, and technical approaches to the project. The owner team includes members from the project development, project management, operations and maintenance sub organizations. The design team includes representatives from all the technical design disciplines involved in the project. Finally, the construction team, which includes general and/or prime contractors, subcontractors, and vendors and suppliers. The traditional approach in building construction projects precludes effective integration of all these parties within the project team At different stages of the facility development process, individuals from these organizations need to communicate with each other; exchange technical and management data and information (e.g., plans and specifications, change requests and orders, as-built drawings); analyze and comment on this information to resolve issues and make decisions; and when necessary, negotiate to reach agreements among all parties. In many projects these are complex tasks, which are made even more difficult by the problems created by the differences between the intrinsic nature of design, and of the intrinsic nature of construction operations. The quality of the total project team decision-making and implementation process is a direct result of the availability, accessibility and reliability of information, combined with an ability to visualize what other parties communicate. The design construction interface is especially important since the quality of construction facility many times is a function of the quality of the information generated during the planning and design phases, and especially of the degree of construction input to the design process.

Eliminating the dissonances which exist in peak intensity, enables the projects to be completed

rather successfully. Discords on interfaces of concerned authorities either result in delay in project duration, or compromise on quality or increase in cost. Considering these prominent issues which ultimately shape up any construction project, augments the need to have better comprehensive solutions of those discords and to coordinate on the interfaces. The most important aspect is to figure out the most potential interface issues that occur in project life cycle. These potential areas are the actual causes which linger the project progress substantially. This research work is to assess the professional interfaces between design and construction and to identify causes of discrepancies at the design and construction interface and finally to provide suggested solutions and recommendations to trounce the interface dissonances. This research study would cover all construction projects.

## 2. Need for the study

It is in the design stage where the requirements of the client are identified and the constructive aspects and the standards of quality are defined through procedures, drawings and technical specifications. Currently, the work within the design stage is split into several temporary sequences, and it is delivered to different specialists for its execution. In building projects, first the owner selects the architects who prepare the architectural designs and specifications, and then the structural design and other specialty designs are developed. Generally, the construction stage is the responsibility of a contractor selected by the owner.

The problems of this work sequence have been discussed for many years. The main problems that have been detected are the little interaction among design and construction and among the specialists, this situation compels the succeeding phases to work on incomplete designs. The consequences are suboptimal solutions, lack of constructability and a great number of change orders. Interface issues leads to low productivity, poor quality, waste, delays, claims, and cost overruns, these issues have significantly lowered overall project performance and implicitly hindered industrialization of construction. This study will assist both owners and contractors to plan effectively before starting a project and during the design phase to minimize chances for design construction interface issues in any construction projects.

## 3. Literature Review

**Assaf and Al-Hammad (1988)** revealed that the construction industry in Saudi Arabia employed 15% of the total labour force and used 19% of the total energy consumed in the country. As projects were being constructed, the construction industry faced many problems such as a shortage of manpower, inadequate infrastructure and a lack of sophisticated technology. Most of the design inputs were completed abroad where the designer does not have the statistical data or enough knowledge of the environmental, social and cultural factors which could affect building projects.

**Jorge A. Vanegas and Augusto Opdenbosch (1995)** described a methodology for simulating construction operations, which strengthens the design/ construction interface. The methodology enables both designers and constructors to run interactive and real-time simulation of construction operations in a virtual environment, thus bringing the user closer to the real world than ever before during the design phase. This environment also enables users to identify problems visually during the planning or design phases of a project, and solve them prior to actual construction of the facility Simulating the construction of a building using this methodology consists of five steps: First, the building must be designed using Computer Aided Design and Assembly (CADA). Second, the simulation is run with all the relevant elements in the environment. Next, the virtual equipment is chosen. Then the assembly process is started. Finally, machines are changed, added, and deleted, cameras are switched, and the user turns to Virtual Reality. After the interaction with the building model, the user can choose to go back to CADA, make changes to the building design, and repeat the entire process.

**Songer and Molenaar (1996)** expressed the historical proof of design-construction interfaces, and articulated that design-construction interface has been traced to ancient Mesopotamia, where the Code of Hummurabi (1800 BC) fixed absolute accountability upon master builders for both design and construction. In Classical Greece, great temples, public buildings, and civil works were both designed and built by master builders. Enduring structures such as the Perthenon and Theater of Dionysis are testimony to this master builder process.

**Mendelsohn (1997)** observed that probably 75% of the problems encountered on site were generated at the design phase. This is not to say that contractors do not create a slew of problems of their own but that these problems were often compounded by inherent design flaws. If one were to seriously consider ways to reduce problems on site, an obvious place to begin with is to focus on what the project team can do to eliminate these problems at the design phase.

**Roy Mendelsohn (1997)** articulated that a Designer has a conceptual mind and a contractor has a concrete mind. One relates to intangibles and the other relates to tangibles.

Focusing on interfaces, **Fredrickson (1998)** noted that each project, client and design-construct delivery team has unique design needs. There is no "one size fits all" way of identifying the right design approach to a particular project. However, the guidelines adopted from previous projects can help to assist a project delivery team to determine how the design should be handled that can greatly improve the project's chances of success and hence objective of the project can be achieved.

**Luis F. Alarcón and Daniel A. Mardones (1998)** studied the performance of the design-construction interface. This study comprises interviews with experts, data collection from several projects and design and implementation of improvement tools. Problems that affect the design-construction interface were identified through data from four project sites. A review of the most frequent design defects found during the construction phase in four building projects allowed the researchers to design several tools to prevent the occurrence of these defects. QFD (Quality Functional Deployment) was used to identify the most effective tools and to set priorities for implementation. A methodology to improve design quality to adapt with the construction was suggested. The 'House of Quality' was used to select the technical responses that would be the most effective method to avoid the defects in the designs detected in the exploratory study. The main problems affecting design – construction interface in his paper are were identified as Poor Design Quality, Lack of Design Standards, Lack of Constructability.

**Ballard and Koskela (1998)** studied and derived new concepts and agenda for design management. It is suggested that Design processes can be conceived in at least three different ways, as a process of converting inputs to outputs, as a flow of materials and information through time and space and as a process of generating value for customers. The concept of concurrent engineering which is a conceptualization of the product development process found in the world of product design and manufacturing has been explained. Although there is some range of meanings, generally "concurrent" refers to the simultaneous or integrated consideration of multiple design criteria expressing the needs or wants of multiple stakeholders.

## 4. Research Methodology

Interface Management is defined as the management of communication, coordination, and responsibility across a common boundary between two organizations, phases, or physical entities which are independent. It is managing the problems that often occur among people, departments, and disciplines rather than within the project team itself. Each member of the project team plays a key role in the project, the owner team sets the project's objectives, which drive design and construction, with all disciplines being subordinate to the owner's goals and needs and the design team, including architectural, structural, mechanical, electrical and other designers, control most of the planning phase and the construction team controls the execution of the project. However, it is very common for the construction team not to be involved at all in the planning phase but still to assume the responsibility for carrying out a project successfully to completion when the design arrives for execution. This lack of an integrated approach often causes adversarial relations between project participants, increases the opportunity for things to go wrong, and often misses important opportunities for improved project performance. A second obstacle for a stronger design construction interface is that each phase of the overall process (planning, design, construction, startup, and operation) contains a complex system of relations, interdependencies, and data exchange between its principal activities.

Most of the researchers use tools such as factor analysis techniques, cause and effect analysis, work breakdown structure concept are also used to improve design construction interface issues. This research involves evaluation of the interface between design and construction and also identifies the potential causes of discrepancies at the interface between design and construction. Through a detailed review of literature and pilot studies various causes dominating design construction interface issues have been identified and based on those causes a questionnaire has been prepared to analyze the causes of discrepancy based on the response from design consultants and contractors. The output of this survey has been developed a model to simulate the design construction interface issues and to identify solutions for this problem.

## 5. Pilot Study

Through the Pilot Study the following causes for discrepancy in design and construction interface has been identified. Based on the literature review carried out and discussion with practicing engineers and consultants the survey Questionnaire has been prepared. Survey Questionnaire is shown in Appendix A.

The major causes for discrepancy in design and construction interface identified from Pilot studies are as follows

*1. Delay in Preparing Construction documents*

Construction documents are important for timely project commencement and accomplishment. Delay in their preparation can affect procurement and scheduling activities. Client may take time to fix the sub contractor for the work and also the contract documents bound to legal aspects and involves approval procedures hence preparing contract documents may be delayed sometimes which inturn affects design construction interface

*2. Lack of Data*

A lack of data can result in misinterpretation of the actual requirements of a project. Considering all the relevant data and information in the design can help participants understand the actual situation. Where there is insufficient data, designers are compelled to develop designs based on their own perceptions, which clients' may not deserve or which may result in rework.

*3. Communication gap between designer and contractor*

Communication is vital in a multi-player environment like construction. Strong and incessant communication is necessary for optimum coordination. Through better communication, both the constructor and designer can overcome various problems which occur at different phases of a project.

*4. Lack of specialty construction manager*

The construction manager is the professional who manages the construction phase. The construction manager carries out the construction phase in an organized way to eliminate the risks of delays and other problems. Consequently, inexperienced and unskilled manager may increase interface problems between the contractor and the designer.

*5. Procurement Delays*

Delays in the procurement of construction materials or equipments have various adverse affects on other processes in the construction cycle. Occasionally, the procurement delay may cause an entire change or replacement of originally specified materials or equipment for the project. Therefore it may cause a need for project activities to be reworked.

*6. Materials Approval*

This is a process in which the contractor gets approval from the consultant before using the material. This may cause discrepancies if the process or paperwork involved is long and the contractor needs to interrupt the construction process to get the materials approved.

*7. Time Limitation in Design phase*

Time limitation may occasionally force the designer to wrap up the necessary design works at a lower quality. If time is not adequate, the design cannot be developed in proper way. This may cause misunderstandings between professionals.

*8. Lack of Human Resources in Design Firm*

Quality work and timely schedule would be affected in the absence of adequate manpower support. A lack of human resources can lead to discrepancies between the designer and the contractor. This is because a delay in the design process or a poorly executed design can eventually affect a wide range of jobs in the supply chain.

*9. Design Errors*

Design errors can affect a project adversely depending on the timing of the occurrence of the errors. Even though it is impossible to create a perfectly error free design it can definitely be minimised. Design errors which are not rectified during the design phase, will eventually appear in the construction phase where the impact can be more severe than in the design phase.

*10. Change orders*

Changes are inevitable in any construction project. Needs of the owner may change in the course of design or construction, market conditions may

impose changes to the parameters of the project, and technological developments may alter the design and the choice of the engineer. The engineer's review of the design may bring about changes to improve or optimize the design and hence the operation of the project. Further, errors and omissions in engineering or construction may force a change.

## 6. Survey Questionnaire

The questionnaire design was developed while considering the vital objective of the study. Pilot study and meetings with professionals of the construction industry were carried out to identify the appropriate questionnaire stipulated and to convey them in unambiguous format. Special considerations were taken care off in phrasing the questions in simple and comprehensive language that would be conveniently comprehended by the respondents. Sequencing of the questions was done carefully in order to avoid boredom, stress, fatigue, etc., The questionnaire comprises of instructions to respondents defining the key terms in the study and providing respondents with instructions on completing the questionnaire and also it contains general information about the respondents such as contact address, company size, type etc

## 7. Results and Discussions

The analysis of the data obtained from the questionnaires received and conclusion drawn are presented in this chapter. The first section discusses the results on general information and the prevailing construction industry characteristics, that includes type of firms and designation level of professionals etc., these features would provide comprehensive manifestation about the perception of the particular participants' about the actual origin of professional dissonances on design – construction interfaces. In the second section, data on professional dissonances origins is analyzed. The result of analysis is presented in the form of mean, confidence level, median, maximum minimum, variance and standard deviation as well as Standard error. Each professional dissonances origin is ranked according to the mean value as the representation of the responses of respondents.

The responses on the origin of potential dissonance between the professionals are analyzed into segments. The first segment contains the responses from the designers only. The second segment contains the same procedure for the responses from the contractors.

*1. Effect of Incomplete Plans*

If the specifications or plans are incomplete, or unclear, it will create interpretation problems which will affect the quality of the project. This creates discrepancies at the design and construction interface. Figure1 shows the response of design consultants on this particular factor and hence according to their response the effect of incomplete plans remains least important origin for dissonance, while figure 2 represents the response of contractors in which it can be inferred that the effect of incomplete plans remains most important cause for design construction interface issues according to contractors

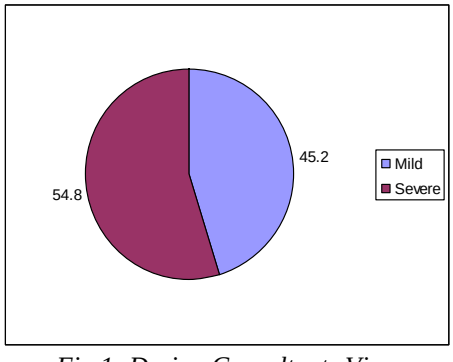


*Fig 1: Design Consultants View*

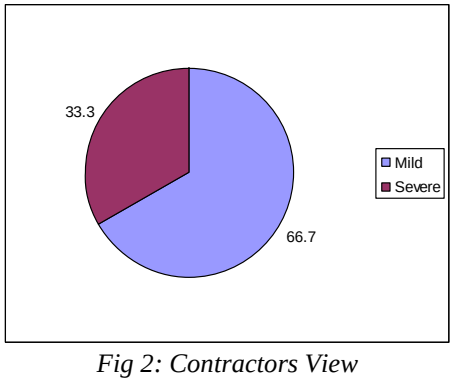


*Fig 2: Contractors View*

*2. Obstinate nature of project participants*

Obstinate nature of project participants may results in poor performance hence it will affect the coordination and results. Figure 3 and 4 show the response of design consultants and contractor on this particular factor and

it can seen that hence according to their response this factor is least important origin for dissonances.

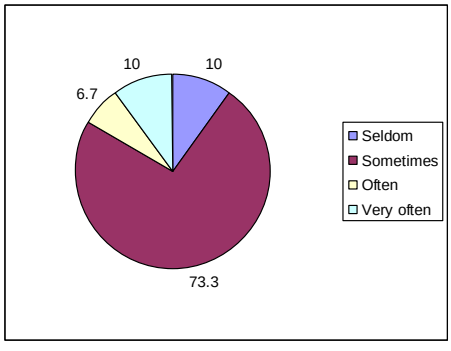


*Fig 3: Design Consultants View*

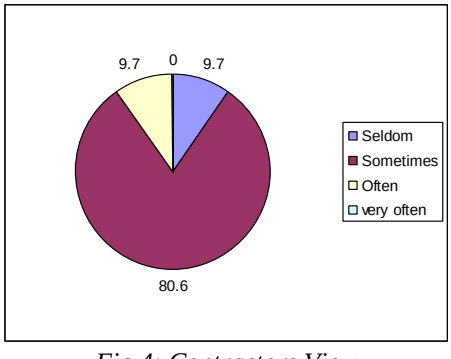


*Fig 4: Contractors View*

### *3. Lack of Data*

A lack of data will result in misinterpretation of the actual requirements of a project. Considering all the relevant data and information in the design can help participants understand the actual situation. Where there is insufficient data, designers are compelled to develop designs based on their own perceptions, which clients' may not deserve. Figure 5 and 6 shows the response of design consultants and contractors on this particular factor and hence according to their response they have experienced this particular factor in most of their previous projects.

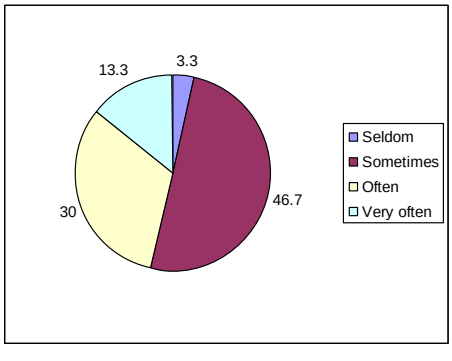


*Fig5: Design Consultants View*

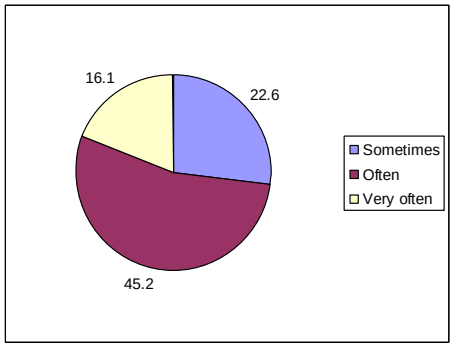


*Fig 6: Contractors View*

### *4. Influence of Build ability*

Build ability is defined as "the extent to which the design of a building facilitates ease of construction, subject to the overall requirements for the completed building". From response of contractor and design consultants it is identified that influence of build ability affects design construction interface and contractor and design consultants perception on this factor is represented in figure 7 and 8

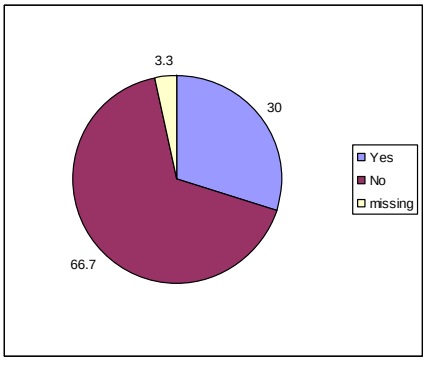


*Fig7: Design Consultants View*

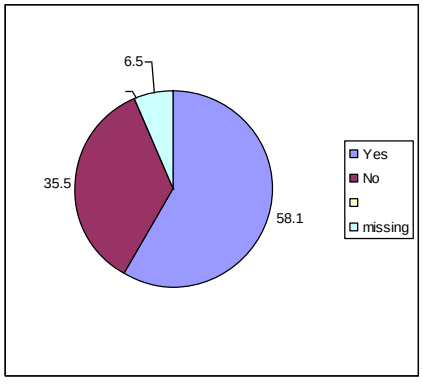


*Fig 8: Contractors View*

*5. Lack of Human Resources in Design Firm*

Quality work and timely schedule would be affected in the absence of adequate manpower support. A lack of human resources can lead to discrepancies between the designer and the contractor. This is because a delay in the design process or a poorly executed design can eventually affect a whole range of jobs in the supply chain. Figures 9 and 10 represents the perception of design consultants and contractors on this factor.

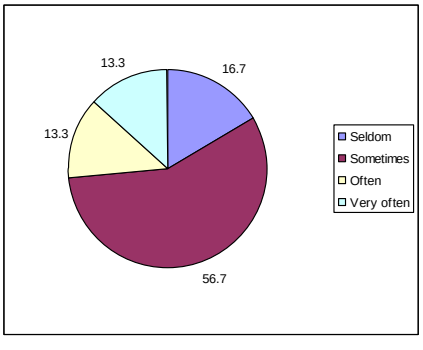


*Fig 9: Design Consultants View*

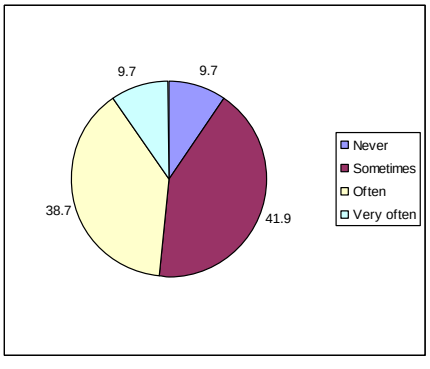


*Fig 10: Contractors View*

*6. Insufficient Work Drawing Details*

Working drawing details are the graphical forms of communication between the designer and the contractor. To convey a complete concept of the project design, the working drawings must be clear and concise. Insufficient working drawing details causes discrepancies at the design and construction interface. From the contractors response it is found that most of design construction interface issues arise due to insufficient working drawing details as represented in figure 11 while Figure 12 represents the designers perception on this particular cause.

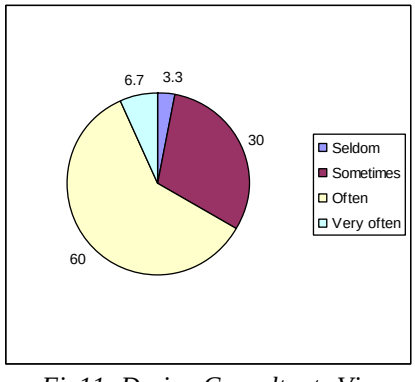


*Fig11: Design Consultants View*

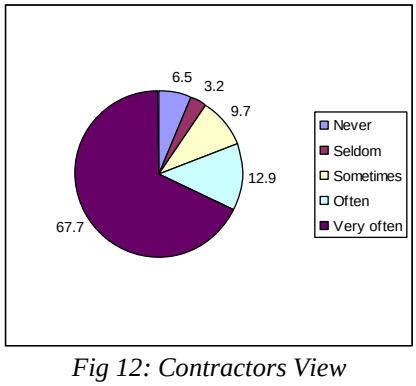


*Fig 12: Contractors View*

*6. Change order*

A change order is a written order to the contractor, signed by the owner, and issued after execution of the contract, authorizing a change in the work or an adjustment in the contract sum or the contract time. Changes in drawings and contract documents usually lead to change in contract price or contract schedule. Changes also increase the possibility of contractual disputes. A figure 13 and 14 represents designer and contractors perception on change order in design construction interface

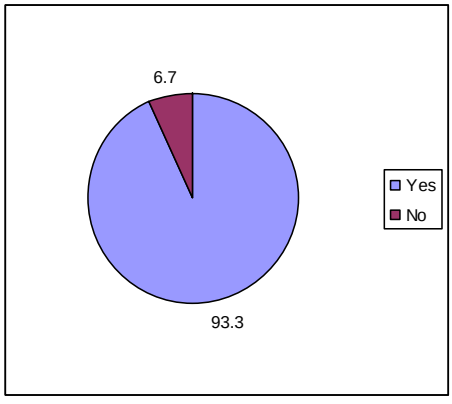


*Fig13: Design Consultants View*

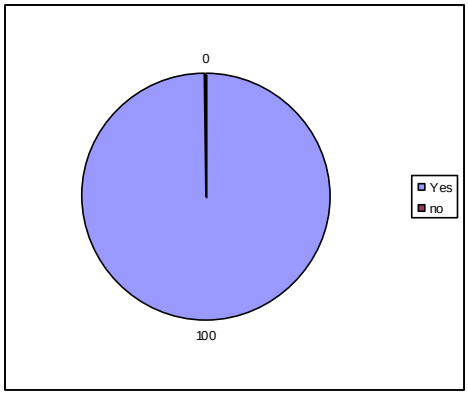


*Fig 14: Contractors View*



## APPENDIX A

### *Survey Questionnaire*

### *Questionnaire (design consultant)*

Some of the causes for discrepancy in design construction interface are formed as questions for your response to evaluate their effects and severity.

Q_1) Time limitation in design phase?

Very Often [ ]

Often [ ]

Sometimes [ ]

Seldom [ ]

Never [ ]

Q_2) Effect of incomplete and inadequate plans and specification in design – construction interface?

Severe [ ]

Mild [ ]

Nil [ ]

Q_3) Obstinate nature of participants Encountered?

Very Often [ ]

Often [ ]

Sometimes [ ]

Seldom [ ]

Never [ ]

Q_4a) Do the Drawings lack details ,specifications, etc.,

a. yes b. no

Q_4b) If yes, Mention it's inference in your past projects?

Very Often [ ]

Often [ ]

Sometimes [ ]

Seldom [ ]

Never [ ]

Q_5a) Do you think lack of coordination between design team and project management team affects the interface between design and construction?

a. Yes b. No

Q_5b) If yes, mention suitable technique to improve coordination between construction

team

a. Web based project management
b. Implementation of project centre
c. Other _____

Q_6) Contractor's lack of comprehension of Drawings details and specifications provided by you?

Very Often [ ]

Often [ ]

Sometimes [ ]

Seldom [ ]

Never [ ]

Q_7a) Influence of Buildability?

a. Yes b. No

Q_7b) If Yes, what is your opinion about influence of buildability

_____
_____

Q_8) Lack of human resources in your firm?

Very Often [ ]

Often [ ]

Sometimes [ ]

Seldom [ ]

Never [ ]

Q_9) Complexity in design?

Very Often [ ]

Often [ ]

Sometimes [ ]

Seldom [ ]

Never [ ]

Q_10) Lack of insufficient working drawing details ?

Very Often [ ]

Often [ ]

Sometimes [ ]

Seldom [ ]

Never [ ]

Q_11) Lack of mutual respect between designer and contractor?

Very Often [ ]

Often [ ]

Sometimes [ ]

Seldom [ ]

Never [ ]

Q_12) Involvement of contractor in design conceptual phase?

Severe [ ]

Mild [ ]

Nil [ ]

Q_13) Involvement of contractor in design development phase?

Severe [ ]

Mild [ ]

Nil [ ]

Q_14) Nationality of both Construction and Design firms?

Severe [ ]

Mild [ ]

Nil [ ]

Q_15**)** Lack of Designer knowledge of available material and equipments?

Strongly Agree [ ]

Agree [ ]

Neutral [ ]

Disagree [ ]

Strongly disagree [ ]

Q_16) Your view on project construction management team in promoting design construction interface

_____
_____

Q_17) Do you think change order affects design construction interface

a) Yes b)No

Q_17a) If yes rank the causes for change order

**Rank the following according to your preference from 1-5 with**

**(1-highest preference 2, 3, 4-next preferences and 5-lowest preference)**

Q_18a) What are the effects of lack in design and construction interface?

Construction delays [ ]

Decrease in productivity [ ]

Increase in project cost [ ]

Decrease in quality of work [ ]

Dispute between owner and contractor[ ]

***Questionnaire (Contractor)***

Some of the causes for discrepancy in design construction interface are formed as questions for your response to evaluate their effects and severity.

Q_1) Does Change order affect the constructions phase?

a. Yes b. No

Q_2) Effect of incomplete and inadequate plans and specification?

Severe [ ]

Mild [ ]

Nil [ ]

Q_3) Obstinate nature of participants encountered?

Very Often [ ]

Often [ ]

Sometimes [ ]

Seldom [ ]

Never [ ]

Q_4a) Do the Drawings lack specifications, details etc,..

a. yes b. no

Q_4b) If yes, Mention it's inference in your past projects?

Very Often [ ]

Often [ ]

Sometimes [ ]

Seldom [ ]

Never [ ]

Q_5a) Do you think lack of coordination between contractor and project management team affects the interface between design and construction?

a. Yes b. No

Q_5b) If yes, mention suitable technique to improve coordination between construction team

a. Web based project management
b. Implementation of project centre
c. Other _____

Q_6) Participant's honest wrong belief?

Very Often [ ]

Often [ ]

Sometimes [ ]

Seldom [ ]

Never [ ]

Q_7a) Influence of buildability?

a. Yes b. No

Q_7b) If Yes, what is your opinion about influence of buildability

_____
_____

_____
_____

Q_8) Lack of human resources in design firm?

Very Often [ ]

Often [ ]

Sometimes [ ]

Seldom [ ]

Never [ ]

Q_9) Lack of insufficient working drawing details?

Very Often [ ]

Often [ ]

Sometimes [ ]

Seldom [ ]

Never [ ]

Q_10) Lack of mutual respect between designer and contractor?

Very Often [ ]

Often [ ]

Sometimes [ ]

Seldom [ ]

Never [ ]

Q_11) Unforeseen problems at site

Very Often [ ]

Often [ ]

Sometimes [ ]

Seldom [ ]

Never [ ]

Q_12) Involvement of contractor team in design development phase?

Very Often [ ]

Often [ ]

Sometimes [ ]

Seldom [ ]

Never [ ]

Q_13) Nationality of both Construction and Design firms?

Very Often [ ]

Often [ ]

Sometimes [ ]

Seldom [ ]

Never [ ]

Q_14**)** Lack of professional experience and judgments?

Strongly Agree [ ]

Agree [ ]

Neutral [ ]

Disagree [ ]

Strongly disagree [ ]

Q_15) Your view on project construction management team in promoting design construction interface

_____

Q_16) Effect of material changes during construction phase?

Strongly Agree [ ]

Agree [ ]

Neutral [ ]

Disagree [ ]

Strongly disagree [ ]

Q_17) Design errors incurred?

Very Often [ ]

Often [ ]

Sometimes [ ]

Seldom [ ]

Never [ ]

Q_18) Procurement delays during construction phase

Very Often [ ]

Often [ ]

Sometimes [ ]

Seldom [ ]

Never [ ]

Q_19a) Is construction error at job site cause discrepancy in design and construction interface

a. Yes b. No

**Rank the following according to your preference from 1-5 with**

**(1-highest preference 2, 3, 4-next preferences and 5-lowest preference)**

Q_20a) What are the effects of lack in design and construction interface?

Construction delays [ ]

Decrease in productivity [ ]

Increase in project cost [ ]

Decrease in quality of work [ ]

Dispute between owner and contractor [ ]



## 7. References

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