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ONSITE DESIGN

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ONSITE DESIGN

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A Report to
Construction Industry Institute
The University of Texas at Austin

Under the Guidance of
CII Project Team 163
Evaluating Onsite Design

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1.0 Executive Summary

The process of delivering capital projects is both information intensive and information dependent. The communication interface between design and construction is undoubtedly one of the most critical points of information exchange within a project. When the communication of design information is timely, unambiguous, and easily understood, downstream construction activities are more efficiently performed. As such, improvements to the communication interface between design and construction will likely benefit all measures of project performance including safety, quality, schedule, and cost.

Performing selected design activities onsite, to some degree, is a commonly employed technique to improve the design / construction communications interface. However, the extent to which onsite design is utilized varies widely between projects and is understood to be a function of the project's scope, complexity, location, team composition, execution strategy, and many other factors. An important question to answer is "when" and "how much" onsite design should be employed to favorably influence project performance for a given set of project conditions.

The CII Evaluating Onsite Design Project Team was created to address this issue. A computer based decision support tool was developed that permits users to identify specific design activities that should be performed onsite to maximize the likelihood that selected performance measures will be met or exceeded. Additionally, the tool allows users to quickly and simply generate onsite design strategies for the various project phases and for combined, or multiple decision criteria.

The research found conclusive evidence that onsite design is beneficial and contributes to project success. Previous CII research was referenced to generate a comprehensive list of 29 project performance measures. These performance measures are broadly categorized as being related to safety, quality, schedule, and cost. It is important to note that projects utilizing onsite design were more constrained by cost, schedule, and technical complexity than projects not using onsite design. Even so, projects utilizing onsite design performed as well as those projects not utilizing onsite design in every performance measure category. Furthermore, the research found that effective implementation of an onsite design strategy significantly improved 16 of the 29 project performance measures.

2.0 Introduction

2.1 Background

Effective communication between design and construction personnel on capital projects is essential for project success. Unfortunately, this communication interface is often plagued with inefficiencies. One method of improving the communication interface is to execute certain portions of the design work on site. According to Rizzo (1998), improved communication between the designer and contractor significantly reduces the frequency of design conflicts, resulting in a more effective transformation of the design concepts into physical reality. Owners and contractors alike will benefit by adopting proactive strategies to overcome the fragmentation that is inherent in the traditional project delivery process.

The existing fragmentation of the project delivery process can be attributed, to a large degree, to the physical distance between contract parties, weak channels of communication, and the lack of timeliness and accuracy during information exchange. According to Fredrickson (1998), an accelerated level of communication by the designer and constructor can result in a more successful plan and schedule of construction. Today's market pressures demand an efficient, streamlined construction process in order to meet project objectives. Unfortunately, the fragmented nature of the industry encumbers the current construction process with inefficiencies.

The consequences of inefficient communication are numerous, but excessive rework and change orders are typical examples. Anumba and Evbuomwan (1997) determined a significant amount of rework occurred where the design consultants did not maintain effective communication with the contractor. Additionally, Burke (1999)

determined making any changes in scope drastically increases the cost of the project over the construction life cycle. Numerous CII studies support this conclusion. In order to achieve significant improvements to overall project performance measures of safety, time, cost, and quality, parallel activity between the designer and constructor must take place; and multifunctional teams must identify techniques that facilitate timely and effective communication (Anumba and Evbuomwan, 1997).

Recent industry trends such as owner company down-sizing has increased the complexity of the communication interface. As design individuals and other project specialists have been released by owner organizations, the design expertise that was historically present has been lost. Many of these individuals gained employment with firms where design is a core competency, but rarely are the designers based on site. Other industry trends such as schedule acceleration and important project activities such as start-up and operations require seamless communication in order to be effective. In cases where schedule acceleration is required, any lag time in Requests for Information (RFI's), design changes, or drawing approvals is counter productive. Similarly, as the owner-contractor work structure evolves, expertise on issues such as start-up and commissioning will often be shifted to the contractor who may not fully understand the process side of the capital project under construction. Again, the optimization of communication allows for a successful transition from construction to operations. Onsite design addresses these communication challenges.

Additionally, onsite design directly impacts several of the CII Best Practices. When incorporated with effective Pre-Project Planning, onsite design can address critical design issues early in the project cycle thereby reducing potential design changes.

Improved communication through the use of onsite design increases design effectiveness, constructability, and promotes effective change management. In fact, onsite design supports all of the industry best practices to some degree.

Because the success of any project is based upon efficient and open communication, alternatives to the current project delivery process must be identified and evaluated. The identification of viable alternatives to the current project delivery process was an objective of previously completed research by Project Team 124.

CII Project Team 124, “Re-Engineering the EPC Process”, evaluated the performance of 30 “crisis projects” that were exceptional performers. The crisis projects were the result of fires, explosions, natural disasters, or market conditions that mandated a significant reduction in project duration. Although the projects were severely constrained with respect to schedule, project teams utilized “extraordinary” approaches to achieve project objectives. Team 124 sought to identify the “extraordinary” approaches utilized that yielded exceptional results. Placing designers in the field is one of the extraordinary approaches that yielded benefits. Team 124 found that placing the designers in the field improved communications, reduced turnaround of reviews, reduced handoffs, and provided rapid response to inquiries (RR-124-11, 2000). These benefits were the direct result of an improved designer-constructor communication interface.

2.2 Problem Statement

Onsite design is a commonly employed technique of improving the communications interface between design and construction. As such, nearly every project enjoys some level of field design support during construction execution; however the split between home office and onsite design has varied widely among projects. In

some cases, onsite design has been limited to field engineering functions such as formwork design or drawing interpretation. In other cases, onsite design has been expanded to include such initiatives as the relocation of design disciplines to the jobsite.

While it is generally agreed that the timely and accurate exchange of information between design and construction is critical to project success, it is often unclear what criteria should determine the appropriate level of onsite design support for a given project. Until now, it has been unknown how onsite design specifically impacts project cost, schedule, quality and safety. As a result, without a means to provide a quantitative measure, CII member companies have been unable to compare costs to benefits. Moreover, owners and contractors alike have refined and expanded the list of project characteristics that describe successful projects as the construction industry has evolved.

While cost, schedule, quality, and safety have historically been the benchmarks for project success, often times other performance criteria are equally important to project success. The expanded list of successful project criteria includes cost control, earned value, ease of start-up, operability, maintainability, reliability, availability and many more. The Project Team identified a comprehensive list of project performance measures utilized by CII member companies to determine how each may be affected by the use of onsite design. The CII Evaluating Onsite Design Project Team undertook a research initiative to address this issue and several others. Specifically, the project team sought to answer these questions:

- Does onsite design truly yield benefits?
- If so, which performance measures are improved?
- When should onsite design be employed?
- How much onsite design is recommended?
- Does the design executed on site vary by project phase?

Project Team 163 also wished to evaluate issues impacting the use of onsite design. What motivates and necessitates the use of onsite design? In Project Team 124's research, the answer to that question was the existence of a project crisis condition. Project Team 163 suspected that the use of onsite design may be driven by a much broader range of issues. Could any trade-offs associated with the use of onsite design be identified? Certainly a narrow evaluation of project performance such as "design as a percentage of total installed costs" could be adversely affected, but as mentioned previously, criteria for project performance cover a much broader range of issues. If Project Team 163 could identify the incentives for the use of onsite design, CII member companies could effectively evaluate the cost-benefit ratio of using onsite design on a particular project.

Lastly, this research sought to determine if differences in owner and contractor perspectives, as well as the various industry sectors, may impact the applicability of onsite design. The Project Team suspected that onsite design could yield benefits for both owners and contractors, regardless of the market sector.

Until now, no detailed studies have been undertaken to quantify the benefits of onsite design, or to develop decision support tools to aid in the determination of when and how much onsite design is appropriate and beneficial. It has long been suspected that the most beneficial level of onsite design support is not a constant, unchanging quantity, but varies with project phase and project specific requirements and conditions.

2.3 Research Objectives

The research objectives were defined as follows:

- Determine the type and magnitude of benefits resulting from onsite design with respect to improving the interface between design and construction

Previously completed CII research concluded placing designers in the field was an “exceptional” strategy typically utilized on “crisis” projects for improving the communication interface between design and construction. However, it was but one of the “exceptional” measures identified in the “Re-Engineering the EPC Process” research. Determining the type and magnitude of benefits resulting from onsite design alone was paramount to Project Team 163.

- Quantify and validate the impact of onsite design support with respect to overall project performance measures such as cost, schedule, quality, rework, change orders, etc.

Identifying the “benefits” from the utilization of onsite design was not sufficient. Project Team 163 realized that the quantification of such benefits was necessary to determine if onsite design was a viable design strategy. Moreover, the determination of how onsite design impacts the various project performance measures was required so individuals could make informed decisions based on the impact of onsite design to the project performance measures “critical” to their unique project.

- Provide a methodology to determine the level of onsite design support that is optimal for project specific conditions and variables.

The last objective of the CII Evaluating Onsite Design Project Team was to provide a systematic method of determining the appropriate level of onsite design based on the specific needs and objectives of individual projects. The Project Team determined a decision support tool (DST) was the best way to structure this methodology. The

Project Team evaluated several options and formats for the DST, including paper-based tools and checklists, stand alone software, and a computer based tool operating within an existing software package. After reviewing the advantages and disadvantages of the various formats, the Project Team selected a computer based tool operating within Microsoft's® Access software. This selection allowed the maximum flexibility for CII member organizations, and eliminated the possible operating conflicts and maintenance issues associated with stand alone software. Additionally, the computer based tool provided greater accessibility and ease of use when compared to paper based tools.

2.4 Methodology

The methodology for this research project was composed of six major phases: Literature Review, Survey Development, Data Collection, Data Analysis, Findings, and Decision Support Tool (DST) Development.

In the first phase of the research project, an extensive review of the existing literature pertaining to Onsite Design and any related topics was conducted. The literature review focused primarily on previously completed CII research and on journals and publications considered to be significant to the construction industry. Chapter Two of this Research Report summarizes the results of the literature review.

In order to achieve the research objectives, Project Team 163 determined the study of a large number of projects executed by CII member companies was required. The Project Team elected to use a survey instrument to complete the initial phase of data collection. The survey instrument was developed after the careful review of the CII literature. In order to provide consistent terminology for the survey respondents, terminology from previously completed CII research was used during the survey

development. The survey instrument was revised several times, and piloted by Project Team members prior to distribution to the CII member companies for completion. A detailed description of the survey instrument is located in Chapter Four of this Research Report.

The survey instrument was distributed to CII member companies in the spring of 2001. The Project Team received 115 survey responses. Additional data was collected through follow-up interviews with the survey respondents. Once the data collection phase was completed, the analysis of the information collected began. A summary of the data collection process with accompanying descriptive statistics is located in Chapter Five of this research report.

The study developed a sufficiently large database of projects to allow segregation of these projects by such characteristics as project type, scale, location and method of execution. More importantly, the survey response rate was robust enough to comparatively analyze projects using onsite design with those projects not using onsite design. Each project record included in the database contains evaluations of the level of onsite design support as well as documentation of project performance measures. This allowed the Project Team to address the benefits of Onsite Design both qualitatively and quantitatively. The analysis of the data is explained in Chapter Six of this Research Report.

Once the analysis of the data was complete, the Project Team was able to evaluate trends within the construction industry, and draw conclusions concerning the benefits of utilizing an onsite design execution strategy. A summary of the findings is located in

Chapter Seven of this Research Report. Additionally, the information was used to develop the DST.

As previously mentioned, Project Team 163 investigated several alternatives for the decision support tool. The purpose of the tool is to provide a methodology to determine the level of onsite design support that is optimal for project specific conditions and variables. The Project Team considered paper-based tools such as checklists and score sheets as well as the development of a computer-based expert system.

The Team determined each of these options presented usability deficiencies so the Project Team decided to develop the OSD Tool using a Microsoft™ Access platform. The OSD Tool allows the user to supply project parameters and provides recommended design activities to be executed on site to optimize critical project performance measures. A detailed description of the OSD Tool is located in Chapter Eight of this Research Summary. The OSD Tool is available, along with all instructional information, in CII Special Publication CII SP 163-2.

Figure 2.1 illustrates the methodology used for this research. As shown, the information collected through the survey instrument was analyzed to determine why onsite design is used, when and how it is applied, and by whom. The same information was collected on projects not implementing onsite design. A comparison of the two groups allowed Project Team 163 to evaluate the impact of onsite design on project performance throughout the project life cycle.

Onsite Design

RESEARCH METHODOLOGY

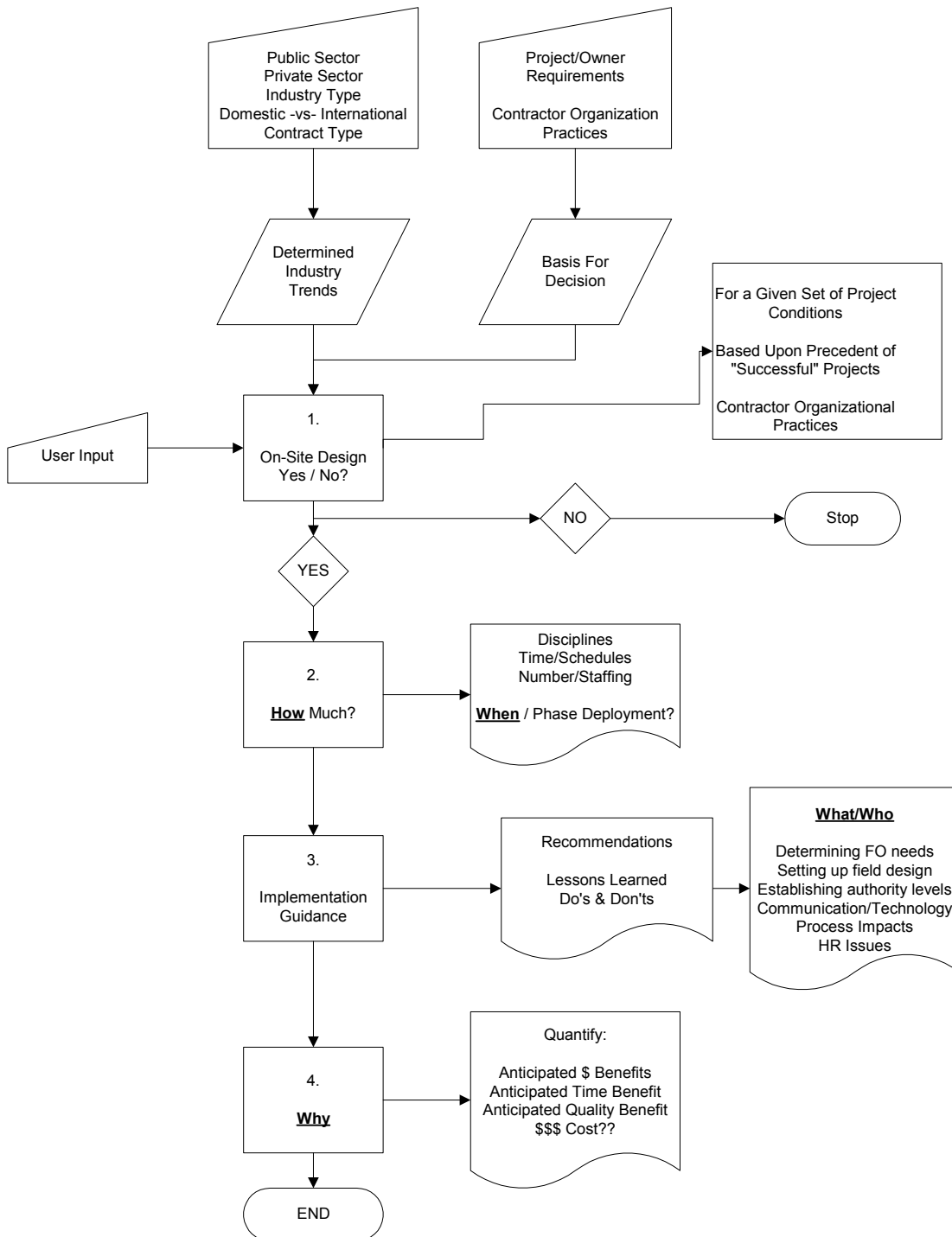


Figure 2.1: Research Methodology Flowchart

3.0 Literature Review

Communication, which may be defined as the transfer of knowledge and information is an integral part of the construction industry. For large capital projects, the vast quantity of information that must be disseminated to project participants requires effective communication interfaces. Whether the communication interface is verbal, written, or electronic, inefficient communication has a negative impact on project success.

Because construction projects involve many participants, the potential for communication breakdown at any of these interfaces is increased. Project success, in an article from the Journal of Management in Engineering, is comprised of planning, communication and teamwork among all parties involved (Stevens, 1996). The integration of the industry is of paramount concern if a more efficient process is to be achieved. According to an article from the International Journal of Project Management the construction industry is viewed, by many, to be extremely fragmented. The existing fragmentation of the project delivery process can be attributed, to a large degree, to the physical distance between contract parties, weak channels of communication, and the lack of timeliness and accuracy during information exchange (Kamara and Anumba and Evbuomwan, 2001).

In an effort to integrate the process, the construction industry has adopted methods of improving communication through organizational solutions such as Alliances, Partnering, Alignment, and Team building. Each of these industry best practices have improved the project delivery process, but none can fully address all of the communication issues at the design and construction interface.

Additional methods of improving communication have focused on developing “information tools” to assist in the transfer of information in a timely, unambiguous fashion. These include expert systems, electronic data management (EDM), and computer assisted design (CAD) programs. These too, are unable to fully address the communication issues alone. In previously completed research, Back cites Workman who determined through field research and interviews that the design process was severely hindered by communication difficulties (CII 125-11).

3.1 The Importance of Effective Communication

Effective communication between the designer and the constructor yields benefits. According to Rizzo (1998), improved communication between the designer and contractor significantly reduces the frequency of design conflicts, resulting in a more effective transformation of the design concepts into physical reality. Moreover, Ndekugri and Turner discovered in their research that owners can realize a cost savings through early and effective communication between the designer and the contractor during the design process. The cost savings occurs because contractors are able to provide initial input on the constructability of the facility (1994).

This initial input is important because if minimal information is provided, the design professional will need to be more involved during the construction process in order to ensure that the processes are completed correctly. According to Fredrickson, the absence of a thorough design early in the process results in more designer involvement later in the project cycle which may cause delays, and idle equipment and labor while

waiting for plans and specifications (Fredrickson, 1998). As Burke indicates, these delays become increasingly more expensive as the project progresses (Burke 1999).

As the construction industry shifts to engineer, procure, construct (EPC) or design-build (DB) project delivery strategies, early communication at the design-construction interface is critical. Previously completed CII research determined that more emphasis is now placed on the initial project stages, especially pre-project planning, because early involvement and communication has a greater influence on project success than involvement at any other stage (CII RR 111-11).

As the construction industry has streamlined the project delivery process, several methods of improving communication have been developed. Recall that these methods can be characterized as organizational solutions and technological solutions.

3.2 Organizational Solutions for Improved Communication

Previous CII research developed several organizational solutions for improving communication, and as such, the project delivery process as a whole. The following discussion focuses on three of these solutions that are now considered to be industry best practices.

Project Team Alignment is critical to project success. Alignment is defined as the condition where appropriate project participants are working within acceptable tolerances to develop and meet a uniformly defined and understood set of project objectives (CII IR 166-3). Prior to the development of this best practice, project teams did not have a systematic method of developing a shared set of project goals. Effective communication is a requisite for developing and maintaining alignment throughout the project cycle.

Project success depends on alignment existing in three dimensions as illustrated in Figure 3.1.

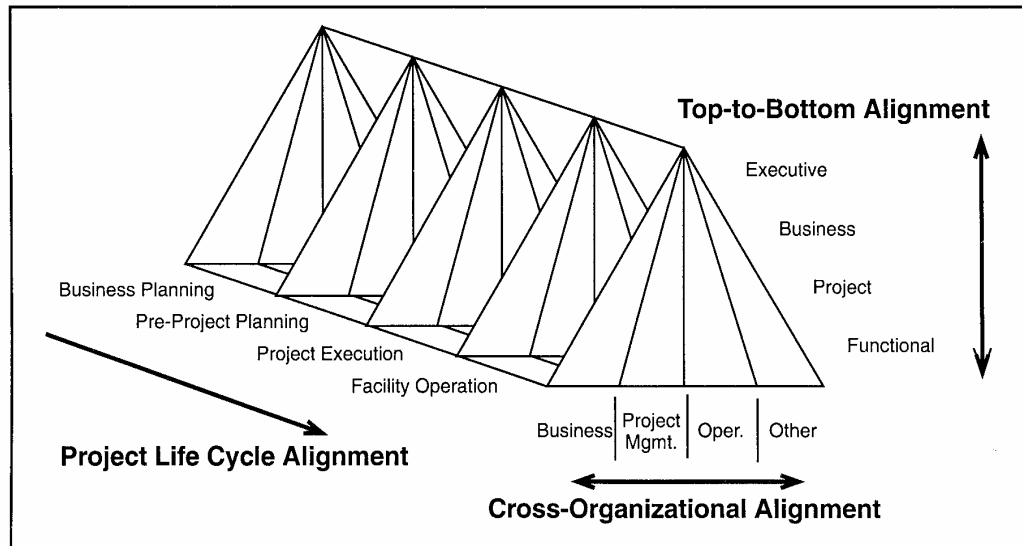


Figure 3.1. 3-D Schematic for Organizational Alignment for a Project

The first dimension, vertical, involves top-to-bottom alignment within an organization. The company executives, business managers, project managers, and functional specialists within each stakeholder organization must be well aligned.

The second dimension, horizontal, involves the cross-organizational alignment between functional groups within organizations. Different organizations with a stake in the project must also be well aligned. For example, the business, project management, and operations group, as well as other stakeholder groups such as outside contractors must be well aligned with the project objectives and priorities.

The third dimension, longitudinal, involves alignment of objectives throughout the project life cycle (CII IR 166-3). Alignment must be maintained in all three

dimensions for project success. By maintaining alignment, effective communication is facilitated through a shared set of common project goals and objectives.

In previously completed research, Alshawhi and Hassan, observed that the construction process is extremely dependent upon multidiscipline communication. These disciplines include, but are not limited to, management, design, estimation, material purchasing and construction. Any absence of direction and cooperation by these disciplines has a direct and potentially negative effect on the project that may last through the project life cycle (Alshawhi and Hassan, 1999). In order to facilitate effective communication and cooperation between these disciplines, the best practice of team building may be employed.

At a glance, teamwork, team building and alignment may seem to be a variation of the same concept. They are, however, three distinct concepts with complementary and different definitions. Team building is defined as a project-focused process that builds and develops shared goals, interdependence, trust and commitment, and accountability among team members and that seeks to improve team members' problem solving skills (CII IR 166-3).

Alignment concerns whether team members are all working toward the same, correct goal. Teamwork involves how well the members interact, communicate, cooperate, and support one another while working together. Team building is the process used to develop and enhance teamwork. Communication is essential for team building to be successful.

For a project team to operate effectively, the team must be aligned as discussed previously. In addition, team building requires an assessment of the effectiveness of

communications on a project. The communication assessment process consists of: developing a communication assessment questionnaire, comparing the results to a reference database, developing an improvement strategy, implementing the improvement strategy, and reassessing the results at regular intervals (CII IR 166-3). This methodology, when employed properly, allows team building to function as an organizational solution for improved communication.

The last organizational solution for improved communication to be examined is the best practice of Partnering. Partnering may be a long term commitment between two or more organizations as in an alliance or it may apply to a shorter period of time such as the duration of a project. The purpose of partnering is to achieve specific business objectives by maximizing the effectiveness of each participant's resources. This requires changing traditional relationships to a shared culture without regard to organizational boundaries (CII IR 166-3). The relationship is based on trust, dedication to common goals, and the understanding of each other's individual expectations and values. Once again, communication between the parties is critical to success.

CII research teams have determined that nearly all successful partnering relationships have three common attributes. First, the leadership continues to support partnering ideals in the midst of doubt and questioning. Second, a situation exists where those involved adapted and accepted each respective manner of business with rewards tied to team accomplishments. Lastly, there exists a belief in the potential for win/win outcomes to grow from collaboration, and a willingness to pursue such joint gains (CII IR 166-3). These attributes foster a change in attitude from adversarial to cooperative, self-

centered to team focused, and win/lose to win/win, thus improving and promoting effective communication among all parties involved.

These industry best practices, as well as others, all promote effective communication with the goal of improving the project delivery process. While these solutions are based on organizational changes, advancements in technological solutions for improving communication also have been made.

3.3 Technological Solutions for Improved Communication

Communication is critical for effective information management. As technology has improved, technological improvements for managing information have been developed. Unfortunately, these advances have not been widely implemented.

Luiten and Tolman contend that while the construction industry is making an effort to improve the transfer of information, the “islands of information” concept continues to dominate the daily information exchange landscape (1997). Moreau and Back concur stating that the design industry is riddled with inefficiencies, and despite substantial investments in computing technology, the ability to integrate information across functional boundaries is a major barrier (Moreau and Back, 2000). Koulopoulos states a new information management paradigm must be adopted where the process defines the information instead of information defining the process (Koulopoulos,1995)

While different methods of improving the communication interface have been developed, the integration of design and construction has not changed. Moreau and Back suggest that the integration of design and construction could be more easily facilitated through the use of high-level computer interpretation systems.

The system would have the ability to manage information transfer at a semantic level. However, due to the fragmentation of the construction industry, a standard level of communication would be difficult to implement and standards of information need to be created (Luiten, Tolman, 1997).

In the Journal of Management in Engineering, Back and Moreau raise the question what information strategies can be successful in engineering? They concluded that current process of information management needed to be evaluated holistically in order to avoid addressing each facet of the organization individually, which could create “islands of automation” and further segment the information management process.

This conclusion is supported by Latham who determined the integration of the processes and project teams is required to produce a more efficient project delivery process (Latham, 1994). Latham also concluded the implementation of an information management system needed to be championed by upper management and that the process must be integrated throughout the organizational infrastructure. Doing so would allow the quantification of the cost savings associated with various information management strategies, but because companies commonly use a “functionally-isolated” approach, many companies are never able to quantify the true benefits (Back and Moreau, 2000).

While fully integrated information management systems are not available, several technologies are currently in use, to varied degrees, to manage specific components of project information. For example, with respect to design issues, Koo and Fischer (2000) determined that the construction planners typically utilize a CPM-based network in conjunction with 2-D CAD drawings. In research previously completed for CII, research

participants unanimously agreed that the use of 2-D CAD in conjunction with CPM networks is an effective method of managing design information (Choi, 1990).

Research into the next generation of this type of technology is currently underway at the Center for Integrated Facility Engineering (CIFE). The research is testing the feasibility of 4-D CAD drawings that utilize 3-D CAD and incorporate the fourth dimension of time. The creation of a 3-D visual model associated with the corresponding schedule has positive implications on the speed with which drawings are comprehended. However, extensive knowledge of 3-D CAD as well as the inability to account for all activities on a given project has hindered progress (Koo and Fischer, 2000).

Research from Stanford University also recognizes the difficulties associated with detailed project scheduling. Fischer and Aalami consider the visual representation of construction knowledge as one of the most important elements interfacing design and construction (Fischer and Aalami, 1996). In order to address this issue, they proposed a 3-D CAD model which translates the design into a construction schedule with various levels of detail. These computer-interpretable construction method models allow the construction methods to become highly detailed as well as providing the ability to view the impacts of utilizing alternative construction methodologies prior to construction.

In similar research using Monte Carlo Simulation to analyze construction processes, Back, Maxwell and Isidore maintain that the engineering and construction industries could be reengineered in order to create improvements in project cost and schedule by simulating workflow processes (Back, Maxwell and Isidore, 2000). Project functional areas such as materials management, purchasing, field material control and accounts payable all can be simulated. The creation of this analogous system allows

the pre-operation of processes without incurring the cost of implementing the organizational changes. Thus, engineering and construction companies could maintain and implement proactive measures with respect to their operations in order to improve the quality of their decision making (Back and Bell, 1995). To date, however, this capability has not been widely implemented.

Similarly, Elzarka and Bell maintain that the interface between the project design and the construction schedule should be facilitated by an expert materials management system. They maintain enhancing the interface between the design and the construction schedule using an integrated materials management system (MMS), could improve project cash flow, eliminate double handling, and reduce warehouse space (Elzarka and Bell, 1995).

In related studies conducted for the Construction Industry Institute (CII), Back and Bell concluded that the implementation of Electronic Data Management (EDM) could provide substantial benefits to the engineering and construction industry. According to the research, the traditional methods of communication are facilitated by “hand-offs” or physical interfaces, each with the potential for misinterpretation and/or information delay and error. The use of EDM tools would allow for the timely, accurate and multi-locational exchange of information, which would increase productivity (1995).

In a Cost Engineering article, Back and Bell state the barriers to implementation continue to be tangible time and cost benefits associated with large monetary investments required by engineering and construction companies to implement the technology (Back and Bell, 1996). Back and Bell cite Burger who supports the elusiveness of tangible benefits due to the difficulty in quantifying the corporate benefits and impacts upon the

process (Burger, 1993). The use of EDM technology has been hindered by the complexities surrounding design disciplines, construction methods, and their specific workflow processes (Back and Bell, 1995).

In research published in the Journal of Management in Engineering, Tippet and LaHoud maintain the use of computer-aided engineering (CAE) can eliminate many of the problems associated with the design of an individual project. CAE has the ability to improve the quality control of design by cross-referencing code and design requirements as well as conducting cost validation and constructability assessments, during the design phase. Even within this emerging technology, “islands of automation” connected to low level technologies continue to exist within the A-E design profession. Identifying an appropriate methodology for implementation, and the current organizational structures of design firms, seem to be the major obstacles inhibiting the use of such technologies (Tippet and LaHoud, 1999).

In an article from the Journal of Management in Engineering, Ahmad suggests information technology (IT), in the form of electronic data interchange (EDI) and bar coding technology have the ability to streamline materials and procurement processes. Ahmad determined that the coordination between the EDI and bar coding technologies can eliminate most external purchasing documents and enable the user to integrate material control and accounts payable, electronically. These types of technologies require a more integrated office environment and the requirements for managing this interdependence have, and will continue to be, the primary barriers to a fully integrated information process (Ahmad, 1999).

The e-mail information exchange has grown to a status that cannot be ignored. According to Schwartz, many of the United States' largest corporations have multiple information exchange networks and consequently, the fragmented nature of the system is inadequate. New technology platforms have been created which will accommodate large numbers of information exchange systems with little regard to their size (Schwartz, 1998). This type of technology could have a large impact upon the design and construction interface because of the ease with which information can be disseminated. Cost and time associated with operations continue to be barriers for the implementation of this technology.

While these new technologies exist and are readily available, Sawyer and Angelo, in an article from Engineering News Record (ENR), cite Voller, who claims that the construction companies are only using 5-10% of the technology capacity already at hand (Sawyer and Angelo, 2001). The key obstacles to the use of the existing technology, as noted at the ENR summit, are the competitive and fragmented nature of the construction industry. In addition, when multiple parties are involved, as is the case on most capital projects, the barriers are multiplied.

A substantial contributing factor for fragmentation of the process is that the construction phase is solely concerned with the production of the project solution. Only by changing the attitudes of the project participants, can the full benefits of communication barrier dissolution be realized (Kagioglou and Cooper and Aouad and Sexton, 2000).

Fischer, director of the Center for Integrated Facilities at Stanford University, maintains that there are good tools for design, scheduling and estimation but they are still

information silos and the industry must use the data “across disciplines.” Fischer also states that while design and construction are both highly collaborative, the connection between the two remains highly static (Fischer 2002).

3.4 Onsite Design - Bridging the Gap

As stated previously, neither organizational nor technological solutions for improving communication can fully address all of the communication issues at the design-construction interface.

Research concerning the use of onsite design was initiated as a follow up topic to CII Project Team 124, “Re-Engineering the EPC Process”. As previously mentioned, CII Project Team 124 evaluated the performance of 30 “crisis projects” that were exceptional performers. Team 124 found that placing the designers in the field improved communications, reduced turnaround of reviews, reduced handoffs, and provided rapid response to inquiries (RR-124-11, 2000). These benefits support an efficient design execution which according to Friedlander must fast track the construction, provide supplemental design information and approve design changes in a cooperative manner (Friedlander, 1997).

According to Back, Moreau and Toon, 28% of project labor costs and 22% of project activity time is consumed by the design process. The magnitude of these percentages warrant the implementation of methods that would reduce the time needed to fulfill contractual requirements (CII 125-11). Although time reductions are not a given, proactive management can address potential problems that may create project delays. In related research, Stevens determined that an effective method of managing proactively is

to have a designer on site (Stevens, 1996). Furthermore, Rizzo maintains that the presence of a full-time field staff can ensure that all procedures are completed according to the design and specifications (Rizzo, 1998). Onsite design addresses these issues directly.

An article by Goddeau, Mock and Stehmeyer (1992) exemplifies the essence of the onsite design research. Often the solutions to problems encountered on the project site are easily discovered if the information can be disseminated in a timely manner. Timeliness can be achieved through the use of a design representative on site. They list other possible advantages to having a designer onsite including the following:

Owner Benefits

- Quick coordination and field investigation concerning design changes, owner changes and other unforeseen conditions encountered
- Reduced time for dispute resolution
- Possible early completion as a result of reduced delay time

Contractor Benefits

- Rework reduction
- Increased conceptual understanding of the project scope due to a constant information source

Designer Benefits

- Fewer claims as a result of misunderstandings
- Provision of constant consultation to contractor and the ability to monitor progress on owner's behalf
- Possible creation of an amiable working relationship because of constant interaction
- Creation of possible work in the future because of desirable completion time and cost

Furthermore, Goddeau, Mock and Stehmeyer suggest the presence of a design engineer on site is integral to the success of the project and that the system should become common practice (1992).

Recall that the objectives of Project Team 163 are as follows:

- Determine the type and magnitude of benefits resulting from onsite design with respect to improving the interface between design and construction
- Quantify and validate the impact of onsite design support with respect to overall project performance measures such as cost, schedule, quality, rework, change orders, etc.
- Provide a methodology to determine the level of onsite design support that is optimal for project specific conditions and variables.

By addressing each of these research objectives, Project Team 163 will provide a method of improving communication at the design-construction interface that bridges the gap between the organizational and technological methods of improving communication. Placing design professionals on site may be an organizational change for some project teams. However, a technological solution is also provided through the development of the OSD Tool. By integrating the two, onsite design provides an alternative design execution strategy that facilitates an accelerated level of communication between the designer and constructor, thereby improving the project delivery process.

4.0 Survey Questionnaire Development

In order to achieve the research objectives, Project Team 163 determined the study of a large number of projects executed by CII member companies was required. The Project Team elected to use a survey instrument to complete the initial phase of data collection. The survey instrument was composed of the following five sections: Project Characteristics, Design Definition and Process, Basis for Decision, Retrospective Project Assessment, and General Questions and Remarks. After the careful review of the CII literature, the development of the survey instrument began. In order to provide consistent terminology for the survey respondents, previously completed CII research was used during the survey development. The survey instrument underwent six revisions and was piloted by the Project Team members prior to distribution to the CII member companies.

The first section, survey section A, collected general project information concerning the following characteristics:

- | | |
|---|---------------------------------|
| • Domestic or International | • Public or Private |
| • New, Retrofit or Upgrade Construction | • New or Known Technology |
| • Total Installed Cost | • Market Sector |
| • Execution Method/Strategy | • Project Complexity |
| • Regulatory/Legal Constraints | • Contract Type |
| • Contract Incentives | • Respondent Roles/Services |
| • Number of Design Personnel | • Design Hours Executed on Site |

A sample of survey section A is located in Figure 4.1 below. The information was used to develop descriptive statistics for the project database. Additionally, information from this section provided some general trends concerning the types of projects utilizing and benefiting from onsite design.

A. PROJECT CHARACTERISTICS

Identify the characteristics that best describe the subject project by selecting the appropriate checkbox.

1. Is the project a domestic or international project?
☐ Domestic ☐ International
2. Was the project a public (government) or private sector project?
☐ Public ☐ Private
3. Was the technology aspect of the project a “new” or “known” technology to your firm?
☐ New Technology ☐ Known Technology
4. Was the project a new, a retrofit, or an upgrade project?
☐ New ☐ Retrofit ☐ Upgrade
5. Dollar value of total project, TIC (Total Installed Cost).
\$ _____
6. Project Type.

☐ General Building	☐ Light Industrial	☐ Pharmaceutical
☐ Power	☐ Petroleum	☐ Pulp/Paper
☐ Chemical	☐ High Tech & Electronics	☐ Heavy Industrial
☐ Manufacturing	☐ Highway & Infrastructure	
☐ Other _____		
7. Execution Method/Strategy.

☐ Design/Bid/Build (traditional)	☐ Design/Build (EPC)	☐ Construction Management (EPCM)
☐ Other _____		

Figure 4.1: Sample of Survey Section A

The next section of the survey, survey section B, was designed to collect the quantitative data concerning the use of onsite design. For this section of the survey instrument, the Project Team had to determine what constitutes onsite design. Because the concept of onsite design is open to many interpretations, Project Team 163 revisited this issue several times.

In order to reduce the possibility of misinterpretation, and to improve the consistency of the survey responses, the Project Team identified 50 distinct design activities commonly performed on industrial and commercial type projects. The majority of the activities were taken from previously completed CII research publications, particularly CII publication 125-2, and the remaining activities were generated from the Project Team member's past experience and expertise. These activities are summarized in Table 4.1. Such activities may or may not be performed on site. For any given project, the decision to perform an activity on site varied with the specific project requirements and the detailed plan for project execution.

Table 4.1: Design Activity List

Activity #	Design Activity
1	Process and Facility Planning
2	Develop Utilities and Offsite Scope
3	Develop Environmental Scope
4	Develop/Modify Site Plan
5	Develop/Utilize Work Breakdown Structure
6	Develop Preliminary Design, Including PFDs & P&IDs
7	Prepare/Revise Preliminary Estimates
8	Address Project Safety Issues
9	Prepare, Monitor, or Maintain Project Execution Plan
10	Prepare, Monitor, or Maintain Project Scope
11	Develop, Monitor, or Execute Start-up Plan
12	Finalize/Update Design Criteria, Including PFDs & P&IDs
13	Develop, Update, or Complete Facility Plans
14	Define Major Equipment and Material Specifications
15	Finalize/Update Utilities and Offsite Scope
16	Address Codes, Standards, HAZOP, & Environmental Requirements
17	Acquire/Maintain Permits & Regulatory Approvals
18	Conduct Site Evaluation
19	Prepare, Monitor, or Maintain Detailed Cost Estimate
20	Prepare, Monitor, & Maintain Schedule
21	Develop and/or Revise Civil Drawings
22	Develop and/or Revise Structural Drawings
23	Develop and/or Revise Electrical Drawings
24	Develop and/or Revise Architectural Drawings
25	Develop and/or Revise Mechanical Drawings
26	Develop and/or Revise Instrumentation & Controls Drawings
27	Conduct Cost & Schedule Analysis

Table 4.1: Design Activity List (continued)

Activity #	Design Activity
28	Conduct Design/Engineering Review
29	Review / Approve Changes in Scope
30	Conduct Constructability Evaluation
31	Conduct QA / QC Evaluation
32	Coordinate Supplier / Engineering Interface
33	Finalize Drawings & Construction Specifications
34	Distribute Documents / Distribute Bid Documents
35	Develop, Modify, or Process Material Requisitions
36	Develop Bill of Materials
37	Specify Bulk Materials
38	Specify Standard Engineered Equipment
39	Specify Fabricated Items
40	Specify Specialized Engineered Equipment
41	Technical Evaluation of Vendor Submittals
42	Review / Approval of Submittals & Shop Drawings
43	Respond to Request for Information
44	Review Changes and Approvals
45	Monitor Cost / Schedule Performance
46	Generate Information/Documentation for As-Built Drawings
47	Complete Legal Closure for Project
48	Turnover Documents
49	Finalize As-Built Drawings
50	Obtain Final Acceptance (Certificate of Occupancy)

To further reduce the possibility of misinterpreting the design activities listed in Table 4.1, a glossary containing all fifty design activities was provided to the survey respondents. This glossary is located in appendix B.

Once the design activities were identified, the Project Team devised a method of allowing the survey respondents to quantify the effort executed on site. Numeric values were obtained by asking the respondents to indicate a level of onsite design effort, expressed as a percentage, on a slider bar. The survey also allowed the respondents to indicate in which project phases the onsite design effort occurred for each of the design activities identified above. This allowed the Project Team to answer the question “When was onsite design utilized?”. Ultimately, this survey response approach allowed the decision support tool (DST) to provide detailed information concerning the most

appropriate time to employ onsite design for the optimum result. A sample of survey section B illustrating this procedure is located in Figure 4.2.

B. DESIGN DEFINITION AND PROCESS

For each design activity listed in the following table, mark the percentage of on-site design capability utilized, if any, on the sliding scale. In the boxes that follow the scale, identify the construction phases during which on-site design was used by listing the corresponding letter. If “not applicable”, leave cell blank.

Construction Phases:

- A. Develop Concept
- B. Preliminary Design
- C. Detailed Design
- D. Procurement of Materials and Equipment
- E. Construction
- F. Start-Up

A completed example follows. (Mark total % of on-site Design) (Construction Phases)

Complete Constructability Review	0 50 100 X C D E
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Project Activities

Process and Facility Planning	0 50 100
Develop Utilities and Offsite Scope	0 50 100
Develop Environmental Scope	0 50 100
Develop Site Plan	0 50 100
Detail Work Breakdown Structure	0 50 100

Figure 4.2: Sample of Survey Section B

The third section of the survey, section C, was developed to collect information concerning why the project design was executed in a particular fashion. Again, CII publications were reviewed to identify these “basis of decisions” or project drivers. While many individuals involved in the construction industry are familiar with the term “project driver”, the CII Project Team elected to use the terminology “Basis of Decision”