Analysis of Techniques Leading to Radical Reduction in Project Cycle Time

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Abstract: Today's construction business relies on first-to-market product strategies to gain competitive advantages and increase profit margins. This has created an increased demand for a high performance capital project delivery system that can achieve a dramatic reduction in project cycle time. Very few decision tools and guidelines exist to assist owners in choosing appropriate delivery systems and project strategies to radically reduce the project cycle time from the preplanning stage through start up. The research presented in this paper surveyed the construction owners and architectural/engineering/construction firms to identify projects that have achieved greater than 25% reduction in overall project cycle time when compared to current industry standards. The data collected were analyzed to determine the techniques that facilitate radical reduction in project cycle time. These techniques include, best practices and schedule reduction techniques as well as the various management techniques employed on the projects identified by the Construction Industry Institute (CII). This research also identified the barriers to radical schedule reduction. The research concludes that radical schedule reduction well in excess of 25% can be achieved through the selective employment of management techniques, schedule reduction techniques and CII best practices. Almost every construction manager can utilize this research to improve project performance whether for radical reduction or simply more effective execution.

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Introduction

From automotive industry to process industries and from information technology to e-commerce, businesses today rely on first-to-market product strategies to gain competitive advantages and increase profit margins. This has created an increased demand for a high performance capital project delivery system that can achieve a dramatic reduction in project delivery time. The cost of short cycle time can manifest itself as trade-offs with other project objectives, such as project quality, safety, and project cost. Owners and project mangers are well served in utilizing reduced cycle time techniques selectively, on a project-by-project basis, where they yield the greatest return (Hastak et al. 1993).

The competitive nature of business requires that owners make scope changes at the last moment even in the face of shortened cycle times. Construction Industry Institute (CII) chartered the Research Team-193 (RT193) on "radial reduction in project cycle time" to investigate the reality, requirement, and barriers to such radical reduction in project cycle time. For the purpose of this research, "radical reduction" was defined as a reduction of 25% or more in overall project cycle time (preplanning through startup) when compared to current industry standards for projects of similar size and scope. The purpose of this research was to investigate methods and processes that facilitate reduction in project cycle time, and develop guidelines and techniques related to shortened cycle times for capital project delivery systems.

This paper presents the results of this research and describes the methodology including various assumptions and research criteria with an overview of the literature for radical reduction techniques. This paper also describes the data gathered from various questionnaire surveys and the essence applicability matrices (EAM), as well as the analysis of the data thus obtained. Finally, the results and findings of the seven case studies conducted in this research are discussed.

Research Approach

The objectives of this research were to identify practices that can improve project delivery time, prioritize the changes or improvements based on their potential for cycle time reduction, identify barriers to radical reduction in cycle time, and identify techniques for radical reduction. To achieve these objectives, four specific data collection modes were used namely: (1) literature review; (2) questionnaire surveys; (3) EAM; and (4) case studies of selected projects. Some key/major issues were identified by analyzing management techniques, CII best practices, and schedule reduction techniques, which led to the development of the EAM, explained later.

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Table 1. Schedule Reduction Techniques

Number	Schedule reduction techniques
1	Advanced construction equipment
2	Alternative construction methods
3	Avoidance of interruption
4	Craftsmen: a variety of incentives for craft workers can be included in a project, which will encourage better schedule performance
5	Crew (Specialty crew): training before the start of the project and during the project can really help boost productivity
6	Critical equipment contingency planning: needed for timely repair and return service after a breakdown
7	Concurrent engineering: it is a systematic approach to include all entities affecting or affected by the project in the planning, engineering, and design of the project
8	Construction-driven schedule: scheduling software to prepare and track an integrated engineering/ construction schedule that takes into account the time required for construction
9	Dual-purpose design: designs can be selected that allow components to serve as both construction function and a function in the completed structure
10	Efficient packaging for transportation
11	Empowerment: owner's project manager must be a team leader with authority to make decisions and be supported by upper management
12	Expedite payment
13	Fast track scheduling
14	Frequent inspection: it suggests increased testing of the construction materials and also check on the construction process so that time lost in rework can be saved
15	Freezing project scope: prior to commencement of detailed engineering, the owner/architect/engineer should have a clearly defined project scope
16	Incentives: craft worker bonus/award program
17	Job site preassembly: fabrication done on-site
18	Just-in-time material deliveries

Table 2. Management Techniques

Number	Management techniques
1	Inventory reduction
2	Elimination of unneeded items
3	Employee involvement
4	Increase output
5	Improve quality
6	Reducing cycle time
7	Safety in workplace
8	Space reduction
9	Reliability
10	Continuous improvement
11	Prevent mistakes
12	Minimal resources
13	Reducing delivery lead time

Literature Review

The literature review helped in identifying the various schedule reduction techniques, as well as CII best practices currently used in the construction industry. It also helped in identifying the schedule reduction techniques applied in other industries, such as manufacturing, processing, and automotive and were categorized as management techniques.

Forty-six (46) schedule reduction techniques were identified from previous CII literature (CII 2000, 1999a,b, 1998, 1996a, 1995b, 1988). Some of the schedule reduction techniques are shown in Table 1.

Similarly, 13 management techniques were identified to have an obvious applicability to the construction industry (refer to Table 2). In addition, this research analyzed the 11 best practices identified by CII at the time of this study (refer to Table 3). A CII best practice is a process or method recommended by CII, that when executed effectively, leads to enhanced project performance.

Questionnaire Surveys

In addition to the literature review, three sets of questionnaires and the EAM were used to establish the state-of-practice and the state-of-art for cycle time reduction techniques. The engineering, procurement, and construction (EPC) macro model shown in Fig. 1 was used to establish the project life cycle and subsequent data collection. The EPC macro model was proposed by a previous CII research team (RT 125) and represents a set of interrelated activities that span from the owner's earliest involvement with preproject planning to the completion of plant startup (CII 1997a). The EPC macro model consists of a comprehensive list of activities commonly executed in an EPC project organized under five phases, i.e., preproject planning (PPP), design (D), materials management (MM), construction (C), and startup (SU) (refer to Fig. 1).

The main purpose of Questionnaire I was to identify projects that have achieved radical reduction (defined to be a reduction of 25% or greater over normal project cycle time). It was mailed to all 104 CII member companies and 22 responses were received. This questionnaire was divided into three basic sections: (1) company profile; (2) techniques for radical reduction; and (3) conclusion. The conclusion part asked the respondent to indicate whether their company would be willing to share further project information with RT193. Seven case studies were identified based on the information, provided by the respondents (refer to Table 4). The results from these case studies are discussed in the following sections.

The objective of Questionnaire II was to investigate methods, processes, and CII best practices related to shortened cycle times for project delivery systems. It was sent to CII membership as well as case study participants identified through Questionnaire I. A total of 22 responses were received from 104 CII member companies and 15 more from members participating in the seven case studies. This questionnaire helped the team identify the best practices of recently completed projects with unusual success in reducing cycle time. It was composed of two parts: general information and project cycle reduction. In the project cycle reduction, several questions on radical reduction in project cycle time were asked of the respondents. For instance, information about the drivers and barriers for cycle time reduction was collected. Respondents were also asked to rank the problems/issues that caused cycle time extensions.

The primary project types undertaken by the responding companies are summarized in Fig. 2. The respondents to the questionnaire answered based on a scale from 1 to 4, where 1 implies "*strongly agree*" and 4 implies "*strongly disagree*." Therefore, the lower the score, the more important was the particular reduction technique.

Table 3. CII Best Practices

Number	CII Best Practices
1	Preproject planning: CII defines it as the process of developing sufficient strategic information with which owners can address risk and decide to commit resources to maximize the chance for a successful project (CII 1994a)
2	Alignment: In the context of capital projects, it is defined more specifically 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 1997b)
3	Constructability: It is the optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives (CII 1993a)
4	Design effectiveness: It is an all encompassing terms to measure the results of the design effort, including input variables and design execution, against the specified expectations of the owner (CII 1986b)
5	Materials management: It can best de defined as "the planning and controlling of all necessary effort to insure that the correct quality and quantity of materials and equipment are appropriately specified in a timely manner, are obtained at a reasonable cost, and are available when needed" (CII 1986a)
6	Team building: It is a project focused process that brings together key stakeholders in the project outcome, usually representatives of the project owner, designer and/or contractor to build consensus on common project objectives (CII 1993b)
7	Partnering: It is 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 (CII 1996b)
8	Quality management: It implies meeting the requirements of all customers. This involves being proactive in helping customers articulate their requirements so that their expectations are met (CII 2001, 1990)
9	Change management: Changes like additions, deletions, or other revisions within the general scope of a contract cause an adjustment to the contract price or contract time. This may present a variety of challenges for every party to a construction project. To overcome the problems associated with changes to a project, project teams must be able to effectively manage changes (CII 1994b)
10	Dispute resolution: Three main underlying cause of construction disputes are project uncertainty, process problem, and people issues (CII 1995a)
11	Zero accidents techniques: These include high-impact zero injury safety techniques that are applicable to small as well as large owners and contractors (CII 1993c)

- Drivers and barriers for cycle time reduction: Owner commitment in projects was considered the most important driver for cycle time reduction [Fig. 3(a)]. Decision making and lack of commitment were ranked as the most important barriers followed by communication [Fig. 3(b)].
- Cycle time extension: Change in scope and client requests were the main causes for extending cycle time (Fig. 4).
- Preferred contracting strategy: Joint venture has been the preferred contracting strategy from the viewpoint of reducing cycle time. A fixed price type of contract was the least preferred by the respondents (Fig. 5).

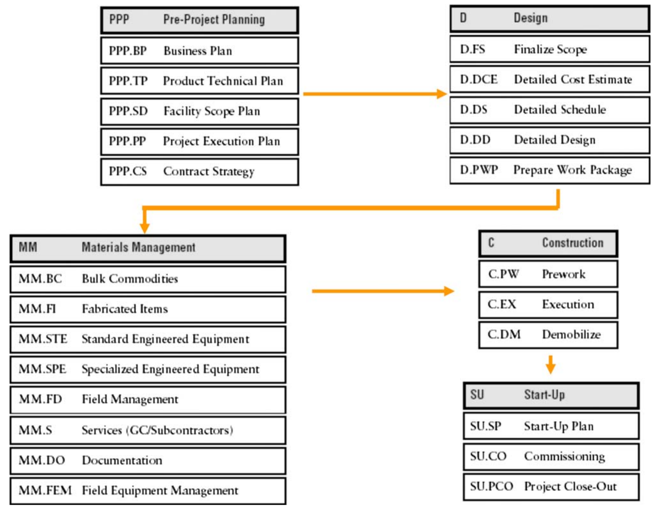

Fig. 1. EPC Macro model

- Typical long duration activities: detailed design (D.DD) and construction execution (C.EX) were ranked as long duration activities on a typical project (Fig. 6). Fig. 6, shows the various macro phases of a typical construction project and respondents were asked to indicate the top five long duration activities in their opinion. Refer to Fig. 3 for the list of elements along the *x* axis in Fig. 3.
- Type of projects that could benefit from implementing radical reduction: Respondents seemed to agree that almost all types of projects would benefit from cycle time reduction techniques (Fig. 7).

Questionnaire III was targeted at the case study participants and was designed to identify best practices that were used on these projects and if applied broadly and routinely, would improve delivery time across the general construction industry. This questionnaire was divided into two parts. Part I dealt with three important project parameters—safety, cost, and quality, whereas, Part II presented a tabular list of "insights," essential for radical reduction of project cycle time, as obtained through the case studies that were conducted. It was sent to the seven (7) case study teams. All seven responses are analyzed in this section.

The purpose of the first part was to determine if reducing cycle time had any adverse impact on safety, cost, and quality in the case study projects. The respondents (case study project teams) were asked to rate if the "overall safety, quality, and cost" on the case study projects were "better, equal, or reduced" as compared to other similar projects. Four respondents indicated that the overall safety was better as compared to other projects, whereas two indicated that it was the same, and one project team felt that the overall safety was reduced due to the accelerated nature of the project [Fig. 8(a)]. For overall quality, four respondents indicated that they achieved better quality on the case study project than other comparable projects whereas three indicated the overall project quality remained unchanged. None of the participants reported reduced overall quality [Fig. 8(b)]. Finally, five respondents indicated that compared to other projects, where reduction was not a driver, the case study project showed a 5–20% decrease in cost, one respondent indicated that they achieved greater than 20% reduction in cost, whereas one respondent indicated that

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Table 4. Case Study Summaries Identified by Questionnaire I

Project name	Offered by	Cost (million $)	Standard duration (months)	Actual duration (months)	% reduction	Benchmarking
A	R Chemicals	9.0	12	9	25	IPA
B	R Chemicals	45	21	10	52	NA
C	S Engineering	335	28	20	30	NA
D	T&M	16	12	6	50	NA
E	AZ Petroleum	13	18	9	50	IPA
F purification plant	UV Incorporated	94	60	36	40	NA
M biotech	LS Construction	25	4	2	50	Internal

their project had a 5–20% cost increase because of reduction [Fig. 8(c)].

The purpose of the second part of the questionnaire was to collect respondents' opinions on insights obtained from all the seven case study responses. The collective insights from the seven case studies were compiled by the research team and shared with the respondents. The respondents were asked to indicate whether they *agreed* or *disagreed* that the mentioned insight could be a valuable cycle time reduction technique (Fig. 9). All the respondents agreed that blanket project agreement, clear alignment, developing a plan and working as per it, early advances in engineering, project execution methodology, SWAT team (for rapid response) and key team were important techniques for achieving radical reduction in project cycle time. A SWAT team is a dedicated management team with the specific task to resolve problems quickly. A majority of the respondents disagreed that "skipping preliminary estimate" was an important radical reduction technique. Clearly, speed could be gained in the short run by skipping some steps of project development. However, this is seldom wise, and most project managers do not recommend skipping steps to accelerate the project unless it is discovered that these steps actually do not provide commensurate value. For detail explanation on each insight, refers to CII Research Report 193-11 (CII 2004).

Essence Applicability Matrices

The EAM were developed in order to determine the applicability of the identified reduction techniques (i.e., schedule reduction techniques, management techniques, and CII best practices) in different project phases (i.e., EPC macro model illustrated in Fig. 1). Accordingly three EAMs were developed: (1) CII best practices; (2) schedule reduction techniques; and (3) management techniques.

The first matrix lists all the 11 best practices as identified by CII, and the respondents were asked to indicate either "yes" or "no," whether they felt that the 11 best practices could be applied to the 24 macro activities (see Fig. 1) of the five project phases namely: PPP, D, MM, C, and SU. A particular reduction technique

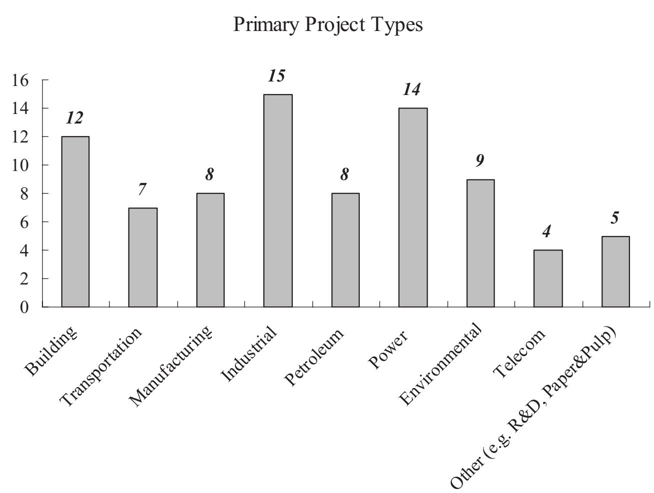
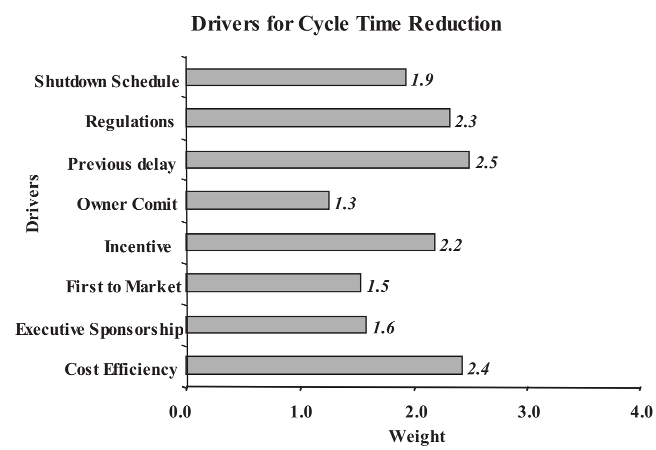
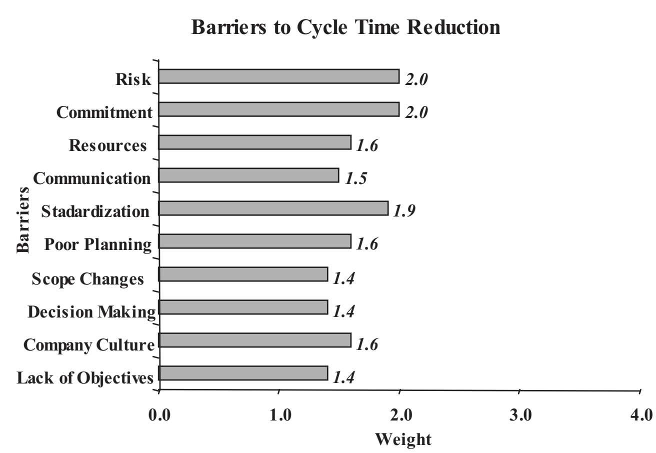


Fig. 2. Types of projects undertaken by the respondents



(a) Drivers for Cycle Time Reduction



(b) Barriers to Cycle Time Reduction

Fig. 3. Drivers and barriers for cycle time reduction

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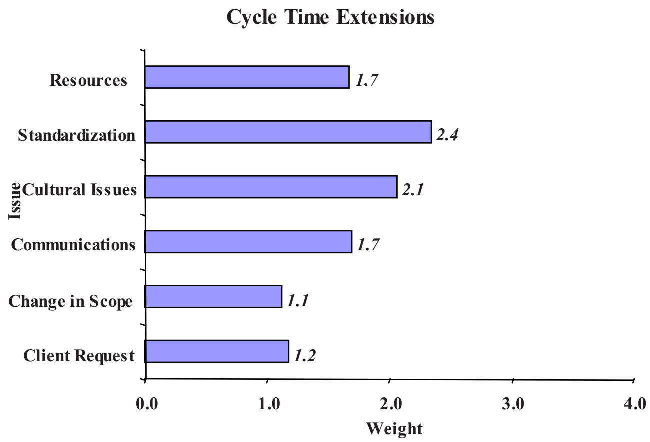

Fig. 4. Cycle time extensions

could be applicable to more than one macro activity and hence the maximum responses that a single person could give to this matrix is $11 \times 24 = 264$ responses, assuming he/she felt that all the best practices could be applied to each one of the macro activities.

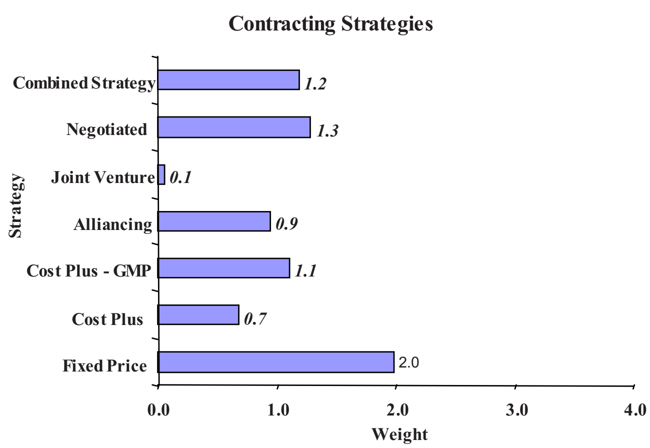

Fig. 5. Preferred contracting strategy

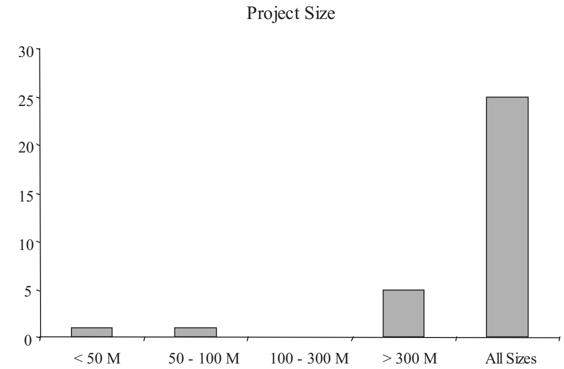

Fig. 7. Projects that would benefit most from cycle time reduction techniques

Similar to the matrix discussed earlier for the CII best practices, EAMs were developed for the schedule reduction techniques and management techniques.

The EAMs were sent to the research team members and also the case study respondents. As mentioned earlier, the respondents were asked to identify techniques that could be applied during a particular project phase to achieve radical reduction in project cycle time. Eleven responses were received from the team members and 15 from respondents participating in the case studies. For each matrix, the total response to each of the five macro activities—PPP, D, MM, C, and SU—were computed. In addition, scores were computed for all reduction techniques as per the five macro phases (refer to Fig. 1). The higher the score of a reduction technique, the better suited it is for achieving radical reduction in project cycle time.

Fig. 10 illustrates the top ten CII best practices, schedule reduction techniques, and management techniques identified through the EAMs based on team and case study responses. Material management, constructability, and alignment have been ranked as the top CII best practices [Fig. 10(a)]. Use of electronic media and employee involvement have been ranked as the most important schedule reduction techniques and management techniques, respectively [Figs. 10(a and b)]. It was determined that material management was a very important phase for implementing CII best practices as well as schedule reduction techniques,

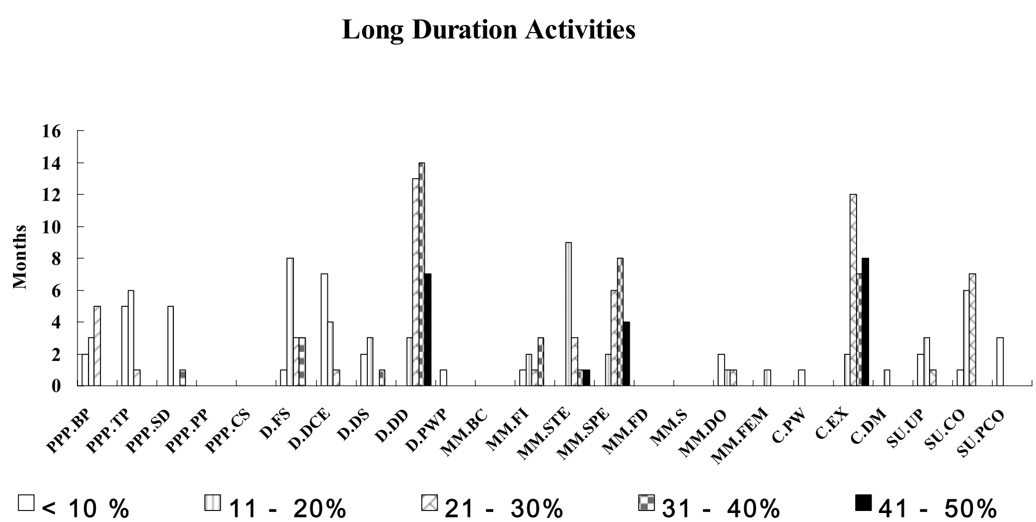

Fig. 6. Typical long duration activities

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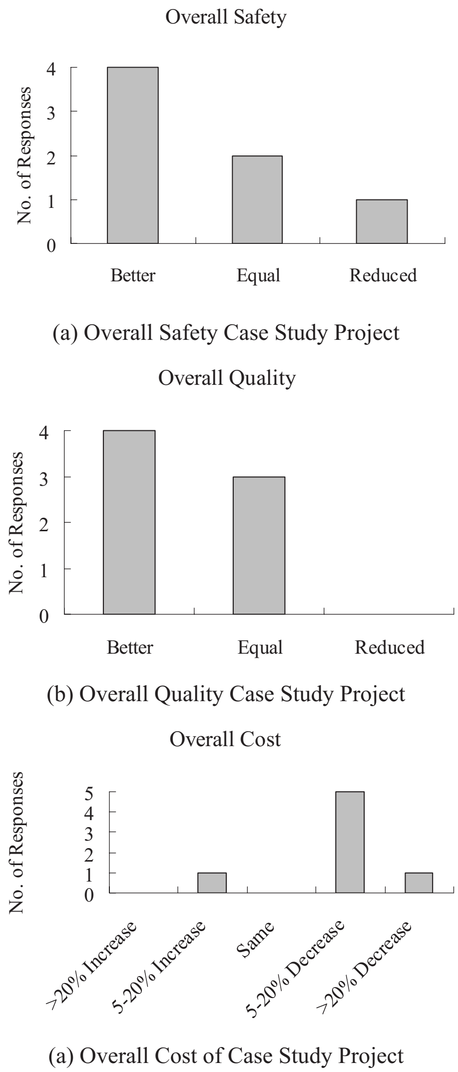
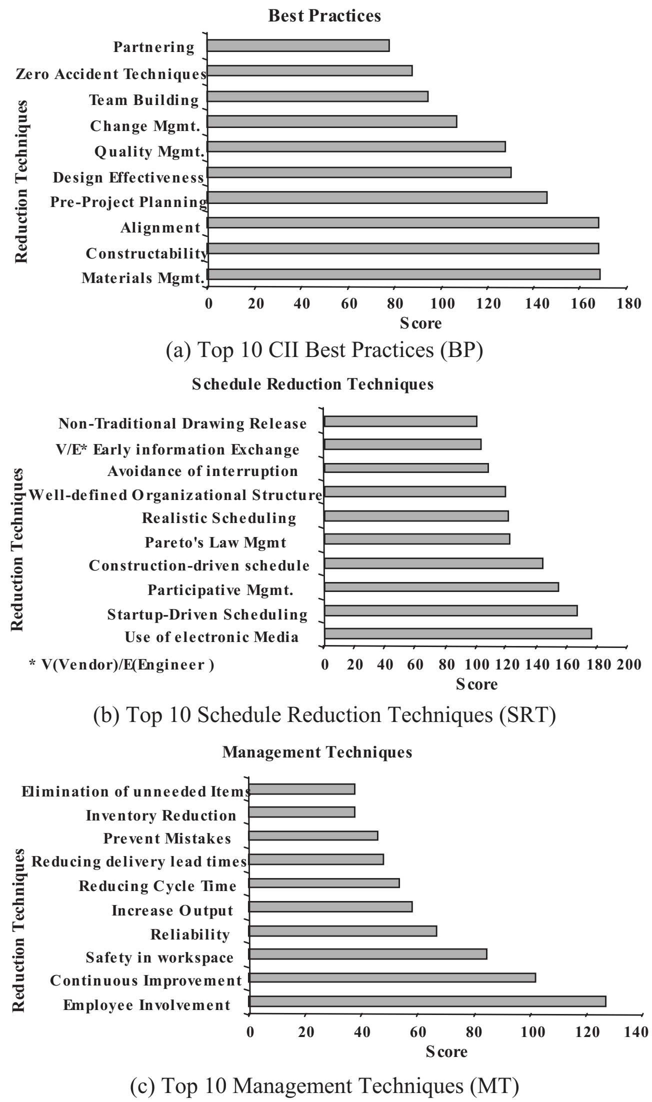


(a) Overall Safety Case Study Project

(b) Overall Quality Case Study Project

(a) Overall Cost of Case Study Project

Fig. 8. Overall safety, quality, and cost on case study project



(a) Top 10 CII Best Practices (BP)

(b) Top 10 Schedule Reduction Techniques (SRT)

(c) Top 10 Management Techniques (MT)

Fig. 10. Top 10 CII BP, SRT, and MT based on EAM

whereas design was the most important phase for implementing management techniques.

EAM—Project Phase Comparison of Results

The results obtained from the EAM data (compiled from the team response and the case study responses) was evaluated for each project phase. The data were converted to a percent score for evaluation. Fig. 11 shows a side-by-side comparison of the importance (in terms of percentage) of a particular project phase, simultaneously implementing CII best practices, schedule reduction techniques, and management techniques. As shown in Fig. 11(a), material management ranked very high at 32% as per the team responses and also case study responses. In case of schedule reduction techniques, material management and preproject planning were important project phases as ranked by the responses [Fig. 11(b)]. In comparing project phases, simultaneously implementing management techniques, design and preproject planning were the important project phases [Figure 11(c)].

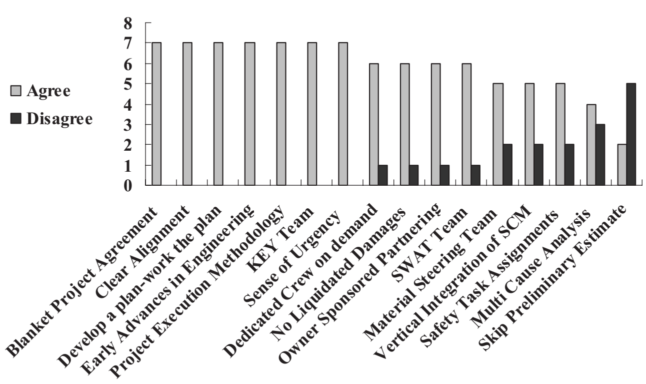


Fig. 9. Insights

EAM—Top Reduction Techniques Identified

Table 5 illustrates the top reduction techniques over the project cycle as per team responses and case study responses. Highlighted activities indicate that they were common to both the responses. The "reference" column indicates whether that particular reduction technique is a CII best practice, schedule reduction technique or a management technique. However, it should be noted that startup-driven scheduling, which was ranked as the most important reduction technique (rank one) by the case study

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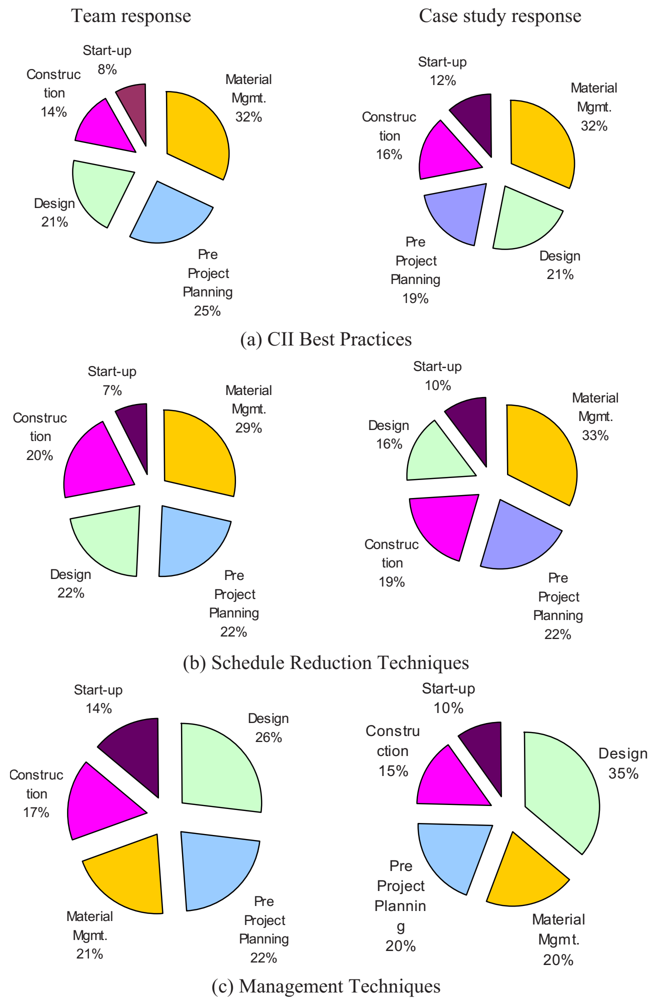

Fig. 11. CII BP, SRT, and MT based on project phase comparison

respondents fails to appear in the top 15 list of the team responses. Also, avoidance of interruption and team building that have been considered as important by the team respondents fails to find a place in the top ranked activities as per the case studies. Similarly, employee involvement has been considered as an important reduction technique by the case study respondents, but not by the team respondents.

Analysis of the Case Studies

The purpose of the case studies was to establish best practices and radical reduction techniques used by the construction industry to achieve radical reduction in project cycle time and to compare them with results obtained through the questionnaire survey and literature review done by RT193. Case studies clarified certain issues (i.e., barriers raised through Questionnaire II) and also helped identify radical reduction techniques through insights as discussed under Questionnaire III. The selection process through Questionnaire I identified seven case studies that were conducted over a period of four months (refer to Table 4). The results of the seven case studies are discussed in this section under the following categories: (1) interview observations/highlights; (2) factors attributed to helping cycle time reduction; (3) CII best practices identified; and (4) insights derived from the case study. Each case study was conducted for approximately 4 h. The essential criterion for selecting a project case study was that the project should have achieved a minimum of 25% cycle time reduction. The percentage reduction varied from 25% to as high as 60%. For detailed information on the case studies refer to CII 193-11 (2004).

Case Study: Project A Offered by R Chemicals

- *Project owner:* R Chemicals is a leading science and technology company that provides innovative chemical and agricultural products.
- *Project description:* 20 in. (50.8 cm) carbon steel, above

Table 5. Top 15 Radical Reduction Techniques

Team response			Case study		
Reference	Activities	Score (%)	Reference	Activities	Score (%)
BP	Constructability	9	SRT	Startup-driven scheduling	8
BP	Alignment	8	SRT	Use of electronic media	7
BP	Materials management	7	SRT	Participative management	6
SRT	Use of electronic media	7	BP	Materials management	6
SRT	Avoidance of interruption	7	SRT	Construction-driven schedule	6
BP	Team building	6	MT	Employee involvement	6
BP	Quality management	5	BP	Alignment	6
BP	Preproject planning	5	BP	Preproject planning	6
BP	Design effectiveness	5	BP	Constructability	5
SRT	Single EPC contractor	5	SRT	Realistic scheduling	5
SRT	Participative management	5	SRT	Pareto's law management	5
BP	Change management	5	BP	Design effectiveness	5
SRT	Construction-driven schedule	4	SRT	Well-defined organizational structure	5
BP	Disputes resolution	4	SRT	Lump-sum contract	5
M	Continuous improvement	4	SRT	On-traditional drawing release	5
SRT	Freezing of project scope	4	BP	Quality management	5
SRT	Pareto's law management	4	SRT	Vendor/engineer early information exchange	5
SRT	Well-defined organizational structure	4	SRT	Empowerment	5

Note: BP=best practices; SRT=schedule reduction techniques; MT=management techniques; and EPC=engineering, procurement, and construction.

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ground insulated pipeline, supplying 300 psi (2,068,427 pa) steam to process plant, 3.5 mi (5.6 km), three water crossings.
- *Driver for radical reduction in project cycle time:* environmental considerations—Clean Air Act compliance

At R Chemicals, a typical project team consists of the project manager, manufacturing representative, project engineer, and process control representative. All projects originate from a division and a project manager is assigned to each division depending on the market conditions. A typical project goes through different stages and could be canceled at any stage. The following are the different stages in a project life cycle: (1) Stage I: preplanning; (2) Stage II: detailed work, purchasing, engineering; (3) Stage III: material management, design and construction; and (4) Stage IV: start-up, wrap-up, and completion.

Interview Observations/Highlights

The contract was hard bid and innovative techniques were used for detailed design, as well as for the construction phase of the project. The construction schedule and master project schedule are initiated at Stage I of the project life cycle. The construction manager and project engineer got involved only at Stage II of the project. Constructability was very important to R Chemicals and many unique techniques were used during this project. One of them being a technique called value improvement packages in which a dedicated individual is assigned to learn about all the new team building and management exercises. This person then trains the others in these new exercises. To show a sense of harmony, the entire crew was treated to lunch occasionally. The other technique is "global project methodology," which is a detailed process used on all projects. It includes "contracting strategies, matter plan schedule, procurement plan, construction plan, etc."

SWAT Team is R Chemicals terminology for a dedicated management team with the specific task to resolve problems quickly. It is essentially comprised of individuals at the level of project managers. R chemicals has a capital program of approximately $1.2 billion and this justified conducting most of the engineering in-house to be cost effective. It has a large purchasing organization, which helps them get better prices and ultimately cost saving. Multiple parallel contracts were initiated to realize radical reduction in project cycle time. The project was judged to be easy from an engineering, as well as construction, point of view. Safety was the main concern and was stressed throughout the project. It was suggested that the techniques used for radical reduction would have been equally effective on a more complex project.

Factors Attributed to Helping Cycle Time Reduction

(1) Detailed construction plan; (2) selection of laborer contractor early; (3) ordered pipe, valves and other long lead items early; (4) followed a different method of welding to reduce welding time by 50%; (5) prefabrication and standardization of pipe racks and pipe loop elements; (6) preassembly of bridge support in river crossing, transported to site and raised in place; (7) improved material staging; (8) sticking with the plan and making the plan work; and (9) project steering team met weekly and had good communication between them.

CII Best Practices Identified

(1) Preproject planning; (2) constructability; (3) team building; (4) materials management; and (5) quality management.

Insights Derived from the Case Study

(1) Master project schedule; (2) multiple parallel contracts; (3) value improvement package; (4) SWAT team—dedicated management team with a specific task to resolve problems quickly. It is essentially comprised of individual at the project manager's level; and (5) project execution methodology—detailed process used in all projects. It could have contracting strategies, master plan schedule, procurement plan, construction plan, as well as several different plans.

Case Study: Project B Offered by R Chemicals

- *Project owner:* R Chemicals is a leading science and technology company that provides innovative chemical and agricultural products and services.
- *Project description:* Modifications to an existing plant that manufactured synthetic rubberized roofing material.
- Driver for radical reduction in project cycle time: Product to market.

Interview Observations/Highlights

There were four different engineering companies involved in the project. Colocation of over 100 engineering personnel mobilized to do detailed engineering work at one location at a cost of $1 million. Engineering hours were greater than budgeted hours, however, savings came from negotiating a better (lower) rate. MicroStation (Bentley, USA), which is a CAD software product for two- and three-dimensional (3D) design and drafting, was used for all drawing. There was no liquidated damages clause for the project.

In addition, there was no formal constructability program. As the project involved extensive demolition and reconnecting of conduits and wires, everything had to be strategically planned. A Lot of energy and teamwork was required and a dedicated team was employed for this project. Materials management was carried out along with priority alignment. Problems were handled through the SWAT team approach. The cost of such a project is not more than an average project of this kind. One senior project manager and four project mangers were employed for this project. They concluded that the strategies and techniques used for this project could be used on another project, even if it was not in a crisis mode.

Factors Attributed to Helping Cycle Time Reduction

(1) No liquidated damages; (2) 24 h change approval; (3) SWAT team; and (4) resident contractor.

CII Best Practices Identified

(1) Preproject planning; (2) alignment; (3) materials management; (4) team building; (5) partnering; (6) quality management; and (7) change management.

Insights Derived from the Case Study

(1) No liquidated damages; (2) 24 h change approval; and (3) SWAT team.

Case Study: Project C Offered by S Engineering

- *Project owner:* S Engineering Corporation is a leading global engineering, construction and consulting company specializing in infrastructure development in the fields of energy, water, and information.
- *Project description:* 2–1 combined cycle, F class, power plant.
- *Driver for radical reduction in project cycle time:* Product to market.

This project was delivered by the joint venture of S Engineering and Z Construction. S Engineering is the lead but it is a 50–50

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joint venture. This project used an EPC negotiated lump-sum contract with an incentive clause for early completion. If the project can be completed in 21 months, the owner promises to pay a bonus of $3.7 million. About 1 year after the project started up, the project was accelerated for a 20-month duration. The owner wanted to be sure that they could have a plan which was 100% running by June (21 months after start-up) and hence set for project completion goal to May (20 months after start-up) to have a month to work out the bugs. The cost of acceleration is $5 million. There was no liquidated damages clause for the project. All risk was born by the owner. There were more than 1,200 people working on the project. 6,000 S Engineering drawings and 14,000 vendor prints were created. Eighty-five vendor contracts were signed. The start-up took about 275,000 man-hours, whereas construction required 1.9 million man-hours.

Interview Observations/Highlights

The joint venture relationship worked very well. The team had a lot of challenges getting all the permits approved. The power plant was in the natural drainage path, hence they had to make some modifications (i.e., modify the drainage to flow along a different path and then merge it with the original path). Essentially, it was a zero discharge site (i.e., no water could go out of the site, so evaporation ponds had to be constructed). Early advances were made in engineering (underground design) as the team waited for all other equipment to come in. This was a huge effort well executed by Z Construction and was done even before acceleration was decided. Many estimates had to be done, however it worked well. This later became a key factor in reducing cycle time. The owner was very supportive of the partnering concept and shared a lot of time with the high performing team. Good relations were also maintained with vendors. Team shirts were made for all team members including vendors.

S Engineering had a “blanket project agreement” (BPA) with vendors, which helped in faster procurement. As per this approach, they selected vendors even before the start of the project and worked with them from the engineering viewpoint. As engineering was almost done, the reduction in schedule (due to acceleration) had to come from construction. One individual was dedicated to procurement of supplies coming in from different parts of the country including outside the United States.

All members of the team had access to complete project information, using a tool called “Documentum,” which stored all data electronically. Data could be accessed via laptop and there were locators in all communications that took the user directly to the required document. Drawings were transferred to the site electronically, saving printing and delivery costs. The normal 2–3 days turn around time for printing and shipping documents was now being saved.

Factors Attributed to Helping Cycle Time Reduction

Modularization saved SZ a lot of time as well as money. They are committed to trying it on other projects as well. Start up engineers participated in 4 weeks of factory testing of various control systems before shipping it out. This reduced failure rate. Also, a joint venture approach helped facilitate the ability to accelerate and take on the extra work. Also more than typical on-site engineering support was considered a contributing factor for radical reduction.

CII Best Practices Identified

(1) Preproject planning; (2) alignment; (3) constructability; (4) design effectiveness; (4) materials management; (5) team building; (6) partnering; (7) quality management; and (8) zero accident techniques.

Insights Derived from the Case Study

(1) Owner sponsored partnering; (2) no liquidated damages; (3) early advances in engineering (till before equipment came in); (4) BPA (blanket project agreement)—faster procurement; and (5) personnel devoted exclusively to procurement.

Case Study: Project D Offered by T & D

- *Project owner:* T Incorporated is a recognized leader in the development, distribution, and marketing of beauty care, snacks and beverages, and health care products. T Incorporated markets nearly 300 brands in more than 160 countries around the world.
- *Project description:* Double the capacity of existing mixing/bottling plant to incorporate the newly acquired D care product line.
- *Driver for radical reduction in project cycle time:* Product supply/business merger/consolidation cost savings.

The T Incorporated plant was constructed in 1956 as the largest healthcare facility for T Incorporated in the world. Incorporating D care with the existing facility would require doubling of plant capacity. The main objective of this project was product supply consolidation. All the transition costs had to be absorbed in the given fiscal year for book keeping purposes. Also D care products had a batch cycle time 4 times that of products manufactured at the Midwest plant and hence this had to be improved.

Interview Observations/Highlights

Active project management was pursued with front end loading being one of them. There were a lot of known, as well as unknown, factors. The contingency plan was to keep the acquired facility running and production going. A feasibility study was started in the months of December/January and went all the way through February. Four months of work was crammed into 2 months. As per the integrated plan, every single down time was used constructively; focus was on 80/20 cost items as the key to achieving the schedule. Also “known” and “unknown” bins were established and each was dealt separately. The organization held off the strong desire to jump into “execution” and instead waited until conceptual design was complete and sourcing decisions were made before going into action.

Increased safety was observed on this project. Some of the steps initiated were having a safety orientation, on-site drug testing, implementing safety task assignments, and conducting behavior observation surveys. There were safety technicians to provide support for all the shifts. Besides all these, job safety analysis was started during the planning phase itself.

Constructability resulted in a total of $950,000 in savings. Construction personnel were involved right from the definition stage of the project. This encouraged out of the box ideas. There were coordination meetings with large groups every week. Many methods and techniques were used for schedule compression such as developing the EPC fast track schedule early. Overtime and second shift work was performed as and when needed, but not done on a routine basis. Change management was handled weekly and prior to construction. Standard equipment and materials were used. All engineering was done on site. Modularization was not used because of the schedule; however an attempt was made to use standard design and standard equipment.

Construction start-up documentation was developed early in the project, which identified systems; and developed start up plans. There was excellent coordination between the start-up team, operations, construction, and engineering. High quality in-

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stallation avoided rework. Implementation for reduction in cycle time had barriers like equipment and materials. They had to wait for the equipment to get there before the project could be started.

Factors Attributed to Helping Cycle Time Reduction

(1) Plant safety resources involved in the design review process; (2) single points of contact—tech engineers lead the process, versus plant contact; (3) designated days to work on specific projects—engineering, construction, PM, operations; (4) single point-dedicated contact for all purchasing; (5) cell phones for quick communication; (6) schedule driven decisions, all upper management available; (7) weekly overall project integration meeting that includes engineering, PM construction key resources; and (8) colocation of T Incorporated tech engineer and construction.

CII Best Practices Identified

(1) Preproject planning; (2) alignment; (3) materials management; and (4) quality management.

Insights Derived from the Case Study

(1) Material steering team; (2) drug testing; (3) safety task assignments; (4) behavior observation survey; and (5) multicause analysis.

Case Study: Project E Offered by AZ Petroleum

- *Project owner:* AZ Petroleum is an international integrated energy company and one of the largest energy companies in the United States. AZ Petroleum is known for its technological expertise in deepwater exploration and production, reservoir management and exploitation, and 3D seismic technology. It operates in more than 40 countries and has assets of $80 billion.
- *Project description:* liquefied petroleum gas (LPG) to be moved over a distance of 55 miles from location A to location B using a 12 in. pipeline, 1,440 psi.
- *Driver for radical reduction in project cycle time:* Business decision to ship LPG on self-owned/operated pipeline versus leased pipeline.

AZ Petroleum is an international integrated energy company and one of the largest energy companies in the U.S. AZ Petroleum moves LPG, generally through a third party. There was a need to develop a pipeline to take LPG from Location A to Location B and bridge it back to Location A during the summer months. Location B had many underground caverns for storage. A 12 in. pipeline was required for achieving this. Actual cost ($10 million) was less than the estimated cost ($12.1 million). The preliminary cost estimate was below the prevailing industry standard, and not an inflated number.

Interview Observations/Highlights

The project was awarded to an EPC contractor as a cost-plus contract and they were involved with the project right from the start. The team skipped the preliminary estimate (as AZ Petroleum had done similar projects earlier they were confident about doing this one also without any additional risk; the same integrated team was used for other projects). Having had an alliance with AZ Petroleum for almost 12–13 years, the F construction crew knew everybody on the team. Several of their employees even worked at the AZ Petroleum office.

Regular team building exercises were conducted with lunches, recognitions, etc. An electronic access program was used for daily roll calls. There was no use of personal digital assistants, because the inspectors were technology aware, but not "tech savvy." Construction time was not changed, and there was no fast tracking. Neither was the schedule altered or modified in any way. Welding of pipes was on critical path. The selected contractors had to have a good safely record. If their record went down, they were struck off the preferred contractors list until they improved their records. Most contractors worked overtime especially as that was their preferred method of working. They had a six-day week, and a ten-hour day.

There were no cost penalties or premiums levied for finishing any later or earlier. The only penalty was that the contractor would not be given the next project if he failed to meet deadlines on this project. The project team had worked together on similar projects and was able to use previous designs as a reference. The preliminary estimates were skipped on this project as the owner had worked on similar projects with the same team. Also, the team was confident that they could repeat a similar performance on other similar projects, but any further improvements in cycle time would be almost impossible.

Factors Attributed to Helping Cycle Time Reduction

(1) Skipped preliminary estimate; (2) no increase in cost; (3) good support by vendors; (working with them for a long time); (4) very favorable terrain for work and good weather; and (5) all contractors work overtime (preferred method of working).

CII Best Practices Identified

(1) Preproject planning; (2) constructability; (3) materials management; (4) team building; and (5) partnering.

Insights Derived from the Case Study

(1) Skip preliminary estimate; (2) same team for years (very little change); (3) dedicated crew available on demand; and (4) selected list of contractors allowed to bid.

Case Study: Project F Purification Plant Offered by UV Incorporated

- *Project owner:* UV is one of the world's leading experts on power, water, and wastewater issues,… With more than $975 million in revenue, and 6,500 specialists in 36+ countries providing industry-leading solutions to municipalities, government agencies, multinational companies, industrial concerns, and military organizations worldwide.
- *Project description:* 40 MGD plant, 120 MGD intake structure, raw water intake lines 66–78 in., 2 mi of 42–84 in. steel/DIP transmission mains.
- *Driver for radical reduction in project cycle time:* Groundwater reduction credits—Environmental Protection Agency (EPA)—Regulatory Requirements.

In early 2000, the city of YA (name withheld) issued a request for proposal (RFP) to solicit ideas for a new water purification facility. A performance criterion was stipulated (i.e., "x" millions of gallons per day (mgd) of raw water intake and output of "y" mgd of treated water). The city did not have to comply with EPA regulations (converting from groundwater to surface water) until a much later date, but decided to start the project early to "book credits."

Typical duration for city projects of similar size and scope is 1 year for RFP +6 months for contract negotiation +1 year for design +3 years for construction. Design was completed in 6 months, whereas construction through acceptance is schedule to

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be completed in 2 years. A 50% reduction in design phase and 33% in construction phase was realized although there was no significant reduction in overall delivery time due to "regulatory hold ups." The city exercised a great deal of caution, as it was the first design/build/operate project they had undertaken. It was also the largest design/build/operate project undertaken in the history of UV Company.

Interview Observations/Highlights

Teams of dedicated and experienced people were assembled from various office locations like Cleveland, Houston, Florida, and California. The rest of the team moved out of regular offices to a special suite of offices to avoid distractions. There were weekly web-based net meetings and conference calls. Other people were flown in from other locations for "team building" exercises. The instrumentation, architecture, and electrical were done at satellite locations. Brainstorming sessions were conducted to evaluate potential for risk at every stage of the project. A risk management strategy was developed and a formal risk evaluation was undertaken using Monte Carlo simulation. Regulatory agencies were brought on board very early to better understand their needs and concerns and incorporate a solution in design that would speed up permissions.

Engineers were moved to the site and the construction team was assembled with people experienced in contracting. Some employees were specifically assigned to quality control/quality assurance. The UV Company acted as the general contractor, procured all equipment, simultaneously not self-performing any work. The subcontractors were contracted through competitive bidding in most cases. Experienced supervisors were hired. As procurement was going to be the key, an outside, experienced firm was hired. Equipment replacement and maintenance was planned into the operation portion of the contract. Modularization strategy helped in construction. The longest lead times were between 90 and 120 days. Several firms were pooled to shrink the lead times on equipment. Most other items had a lead time of 30 days or less. "Zero" loss time was recorded in construction.

Factors Attributed to Helping Cycle Time Reduction

(1) No bonus or incentive, high liquidated damages; (2) dedicated team; (3) 3D design; (4) formal risk evaluation; (5) Web-based net meetings; and (6) regulatory agencies consulted early into the design phase itself, hence fewer hold-ups later.

CII Best Practices Identified

(1) Preproject planning; (2) alignment; (3) constructability; (4) design effectiveness; (5) team building; and (6) quality management.

Insights Derived from the Case Study

(1) High liquidated damages and (2) 3D design.

Case Study: Project M Biotech Facility Offered by LS Construction

- *Project owner:* LS Construction is a global industrial engineering and construction leader with more than $1 billion in annual revenues and 3,000 salaried professionals worldwide. LS Construction was selected by M Biotech to design a biotech research and development (R&D) facility. Working closely with M Biotech research scientists and operation specialists, LS Construction produced a complete conceptual and preliminary basis of design for the new facility to be housed in an existing building shell on the site.
- *Project description:* A biotech R&D facility to be housed in an existing building shell on the site.
- *Driver for radical reduction in project cycle time:* Product to market and increased growth of company's R&D.

Initially, the project was being handled by a construction company T. The owner had a particular product they thought was key to their business model. They had a tight budget, and the owner decided to accelerate the project even though it would cost more money. However, the current team of T construction thought that it was impossible to complete the project in the owner's time frame and were replaced by LS. Based on the criteria the owner had given, LS performed value engineering and concluded that they could achieve the construction in two months time. When LS came on board, engineering was only about 30–40% done, although in the first meeting with M Biotech, they were told otherwise. Termination of contract T was handled by LS. Later, when LS agreed to the scenario it was found that work was only 35% complete and the plans were without any details as the owner had little construction experience. The LS team was put together with people selected based on their skills and previous experiences of meeting challenges. After mobilization, the LS team had 58 days to finish the project.

Interview Observations/Highlights

T construction had purchased some major mechanical equipment and systems for the job. The owner purchased all the laboratory equipment. The project was divided into two phases. For Phase I, most of the work was modularized construction. LS came in when almost all of the preproject planning was done. The location was also helpful as many subcontracting parties had their offices in that area. Subcontractor relations were good and most had past experience.

Drawings were all standard two-dimensional drawings. Modeling was done only for the second phase. Work was done 7 days a week performed in two 10-h shifts each day. A 500-activity schedule using Primavera was developed and updated weekly. Under normal circumstances, the project would have taken 8 months utilizing a 40-h week. The quality was a bit compromised because of the accelerated schedule. There were to be no liquidated damages, however, there was a bonus if work was finished early. Work was completed a day in advance and hence no substantial bonus was received. Work was monitored daily with subcontractor coordination meetings. There was a full time person on site to strictly enforce and ensure safety. There were no serious problems on the project. Also there were not many change orders as a "not to exceed contract value" was issued to the subcontractors. Critical items were the long lead items like HVAC equipment. The only risk to LS was that if they failed to perform. They would not get the next phase. Also at stake was the company's reputation.

The most important factor was to be able to put together a good project team with engineering and construction together to complete the schedule in time. A similar type of project from concept to operation would take 6 months if done on fast track and 8–10 months, in a reasonably controlled environment. The owner found the work quality satisfactory and well worth the money invested.

Factors Attributed to Helping Cycle Time Reduction

(1) Value engineering; (2) 10-h shifts; 7 days a week; (3) advance payment to subcontractors; and (4) modularized construction.

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CII Best Practices Identified
(1) Quality management; (2) constructability; and (3) materials management.

Insights Derived from the Case Study
(1) Modularization; (2) expedited subcontractor payment; and (3) 7 day a week, two shift schedule, does not have to compromise safety.

Conclusions

The objectives of this research were to investigate methods and processes related to shortened cycle times including supply chain, design, and contractual changes for capital project delivery systems. This research helped in identifying practices that could improve project delivery time, barriers to implementing these radical reduction techniques, and prioritization of activities based on their potential for cycle time reduction. For the purpose of this research, radical reduction was defined as a reduction of 25% or more in overall project cycle time (preplanning through startup) when compared to current industry standard for projects of similar size and scope. Schedule reduction techniques, CII best practices and management techniques were identified through a comprehensive literature review.

The starting point of this research was a comprehensive literature review that assisted the research team in identifying a set of criteria that were important to establish the state of practice and evaluation of project cycle time reduction techniques. Schedule reduction techniques, CII best practices currently used in the construction industry and management techniques applied in other industries such as manufacturing, processing and automotive industry were studied. This data assisted in developing Questionnaire I that helped identify companies that have implemented methods and techniques to radically reduce project cycle time. Questionnaire II was a follow-on questionnaire after responses to Questionnaire I were received and Questionnaire III was a follow-up to Questionnaire II and the seven case studies that were conducted.

Radical reduction in project cycle time is achievable. This research demonstrated that selective and timely use of established CII best practices, schedule reduction techniques, and management techniques decreases project completion time, improves project performance, and does not increase project cost. The following conclusions were identified in projects that successfully achieved greater than 25% reduction in project cycle time.

1. Radical reduction in project cycle time requires four key drivers. The first two are significant owner responsibilities describing the need (or "why") and must be maintained throughout the life of the project: A compelling need and Owner commitment. The second two drivers represent the execution (or "how") and are the joint responsibility of the owner and contractor: high performance team and detailed project planning.
2. Use of CII best practices are key components to radical reduction in project cycle time. This was confirmed through case studies that utilized 7 of 11 best practices.
3. The CII best practices most frequently and successfully used in the case studies are: (1) alignment; (2) material management; (3) preproject planning; (4) constructability; and (5) design effectiveness.
4. In conjunction to CII best practices, management and schedule reduction techniques from other industries are required to achieve radical reduction. The top five include: start-up driven scheduling, use of electronic media, participative management, construction-driven schedule, and employee involvement.

In summary, the following recommendations relative to radical reduction of project cycle time could be made. If radical reduction of project cycle time is the goal, the owner is the primary force in the process and must stay committed from conception to completion. In addition, to achieve this goal, the four key ingredients (1) compelling business need; (2) owner commitment; (3) high performance team; and (4) detailed project planning must exist for project success. Virtually every construction manager will achieve certain benefit in schedule, cost, safety, and quality from utilizing the CII best practices, management techniques, and schedule reduction techniques identified in this research, even when "radical" reduction is not necessarily the goal.

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