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## TRADE-OFF BETWEEN COST AND SCHEDULE

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Research Report 214-11

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# TRADE-OFF BETWEEN COST AND SCHEDULE

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

Under the Guidance of  
CII Project Team 214  
Trade-Off Between Cost and Schedule

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## ABSTRACT

Projects must meet budget, schedule, safety, and quality goals to be regarded as a success. Many factors come into play and many decisions are made that influence a project's outcome. Today, owners are often faced with deciding between a project execution strategy that emphasizes either cost or schedule. Such a decision in favor of emphasizing cost versus schedule may be made not once, but throughout the life cycle of the project.

CII established the Trade-off between Cost and Schedule Research Team to determine answers to the following questions:

- Once the decision is made to emphasize cost / schedule trade-off, is it possible to identify factors that consistently lead to a successful project?
- Once these factors are identified, is it possible to develop a tool that can be used to guide users into making the right decisions that will produce repeatable results?

Project teams, when informed that an owner has made a cost/schedule trade-off, will meet and through a brainstorming session, generate common sense ideas, best practices, and other means of achieving the trade-off. What this research offers is a tool for systematically generating these ideas, and for identifying which factors are most effective by project phase.

Through a survey of CII member organizations, the Trade-off between Cost and Schedule Research Team identified 23 techniques that consistently influence project success. In addition, survey participants indicated to what degree those techniques have led to project success. RT214 team has developed a simple yet effective tool to assist project teams in selecting the optimum group of techniques to achieve a specific cost-schedule trade-off. The Cost-Schedule Trade-off Tool (CSTT) offers the following advantages:

- Applies to projects that are either schedule or cost-driven.
- Recommends techniques for success unique to each stage of the project.
- Provides references to selected CII Best Practices for further guidance to the user.
- Applies not only to trade-off projects, but virtually any project.

The techniques recommended by the tool are not unique: they are routinely used in successful project management. In fact, many of the techniques are CII Best Practices. The key, however, is that CSTT helps the user in knowing the specific techniques to employ at each stage of the project. Project teams can then use these techniques in a more timely fashion to increase the likelihood of project success, particularly in an era when trade-offs are continually being made to favor cost or schedule.



## LIST OF ABBREVIATIONS

| ABBR | DESCRIPTION                              | ABBR      | DESCRIPTION                     |
|------|------------------------------------------|-----------|---------------------------------|
| A    | Agree                                    | LSTK      | Lump Sum Turn Key               |
| AE   | Architect/Engineer                       | MA        | Manufacturing                   |
| BE   | Business Executive                       | MM        | Material Management             |
| C    | Construction                             | N         | No opinion                      |
| C&D  | Construction & Demolition                | NGL       | Natural Gas Liquidation         |
| CBS  | Cost Breakdown Structure                 | NTP       | Normalized Tradeoff Points      |
| CE   | Concurrent Engineering                   | OW        | Owner                           |
| CERC | Concurrent Engineering Research Center   | PDRI      | Project Definition Rating Index |
| CICE | Construction Industry Cost Effectiveness | PE        | Project Engineer                |
| CII  | Construction Industry Institute          | PO        | Power                           |
| CIP  | Cost Impact Points                       | PPP       | Pre Project Planning            |
| CM   | Construction Management                  | RT<br>214 | Research Team 214               |
| CO   | Construction                             | SA        | Strongly Agree                  |
| D    | Design                                   | SD        | Strongly Disagree               |
| D    | Disagree                                 | SIP       | Schedule Impact Points          |
| DB   | Design Build                             | SU        | Start up                        |
| DBSP | Design Build Scoping Paper               | T&M       | Time and Material               |
| EM   | Engineering Management                   | TIP       | Total In Place                  |
| EN   | Environmental                            | TL        | Telecommunication               |

|     |                                          |      |                             |
|-----|------------------------------------------|------|-----------------------------|
| EPC | Engineering Procurement and Construction | TPC  | Total Project Cost          |
| FPE | Facility Planning and Engineering        | TR   | Transportation              |
| GB  | General Building                         | TWIV | Total Weighted Impact Value |
| GC  | General Contractor                       | V/S  | Vendor/Supplier             |
| IAS | Impact Assessment Survey                 | VE   | Value Engineering           |
| IF  | Impact Factors                           | WBS  | Work Breakdown Structure    |
| IP  | Industrial Process                       | WIF  | Weighted Impact Factors     |
| IV  | Impact Value                             | WIV  | Weighted Impact Values      |
| LD  | Liquidated Damages                       |      |                             |

# CHAPTER 1

## INTRODUCTION

### 1.1 Introduction

With many traditional companies facing their biggest financial challenges, the first-to-market focus of the companies has been equivocally challenged by renewed focus to keep the costs of capital projects under control. A recent report from McKinsey's Global Institute, a research arm of McKinsey & Company, states: "The trend towards price as the focus of entry will fundamentally challenge the business model for most traditional businesses in North America (McKinsey & Company 2003)."

This demand for lean structure is customer driven. The customer is increasingly asking the highest value for their money and nowhere is this more evident than the retail industry. The dramatic growth of "value" retailers such as Wal-Mart and Target is in sharp contrast to the sale of traditional retailers driven to bankruptcy. To keep the end product as economical as possible, the owners have to change their paradigms and put more emphasis on cost control and cost reduction at the expense of schedule. This has led to a need for new metrics, best practices, and techniques to manage a project that gives precedence to cost over schedule. The Construction Industry Institute (CII) addressed this need by issuing an RFP in 2003. Research team (RT214) was constituted to investigate the trade-off between cost and schedule for capital projects. Purdue University and Vanderbilt University were academic leads in this project. This research summary is a result of this endeavor.

## **1.2 Purpose of Research**

The purpose of this research is to investigate methods and processes used to achieve the desired trade-off between cost and schedule on the basis of specific project partners and propose a CII Best Practice related to Lean-cost projects including supply chain, design, and contractual relationships for execution of capital project delivery systems.

## **1.3 Scope of Research**

The scope of this research includes investigation of case studies and best practices of recently completed projects with unusual success in optimizing cost and schedule. Thus, projects studied are predominantly in the industrial, infrastructure, and commercial categories. Consequently, the results of the research are most applicable to similar projects.

This research investigates the circumstances that lead to the trade-off between project cost and schedule. The research assesses the barriers to cost-optimizing a project and investigates the interrelationships between project cost and project schedule. Sample projects are analyzed for changes that allowed cost reduction and schedule optimization. Sample projects are also used to identify innovative concepts or strategies for phasing and staging projects that result in lowest initial cost.

## **1.4 Objectives of Research**

The research has five main objectives:

- Identify practices that can optimize cost and schedule
- Identify barriers to achieving trade-offs between cost over schedule
- Prioritize the trade-offs based on their potential for cost over schedule optimization

- Develop a user friendly decision tool to assist in the evaluation of trade-offs between cost and schedule
- Develop a list of topics for follow-on research aimed at removing or eliminating barriers to cost-schedule optimization.

## 1.5 Research Approach

This research postulates that a study of high performing projects will lead to the discovery of best practices, which, if applied broadly and routinely, would facilitate cost-optimized schedules for construction projects across the industry. Data was collected through questionnaire survey, case studies, interviews, site visits, and literature review. The research methodology included the following:

- Perform extensive literature review, including use of extensive information in the Construction Industry Institute (CII)'s knowledge structure.
- Conduct case study evaluations of successful projects to identify practices that can facilitate cost-optimization of a project as well as to identify barriers and trade-offs to cost-optimizing a project versus schedule constraints. Then incorporate these findings into the overall development effort.
- Develop a procedure to evaluate the trade-offs between cost and schedule.
- Develop a user friendly decision tool to assist in the evaluation and optimization process.
- Invite comments on the decision tool and appropriateness of individual priorities assigned to enabling and hindering practices.

## **1.6 Report Organization**

The need for the research has already been discussed above. Chapter 2 describes the research methodology followed in this research. Chapter 3 provides an overview of the background literature for cost and schedule reduction techniques. Chapter 4 discusses the data gathered from various questionnaire surveys and the Impact Assessment Surveys (IAS) during the research as well as analysis of the data thus obtained. Chapter 5 presents results and findings of the case studies. Chapter 6 illustrates the framework of the implementation resource (decision tool) and describes the development of the tool. Chapter 7 discusses the conclusions made from the questionnaire surveys, Impact Assessment Surveys, case studies, and the implementation resource. Finally, recommendations are made regarding directions for future work.

## **1.7 Research Team**

This research has been conducted under the direction of the CII Research Team 214 (RT 214): Trade-Off between Cost and Schedule. The CII members of the research team (Appendix-4) have played a significant role in the development of the questionnaires, case studies, identifying metrics, and in developing the framework of the decision aid.

## **CHAPTER 2**

### **RESEARCH METHODOLOGY**

#### **2.1 Research Approach**

As discussed earlier, the objective of this research is to identify techniques which can be used to optimize cost and schedule and prioritize them on the basis of their potential for achieving the trade-off between cost and schedule. For accomplishing these objectives, the following tasks were completed.

- Identification of the techniques which lead to reduction in cost and/or schedule
- Estimation of the relative impact of these techniques on the cost and schedule of various project phases
- Identification of the drivers and barriers that govern decisions regarding the trade-off between cost and schedule

Once these tasks were done, the data obtained was used to set up a decision tool that identified the trade-off requirement of the project team and provided the list of techniques which would be best suited to help achieve this established trade-off. The research approach is summarized in Figure 2.1.

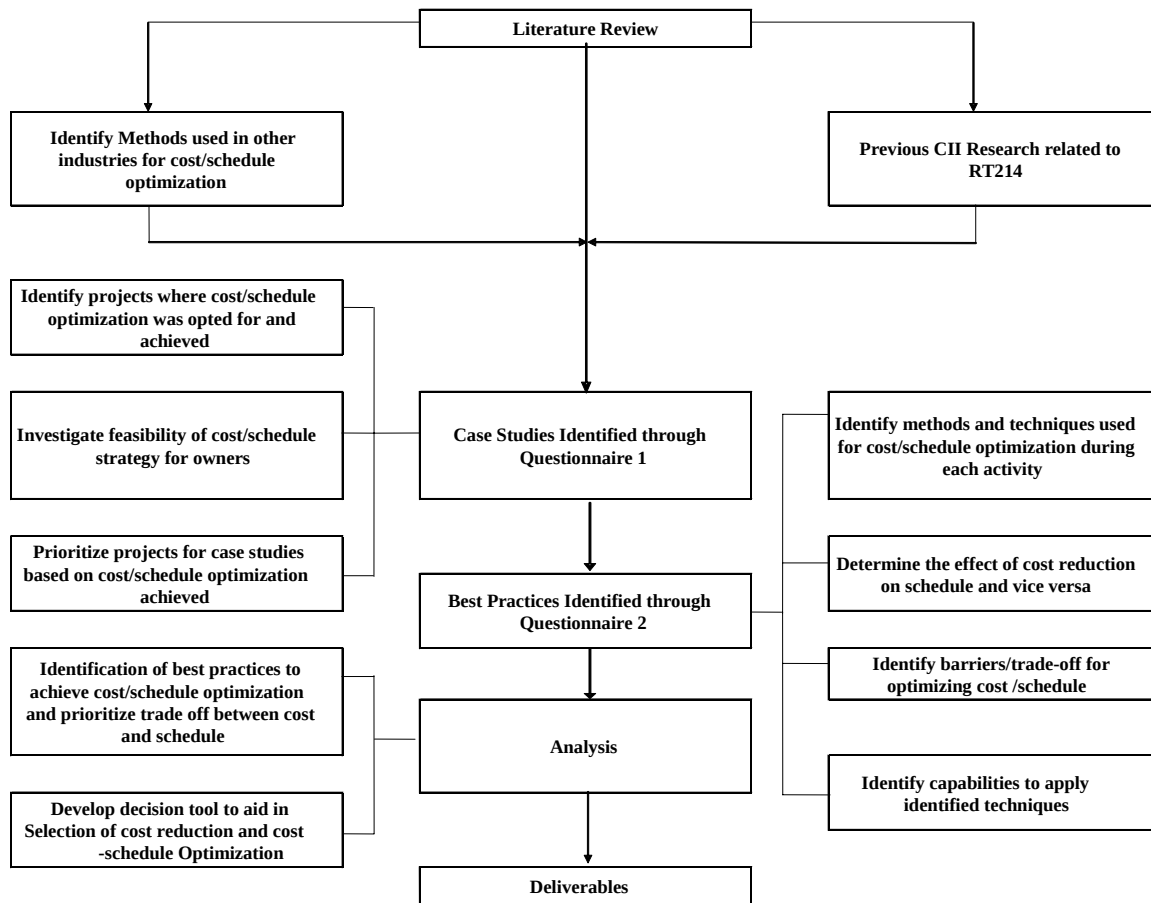


Figure 2-1 Research Approach

## 2.2 Data Requirements

With the research approach in mind, data requirements were identified. First and foremost, the techniques which lead to cost and schedule reduction were identified. This was done with the help of literature review which identified a list of techniques that have historically caused reduction in cost and/or schedule of the project life cycle. The current practices used in the industry were identified using questionnaires and case studies.

The next logical step was to identify the drivers that affect the trade-off decision for the project team. This was accomplished through case studies and a questionnaire to the industry representatives.

After subsequent sorting and selection of the techniques, it was necessary to identify the impact that the techniques had on the cost and schedule of the project phases. This was accomplished through Impact Assessment Surveys to the industry experts.

## **2.3 Data Sources**

As discussed earlier, the data required for this research was collected by four modes.

- Literature review
- Questionnaires
- Impact Assessment Surveys
- Case Studies

### **2.3.1 Literature Review**

The literature review helped in identifying various schedule and cost reduction techniques as well as CII best practices for projects. The literature review also helped identify certain other techniques that are applied in other industries such as manufacturing and services industries. All these techniques are elaborated in Chapter 3.

### **2.3.2 Questionnaires**

#### ***Questionnaire-1***

Questionnaire-1 was developed to identify companies that have been successful in implementing methods and techniques to achieve cost and schedule reduction. This questionnaire was mailed out to all CII member organizations (104 in total). 64 responses from 45

organizations were received. The questionnaire was divided into 3 basic sections: (refer to Appendix 1):

### *(1) Company Profile*

This section collected information regarding the respondent and the organization.

### *(2) Techniques for Cost or Schedule Reduction*

The questionnaire asked the respondents to identify if their company had implemented any techniques for cost or schedule reduction. They were asked to briefly describe what techniques were used for achieving the reduction. This section further asked the respondents to give project details like the location, estimated cost, actual cost, estimated duration, and actual duration after achieving reduction. The organizations' cost and schedule trade-off philosophies were also explored.

### *(3) Conclusion*

This section asked the respondent to indicate whether they/their company would be willing to share further information with RT 214 through participating in a case study analysis. Also, the respondents were asked if they were aware of any other projects that may have achieved exceptional trade-off between cost and schedule.

## **Questionnaire-2**

Questionnaire-2 enquired about the drivers and barriers to cost over schedule trade-off as well as the effects of cost over schedule trade-off on quality and safety. It also enquired about contracting strategies that would help achieve the cost over schedule trade-off (Appendix-2). The questionnaire was sent out to CII member company representatives (104) including RT-214 members (16) and Questionnaire-1 respondents (64). Thirty five responses were received.

### **2.3.3 Impact Assessment Surveys**

Impact Assessment Surveys (IAS) gathered feedback from engineers, owners, contractors, suppliers, construction managers, project managers, and others who are involved in the EPC process. RT-214 identified 23 techniques through Q-1, Q-2., and case study analyses that show the greatest potential for cost and/or schedule reduction. The Impact Assessment Surveys (IAS) were designed to ascertain whether a particular technique, if applied within a particular phase of the project, would bring about an increase, decrease, or no change in the cost and schedule of that phase, subsequent phases, or the entire project (Appendix-3). Eighty three responses to the IAS were received.

### **2.3.4 Case Studies**

Questionnaire-1 helped identify 5 case studies. The case studies were conducted to develop a better understating of the decision-making process used by the project teams to determine the cost over schedule trade-off. The case studies were also useful in understanding the enablers and barriers, as well as impact of cost and/or schedule reduction on projects. The major objective of the case studies was to benchmark techniques that were successfully applied in achieving cost schedule trade-off in project cycle time.



## **CHAPTER 3**

### **LITERATURE REVIEW**

To achieve the objectives of this research, the first step was to look at existing literature addressing cost reduction, schedule reduction, and impacts of such reduction on each other and on project quality and safety. The results of the literature review are presented in this chapter.

#### **3.1 Anatomy of a Capital Project**

To optimize any system, it is imperative that its structure and processes are perfectly understood. Therefore, to optimize a capital project, the work break-down structure of the capital project should be established. Extensive work has been done in this field as discussed below.

One of the most effective generic models was developed by CII-RT 125. The EPC process is represented as a set of interrelated activities that spans from the owner's earliest involvement with pre-project planning to the completion of plant start-up (Back et al. 1998). In this model, the actual performance and the responsibility of the activities are not assigned. The EPC macro model encompasses all the activities that are commonly carried out in any capital project. There are three levels of breakdown in this model. The first level is called activity level or also referred to as project phases. This level includes five primary phases, into which the process can be divided:

- Pre-Project Planning (PPP)
- Design (D)
- Materials Management (MM)
- Construction (C)

- Start-Up (SU)

The next level is called task level. In this level, the project phases mentioned above are further divided into tasks which constitute the functions to be performed during each of the phases. The EPC Macro Model shown in Figure 3-1 illustrates this level of break up into 24 subtasks.

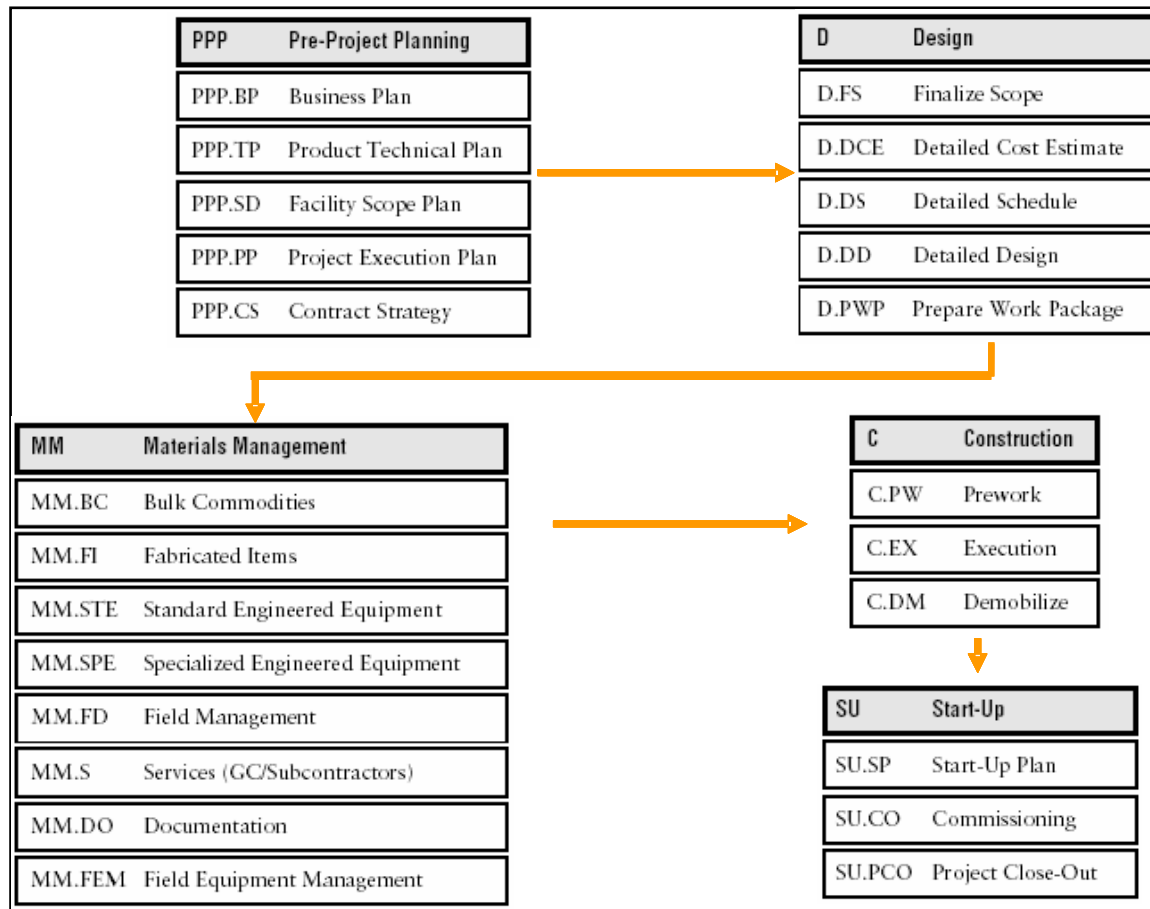


Figure 3-1 EPC Macro Model

(Determining the Impact of Information Management on Project Schedule and Cost, June '98, by

Back, Moreau and Toon, © Construction Industry Institute)

Level-3 further breaks down the structure to specific project activities which are commonly carried out in capital projects. However, for this research, a two-level classification was deemed to be sufficient.

### **3.1.1 Pre-Project Planning Phase**

Pre-project planning involves gathering of strategic information to make a decision about the purpose and scope of the project. This involves information about risks and resources involved with the project under consideration. It includes development of business plans constituted of goals and objectives of the business entity considering the capital project (Gibson et al. 1993). It also includes the product technical plan, facility scope plan, project execution plan, and a contract strategy.

### **3.1.2 Design Phase**

The design phase involves complete engineering of the project including all the numerical engineering analysis. This phase includes involvement of all the preliminary information provided by the owner to enable finalization of scope. The adherence to permits, codes, and bylaws of the facility being designed is also important and hence these legal and regulatory issues are addressed in the design phase.

In the finalized scope, a detailed estimate of equipment, materials, and services is developed as along with a detailed schedule for design, materials management, construction, and start up (Choi and Ibbs 1989). The design phase includes the reviews and approvals obtained from within design disciplines, between disciplines, from the owner, as well as all efforts to finalize design deliverables. Once this is done, the scope is broken down into work packages based on the specialization required in each kind of work task. This serves a dual purpose – specialized work for each work task and also easier monitoring of the project (Russell et al. 1992).

### **3.1.3 Materials Management**

The success of any project inevitably requires that the materials and equipment of right quality and right quantity are available at the site at the right time and right price. This would involve many steps starting from specification to shipment and storage if required. The items to be procured in this phase are divided into four major categories including bulk commodities, fabricated items, standard engineering items, and specialized engineering items.

The field management including the general contractor is required to consolidate these materials once they are on site. But this might be different considering the different type of contractual agreements with various partners in the project. To illustrate this point, a turnkey contractor might take charge of all the material management by himself while a standard general contractor in a construction contract might have to take charge of the material only once it has arrived at the site.

Documentation and products identifying techniques for the purpose of getting the right material in the right place is also an important activity in this phase which is carried out by the field management once the material is on site.

### **3.1.4 Construction**

All the activities required to take the facility from drawings to reality are included in this phase. It includes site mobilization activities, actual construction activities, and, also, final cleaning up and demobilizing activities. This phase works in conjunction with the deli phase of material management. The effort in this phase for the project team is to keep a close watch on cost, schedule, quality, and safety.

### 3.1.5 Start-Up

The start-up comprises all the post construction activities which involve requirements, procedures, and tests to start operating the facility (Mathews and Ashley 1986, Smith and Pritchett 1986). This stage has been divided into three major subgroup activities: Start-Up Plan, Commissioning, and Project Close- Out.

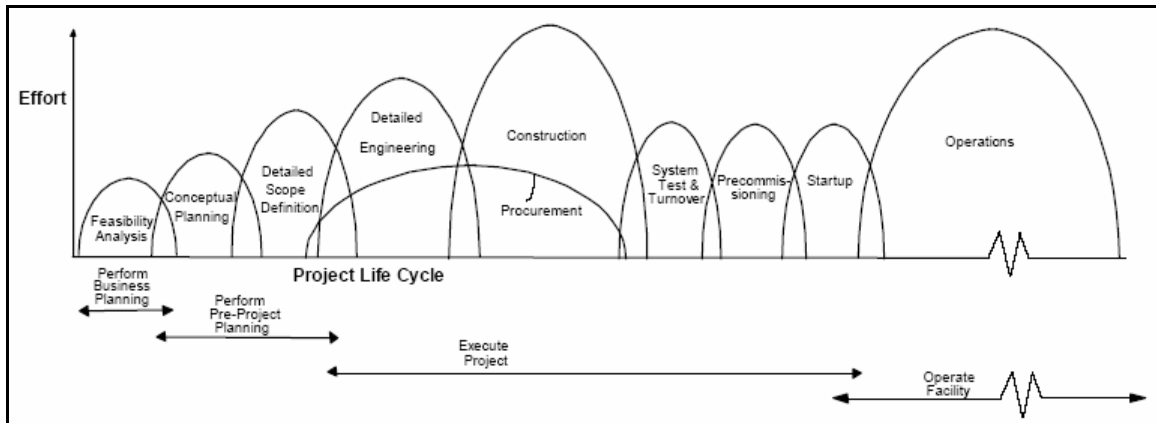


Figure 3-2 Project Lifecycle Overlap Diagram

(Development of the Project Definition Rating Index (PDRI) For Building Projects, Dec 1999,  
by Cho, Furman and Gibson, Jr., © Construction Industry Institute)

The project phases can be well represented by the Project Lifecycle Overlap Diagram (Figure 3-2), where the overlaps are the transition phases where important decisions are made about the future course of the project. The heights of the arcs represent the effort spent in each of these phases.

### 3.2 Codes for Project Tasks

All these major phases have been assigned a code for identification and ease of reference in the models developed and ensuing work. The code for pre-project planning is “PPP” and

similarly that for the design phase is “D, for material management is “MM, for construction is “C”, and for start up is “SU”.

Each subsequent activity in these phases which belong to the second level of classification is also given a code. Thus, the business plan task of pre-project planning can be identified by the “PPP.BP”. All these codes can be found in the EPC Macro Model shown in Figure 3-1.

### **3.3 Metrics for Project Success**

Many studies have attempted to define the elusive concept of project success. Before achieving this goal, it is imperative that the nature of this goal is known. While some researchers claim that the definition of project success in solely objective terms is an impossible task (De Wit 1986, Morris 1986, Stuckenbruck 1986), others have tried to measure it more subjectively at different times in the project (De Wit 1986, Cleland 1986 and 1988, McCoy 1986, Salaptas and Sawle 1986, Stuckenbruck 1986, Tuman 1986, Ashley et al. 1987). This second approach is applied because of complexities which arise due to the fleeting nature of project objectives which are subject to change over time, plurality of project participants and their objectives and the subjective nature of some of the project objectives (De Wit 1986).

However, recent research has shown that the project participants are adopting a prudent and professional approach for selecting the objectives of the projects in measurable attributes making it easier for project success to be defined.

### **3.4 CII Best Practices**

After extensive research, CII has developed a list of tools and techniques which when fully employed lead to enhanced project performance in cost schedule, quality, and safety. The application of some of these tools and techniques can begin in any phase and may continue for more than one project phase, while some of them may be implemented only in some of the phases. At the time of this study CII has identified 12 best practices but additional techniques are constantly being evaluated to be considered as best practices.

#### **3.4.1 Pre-Project Planning**

Pre-project planning is defined as “the process of developing sufficient strategic information for owners to address risk and decide to commit resources to maximize the chance for a successful project” (CII 1994). The outcome of this process is a project execution plan. According to CII Publication 6-2, “Scope Definition and Control,” a Business Pre-project planning effort encompasses the feasibility analysis, conceptual planning and detailed scope definition phases. The Roundtable Report (CII 1986) names inadequate scope definition as the primary cause for cost overruns in the construction industry.

Many researchers conclude that the importance of pre-project planning cannot be overemphasized. The efficacy employed in performing the activities of this phase can substantially affect the outcome of the project in improving cost and schedule performance, operating characteristics of the facility, and also overall financial success of the project. When sufficient and proficient effort is put forth in this phase, a project should have few scope changes during project execution with high probability of success.

CII’s “Pre-Project Planning Handbook” facilitated planning efforts at this stage of the project. The Pre-Project Planning Handbook (CII SP39-2, now replaced by Implementation

Resource 213-2, Front End Planning Toolkit) provided a pattern for an organization's pre-project planning process and gives insight into critical tasks that must be performed. It concludes that the pre-project planning effort can accomplish the following:

- Reduce total project design and construction costs by as much as 20% (versus authorization estimate)
- Reduce total project design and construction schedule by as much as 39% (versus authorization estimate)
- Improve project predictability in terms of cost, schedule, and operating performance
- Increase the chance of the project meeting environmental and social goals.

Six pre-project planning factors that significantly affect project success are outlined in this publication. Among these are the following:

- The need to increase total project design work-hours completed to between 10 and 25 percent prior to project authorization
- Development of a written charter
- Development of project control guidelines
- Preparation of an execution approach prepared
- An adequate number of organizations participating in pre-project planning
- A Pre-project planning plan in place (CII PT39-1 1997).

Another tool to this effort was CII's "Project Definition Rating Index (PDRI)," which was also a product of CII research (CII-PT155 1999, CII-PT113 1997). A sample of 40 projects using the PDRI–Industrial Projects indicated that those projects with PDRI scores below 200 versus those scoring above 200 had the following characteristics:

- Average cost savings of 19 percent

- Schedule reduction by 13 percent
- Fewer project changes
- Increased predictability of operational performance.

The final version of CII’s “PDRI–Buildings” consists of 64 elements, which are grouped into 11 categories and further grouped into three main sections.

### **3.4.2 Alignment**

The project management system and process uses a team approach to carry out a project. Project teams are formed by organizations with the explicit purpose of managing a project from inception to completion, where some individuals may find themselves working on more than one project team at a time (Webster 1993). Once a team has completed the project, it is normally disbanded and the individuals are assigned to new project teams or they are returned to the functional area from which they came (Kerzner 1995). Because of the diverse nature of a project which has varied ensuing requirements in terms of talent and expertise, members of several separate functional areas or “departments” or sometimes firms are often part of a project team. These teams are expected to form a cohesive unit and accomplish a goal within both time and budget constraints (Pinto and Kharabanda 1995). Such teams are often referred to as “cross-functional teams”. According to Ross (1989), for a collection of people to form a true group, the individuals would have to exhibit at least five interdependent characteristics to be considered a true group. These five characteristics are (Ross 1989) as follows:

- Communication between group members
- Shared knowledge of common goals
- They have structure

- They experience pressure to conform
- They take unitary actions

Out of these, to have the project run smoothly within cross-functional teams, goal formation and acceptance is further complicated by the fact that individual members from different functional areas differ in terms of goals, values, attitudes, and time frames (Pinto and Kharabanda 1995). It was discovered that success of the project and project goals are subjugated to the goals of the functional organization or department to which the member belongs (Lawrence and Lorsch 1967). The major focus of alignment is to have objectives of all the project stakeholders find a different phrase or word for your definition towards project objectives and goals.

In a study funded by the CII, researchers investigated objective setting by owner and contractor organizations in the construction industry. This investigation involved a case study of five capital projects. The focus of the study was on how project teams establish objectives for the project and what affects the objective setting process have on project outcomes. The research arrived at the following conclusions (Rowings, Nelson, and Perry 1987):

- In the successful project, there was a strong feeling of teamwork between major participants
- In the successful project, there was a congruency of objectives between the major participants
- In projects experiencing difficulties, the objectives lacked definition, clarity, and consistency
- In projects experiencing difficulties, there did not appear to be a sense of teamwork between participants

- In projects experiencing difficulties, the major participants did not have the same priorities or objectives

Thus, from the above discussion a few basic facts became evident:

- Project management teams are omnipresent
- The team consists of members who are from different functional departments or organizations and these departments and organizations have their own set of goals
- Individual(s) with definite sets of goals perform much better than those with loose or no goals
- The team with a common set of goals performs much better than one which has conflicting sets of goals.

Thus, to achieve a state where team participants have common goals that lead to the success of a project, CII has made alignment a best practice. CII defines alignment as “a condition where the appropriate project participants are working within acceptable tolerances to develop and meet a uniformly defined and understood set of project objective.”

This research identified 10 critical alignment issues that most effect the alignment of a pre-project planning team:

1. Stakeholders are appropriately represented on the project team.
2. Project leadership is defined, effective, and accountable.
3. The priority between cost, schedule, and required project features is clear.
4. Communication within the team and with stakeholders is open and effective.
5. Team meetings are timely and productive.
6. The team culture fosters trust, honesty, and shared values.

7. The pre-project planning process includes sufficient funding, schedule, and scope to meet objectives.
8. The reward and recognition system promotes meeting project objectives.
9. Teamwork and team building programs are effective.
10. Planning tools (e.g., checklists, simulations, and work flow diagrams) are effectively used.

CII developed a tool called the Alignment Thermometer that can be used to measure the degree of alignment which exists in a project group (Front End Planning Research Team 1997).

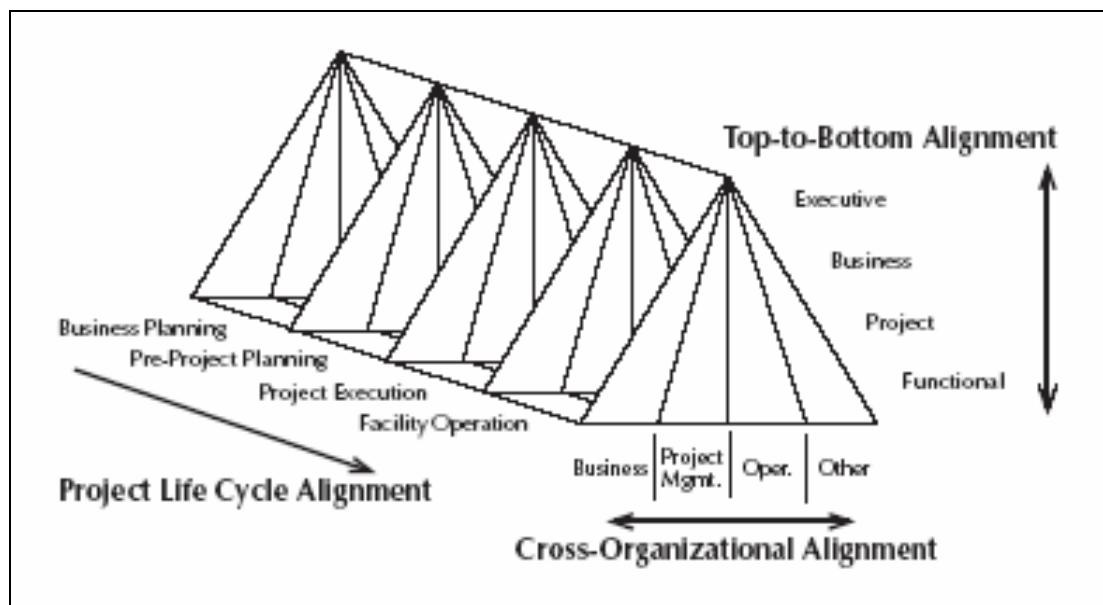


Figure 3-3: 3-D Schematic Organizational Alignment for a Project

(Source: Pre-Project Planning Tools: PDRI and Alignment,  
Construction Industry Institute, 1997)

### 3.4.3 Constructability

CII has defined constructability as “the optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives.” Constructability demands active and timely involvement from construction personnel throughout all phases of the constructed project cycle, and requires much more than optimizing field operations after construction mobilization, construction review of engineering documents, or the use of modularization and preassembly. These activities are certainly indispensable activities for constructability, but maximum benefits occur only with extensive, proactive early involvement of construction personnel in all major project decisions (CII 1986).

Constructability was first identified as important in The Business Roundtable Construction Industry Cost Effectiveness (CICE) study. Report B-1 of this series demonstrated that significant benefits may be obtained through integration of constructor knowledge into project engineering, including reduced project cost and schedule. The report touts constructability as the method for achieving this integration (BR 1982).

A great deal of research has been done on this subject matter by CII. “Constructability: A Primer” defines constructability and, through mini-case studies, describes potential benefits from constructability efforts such as documented project cost savings of 6% to 23% and project schedule savings of up to fourteen months (CII 1986). “Constructability Concepts” describes fourteen fundamental concepts of constructability which form a foundation for constructability program efforts (CII 1987a).

Documentation of constructability efforts shows that owners accrued an average reduction in total project cost and schedule of 4.3 percent and 7.5 percent, respectively. These savings represented a 10 to 1 return on owners’ investment in constructability (CII RS34-2).

#### **3.4.4 Design Effectiveness (Measuring Design Effectiveness against Project Objectives)**

Design effectiveness is an all encompassing term to measure the results of the design effort including input variables and design execution against the specified expectations of the owner. The owner's expectations include such criteria as cost, schedule, quality, and others either explicit or implicit in the project objectives.

Design, a complex process involving the reconciliation of competing objectives and constraints, is a major determinant of project success. The interplay of “numerous factors, including physical, financial, and environmental constraints and technical and managerial knowledge, harmonize and result in plans, specifications, and models that are aimed at satisfying the owner's project needs. Effective design is the product of effective teamwork among the owner, the designer, and the construction contractor” (BIR 1987). The blueprint for project success or failure is created in this phase. The effectiveness of this phase is a direct determinant of how successful the project is going to be. Though this phase is not the most expensive, the decisions made here have great impact on the project success in terms of cost, schedule, safety, and quality.

Fully understanding the importance of the output of the phase, research has attempted to understand the parameters that affect the effectiveness of the design process. Because of the intellectual and highly abstract nature of work, it becomes difficult to measure properly the characteristics of design output. Hence CII funded research to understand and put forth a method to effectively gauge the output of the design process.

The CII publication 8-2, “Input Variables Impacting Design Effectiveness,” identified 10 input variables as having the greatest impact on design effectiveness:

- Scope Definition
- Owner Profile and Participation
- Project Objectives and Priorities
- Pre-Project Planning
- Basic Design Data
- Designer Qualification and Selection
- Project Manager Qualifications
- Construction Input
- Type of Contract
- Equipment Sources

Using data from 16 projects, the researchers correlated these input variables with seven output parameters, which are the factors on which a design can be evaluated. These factors are:

- Final Project Schedule
- Constructability
- Quality of Design
- Final Project Cost
- Plant Start-Up
- Performance
- Safety

CII Source Document 26 also elucidates a system approach to achieve the design effectiveness, i.e., a set of input variables that correlate among each other in multiple layers lead to a set of outcome characteristics. This research used these relationships and correlations to develop a tool that, based on the input variables described by the owner and the project team,

would give the expected results of the project and how much they would vary from the expectations of the owners. This tool is mentioned in CII publication RS 8-1.

Failure to effectively manage any one of the design inputs could adversely affect project cost by 5 to 15 percent. Overall failure to manage design input could increase total project cost by 25 percent or more (CII RS 8-2 1987).

### **3.4.5 Materials Management**

Materials management is the planning and controlling of all necessary efforts to insure that the correct quality and quantity of materials and equipment are appropriately specified, procured, received, warehoused, and retrieved in a controlled manner, at a reasonable cost, and are made available when needed.

A materials management system includes the major functions of identifying, acquiring, distributing, and disposing of materials needed on a construction project. The logical components of this system are shown in Figure 3-4. Not shown are the most important functions of planning and controlling the entire system. There are four more important objectives of materials management (CII Material Management Task Force 1988):

- Assure quality materials are on hand when and where required.
- Obtain the best value for purchased materials.
- Provide efficient, low cost transport, security, and storage of materials within construction sites.
- Reduce surplus to the lowest level possible.

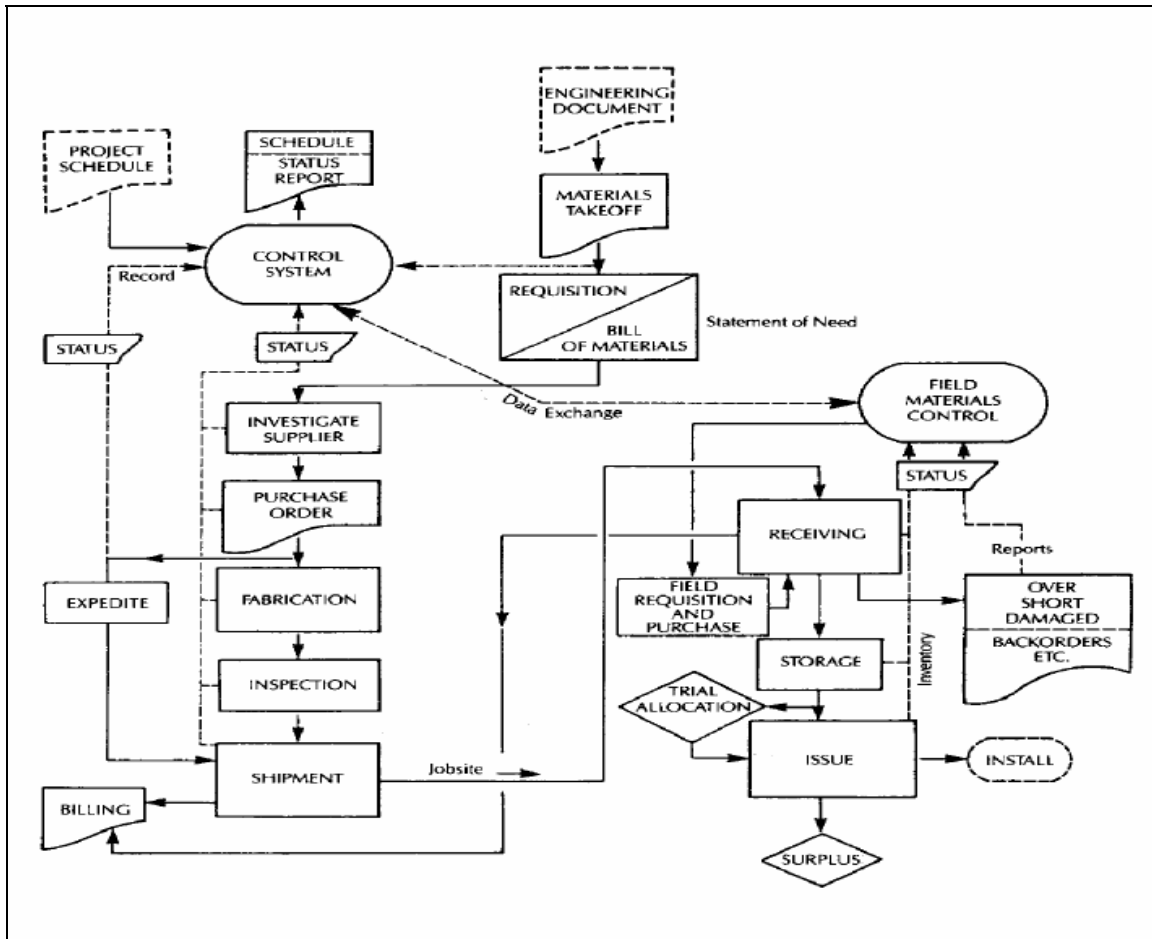


Figure 3-4: Construction Material Management System

(Source: Project Materials Management Primer, CII Publication 7- 2, 1988)

The CICE report titled "Modern Management Systems" states, "The construction industry lags far behind the manufacturing industry in applying the concepts of materials management" (1982). The report further claims that "senior management of firms in the construction industry has not always recognized the significant contribution that materials management can make to the cost effectiveness of projects." In an effort to address these and other critical conclusions of the report, the CII established in January 1984 its Materials Management Task Force, composed of owners, contractors, and academicians knowledgeable in construction materials management. The group undertook the task of developing and disseminating information and concepts that

prove the value and cost effectiveness of what the task force has defined as an "integrated and proactive" or "total-concept" materials management systems.

CII and its Materials Management Task Force directed a number of studies and investigations, including two formal research projects conducted jointly by Auburn University and Texas A&M University. The results of the research, which was conducted in the real world of construction project execution, established several basic premises.

These research studies concluded that materials management is a clearly defined task that, when properly planned and executed, provides project management with an invaluable tool to optimize schedules and improve labor productivity. Substantial savings accrue to both the owner and the contractor, with the CICE estimate of six percent savings on project craft labor costs being conservative for most applications. As with any management system, however, top management support is required. A major hurdle is the resistance to accepting the obvious cost of a well-planned materials management effort. This cost will always be less than the hidden cost of historical material handling and material control. Training is an essential element in the successful application of the materials management concept. Training must include not only the materials management organization itself, but even more importantly, the users at all levels of the project management team (Material Management Task Force, 1986).

#### **3.4.6 Planning for Start-Up**

“Start-up is the transitional phase between construction and operations. CII has previously defined the start-up phase as the progressive initiation of systems within a facility, where a system is any assemblage of structural, mechanical, electrical and instrumentation components providing a function or service” (O’Connor et al. 1999). Most of the previous

research was focused on start-up planning either as a component of the construction completion process or as an element of operator training programs.

Industrial plant start-ups are generally conducted in stages, reflective of the industrial processes and sub-processes involved. While the specific stages and sequencing do vary depending on the project, the general sequence is as follows (as illustrated by the research report 121-11 by construction Industry institute):

1. Mechanical Completion of Construction
2. Check Systems
3. Commission systems
4. Introduce Feedstock
5. Conduct Performance Testing
6. Begin Production or Commercial Operations

Planning for start-up is difficult due to the extensive coordination and input needed early in the project. A successful start-up requires not only that many disciplines work together, but also that these disciplines view the project from a systems perspective. Converting from a discipline-based construction paradigm to the systems paradigm is not easy. Furthermore, since the early phases of the project have the greatest impact on project success, it is critical that start-up planning occur early in the project cycle (O'Connor 1999).

A successful start-up is generally considered essential to overall project success for the following reasons:

- Start-up costs are significant. Start-up costs average approximately 5.5% of construction costs.

- Start-up delays can be expensive. A delayed start-up costs between 4% and 8% of the fixed capital cost per month of delay can be expected depending on the type and magnitude of the project (King 1977).
- Start-up is risk-intensive. Start-up often reveals problems overlooked in planning, design, and/or construction. Risks range from contractual risks due to delays in product delivery to human health and environmental risks (O'Connor et al. 1999).
- Aspects of start-up are keenly memorable. The start-up phase is typically the last phase where both the construction manager and constructor are involved. (O'Connor et al. 1999)

CII has developed a tool for effectively devising the start up .This “Planning for Start-Up” (Publication IR -121 -2) is a notebook-style toolkit that contains 26 tools to help plan a successful start-up. It details 45 activities that should be noted as part of planning for start-up over eight typical phases of a project.

### **3.4.7 Team Building**

Team building is a project focused process that brings together team members of the owner, designer, and/or contractor to resolve differences, remove roadblocks, and also develops trust and commitment, a common mission statement, and accountability among team members. The multitude of parties involved in any project has been a long standing scenario in construction industry. The requirements to address the variety of problems and challenges require a diverse skill set which warrants this multitude of parties to form a team to pool in their individual expertise. Although the pool of skill sets may be perfectly selected, to create a synergy between these individual areas of expertise is a much more difficult process owing to the diverse

interest of each of the team participants. This process of synergizing the skill set by creating conditions where each team member can perform most efficiently contributing his efficient effort completely to project success, is called as the team building process.

The CII Project Team Building Task Force has defined the team building process and an effective project team in CII 37 -1 as follows:

“The team building process is a project focused process that brings together key stakeholders in the project outcome, usually representatives of the project owner, designer, and/or contractor. It seeks to resolve differences, remove roadblocks, and build and develop trust and commitment, a common mission statement, shared goals, interdependence, accountability among team members, and problem solving skills. An effective project team is a group who shares a common mission or a reason for working together, is interdependent in effectively achieving shared goals, shares a commitment to working together toward identifying and solving problems (rather than finger pointing and fault finding) and is accountable as a functioning unit within a larger inter-organizational context.”

In response to a survey conducted by the task force, 79% of the respondents estimated 10 to 30% cost reductions could be achieved.

### **3.4.8 Partnering**

CII publication RS 37-1 mentions that partnering and team building are similar, but not the same. The difference lies in the duration of relations as the team building relation lasts for the duration of the project, while partnering is a more long-term concept. Another difference is that the collaboration in partnering among team members is made more seamless since it is supposed to be lasting longer than team building. It can be safely hypothesized that the alignment of

objectives can be more easily achieved in the case of partnering than in the case of team building.

The CII Partnering Task Force defined the concept of partnering as “a long-term commitment between two or more organizations for the purpose of achieving specific business objectives by maximizing the effectiveness of each participant’s resources. This requires changing traditional relationships to a shared culture without regard to organizational boundaries. The relationship is based on trust, dedication to common goals and an understanding of each other’s individual expectations and values. Expected benefits include improved efficiency and cost effectiveness, increased opportunity for innovation and the continuous improvement of quality products and services.”

Table 3-1 : Benchmark Results: Partnering vs. Traditional Construction

| Category | Result Area         | Result                     |
|----------|---------------------|----------------------------|
| Cost     | Total Project Cost  | 10% reduction              |
|          | Administration      | 24% reduction              |
|          | Marketing           | 50% reduction              |
|          | Engineering         | \$10 per hour reduction    |
|          | Value Engineering   | 337% increase              |
|          | Claims (% of TPC)   | 87% reduction              |
|          | Profitability       | 25% increase               |
| Schedule | Overall Project     | 20% reduction              |
|          | Schedule Changes    | 48% reduction              |
|          | Schedule Compliance | Increased from 85% to 100% |

Source: CII RS-102-1: Model for partnering Excellence, Partnering II Research Team

The special publication 17-1 of CII enumerates 17 elements for partnership. The key elements are long-term commitment [emphasis added], trust, shared vision, equity, investment, synergism, shared risk, rewards, systemic and competitive edge.

The CII publication RS 102-1 has the following table showing the number of ways the project can be affected by Partnering and the extent to which it can be affected.

The Partnering II Research Team developed the Partnering Toolkit, CII Implementation Resource 102-2, to guide organizations through this partnering planning and implementation model.

### **3.4.9 Quality Management**

According to CII Research Summary 10-1, the average cost of rework in industrial construction is pegged at 12%. Out of this total, design deviation accounts for 80 % of the rework and construction accounts for the remaining 20% of rework. Further research was conducted in which 17 participants were interviewed including eight owners and nine contractors. Some interesting insights were observed:

**Engineering and Procurement:** In this phase, the following observations were made:

- Reduced CADD error rate 87% over 6 months
- Saved \$300,000 in structural steel by implementing changes from a brainstorming session
- Cut transactions 50%, processing time from 15 to 5 days
- Improved supplier's on-time deli from 86% to 98%
- Supplier QM system saved over \$230,000 (30%) compared to usual methods

**Procurement and Plant Start-Up:** In this phase, the following observations were significant:

- Identified \$2,000,000 per year savings in transportation costs
- Reduced packing and process time by 50%
- Reduced costs by \$200,000 per year in equipment subsidiary

- Start-up to full-scale production time reduced from 18-24 months to only 6 months using TQM

**Project Execution:** Some of the significant observations in this phase are as follows:

- Saved \$550,000 after investing \$30,000 in statistical training
- Project \$6,000,000 under budget and 8 weeks ahead of schedule with TQM in project operations
- Reduced costs by \$670,000 on refinery expansion project

The benefits of the Quality Management can not be overemphasized. CII research summary RS31 -1 gives guidelines and a roadmap to achieve Total Quality Management in projects. Much effort has also been made by CII in setting up system for measuring quality for a project.

### **3.4.10 Change Management**

Change management is a formal process of recognizing, evaluating, and implementing changes. This process includes an approval and implementation schedule. A change is any modification in the original scope, time, or cost of the work. Changes may be prompted by a contractor claim, owner deletion or addition of work, designer clarification of the contract, or any other change in the work, contract time, or compensation. A change may be as simple as a modification in paint color, or as major as a substantial redesign of previously completed work. Sixty-five percent of process changes occurred during the early project phases (planning and design) (Songer and Deikman 2000).

According to the CII publication RS 43-2, greater magnitudes of change in a project have significant effects on the productivities of labor and also in the productivity of engineering. Thus, significant savings can be made if proper and effective change management is in place.