Measuring the Effects of a Step Change in the EPC Process

by

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(ABSTRACT)

Strategic procurement items, including complex engineered equipment and systems essential for project performance, are frequently designed, manufactured, and delivered by suppliers who are outside the circle of cooperation between owner, engineer, and contractor. When suppliers are excluded from the design and planning stages of a project, much of the knowledge needed for successful design and integration is lost or underutilized. This research was done as part of a Construction Industry Institute sponsored project to develop and quantify a step change to the EPC process that will bring the supplier into the circle of cooperation between the owner, engineer, and contractor. The result was a step change entitled PEpC (Procure, Engineer, procure, and Construct). This research also sought to provide implementation guidelines for the recommended step change.

Through an examination of the literature, a survey of industry experts, and the review of four case studies, this research found that PEpC, the step change recommended by the Construction Industry Institute research team, may reduce both the time and cost required to complete a project. The anticipated savings in project duration is expected to fall between 10 and 15 percent, while the anticipated reduction in project direct labor cost is expected to fall between 4 and 8 percent.

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Chapter 1

Problem Statement

1.1 Introduction

Strategic procurement items, including complex engineered equipment and systems essential for project performance, are frequently designed, manufactured and delivered by suppliers who are outside the circle of cooperation between owner, engineer and contractor. The knowledge embedded in the design of this equipment, as well as the knowledge needed for its successful integration, operation, and maintenance is frequently lost or underutilized. The resulting inefficiencies impact the time, cost, and quality of construction as well as the lifecycle performance of constructed facilities.

Research Team 130 (the Research Team) was established and funded by the Construction Industry Institute (CII) in Spring 1996 to address this problem by identifying and recommending a step change in the well established Engineering, Procurement, Construction (EPC) process. The basic hypothesis for the research was stated as follows:

> It is possible to systematically reform relationships between Owner, Contractor and Supplier so that suppliers of strategic procurement items and/or systems can be included in the full EPC process and thereby have a significant positive impact on the time, cost and quality of construction as well as the lifecycle performance of constructed facilities.

The hypothesis was based on the belief that substantial savings in time and cost could be achieved if a step change in owner/contractor/supplier relationships made it possible for suppliers to contribute effectively in every phase of the total facility lifecycle. It was clearly felt that owners, engineers, and contractors would benefit from new and dramatically different relationships with suppliers, who should no longer be silent partners in the EPC process.

This research will contribute to testing the hypothesis proposed the Research Team by quantifying the time and cost savings that can be achieved through implementation of the recommended step change.

1.2 The Step Change

The creativity and inspiration of the Research Team led to the development of PEpC, the step change to the EPC process which forms the subject of the CII research project.

The change, in its simplest form "takes the big **P** for *procurement* in the **EPC** process and places it before the **E** for *engineering* so that supplier expertise can be integrated into all phases of the project from the very beginning" (Ruane 1997). In recognition of this change and the fact that a number of non-strategic procurement items would continue to be procured in the traditional way, the Research Team came to call the process **PEpC.**

1.3 The Challenge

Quantifying the outcome of a recommended change is an essential part of all research. The proposed change must have demonstrable benefits if it is to be accepted and successfully implemented. The process to measure the impact of the step change recommended by the Research Team involved three primary steps.

1. Develop a baseline for comparison using the model of the EPC process produced by CII Research Team 125 (RT125).
2. Model the impact of PEpC as anticipated by the Research Team.

3. Model the PEpC-like changes that four companies have implemented on actual projects.

1.4 Purpose of the Report

The report will provide a detailed and complete description of the research activities performed to quantify the effects of the recommended step change, present the results of the analysis, and provide core competency guidelines for implementation. It will also demonstrate the time and cost savings associated with the implementation of PEpC.

1.5 Research Objectives

The two main objectives of the research are as follows.

1. To model the anticipated effects of PEpC on the time and cost of the traditional EPC process and verify that these results are reasonably attainable by reviewing four case studies.
2. To provide guidelines for implementation based on the core competency work of CII Research Team 111 (RT111).

Attainment of these objectives required the following key research steps:

<u>Establish a baseline</u>. A baseline was established using a model of the EPC process developed by RT125. The model developed by RT125 consists of 180 activities with corresponding time and cost distributions for each, as well as sequence logic. This model was entered into the simulation program ABC-SIM (Back and Maxwell 1996) by RT 125. The work of RT125 will be described in further detail in Chapter 4.

This model was reviewed and adjusted to serve as a basis of comparison on which to evaluate the recommended step change.

Consult the experts. The Research Team was asked to provide their expert opinions regarding the anticipated impact of the step change on the baseline EPC model. The assessments provided by the Research Team were used to change the baseline EPC model and simulate the impact of the step change on overall project time and cost.

Conduct field studies. In an effort to provide additional support for the predictions of the Research Team, several field studies were conducted. Case studies were performed with companies that have completed projects where changes similar to the recommended step change were implemented. The information gathered from each case study was used to construct simulation models to measure the impact of the PEpC-like practices implemented in each study. These studies serve as a guide as to the attainability of the anticipated impacts identified by the Research Team.

Review of Core Competencies. In addition to quantifying the anticipated impacts of the step change, it is important to provide guidelines for its implementation. These guidelines are based upon the core competency work performed by RT111 and were further developed and specialized with the aid of several industry experts. The work performed by RT111 will be discussed in further detail in Chapter 7.

1.6 Scope and Limitations

The scope of the research is limited by the following:

1. It is primarily concerned with supplier relationships in the EPC process as practiced in the industrial construction sector. Other project delivery systems and other industry sectors certainly share many of the characteristics discussed, but fall outside the scope of the work.

2. The relationships between owner, contractor, and supplier are examined only in so far as strategic procurement items and/or systems are concerned. Relationships with suppliers of items that have little or no engineering content, short lead times, or no strategic impact on project success are not considered.

3. The baseline model developed by RT125 was accepted as the foundation used to measure the impact of PEpC. The data used by RT 125 to construct the baseline was used in its entirety, without change.

Time and practical limitations on modeling and measuring the impact of change to the EPC process impose limitations on the quantitative aspects of the research. Measures for the impact on construction time and cost have been possible subject to limitations that will be discussed in Chapters 5 and 6. Measures for improvement in quality and life cycle performance are outside the scope of the research.

1.7 Research Methodology

Meeting the challenge posed by the research requires that several different methodologies be used.

1. A classic literature survey was performed to study and understand instances where owners, contractors, or suppliers have developed innovative or different relationships within the EPC process; how this led to the development of PEpC; and how simulation techniques can be used to quantify the effects of the recommended step change.

2. The work done by RT 125 to model the time and cost characteristics of the classic EPC process was used to measure the effect of the proposed step change based on the research team members' expert opinions. The input of the Research Team was used to create simulation models for the purpose of quantifying the anticipated impact of PEpC on the time and cost of the traditional EPC process.
3. The EPC model developed by RT125 was also used to measure the effects of the PEpC-like changes implemented in the case studies that will be reviewed in Chapter 6. Simulation models were developed from the information provided in each case study. These models were used to quantify the impact of the PEpC-like changes to the EPC process.
4. The experience of the Research Team, together with their knowledge of the proposed change will be used to review the core competencies necessary for successful implementation.

1.8 Outline of the Report

The report will consist of eight chapters.

Chapter 1 – Problem Statement

This chapter will introduce the problem and outline the research methodology.

Chapter 2 – Literature Review

Chapter 2 will review the available literature regarding supplier relationships within the construction industry and in other industries as well. This chapter will also review the available literature on simulation as a tool for measuring the impact of the step change.

Chapter 3 – Definition of PEpC

This chapter will present the definition of PEpC developed by the Research Team. It will explain the principle tenets of the recommended step change.

Chapter 4 – Establishing a Baseline

Chapter 4 will define EPC, describe the work done by RT125 and how it was used to develop the baseline model, and show how the model developed by RT125 was altered to better suit this project. The method used to analyze the impact of PEpC will be described.

Chapter 5 – Theoretical Scenarios

This chapter will describe the instrument used to collect the research team members' input regarding the impact PEpC will have on the time and cost of a traditional EPC project. It will also discuss the results of the simulation models developed from the input of the Research Team.

Chapter 6 – Field Implementations

Chapter 6 will describe four projects where PEpC-like principles have been implemented. This chapter will also discuss the resulting effect on project time and cost for each case study, compare the results of the case studies, and compare the results of the case studies to the results of the theoretical scenarios.

Chapter 7 – Core Competencies Guidelines

Chapter 7 will address the core competencies identified in the research conducted by RT111. This chapter will also discuss how these competencies should be distributed among the owner, contractor, and supplier to achieve successful implementation of PEpC.

Chapter 8 – Conclusions

This chapter will present the conclusions to be drawn from this research, and present recommendations for further research.

1.9 Companion Documents

This document draws extensively from three companion documents in related areas.

1. McNeil, Blair W., (1997) *Reforming the Owner/Contractor/Supplier Relationship*, Virginia Tech, Blacksburg, VA.

    This document was used in part for the literature review (Chapter 2).

2. CII Research Team 125, (1997) *Cost and Schedule Impacts of Information Management*, Texas A&M University, College Station, TX.

    This document was used to establish the baseline model (Chapter 4).

3. CII Research Team 111, (1996) *Owner/Contractor Work Structure: A Process Approach*, Texas A&M University, College Station, TX.

    This document was used in the review of core competencies (Chapter 7).

Chapter 2

Literature Review

2.1 Introduction

There is a very substantial body of literature in the subject areas of the supply chain and supplier relationships. The vast majority relates to industries other than construction and relevance must thus be carefully screened especially when experience is drawn from industries that rely on high volume mass production processes. This literature will be used to establish a basis of understanding for the proposed step change.

The supply chain and supplier relationship literature will be presented under three headings. The first will provide a broad overview of the influence that total quality management (TQM) has had on the supply chain and supplier relationships. The second will narrow the scope of the material and present a review of literature published in procurement management journals. The third heading will narrow the focus even further by examining examples of innovative relationships that have been utilized in the construction industry.

Lastly, literature regarding the use of simulation as an analysis tool in construction will be reviewed. This review will explain the reason simulation was used as the modeling tool for this project.

2.2 Influence of TQM on the Supply Chain and Supplier Relationships

The pursuit of quality has been the driving force behind supplier relationships for many companies in many different industries. This has created a need for relationships more tightly linked with suppliers. The drive and responsibility for quality has spread throughout the entire supply chain, from the supplier of raw materials to the distributor of finished goods (Forker, Mendez, and Hershauer 1997). By developing relationships with suppliers, customers are better able to consistently achieve the desired level of quality without maintaining the resources in-house to oversee and improve quality.

AlliedSignal is a good example of a company that has developed supplier relationships in an effort to improve both quality and service. Raymond Stark, Vice President for Materials Management at AlliedSignal, describes the evolution of AlliedSignal's supplier relationships:

> 'Not long ago, buyers saw suppliers as adversaries that were to be squeezed for the lowest possible price and then clubbed for good quality…We were doing business on a contract by contract basis. Suppliers had to bid on every piece of business they got. We had no continuity, no supplier improvement programs, and no relationships' (Minahan 71, 1996).

Today, AlliedSignal has reduced the size of their supplier base from 10,000 to less than 3000 and has buying teams working with suppliers to tackle quality issues (Minahan 1996).

Similar patterns of evolution have taken place at Unisys. Quality efforts were first supported by management commitment, but over time the drive for quality became a corporate focus (Porter 1996). Porter (1996) describes the changes that took place at Unisys:

> The procurement organization began to establish long-term supply relationships after balancing price with other performance criteria, and procurement began to work cooperatively with suppliers, mutually defining performance metrics and goals (76).

Many other companies have also developed supplier relationships, and repeatedly, they have sought these relationships to improve quality. These reports show that by working together, the client and the supplier can deliver higher quality more efficiently than either party could alone. By optimizing the supply chain employees can perform more efficiently, customers receive improved service, and the company is more productive overall (Bodington and Shobrys 1996).

2.3 Procurement Management Literature

There is no consensus among procurement mangers as to whether companies should form partnerships. Some argue that to remain cost competitive, companies need to maintain an arm's length relationship with suppliers (Tompkins 1995). However, other authors argue that for companies to meet customer's expectations of quality and cost they must have the close support of suppliers (Lamming 1993). The level of involvement for suppliers varies from industry to industry but with the increasing complexities of products, suppliers are being relied upon for a greater involvement in the process. Lynch (1993) states in his book, *Business Alliances Guide: the Hidden Competitive Weapon*:

> Competition has traditionally been thought of as the antithesis of cooperation. Only recently have strategists and scholars shifted to a fresh perspective and recognized how powerful a weapon cooperation can be in playing the global competitive game (5).

Lynch describes the importance of creating cooperative supplier relationships for companies to be competitive in the global marketplace. This section will discuss the advantages of forming supplier relationships as viewed by procurement professionals.

Procurement managers have defined several differences between traditional relationships and partnerships. Examining these differences allows a company to understand the benefits of forming a partnership. The major difference between a partnership and a traditional relationship is that a partnership is a long-term commitment that emphasizes quality, schedule and price. A traditional relationship is a short-term relationship that only emphasizes price. Additional differences are summarized in Table 2.1 (Lynch 1993).

Table 2.1 – Traditional Supplier Relationships vs. Supplier Partnerships
Adapted from Lynch 1993

Factor	Traditional Relationship ⟷	Partnership
Time Frame	Short/Indefinite/ Renewable	Long Term
Relationship	Purchaser is Superior, Supplier is Subordinate	Purchaser is Leader, Supplier is Teammate
Information Flow	One Way	Two Way
Product/ Service Improvement	Defined by Contract	Ever Changing, Fluid
Control	Traditional Hierarchy	Multi-Disciplinary "Teamwork"
Primary Objective	Price	Quality, Price, Schedule
Profit	Buyer Controlled	Mutually Controlled
Benefit	?/?	Win/Win

One reason companies are choosing to form supplier partnerships is that they believe suppliers can help avoid problems during production. They bring suppliers in earlier in the process so they can provide suggestions to prevent problems from occurring. Thomas Stallkamp, Vice President for Procurement and Supply at Chrysler Corporation, states:

> Eighty percent of quality is built into the design of a product. If you can spend time up front with the supplier on the design of the component, the quality will be there when he manufactures it (Carbone 68, 1996).

The key point of this statement is that suppliers are "proactive." Preventative solutions are easier and cost less than fixing problems after they have occurred. This is another reason why involving suppliers earlier in the process is beneficial.

Procurement professionals have identified several advantages to forming supplier partnerships that are different than benefits from forming partnerships in the automotive industry. Lamming (1993) has developed a list of the benefits from forming supplier partnerships:

- Risk reduction
- Economies of scale and/or rationalization
- Technology exchanges
- Coopting or blocking competition
- Overcoming government-mandated trade or investment barriers
- Facilitating initial international expansion of inexperienced firms
- Vertical quasi-integration advantages of linking the complementary contributions of the partners in a value chain

2.4 Construction

There is little literature on supplier relationships in the construction industry. This could be indicative of the fact that few companies have formed partnerships with their suppliers. Because of the limited availability of literature, this section will draw heavily from three documents that describe supplier relationships in the construction industry. They are: “Upside-Down Contracting” by Michael T. Kubal (1995), “Fast Track Pros and Cons: Considerations for Industrial Projects” by Gareth Vaughn Williams (1995), and the Construction Industry Institute publication *2% Engineering*. These reports provide insight into the current use of suppliers of strategic procurement items in construction. The information gathered from these sources will be presented under the following headings: current construction procurement system, fast track projects, partnerships, and benefits of forming alliances in construction.

It is important to note that while the above referenced documents and the other literature in this section refer to the construction industry in general, it is the belief of Research Team 130 that these ideas can also be applied to the EPC process. Therefore, when a reference is made to the construction industry, the reader should also think of the concept in terms of the EPC process.

2.4.1 The Current Construction Procurement System

Most companies in the construction industry use suppliers in a traditional or narrow role (Williams 1995). This indicates that suppliers are involved late in the process and their design and engineering capabilities are underutilized. Williams (1995) comments about suppliers in the construction industry:

> Suppliers, vendors, and subcontractors have never traditionally been thought of as part of the project team. The project team normally thinks of vendors as indifferent third parties interested only in turning a profit for themselves. As a result, the design-build team often treats them with caution and distrust. The traditional purchasing department role is to keep the vendors and suppliers and subcontractors in line. They are responsible for making sure the vendors provide the correct material, equipment, or service and for cracking the whip as necessary (29).

This passage demonstrates that suppliers are not involved as part of the project team. Williams suggests that using suppliers in a traditional role will encourage caution and distrust. These relationships tend to be adversarial rather than cooperative. The article, “Partnership: A Commitment to Excellence” (Tompkins Associates Incorporated) expands on this issue of distrust by commenting:

> Unfortunately, many suppliers and customers are in a state of distrust. Many unpleasant past experiences around poor service, poor quality, price squeezing, and disloyalty have resulted in this distrust (8).

The construction industry currently treats suppliers as vendors in the EPC process. Suppliers are not included in the circle of cooperation between the owner, design contractor, and construction contractor. As a result, companies using traditional procurement systems suffer higher life-cycle costs, longer schedules and decreased quality (Kubal 1995).

Many believe that suppliers are not effectively utilized in the EPC process. Kubal (1995) remarks:

> In construction, subcontractors and suppliers control the majority of actual field construction, but continue to operate in contracting relationships reminiscent of the bygone automotive industry. Contracting practices continue to emphasize selection based solely on pricing with no input into the design or construction processes in terms of scheduling, quality control, or innovation (51).

This passage describes how subcontractors and suppliers are responsible for a majority of field construction; but are not included in the process until after the detail design phase is complete. This strategy is not logical considering the expertise suppliers could provide during design. This procurement approach prevents suppliers from offering suggestions during the engineering and design phase of the project when value engineering and analysis decisions are made. Kubal (1995) urges the construction industry to change by stating:

> This is a wake-up call to realize that subcontractors who control 70 to 80 percent of the overall construction process must be included through all project stages including design and pricing (53).

It is important to realize the significant role suppliers and subcontractors play in the overall construction process. These parties, who control such a large percentage of the construction processes, must be involved from the initial stages of project conception for the project to benefit from their expertise. Companies who treat suppliers as vendors are enforcing the negative aspects of an inefficient procurement system.

2.4.2 Fast-Track Projects

Fast-track projects have led the way in non-traditional supplier relationships in the construction industry. These projects require suppliers to be involved earlier in the process to meet tight schedules. Williams (1995) discusses this issue:

> Fast-track projects, however, cannot afford the traditional procurement processes and paradigms. To trim 30-50% off the time it takes to design and build one of these facilities, this process has to be streamlined. It is painfully obvious that the project has no time to spec, quote, and procure material in the tried and proven ways. The team has to enlist vendors' help in the process, and it is quite remarkable how anxious vendors are to take part (29).

On fast track projects, a limited number of suppliers compete on a preferred supplier list. These suppliers have a proven track record and are familiar with the customer and their specifications (Williams 1995). This enables the customer to streamline or eliminate the bidding process and therefore save time. The nature of fast track projects also enables the project to benefit from supplier experience and expertise. Because construction begins before design is complete, suppliers are likely to be on board during design. When suppliers are on board during design they can provide suggestions that may result in improved quality, increased production, and reduced costs.

Fast-track projects use suppliers in non-traditional roles by including them early in the project lifecycle, but fail to truly incorporate them into the project team. It is important to note that early supplier involvement on fast- track projects is a result of an early construction start, not a change in procurement strategy.

2.4.3 Partnerships

This section is drawn largely from Kubal's article "Upside-Down Contracting." This article discusses partnerships in the construction industry at length.

Suppliers in the construction industry have the capability to assume many of the project design and engineering responsibilities. Kubal (1995) explains:

> Typically the suppliers and subcontractors have the necessary expertise to develop effective design input for their portion of any building project. These suppliers and subs are often considerably more effective at incorporating their components into functional designs than designers working in a vacuum (52).

In this passage, Kubal argues that suppliers have the expertise to provide designs that are more effective than traditional designs by engineers or architects. This is another way in which clients will benefit from forming project teams that include suppliers as full partners. Partnerships give suppliers an opportunity to use their expertise and provide suggestions or productivity improvements over the entire life of the project.

As more clients realize the benefits of forming supplier partnerships, the number of partnerships will continue to increase in the construction industry. Some people in the industry argue it is likely that companies will have to form supplier partnerships to remain competitive. Kubal (1995) remarks:

> Subcontractors and suppliers will become integrally networked with contractors and design teams, forming strategic alliances to change the direction of the industry (51).

This indicates that supplier alliances are becoming more common and will transform the industry into a more efficient process. Partnerships are not successful unless suppliers are integrated into the project teams.

General contractors who form supplier partnerships will have a competitive advantage in the industry. Kubal (1995) predicts that:

> General contractors who can take a leadership role in implementing the paradigm of construction management will become the leaders of the virtual construction age. Virtual processes will assuredly move the industry towards further implementation of design-build contracting that mandates the participation of suppliers and subcontractors in the design process (53).

He defines the virtual construction age as the future of construction projects, which will include integrated project teams that use technology and alliances to their fullest capacities.

The construction industry appears to be following other industries by reforming their supplier relations. Williams (1995) summarizes the direction of supplier relations in the construction industry by stating:

> All the groups, engineering, procurement, construction, operations, and the suppliers, must be integrated as one team. When the individual groups are all working together helping each other out, recognizing and compensating for each others weaknesses and highlighting and taking advantage of each other's strengths, then the team is united. When everybody on the team feels that they will all succeed or fail together as a team, then a fast-track project is viable (27).

The construction industry has much to gain from reforming supplier relationships. The industry is moving in this direction and as more companies become aware of the benefits of supplier alliances more companies will form partnerships.

2.4.4 Benefits of Forming Alliances in Construction

Rohm and Haas has produced a manual for creating and developing partnerships with their suppliers. The goal of the manual was to help Rohm and Haas choose preferred suppliers and to develop alliances which benefit both Rohm and Haas and the supplier. The following is a list summarizing the benefits they expect to realize by forming alliances with suppliers.

- Reduce time to deliver
- Reduce cost to deliver
- Improve quality
- Quicker solutions to problems
- Reduced life cycle costs
- Benefits through standardization
- Improved services
- Reduction in paperwork
- Improved efficiency of construction
- Site-to-site consistency and repeatability
- Reduced training requirements
- Elimination of non-value-added work

Many of the benefits on this list are similar to the benefits other industries have achieved from reformed supplier relationships. However, this list also includes items that are specific to the construction industry such as site-to-site consistency and repeatability, and improved efficiency in construction.

Although Rohm and Haas had only participated in a few alliance relationships at the time this manual was written, they had already achieved some of these benefits on projects with alliance relationships in place (Corn et al. 1995).

Other companies are also using innovative relationships with their suppliers to achieve similar benefits. Construction Industry Institute Research Team 112 investigated the innovative practices that some companies are using to reduce their engineering and capital costs in their study entitled *2% Engineering*. The information contained in the following section was obtained from CII Research Summary 112-1.

This study was initiated when NUCOR reported that it could achieve its business objectives at reduced costs through innovative practices. The study conducted by RT 112 identified 20 innovative practices used by NUCOR and other companies. Several of the practices identified involve working with suppliers in non-traditional roles. One recommended practice suggested buying as much service as possible from reliable fabrication and field subcontractors. Other practices include purchasing high quality process equipment without a design review from reliable suppliers and streamlining the preliminary engineering process by using a small, focused group of key professionals and relying heavily on the past experiences and intuitive technical judgement of the group. Each of these practices involves working with suppliers outside of the traditional role to achieve cost and schedule reductions.

This study identified several benefits to these innovative practices. The following is a list of some of the benefits documented by Research Team 112.

- Decreased capital costs
- Enhanced overall project schedule
- Increased project efficiency at all levels as well as technical consistency within the project
- Reduced design time for specific components
- Decreased number of suppliers and/or contractors
- Experts (suppliers) recommend the equipment that best meets functional goals
- Reduced engineering costs
- Avoid redundancy of engineering activities

This study demonstrated that innovative practices, such as using suppliers in a non-traditional role, creates many benefits for an organization in the construction industry.

2.5 Simulation

Construction planning and scheduling have traditionally used methods such as Gantt charts and CPM, but these tools are limited in their ability to address uncertainty. Program Evaluation and Review Technique (PERT) was developed by a research team consisting of Lockheed Aircraft Corporation, the U.S. Navy's special project office, and the consulting firm of Booz, Allen, and Hamilton to resolve some of these limitations.

PERT was designed to assist the Navy in getting better estimates of project duration and cost (Callahan, et. al. 1992). PERT allows the most probable project cost and duration to be estimated without historical time and cost data. A model distribution is created using estimates for the most likely, optimistic, and pessimistic duration (Callahan et. al. 1992). The distribution for each activity can then be reduced to a time estimate and variance and can be used to estimate the completion of the total project.

Unfortunately, PERT also has its limitations. First, PERT assumes that the probability distributions of activities fit the standard beta curve, which is only an approximation (Sha'ath and Singh 1994). Second, PERT is based on the Central Limit Theorem, which ignores sub-critical paths. By ignoring sub-critical paths PERT creates a bias that can produce overly optimistic results (Sha'ath and Singh 1994). For example, suppose a project consists of two parallel activities, Activity A and Activity B. Both activities have a 50 percent chance of requiring 2 days and a 50 percent chance of requiring 4 days to complete. The mean duration for each activity is therefore 3 days, however, the expected duration for the entire project is 3.5 days. The expected duration is greater than 3 days because of merge event bias. The total project duration is governed by the activity with the longest duration, and therefore, parallel paths are very important. In this case, there are four possible combinations of activity durations. Both activities could require 2 days, Activity A could require 2 days and Activity B require 4 days, Activity A could require 4 days and Activity B could require 2 days, or both activities could require 4 days. The result is a 25% chance that the project will require 2 days and a 75% chance that the project will require 4 days, therefore, the expected duration is 3.5 days (0.25*2 + 0.75*4 = 3.5). However, PERT does not recognize more than one critical path. The result of a PERT analysis would therefore indicate an expected duration of three days, ignoring the possibility of an extended duration for a parallel activity. This merge bias that occurs in PERT produces event times that tend to be lower than the true values and overly optimistic predictions are often the result (Harris 1978).

Simulation provides a means to overcome the limitations of Gantt charts, CPM, and PERT. Simulation utilizes statistical distributions for time and cost, based on historical data. Because distributions are based on historical data, they can be of any shape. This allows the distribution to reflect the true probability of occurrence for each duration. Simulation uses many passes through the model to establish durations and costs. For each pass through the model, random samples are taken from each distribution to obtain a value for time or cost. The values obtain for all the passes are then averaged to determine the most likely cost or duration. Because simulation uses many passes through the model and collects random samples for each pass, it is possible to have multiple critical paths, and thus eliminate the bias problem encountered by PERT.

Therefore, simulation is a better tool for analysis, providing that there is access to historical data to construct the distributions.

2.6 Conclusion

Many changes in supplier relationships have been driven by a quest for quality. Some companies have reduced the size of their in-house engineering staff responsible for design, quality control, and improvement. Therefore, these companies must now rely on suppliers to provide the functions that were once performed in-house. Reformed relationships with suppliers have helped companies to increase quality while simultaneously reducing costs.

While quality has clearly driven the change in supplier relationships at some companies, procurement managers remain divided. Some managers fear a loss of cost competitiveness, but others believe that supplier partnerships will be the key to competitiveness in the future. Partnerships allow suppliers to be proactive. They give suppliers the opportunity to provide suggestions that simplify the process, reduce time and cost, eliminate duplicate engineering, or improve reliability, efficiency, life cycle costs, and quality.

Innovative supplier relationships in the construction industry have been uncommon, but some companies have demonstrated their benefits. Fast track projects have consistently led the way in attempts to work with suppliers in non-traditional relationships. The need for a shortened schedule has resulted in the reduction or elimination of the bidding process. As a result, suppliers are often involved early in the process when they are able to contribute to design and value engineering decisions. Suppliers have also played non-traditional roles on projects without compressed schedules. These relationships have also yielded benefits such as reduced construction time, improved quality, and reduction of life cycle costs.

In summary, it is clear that there are benefits that can be achieved through reformed supplier relationships. It is now up to the construction industry to follow the lead of other industries and realize these benefits.

Chapter 3

Defining PEpC

3.1 Defining PEpC

A search for innovation performed by

- surveying CII member companies
- interviewing selected suppliers
- studying associated industries

sharpened the Research Team's awareness for innovation and showed that innovative approaches to supplier involvement were to be found in practice. The surveys, interviews, and studies also confirmed more than anecdotal evidence of significant improvement arising from the reported innovations.

The challenge was thus not so much to find innovation but to describe and codify it so that it could be better understood and systematically implemented when appropriate conditions are present.

Substantial discussion and the focused expertise of the Research Team led to the belief that much could be achieved if it were possible to formalize a project delivery system which "takes the big **P** for *procurement* in the **EPC** process and places it before the **E** for *engineering* so that the technical knowledge and expertise of suppliers can be integrated into all phases of the project from the very beginning" (Ruane 1997). In recognition of this change and the fact that a number of non-strategic procurement items would continue to be procured in the traditional way, the Research Team came to call the process **PEpC.**

This, together with the need to allow for many points of view, led to the following broad definition.

> PEpC (Procurement, Engineering, procurement and Construction) is an innovative project delivery system which makes it possible to utilize supplier expertise in all phases of the project life cycle by developing an advance procurement strategy and reaching agreement with suppliers on strategic procurement items and/or systems prior to the associated principle project engineering activities.

3.2 Key Concepts

Key phrases in the definition follow

1. *<u>. . . innovative project delivery system . . .</u>*

   PEpC is a project delivery system like EPC but it is neither EPC nor a subtle mutation of EPC. It is also not simply early procurement. It changes the EPC process by developing early agreements with selected strategic suppliers so that their expertise can be - and is - used to advantage in the preliminary design, selection, sizing, specification, detail design, and construction phases of the work. PEpC is different; it has its own characteristics and its own requirements.

2. *<u>. . . utilize supplier expertise . . .</u>*

   PEpC clearly relies on the fact that supplier expertise is available and held as a core competency. This expertise needs to extend beyond the narrow confines of the catalog description and must include all aspects of system design, integration and lifecycle performance

3. *<u>. . . advance procurement strategy . . .</u>*

   PEpC requires that a strategy, which identifies procurement items and potential sources of supply and details how each item may best be procured, be developed in the early stages of project. An aggressive, competitive low-bid approach will form part of the strategy where appropriate but will not to be the assumed approach for all items.

4. *<u>. . . agreement with suppliers . . .</u>*

   PEpC requires that agreement be reached with suppliers of strategic items and/or systems in the early stages of project development. Such agreement would normally be achieved before engineering has reached the level of detail required to obtain full funding approval or develop detailed bid packages. Changes in the project authorization process, contingent commitments to suppliers, and innovative agreements covering both technical and commercial terms would thus be required. Early formal agreement gives a basis for the use of supplier expertise in all aspects of system design, integration and lifecycle performance. It brings suppliers into the circle of cooperation between owner and contractor.

5. *<u>. . . strategic procurement items and/or systems . . .</u>*

   The procurement strategy will identify all requirements but pay particular attention to those items that have a significant strategic impact on the project as a whole. Complex systems with substantial engineering content, systems that incorporate specialized or unique process technologies, and systems that have long lead times or complex interfaces clearly fall into this description.

6. *<u>. . . prior to associated principle project engineering activities . . .</u>*

   PEpC requires that agreement with suppliers of strategic procurement items and/or systems is reached prior to the associated principle engineering activities when the potential for supplier impact is highest. This permits supplier knowledge and experience to be used to advantage throughout the preliminary design, selection, sizing, specification, detail design, and construction phases of the work.

3.3 Principle Tenets

Implementation of PEpC can be initiated by the owner or the contractor or proposed by suppliers (Fisher Rosemount 1997, ABB 1997). The process can start either at the very beginning of pre-project planning phase when strategy is developed, agreements are reached and commitments are made or it can start at any other time during project procurement when either owner or contractor see it as an advantage.

The implementation process is based on five principle tenets, which may be stated as follows

1. Acceptance

   There is acceptance of the fact that the selection, installation, integration, operation, and maintenance of complex engineered equipment and systems requires specialized knowledge which is frequently a core competency of the supplier rather than the owner, engineer, or contractor.

2. Process

   There is a structured process to identify the suppliers of strategic procurement items and/or systems and their sub-suppliers early in the material coordination and contracting strategy phase of the project life-cycle. The process defines the competencies required from strategic suppliers so that they can be selected on their demonstrated ability to contribute beyond the narrowly defined scope of traditional relationships.

3. Focus

   Supplier selection focuses on competency in the selection, delivery, installation and integration of completed systems with supplier responsibility for total system performance. Early identification and a focus on systems performance, rather than component supply, simplifies design information exchange and improves integration both within and between systems.

4. Competence

   Emphasis is placed on the core competencies of the parties involved and it is recognized that efficiency is maximized and duplication is minimized when work is done by those who have the required knowledge as a long-term core competency.

5. Relationships

   Business relationships are developed beyond those normally associated with the typical low-bid process. Emphasis is placed on competency and performance so as to create new opportunities for suppliers who wish to develop long-term relationships and share more fully in risks and rewards in a broader definition of their business.

Implementation of PEpC will require a better understanding and recognition of the competencies available in supplier organizations. It will, in many cases, require that these be expanded to reflect the role required of the strategic suppliers involved in the PEpC process.

Benefits of PEpC are likely to be highest when the engineering and system integration component of the work package is high and when efficiencies can be achieved by developing and using the core competencies developed and retained by suppliers. Long-term business relationships between owners, suppliers, and contractors will certainly facilitate the process and maximize benefits. They are, however, not a pre-requisite.

3.4 A Developing Process

Implementation of PEpC can be seen as a developing process that starts by recognizing the fact that specialized expertise is frequently a core competency of the supplier. This process brings suppliers into an expanded circle of cooperation between owner, design contractor, and construction contractor, which will, as the process develops, lead, to a broader definition of their business. This acceptance of supplier expertise, together with other steps in the process, is shown in Figure 3.1.

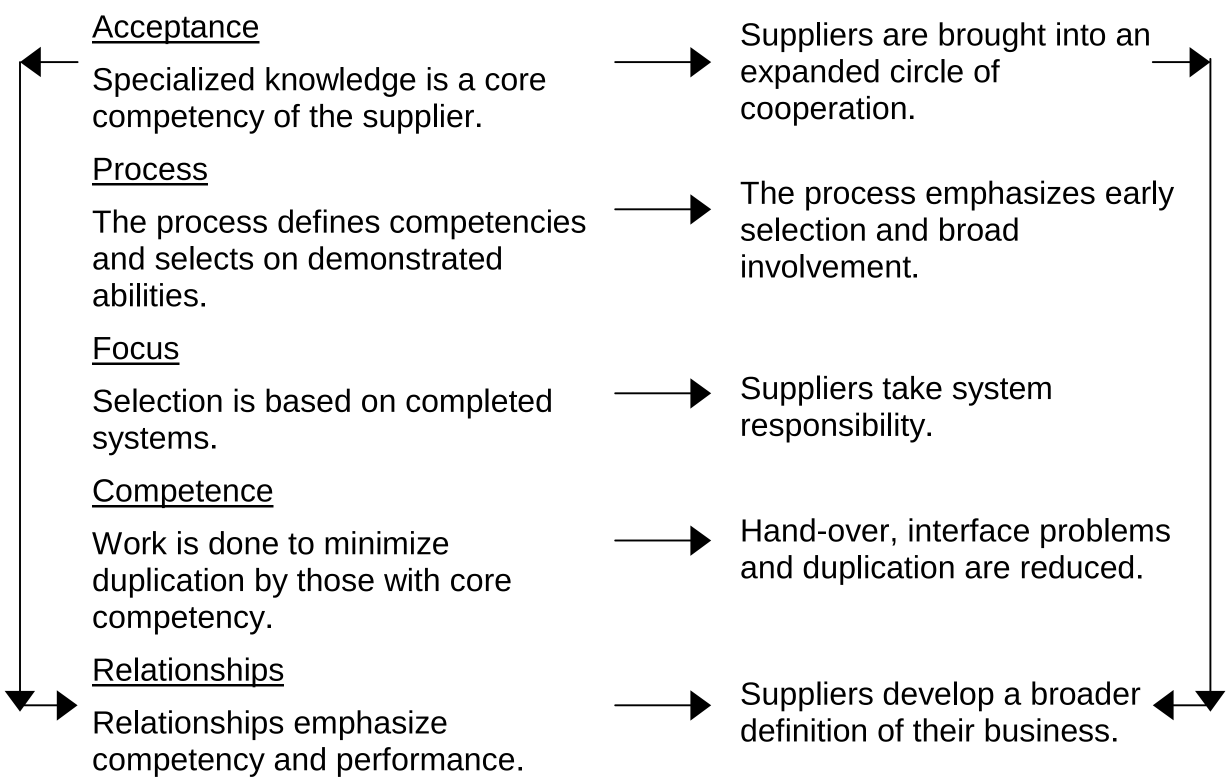


Figure 3.1 – The Developing Process

3.5 Review

This chapter has defined PEpC and provided a starting point for the quantification of the effects of the step change. The next several chapters focus on measuring the effects of PEpC on the total time and labor cost required for project completion.

- A baseline for measuring the effect of PEpC on the classic EPC process is developed in Chapter 4.
- The potential impact of implementing PEpC on a number of assumed scenarios is presented in Chapter 5.
- The effect of PEpC-like implementations on a number of actual projects is measured relative to the baseline in Chapter 6.

Chapter 4
Establishing a Baseline

4.1 Quantifying the Benefits of PEpC

The next three chapters seek to quantify the possible benefits of implementing PEpC as the chosen project delivery system. The methodology used is complex because an attempt is being made to measure–or at the very least assess–the impact of a step change to the EPC process which has, by definition, not been fully implemented in practice.

The methodology is presented in three chapters as follows.

1. This chapter will develop a baseline model of the EPC process to provide a metric for measuring the impact of PEpC implementation using a standard definition of the EPC process. The EPC process model developed by RT 125 in their study *Determining the Impact of Process Change on the EPC Process* will be used as a starting point with minor changes made to facilitate data processing and produce outputs unique to the requirements of this report.
2. Chapter 5 will use the collected expertise of the Research Team to develop a number of theoretical PEpC implementation scenarios. The baseline model developed in Chapter 4 will be used to analyze these scenarios and show the effect of PEpC implementation under the assumed conditions.
3. Chapter 6 will describe four case studies where the EPC process has been changed to reflect many but not all of the principal PEpC tenets presented in Chapter 3. The Scaled Baseline Model will again be used to analyze the case studies and show the effect of these “partial PEpC implementations.”

Chapter 6 will conclude with a summary of this section of the report and show that both the scenarios and the case studies support the assertion that savings between 10 and 15 percent of total project time and between 4 and 8 percent of project labor cost can be achieved through the implementation of PEpC.

4.2 The EPC Model Developed by RT 125

EPC has been defined by the Construction Industry Institute as

> a contract arrangement where an owner hires an engineer/constructor firm to completely design and build a facility (CII 1997b).

This definition was used by RT 125 who defined the EPC process as

> one set of interrelated activities that span from the owner's earliest involvement with pre-project planning responsibilities to the completion of plant start-up (CII 1997a).

Using these definitions of EPC, RT 125 developed a baseline model of the EPC process to measure the impact of information management technologies. The model of the EPC process developed by RT 125 consists of three parts:

1. a set of inputs that describe the activities, the sequence logic, duration estimates, and cost estimates that RT 125 defined as making up the total EPC process;
2. an analysis tool that receives the inputs and processes them to produce the required results;
3. a report generator that presents and prints the results of the analysis.

The sections that follow will describe each of the above parts in sufficient detail for the reader to understand the process, assumptions, and methodology used by RT 125. A full description of the activity definitions, the flow sheets, the analytical process and the results can be found in the RT 125 document, *Cost and Schedule Impacts of Information Management*. This document should be used to obtain any required additional information.

Evaluation of, and comment on the methodology or values used to develop the RT125 EPC Model falls outside the scope of this report.

4.2.1 Inputs

Activities. The model of the EPC process developed by RT 125 consisted of 164 activities and 16 milestones. These were developed with the input of 40 CII member companies and covered all aspects of the project, from the owner's conception of the idea to the final project start-up and acceptance. The list was divided and coded into five categories; Pre-Project Planning, Design, Materials Management, Construction, and Start-Up. It is important to note that the activity list does not represent any single company's process but, instead, includes "the activities that are most commonly executed on a conventional EPC project" (CII 1997a). The full list divided into the five categories is given in Appendix A.

Sequence Logic. In addition to identifying the typical activities in an EPC project, RT 125 also created a logic diagram that showed the sequence and logic relationships between the activities. As with the activity list, the logic relationships in the RT 125 EPC model are "a consensus view from many CII member companies" (CII 1997a). The logic diagram represents a typical progression of activities, and will be different from the specific approach of any one company. The logic diagram can be found in Appendix B.

Duration Estimates. RT 125 collected data regarding the 164 activities from 20 EPC projects volunteered by CII member companies (CII 1997a). The information was obtained from experienced personnel who were familiar with the projects from which the data was collected (RT125 1997). To account for variations in project size and to normalize the data, all values obtained from member companies were expressed as a percent of the total project time taken up by each activity on its own, with no allowance for concurrent activities (CII 1997a). To account for variations due to differing facility types, geographic locations, and individual experiences, the raw data was used to construct triangular probability distributions for the duration of each activity.

Cost Estimates. Cost data associated with each of the 164 activities in the model were collected in conjunction with the time data. To eliminate any bias that may be associated with a particular type of project and to eliminate the effects of project size, cost data refers only to the labor costs incurred to complete each activity (CII 1997a). Material and equipment costs are not considered. Just as the time data were converted to percentages of total project time, cost data were converted to percentages of total labor cost to account for differences in project type, location, and size. Triangular cost distributions were used to express each activity's contribution to total labor cost.

4.2.2 Analysis Tool

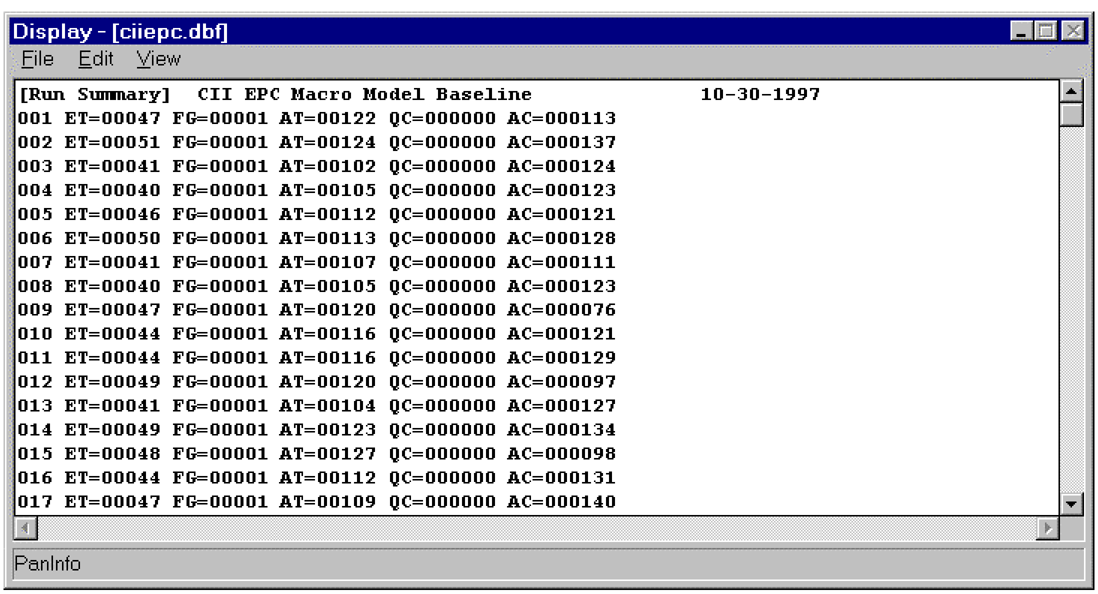
The time and cost data collected by RT 125 were input into ABC-SIM, a simulation program specifically developed for the research performed by RT 125 (CII 1997a).

The ABC-SIM program is designed to apply the principles of activity-based costing to the construction engineering process (CII 1997a). Activities are input as nodes and assigned time and cost distributions. In cases where an activity is followed by more than one activity, a dummy node is required. When multiple activities feed into a single node, a queue node is required. Dummy and queue nodes do not have any duration or cost assigned to them; they are simply there to allow the logic to proceed properly.

ABC-SIM is a fairly simple and straightforward tool, but it has three primary drawbacks with respect to this research. First of all, it is a very time consuming process to construct the simulation model due to the need for queue and dummy nodes. Secondly, ABC-SIM lacks a means by which to specify a seed value for the random number sampling in the simulation. Without a constant seed value, variations in results may be due only to a variation in the random number stream. Lastly, ABC-SIM simulation models require long processing times ranging from 2.5 to 5 hours per model.

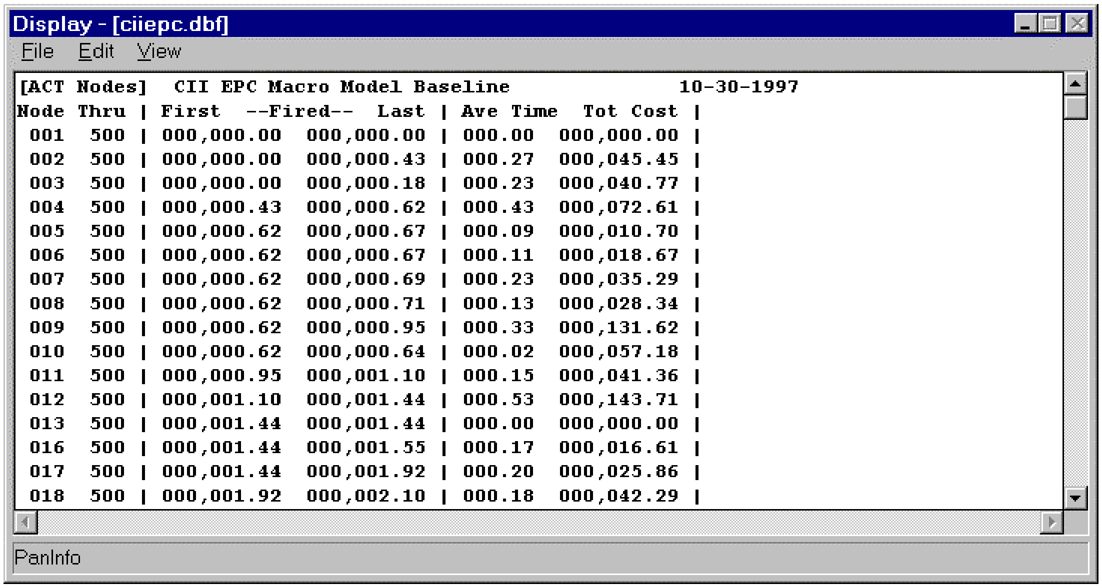
4.2.3 Output Formats

The output reports generated by ABC-SIM are shown in Figures 4.1 and 4.2. Figure 4.1 shows the expected Elapsed Time, flag count, Activity Time, Queue Cost, and Activity Cost. Figure 4.2 is a sample of the activity node summary produced by ABC-SIM. In this report activities are identified by node number, which is followed by the times at which the activity first and last fired. Also included in this report are the average duration and total cost associated with each activity.




```
[Run Summary]  CII EPC Macro Model Baseline          10-30-1997
001 ET=00047 FG=00001 AT=00122 QC=000000 AC=000113
002 ET=00051 FG=00001 AT=00124 QC=000000 AC=000137
003 ET=00041 FG=00001 AT=00102 QC=000000 AC=000124
004 ET=00040 FG=00001 AT=00105 QC=000000 AC=000123
005 ET=00046 FG=00001 AT=00112 QC=000000 AC=000121
006 ET=00050 FG=00001 AT=00113 QC=000000 AC=000128
007 ET=00041 FG=00001 AT=00107 QC=000000 AC=000111
008 ET=00040 FG=00001 AT=00105 QC=000000 AC=000123
009 ET=00047 FG=00001 AT=00120 QC=000000 AC=000076
010 ET=00044 FG=00001 AT=00116 QC=000000 AC=000121
011 ET=00044 FG=00001 AT=00116 QC=000000 AC=000129
012 ET=00049 FG=00001 AT=00120 QC=000000 AC=000097
013 ET=00041 FG=00001 AT=00104 QC=000000 AC=000127
014 ET=00049 FG=00001 AT=00123 QC=000000 AC=000134
015 ET=00048 FG=00001 AT=00127 QC=000000 AC=000098
016 ET=00044 FG=00001 AT=00112 QC=000000 AC=000131
017 ET=00047 FG=00001 AT=00109 QC=000000 AC=000140
```

Figure 4.1 – ABC-SIM Sample Output, Run Summary



[ACT Nodes] CII EPC Macro Model Baseline 10-30-1997

Node	Thru	First	--Fired-- Last	Ave Time	Tot Cost
001	500	000,000.00	000,000.00	000.00	000,000.00
002	500	000,000.00	000,000.43	000.27	000,045.45
003	500	000,000.00	000,000.18	000.23	000,040.77
004	500	000,000.43	000,000.62	000.43	000,072.61
005	500	000,000.62	000,000.67	000.09	000,010.70
006	500	000,000.62	000,000.67	000.11	000,018.67
007	500	000,000.62	000,000.69	000.23	000,035.29
008	500	000,000.62	000,000.71	000.13	000,028.34
009	500	000,000.62	000,000.95	000.33	000,131.62
010	500	000,000.62	000,000.64	000.02	000,057.18
011	500	000,000.95	000,001.10	000.15	000,041.36
012	500	000,001.10	000,001.44	000.53	000,143.71
013	500	000,001.44	000,001.44	000.00	000,000.00
016	500	000,001.44	000,001.55	000.17	000,016.61
017	500	000,001.44	000,001.92	000.20	000,025.86
018	500	000,001.92	000,002.10	000.18	000,042.29

Figure 4.2 – ABC-SIM Sample Output, Activity Summary

4.2.4 RT 125 Simulation Results

This research is concerned only with the values for Elapsed Time, Activity Time, and Activity Cost. These terms are defined as follows.

Activity Time is defined as the time that would accrue if all activities were performed in succession; that is to say, no two activities would occur concurrently. Activity Time in the baseline simulation equals 115.3 percent. This value is greater than the anticipated value of 100 percent because the simulation process takes random samples from the input distributions. These input distributions are defined as distributions with in most cases, the mean greater than the mode. This is illustrated in Figure 4.3. While the modes of all distributions total 100 percent, the sum of the means of all distributions will be greater than 100 percent. For this reason, it is expected that the total Activity Time will be greater than 100 percent.

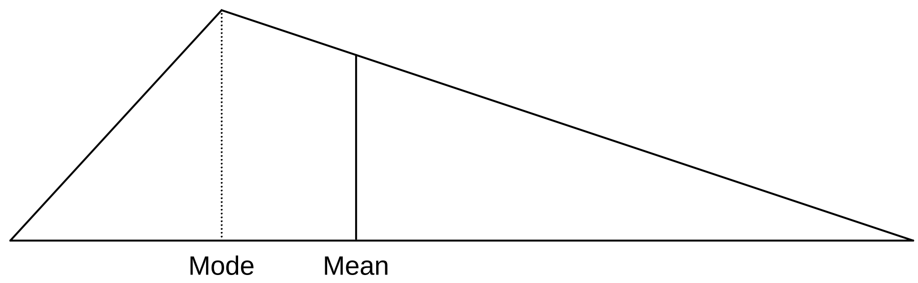


Figure 4.3 - Sample Triangular Distribution

Although Activity Time cannot provide any insight into the impact of PEpC on critical path time, it can be used to validate simulation tools other than ABC-SIM. Activity Time will be discussed in Section 4.4 in the comparison of results from ABC-SIM and another simulation tool, Stroboscope.

Elapsed Time is the total project or critical path time. Elapsed Time is, by definition, less than 100 percent because activities occur concurrently. The Elapsed Time for the baseline simulation equals 43.9 percent to reflect the fact that slightly more than half of the time-consuming activities occur in parallel with the activities which define the critical path.

Activity Cost is the sum of all individual activity labor costs. As indicated in Section 4.2.1, costs for materials and equipment are not included in this cost estimate. Only the labor costs required to complete the project are considered. The value given in the baseline simulation is 112.9 percent. This deviation from the expected 100 percent is again a product of the simulation and the triangular shape of the input distributions.

These results obtained from the simulation of the RT 125 EPC model are summarized in Table 4.1.

Table 4.1-RT125 EPC Model Simulation Values

	Activity Time	Elapsed Time	Activity Cost
RT 125 EPC Model	115.3%	43.9%	112.9%

4.3 The Baseline Model

ABC-SIM satisfied the needs of RT 125 insofar as it was able to model the EPC process and measure the effect of change on the total project cost and time. The analysis required to quantify the effect of PEpC differs from that performed by RT 125, and so additional requirements are placed on the model used as a baseline for this research. The following specific points are important.

1. It must be simple and quick to add or delete activities or alter sequence logic so that different scenarios or case studies can be accurately modeled.
2. It must be possible to identify early and late start and finish dates as well as criticality for individual activities so that areas where PEpC implementation can have the greatest effect can be identified.
3. It must be possible to group or hammock activities and produce simple graphical outputs so that the effect of PEpC implementation can be easily understood.

The above three factors meant that changes had to be made to the RT 125 model and ABC-SIM so that the special features required for this research could be developed. These changes will be discussed in the sections that follow.

4.3.1 Inputs

No changes were made to any of the inputs developed by RT 125. All activities, logic, duration estimates, and cost estimates were taken straight from the RT 125 EPC model. The PEpC implementations and their effects described in Chapters 5 and 6 can thus be taken as directly comparable to the EPC process modeled by RT 125.

4.3.2 Analysis Tool

The flexibility required to model the scenarios and case studies required for this research was beyond that built into ABC-SIM, and thus an alternate modeling tool had to be used. Substantial research, including an investigation into the use of Primavera Project Planer® with Monte Carlo™, led to a decision to use Stroboscope (Martinez 1996). Stroboscope, along with a Microsoft Excel® add-on, provides an interface that simplifies the process required to produce changes in activity time and cost distributions by making use of the mathematical capabilities of Excel®. This made it possible to provide the following data for each activity.

- estimated time
- early and late start
- early and late finish
- free and total float
- criticality
- estimated cost

The time and labor cost of the project as a whole are also calculated and all values can be exported in various file formats to produce tabular and graphical outputs.

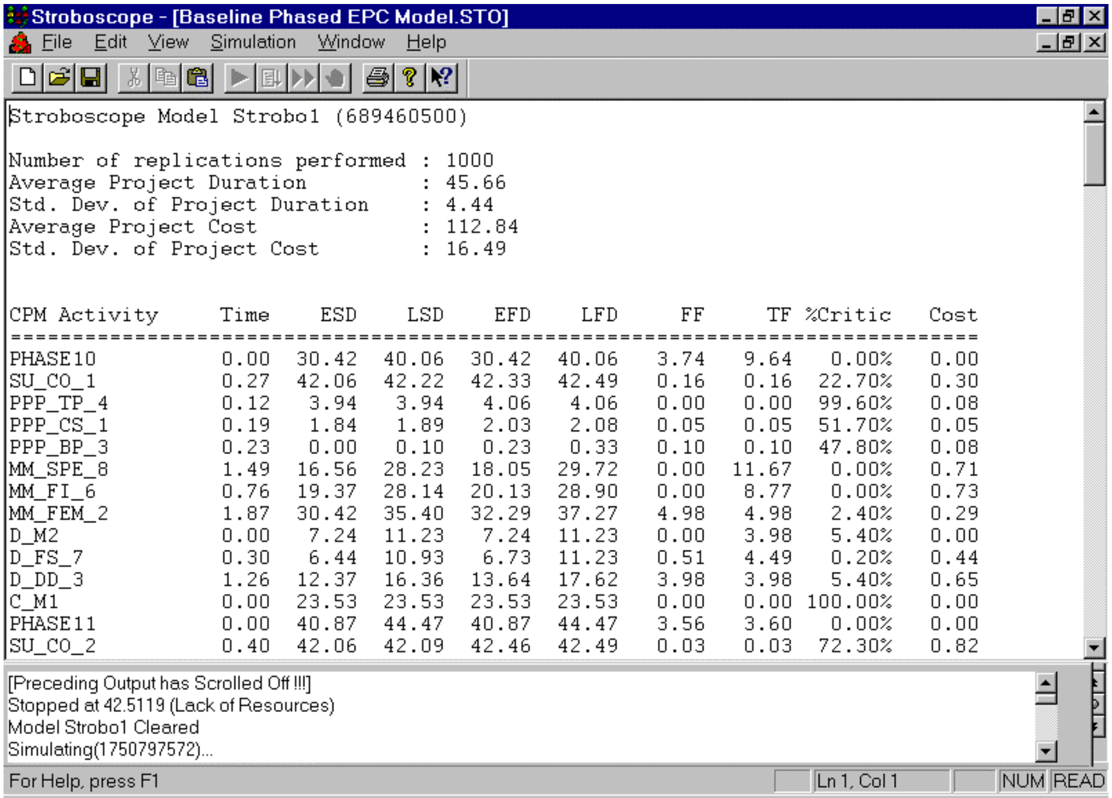
Stroboscope also made it possible to introduce the following 12 summary-level hammock activities to aid in understanding and analyzing the impact of change on the 164 detail activities that make up the detail logic diagram.

- Preliminary Feasibility
- Team Selection
- Preliminary Design, Estimate, and Scope
- Estimate, Schedule, and Review
- Procure Standard and Specialized Equipment
- Procure Fabricated and Bulk Materials
- Detail Design
- Work Packages
- Preliminary Construction
- Field Construction
- Start-Up
- Documentation

4.3.3 Output Formats

The data used to construct the RT 125 EPC model was entered into Stroboscope, and the simulation was run using Stroboscope. An example of the tabular output produced by Stroboscope is given in Figure 4.4. A summary level bar chart and milestone chart were especially developed to assist in understanding and presenting the scenarios and case studies discussed in Chapters 5 and 6. These will be used as templates to measure the time impacts of PEpC implementation in each phase and are discussed in Section 4.6.

Stroboscope also produced a summation of Activity Cost, which after the scaling operation described in Section 4.5, is equal to 100 percent. This baseline value of 100 percent will be used as a template to measure the labor cost savings produced by PEpC implementation.



Stroboscope - [Baseline Phased EPC Model.STO]

File Edit View Simulation Window Help

Stroboscope Model Strobo1 (689460500)

Number of replications performed : 1000
Average Project Duration : 45.66
Std. Dev. of Project Duration : 4.44
Average Project Cost : 112.84
Std. Dev. of Project Cost : 16.49

CPM Activity	Time	ESD	LSD	EFD	LFD	FF	TF	%Critic	Cost
PHASE10	0.00	30.42	40.06	30.42	40.06	3.74	9.64	0.00%	0.00
SU_CO_1	0.27	42.06	42.22	42.33	42.49	0.16	0.16	22.70%	0.30
PPP_TP_4	0.12	3.94	3.94	4.06	4.06	0.00	0.00	99.60%	0.08
PPP_CS_1	0.19	1.84	1.89	2.03	2.08	0.05	0.05	51.70%	0.05
PPP_BP_3	0.23	0.00	0.10	0.23	0.33	0.10	0.10	47.80%	0.08
MM_SPE_8	1.49	16.56	28.23	18.05	29.72	0.00	11.67	0.00%	0.71
MM_FI_6	0.76	19.37	28.14	20.13	28.90	0.00	8.77	0.00%	0.73
MM_FEM_2	1.87	30.42	35.40	32.29	37.27	4.98	4.98	2.40%	0.29
D_M2	0.00	7.24	11.23	7.24	11.23	0.00	3.98	5.40%	0.00
D_FS_7	0.30	6.44	10.93	6.73	11.23	0.51	4.49	0.20%	0.44
D_DD_3	1.26	12.37	16.36	13.64	17.62	3.98	3.98	5.40%	0.65
C_M1	0.00	23.53	23.53	23.53	23.53	0.00	0.00	100.00%	0.00
PHASE11	0.00	40.87	44.47	40.87	44.47	3.56	3.60	0.00%	0.00
SU_CO_2	0.40	42.06	42.09	42.46	42.49	0.03	0.03	72.30%	0.82

[Preceding Output has Scrolled Off !!!]
Stopped at 42.5119 (Lack of Resources)
Model Strobo1 Cleared
Simulating(1750797572)...

For Help, press F1 | Ln 1, Col 1 | NUM | READ

Figure 4.4 – Stroboscope Tabular Output

4.4 Comparison of Results

A comparison of the results obtained from the RT 125 EPC model described in Section 4.2 and the Stroboscope-driven baseline model described in Section 4.3 is given in Table 4.2. Activity Time, Elapsed Time, and Activity Cost from each simulation tool are presented to validate the use of Stroboscope. Table 4.2 shows that the results are identical within tolerances due to the simulation process. The change from ABC-SIM to Stroboscope does thus not affect the results but does provide additional flexibility and graphical capability provided by Stroboscope.

Table 4.2 – Summary of RT 125 EPC Model and Baseline Model Output

	Activity Time	Elapsed Time	Activity Cost
RT125 EPC Model (ABC-SIM)	115.3%	43.9%	112.9%
Baseline Model (Stroboscope)	115.2%	45.7%	112.8%

4.5 Scaling

Because Activity Time, Elapsed Time, and Activity Cost values produced by the simulation were not an even 100 percent, the simulation output was scaled so that the impacts of PEpC could be clearly understood without the confusion of a baseline value not equal to 100 percent. Each category of output was factored to set the baseline values equal to 100 percent. Scaling the output makes it easier to identify the true impact of PEpC on project time and cost. This scaling process is particularly important when examining Elapsed Time or critical path time, because this metric measures one of the most important benefits of PEpC. For example, a simulation output for a given scenario of 42.4 for Elapsed Time would appear to be a savings of 3.3 percent when compared to the baseline value of 45.7 percent. However, this is actually a critical path savings of 7.2 percent (3.3 divided by 45.7). By presenting the results in a scaled fashion, the baseline value becomes an even 100 percent and the scenario value for Elapsed Time is 92.8 percent. This format more clearly depicts the savings that result from PEpC implementation. Table 4.3 summarizes the output of the RT 125 EPC model, the Baseline model, and the Scaled Baseline Model.

Table 4.3 – Output Summary

	Activity Time	Elapsed Time	Activity Cost
RT 125 EPC Model (ABC-SIM)	115.28%	43.9%	112.85%
Baseline Model (Stroboscope)	115.21%	45.7%	112.84%
Scaled Baseline Model (Stroboscope)	100%	100%	100%

4.6 Templates for Evaluating PEpC

The full effect of the scenarios and case studies presented in Chapters 5 and 6 can best be understood if the savings are measured and compared to the baseline on a phase by phase basis. The bar chart and milestone chart discussed as a Stroboscope output in Section 4.3.3 can be used for this purpose once the various times are scaled as discussed in Section 4.5.

A scaled bar chart giving the baseline values for each phase is given in Figure 4.5. A scaled milestone chart giving the milestone values for each phase is given in Figure 4.6.

All time savings arising from PEpC implementation will be measured using these two charts as templates. Savings will be expressed as a reduction in the critical path completion time for each phase and for the project overall. Cost savings will be expressed as a reduction in total project labor costs. Values will be measured relative to the baseline values of 100 percent.

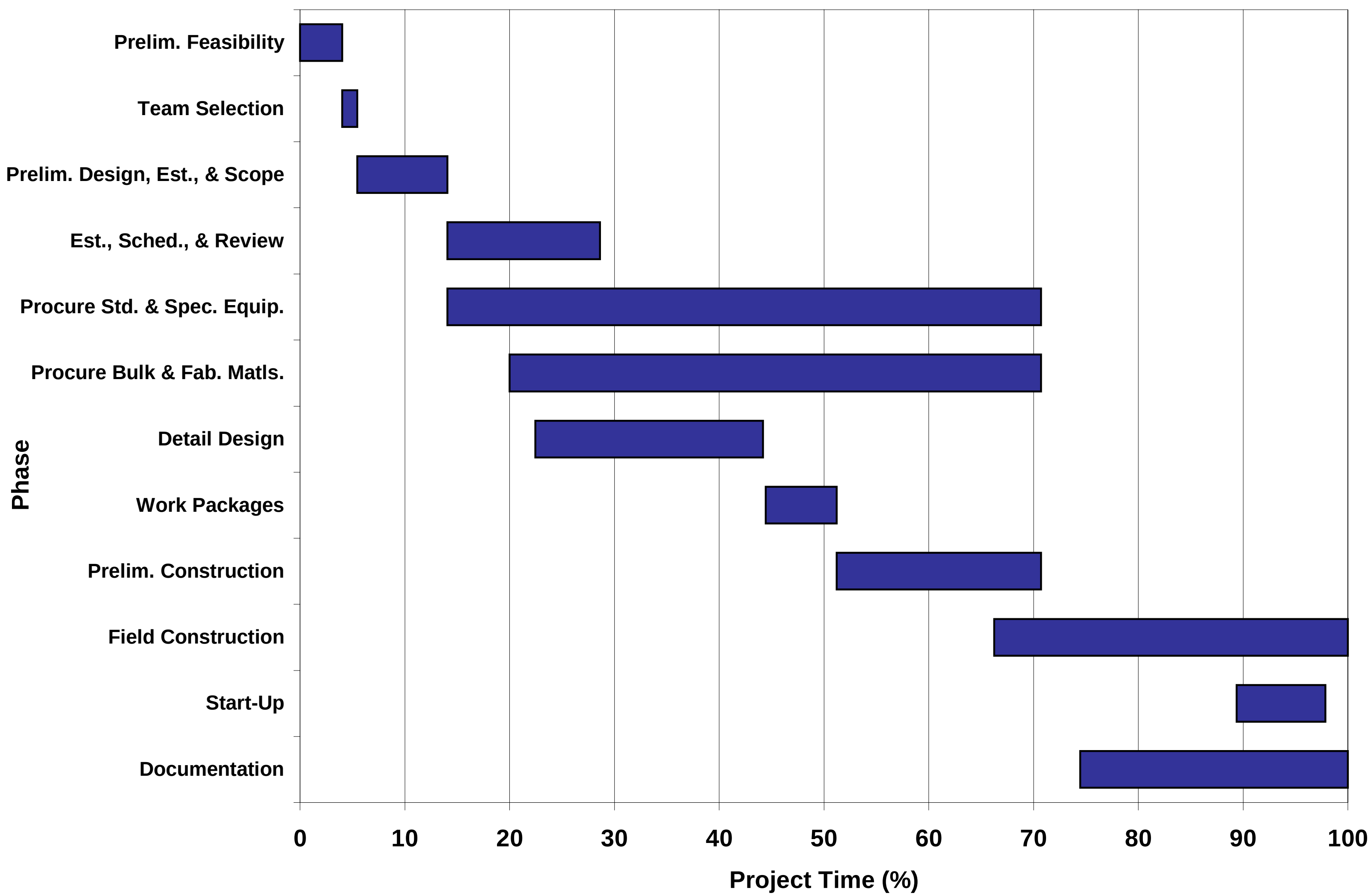


Figure 4.5 – Scaled Bar Chart Giving Baseline Phased Values

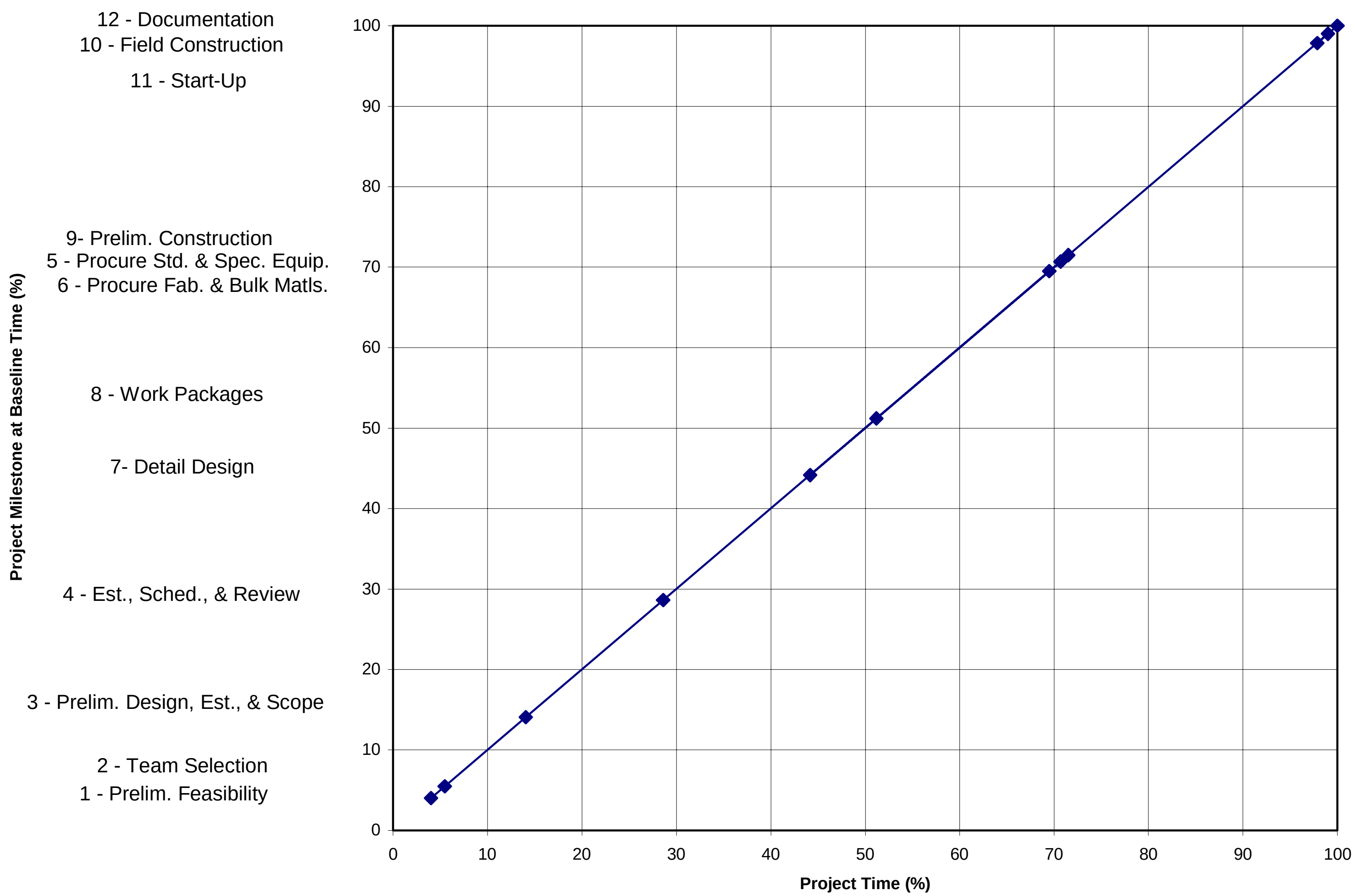


Figure 4.6 – Scaled Milestone Chart Giving Baseline Milestone Values

4.7 Conclusions

This chapter has described the importance of quantifying the impacts of the proposed change to the EPC process. Measuring the impact of PEpC implementation is an especially challenging task because PEpC has never been fully implemented on a project. To address this challenge, it was necessary to develop an understanding of the EPC process model developed by RT 125 and to establish a Scaled Baseline Model for use in the analysis of PEpC.

The Scaled Baseline Model used the inputs and logic developed for the RT 125 model in their entirety. Only the analysis tool and output format were altered. The RT 125 EPC model was moved from ABC-SIM, the simulation tool developed for the research performed by RT 125, to Stroboscope because of the added flexibility provided by Stroboscope. The output was scaled to establish baseline values of 100 percent for Activity Time, Elapsed Time, and Activity Cost to simplify the interpretation of the simulation output. The resulting model has been termed the Scaled Baseline Model. The change from the RT 125 model to the Scaled Baseline Model is shown diagrammatically in Figure 4.7. In addition, two tools for analysis were developed: the Bar Chart and the Milestone Chart. These analysis tools will be used in the next two chapters to assess the impact of PEpC on the EPC process. The effects of PEpC will be assessed by presenting ten theoretical scenarios and four partial implementation of PEpC, and comparing the results of the corresponding simulations with the values produced by the Scaled Baseline Model.

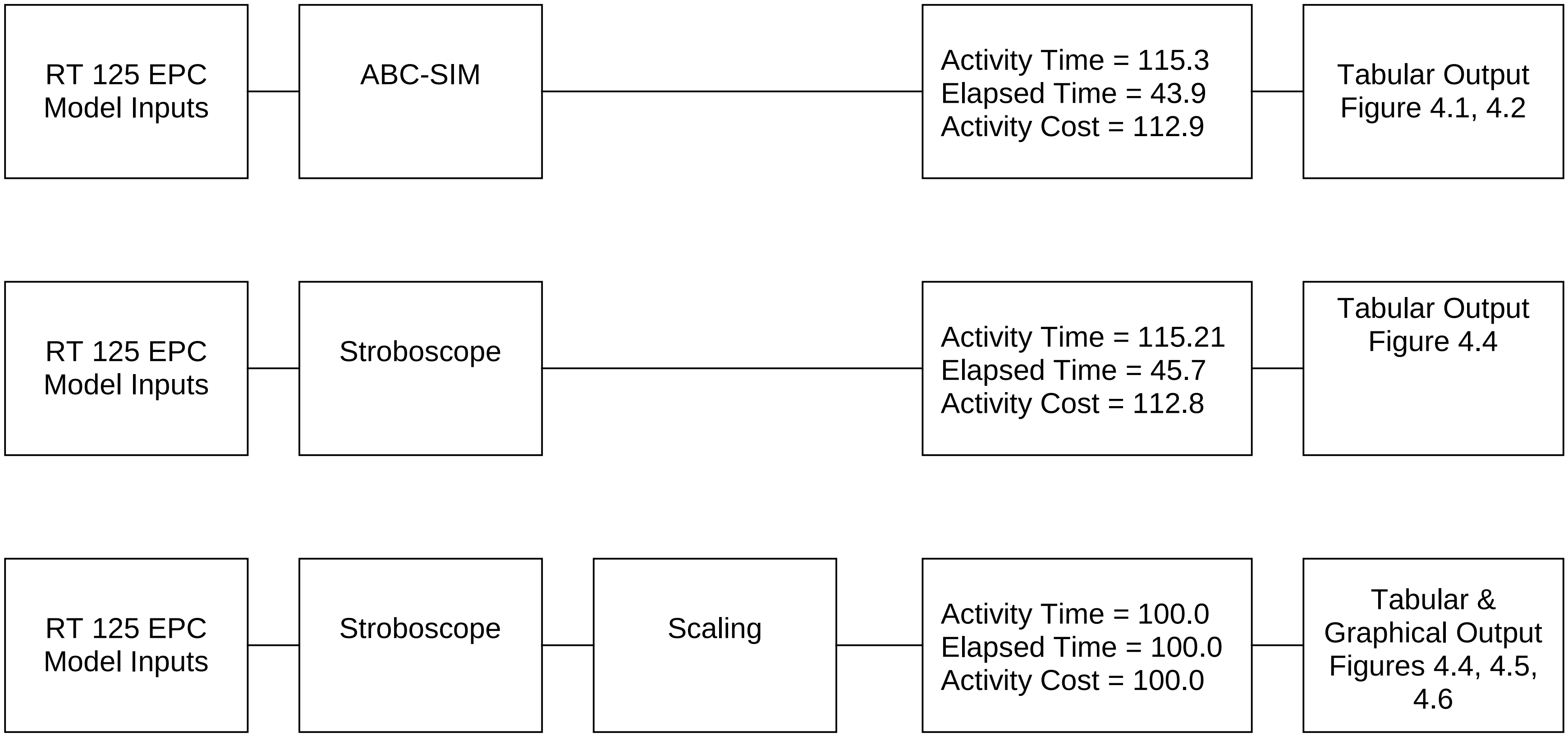


Figure 4.7 – Change Process from ABC-SIM to Stroboscope

Chapter 5
Theoretical Scenarios

5.1 The Challenge

Chapter 4 addressed the difficulty of attempting to measure the impact of a step change that has never been fully implemented. This challenge required that a complex methodology be developed to quantify the effects of PEpC. The first requirement of this methodology was fulfilled in Chapter 4 by establishing a baseline against which PEpC implementation scenarios can be measured. This chapter forms the next step in the methodology by presenting several theoretical scenarios and their resulting impact on the traditional EPC process. The transition from the Scaled Baseline Model developed in Chapter 4 to the theoretical PEpC implementation scenarios described in this chapter is shown in Figure 5.1.

5.2 Scenarios

This section will present two types of theoretical scenarios used to assess the anticipated impact of PEpC on the traditional EPC process. First, a group of theoretical PEpC implementations developed by the Research Team will be analyzed to illustrate the effect of PEpC on the time and cost of the classic EPC process. These scenarios are direct manipulations of the Scaled Baseline Model arising from the implementation of the principal tenets of PEpC. Second, a theoretical model developed by DuPont Engineering will be examined to understand how DuPont’s effort to improve their procurement of compressed air systems is similar to PEpC. The DuPont model will be discussed in Section 5.4 as another implementation scenario to quantify the effects of PEpC. The results of both the theoretical scenarios and the DuPont Model will be presented in Section 5.5.

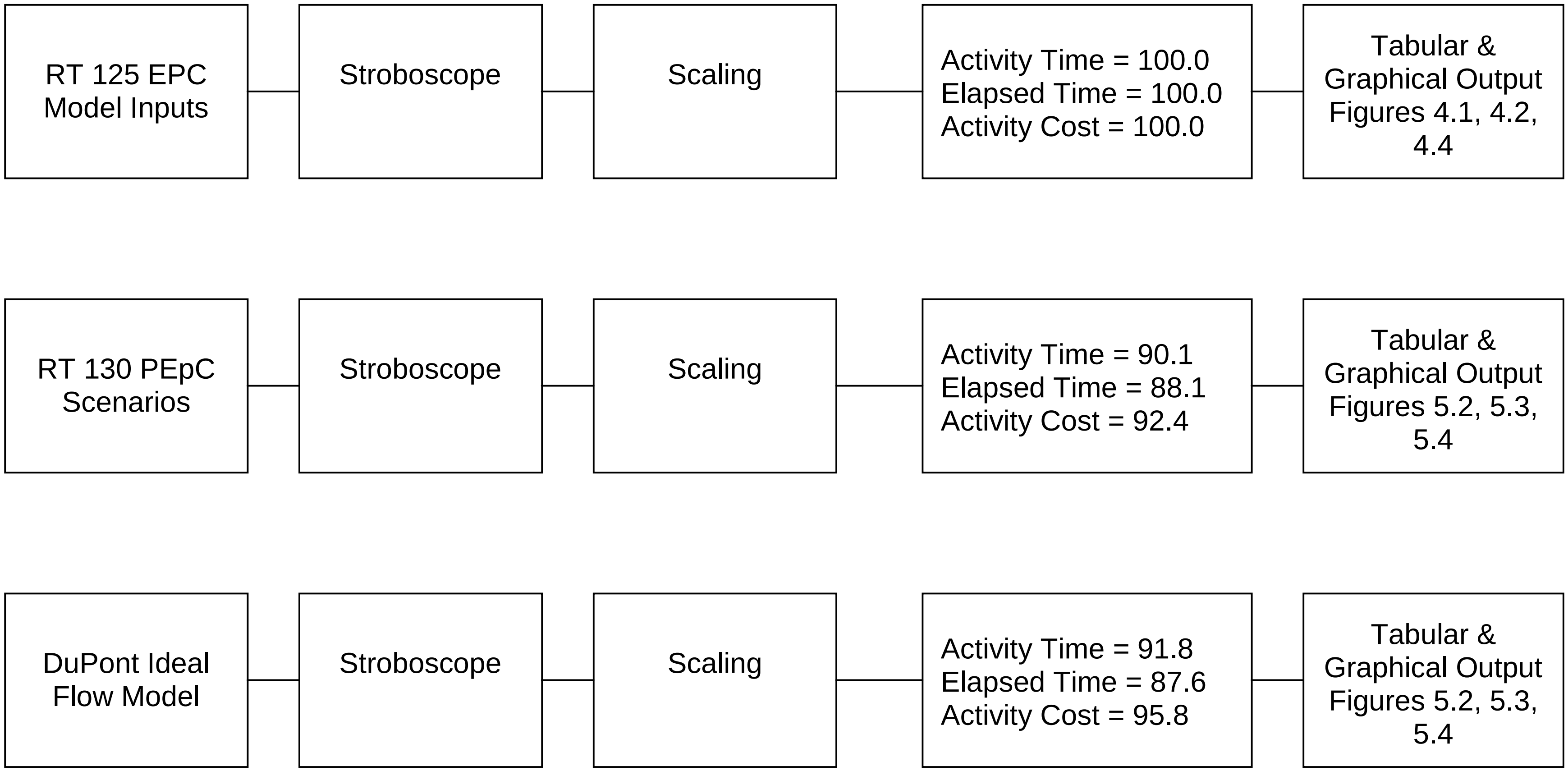


Figure 5.1 – Transition from Scaled Baseline Model to Theoretical Scenarios

5.3 Theoretical Implementation Scenarios

The experience of the Research Team made it possible for them to provide reasonable estimates regarding the potential impact of PEpC on the EPC process. Therefore, the members of the Research Team were asked to develop theoretical PEpC implementation scenarios based on their understanding of PEpC and their experience in procurement and project management.

5.3.1 Survey Tool

A survey tool was developed to assist the Research Team in the development of the PEpC implementation scenarios. A copy of the survey can be found in Appendix C. The survey document includes a description of the principals of PEpC, together with the activities, costs, and durations contained in the Scaled Baseline Model. This is grouped according to the twelve project phases. The activities in each phase are presented with their baseline values for expected time and cost, projected early and late start and finish, and criticality. Research team members were asked to use the baseline information and indicate the impact that they believe PEpC will have on each project phase. Nine research team members completed the survey. Each survey response was given a unique identifier to facilitate the analysis and discussion of the feedback provided by team members. The identifiers range from PEpC1 to PEpC9.

5.3.2 Survey Results

Research team members provided their thoughts regarding the impact of PEpC on activities, duration estimates, cost estimates, and logic relationships using the survey. These survey results can be found in their entirety in Appendix D and are summarized in the sections that follow.

Activities

In many cases, research team members indicated the need for additional activities in the early phases of the project. These additional activities were always related to achieving early supplier involvement in the project and allowing the supplier to participate in the definition and design of strategic items. Activities were created to identify strategic procurement items, select the suppliers of these items, and review the work of the supplier. When activities were added, research team members also indicated time and cost estimates for those activities.

In other cases, some activities were deleted from the project. Many of the deletions occurred because early supplier involvement eliminated the need for practices such as prequalification, the call for and receipt of bids, and the award of the contract later in the project.

Duration Estimates

Duration estimates were both increased and decreased by most respondents. Respondents either indicated a factor by which to adjust the distribution, or a whole amount by which to increase or decrease the expected duration. When a factor was provided, it was simply applied to the time distribution in the Scaled Baseline Model. If an amount of increase or decease was provided, a factor was calculated based on the activity's expected baseline duration. This factor was then applied to the distribution.

In general, additional time was allotted to some activities that occur early in the project that might be extended due to supplier involvement. However, all increases in duration were offset by decreases made in the duration estimates of other activities. The predicted reductions in completion time were a result of the reduction in duplication of work, improved communications, and increased expertise in the design phase.

Cost Estimates

Cost estimates were altered in a pattern similar to the changes in duration estimates. The same methodology was used to modify the distributions. If the respondent provided a factor, it was directly applied to the distribution in the Scaled Baseline Model. However, if a whole amount of increase or decrease was stated, it was necessary to calculate a factor in the same manner used to modify the time distributions.

Additional costs were assumed to occur early in the project when suppliers are initially brought on board, but the downstream effect is a decrease in labor costs for latter activities. Reductions in labor costs were recognized as a result of improved design, increased and enhanced communication, and reduced rework.

Logic Relationships

Several respondents indicated that the project logic would be altered with PEpC implementation. The changes in logic described by the Research Team were a result of early supplier involvement. In many cases, activities can begin earlier when the supplier is part of the project team from the beginning. By rearranging logic relationships based on early supplier input, some items moved off the critical path and therefore decreased the total project completion time.

5.3.3 Simulation Results

The theoretical scenarios developed by the Research Team were used to construct nine different simulation models. The results of the simulations quantify the impact of PEpC on the traditional EPC process.

The simulations demonstrated potential time savings between 5.6 and 19.6 percent and potential cost savings between 0.3 and 17.8 percent of baseline values. The simulation results, presented as summary tables, histograms, bar charts, and milestone charts, are discussed in Section 5.5.

5.3.4 PEpC Survey Example

In an effort to more clearly describe the analysis process applied to each survey received from the Research Team, this section will examine the process step by step as it was applied to the survey with the identifier PEpC1.

In some cases, survey respondents used absolute amounts of time or cost to indicate the effects of PEpC on the EPC process while others provided factors indicating the impact of PEpC on the EPC process. When respondents provided absolute amounts by which to increase or decrease the time or cost of an activity this amount was converted to a factor based on the activity's value in the baseline model. All data given in Appendix D has been converted to time and cost factors for clarity purposes.

For example, the respondent completing the survey PEpC1 provided absolute amounts by which activity durations and cost should be altered. The respondent indicated that the activity PPP.BP.7, Develop Funding Plan, would require approximately 0.04 more time compared to its baseline value of 0.56. This corresponds to a time factor of 1.071 ((0.56 + 0.04)/0.56). The respondent also indicated that the activity PPP.BP.7 would require approximately 0.03 more labor cost compared to its baseline value of 0.30. This corresponds to a cost factor of 1.1 ((0.30 + 0.03)/0.30). This process was repeated for all activities that the respondent indicated would be affected by the PEpC process.

After all survey data had been converted to time and cost factors, the time and cost factors were applied to the original input distributions for the corresponding activities. Each value in the distribution was multiplied by the time or cost factor to create a new distribution reflecting the anticipated impact of PEpC on the time and cost of the traditional EPC process. The new distributions were then used in the simulations.

5.4 DuPont Model

This model implements the principal tenets of PEpC to improve the method by which DuPont procures compressed air systems in manufacturing facilities designed by DuPont Engineering. This scenario is an ideal flow model of the procurement of compressed air systems from Ingersoll Rand. It is based upon the early involvement of equipment suppliers. The model also applies concepts similar to PEpC to the procurement of all standard and specialized equipment, bulk commodities, and fabricated items.

Another feature of the model is that it is based on the concept that long-term relationships have been established with preferred suppliers. These relationships enable DuPont to get suppliers involved early and bring supplier expertise to the design table, resulting in improved quality, reduced life cycle costs, reduced document hand-offs, and reduced project time.

5.4.1 Simulation Inputs

The concepts used in the DuPont Ideal Flow Model make it possible to study another theoretical implementation of PEpC. As with the Research Team assessments of PEpC, this process can be analyzed by examining changes in activities, duration and cost estimates, and logic relationships.

Activities

Table 5.1 summarizes the activities that were deleted from the Scaled Baseline Model and the reasoning behind the action.

Table 5.1 – Summary of Deleted Activities

Activity Code	Activity Name	Reason
MM.SPE.6	Coordinate Vendor Design	Early supplier involvement & cooperative relationship eliminate need
D.DCE.1	Estimate Installation Cost	Incorporated into supplier's scope of supply
D.DD.10	Coordinate Vendor/Engineering Interface	Early supplier involvement & cooperative relationship eliminate need

Only one activity was added to the baseline model to account for the selection of strategic item suppliers.

Duration Estimates

Several duration distributions were altered to reduce the time required to perform certain activities. These reductions can be made because of early supplier involvement and increased expertise during the design phase. All duration alterations were made using factors to express the magnitude of the change in each distribution.

The majority of alterations were made to activities involving the procurement of standard or specialized equipment and bulk and fabricated materials. The details of these changes are described in Appendix E.

Cost Estimates

Cost distributions were altered in the same manner as the time distributions. There was a corresponding cost distribution for each activity that had a duration distribution reduced. The details of these changes are also described in Appendix E.

Logic Relationships

Several logic relationships were altered in the Scaled Baseline Model to reflect the early supplier involvement within the DuPont Ideal Flow Model. Activities such as Specify Specialized Equipment (MM.SPE.1) were allowed to start earlier because suppliers were already on board. The details of these changes are also described in Appendix E.

5.4.2 Simulation Model

A simulation model was constructed using the changes to the Scaled Baseline Model found in the DuPont Ideal Flow Model. The simulation results indicated that PEpC could save 12.4 percent in project completion time and 4.2 percent in project labor cost.

5.5 Summary of the Results

Although the scenarios developed by the Research Team and DuPont Engineering arose from different origins, both can be used to measure the theoretical impact of PEpC on the EPC process. The sections which follow present the results achieved for the project overall and for each project phase.

5.5.1 Impact on Overall Project

The impact of each theoretical scenario developed by the Research Team and the DuPont Model on the overall project are presented in summary table and histogram format in the sections that follow.

Summary Table

Table 5.2 shows the reduction in total project duration and labor cost resulting from each of the nine scenarios developed by the Research Team, and the DuPont Model. All comparisons are made against the baseline time and cost values of 100 percent. Time savings are expressed as a reduction in critical path completion time for the project overall (i.e. reduction in total elapsed time).

Table 5.2 – Simulation Summary of Theoretical Scenarios

Model	Average Project Duration (%)	Reduction in Project Duration (%)	Average Project Cost (%)	Reduction in Project Labor Cost (%)
Baseline	100.0	0.0	100.0	0.0
PEpC1	94.4	5.6*	94.2	5.8
PEpC2	88.6	11.4	86.3	13.7
PEpC3	90.7	9.3	97.1	2.9
PepC4	91.9	8.1	97.5	2.5
PEpC5	83.8	16.2	99.7	0.3*
PEpC6	91.1	8.9	85.4	14.6
PEpC7	80.4	19.6^{+}	82.2	17.8^{+}
PEpC8	93.3	6.7	94.3	5.7
PEpC9	81.5	18.5	99.2	0.8
DuPont	87.6	12.4	95.8	4.2

* Minimum Values

$^{+}$ Maximum Values

Table 5.2 also illustrates the fact that each theoretical scenario anticipates reductions in both time and cost to occur as a result of PEpC. Reduction in project completion time ranges from 5.6 to 19.6 percent and reduction in project labor cost ranges from 0.3 to 17.8 percent.

Histogram of Results

By grouping the scenario simulation results into ranges, it is possible to observe a trend in the results. Figure 5.2 is a histogram of the simulation results for reduction in project duration grouped in ranges of four percentage points. The histogram shows a concentration of values in the 8 to 12 percent range and another concentration in the 16 to 20 percent range. This distribution indicates that a significant portion of the respondents felt that moderate reductions in project duration could be achieved, while several other respondents felt that PEpC could result in breakthrough levels of reduction in project duration.

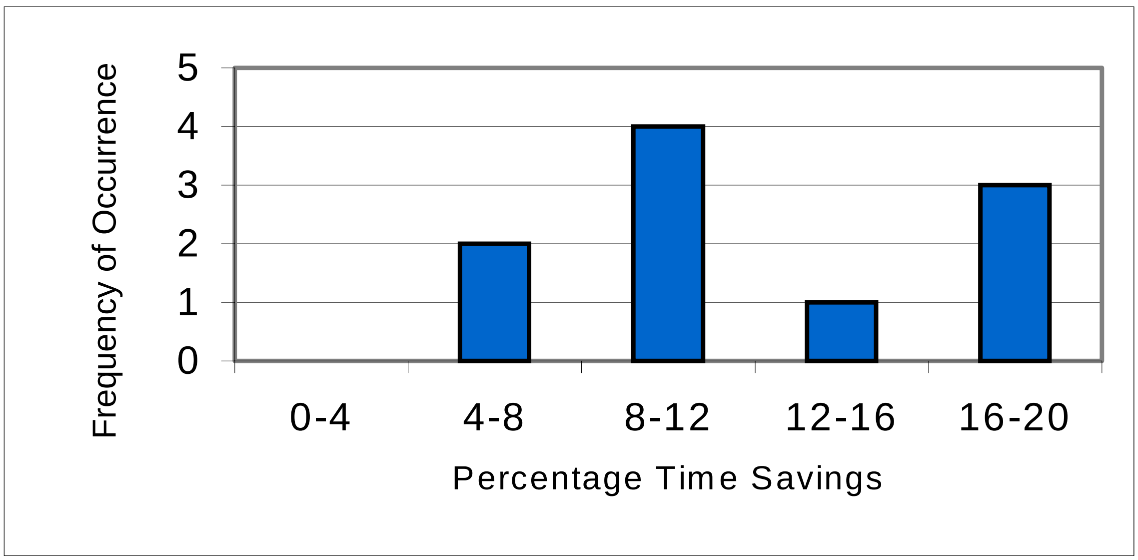


Figure 5.2 – Histogram of Results, Reduction in Project Duration

The histogram shown in Figure 5.3 illustrates the simulation results for reduction in project labor cost grouped in ranges of four percentage points. The majority of respondents indicated that a reduction in project labor cost up to 8 percent could be achieved through the implementation of PEpC. However, three respondents indicated that breakthrough levels of reduction in project labor cost could be achieved.

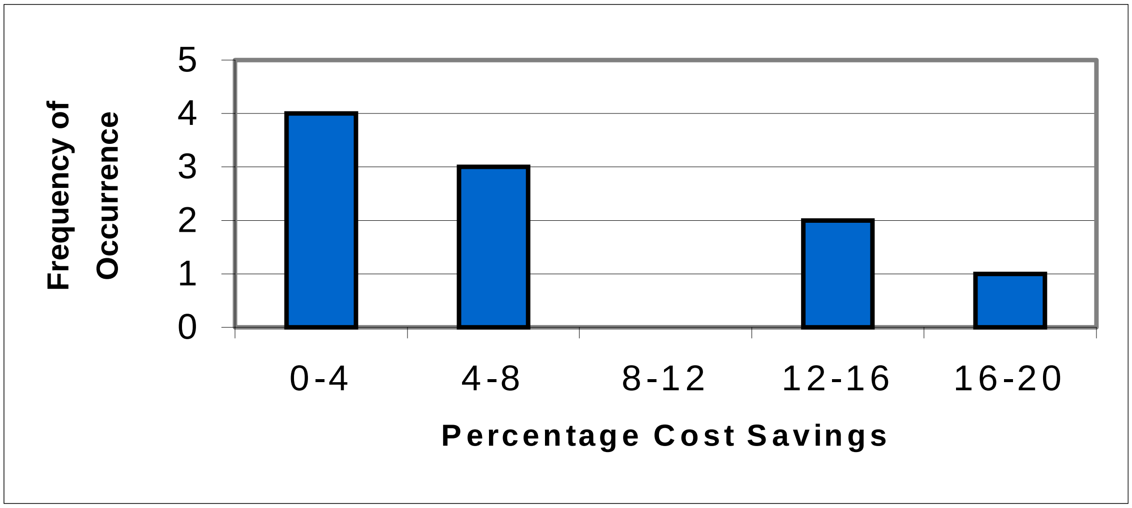


Figure 5.3 – Histogram of Results, Reduction in Project Labor Cost

5.5.2 Impact on Individual Project Phases

In addition to analyzing the impact of PEpC on the overall time and cost for the project, it is also important to examine the impact of PEpC on each project phase. To accomplish this task, the results of the theoretical scenarios were analyzed as a group. The maximum and minimum value for each phase will be presented using a summary table, a summary bar chart, and a milestone chart.

Summary Table

Table 5.3 presents the reduction in completion time for each project phase compared to the baseline completion time for each project phase. As this table illustrates, PEpC did not produce a reduction in the completion for every project phase. In fact, PEpC caused the completion time for the first four phases to increase. This increase is a result of additional supplier involvement in the early project phases. It is important to note, however, that the reductions achieved in later phases more that compensates for the increases in initial phase durations. This combination of increased

Table 5.3 – Summary of Reduction in Completion Time by Phase

	Time	
Phase	Minimum Reduction	Maximum Reduction
1 Preliminary Feasibility	-0.8	0.1
2 Team Selection	-1.3	0.9
3 Preliminary Design, Estimate, & Scope	-3.1	2.8
4 Estimate, Schedule, & Review	-4.2	9.4
5 Procure Std. & Spec. Equipment	3.1	15.7
6 Procure Fabricated & Bulk Materials	3.2	15.7
7 Detail Design	3.1	14.1
8 Work Packages	3.3	14.7
9 Preliminary Construction	3.3	15.8
10 Field Construction	5.2	19.5
11 Start-Up	5.2	19.6
12 Documentation	5.3	19.6

completion time in early phases and reduced completion time in later phases produces the net reduction in project time discussed in Section 5.5.1. This table also illustrates a consistency among the theoretical scenarios regarding the predicted impact of PEpC on project time. It is clear that research team members felt that there could be an initial increase in phase completion time, but that greater savings would be achieved in later phases.

Analysis of the simulation results for the theoretical scenarios did not reveal a clear pattern with regard to reduction in project labor cost. For each phase there was at least one scenario that predicted reduced labor cost and at least one scenario that predicted increased labor cost. This is shown in Table 5.4, which presents the minimum, maximum, and baseline cost for each phase.

It is important to note that despite predictions of possible increased labor cost in all phases, the average result is a predicted reduction in labor cost relative to the baseline value for each individual phase.

Bar Chart

Figure 5.4 illustrates the savings in completion time for each project phase in bar chart format. The dark portion of the bar shows the minimum duration and completion time resulting from the scenario simulations and the light portion of the bar shows the range up to the maximum completion time determined by the scenario simulations. A single dark line along each bar represents the baseline value for the phase completion time. Table 5.3 shows a reduction in completion time for phases five through twelve, and overall savings in completion time between 5.3 and 19.6 percent. The savings in completion time accumulated in these phases more than offsets the increase in completion time for phases one through four required for increased supplier involvement.

Table 5.4 – Summary of Project Labor Cost by Phase

	Labor Cost		
Phase	Minimum	Maximum	Baseline
1 Preliminary Feasibility	1.1	1.4	1.1
2 Team Selection	0.1	0.7	0.5
3 Preliminary Design, Estimate, & Scope	4.6	6.6	6.4
4 Estimate, Schedule, & Review	3.6	4.1	4.1
5 Procure Std. & Spec. Equipment	2.3	4.2	4.1
6 Procure Fabricated & Bulk Materials	4.5	5.6	5.6
7 Detail Design	9.1	18.4	18.1
8 Work Packages	2.4	2.7	2.6
9 Preliminary Construction	10.1	11.5	11.2
10 Field Construction	26.7	35.8	35.6
11 Start-Up	5.6	6.5	6.5
12 Documentation	3.6	4.1	4.1

Milestone Chart

Figure 5.5 is a milestone chart illustrating the reduction in project duration achieved by the theoretical implementation scenarios. The line represents the Scaled Baseline Model with the symbols used to show the earliest and latest completion times produced in the scenarios. The earliest and latest theoretical points form an envelope that defines the anticipated reduction in project completion time generated by PEpC.

5.6 Conclusions

This chapter has identified two types of scenarios that were used to assess the impact of PEpC on the time and cost of the traditional EPC process. First, theoretical scenarios were developed by research team members who utilized their expertise in the areas of project management and procurement. Second, a model developed by DuPont utilized their experience in procurement with Ingersoll Rand. The scenarios developed by the Research Team and the scenario resulting from the DuPont Model were both used to alter Scaled Baseline Model by adding and deleting activities, altering duration and cost distributions, and changing logic relationships.

The results of these scenarios confirm that PEpC will reduce project completion time and project labor cost. The histogram for reduction in project duration (Figure 5.2) illustrates that all results fell between 4 and 20 percent, with most in the 8 to 12 percent range. The histogram for reduction in project labor cost (Figure 5.3) demonstrated that all results fell between 0 and 20 percent, with a concentration in the 0 to 4 percent range. The bar and milestone charts illustrate the effects of PEpC graphically and show the changes that can be obtained in each phase.

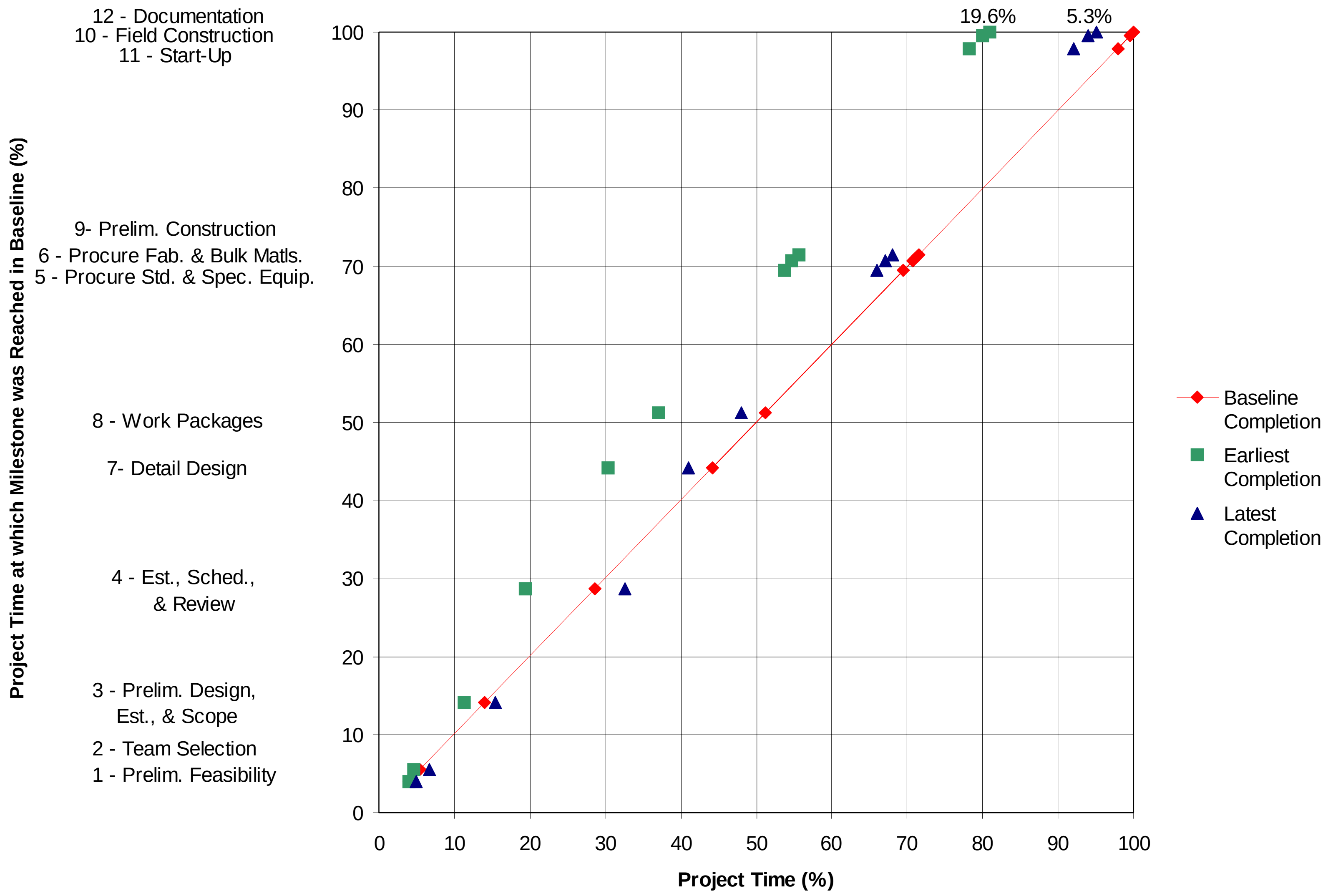


Figure 5.5 - Milestone Chart, Project Time

Chapter 6

Field Implementations

6.1 Introduction

Chapter 5 described a series of theoretical scenarios developed by the Research Team and DuPont Engineering to assess the anticipated impact of PEpC on the EPC process. These scenarios represented the best estimates of a team of experts in response to the question “What impact do you believe a full PEpC implementation would have on the EPC process?”

Because research team members were involved in both the development of PEpC and the development of the theoretical scenarios, it was felt that the validity of the predicted results would be improved if a number of actual projects where “PEpC-like” changes to the EPC process had been implemented could be studied. To do this, the Research Team identified four projects that had used partial implementations of PEpC. The Research Team also identified two supplier marketing presentations that contained PEpC principals, one from Emerson/Fisher-Rosemount, and another from ABB. These partial implementations and supplier presentations provide guidelines against which to compare the attainability of the theoretical scenarios under actual field conditions.

The sections that follow will describe the “PEpC-like” changes made to the EPC process used in the four case studies. It will also summarize the two supplier presentations that utilize PEpC-like concepts. The results of the case studies and presentations will be summarized and compared to the results of the theoretical scenarios developed in Chapter 5.

6.2 Case Study 1

6.2.1 Project Description

This case study describes how a paper manufacturer and a contractor were able to modify the classic fixed price lump sum EPC process to save six months in the project schedule for the construction of a new $290 million paper mill in Port Hudson, Louisiana. This project used practices and relationships that are similar to PEpC. The following significant changes were made to the traditional EPC process.

1. The contractor was involved in the preliminary feasibility phase of the project. Both the owner and contractor knew that the new facility would be a repeat of a plant built some years before.
2. The paper machine supplier was selected and appointed during the team selection phase. The selection was based on
   - competency in and knowledge of the process technology,
   - knowledge of the new facility based on the construction of the previous paper mill, and
   - the acceptance, by both the owner and contractor, that the paper machine supplier would meet time and cost goals.
3. Four other strategic suppliers were nominated by the contractor and selected during the preliminary design, estimating, and scope definition phase, based on knowledge of cost standards and supplier performance. These suppliers provided:
   - control valves
   - stainless steel piping
   - bulk electrical supplies
   - bulk valves.

Changes to the baseline EPC model outside the scope of this analysis included the following:

1. substantial overlapping or fast tracking of design, subcontractor selection, and construction;
2. substantial reductions in detail engineering due to a decision to field all small pipe.

6.2.2 Modeling the Change

Very few, if any, of the activities in the baseline EPC model were entirely eliminated because changes were limited to the supply of five strategic items:

- the paper machine, where process technology, design, integration, and delivery were important;
- the control valves, where benefits were achieved in specification, design, engineering, and standardization;
- the stainless steel piping, where long lead times were reduced;
- the bulk electrical supplies, where the standardization and supply were improved and waste was reduced;
- the bulk valves, where standardization and supply were improved.

Other equipment, materials, and commodities were handled in the normal way with a minimum change from the baseline condition. The effect of the changes can therefore best be modeled by

1. adding activities to the baseline EPC model to reflect the way in which the five strategic items were handled (added activities are given in Appendix F);
2. factoring the time and cost associated with the remaining procurement activities to reflect the fact that a substantial portion of the work was done in the added activities (reduced activities are given in Appendix F);
3. factoring the time and cost of other activities in the baseline EPC model to reflect the impact of early strategic decisions (these activities are listed in Appendix F).

6.2.3 Effect of the Change

The changes detailed in Appendix F were made to the baseline model. The simulation showed a reduction in project completion time of 5.5 percent. This savings was a result of reductions in the following project phases.

- Procure Standard and Specialized Equipment
- Procure Fabricated and Bulk Materials
- Detail Design

The reduction in project completion time produced by these changes to the baseline model are illustrated in bar chart format in Figure 6.1. The ends of the bars indicate the completion times of each phase in the Case Study 1 model, while the single dark lines indicate the baseline completion time of each phase. These savings are also shown using a milestone chart in Figure 6.2.

This study did not show any significant reduction in project direct labor cost.

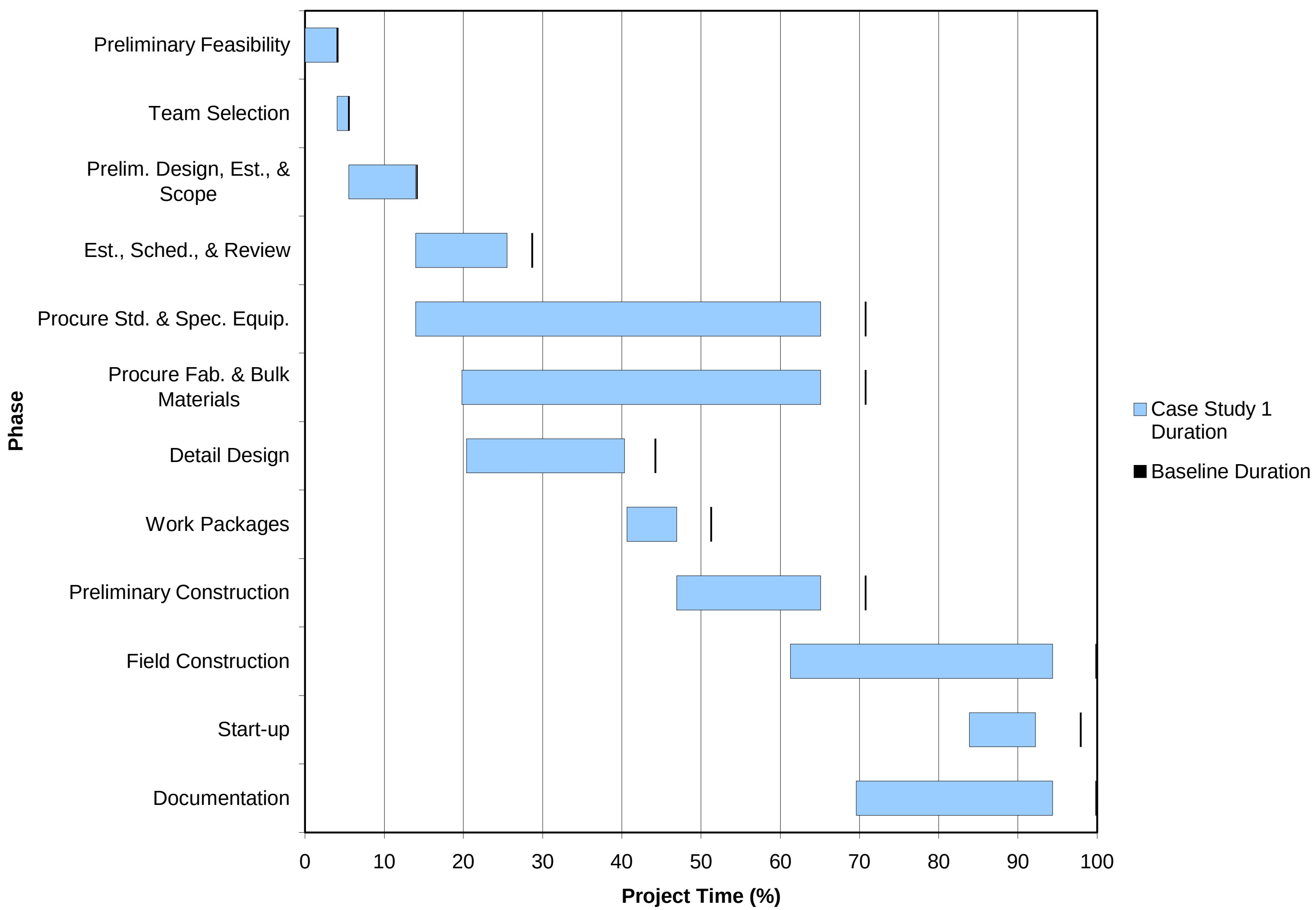


Figure 6.1 – Case Study 1 Bar Chart, Time Savings

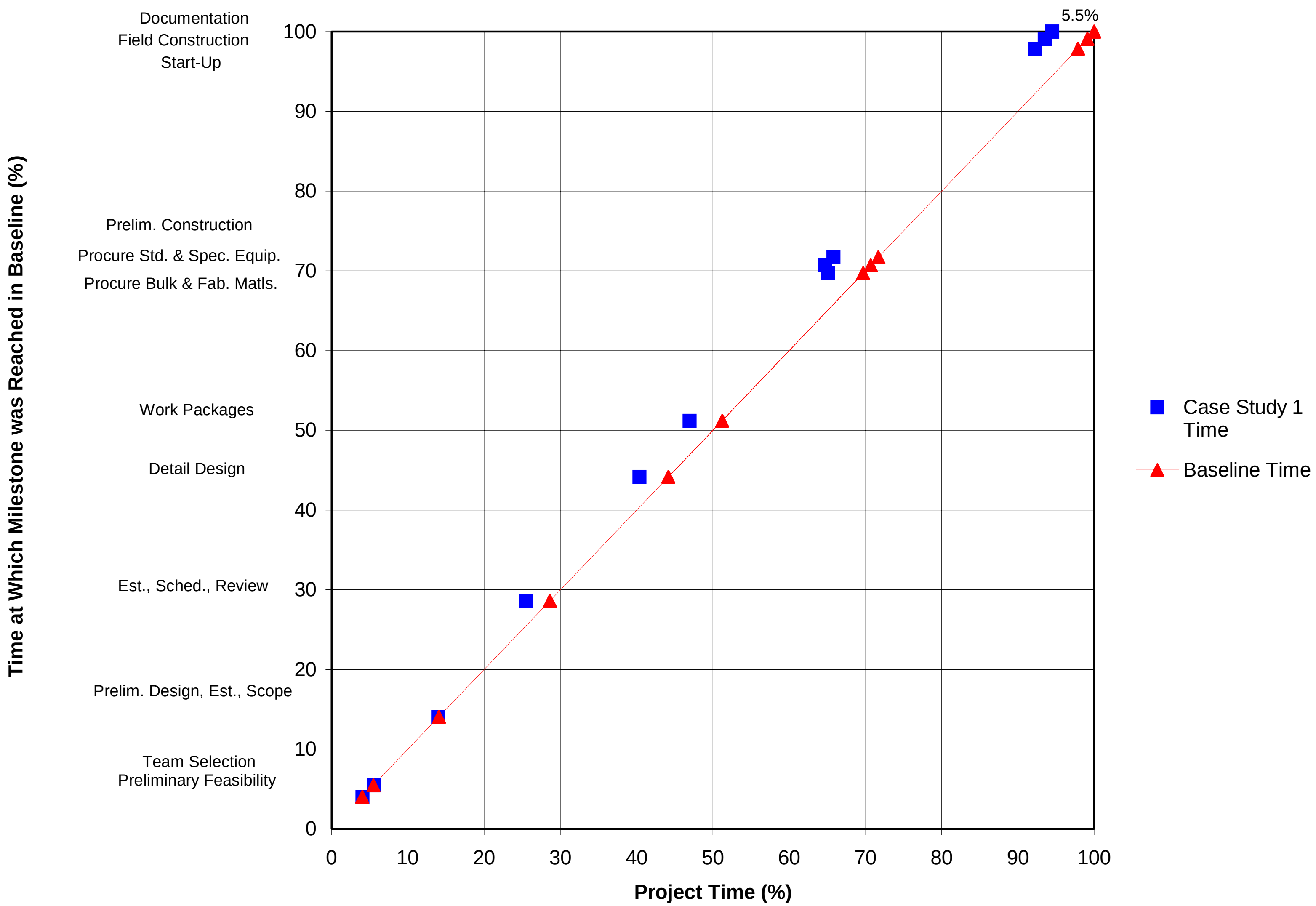


Figure 6.2 – Case Study 1 Milestone Chart, Time Savings

6.3 Case Study 2

6.3.1 Project Description

This case study describes how an owner in the chemical industry, a contractor, and a strategic equipment supplier were able to modify the traditional EPC process to achieve both time and cost savings on the construction of a $76 million chemical reactor train project in Houston, Texas. This project was an immediate successor to an identical project, and, therefore a portion of the savings achieved on this project was due to the copy effect. This case study however, focuses only on the savings achieved through the implementation of PEpC concepts.

Several factors were important to the success of this project.

1. The owner began working with the reactor supplier very early in the process, prior to any formal agreements.
2. The owner invited contractor representatives to be involved in the development stages.
3. Most of the critical equipment was purchased before the EPC contractor was formally involved.
4. The reactor system equipment had been ordered by the midpoint of the design phase.

6.3.2 Modeling the Change

Activities were added to reflect the early selection of the reactor supplier and the early purchase of the reactor. In addition, one activity was eliminated. These are detailed in Appendix G. The majority of changes were modifications to logic only, with time and/or cost factors applying to only a few activities. Time and cost savings were known to exist for several activities, but had not yet been quantified in sufficient terms to apply to this model. These changes are detailed in Appendix G. Last, changes were made to the time and cost distributions for a few equipment activities to reflect the simplified process due to early supplier involvement. These changes are shown in Appendix G.

6.3.3 Effect of the Change

The changes outlined in Appendix G were made to the baseline model. The simulation showed a reduction in project completion time of 6.6 percent. These savings were realized through reductions in the following project phases:

- Preliminary Design, Estimate, and Scope
- Estimate, Schedule, and Review
- Procure Standard and Specialized Equipment
- Procure Fabricated and Bulk Materials.

Again, it is important to note that this value represents only a portion of the total savings achieved because this model was constructed using only the changes that resulted from the implementation of "PEpC-like" changes. It does not include the savings that resulted from the copy effect. The time savings produced by these changes are illustrated in bar chart format in Figure 6.3. This bar chart follows the format developed in Chapter 4. The ends of the bars indicate the completion times of each phase in the Case Study 2 model, while the single dark lines indicate the baseline completion times of each phase. These savings are also shown using a milestone chart in Figure 6.4.

The simulation results showed only a minor decrease in project direct labor cost at 0.7 percent.

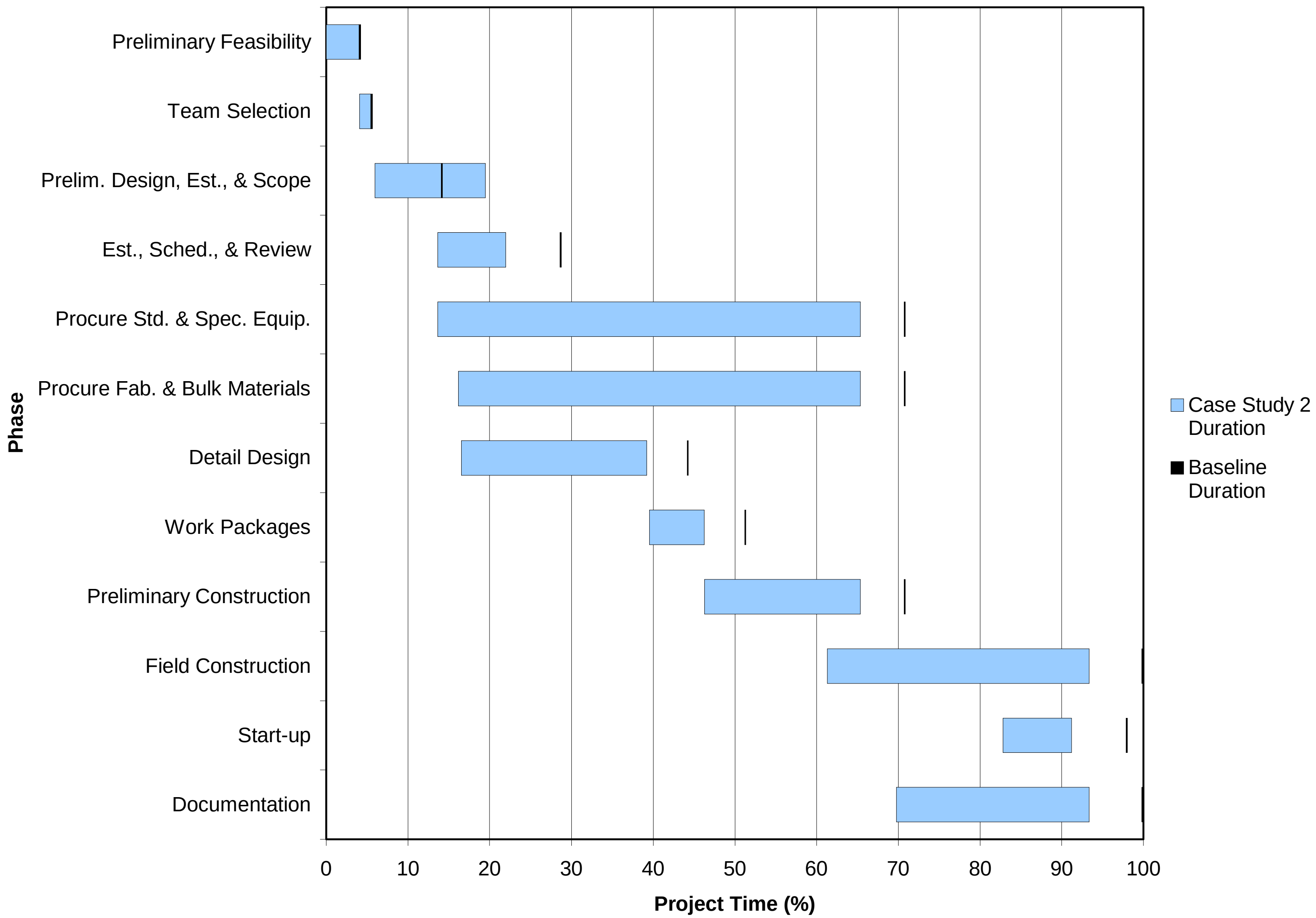


Figure 6.3 – Case Study 2 Bar Chart, Time Savings

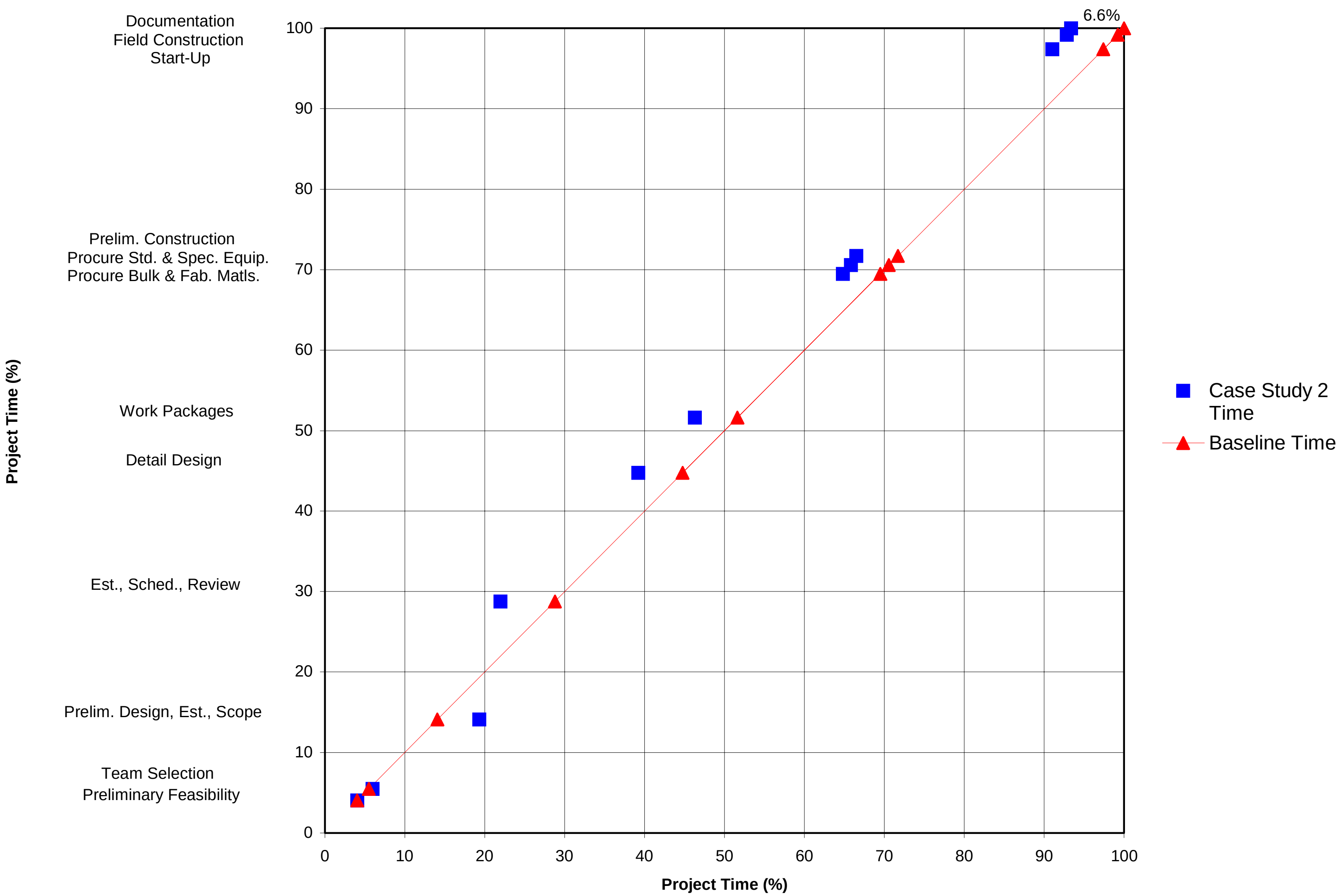


Figure 6.4 – Case Study 2 Milestone Chart, Time Savings

6.4 Case Study 3

6.4.1 Project Description

This case study describes the action taken by an owner in the paper industry to shorten the classic EPC cycle time by selecting the supplier of the main process equipment earlier in the preliminary design phase in the expansion of a wood chip screening plant located in Valliant, Oklahoma. The owner appointed the contractor at the commencement of the project with the intention of entering into a normal lump sum EPC contract upon completion of the conceptual design and estimate, and upon approval of the capital authorization request. The contracting strategy was changed early in the development of the design basis when a work package covering the engineering, design, and supply of the chip line and associated systems was defined and taken out of the overall EPC scope of work. This change in contracting strategy was adopted to give the owner better control over three areas:

- the schedule associated with the delivery and installation of the chip line
- the delivery and scheduling of the drawings associated with the chip line
- the performance guarantees associated with the chip line equipment.

The owner worked with the contractor to develop a detailed request for quotations. Responses were received from the relatively small number of organizations with the technology and capability needed to perform the required work. The owner's central project engineering team, the management of the facility, and the contractor reviewed the responses received, and reached the agreements needed to issue a letter of authorization to the selected supplier. The letter defined the basis of payment and authorized the supplier to continue with early engineering and procurement.

The project received capital authorization shortly after the negotiations with the supplier had been concluded. The fact that the contractor had been involved with the preliminary feasibility studies and the fact that the chip line equipment supplier was already working under a letter of authorization made it possible to conclude contracts with these two parties within days of capital authorization. This reduced the time required for team selection and preliminary design by approximately 6 weeks. Expedited drawing deliveries and other efficiencies led to project completion in 12 months as opposed to the normal 13-14 months.

6.4.2 Modeling the Change

The contractor performed the balance of procurement, all non-vendor engineering, and all construction. Therefore, it was not possible to eliminate any activities from the baseline EPC model. Activities for the selection of the EPC contractor and the chip line equipment supplier in the preliminary feasibility stage were added, and activities associated with the chip line equipment supplier were factored. These changes are detailed in Appendix H.

6.4.3 Effect of the Change

The changes detailed in Appendix H were made to the baseline model and simulation runs performed. These showed an overall reduction in project completion time of 8.1 percent. This savings came through reductions in the following phases:

- Team Selection
- Procure Standard and Specialized Equipment
- Detail Design
- Field Construction.

The time savings produced by these changes are illustrated in bar chart format in Figure 6.5. The ends of the bars indicate the completion times of each phase in the Case Study 3 model, while the single dark lines indicate the baseline completion times of each phase. These savings are also shown using a milestone chart in Figure 6.6.

Table 6.1 summarizes project direct labor costs by phase for the baseline model and for the Case Study 3 implementation. A review of this table indicates that direct labor cost savings were achieved in the following phases:

- Team Selection
- Preliminary Design, Estimate, and Scope
- Procure Standard and Specialized Equipment.

This implementation of PEpC-like concepts produced overall direct labor cost savings of 6.1 percent.

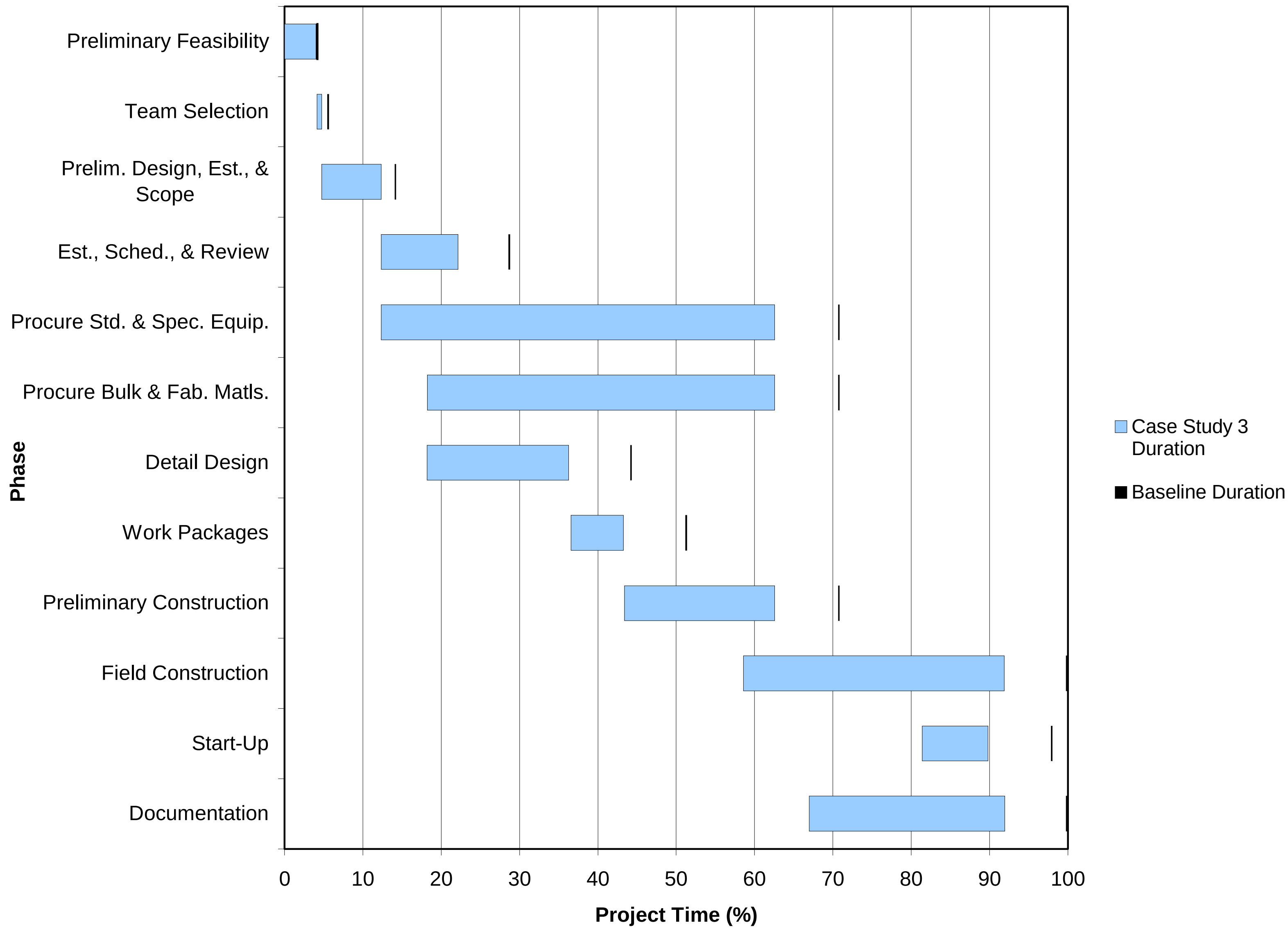


Figure 6.5 – Case Study 3 Bar Chart, Time Savings

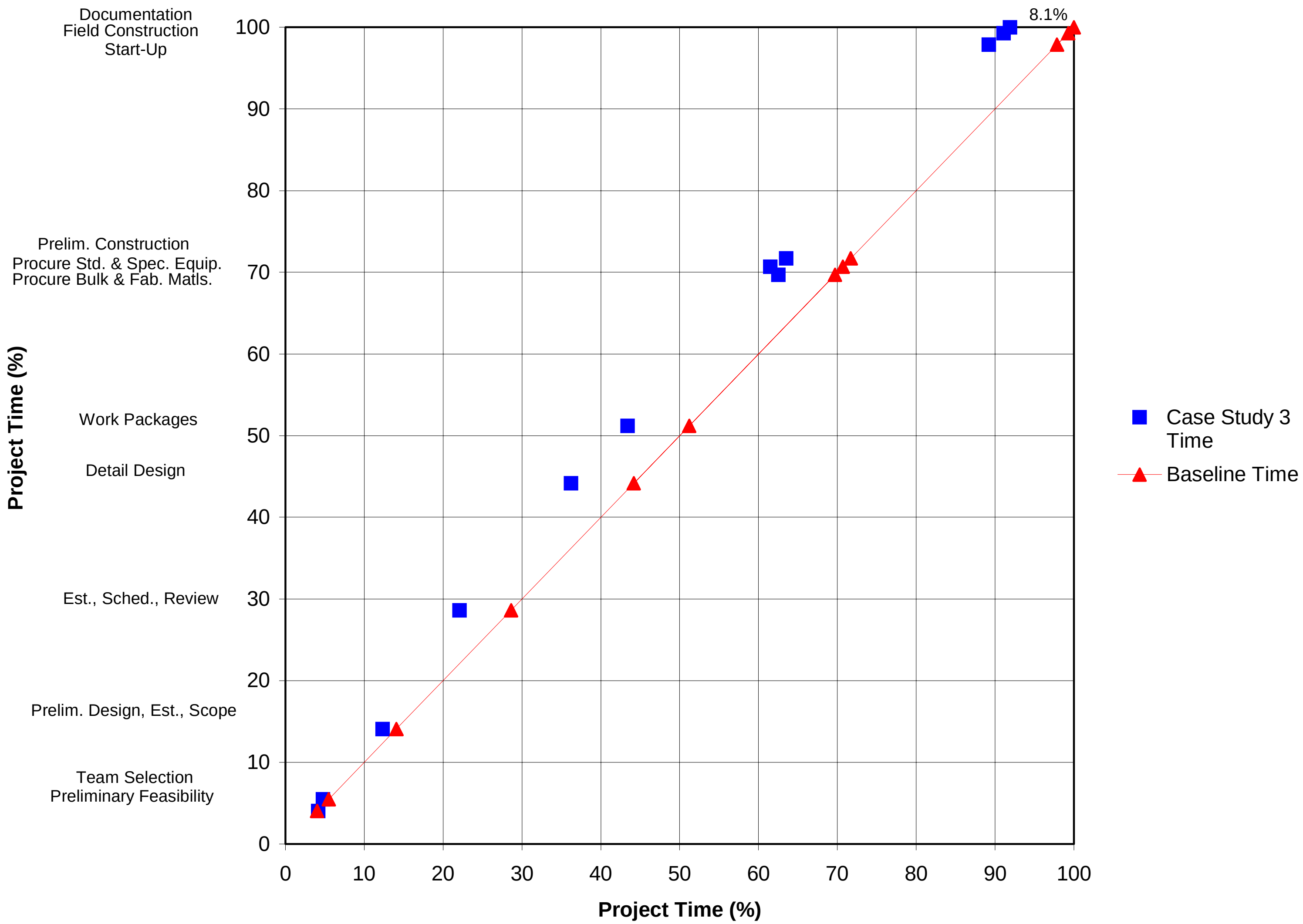


Figure 6.6 – Case Study 3 Milestone Chart, Time Savings

Table 6.1 – Case Study 3 Cost Summary

Phase	Baseline Cumulative Cost	Case Study 3 Cumulative Cost	Savings
Preliminary Feasibility	1.1	1.3	-0.2
Team Selection	1.6	1.4	0.3
Prelim. Design, Est., & Scope	8.1	6.4	1.7
Est., Sched., & Review	12.2	10.5	1.7
Procure Std. & Spec. Equip.	16.2	14.0	2.3
Procure Fab. & Bulk Matls.	21.8	19.5	2.3
Detail Design	40.0	34.1	5.9
Work Packages	42.6	36.7	5.9
Prelim. Construction	53.9	48.1	5.8
Field Construction	89.5	83.5	6.0
Start-Up	95.9	90.0	5.9
Documentation	100.0	93.9	6.1

6.5 Case Study 4

6.5.1 Project Description

This case describes how a brewing company selected and appointed a bottle line equipment supplier to provide all equipment, piping, and electrical control systems required for a new 1200-bottle-per-minute bottle line located in Syracuse, New York. The total installed cost was $22 million. The project used various contractors in a multiple prime format. The supplier had previously provided only major equipment items to the owner, but had provided “turnkey” installations to other clients at other locations.

A steel fabricator with a proven track record for quality and schedule adherence was selected and appointed early in the project to design, fabricate, and deliver structural steel according to a phased schedule established by the owner and the general contractor.

The owner's in-house engineering generated all designs for sitework and utilities. Contracts for these work packages were completely awarded immediately after the layout of the bottle line had been finalized. A general contractor with an established record was appointed to perform remaining engineering and construction activities. All engineering and construction schedules were specifically directed to achieve dates set by the owner and the bottle line supplier/contractor.

6.5.2 Modeling the Change

The project delivery methodology used by the owner for this project is, in many ways, different from the EPC process that forms the baseline for measuring the effect of PEpC or PEpC-like implementations. The fact that the supplier of a strategic system–the bottle line–was appointed early to supply, design, and integrate a complete system is, however, consistent with PEpC tenets.

Consistency requires that the changes made by the owner to achieve substantial reductions in cost and time be modeled as if they occurred relative to the baseline EPC model. The changes made reflect the following:

- the addition of activities in the team selection phase to reflect work done to appoint the bottle line supplier and steel fabricator;
- substantial reductions in the preliminary design, estimate, and scope phase to reflect the work done by the two strategic suppliers;

- reductions in the Procure Specialized Equipment phase activities and a change in the logic to place them at an earlier position in the logic diagram;
- similar changes to the Fabricated Materials activities to reflect the appointment of the steel fabricator;
- reductions in the Detail Design activities to reflect the actual reductions in time achieved through the appointment of the bottle line supplier;
- reductions in the Start-Up time to reflect the actual conditions achieved.

These changes are detailed in Appendix I.

6.5.3 Effect of the Change

The changes described in Appendix I were made to the baseline model. The simulation showed an overall reduction in project completion time of 18.6 percent and an overall reduction in project direct labor cost of 6.6 percent. Reductions in project completion time were obtained through changes in the following phases:

- Estimate, Schedule, and Review
- Procure Standard and Specialized Equipment
- Procure Fabricated and Bulk Materials
- Detail Design.

The reduced completion times for these phases can be seen graphically in the bar chart presented in Figure 6.7. The milestone chart presented in Figure 6.8 also reveals the overall savings in project completion time.

Table 6.2 summarizes the direct labor cost reduction achieved in the Case Study 3 implementation by phase. Reductions in project direct labor cost were obtained through changes in the following phases.

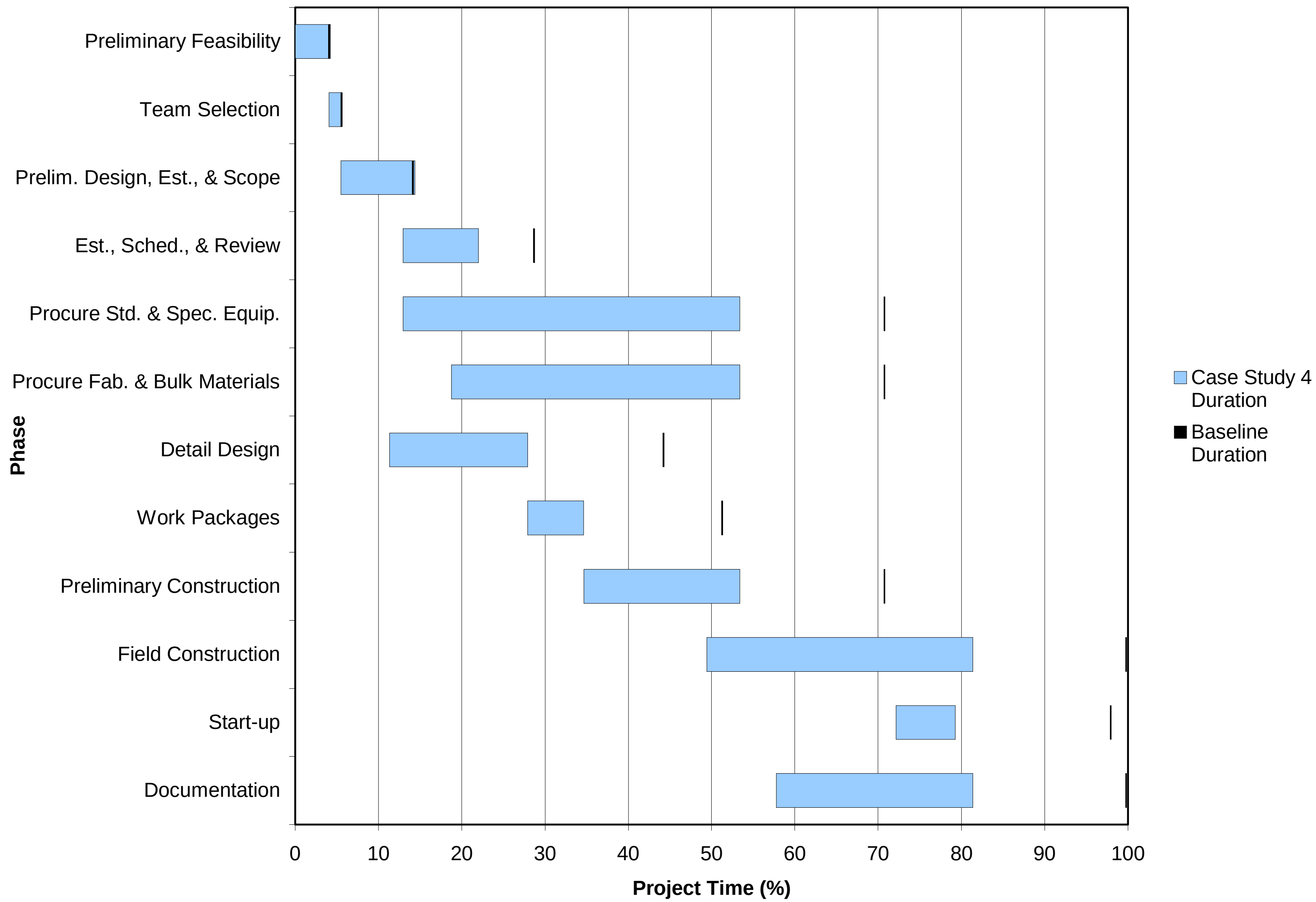


Figure 6.7 – Case Study 4 Bar Chart, Time Savings

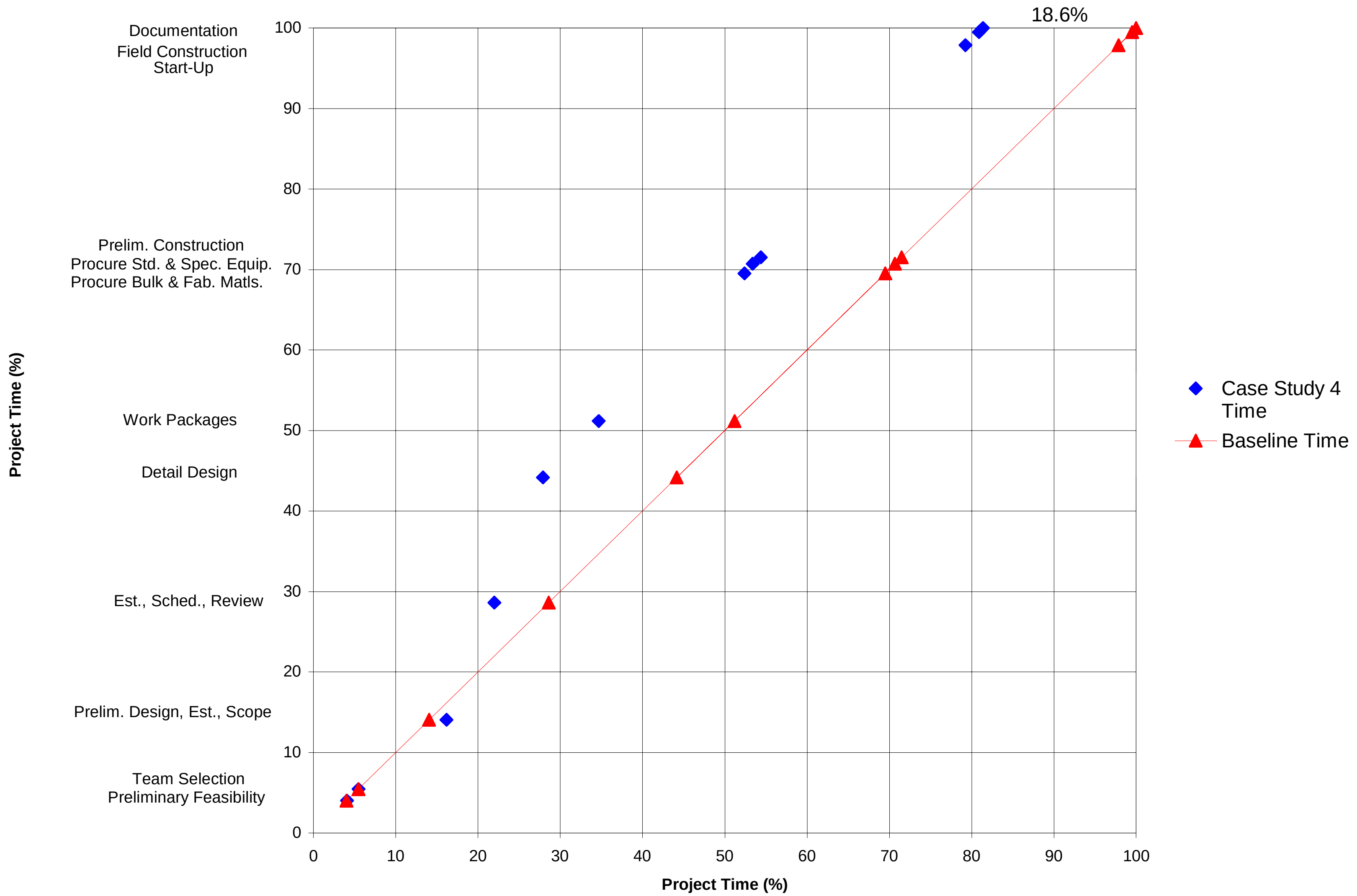


Figure 6.8 – Case Study 4 Milestone Chart, Time Savings

Table 6.2 – Case Study 4 Cost Summary

Phase	Baseline Cumulative Cost	Case Study 4 Cumulative Cost	Savings
Preliminary Feasibility	1.1	1.1	0.0
Team Selection	1.6	1.4	0.2
Prelim. Design, Est., & Scope	8.1	7.3	0.8
Est., Sched., & Review	12.2	11.5	0.7
Procure Std. & Spec. Equip.	16.2	15.0	1.2
Procure Fab. & Bulk Matls.	21.8	19.6	2.2
Detail Design	40.0	33.9	6.1
Work Packages	42.6	36.5	6.1
Prelim. Construction	53.9	47.9	6.0
Field Construction	89.5	83.8	5.7
Start-Up	95.9	89.5	6.4
Documentation	100.0	93.4	6.6

- Team Selection
- Procure Standard and Specialized Equipment
- Procure Fabricated and Bulk Materials
- Detail Design.

Changes in these phases resulted in overall cost savings of 6.6 percent for the project.

6.6 Emerson/Fischer-Rosemount Presentation

Emerson/Fisher-Rosemount (F-R), a producer of process control products and systems, presented PEpC-like principles in a recent marketing presentation. These PEpC-like concepts include

- working cooperatively with key contractors to provide the best total value to mutual customers
- streamlining the procurement cycle
- total lifecycle approach (Fisher-Rosemount 1997).

The presentation by F-R also includes statements as to why these items are important to end users of their equipment and systems. F-R states that, by performing the tasks described above, they can significantly improve reliability and safety, reduce variability, reduce overhead and engineering costs, reduce maintenance costs, and increase process availability (Fisher-Rosemount 1997). For a typical $300 million plant, the result is a savings of approximately 5.5 percent of the cost of goods sold (Fisher-Rosemount 1997). These benefits can be accomplished because F-R has the "expertise to assist process evaluations, project planning, and implementation" (Fisher-Rosemount 1997).

Other benefits that F-R indicates may result from working cooperatively, streamlining the procurement cycle, and focusing on lifecycle costs include

- reduced change orders
- reduced inspection time and cost
- reduced engineering and procurement time
- reduced revisions for initial design specifications
- reduced project risk
- reduced overall project costs (Fisher-Rosemount 1997).

The concepts and benefits presented by F-R are similar to the principal tenets of PEpC and their anticipated effects. This presentation is comparable to the field implementations that were used to create simulation models. Although the results postulated by F-R are of interest and confirm the results obtained in the field implementations, they will not be used in the comparison and conclusions of this chapter.

6.7 ABB Presentation

ABB is an international organization that supplies automation, instrumentation, and optimization equipment and systems to the chemical and related industries (ABB 1997). In addition, ABB participates in innovative project relationships that go beyond the scope of the traditional owner/contractor/supplier relationship. Several of the concepts that ABB describes in its marketing presentation are similar to the tenets of PEpC. ABB participates in partner-based relationships that occur at the initial phase of a project, continue through design into start-up, and continue through the maintenance stages (ABB 1997). In addition to these added dimensions of their role as a supplier, ABB foresees long-term teamwork, minimum sources, focus on total cost of ownership, supplier involvement in design stage, and continuous improvement as the way of the future (ABB 1997). The new role of suppliers is expected to produce many benefits, including the following:

- single point responsibility
- greater exploitation of equipment functionality at an early stage
- efficient problem solving and change control
- reduced interface risks
- proactive use of technology and problem solving (ABB 1997).

ABB predicts that their involvement from initial project phases through to maintenance will produce approximately 30 percent savings compared to traditional EPC methods (ABB 1997). Although this information provides another partial implementation, it will, like the F-R study reported in Section 6.6, not be used in the comparisons and conclusions of this chapter.

6.8 Comparison of Field Implementations

The projects selected for the case studies described in this chapter differ greatly in the type of project and the aggressiveness of PEpC-like practices. Case studies were drawn from a paper mill project, a chemical reactor train, a wood chip screening plant, and a bottling line. In each of the case study projects agreement was reached with suppliers of strategic procurement items and/or systems prior to the associated engineering activities so that better use could be made of supplier expertise. As anticipated, the case studies did not achieve the same results. This is particularly true for case study four which achieved a savings in project completion time of 18.6 percent compared with savings of 5.5, 6.6, and 8.1 percent achieved in the other three studies. This difference in results can be explained through a review of the changes made in each case study and a closer examination of the milestone charts.

All four case studies involved suppliers during the early phases of the project, which resulted in the reduction of several procurement-related activities. Case study four, however, continued to utilize the input and expertise of the supplier throughout the detail design and start-up phases of the project. Therefore, case study four reflects savings in the early project phases, as well as savings in the detail design and start-up phases of the project. Milestone charts for case studies one, two, and three illustrate that savings were achieved in the first four project phases. These savings were then carried through to the end of the project with little additional change. Case study four savings are achieved in the first four project phases, as well as in the detail design and start-up phases. The savings achieved during detail design and start-up phases made it possible to achieve greater reductions in total project completion time.

6.9 Comparison of Theoretical Scenarios and Field Implementations

Table 6.3 builds on the information presented in Table 5.3 to compare the phase completion times obtained in the theoretical scenarios with the phase completion times obtained in the case studies. This table illustrates that the results of the theoretical scenarios (savings between 5.6 and 19.6 percent) are comparable to the results of the field implementations (savings between 5.5 and 18.6 percent). The anticipated impacts of PEpC predicted by the Research Team are similar to the implementations of PEpC-like concepts in the field. Therefore, it is reasonable to state that the time impact of PEpC, as predicted by the Research Team, is attainable under field conditions.

Figure 6.9 shows the information in Table 6.3 graphically. This figure illustrates the range of savings in the completion time of each phase determined by the theoretical scenarios as a bar. The savings in the completion time of each phase achieved in the field implementations are shown relative to this bar using symbols for each case study. The results for case studies one, two, and three are clustered around the conservative end of the bar, indicating that moderate savings were achieved. The results for case study four fall at the other end of the bar, indicating that high levels of savings were achieved. This distribution is a result of the differences in the aggressiveness of PEpC-like practices described in Section 6.8.

Only two field implementations demonstrated a significant reduction in cost. The cost reductions reported in these two field implementations do, however, fall within the range predicted by the theoretical scenarios. The theoretical scenarios predicted reductions in project labor cost between 0.3 and 17.8 percent and the two field implementations indicated labor cost savings of 6.1 and 6.6 percent. This is shown in summary a table, Table 6.4. Therefore, it is reasonable to believe that full PEpC implementation under actual field conditions could yield project labor cost savings similar to those presented in Chapter 5.

Table 6.3 – Comparison of Theoretical Scenarios and Field

Phase	Project Time					
	Theoretical Scenarios		Case Studies			
	Minimum Savings	Maximum Savings	1	2	3	4
1 Preliminary Feasibility	-0.8	0.1	-4.9	0.0	-0.1	-4.9
2 Team Selection	-1.3	0.9	-0.1	-0.5	0.7	0.00
3 Preliminary Design, Estimate, & Scope	-3.1	2.8	0.1	-5.3	1.7	-2.1
4 Estimate, Schedule, & Review	-4.2	9.4	3.1	6.7	6.5	6.6
5 Procure Std. & Spec. Equipment	3.1	15.7	5.6	5.3	8.3	17.3
6 Procure Fabricated & Bulk Materials	3.2	15.7	5.6	5.3	8.3	17.3
7 Detail Design	3.1	14.1	3.8	5.0	8.0	16.3
8 Work Packages	3.3	14.7	4.2	4.9	7.8	16.5
9 Preliminary Construction	3.3	15.8	5.6	5.3	8.2	17.3
10 Field Construction	5.2	19.5	5.6	6.6	8.2	18.6
11 Start-Up	5.2	19.6	5.6	6.7	8.1	18.6
12 Documentation	5.3	19.6	5.6	6.6	8.1	18.6

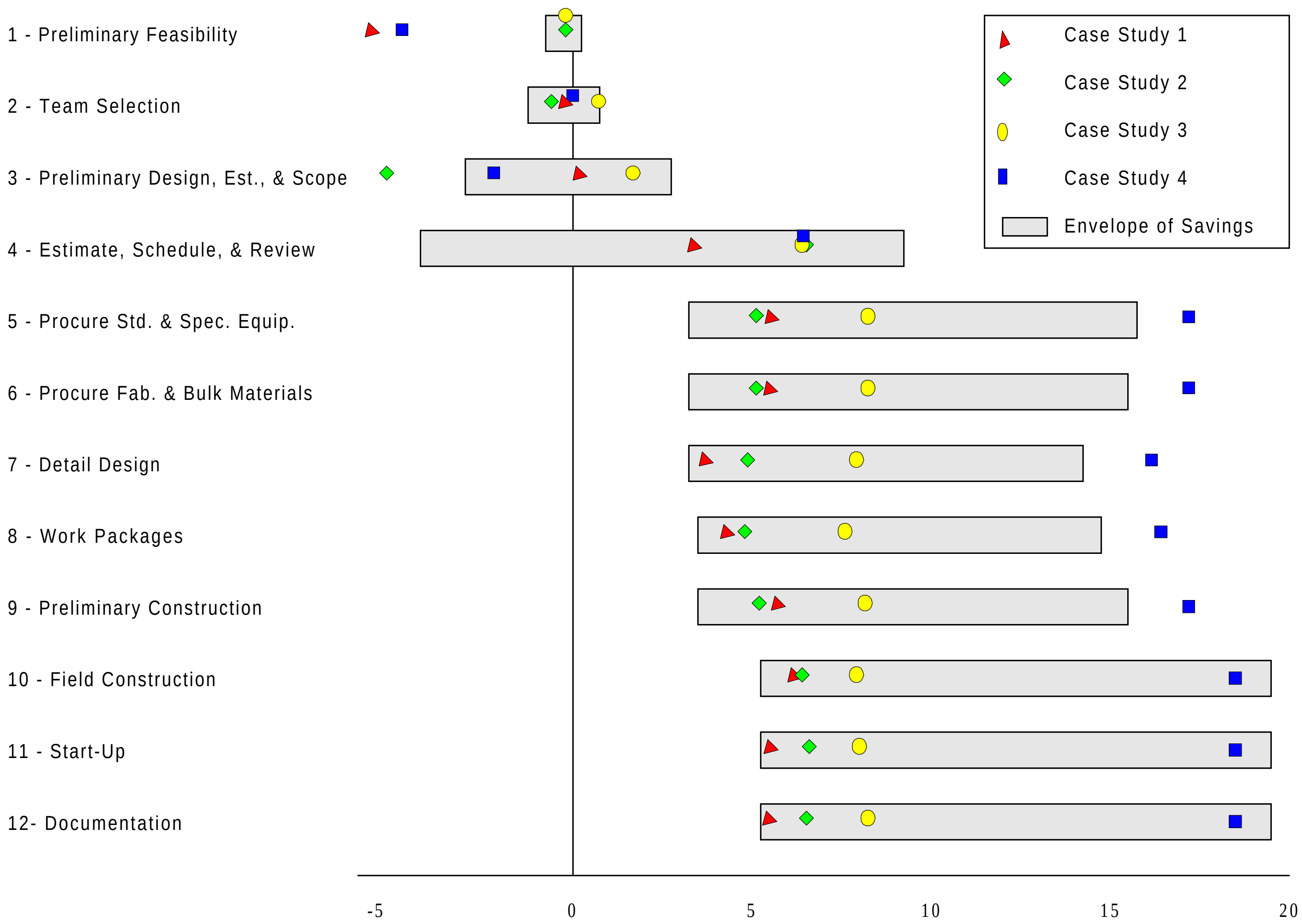


Figure 6.9 – Range of Time Savings from Theoretical Scenarios Compared to Case Studies

Table 6.4 – Comparison of Theoretical Scenarios and Field Implementations Direct Labor Cost

Phase	Project Cost			
	Theoretical Scenarios		Case Studies	
	Minimum Cost	Maximum Cost	3	4
1 Preliminary Feasibility	1.1	1.4	1.3	1.1
2 Team Selection	0.1	0.7	0.1	0.3
3 Preliminary Design, Estimate, & Scope	4.6	6.6	5.0	5.9
4 Estimate, Schedule, & Review	3.6	4.1	4.1	4.2
5 Procure Std. & Spec. Equipment	2.3	4.2	3.5	3.5
6 Procure Fabricated & Bulk Materials	4.5	5.6	5.5	4.6
7 Detail Design	9.1	18.4	24.6	14.3
8 Work Packages	2.4	2.7	2.6	2.6
9 Preliminary Construction	10.1	11.5	11.4	11.4
10 Field Construction	26.7	35.8	35.4	35.9
11 Start-Up	5.6	6.5	6.5	5.7
12 Documentation	3.6	4.1	3.9	3.9

6.10 Conclusions

This chapter examined the results of four partial field implementations of PEpC. Each project used PEpC-like concepts in the project delivery method or relationships. Because the tenets of PEpC have never been fully implemented on a project, these examples provide an estimate of the true savings that are attainable through PEpC implementation under field conditions. The case studies produced savings in project time between 5.6 and 18.6 percent. Table 6.3 compared these savings to the savings predicted by the theoretical scenarios developed in Chapter 5. This table and Figure 6.9 showed that the savings predicted by the theoretical scenarios were comparable to those obtained in the case studies. Table 6.3 and Figure 6.9 demonstrate that the savings predicted by the theoretical scenarios could be attainable under actual field conditions. Table 6.4 illustrated that the cost savings predicted by the theoretical scenarios were also comparable to those obtained in the case studies.

This notion is further supported by the information provided in the supplier presentations from Emerson/Fisher-Rosemount and ABB. These suppliers have also performed actual field implementation of PEpC-like concepts. The results have included reduced costs and reduced project time, as well as many other benefits in the areas of quality and relationships.

The theoretical scenarios, field implementations, and supplier presentations each demonstrated that the implementation of PEpC could produce savings to both project time and cost. This analysis, based on ten theoretical implementation scenarios and four case studies, showed that savings in time between 10 and 15 percent and savings in project labor cost of between 4 and 8 percent were possible.

Chapter 7

Core Competency Guidelines

7.1 Introduction

All capital projects have a basic set of competencies that are required for successful project completion. These competencies represent the skills necessary to complete all tasks associated with project conception, design, construction, and start-up. The purpose of this chapter is to present the results of a core competency review process that facilitates the review and reassignment of project core competencies under PEpC. This review process is a critical step in the implementation of PEpC because it allows all parties involved with the project to define project responsibilities and align expectations prior to the start of the project.

The process of review and reassignment also provides an opportunity to check that the project participants do, in fact, possess the necessary competencies. Without this step, it is possible to make incorrect assumptions that may result in an unsuccessful project. It is therefore recommended that the concepts presented in this chapter be used to define responsibilities, build relationships, and identify gaps in core competencies for the organizations participating in the project. This will facilitate PEpC implementation and lead to more successful projects.

7.2 Competencies in the EPC and PEpC Process

In December 1996, CII Research Team 111 completed a research project entitled *Owner/Contractor Work Structure: A Process Approach*. (CII 1996b) The purpose of the project was to define and investigate the competencies needed for EPC projects and to recommend a process by which responsibility for these competencies could be allocated to either owner or contractor. The research identified and defined 30 project competencies as summarized in Table 7.1 and listed in full in Appendix J.

Table 7.1 – Project Competencies Identified by RT 111

Alliance/Partnering	Maintenance and Operability
Benchmarking/Metrics	Preliminary Design/Scope Development
Business Development	Process/Conceptual Design
Commissioning/Start-Up/Performance Testing	Procurement
Conceptual Cost Estimating	Project Controls
Constructability	Project Management
Construction Management	Project Management Oversight
Convert Research to Project/Scale-Up	Project Planning/Scheduling
Definitive Cost Estimating	Risk Management
Detail Design	Safety
Environmental/Permits	Setting Project Goals, Objectives, & Priorities
Field Quality Control	Team Building
Financial Approval	Technical Expertise
Legal/Contract Administration	Total Quality Management
Lessons Learned	

RT 111 defined a core competency as

> a competency that is critical to having a successful project and must reside with the owner (CII 1996b).

Four competencies were identified as owner core competencies. These were; Business Development, Financial Approval, Project Management Oversight, and Setting Project Goals, Objectives, and Priorities. The only competency that was always recommended for the contractor is Construction. The remaining twenty-five competencies were described as being subject to “structural alignment” on a project by project basis. A methodology to achieve this structural alignment based on the unique demands of each project was defined in the RT 111 report. (CII 1996b)

Successful implantation of a new and innovative project delivery system such as PEpC clearly requires a review and realignment of the competencies required of the parties involved. New competencies must be added and alignment must be changed to ensure that suppliers are indeed brought into the circle of cooperation between owner and contractor.

A special sub-team of RT 130 was established to review the work done by RT 111 and recommend on how this could be used to support PEpC implementation. The team included owner, contractor, and supplier representatives. Work was done in two stages:

> First The list of competencies developed by RT 111 was reviewed and special competencies unique to the PEpC process were defined.
>
> Second Competencies were allocated to owner, contractor, and supplier so that PEpC implementation may be expedited.

The review of competencies needed for PEpC is described in Section 7.3. The process developed for allocating competencies between owner, contractor and supplier is discussed in Section 7.4.

7.3 Competencies Needed for PEpC

The list developed by RT 111 was accepted by the sub team to be complete and sufficient with the exception of six competencies seen to be unique to the PEpC process. These are given in the sections that follow.

7.3.1 Defining Facility Requirements

The first additional competency is Defining Facility Requirements. This includes the ability to predict accurately the conditions that the facility must satisfy so that changes are eliminated or greatly reduced. The owner should possess this competency because it is the owner that understands the performance requirements of a new facility.

7.3.2 Ability to Price a Design and Build to It Without Change

This competency includes the ability to estimate the cost of constructing a given design, and build the project at that estimated price, without changes. The contractor should be responsible for this competency.

7.3.3 Equipment Manufacturing

This competency includes the manufacture of equipment as well as delivery to the site. It should be a core competency for the supplier, but this does not mean that the supplier must perform the actual manufacturing. The supplier may perform the design work but outsource the manufacture of the equipment or system. Therefore, the supplier should be responsible for overseeing the manufacturing process.

7.3.4 Performance Guarantee Responsibility

This competency includes the performance guarantee for each piece of equipment. Although the contractor may be responsible for the installation of the equipment, the supplier should possess this competency. The supplier should be responsible for the equipment's performance.

7.3.5 Proper Equipment Sizing

Suppliers receive some type of Owner Request for Quote that includes a design basis. Therefore, the supplier should be responsible for properly sizing the requested equipment. The ability to size equipment properly should be a core competency for the supplier.

7.3.6 Supplier Engineering

Suppliers will often subcontract a portion of their engineering responsibilities to a consulting engineer, but will maintain engineering for their own equipment in-house. The supplier should have as a core competency the ability to complete the required engineering and effectively oversee any out-sourced engineering.

7.4 Guidelines for the Alignment of Competencies for PEpC

PEpC requires project relationships and a division of responsibilities that differ from the traditional EPC process. Because the goal of PEpC is to assign tasks to the party that will perform the task most effectively, competencies must be distributed among the owner, contractor, and supplier.

The list developed by RT 111 divides some competencies between Owner and Contractor but leaves the majority in a third group subject to “structural alignment” on a project by project basis. This list is shown in Figure 7.1.

Owner	Structural Alignment		Contractor
Business Development	Alliances/Partnering	Lessons Learned	Construction
	Benchmarking/Metrics	Maintenance & Operability	
Financial Approval	Commissioning/Start-Up/ Performance Testing	Preliminary Design/Scope	
	Conceptual Cost Estimating	Process/Conceptual Design	
Project Management Oversight	Constructability	Procurement	
	Construction Management	Project Controls	
	Convert Research to Project/ Scale-Up	Project Management	
Setting Project Goals, Objectives, & Priorities	Definitive Cost Estimating	Planning & Scheduling	
	Detail Design	Risk Management	
	Environmental/Permits	Safety	
	Field Quality Control	Team Building	
	Legal/Contract Administration	Technical Expertise	
		TQM	

Figure 7.1–Owner/Contractor Distribution of Competencies

A three cornered or triangular allocation of competencies is required to bring suppliers into the circle of cooperation between owner and contractor. This triangle divides the competencies into seven categories with each corner depicting one of the parties responsible for the project. Competencies that should be possessed by all three parties are shown in the center of the triangle, and any competency that should be possessed by two parties is shown along the edge of the triangle between the two parties. The structure of the triangle is illustrated in Figure 7.2.

Much consideration was given to the distribution of the competencies among the owner, contractor, and supplier. Originally, sub-team members were asked to identify which party they felt should possess each competency for successful implementation of PEpC. The results showed that all three parties are expected in some way to possess most of the competencies.

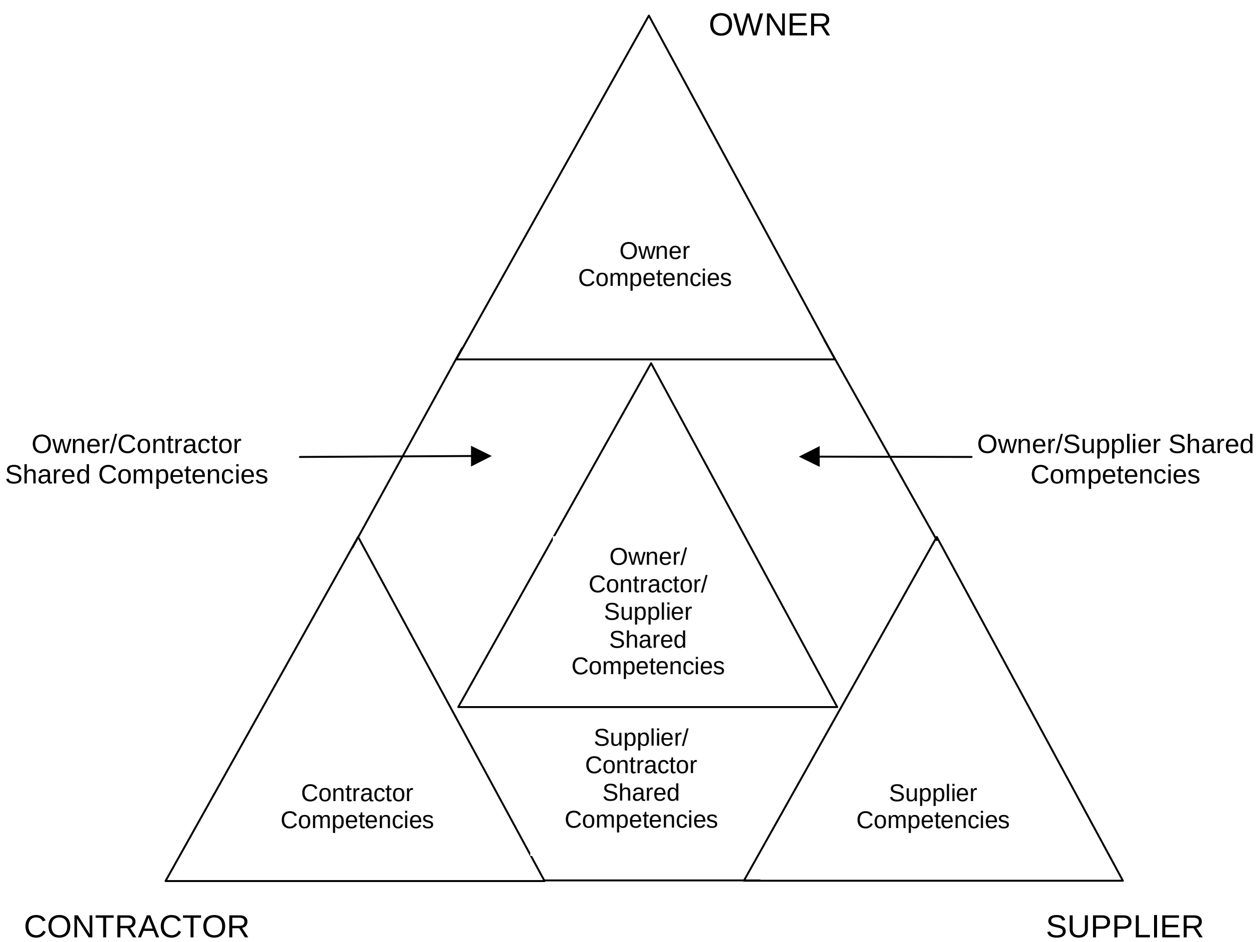


Figure 7.2–Owner/Contractor/Supplier Distribution of Competencies

Members of the sub-team indicated that multiple responses were indicative of the cooperative nature of PEpC and arose from the need to provide specific answers to an issue that varies from project to project. This result confirmed that allocation is, as stated by RT 111 (CII 1996b), subject to structural alignment on a project by project basis.

To address this difficulty and aid in the implementation of PEpC, the sub-team decided to identify which party should take the lead role in each competency. Again, there were some difficulties because of the unique nature of individual projects and there were a few cases where more than one party was identified to lead the process. This distribution of lead roles in project competencies is shown using the triangle structure in Figure 7.3. This figure includes the competencies identified in the RT 111 document (see Appendix J), as well as the new project competencies discussed in Section 7.3.

Sections 7.4.1 through 7.4.17 address the core competencies where more than one lead is specified, or where there is disagreement among special team members.

7.4.1 Alliance/Partnering

Experts from all three perspectives agreed that the owner, contractor, and supplier need to participate in the Alliance/Partnering process. However, suppliers and some contractors felt that the owner should have this as a core competency and take the lead role in developing alliances and partnerships.

7.4.2 Benchmarking/Metrics

Representatives from all three perspectives believed that the Benchmarking and Metrics process should include input from all three parties, but suppliers and some contractors indicated that the owner should take the lead role and set expectations for others.

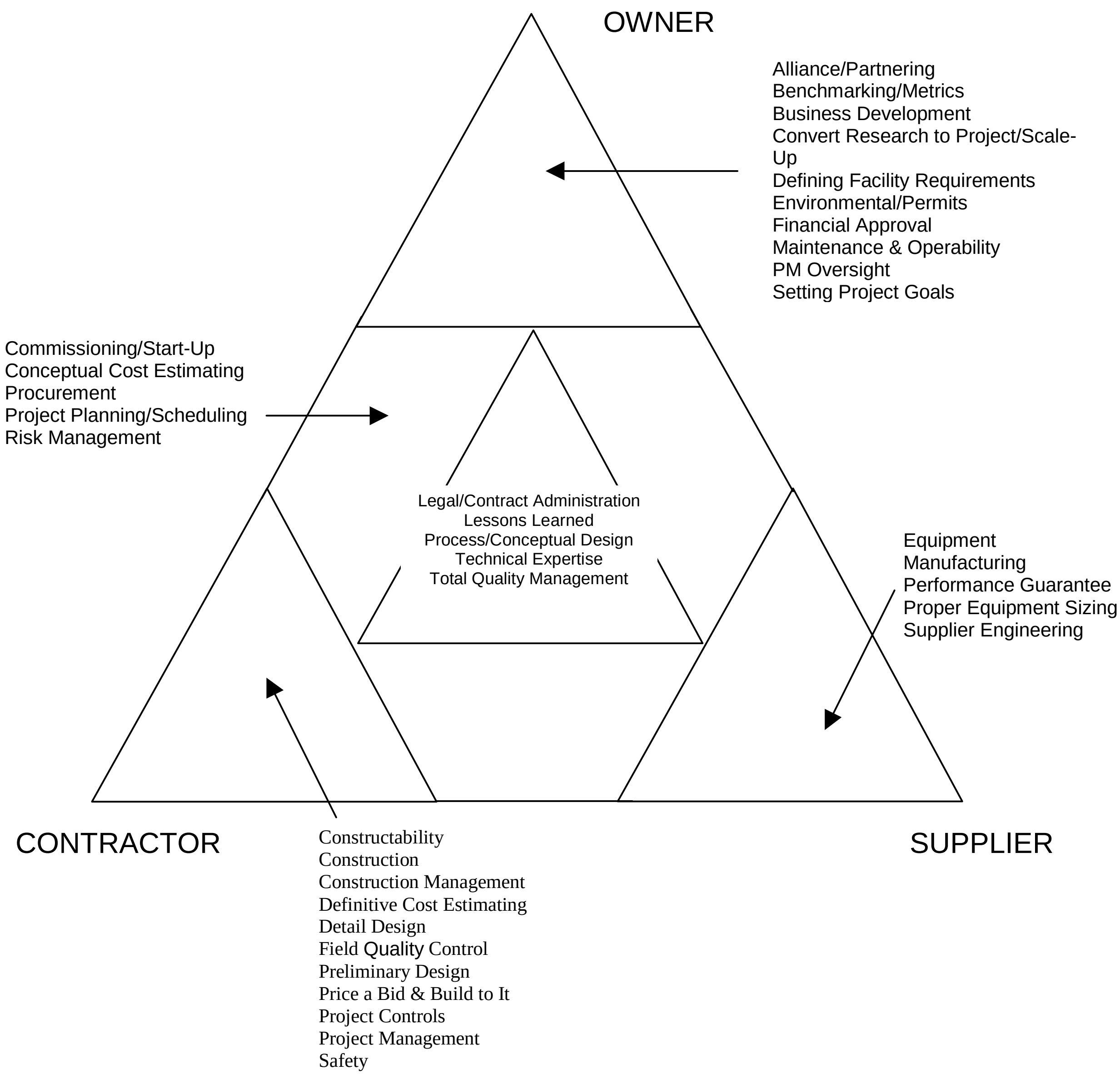


Figure 7.3 - RT 130 Distribution of Competencies

7.4.3 Commissioning/Start-Up/Performance Testing

Owners and some contractors felt that this should be a core competency for both the owner and contractor. Other contractors and suppliers, however, believe that only the contractor needs to have Commissioning/Start-Up/Performance Testing as a core competency.

7.4.4 Conceptual Cost Estimating

Opinions were divided as to which party should hold Conceptual Cost Estimating as a core competency. Owners felt that it should be a core competency of the owner, while suppliers felt it should be a core competency of the contractor. The contractors, however, indicated that either the owner or contractor should have Conceptual Cost Estimating as a core competency, depending on the industry in which the owner operates. Owners in some industries have the capability to perform conceptual cost estimating, while others do not.

7.4.5 Legal/Contract Administration

The team believed that each party should have a core competency in the Legal/Contract Administration area to produce a successful project. It is important that all parties understand the terms of the agreements that they enter.

7.4.6 Lessons Learned

Lessons Learned was identified as a core competency each party should have to maintain the competitiveness of their business. It was also suggested that perhaps the contractor should take the lead because EPC is their business.

7.4.7 Maintenance and Operability

Responses were split on the issue of Maintenance and Operability. One perspective indicates that the owner should have the core competency of Maintenance and Operability because the equipment is the basis of their business. Another perspective indicates that the contractor should have this competency because the contractor is responsible for the facility design and directly impacts the maintenance and operability of the equipment and systems. This is another case in which the response is very dependent on the type of industry in which the owner operates.

7.4.8 Preliminary Design/Scope Definition

Contractors and suppliers agreed that the contractor should take the lead role in Preliminary Design/Scope Definition. However, owners felt that the supplier might also play a lead role, particularly in the paper and chemical industries where the facilities require a very large and complex piece of equipment that can be provided by only a limited number of suppliers.

7.4.9 Process/Conceptual Design

Owners and contractors both indicated that all three parties could lead this competency, due primarily to the fact that the owner of the project may not own the process. Contractors and suppliers both have proprietary processes. Therefore, the party that owns the process should carry this competency.

7.4.10 Procurement

Owners and some contractors believed that both the owner and contractor should have a lead role in procurement. However, suppliers and other contractors felt that only the contractor needs to have a core competency in procurement, based upon the fact that owners mainly procure raw materials and maintenance supplies, but contractors procure large equipment and systems. Comparatively, the contractor has much more at stake. Therefore, it is argued that it is most important for the contractor to have a core competency in procurement.

7.4.11 Project Controls

Contractors and suppliers agreed that the contractor should have a core competency in project controls. However, some owners felt that the owner should be responsible for having a core competency in project controls. This argument is based on the fact that some owners have their own standards for reporting that they require the contractor to follow.

7.4.12 Project Management

Although owners, contractors, and suppliers agreed that the contractor should take the lead in project management, owners felt that both owners and suppliers also have a role in project management because the contractor is not on board during development and the owner manages the project during that time.

7.4.13 Project Planning/Scheduling

All three parties expressed different opinions with regard to the competency of Project Planning/Scheduling. Contractors felt that they should be responsible for this competency. Owners felt that all three parties should have Project Planning/Scheduling as a competency because they some relationships with suppliers that also act as engineer and contractor. Therefore, it is necessary for all three parties to have a competency in this area. Last, suppliers felt that owners should have ultimate responsibility for the Project Planning/Scheduling competency because they ultimately determine the timeframe in which they want the project completed.

7.4.14 Risk Management

Each party expressed a different opinion regarding risk management. Contractors felt that it was a competency that should be shared between the owner and contractor, with each party responsible for managing different types of risk associated with the project. Owners felt that it was solely their responsibility to manage risk, and suppliers felt that it was the sole responsibility of the contractor.

7.4.15 Safety

Suppliers and contractors felt that safety is the contractor's responsibility because the contractor is the party directly involved with project operations. However, owners felt that it should be their responsibility to set the expectations for the project.

7.4.16 Technical Expertise

Owners and contractors agreed that each party must have a core competency in Technical Expertise, because each party has of expertise in a particular area and all must come together to produce a successful project. Suppliers indicated that the supplier should have the core competency in Technical Expertise if a single party takes the lead. This preference is based on the fact that the expertise the supplier contributes to the equipment or system is critical to both project completion and facility performance.

7.4.17 Total Quality Management

Responses from both owners and contractors indicated that all parties should be responsible for the Total Quality Management on the project because each party can impact a different aspect of the project. Suppliers stated that contractors should ultimately take the lead in Total Quality Management because they are directly responsible for field operations.

7.5 Conclusions

Owner, contractor, and supplier must possess the necessary competencies to complete a project successfully using PEpC. Currently, many of the competencies reside with more than one party. There is overlap in abilities, but clearly one party needs to be strongest in each competency. PEpC will be most effective if the guidelines developed in this chapter are followed.

As owners, contractors, and suppliers begin to work on projects using PEpC, they will be able to focus their efforts and concentrate on the core competencies necessary for PEpC. Each party must understand the significance of core competencies and learn to relinquish control when it is to the benefit of the project.

Therefore, it is recommended that this chapter be used as a tool in the process of implementing PEpC. The review process developed can be used to determine the competencies of the owner, contractor, and supplier organizations, and to align responsibilities with the most appropriate party. This process will also facilitate the identification and development of missing competencies, assign project responsibilities, build relationships, and identify gaps in core competencies.

Chapter 8

Conclusions

8.1 Summary of the Research

Chapter 1 identified two primary research objectives. These were:

1. To model the anticipated effects of PEpC on the time and cost of the traditional EPC process and verify that these results are reasonably attainable by reviewing a limited number of case studies.
2. To provide guidelines for implementation based on the core competency work of RT 111.

Prior to directly addressing these objectives, it was necessary to lay a foundation of understanding for the recommended step change. Chapter 2 reviewed the available literature regarding supplier relationships, the supply chain, and simulation as an analysis tool. This was necessary to establish the reasoning behind and need for the research. The literature review discussed the influence of TQM on supplier relationships and revealed the successes of reformed supplier relationships in industries other than construction. The limited availability of literature regarding supplier relationships in the construction industry served as an indicator that little work has been done in this area. With these ideas established, the next step was to describe the recommended step change to improve the owner/contractor/supplier relationship in the construction industry. The goal of this change is also to bring the supplier into the circle of cooperation and make full use of supplier expertise.

Chapter 3 focused on defining the step change, PEpC, which was developed by RT 130. PEpC is based on the belief that much could be achieved if it were possible to formalize a project delivery system which “takes the big **P** for procurement in the **EPC** process and places it before the **E** for engineering so that the technical knowledge and expertise of suppliers can be integrated into all phases of the project from the very beginning.” (Ruane 1997). Having defined the recommended step change, the next step was to directly address the research objectives set out in Chapter 1.

The research objectives were fulfilled through the following steps:

1. Develop a baseline for comparison using the model of the EPC process produced by RT125 (Chapter 4).
2. Model the impact of PEpC as anticipated by the Research Team (Chapter 5).
3. Model the PEpC-like changes that several companies have implemented on actual projects (Chapter 6).
4. Recommend assignment of core competency requirements for successful implementation (Chapter 7).

The first step required to directly address the research objectives was to establish a baseline against which the impact of PEpC on the EPC process could be compared. This model was developed using the baseline EPC model developed by RT 125. The activities, time and cost distributuions, and logic of the RT 125 model were unchanged. Only the simulation tool and output format were changed to provide added flexibility for the analysis, presentation, and understanding of results. In establishing the baseline, two tools were also developed to aid in the presentation and interpretation of the results. Bar charts and milestone charts were created to present the results graphically and provide an easy means by which to compare the results of the theoretical scenarios and field implementations to the baseline.
Because PEpC is an innovative concept in project delivery systems, the tenets of PEpC have not been fully implemented on a project. For this reason, the research relied on several theoretical scenarios developed by

the Research Team to assess the impact of PEpC on the time and cost of traditional EPC projects. Chapter 5 described the theoretical scenarios that were developed by research team members, modeled these scenarios, and presented the results. The Research Team members indicated that PEpC would result in both time and cost savings compared to a traditional EPC project. Time savings were anticipated to be between 5.6 and 19.6 percent of total project time, and cost savings were expected to be between 0.3 and 17.8 percent. These savings were expected to result from early supplier involvement that allows for reduced lead times, reduced change orders, and increased constructability. The next step was to test the impact of PEpC under actual field conditions.

Chapter 6 modeled four field implementations and described two supplier presentations that utilized PEpC-like concepts to achieve time and/or cost savings on actual projects. These examples were examined to improve the validity of the theoretical scenarios. Although these implementations did not utilized PEpC to its fullest extent, they provide a guideline by which to evaluate the theoretical scenarios. The four partial implementations demonstrated time savings between 5.5 to18.6 percent and cost savings between zero and 6.6 percent. These savings are comparable to those predicted by the Research Team in the theoretical scenarios, therefore it is reasonable to state that PEpC can result in the savings predicted by the theoretical scenarios.

Having quantified the time and cost savings associated with PEpC implementation, the next step was to provide guidelines for implementation. Chapter 7 focused on the importance of core competencies to the implementation of PEpC. While there are other issues to be considered regarding PEpC implementation, core competency assignment is perhaps the most important. This chapter built upon the project competencies developed by RT 111, and discussed the importance of distributing the competencies among all three parties, not just the owner and contractor. It was determined that the process to evaluate the competencies of each party is critical to successful implementation because it allows the project participants to define project responsibilities and align expectations prior to the start of the project. This process of review and reassignment also provides an opportunity to check that the project participants do, in fact, possess the necessary competencies. The tables provided in Chapter 7 can be used for this review process.

8.2 Recommendations for Further Study

This research has examined PEpC, a step change to the EPC process, and has predicted the impact of PEpC on the time and cost of traditional EPC projects. The quantification was based on theoretical scenarios and partial field implementations. Therefore, the next step in the research should be to identify and evaluate full-scale field implementations of PEpC. This study might include areas such as the actual impact of project time and cost, as well as the barriers to implementation. Because this step change gives the supplier a larger role, the contractor's role may be reduced and this could create difficulties in establishing relationships. This and other relationship issues should be investigated to assess the degree to which they represent barriers to implementation.

While PEpC can be implemented in a competitive bid or a cooperative relationship situation, it is anticipated that the effects may differ. It would be beneficial to examine the effects of PEpC using competitive bidding versus the effects of PEpC using long-term relationships. This would serve to further refine the guidelines and considerations for implementation of PEpC.

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APPENDIX A

EPC ACTIVITY LIST DEVELOPED BY RT 125

This appendix contains the activities developed by RT 125 to describe the EPC process. Activities are presented in five categories, pre-project planning, design, materials management, construction, and start-up.

EPC Macro Model Activity Summary

PPP Pre-Project Planning	D Design	MM Materials Management	C Construction	SU Start-Up
PPP.BP Business Plan	D.FS Finalize Scope	MM.BC Bulk Commodities	C.PW Prework	SU.SP Start-Up Plan
PPP.TP Product Technical Plan	D.DCE Detailed Cost Estimate	MM.FI Fabricated Items	C.EX Execution	SU.CO Commissioning
PPP.SD Facility Scope Plan	D.DS Detailed Schedule	MM.STE Standard Engineered Equipment	C.DM Demobilize	SU.PCO Project Close-Out
PPP.PP Project Execution Plan	D.DD Detailed Design	MM.SPE Specialized Engineered Equipment		
PPP.CS Contract Strategy	D.PWP Prepare Work Package	MM.FD Field Management		
		MM.S Services (GC/Subcontractors)		
		MM.DO Documentation		
		MM.FEM Field Equipment Management		

PPP Pre-Project Planning

PPP.BP Business Plan

- PPP.BP.1 Define Business Objectives
- PPP.BP.2 Define Facility Objectives/Determine Capacity Demands
- PPP.BP.3 Conduct Market Research and Analysis
- PPP.BP.4 Establish Image and Public Relations
- PPP.BP.5 Finalize Site Selection
- PPP.BP.6 Address Regulatory Issues
- PPP.BP.7 Develop Funding Plan
- PPP.BP.8 Raw Material Sourcing
- PPP.BP.9 Develop Labor Plan and Address Human Resource Issues
- PPP.BP.10 Define Start-Up Requirements

PPP.TP Product Technical Plan

- PPP.TP.1 Conduct Technical Surveys & Process Analysis
- PPP.TP.2 Product Development/ Identify Certification & Testing Procedures
- PPP.TP.3 Obtain Patent and Licenses
- PPP.TP.4 Establish Security and Secrecy Agreement

MILESTONES

- PPP.M1 Process Start
- PPP.M2 Preliminary Funding Approved
- PPP.M3 Preliminary Execution Plan Approved
- PPP.M4 EPC Contractor Team Selected

PPP.SD Facility Scope Plan

- PPP.SD.1 Process & Facility Planning
- PPP.SD.2 Develop Utilities and Offsite Scope
- PPP.SD.3 Develop Environmental Scope
- PPP.SD.4 Develop Site Plan
- PPP.SD.5 Detail Work Breakdown Structure

PPP.PP Project Execution Plan

- PPP.PP.1 Develop Preliminary Design Criteria, including PFDs and PI&Ds
- PPP.PP.2 Formulate Preliminary Organization
- PPP.PP.3 Complete Preliminary Estimates
- PPP.PP.4 Establish Master Project Schedule
- PPP.PP.5 Address Quality and Safety Issues
- PPP.PP.6 Develop Preliminary Execution Plan
- PPP.PP.7 Summarize Project Scope
- PPP.PP.8 Develop Start-Up Plan

PPP.CS Contract Strategy

- PPP.CS.1 Develop Contract Strategy
- PPP.CS.2 Develop Bid Package Scope
- PPP.CS.3 Review Potential EPC Contractor Bidders
- PPP.CS.4 Select EPC Contractor
- PPP.CS.5 Develop Labor Strategy

D DESIGN

D.FS Finalize Scope

D.FS.1 Finalize P&IDs and PFDs

D.FS.2 Finalize Facility Plans

D.FS.3 Define Major Equipment & Material Specifications

D.FS.4 Finalize Utilities and Offsite Scope

D.FS.5 Address COdes, Standards, HAZOP, & Environmental Impact Requirements

D.FS.6 Acquire Permits and Regulatory Approvals

D.FS.7 Conduct Site Evaluation

D.DCE Detailed Cost Estimate

D.DCE.1 Estimate Equipment Cost

D.DCE.2 Estimate Installation Cost

D.DCE.3 Estimate Support Services Cost

D.DCE.4 Estimate Indirects Cost

D.DCE.5 Estimate Materials Cost

D.DCE.6 Estimate Other Costs: Escalation, Spare Parts, Contingency

D.DS Detailed Schedule

D.DS.1 Detail Design Schedule

D.DS.2 Detail Materials Management Schedule

D.DS.3 Detail Construction Schedule

D.DS.4 Detail Start-Up Schedule

D.DD Detailed Design

D.DD.1 Detail Engineering Discipline Drawings
D.DD.2 Finalize Drawings and Construction Specifications
D.DD.3 Conduct Cost and Schedule Review Analysis
D.DD.4 Design/ Engineering Review
D.DD.5 Obtain Intermediate Owner Review and Approvals
D.DD.6 Review Changes and Approve
D.DD.7 Complete Constructability Review
D.DD.8 Complete QA/QC Review
D.DD.9 Conduct Scope/ Estimate Review
D.DD.10 Coordinate Vendor Design/ Engineering Interface
D.DD.11 Distribute Documents

D.PWP Prepare Work Package

D.PWP.1 Draft Project Plan

D.PWP.2 Prepare Material Requisition

D.PWP.3 Develop Bill of Materials

MILESTONES

D.M1 Preliminary Scope Definition Complete
D.M2 Detail Estimate Complete
D.M3 Detailed, Integrated Project Schedule Complete
D.M4 Detailed Design
D.M5 Owner Review & Approval of Detailed Scope & Estimate

MM MATERIALS MANAGEMENT

MM.BC Bulk Commodities

MM.BC.1 Specify Materials

MM.BC.2 Issue Inquiry

MM.BC.3 Receive Vendor Bid

MM.BC.4 Evaluate Vendor bid

MM.BC.5 Award Contract

MM.BC.6 Release Materials

MM.BC.7 Ship Materials

MM.DO Documentation

MM.DO.1 Prepare Final Report/ Turnover Documents

MM.FI Fabricated Items

MM.FI.1 Finalize Materials Specifications

MM.FI.2 Issue Inquiry

MM.FI.3 Receive Vendor Bid

MM.FI.4 Evaluate Vendor bid

MM.FI.5 Award Contract

MM.FI.6 Vendor Document Management

MM.FI.7 Fabricate Materials

MM.FI.8 Ship Materials

MM.FEM Field Equipment Management

MM.FEM.1 Coordinate Materials Management Schedule

MM.FEM.2 Coordinate Materials Management

MM.STE Standard Engineered Equipment

MM.STE.1 Specify Equipment
MM.STE.2 Issue Inquiry
MM.STE.3 Receive Vendor Bid
MM.STE.4 Evaluate Vendor Bid
MM.STE.5 Award Contract
MM.STE.6 Release Data Sheets
MM.STE.7 Vendor Document Management
MM.STE.8 Vendor Fabrication
MM.STE.9 Ship Equipment

MILESTONES

MM.M1 Procurement Accounting Complete

MM.SPE Specialized Engineered Equipment

MM.SPE.1 Specify Equipment
MM.SPE.2 Issue Inquiry
MM.SPE.3 Receive Vendor Bid
MM.SPE.4 Evaluate Vendor Bid
MM.SPE.5 Award Contract
MM.SPE.6 Coordinate Vendor Design
MM.SPE.7 Vendor Document Management
MM.SPE.8 Vendor Fabrication
MM.SPE.9 Ship Equipment

MM.FD Field Management

MM.FD.1 Receive & Inspect Materials
MM.FD.2 Inventory, Store, & Maintain Materials
MM.FD.3 Issue Materials
MM.FD.4 Vendor Inspection
MM.FD.5 Conduct Accounting Activities

MM.S Services (GC/ Subcontractors)

MM.S.1 Work Packaging/ Scope of Services
MM.S.2 Prequalify Vendors/ Subcontractor and Issue Inquiry
MM.S.3 Receive Vendor/ Subcontractor Bid
MM.S.4 Evaluate Vendor/ Subcontractor Bid
MM.S.5 Award Contract

C CONSTRUCTION

C.PW Prework	C.EX Execution	C.DM Demobilize
C.PW.1 Site Mobilization C.PW.2 Mobilize Facilities C.PW.3 Provide Construction Utilities C.PW.4 Submit Project Documents C.PW.5 Obtain Permits/ Licenses C.PW.6 Establish Safety/Quality C.PW.7 Establish Security C.PW.8 Develop Materials Management Plan C.PW.9 Define Training Procedures C.PW.10 Develop Execution Strategy C.PW.11 Install Communication Systems	C.EX.1 Develop Work Plan C.EX.2 Execute Labor Management and Construction C.EX.3 Monitor Schedule Status/Maintain Schedule C.EX.4 Establish Design Support C.EX.5 Issue Progress Reports C.EX.6 Submittals & Document Control Management C.EX.7 Execute Materials Management and Monitor Status C.EX.8 Change Management C.EX.9 Process Invoices C.EX.10 Monitor Cost/ Budget Status C.EX.11 Execute Human Resources Management C.EX.12 Inspect & Test Equipment C.EX.13 Execute Subcontractor Mgt. & Administration C.EX.14 Document QA/QC	C.DM.1 Coordinate with Post Start-Up Problem Resolution C.DM.2 Return Excess Materials for Credit C.DM.3 Remove Construction Equipment, Temporary Buildings, & Construction Utilities/ Project Site Cleanup

MILESTONES

C.M1 Construction Phase Begins

SU START-UP

SU.SP Start-Up Plan	SU.CO Commissioning	SU.PCO Project Close-Out
SU.SP.1 Prepare Start-Up Procedures	SU.CO.1 Commission Major Systems	SU.PCO.1 Identify Warranty Items
SU.SP.2 Staff Start-Up Crew	SU.CO.2 Commission Process Units	SU.PCO.2 Complete Final Punchlist
SU.SP.3 Train Personnel	SU.CO.3 Commission Offsite Facilities	SU.PCO.3 Process Final Change Orders
SU.SP.4 Vendor Supervision	SU.CO.4 Conduct Product Test Run	SU.PCO.4 Complete Legal Closure for Project
SU.SP.5 Obtain Catalyst/ Chemicals	SU.CO.5 Provide Raw Material Feed	SU.PCO.5 Generate Final Cost Statement
SU.SP.6 Obtain Spare Parts	SU.CO.6 Complete Punchlist for Commission	SU.PCO.6 Submit Close-Out Report
SU.SP.7 Review Operations and Maintenance Manuals	SU.CO.7 Review License/ Performance Guarantee	SU.PCO.7 Submit Final Report/ Turnover Documents
		SU.PCO.8 Finalize As-Built Drawings
		SU.PCO.9 Obtain Regulatory Acceptance
		SU.PCO.10 Obtain Final Acceptance

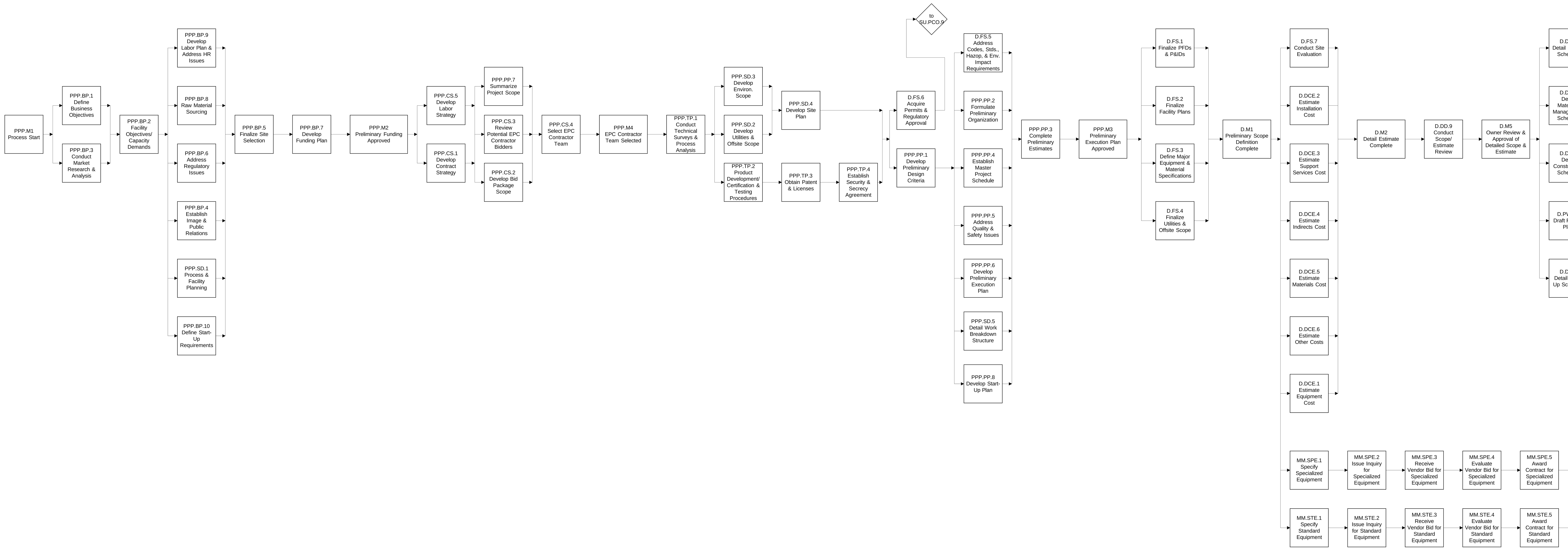
MILESTONES

SU.M1 Begin Start-Up

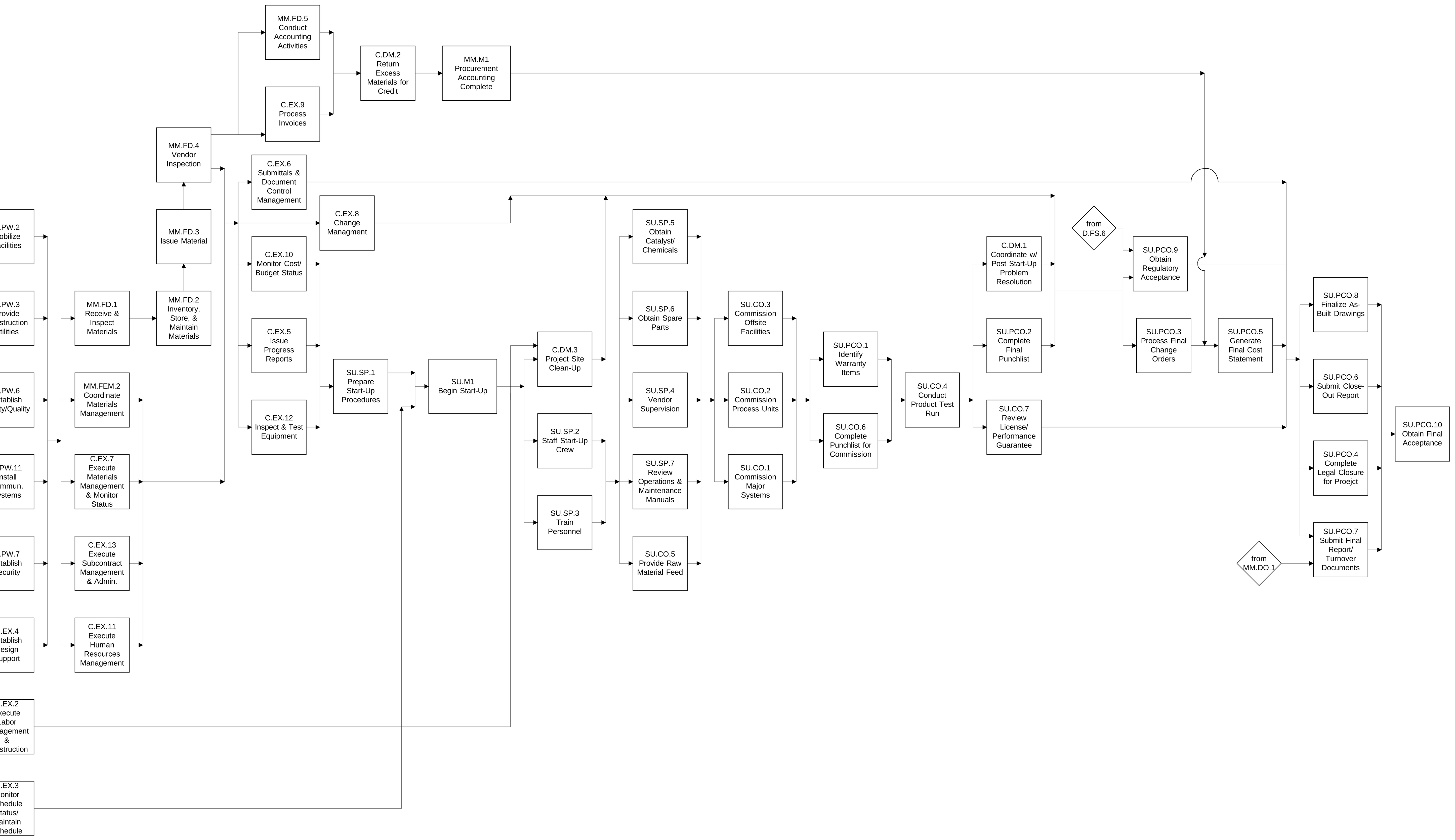
APPENDIX B

EPC LOGIC DIAGRAM DEVELOPED BY RT 125

This appendix contains the logic diagram developed by RT 125 to describe the EPC process.


PPP.M1 Process Start
PPP.BP.1 Define Business Objectives
PPP.BP.3 Conduct Market Research & Analysis
PPP.BP.2 Facility Objectives/ Capacity Demands
PPP.BP.9 Develop Labor Plan & Address HR Issues
PPP.BP.8 Raw Material Sourcing
PPP.BP.6 Address Regulatory Issues
PPP.BP.4 Establish Image & Public Relations
PPP.SD.1 Process & Facility Planning
PPP.BP.10 Define Start-Up Requirements
PPP.BP.5 Finalize Site Selection
PPP.BP.7 Develop Funding Plan
PPP.M2 Preliminary Funding Approved
PPP.CS.5 Develop Labor Strategy
PPP.CS.1 Develop Contract Strategy
PPP.PP.7 Summarize Project Scope
PPP.CS.3 Review Potential EPC Contractor Bidders
PPP.CS.2 Develop Bid Package Scope
PPP.CS.4 Select EPC Contractor Team
PPP.M4 EPC Contractor Team Selected
PPP.TP.1 Conduct Technical Surveys & Process Analysis
PPP.SD.3 Develop Environ. Scope
PPP.SD.2 Develop Utilities & Offsite Scope
PPP.TP.2 Product Development/ Certification & Testing Procedures
PPP.SD.4 Develop Site Plan
PPP.TP.3 Obtain Patent & Licenses
PPP.TP.4 Establish Security & Secrecy Agreement
to SU.PCO.9
D.FS.6 Acquire Permits & Regulatory Approval
PPP.PP.1 Develop Preliminary Design Criteria
D.FS.5 Address Codes, Stds., Hazop, & Env. Impact Requirements
PPP.PP.2 Formulate Preliminary Organization
PPP.PP.4 Establish Master Project Schedule
PPP.PP.5 Address Quality & Safety Issues
PPP.PP.6 Develop Preliminary Execution Plan
PPP.SD.5 Detail Work Breakdown Structure
PPP.PP.8 Develop Start-Up Plan
PPP.PP.3 Complete Preliminary Estimates
PPP.M3 Preliminary Execution Plan Approved
D.FS.1 Finalize PFDs & P&IDs
D.FS.2 Finalize Facility Plans
D.FS.3 Define Major Equipment & Material Specifications
D.FS.4 Finalize Utilities & Offsite Scope
D.M1 Preliminary Scope Definition Complete
D.FS.7 Conduct Site Evaluation
D.DCE.2 Estimate Installation Cost
D.DCE.3 Estimate Support Services Cost
D.DCE.4 Estimate Indirects Cost
D.DCE.5 Estimate Materials Cost
D.DCE.6 Estimate Other Costs
D.DCE.1 Estimate Equipment Cost
D.M2 Detail Estimate Complete
D.DD.9 Conduct Scope/ Estimate Review
D.M5 Owner Review & Approval of Detailed Scope & Estimate
MM.SPE.1 Specify Specialized Equipment
MM.SPE.2 Issue Inquiry for Specialized Equipment
MM.SPE.3 Receive Vendor Bid for Specialized Equipment
MM.SPE.4 Evaluate Vendor Bid for Specialized Equipment
MM.SPE.5 Award Contract for Specialized Equipment
MM.STE.1 Specify Standard Equipment
MM.STE.2 Issue Inquiry for Standard Equipment
MM.STE.3 Receive Vendor Bid for Standard Equipment
MM.STE.4 Evaluate Vendor Bid for Standard Equipment
MM.STE.5 Award Contract for Standard Equipment

D.DS.1 Detail Design Schedule
D.DS.2 Detail Materials Management Schedule
D.DS.3 Detail Construction Schedule
D.PWP.1 Draft Project Plan
D.DS.4 Detail Start-Up Schedule
D.M2 Detail Estimate Complete
D.DD.9 Conduct Scope/ Estimate Review
D.M5 Owner Review & Approval of Detailed Scope & Estimate
D.M3 Detailed, Integrated Project Schedule Complete
D.PWP.2 Prepare Material Requisitions
MM.SPE.2 Issue Inquiry for Specialized Equipment
MM.SPE.3 Receive Vendor Bid for Specialized Equipment
MM.SPE.4 Evaluate Vendor Bid for Specialized Equipment
MM.SPE.5 Award Contract for Specialized Equipment
MM.SPE.6 Coordinate Vendor Design
MM.STE.2 Issue Inquiry for Standard Equipment
MM.STE.3 Receive Vendor Bid for Standard Equipment
MM.STE.4 Evaluate Vendor Bid for Standard Equipment
MM.STE.5 Award Contract for Standard Equipment
D.DD.1 Detail Engineering Discipline Drawings
MM.STE.6 Release Data Sheets
D.DD.10 Coordinate Vendor/ Engineering Interface
MM.SPE.7 Vendor Document Mgmt. for Specialized Equipment
MM.STE.7 Vendor Document Mgmt. for Standard Equipment
D.DD.4 Design/ Engineering Review
D.M4 Detailed Design Milestone
D.DD.7 Complete Constructability Review
D.DD.8 Complete QA/ QC Review
MM.BC.1 Specify Bulk Materials
MM.BC.2 Issue Inquiry for Bulk Materials
MM.BC.3 Receive Vendor Bid for Bulk Materials
MM.BC.4 Evaluate Vendor Bid for Bulk Materials
D.DD.3 Conduct Cost & Schedule Review Analysis
MM.FI.1 Finalize Fabricated Items Materials Specs.
MM.FI.2 Issue Inquiry for Fabricated Items
MM.FI.3 Receive Vendor Bid for Fabricated Items
MM.FI.4 Evaluate Vendor Bid for Fabricated Items
MM.STE.8 Vendor Fabrication of Standard Equipment
MM.STE.9 Ship Standard Equipment
MM.SPE.8 Vendor Fabrication of Specialized Equipment
MM.SPE.9 Ship Specialized Equipment
D.DD.5 Obtain Intermediate Owner Reviews & Approval
D.DD.6 Review Changes & Approve
MM.BC.5 Award Contract for Bulk Materials
MM.BC.6 Release Materials for Bulk Materials
MM.BC.7 Ship Bulk Materials
MM.FI.5 Award Contract for Fabricated Items
MM.FI.6 Vendor Document Management
MM.FI.7 Fabricate Fabricated Item Materials
MM.FI.8 Ship Fabricated Items
D.DD.2 Finalize Drawings & Construction Specifications
MM.S1 Work Package/ Scope of Services
MM.S.2 Prequalify Vendor/ Subcontractor & Issue Inquiry
MM.S.3 Receive Vendor/ Subcontractor Bid
MM.S.4 Evaluate Vendor/ Subcontractor Bid
MM.S.5 Award Contract
C.M1 Construction Phase Begins
D.PWP.3 Develop Bill of Materials
D.DD.11 Distribute Documents
C.PW.8 Develop Materials Management Plan
C.PW.10 Develop Execution Strategy
MM.DD.1 Prepare Final Report/ Turnover Documents
to SU.PCO.7
C.PW.9 Define Training Procedures
C.PW.4 Submit Project Documents
C.PW.5 Obtain Permits/ Licenses
MM.FEM.1 Coordinate Materials Management Schedule
C.EX.1 Develop Work Plan
C.PW.1 Site Mobilization
C.EX.14 Document QA/QC
C.PW.2 Mobilize Facilities
C.PW.3 Provide Construction Utilities
C.PW.6 Establish Safety/Quality
C.PW.11 Install Commun. Systems
C.PW.7 Establish Security
C.EX.4 Establish Design Support
C.EX.2 Execute Labor Management & Construction
C.EX.3 Monitor Schedule Status/ Maintain Schedule
MM.FD.1 Receive & Inspect Materials
MM.FEM.2 Coordinate Materials Management
C.EX.7 Execute Materials Management & Monitor Status
C.EX.13 Execute Subcontract Management & Admin.
C.EX.11 Execute Human Resources Management
MM.FD.4 Vendor Inspection
MM.FD.3 Issue Material
MM.FD.2 Inventory, Store, & Maintain Materials
MM.FD.5 Conduct Accounting Activities
C.EX.9 Process Invoices
C.EX.6 Submittals & Document Control Management
C.EX.10 Monitor Cost/ Budget Status
C.EX.5 Issue Progress Reports
C.EX.12 Inspect & Test Equipment



MM.FD.5 Conduct Accounting Activities
C.EX.9 Process Invoices
C.DM.2 Return Excess Materials for Credit
MM.M1 Procurement Accounting Complete
MM.FD.4 Vendor Inspection
MM.FD.3 Issue Material
MM.FD.2 Inventory, Store, & Maintain Materials
MM.FD.1 Receive & Inspect Materials
MM.FEM.2 Coordinate Materials Management
C.EX.7 Execute Materials Management & Monitor Status
C.EX.13 Execute Subcontract Management & Admin.
C.EX.11 Execute Human Resources Management
C.EX.6 Submittals & Document Control Management
C.EX.8 Change Managment
C.EX.10 Monitor Cost/ Budget Status
C.EX.5 Issue Progress Reports
C.EX.12 Inspect & Test Equipment
SU.SP.1 Prepare Start-Up Procedures
SU.M1 Begin Start-Up
C.DM.3 Project Site Clean-Up
SU.SP.2 Staff Start-Up Crew
SU.SP.3 Train Personnel
SU.SP.5 Obtain Catalyst/ Chemicals
SU.SP.6 Obtain Spare Parts
SU.SP.4 Vendor Supervision
SU.SP.7 Review Operations & Maintenance Manuals
SU.CO.5 Provide Raw Material Feed
SU.CO.3 Commission Offsite Facilities
SU.CO.2 Commission Process Units
SU.CO.1 Commission Major Systems
SU.PCO.1 Identify Warranty Items
SU.CO.6 Complete Punchlist for Commission
SU.CO.4 Conduct Product Test Run
C.DM.1 Coordinate w/ Post Start-Up Problem Resolution
SU.PCO.2 Complete Final Punchlist
SU.CO.7 Review License/ Performance Guarantee
from D.FS.6
SU.PCO.9 Obtain Regulatory Acceptance
SU.PCO.3 Process Final Change Orders
SU.PCO.5 Generate Final Cost Statement
SU.PCO.8 Finalize As-Built Drawings
SU.PCO.6 Submit Close-Out Report
SU.PCO.4 Complete Legal Closure for Proejct
SU.PCO.7 Submit Final Report/ Turnover Documents
from MM.DO.1
SU.PCO.10 Obtain Final Acceptance

APPENDIX C

SURVEY TOOL

The survey contained on pages 131 through 150 was designed to aid the Research Team in the analysis of the time and cost impacts of PEpC implementation.

Rt130 Assessment of the Effect That PEpC Implementation Will Have on the Baseline EPC Model

PEpC includes the following steps:

1. Identify the suppliers of the critical process equipment and/or systems (CPE Suppliers) at start of project.
2. Obtain Project and funding approval such that limited commitments can be made to CPE suppliers.
3. Develop procurement and contracting strategy methodology so that CPE suppliers can be included in the team selection and preliminary design phases.
4. Use CPE supplier knowledge in the preliminary design phase to advance procurement of standard, specialized, and critical process equipment so that detail design phase can start earlier.
5. Use CPE supplier knowledge in completing the detail design phase.
6. Utilize expertise of CPE suppliers in preliminary construction, field construction, and start-up phases to complete these phases of the project.

Phase I - Preliminary Feasibility

This phase covers the following activities in the baseline EPC model.

Code	Activity Name	Time	Cost	ES	LS	EF	LF	%Critical
PPP.BP.3	Conduct Market Research & Analysis	0.23	0.08	0.00	0.10	0.23	0.33	48.30%
PPP.BP.1	Define Business Objectives	0.25	0.09	0.00	0.08	0.25	0.33	51.70%
PPP.BP.2	Define Facility Objectives/Capacity Demands	0.40	0.13	0.33	0.33	0.73	0.73	100.00%
PPP.BP.10	Define Start-Up Requirements	0.02	0.11	0.73	1.10	0.75	1.12	0.00%
PPP.BP.9	Develop Labor Plan & Address HR Issues	0.09	0.02	0.73	1.03	0.82	1.12	0.30%
PPP.BP.8	Raw Material Sourcing	0.11	0.04	0.73	1.00	0.84	1.12	3.60%
PPP.BP.4	Establish Image & Public Relations	0.13	0.06	0.73	0.98	0.86	1.12	4.00%
PPP.BP.6	Address Regulatory Issues	0.23	0.07	0.73	0.88	0.96	1.12	29.40%
PPP.SD.1	Process & Facility Planning	0.34	0.28	0.73	0.78	1.07	1.12	62.70%
PPP.BP.5	Finalize Site Selection	0.15	0.08	1.12	1.12	1.27	1.27	100.00%
PPP.BP.7	Develop Funding Plan	0.56	0.30	1.27	1.27	1.82	1.82	100.00%*

*Governs the start of the Team Selection phase.

Total Duration for Phase = 1.82
Total Cost for Phase = 1.26

Review the listed activities and describe the effect that the implementation of PEpC will have on the cost and duration of the phase.

Change Caused by the Implementation of PEpC	Effect

Phase II - Team Selection

This phase covers the following activities in the baseline EPC model.

Code	Activity Name	Time	Cost	ES	LS	EF	LF	%Critical
PPP.CS.1	Develop Contract Strategy	0.19	0.05	1.82	1.87	2.01	2.06	49.20%
PPP.CS.2	Develop Bid Package Scope	0.24	0.18	2.06	2.11	2.30	2.35	50.30%
PPP.CS.3	Review Potential EPC Contractor Bidders	0.17	0.14	2.06	2.18	2.24	2.35	21.80%
PPP.CS.4	Select EPC Contractor Team	0.13	0.11	2.35	2.35	2.48	2.48	100.00%*
PPP.CS.5	Develop Labor Strategy	0.17	0.03	1.82	1.89	1.99	2.06	50.80%
PPP.PP.7	Summarize Project Scope	0.18	0.08	2.06	2.17	2.24	2.35	27.90%

*Governs start of Preliminary Design, Estimate, and Scope phase.
Total Duration for Phase = 0.66
Total Cost for Phase = 0.59

Review the listed activities and describe the effect that the implementation of PEpC will have on the cost and duration of the phase.

Change Caused by the Implementation of PEpC	Effect

Phase III - Preliminary Design, Scope, and Estimate

This phase covers the following activities in the baseline EPC model.

Code	Activity Name	Time	Cost	ES	LS	EF	LF	%Critical
PPP.TP.1	Conduct Tech. Surveys & Process Analysis	0.40	0.28	2.48	2.48	2.88	2.88	100.00%
PPP.SD.3	Develop Environmental Scope	0.38	0.14	2.88	3.42	3.26	3.80	0.70%
PPP.SD.2	Develop Utilities & Offsit Scope	0.23	0.20	2.88	3.57	3.11	3.80	0.00%
PPP.TP.2	Product Dev./ Certification & Testing Procedures	0.69	0.10	2.88	2.88	3.57	3.57	99.30%
PPP.SD.4	Develop Site Plan	0.21	0.17	3.28	3.80	3.50	4.01	0.70%
PPP.TP.3	Obtain Patent & Licenses	0.32	0.36	3.57	3.57	3.89	3.89	99.30%
PPP.TP.4	Establish Security & Secrecy Agreement	0.12	0.07	3.89	3.89	4.01	4.01	99.30%
D.FS.6	Acquire Permits & Regulatory Approval	0.56	0.38	4.01	40.55	4.57	41.11	0.00%
PPP.PP.1	Develop Preliminary Design Criteria	0.37	0.65	4.01	4.01	4.38	4.38	100.00%
D.FS.5	Address Codes Stds., HAZOP, & Envir. Impact Reqmts.	0.44	0.34	4.38	4.58	4.83	5.03	36.40%
PPP.PP.2	Formulate Preliminary Design Organization	0.15	0.04	4.38	4.87	4.54	5.03	0.60%
PPP.PP.4	Establish Master Project Schedule	0.31	0.13	4.38	4.72	4.70	5.03	18.20%
PPP.PP.5	Address Quality & Safety Issues	0.13	0.05	4.38	4.90	4.51	5.03	1.00%
PPP.PP.6	Develop Preliminary Execution Plan	0.24	0.05	4.38	4.79	4.62	5.03	9.70%
PPP.SD.5	Detail Work Breakdown Structure	0.41	0.22	4.38	4.62	4.79	5.03	34.10%
PPP.PP.8	Develop Start-Up Plan	0.06	0.05	4.38	4.97	4.44	5.03	0.00%
PPP.PP.3	Complete Preliminary Estimates	0.23	0.16	5.03	5.03	5.25	5.25	100.00%
D.FS.1	Finialize P&ID's and PFD's	0.77	1.21	5.25	5.57	6.03	6.35	37.10%*
D.FS.2	Finalize Facility Plans	0.67	0.53	5.25	5.68	5.92	6.35	25.20%*
D.FS.3	Define Major Equipment & Material Specifications	0.60	1.14	5.25	5.74	5.86	6.35	15.20%*
D.FS.4	Finalize Utilities & Offsite Scope	0.66	0.82	5.25	5.69	5.91	6.35	22.50%*

*Governs start of Estimate, Schedule, and Review phase.

Total Duration for Phase = 3.87
Total Cost for Phase = 7.09

Review the listed activities and describe the effect that the implementation of PEpC will have on the cost and duration of the phase.

Change Caused by the Implementation of PEpC	**Effect**

Phase IV - Estimate, Schedule, and Review

This phase covers the following activities in the baseline EPC model

Code	Activity Name	Time	Cost	ES	LS	EF	LF	%Critical
D.FS.7	Conduct Site Evaluation	0.29	0.42	6.35	11.85	6.64	12.14	0.00%
D.DCE.2	Estimate Installation Cost	0.39	0.39	6.35	11.75	6.74	12.14	0.10%
D.DCE.3	Estimate Support Services Cost	0.32	0.16	6.35	11.83	6.66	12.14	0.00%
D.DCE.4	Estimate Indirects Cost	0.28	0.18	6.35	11.86	6.63	12.14	0.00%
D.DCE.5	Estimate Materials Cost	0.41	0.43	6.35	42.00	6.76	42.41	0.00%
D.DCE.6	Estimate Other Costs	0.52	0.11	6.35	11.62	6.87	12.14	0.20%
D.DCE.1	Estimate Equipment Cost	0.38	0.25	6.35	11.76	6.72	12.14	0.00%
D.DD.9	Conduct Scope/Estimate Review	0.68	0.56	7.11	12.14	7.78	12.82	0.30%
D.DS.1	Detail Design Schedule	0.65	0.51	7.78	13.35	8.43	13.99	0.00%*
D.DS.2	Detail Mat. Mgmt. Schedule	0.59	0.23	7.78	13.40	8.38	13.99	0.10%*
D.DS.3	Detail Construction Schedule	0.82	0.55	7.78	13.17	8.61	13.99	0.10%*
D.PWP.1	Draft Project Plan	0.72	0.40	7.78	13.28	8.50	13.99	0.10%*
D.DS.4	Detail Start-Up Schedule	0.32	0.34	7.78	42.10	8.10	42.41	0.00%*

*Governs start of Procure Fabricated and Bulk Materials phase.

Total Duration for Phase = 2.61
Total Cost for Phase = 4.53

Review the listed activities and describe the effect that the implementation of PEpC will have on the cost and duration of the phase.

Change Caused by the Implementation of PEpC	Effect

Phase V - Procure Standard and Specialized Equipment

This phase covers the following activities in the baseline EPC model

Code	Activity Name	Time	Cost	ES	LS	EF	LF	%Critical
MM.SPE.1	Specify Specialized Equipment	0.68	0.29	6.35	6.37	7.03	7.06	93.00%
MM.SPE.2	Issue Inquiry for Specialized Equipment	0.45	0.13	7.03	7.06	7.48	7.50	93.00%
MM.SPE.3	Recieve Vendor Bid for Specialized Equipment	0.51	0.08	7.48	7.50	7.99	8.01	93.00%
MM.STE.1	Specify Standard Equipment	0.57	0.28	6.35	7.64	6.92	8.21	6.70%
MM.STE.2	Issue Inquiry for Standard Equipment	0.35	0.11	6.92	8.21	7.26	8.56	6.70%
MM.STE.3	Receive Vendor Bid for Standard Equipment	0.35	0.07	7.26	8.56	7.61	8.91	6.70%
MM.STE.4	Evaluate Vendor Bid for Standard Equipment	0.50	0.31	7.61	8.91	8.12	9.41	6.70%
MM.SPE.4	Evaluate Vendor Bid for Specialized Equipment	0.51	0.26	7.99	8.01	8.49	8.52	93.00%
MM.STE.5	Award Contract for Standard Equipment	0.49	0.09	8.12	9.41	8.60	9.90	6.70%*
MM.SPE.5	Award Contract for Specialized Equipment	0.51	0.17	8.49	8.52	9.00	9.03	93.00%
MM.SPE.6	Coordinate Vendor Design	0.87	0.30	9.00	9.03	9.87	9.90	93.00%*
MM.STE.6	Release Data Sheets	0.48	0.14	11.95	12.17	12.43	12.65	76.70%
MM.SPE.7	Vendor Doc. Mgmt. for Specialized Equip.	1.05	0.17	13.83	14.16	14.89	15.22	54.50%
MM.STE.7	Vendor Doc. Mangement for Standard Equip.	0.69	0.25	13.83	14.53	14.52	15.22	22.20%
MM.STE.8	Vendor Fabrication of Standard Equip.	1.09	0.87	16.17	28.18	17.26	29.27	0.00%
MM.SPE.8	Vendor Fabrication of Specialized Equip.	1.50	0.67	16.17	27.66	17.66	29.16	0.00%
MM.STE.9	Ship Standard Equipment	0.60	0.12	17.26	29.27	17.86	29.87	0.00%
MM.SPE.9	Ship Specialized Equipment	0.71	0.11	17.66	29.16	18.37	29.87	0.00%

*Governs start of Detail Design phase.

Total Duration for Phase = 12.02
Total Cost for Phase = 4.42

Review the listed activities and describe the effect that the implementation of PEpC will have on the cost and duration of the phase.

Change Caused by the Implementation of PEpC	Effect

Phase VI - Procure Fabricated and Bulk Materials

This phase covers the following activities in the baseline EPC model.

Code	Activity Name	Time	Cost	ES	LS	EF	LF	%Critical
D.PWP.2	Prepare Material Requisitions	0.73	0.65	8.96	13.99	9.69	14.73	0.30%
MM.BC.1	Specify Bulk Commodity Materials	0.65	0.83	11.95	13.99	12.61	14.64	16.00%
MM.FI.1	Finalize Fabricated Item Materials Specs.	0.52	0.19	11.98	14.73	12.50	15.24	2.70%
MM.FI.2	Issue Inquiry for Fabricated Items	0.26	0.53	12.50	15.24	12.76	15.50	2.70%
MM.BC.2	Issue Inquiry for Bulk Commodities	0.49	0.14	12.61	14.64	13.10	15.14	16.00%
MM.FI.3	Receive Vendor Bid for Fabricated Items	0.31	0.19	12.76	15.50	13.07	15.81	2.70%
MM.FI.4	Evaluate Vendor Bid for Fabricated Items	0.33	0.30	13.07	15.81	13.40	16.14	2.70%
MM.BC.3	Receive Vendor Bid for Bulk Commodities	0.46	0.08	13.10	15.14	13.56	15.59	16.00%
MM.BC.4	Evaluate Vendor Bid for Bulk Commodities	0.55	0.43	13.56	15.59	14.11	16.14	16.00%
D.DD.3	Conduct Cost & Sched. Review Analysis	1.31	0.70	14.19	16.14	15.50	17.45	18.70%
MM.BC.5	Award Bulk Commodities Contract	0.60	0.13	18.70	27.83	19.30	28.43	0.00%
MM.FI.5	Award Fabricated Items Contract	0.35	0.08	18.70	27.23	19.05	27.57	0.00%
MM.FI.6	Vendor Document Management	0.75	0.72	19.05	27.57	19.80	28.32	0.00%
MM.BC.6	Release Bulk Commodity Materials	0.80	0.30	19.30	28.43	20.10	29.23	0.00%
MM.FI.7	Fabricate Fabricated Items Materials	0.79	0.18	19.80	28.32	20.59	29.11	0.00%
MM.BC.7	Ship Bulk Commodity Materials	0.64	0.13	20.10	29.23	20.74	29.87	0.00%*
MM.FI.8	Ship Fabricated Item Materials	0.76	0.56	20.59	29.11	21.34	29.87	0.00%*

*Governs start of Field Construction phase.

Total Duration for Phase = 12.38
Total Cost for Phase = 6.14

Review the listed activities and describe the effect that the implementation of PEpC will have on the cost and duration of the phase.

Change Caused by the Implementation of PEpC	**Effect**

Phase VII - Detail Design

This phase covers the following activities in the baseline EPC model.

Code	Activity Name	Time	Cost	ES	LS	EF	LF	%Critical
D.DD.1	Detail Engineering Discipline Drawings	2.05	9.91	9.90	9.90	11.95	11.95	99.70%
D.DD.7	Complete Constructibility Review	0.59	0.52	11.95	14.63	12.54	15.22	0.00%
D.DD.8	Complete QA/QC Review	1.21	0.52	11.95	14.01	13.16	15.22	4.60%
D.DD.10	Coordinate Vendor/Engineering Interface	1.40	1.45	12.43	12.65	13.83	14.05	76.70%
D.DD.4	Design/Engineering Review	1.13	0.96	15.03	15.22	16.17	16.35	81.30%
D.DD.5	Obtain Int. Owner Reviews & Approval	1.10	0.71	16.17	16.35	17.26	17.45	81.30%
D.DD.6	Review Changes & Approve	1.25	0.63	17.45	17.45	18.70	18.70	100.00%
D.DD.2	Finalize Dwgs. & Construction Specifications	1.41	3.62	18.70	18.70	20.11	20.11	100.00%
D.DD.11	Distribute Documents	1.05	0.32	20.11	21.68	21.16	22.73	7.80%*

*Governs start of Field Construction phase.
Total Duration for Phase = 10.21
Total Cost for Phase = 18.64

Review the listed activities and describe the effect that the implementation of PEpC will have on the cost and duration of the phase.

Change Caused by the Implementation of PEpC	Effect

Phase VIII -Work Packages

This phase covers the following activities in the baseline EPC model.

Code	Activity Name	Time	Cost	ES	LS	EF	LF	%Critical
MM.S.1	Work Pkg/ Scope of Services	0.67	1.39	20.11	20.47	20.78	21.14	42.00%
D.PWP.3	Develop Bill of Materials	0.79	0.42	20.11	20.35	20.90	21.14	50.20%
MM.S.2	Prequalify Vend./Subcon. & Issue Inquiry	0.52	0.27	21.10	21.14	21.62	21.65	92.20%
MM.S.3	Receive Vend./Subcon. Bid	0.52	0.22	21.62	21.65	22.13	22.17	92.20%
MM.S.4	Evaluate Vend./Subcon. Bid	0.56	0.45	22.13	22.17	22.69	22.73	92.20%
MM.S.5	Award Contract to Vend./Subs.	0.51	0.18	22.73	22.73	23.23	23.23	100.00%*

*Governs start of Preliminary Construction phase.
Total Duration for Phase = 3.22
Total Cost for Phase = 2.93

Review the listed activities and describe the effect that the implementation of PEpC will have on the cost and duration of the phase.

Change Caused by the Implementation of PEpC	Effect

Phase IX - Preliminary Construction

This phase covers the following activities in the baseline EPC model.

Code	Activity Name	Time	Cost	ES	LS	EF	LF	%Critical
C.PW.8	Develop Materials Mgmt. Plan	0.43	0.72	23.23	23.38	23.66	23.81	53.00%
C.PW.10	Develop Execution Strategy	0.40	0.81	23.23	23.41	23.63	23.81	47.00%
MM.DO.1	Prepare Final Report/Turnover Documents	2.14	0.38	23.23	39.67	25.37	41.81	0.00%
C.PW.9	Define Training Procedures	0.18	0.39	23.81	25.67	23.99	25.85	0.00%
C.PW.4	Submit Project Documents	0.39	0.59	23.81	25.46	24.20	25.85	1.00%
C.PW.5	Obtain permits/ Licenses	1.07	0.63	23.81	24.78	24.88	25.85	27.10%
MM.FEM.1	Coordinate Materials Management	1.88	0.25	23.81	23.96	25.69	25.85	71.90%
C.EX.1	Develop Work Plan	0.25	0.93	23.81	42.16	24.06	42.41	0.00%
C.PW.1	Site Mobilization	0.33	1.53	25.85	25.85	26.18	26.18	100.00%
C.EX.14	Document QA/QC	2.61	1.76	26.18	26.18	28.79	28.79	100.00%
C.PW.2	Mobilize Facilities	0.31	0.97	28.79	42.11	29.10	42.41	0.00%*
C.PW.3	Provide Construction Utilities	0.22	1.54	28.79	29.66	29.01	29.87	4.20%*
C.PW.6	Establish Safety/Quality	0.46	0.44	28.79	29.41	29.25	29.87	24.80%*
C.PW.11	Install Communication Systems	0.12	0.59	28.79	29.75	28.91	29.87	0.80%*
C.PW.7	Establish Security	0.85	0.10	28.79	29.02	29.64	29.87	62.30%*
C.EX.4	Establish Design Support	1.01	1.00	28.79	41.40	29.80	42.41	0.00%*

*Governs start of Field Construction phase.
Total Duration for Phase = 6.57
Total Cost for Phase = 12.63

Review the listed activities and describe the effect that the implementation of PEpC will have on the cost and duration of the phase.

Change Caused by the Implementation of PEpC	Effect

Phase X - Field Construction

This phase covers the following activities in the baseline EPC model.

Code	Activity Name	Time	Cost	ES	LS	EF	LF	%Critical
C.EX.2	Execute Labor Mgmt. & Construction	5.11	23.99	28.79	35.59	33.90	40.70	6.00%
C.EX.3	Monitor Sched. Status/Maintain Schedule	2.89	2.73	28.79	34.79	31.68	37.68	1.90%
MM.FD.1	Receive & Inspect Materials	0.89	0.55	29.75	31.05	30.64	31.94	28.60%
MM.FEM.2	Coordinate Materials Management	1.96	0.30	29.75	32.13	31.71	34.09	12.30%
C.EX.7	Execute Mat. Mgmt. & Monitor Status	2.30	1.42	29.75	31.79	32.05	34.09	11.50%
C.EX.13	Execute Subcont. Mgmt. & Administration	3.10	4.16	29.75	30.99	32.85	34.09	39.70%
C.EX.11	Execute Human Resources Management	2.75	0.58	29.75	39.67	32.50	42.41	0.00%
MM.FD.2	Inventory, Store, & Maintain Materials	0.80	0.35	30.64	31.94	31.44	32.74	28.60%
MM.FD.3	Issue Material	0.64	0.30	31.44	32.74	32.08	33.38	28.60%
MM.FD.4	Vendor Inspection	0.71	0.26	32.08	33.38	32.79	34.09	28.60%
C.EX.10	Monitor Cost/Budget Status	2.32	1.94	33.97	34.76	36.29	37.08	38.10%
C.EX.5	Issue Progress Reports	2.22	1.57	33.97	34.86	36.19	37.08	33.60%
C.EX.12	Inspect & Test Equipment	1.78	1.45	33.97	35.30	35.75	37.08	20.30%
SU.SP.1	Prepare Start-Up Procedures	0.60	0.66	36.96	37.08	37.56	37.68	92.00%*

*Governs start of Documentation and Start-Up phases.
Total Duration for Phase = 7.77
Total Cost for Phase = 40.26

Review the listed activities and describe the effect that the implementation of PEpC will have on the cost and duration of the phase.

Change Caused by the Implementation of PEpC	Effect

Phase XI - Start-Up

This phase covers the following activities in the baseline EPC model.

Code	Activity Name	Time	Cost	ES	LS	EF	LF	%Critical
SU.SP.2	Staff Start-Up Crew	0.36	0.32	37.57	37.79	37.94	38.16	47.80%
SU.SP.3	Train Personnel	0.34	0.42	37.57	37.81	37.92	38.16	46.10%
C.DM.3	Project Site Clean-Up	0.22	1.49	38.05	40.70	38.27	40.92	6.00%
SU.SP.5	Obtain Catalyst/Chemicals	0.33	0.20	38.05	38.53	38.38	38.86	7.80%
SU.SP.6	Obtain Spare Parts	0.35	0.17	38.05	38.51	38.40	38.86	13.30%
SU.SP.4	Vendor Supervision	0.61	0.43	38.05	38.25	38.66	38.86	52.00%
SU.SP.7	Review Operations & Maint. Manuals	0.40	0.26	38.05	38.45	38.45	38.86	20.80%
SU.CO.5	Provide Raw Material Feed	0.23	0.17	38.05	42.19	38.28	42.41	0.00%
SU.CO.3	Commission Offsite Facilities	0.23	0.23	38.75	39.06	38.98	39.29	5.30%
SU.CO.2	Commission Process Units	0.40	0.80	38.75	38.89	39.15	39.29	65.30%
SU.CO.1	Commission Major Systems	0.28	0.31	38.75	39.01	39.03	39.29	23.30%
SU.PCO.1	Identify Warranty Items	0.23	0.06	39.18	39.49	39.41	39.72	23.80%
SU.CO.6	Complete Punchlist for Commission	0.40	0.36	39.18	39.32	39.58	39.72	70.20%
SU.CO.4	Conduct Product Test Run	0.48	0.48	39.61	39.72	40.09	40.20	93.90%
C.DM.1	Coordinate w/ Post Start-Up Problems	0.58	1.10	40.09	40.34	40.68	40.92	56.80%
SU.PCO.2	Complete Final Punchlist	0.42	0.15	40.09	40.50	40.52	40.92	37.10%
SU.CO.7	Review License/Perform. Guarantee	0.24	0.19	40.09	41.21	40.34	41.45	0.00%
SU.PCO.9	Obtain Regulatory Acceptance	0.34	0.06	40.92	41.11	41.26	41.45	26.20%*
SU.PCO.3	Process Final Change Orders	0.30	0.08	40.92	40.96	41.22	41.26	73.80%*

*Governs start of intermediate Documentation activities.
Total Duration for Phase = 3.69
Total Cost for Phase = 7.28

Review the listed activities and describe the effect that the implementation of PEpC will have on the cost and duration of the phase.

Change Caused by the Implementation of PEpC	Effect

Phase XII - Documentation

This phase covers the following activities in the baseline EPC model.

Code	Activity Name	Time	Cost	ES	LS	EF	LF	%Critical
MM.FD.5	Conduct Accounting Activities	1.01	0.15	32.79	39.29	33.81	40.30	0.00%
C.EX.9	Process Invoices	2.22	1.14	32.79	38.08	35.01	40.30	0.00%
C.EX.6	Submittals & Document Control Mgmt.	2.16	1.08	33.97	39.29	36.13	41.45	0.00%
C.EX.8	Change Management	2.30	1.21	33.97	38.62	36.27	40.92	0.10%
C.DM.2	Return Excess Materials for Credit	0.96	0.24	35.06	40.30	36.02	41.26	0.00%
SU.PCO.5	Generate Final Cost Statement	0.19	0.07	41.22	41.26	41.41	41.45	73.80%
SU.PCO.8	Finalize As-Built Drawings	0.60	0.28	41.45	41.49	42.05	42.09	72.60%
SU.PCO.6	Submit Close-Out Report	0.20	0.06	41.45	41.88	41.65	42.09	4.80%
SU.PCO.4	Complete Legal Closure for Project	0.27	0.08	41.45	41.82	41.72	42.09	10.30%
SU.PCO.7	Submit Final Report/Turnover Documents	0.28	0.04	41.45	41.81	41.73	42.09	12.30%
SU.PCO.10	Obtain Final Acceptance	0.33	0.07	42.09	42.09	42.41	42.41	100.00%

Total Duration for Phase = 9.62
Total Cost for Phase = 4.42

Review the listed activities and describe the effect that the implementation of PEpC will have on the cost and duration of the phase.

Change Caused by the Implementation of PEpC	Effect

APPENDIX D

PEpC Survey Responses

This appendix contains the responses to the survey tool completed by research team members to assess the effect of PEpC on the traditional EPC process.

PEpC1

Phase 1 - Preliminary Feasibility

Activity	Time Factor	Cost Factor
PPP.BP.9 - Develop Labor Plan & Address HR Issues	1.1860465	1.1333333
PPP.SD.1 - Process & Facility Planning	1.1860465	1.1333333
PPP.BP.7 - Develop Funding Plan	1.0714285	1.1

Respondent's Comments: Labor plan could change slightly because of construction support by supplier. Possibility of impact on process planning, depending on willingness of supplier to participate in project. Funding plan could get more complex.

Phase 2 - Team Selection

Activity	Time Factor	Cost Factor
PPP.CS.1 - Develop Contract Strategy	1.0930232	1.0869565
PPP.CS.2 - Develop Bid Package Scope	1.0930232	1.0869565

Respondent's Comments: A little more time will be needed to determine contract impact by bringing in a number of key suppliers and factoring in their input.

Phase 3 - Preliminary Design, Estimate, & Scope

Activity	Time Factor	Cost Factor
PPP.TP.4 - Establish Security & Secrecy Agreement	1.0589970	1.0795755
PPP.PP.1 - Develop Preliminary Design Criteria	1.0589970	1.0795755
PPP.PP.2 - Formulate Prelim. Design Organization	1.0589970	1.0795755
PPP.PP.4 - Establish Master Project Schedule	1.0589970	1.0795755
PPP.PP.5 - Address Quality & Safety Issues	1.0589970	1.0795755
PPP.PP.6 - Develop Preliminary Execution Plan	1.0589970	1.0795755
PPP.SD.5 - Detail Work Breakdown Structure	1.0589970	1.0795755
PPP.PP.8 - Develop Start-Up Plan	1.0589970	1.0795755
PPP.PP.3 - Complete Preliminary Estimates	1.0589970	1.0795755
D.FS.1 - Finalize P&IDs and PFDs	1.0589970	1.0795755
D.FS.3 - Define Major Equip. & Material Specs.	1.0589970	1.0795755

Respondent's Comments: Additional time required to include suppliers in the noted activities. May gain some time by not having to do as much equipment specification. Net increase in time of 0.2 and net increase in cost of 0.3.

Phase 4 – Estimate, Schedule, and Review

Activity	Time Factor	Cost Factor
D.DCE.2 – Estimate Installation Cost	0.9	0.9
D.DCE.3 – Estimate Support Services Cost	0.9	0.9
D.DCE.5 – Estimate Materials Cost	0.9	0.9
D.DCE.6 – Estimate Other Costs	0.9	0.9
D.DCE.1 – Estimate Equipment Cost	0.9	0.9

Respondent's Comments: Early supplier involvement will reduce the time associated with these activities.

Phase 5 – Procure Standard and Specialized Equipment

Activity	Time Factor	Cost Factor
MM.SPE.2 – Issue Inquiry for Specialized Equipment	0.4444444	0.3846153
MM.SPE.3 – Receive Vendor Bid for Spec. Equip.	0.1960784	0.25
MM.SPE.5 – Award Contract for Specialized Equip.	0.3921568	0.2941176
MM.SPE.6 – Coordinate Vendor Design	0.5747126	0.5
MM.STE.6 – Release Data Sheets	0.5	0.5
MM.SPE.7 – Vendor Doc. Mgmt. For Spec. Equip.	0.7619047	0.5882352
MM.SPE.8 – Vendor Fabrication of Spec. Equip.	0.8	0.8208955
MM.SPE.9 – Ship Specialized Equipment	0.9154929	0.8181818

Respondent's Comments: Move MM.SPE.1 back to Phase 3. Reduce time for MM.SPE.2 to 0.2 and cost to 0.05. Reduce time for MM.SPE.3 to 0.1 and cost to 0.02. Reduce time for MM.SPE.5 to 0.2 and cost to 0.15. Reduce time for MM.STE.6 to 0.24 and cost to 0.07. Reduce time for MM.SPE.7 to 0.8 and cost to 0.1. Reduce time for MM.SPE.8 to 1.2 and cost to 0.55. Reduce time for MM.SPE.9 to 0.65 and cost to 0.09. These reductions are a result of early supplier involvement. Less coordination is required and supplier provides more design.

Phase 6 –Procure Fabricated and Bulk Materials

Activity	Time Factor	Cost Factor
D.PWP.2 – Prepare Material Requisitions	0.2945326	0.665689
MM.BC.1 – Specify Bulk Commodity Materials	0.2945326	0.665689
MM.BC.2 – Issue Inquiry for Bulk Commodities	0.2945326	0.665689
MM.BC.3 – Receive Vendor Bid for Bulk Commodities	0.2945326	0.665689
MM.BC.4 – Eval. Vendor Bid for Bulk Commodities	0.2945326	0.665689
MM.BC.5 – Award Bulk Commodities Contract	0.2945326	0.665689
MM.FI.6 – Vendor Document Management	0.2945326	0.665689
MM.BC.6 – Release Bulk Commodity Materials	0.2945326	0.665689
MM.BC.7 – Ship Bulk Commodity Materials	0.2945326	0.665689

Respondent's Comments: Bulk materials can be acquired through integrated suppliers thus reducing the time required for all aspects of the bulk procurement cycle. Working with fabricated equipment supplier earlier will prevent multiple engineering of most vessels. Reduced time and cost. Total time reduction of 4.0 and total cost reduction of 1.14.

Phase 7 – Detail Design

Activity	Time Factor	Cost Factor
D.DD.1 – Detail Engineering Discipline Drawings	0.9268292	0.9081735
D.DD.5 – Obtain Intermediate Owner Reviews	0.9090909	0.9577464
D.DD.6 – Review Changes and Approve	0.92	0.9206349
D.DD.2 – Finalize Drawings & Construction Specs.	0.9574468	0.9116022
D.DD.10 – Coordinate Vendor/Engineering Interface	1.1428571	1.068965

Respondent's Comments: Some detail design moved to the supplier thus eliminating duplicate work. Reduce D.DD.1 time to 1.9 and cost to 9.0. Reduce D.DD.5 time to 1.0 and cost to 0.68. Reduce D.DD.6 time to 1.15 and cost to 0.58. Reduce D.DD.2 time to 1.35 and cost to 3.3. Increase D.DD.10 for additional supplier activity. Increase D.DD.10 time to 1.6 and cost to 1.55.

Phase 8 – Work Packages

Activity	Time Factor	Cost Factor
MM.S.1 – Work Packages/Scope of Services	0.8208955	0.9424460

Respondent's Comments: Some work packages managed by supplier(s), thus eliminating duplicate work. Reduce MM.S.1 time to 0.55 and cost to 1.31.

Phase 9 – Preliminary Construction

Respondent's Comments: No significant changes here.

Phase 10 – Field Construction

Activity	Time Factor	Cost Factor
C.EX.2 – Execute Labor Management & Construction	0.9099099	0.9254843
C.EX.3 – Monitor Schedule Status/Maintain Schedule	0.9099099	0.9254843
MM.FD.1 – Receive and Inspect Materials	0.9099099	0.9254843
MM.FEM.2 – Coordinate Materials Management	0.9099099	0.9254843
C.EX.7 – Execute Materials Mgmt. & Monitor Status	0.9099099	0.9254843
C.EX.13 – Execute Subcontractor Mgmt. & Admin.	0.9099099	0.9254843
C.EX.11 – Execute Human Resources Management	0.9099099	0.9254843
MM.FD.2 – Inventory, Store, & Maintain Materials	0.9099099	0.9254843
MM.FD.3 – Issue Material	0.9099099	0.9254843
MM.FD.4 – Vendor Inspection	0.9099099	0.9254843
C.EX.10 – Monitor Cost/Budget Status	0.9099099	0.9254843
C.EX.5 – Issue Progress Reports	0.9099099	0.9254843
C.EX.12 – Inspect & Test Equipment	0.9099099	0.9254843
SU.SP.1 – Prepare Start-Up Procedures	0.9099099	0.9254843

Respondent’s Comments: Some improvements in constructability and gains in productivity. Net time improvement for the phase of 0.7. Net cost improvement for the phase of 3.0.

Phase 11 – Start-Up

Activity	Time Factor	Cost Factor
SU.SP.2 – Staff Start-Up Crew	0.9864498	0.9931318
SU.SP.3 – Train Personnel	0.9864498	0.9931318
C.DM.3 – Project Site Clean-Up	0.9864498	0.9931318
SU.SP.5 – Obtain Catalyst/Chemicals	0.9864498	0.9931318
SU.SP.6 – Obtain Spare Parts	0.9864498	0.9931318
SU.SP.4 – Vendor Supervision	0.9864498	0.9931318
SU.SP.7 – Review Operations & Maint. Manuals	0.9864498	0.9931318
SU.CO.5 - Provide Raw Material Fees	0.9864498	0.9931318
SU.CO.3 – Commission Offsite Facilities	0.9864498	0.9931318
SU.CO.2 – Commission Process Units	0.9864498	0.9931318
SU.CO.1 – Commission Major Systems	0.9864498	0.9931318
SU.PCO.1 – Identify Warranty Items	0.9864498	0.9931318
SU.CO.6 – Complete Punchlist for Commission	0.9864498	0.9931318
SU.CO.4 – Conduct Product Test Run	0.9864498	0.9931318
C.DM.1 – Coordinate w/Post Start-Up Problems	0.9864498	0.9931318
SU.PCO.2 – Complete Final Punchlist	0.9864498	0.9931318
SU.CO.7 – Review Licensee/Performance Guarantee	0.9864498	0.9931318
SU.PCO.9 – Obtain Regulatory Acceptance	0.9864498	0.9931318
SU.PCO.3 – Process Final Change Orders	0.9864498	0.9931318

Respondent's Comments: Minor improvements here. Improve phase time to 3.64 and phase cost to 7.23.

Phase 12 – Documentation

Activity	Time Factor	Cost Factor
C.EX.6 – Submittals & Document Control Mgmt.	0.9139784	0.925
C.DM.2 – Return Excess Materials for Credit	0.9139784	0.925
SU.PCO.8 – Finalize As-Built Drawings	0.9139784	0.925

Respondent's Comments: Minor improvement in close out due to improved ongoing documentation. Very little excess material. As-builts more up to date. Reduce time by 0.32 and cost by 0.12.

PepC2

Phase 1 - Preliminary Feasibility

Activity	Time Factor	Cost Factor
PPP.SD.1 - Process & Facility Planning	2.0	1.5

Respondent's Comments:

Phase 2 - Team Selection

Activity	Time Factor	Cost Factor
PPP.CS.1 - Develop Contract Strategy	1.5	1.3
PPP.CS.2 - Develop Bid Package Scope	1.5	1.3
PPP.CS.3 – Review Potential EPC Contractor Bidders	1.5	1.3
PPP.CS.4 – Select EPC Contractor Team	1.5	1.3

Respondent's Comments:

Phase 3 - Preliminary Design, Estimate, & Scope

Activity	Time Factor	Cost Factor
D.FS.3 - Define Major Equip. & Material Specs.	1.3	1.1

Respondent's Comments:

Phase 4 – Estimate, Schedule, and Review

Activity	Time Factor	Cost Factor
D.DCE.1 – Estimate Equipment Cost	0.8	0.8
D.DCE.2 – Estimate Installation Cost	0.8	0.8
D.DCE.3 – Estimate Support Services Cost	0.8	0.8
D.DCE.5 – Estimate Materials Cost	0.8	0.8
D.DCE.6 – Estimate Other Costs	0.8	0.8
D.DD.9 – Conduct Scope/Estimate Review	0.9	0.9
D.DS.2 – Detail Material Management Schedule	0.9	0.9

Respondent's Comments:

Phase 5 – Procure Standard and Specialized Equipment

Activity	Time Factor	Cost Factor
MM.SPE.1 – Specify Specialized Equipment	0.6	0.8
MM.STE.1 – Specify Standard Equipment	0.9	0.9
MM.SPE.2 – Issue Inquiry for Specialized Equipment	0.6	0.8
MM.STE.2 – Issue Inquiry for Standard Equipment	0.9	0.9
MM.SPE.3 – Receive Vendor Bid for Spec. Equip.	0.6	0.8
MM.STE.3 – Receive Vendor Bid for Standard Equip.	0.9	0.9
MM.SPE.4 – Evaluate Vendor Bid for Spec. Equip.	0.6	0.8
MM.STE.4 – Evaluate Vendor Bid for Standard Equip.	0.9	0.9
MM.SPE.5 – Award Contract for Specialized Equip.	0.6	0.8
MM.STE.5 – Award Contract for Standard Equipment	0.9	0.9
MM.SPE.6 – Coordinate Vendor Design	0.8	0.8
MM.SPE.7 – Vendor Doc. Mgmt. For Spec. Equip.	0.6	0.8
MM.SPE.9 – Ship Specialized Equipment	0.6	0.8

Respondent's Comments:

Phase 6 –Procure Fabricated and Bulk Materials

Respondent's Comments: No significant change here.

Phase 7 – Detail Design

Activity	Time Factor	Cost Factor
D.DD.1 – Detail Engineering Discipline Drawings	0.75	0.8
D.DD.2 – Finalize Drawings & Construction Specs.	0.9	0.9
D.DD.7 – Complete Constructability Review	0.9	0.9
D.DD.10 – Coordinate Vendor/Engineering Interface	0.9	0.9

Respondent's Comments:

Phase 8 – Work Packages

Activity	Time Factor	Cost Factor
MM.S.1 – Work Packages/Scope of Services	0.95	0.95
MM.S.2 – Prequalify Vendor/Sub. & Issue Inquiry	0.95	0.95
MM.S.3 – Receive Vendor/Sub. Bid	0.95	0.95
MM.S.4 – Evaluate Vendor/Sub. Bid	0.95	0.95
MM.S.5 – Award Contract to Vendor/Sub.	0.95	0.95
D.PWP.3 – Develop Bill of Materials	0.95	0.95

Respondent's Comments:

Phase 9 – Preliminary Construction

Activity	Time Factor	Cost Factor
C.PW.8 – Develop Materials Management Plan	0.99	0.98
C.PW.10 – Develop Execution Strategy	0.99	0.98
MM.DO.1 – Prepare Final Report/Turnover Docs	0.99	0.98
C.PW.9 – Define Training Procedures	0.99	0.98
C.PW.4 – Submit Project Documents	0.99	0.98
C.PW.5 – Obtain Permits/Licenses	0.99	0.98
MM.FEM.1 – Coordinate Materials Management	0.99	0.98
C.EX.1 – Develop Work Plan	0.99	0.98
C.PW.1 – Site Mobilization	0.99	0.98
C.EX.14 – Document QA/QC	0.99	0.98
C.PW.2 – Mobilize Facilities	0.99	0.98
C.PW.3 – Provide Construction Utilities	0.99	0.98
C.PW.6 – Establish Safety/Quality	0.99	0.98
C.PW.11 – Install Communication Systems	0.99	0.98
C.PW.7 – Establish Security	0.99	0.98
C.EX.4 – Establish Design Support	0.99	0.98

Respondent's Comments:

Phase 10 – Field Construction

Activity	Time Factor	Cost Factor
C.EX.2 – Execute Labor Management & Construction	0.97	0.98
MM.FEM.2 – Coordinate Materials Management	0.85	0.85
C.EX.7 – Execute Materials Mgmt. & Monitor Status	0.9	0.9

Respondent’s Comments:

Phase 11 – Start-Up

Activity	Time Factor	Cost Factor
SU.SP.4 – Vendor Supervision	0.8	0.8

Respondent’s Comments:

Phase 12 – Documentation

Respondent's Comments: No significant change here.

PepC3
Phase 1 - Preliminary Feasibility

Activity	Add Time	Add Cost
New Activity – Select Critical Suppliers	0.25	0.1

Respondent's Comments: Add time and cost to select critical suppliers.

Phase 2 - Team Selection

Activity	Add Time	Add Cost
New Activity – Begin Team Meetings Owners/Suppliers	0.25	0.1

Activity	Time Factor	Cost Factor
PPP.CS.3 – Review Potential EPC Contractor Bidders	0.5882352	1.0

Respondent's Comments: New Activity needed to begin meetings with owners and suppliers. Deduct 0.07 from PPP.CS.3 time. No change to cost.

Phase 3 - Preliminary Design, Estimate, & Scope

Activity	Time Factor	Cost Factor
PPP.TP.1 – Conduct Tech. Surveys & Process Anal.	0.75	0.8
PPP.TP.2 – Product Development/Certification & Testing Procedures	0.5797101	1.0
PPP.PP.1 - Develop Preliminary Design Criteria	0.8108108	0.9
D.FS.3 - Define Major Equip. & Material Specs.	0.5833333	1.0

Respondent's Comments: Deduct 0.10 from PPP.TP.1 time and .05 from cost. Deduct 0.29 from PPP.TP.2 time. Deduct 0.07 from PPP.PP.1 time and 0.06 from cost. Deduct 0.25 from D.FS.3 time. No change to cost for PPP.TP.2 and D.FS.3.

Phase 4 – Estimate, Schedule, and Review

Activity	Time Factor	Cost Factor
D.DD.9 – Conduct Scope/Estimate Review	0.8823529	1.0
D.DS.3 – Detail Construction Schedule	0.8536585	0.9

Respondent's Comments: Deduct 0.08 from D.DD.9 time. Deduct 0.12 from D.DS.3 time and 0.05 from cost. No change to cost for D.DD.9.

Phase 5 – Procure Standard and Specialized Equipment

Activity	Time Factor	Cost Factor
MM.SPE.1 – Specify Specialized Equipment	0.7058823	0.8
MM.SPE.2 – Issue Inquiry for Specialized Equipment	0.4444444	1.0
MM.SPE.3 – Receive Vendor Bid for Spec. Equip.	0.5098039	1.0
MM.SPE.4 – Evaluate Vendor Bid for Spec. Equip.	0.5098039	1.0
MM.SPE.5 – Award Contract for Specialized Equip.	0.5098039	1.0
MM.SPE.6 – Coordinate Vendor Design	0.8045977	0.85
MM.SPE.7 – Vendor Doc. Mgmt. For Spec. Equip.	0.8571428	1.0
MM.SPE.8 – Vendor Fabrication of Spec. Equip.	0.8333333	1.0

Respondent's Comments: Deduct 0.2 from MM.SPE.1 time and 0.06 from cost. Deduct 0.25 from MM.SPE.2 time. Deduct 0.25 from MM.SPE.3 time. Deduct 0.25 from MM.SPE.4 time. Deduct 0.25 from MM.SPE.5 time. Deduct 0.17 from MM.SPE.6 time and 0.04 from cost. Deduct 0.15 from MM.SPE.7 time. Deduct 0.25 from MM.SPE.8 time. No change to cost for MM.SPE.2-MM.SPE.5 or MM.SPE.7, MM.SPE.8.

Phase 6 –Procure Fabricated and Bulk Materials

Respondent's Comments: No change.

Phase 7 – Detail Design

Activity	Time Factor	Cost Factor
D.DD.1 – Detail Engineering Discipline Drawings	0.8780487	0.95
D.DD.10 – Coordinate Vendor/Engineering Interface	0.7142857	0.9

Respondent's Comments: Deduct 0.25 from D.DD.1 time and 0.5 from cost. Deduct 0.40 from D.DD.10 time and 0.15 from cost.

Phase 8 – Work Packages

Activity	Time Factor	Cost Factor
MM.S.1 – Work Packages/Scope of Services	0.7462686	1.0
MM.S.2 – Prequalify Vendor/Sub. & Issue Inquiry	0.8653846	1.0
MM.S.3 – Receive Vendor/Sub. Bid	0.8653846	1.0
MM.S.4 – Evaluate Vendor/Sub. Bid	0.875	1.0
MM.S.5 – Award Contract to Vendor/Sub.	0.862745	1.0

Respondent's Comments: Deduct 0.07 from time for activities MM.S.1 – MM.S.5. No change in cost.

Phase 9 – Preliminary Construction

Activity	Time Factor	Cost Factor
MM.FEM.1 – Coordinate Materials Management	0.893617	1.0
C.EX.14 – Document QA/QC	0.8467432	1.0

Respondent's Comments: Deduct 0.20 from MM.FEM.1 time. Deduct 0.4 from C.EX.14 time. No change in cost.

Phase 10 – Field Construction

Activity	Time Factor	Cost Factor
C.EX.3 – Monitor Schedule Status/Maintain Schedule	0.8304498	1.0
C.EX.13 – Execute Subcontractor Mgmt. & Admin.	0.8387096	1.0
MM.FD.4 – Vendor Inspection	0.8450704	1.0
C.EX.12 – Inspect & Test Equipment	0.8426966	1.0
SU.SP.1 – Prepare Start-Up Procedures	0.8333333	1.0

Respondent's Comments: Deduct 0.49 from C.EX.3 time. Deduct 0.5 from C.EX.13 time. Deduct 0.11 from MM.FD.4 time. Deduct 0.28 from C.EX.12 time. Deduct 0.1 from SU.SP.1 time. No change in cost.

Phase 11 – Start-Up

Activity	Time Factor	Cost Factor
SU.SP.6 – Obtain Spare Parts	0.8571428	1.0
SU.SP.4 – Vendor Supervision	0.6721311	1.0
C.DM.1 – Coordinate w/Post Start-Up Problems	0.6896551	1.0

Respondent's Comments: Deduct 0.05 from SU.SP.6 time. Deduct 0.2 from SU.SP.4 time. Deduct 0.18 from C.DM.1 time. No change in cost.

Phase 12 – Documentation

Activity	Time Factor	Cost Factor
SU.PCO.8 – Finalize As-Built Drawings	0.075	1.0

Respondent's Comments: Deduct 0.15 from SU.PCO.8 time. No change in cost.

PepC4

Phase 1 - Preliminary Feasibility

Activity	Time Factor	Cost Factor
PPP.BP.2 – Define Facility Objectives/Capacity Demands	1.25	1.384615

Activity	Add Time	Add Cost
New Activity – Identify Key Process Equipment	0.10	0.05

Respondent's Comments: Bring in strategic suppliers to help with PPP.BP.2. Add 0.1 to time and 0.05 to cost. Need new activity to identify key process equipment that will fall under PEpC process. New activity will have time of 0.10 and cost of 0.05.

Phase 2 - Team Selection

Activity	Add Time	Add Cost
New Activity – Select Strategic Supplier Partners and Begin Meetings	0.10	0.10

Respondent's Comments: New activity required to select strategic suppliers and begin meetings. New activity will have time of 0.10 and cost of 0.10.

Phase 3 - Preliminary Design, Estimate, & Scope

Activity	Time Factor	Cost Factor
PPP.PP.1 - Develop Preliminary Design Criteria	0.85	0.95
PPP.PP.3 – Complete Preliminary Estimates	0.75	0.85
D.FS.3 - Define Major Equip. & Material Specs.	0.166667	0.3508771

Respondent's Comments: Reduce time for PPP.PP.1 by 0.05 and cost by 0.03. Reduce time for PPP.PP.3 by 0.06 and cost by 0.02. Reduce time for D.FS.3 by 0.5 and cost by 0.74.

Phase 4 – Estimate, Schedule, and Review

Activity	Time Factor	Cost Factor
D.DCE.1 – Estimate Equipment Cost	0.5	0.5
D.DCE.2 – Estimate Installation Cost	0.5	0.5
D.DCE.3 – Estimate Support Services Cost	0.5	0.5
D.DCE.5 – Estimate Materials Cost	0.75	0.75
D.DCE.6 – Estimate Other Costs	0.75	0.75

Respondent's Comments: Reduce D.DCE.1 time by 0.19 and cost by 0.13. Reduce D.DCE.2 time by 0.19 and cost by 0.19. Reduce D.DCE.3 time by 0.16 and cost by 0.08. Reduce D.DCE.5 time by 0.10 and cost by 0.10. Reduce D.DCE.6 time by 0.13 and cost by 0.03.

Phase 5 – Procure Standard and Specialized Equipment

Activity	Time Factor	Cost Factor
MM.SPE.1 – Specify Specialized Equipment	0.25	0.25
MM.SPE.2 – Issue Inquiry for Specialized Equipment	0.25	0.25
MM.SPE.3 – Receive Vendor Bid for Spec. Equip.	0.25	0.25
MM.SPE.4 – Evaluate Vendor Bid for Spec. Equip.	0.25	0.25
MM.SPE.5 – Award Contract for Specialized Equip.	0.25	0.25
MM.SPE.6 – Coordinate Vendor Design	0.75	0.75
MM.SPE.7 – Vendor Doc. Mgmt. For Spec. Equip.	0.75	0.75
MM.SPE.8 – Vendor Fabrication of Spec. Equip.	0.95	0.95

Respondent's Comments: Reduce MM.SPE.1 – MM.SPE.5 time and cost by 75%. Reduce MM.SPE.6 and MM.SPE.7 time and cost by 25%. Reduce MM.SPE.9 time and cost by 5%.

Phase 6 –Procure Fabricated and Bulk Materials

Respondent's Comments: No significant change here.

Phase 7 – Detail Design

Activity	Time Factor	Cost Factor
D.DD.4 – Design/Engineering Review	0.75	0.75
D.DD.7 – Complete Constructability Review	0.75	0.75
D.DD.6 – Review Changes and Approve	0.75	0.75
D.DD.2 – Finalize Drawings & Construction Specs.	0.85	0.85
D.DD.10 – Coordinate Vendor/Engineering Interface	0.9	0.9

Respondent's Comments: Reduce D.DD.4, D.DD.7, and D.DD.6 time and cost by 25%. Reduce D.DD.2 time and cost by 15% and reduce D.DD.10 time and cost by 10%.

Phase 8 – Work Packages

Respondent's Comments: No significant change here.

Phase 9 – Preliminary Construction

Activity	Time Factor	Cost Factor
MM.FEM.1 – Coordinate Materials Management	0.9	0.9
C.EX.14 – Document QA/QC	0.9	0.9
C.PW.8 – Develop Materials Management Plan	0.9	0.9

Respondent's Comments: Reduce MM.FEM.1, C.EX.14, and C.PW.8 time and cost by 10%.

Phase 10 – Field Construction

Activity	Time Factor	Cost Factor
C.EX.2 – Execute Labor Management & Construction	0.9	0.9
C.EX.3 – Monitor Schedule Status/Maintain Schedule	0.9	0.9
MM.FD.4 – Vendor Inspection	1.0	0.9
C.EX.12 – Inspect & Test Equipment	1.0	0.9
SU.SP.1 – Prepare Start-Up Procedures	0.85	0.85

Respondent's Comments: Reduce time and cost for C.EX.2 and C.EX.3 by 10%. Reduce cost only for MM.FD.4 and C.EX.12 by 10%. Reduce time and cost for SU.SP.1 by 15%.

Phase 11 – Start-Up

Activity	Time Factor	Cost Factor
SU.PCO.3 – Process Final Change Orders	0.8	0.8

Respondent’s Comments: Reduce SU.PCO.3 time and cost by 20%.

Phase 12 – Documentation

Activity	Time Factor	Cost Factor
C.EX.8 – Change Management	0.8	0.8
SU.PCO.8 – Finalize As-Built Drawings	0.85	0.85

Respondent's Comments: Reduce time and cost for C.EX.8 by 20%. Reduce SU.PCO.8 time and cost by 15%.

PepC5
Phase 1 - Preliminary Feasibility

Respondent's Comments: No change in this stage. These are purely owner business decisions. PEpC or EPC decision is typically not addressed in this business phase.

Phase 2 - Team Selection

Activity	Time Factor	Cost Factor
New Activity – Review Potential Critical Supplier List	Like PPP.CS.3	Like PPP.CS.3

Respondent's Comments: New activity required to review critical supplier list. Duration and cost similar to PPP.CS.3. New activity should be concurrent with PPP.CS.3. Revise title of PPP.CS.4 to include selection of critical suppliers.

Phase 3 - Preliminary Design, Estimate, & Scope

Activity	Time Factor	Cost Factor
PPP.PP.4 - Establish Master Project Schedule	1.2903225	1.0

Activity	Add Time	Add Cost
New Activity – Review & Develop Strategic Supplier Strategy	0.13	0
New Activity – Initiate Strategic Supplier Negotiations & Pricing Review	0.10	0

Respondent's Comments: PPP.PP.4 would possibly take longer. Extend duration of PPP.PP.4 to 0.40 to better include supplier's input. Additional activity would be needed to review and develop strategic supplier strategy. This activity would have a estimated duration of 0.13 and would occur concurrently with PPP.PP.4. Another new activity would be required to initiate strategic supplier negotiations and pricing review. This activity would have a duration of approximately 0.1.

Phase 4 – Estimate, Schedule, and Review

Activity	Time Factor	Cost Factor
D.DS.1 – Detail Design Schedule	0.8461538	1.0

Activity	Add Time	Add Cost
New Activity – Receive/Review Strategic Supplier Documents and Drawings	0.16	0

Respondent's Comments: Detail design schedule (D.DS.1) should be shortened because critical suppliers' data will be available. Reduce D.DS.1 duration to 0.55. A new activity is required to receive and review strategic supplier documents and drawings. The new activity will have a duration of approximately 0.16 and occur concurrently with D.PWP.1.

Phase 5 – Procure Standard and Specialized Equipment

Activity	Time Factor	Cost Factor
MM.SPE.1 – Specify Specialized Equipment	0.7352949	1.0
MM.SPE.2 – Issue Inquiry for Specialized Equipment	0.7777778	1.0
MM.SPE.3 – Receive Vendor Bid for Spec. Equip.	0.6862745	1.0
MM.SPE.4 – Evaluate Vendor Bid for Spec. Equip.	0.6862745	1.0
MM.SPE.5 – Award Contract for Specialized Equip.	0.6862745	1.0

Respondent's Comments: Reduce MM.SPE.1 time by 0.18, MM.SPE.2 time by 0.10, MM.SPE.3 time by 0.16, MM.SPE.4 time by 0.16, and MM.SPE.5 time by 0.16.

Phase 6 –Procure Fabricated and Bulk Materials

Respondent's Comments: No significant change in this phase.

Phase 7 – Detail Design

Activity	Time Factor	Cost Factor
D.DD.1 – Detail Engineering Discipline Drawings	0.8536585	1.0
D.DD.7 – Complete Constructability Review	0.9	1.0
D.DD.6 – Review Changes and Approve	0.88	1.0
D.DD.2 – Finalize Drawings & Construction Specs.	0.85	1.0
D.DD.10 – Coordinate Vendor/Engineering Interface	0.7857142	1.0

Respondent's Comments: Reduce D.DD.1 time by 0.3, D.DD.7 time by 0.6, D.DD.6 time by 0.15, D.DD.2 time by 0.21, and D.DD.10 time by 0.30. These reductions are a result of earlier supplier involvement and design coordination. There are no anticipated changes in cost.

Phase 8 – Work Packages

Respondent's Comments: No anticipated effect in this phase.

Phase 9 – Preliminary Construction

Activity	Time Factor	Cost Factor
C.PW.8 – Develop Materials Management Plan	0.9	0.9
MM.FEM.1 – Coordinate Materials Management	0.9	0.9
C.EX.14 – Document QA/QC	0.8	0.8
C.EX.4 – Establish Design Support	0.85	0.85

Respondent's Comments: Reduce C.PW.8 time by 0.04, MM.FEM.1 time by 0.19, C.EX.14 time by 0.52, and C.EX.4 time by 0.15.

Phase 10 – Field Construction

Activity	Time Factor	Cost Factor
C.EX.2 – Execute Labor Management & Construction	0.95	1.0
C.EX.3 – Monitor Schedule Status/Maintain Schedule	0.95	1.0

Respondent’s Comments: Reduce C.EX.2 and C.EX.3 by 5% to reflect better delivery, fewer changes, and results of quality constructability reviews.

Phase 11 – Start-Up

Respondent’s Comments: No impact to this phase.

Phase 12 – Documentation

Respondent’s Comments: No impact to this phase.

PEpC6
Phase 1 - Preliminary Feasibility

Activity	Time Factor	Cost Factor
PPP.BP.2 – Define Facility Objectives/Capacity Demands	1.4504504	1.4545454
PPP.BP.10 – Define Start-Up Requirements	1.4504504	1.4545454
PPP.BP.9 - Develop Labor Plan & Address HR Issues	1.4504504	1.4545454
PPP.BP.8 – Raw Material Sourcing	1.4504504	1.4545454
PPP.SD.1 - Process & Facility Planning	1.4504504	1.4545454
PPP.BP.5 – Finalize Site Selection	1.4504504	1.4545454

Respondent's Comments: Add time for supplier involvement for the noted activities. This time is to confirm capacity, address HR & work related issues, confirm material sourcing issues, and obtain input on site selection including access & constructability.

Phase 2 - Team Selection

Activity	Time Factor	Cost Factor
PPP.CS.1 - Develop Contract Strategy	0.6666667	0.6078431
PPP.CS.2 - Develop Bid Package Scope	0.6666667	0.6078431
PPP.CS.3 – Review Potential EPC Contractor Bidders	0.6666667	0.6078431
PPP.CS.4 – Select EPC Contractor Team	0.6666667	0.6078431
PPP.CS.5 – Develop Labor Strategy	0.6666667	0.6078431
PPP.PP.7 – Summarize Project Scope	1.2777778	1.375

Respondent's Comments: Major reductions in activities PPP.CS.1 through PPP.CS.5 due to previous alliance relationships and agreements. Assume greater and earlier involvement of EPC contractor as well as suppliers. Deduct 0.3 from time for these 5 activities and 0.2 from the cost of these 5 activities. PPP.PP.7 would have increased duration and cost to allow increased participation of contractor and suppliers in developing project scope.
More time is needed to obtain and integrate input from contractor and suppliers resulting in a clearer scope and fewer changes.

Phase 3 - Preliminary Design, Estimate, & Scope

Activity	Time Factor	Cost Factor
PPP.PP.3 - Complete Preliminary Estimates	0.6644295	0.8820754
D.FS.4 – Finalize Utilities and Offsite Scope	0.6644295	0.8820754
D.FS.3 - Define Major Equip. & Material Specs.	0.6644295	0.8820754

Respondent's Comments: Reduce time required to obtain preliminary estimates (PPP.PP.3) and define major equipment and material specifications (D.FS.3). Assume that supplier brings suggestions to simplify specifications – use of off the shelf equipment and use of standard drawings which are available earlier. Also reduce time and cost to finalize utilities and offsite scope (D.FS.4). Reduce time for these 3 activities by 0.5 and cost by 0.25.

Phase 4 – Estimate, Schedule, and Review

Activity	Time Factor	Cost Factor
D.DCE.1 – Estimate Equipment Cost	0.8	0.8
D.DCE.2 – Estimate Installation Cost	0.8	0.8
D.DCE.3 – Estimate Support Services Cost	0.8	0.8
D.DCE.5 – Estimate Materials Cost	0.8	0.8
D.DCE.6 – Estimate Other Costs	0.8	0.8
D.DD.9 - Conduct Scope/Estimate Review	0.9	0.9

Respondent's Comments: Reduce D.DCE.1, D.DCE.2, D.DCE.3, D.DCE.5, and D.DCE.6 by 20%. Reduce D.DD.9 by 10%. Less time required by operation to prepare schedule and cost estimates. Fewer revision to cost and schedule estimates and reports.

Phase 5 – Procure Standard and Specialized Equipment

Activity	Time Factor	Cost Factor
MM.SPE.1 - Specify Specialized Equipment	0.6672213	0.5475113
MM.SPE.2 – Issue Inquiry for Specialized Equipment	0.6672213	0.5475113
MM.SPE.3 – Receive Vendor Bid for Spec. Equip.	0.6672213	0.5475113
MM.SPE.4 - Evaluate Vendor Bid for Spec. Equip.	0.6672213	0.5475113
MM.SPE.5 – Award Contract for Specialized Equip.	0.6672213	0.5475113
MM.SPE.6 – Coordinate Vendor Design	0.6672213	0.5475113
MM.SPE.7 – Vendor Doc. Mgmt. For Spec. Equip.	0.6672213	0.5475113
MM.SPE.8 – Vendor Fabrication of Spec. Equip.	0.6672213	0.5475113
MM.SPE.9 – Ship Specialized Equipment	0.6672213	0.5475113
MM.STE.1 - Specify Standard Equipment	0.6672213	0.5475113
MM.STE.2 – Issue Inquiry for Standard Equipment	0.6672213	0.5475113
MM.STE.3 – Receive Vendor Bid for Std. Equip.	0.6672213	0.5475113
MM.STE.4 - Evaluate Vendor Bid for Std. Equip.	0.6672213	0.5475113
MM.STE.5 – Award Contract for Standard Equip.	0.6672213	0.5475113
MM.STE.6 – Release Data Sheets	0.6672213	0.5475113
MM.STE.7 – Vendor Doc. Mgmt. For Std. Equip.	0.6672213	0.5475113
MM.STE.8 – Vendor Fabrication of Std. Equip.	0.6672213	0.5475113
MM.STE.9 – Ship Standard Equipment	0.6672213	0.5475113

Respondent's Comments: Reduce total time for phase by 4.0 and reduce total cost for phase by 2.0. Major reductions to this stage because the use of alliances eliminates bidding and preparation of standard specs. Vendor documents and drawings significantly simplified because previous alliance agreements bring understanding of standards and equipment specs for material and equipment supplied.

Phase 6 –Procure Fabricated and Bulk Materials

Activity	Time Factor	Cost Factor
MM.BC.1 – Specify Bulk Commodity Materials	0.7843666	0.8039216
MM.BC.2 – Issue Inquiry for Bulk Commodities	0.7843666	0.8039216
MM.BC.3 – Receive Vendor Bid for Bulk Commodities	0.7843666	0.8039216
MM.BC.4 – Eval. Vendor Bid for Bulk Commodities	0.7843666	0.8039216
MM.BC.5 – Award Bulk Commodities Contract	0.7843666	0.8039216
MM.BC.6 – Release Bulk Commodity Materials	0.7843666	0.8039216
MM.FI.1 - Finalize Fabricated Item Material Specs.	0.7843666	0.8039216
MM.FI.2 - Issue Inquiry for Fabricated Items	0.7843666	0.8039216
MM.FI.3 - Receive Vendor Bid for Fabricated Items	0.7843666	0.8039216
MM.FI.4 - Evaluate Vendor Bid for Fabricated Items	0.7843666	0.8039216
MM.FI.5 - Award Fabricated Items Contract	0.7843666	0.8039216
MM.FI.7 - Fabricate Fabricated Items Materials	0.7843666	0.8039216
D.DD.3 - Conduct Cost & Schedule Review Analysis	0.7843666	0.8039216

Respondent's Comments: Major reductions of items noted above. Reduce time for these items by 1.6 and cost for these items by 0.8.

Phase 7 – Detail Design

Activity	Time Factor	Cost Factor
D.DD.6 – Review Changes and Approve	0.8461538	0.9371069
D.DD.2 – Finalize Drawings & Construction Specs.	0.8461538	0.9371069
D.DD.7 - Complete Constructability Review	0.8461538	0.9371069

Respondent's Comments: Better communication and interfaces, less mistakes due to lack of communication. Fewer changes. Reduce time for these activities by 0.5 and cost for these activities by 0.3.

Phase 8 – Work Packages

Activity	Time Factor	Cost Factor
MM.S.1 – Work Packages/Scope of Services	0.9212598	0.9596774
D.PWP.3 - Develop Bill of Materials	0.9212598	0.9596774
MM.S.3 - Receive Vendor/Subcontractor Bid	0.9212598	0.9596774
MM.S.4 - Evaluate Vendor/Subcontractor Bid	0.9212598	0.9596774

Respondent's Comments: Reduced work to develop packages. Reduce time for these items by 0.2 and cost by 0.1.

Phase 9 – Preliminary Construction

Activity	Time Factor	Cost Factor
C.PW.9 - Define Training Procedures	0.7368421	0.6357013
C.PW.4 - Submit Project Documents	0.7368421	0.6357013
MM.FEM.1 - Coordinate Materials Management	0.7368421	0.6357013
C.PW.1 - Site Mobilization	0.7368421	0.6357013
C.EX.14 - Document QA/QC	0.7368421	0.6357013
C.PW.2 - Mobilize Facilities	0.7368421	0.6357013

Respondent's Comments: Reduce time by 1.5 and cost by 2.0 for checked items.

Phase 10 – Field Construction

Activity	Time Factor	Cost Factor
C.EX.2 – Execute Labor Management & Construction	0.8132780	0.6297668
MM.FD.2 – Inventory, Store, & Maintain Materials	0.8132780	0.6297668
MM.FD.3 – Issue Material	0.8132780	0.6297668
MM.FD.4 – Vendor Inspection	0.8132780	0.6297668
C.EX.12 – Inspect & Test Equipment	0.8132780	0.6297668
SU.SP.1 – Prepare Start-Up Procedures	0.8132780	0.6297668

Respondent's Comments: Significantly reduce inspection and testing. Reduce time for these items by 1.8 and cost for these items by 10.0.

Phase 11 – Start-Up

Activity	Time Factor	Cost Factor
SU.SP.6 – Obtain Spare Parts	0.7478992	0.5238095
SU.CO.3 – Commission Offsite Facilities	0.7478992	0.5238095
SU.CO.2 – Commission Process Units	0.7478992	0.5238095
SU.CO.1 – Commission Major Systems	0.7478992	0.5238095
SU.CO.6 – Complete Punchlist for Commission	0.7478992	0.5238095
SU.PCO.2 – Complete Final Punchlist	0.7478992	0.5238095
SU.PCO.3 – Process Final Change Orders	0.7478992	0.5238095

Respondent's Comments: Commissioning, punchlist, and change orders reduced. Fewer problems at start-up. Reduce time for these items by 0.6. Reduce cost for these items by 1.0.

Phase 12 – Documentation

Activity	Time Factor	Cost Factor
C.EX.8 - Change Management	0.7757848	0.7379913
C.DM.2 – Return Excess Materials for Credit	0.7757848	0.7379913

Respondent's Comments: Fewer changes and reduced excess materials.
Reduce time for these items by 1.0 and reduce cost for these items by 0.6.

PEpC7

Phase 1 - Preliminary Feasibility

Respondent's Comments: No changes to this phase.

Phase 2 - Team Selection

Activity	Time Factor	Cost Factor
PPP.CS.1 - Develop Contract Strategy	0.1	0.1
PPP.CS.2 - Develop Bid Package Scope	0.1	0
PPP.CS.3 – Review Potential EPC Contractor Bidders	0.1	0
PPP.CS.4 – Select EPC Contractor Team	0.1	0
PPP.PP.7 – Summarize Project Scope	0.5	0.5

Respondent's Comments:

Phase 3 - Preliminary Design, Estimate, & Scope

Activity	Time Factor	Cost Factor
PPP.PP.1 - Develop Preliminary Design Criteria	0.25	0.5
PPP.PP.3 - Complete Preliminary Estimates	0.25	0.5
PPP.TP.3 - Obtain Patent and Licenses	0	0
PPP.TP.4 - Estab. Security and Secrecy Agreement	0	0
D.FS.3 - Define Major Equip. & Material Specs.	0	0

Respondent's Comments:

Phase 4 – Estimate, Schedule, and Review

Activity	Time Factor	Cost Factor
D.DCE.4 - Estimate Indirects Cost	0.75	0.75
D.DD.9 - Conduct Scope/Estimate Review	0.7	0.7

Respondent's Comments:

Phase 5 – Procure Standard and Specialized Equipment

Activity	Time Factor	Cost Factor
MM.SPE.1 - Specify Specialized Equipment	0.5	0.5
MM.SPE.2 – Issue Inquiry for Specialized Equipment	0.25	0.25
MM.SPE.3 – Receive Vendor Bid for Spec. Equip.	0.5	0.5
MM.SPE.4 - Evaluate Vendor Bid for Spec. Equip.	0.25	0.25
MM.SPE.6 – Coordinate Vendor Design	0.5	0.5
MM.SPE.7 – Vendor Doc. Mgmt. For Spec. Equip.	0.5	0.5
MM.STE.2 – Issue Inquiry for Standard Equipment	0.25	0.25
MM.STE.3 – Receive Vendor Bid for Std. Equip.	0.5	0.5
MM.STE.4 - Evaluate Vendor Bid for Std. Equip.	0.25	0.25
MM.STE.7 – Vendor Doc. Mgmt. For Std. Equip.	0.5	0.5

Respondent's Comments:

Phase 6 –Procure Fabricated and Bulk Materials

Activity	Time Factor	Cost Factor
MM.BC.2 – Issue Inquiry for Bulk Commodities	0.25	0.25
MM.BC.3 – Receive Vendor Bid for Bulk Commodities	0.5	0.5
MM.BC.4 – Eval. Vendor Bid for Bulk Commodities	0.25	0.25
MM.FI.2 - Issue Inquiry for Fabricated Items	0.25	0.25
MM.FI.3 - Receive Vendor Bid for Fabricated Items	0.5	0.5
MM.FI.4 - Evaluate Vendor Bid for Fabricated Items	0.25	0.25

Respondent's Comments:

Phase 7 – Detail Design

Activity	Time Factor	Cost Factor
D.DD.1 - Detail Engineering Discipline Drawings	0.25	0.25
D.DD.4 - Design/Engineering Review	0.85	0.85
D.DD.5 - Obtain Intermediate Owner Review & Approval	0.85	0.85
D.DD.6 – Review Changes and Approve	0.5	0.5
D.DD.2 – Finalize Drawings & Construction Specs.	0.75	0.75

Respondent's Comments:

Phase 8 – Work Packages

Activity	Time Factor	Cost Factor
MM.S.3 - Receive Vendor/Subcontractor Bid	0.8	0.8
MM.S.4 - Evaluate Vendor/Subcontractor Bid	0.8	0.8

Respondent's Comments: Reduced work to develop packages. Reduce time for these items by 0.2 and cost by 0.1.

Phase 9 – Preliminary Construction

Activity	Time Factor	Cost Factor
MM.FEM.1 - Coordinate Materials Management	0.85	0.85
C.EX.1 - Develop Work Plan	0.85	0.85
C.EX.4 - Establish Design Support	0.9	0.9

Respondent's Comments:

Phase 10 – Field Construction

Activity	Time Factor	Cost Factor
C.EX.2 – Execute Labor Management & Construction	0.8	0.9
C.EX.3 – Monitor Schedule Status/Maintain Schedule	0.8	0.9
MM.FD.1 – Receive and Inspect Materials	0.8	0.9
MM.FEM.2 – Coordinate Materials Management	0.8	0.9
C.EX.7 – Execute Materials Mgmt. & Monitor Status	0.8	0.9
C.EX.13 – Execute Subcontractor Mgmt. & Admin.	0.8	0.9
C.EX.11 – Execute Human Resources Management	0.8	0.9
MM.FD.2 – Inventory, Store, & Maintain Materials	0.8	0.9
MM.FD.3 – Issue Material	0.8	0.9
MM.FD.4 – Vendor Inspection	0.8	0.9
C.EX.10 – Monitor Cost/Budget Status	0.8	0.9
C.EX.5 – Issue Progress Reports	0.8	0.9
C.EX.12 – Inspect & Test Equipment	0.8	0.9
SU.SP.1 – Prepare Start-Up Procedures	0.8	0.9

Respondent’s Comments:

Phase 11 – Start-Up

Respondent’s Comments: No change to this phase.

Phase 12 – Documentation

Respondent's Comments: No change to this phase.

PEpC8

Phase 1 - Preliminary Feasibility

Respondent's Comments: No change to this phase.

Phase 2 - Team Selection

Activity	Time Factor	Cost Factor
PPP.CS.1 - Develop Contract Strategy	1.25	1.0
PPP.CS.2 - Develop Bid Package Scope	0.75	1.0

Activity	Add Time	Add Cost
New Activity – Select Supplier(s) for Team	Like PPP.CS.4	0
New Activity – Develop Supply Strategy	Like PPP.CS.5	0

Respondent's Comments: PPP.CS.1 requires ¼ additional time to also cover supply. PPP.CS.2 requires ¼ less time because there is need for scope definition, but there is no need for a bid package. Two new activities needed to select supplier(s) for team and develop supply strategy. These activities have time distributions like PPP.CS.4 and PPP.CS.5, respectively.

Phase 3 - Preliminary Design, Estimate, & Scope

Activity	Time Factor	Cost Factor
D.FS.3 - Define Major Equip. & Material Specs.	0.75	1.0

Respondent's Comments: D.FS.3 will require additional time to achieve higher level of detail that supplier involvement will create, however, a reduction in time is possible because work is not duplicated. Net effect is a ¼ reduction in time.

Phase 4 – Estimate, Schedule, and Review

Activity	Time Factor	Cost Factor
D.DCE.1 – Estimate Equipment Cost	0.5	0.5
D.DCE.2 – Estimate Installation Cost	0.5	0.5
D.DCE.3 – Estimate Support Services Cost	0.5	0.5
D.DCE.4 – Estimate Indirects Cost	0.5	0.5
D.DCE.5 – Estimate Materials Cost	0.5	0.5
D.DCE.6 – Estimate Other Costs	0.5	0.5
D.FS.7 – Conduct Site Evaluation	0.5	0.5
D.DD.9 – Conduct Scope/Estimate Review	0.5	0.5
D.DS.1 – Detail Design Schedule	0.5	0.5
D.DS.2 – Detail Materials Management Schedule	0.5	0.5
D.DS.3 – Detail Construction Schedule	0.5	0.5
D.PWP.1 – Draft Project Plan	0.5	0.5
D.DS.4 – Detail Start-Up Schedule	0.5	0.5

Respondent's Comments: This step should be greatly simplified by working with all 3 players. Cut this whole step down by ½.

Phase 5 – Procure Standard and Specialized Equipment

Activity	Time Factor	Cost Factor
MM.SPE.1 – Specify Specialized Equipment	0.75	1.0
MM.STE.1 – Specify Standard Equipment	0.75	1.0
MM.SPE.2 – Issue Inquiry for Specialized Equipment	0	0
MM.STE.2 – Issue Inquiry for Standard Equipment	0	0

Respondent's Comments: Supplier is now taking on large role in specification and design. Cut time for MM.SPE.1 and MM.STE.1 by ¼. Delete MM.SPE.2 and MM.STE.2. These activities are not needed because suppliers are already involved.

Phase 6 –Procure Fabricated and Bulk Materials

Activity	Time Factor	Cost Factor
D.PWP.2 – Prepare Material Requisitions	0.5	1.0
MM.FI.1 – Finalize Fabricated Item Material Specs.	0.5	1.0
MM.FI.2 – Issue Inquiry for Fabricated Items	0.5	1.0
MM.BC.2 – Issue Inquiry for Bulk Commodities	0.5	1.0
MM.BC.5 – Award Bulk Commodities Contract	0	0
MM.FI.5 – Award Fabricated Items Contract	0	0

Respondent's Comments: Development of inquiries and materials specs is done in concert with supplier and contractor. Reduce time by ½ on D.PWP.2, MM.FI.1, MM.FI.2, and MM.BC.2. Eliminate MM.BC.5 and MM.FI.5.

Phase 7 – Detail Design

Activity	Time Factor	Cost Factor
D.DD.2 – Finalize Drawings & Construction Specs.	0.25	0.25

Respondent's Comments: Simplify D.DD.2. Cut this down by ¾.

Phase 8 – Work Packages

Respondent's Comments: No change to this phase.

Phase 9 – Preliminary Construction

Activity	Time Factor	Cost Factor
C.PW.8 – Develop Materials Management Plan	0.75	0.75
C.PW.10 – Develop Execution Strategy	0	0

Respondent's Comments: Materials management plan and execution strategy done in concert with all three players. Simplify and speed the process for C.PW.8. Reduce time and cost by ¼. Cut out C.PW.10.

Phase 10 – Field Construction

Activity	Time Factor	Cost Factor
C.EX.2 – Execute Labor Management & Construction	0.95	0.95
C.EX.3 – Monitor Schedule Status/Maintain Schedule	0.95	0.95
MM.FD.1 – Receive and Inspect Materials	0.95	0.95
MM.FEM.2 – Coordinate Materials Management	0.95	0.95
C.EX.7 – Execute Materials Mgmt. & Monitor Status	0.95	0.95
C.EX.13 – Execute Subcontractor Mgmt. & Admin.	0.95	0.95
C.EX.11 – Execute Human Resources Management	0.95	0.95
MM.FD.2 – Inventory, Store, & Maintain Materials	0.95	0.95
MM.FD.3 – Issue Material	0.95	0.95
MM.FD.4 – Vendor Inspection	0.95	0.95
C.EX.10 – Monitor Cost/Budget Status	0.95	0.95
C.EX.5 – Issue Progress Reports	0.95	0.95
C.EX.12 – Inspect & Test Equipment	0.95	0.95
SU.SP.1 – Prepare Start-Up Procedures	0.95	0.95

Respondent’s Comments: Take advantage of constructability issues brought in by PEpC. Cut this phase by 5%.

Phase 11 – Start-Up

Activity	Time Factor	Cost Factor
SU.CO.2 – Commission Process Units	0.75	1.0
SU.CO.6 – Complete Punchlist for Commission	0.75	1.0

Respondent’s Comments: Start-up plans involve supplier expertise. Punchout and commissioning of systems should be shortened. Reduce the time for SU.CO.2 and SU.CO.6 by 25%.

Phase 12 – Documentation

Respondent's Comments: No changes to this phase.

PEpC9
Phase 1 - Preliminary Feasibility

Activity	Add Time	Add Cost
New Activity – Develop Total Sourcing Strategy	0.19	0
New Activity – Select Contractor and Suppliers Critical to Project	0.2	0

Respondent's Comments: Add two new activities to cover sourcing strategy and selection of contractor and suppliers critical to project. These activities have durations of 0.19 and 0.2 respectively. Develop sourcing strategy is performed simultaneously with PPP.BP.9.

Phase 2 - Team Selection

Activity	Time Factor	Cost Factor
PPP.CS.1 - Develop Contract Strategy	0	0
PPP.CS.2 - Develop Bid Package Scope	0	0
PPP.CS.3 – Review Potential EPC Contractor Bidders	0	0
PPP.CS.4 – Select EPC Contractor Team	0	0

Respondent's Comments: PEpC reduces and eliminates bidding process by selecting earlier in the process. PEpC allows involvement of suppliers in process and project definition phase and permits earlier definition of major equipment and material specifications.

Phase 3 - Preliminary Design, Estimate, & Scope

Activity	Time Factor	Cost Factor
PPP.TP.1 – Conduct Technical Surveys & Process Analysis	0.9	1.0
PPP.PP.1 - Develop Preliminary Design Criteria	0.9	1.0
PPP.SD.5 - Detail Work Breakdown Structure	0.9	1.0
PPP.PP.3 - Complete Preliminary Estimates	0.85	1.0
D.FS.2 – Finalize Facility Plans	0.85	1.0
D.FS.3 - Define Major Equip. & Material Specs.	0.85	1.0

Respondent's Comments: Reduce activities as indicated due to earlier supplier involvement.

Phase 4 – Estimate, Schedule, and Review

Activity	Time Factor	Cost Factor
D.DCE.2 – Estimate Installation Cost	0.9	0.9
D.DCE.3 – Estimate Support Services Cost	0.9	0.9
D.DCE.5 – Estimate Materials Cost	0.8	0.8
D.DCE.1 – Estimate Equipment Cost	0.85	0.85

Respondent's Comments: Early supplier involvement will reduce the time and cost associated with these activities as indicated.

Phase 5 – Procure Standard and Specialized Equipment

Activity	Time Factor	Cost Factor
MM.SPE.1 – Specify Specialized Equipment	0.85	1.0
MM.SPE.2 – Issue Inquiry for Specialized Equipment	0.5	1.0
MM.SPE.3 – Receive Vendor Bid for Spec. Equip.	0.5	1.0
MM.SPE.4 – Evaluate Vendor Bid for Spec. Equip.	0.5	1.0
MM.SPE.5 – Award Contract for Specialized Equip.	0.5	1.0
MM.SPE.6 – Coordinate Vendor Design	0.75	1.0
MM.STE.1 – Specify Standard Equipment	0.75	1.0
MM.STE.2 – Issue Inquiry for Standard Equipment	0.75	1.0
MM.STE.3 – Receive Vendor Bid for Standard Equip.	0.75	1.0
MM.STE.4 – Evaluate Vendor Bid for Standard Equip.	0.75	1.0
MM.STE.5 – Award Contract for Standard Equipment	0.75	1.0

Respondent's Comments: Early and increased supplier involvement allows the time required for these equipment procurement activities to be reduced as indicated.

Phase 6 –Procure Fabricated and Bulk Materials

Respondent's Comments: No change to this phase.

Phase 7 – Detail Design

Activity	Time Factor	Cost Factor
D.DD.1 – Detail Engineering Discipline Drawings	0.8	1.0
D.DD.7 – Complete Constructability Review	0.8	1.0
D.DD.4 – Design/Engineering Review	0.9	1.0
D.DD.6 – Review Changes and Approve	0.8	1.0
D.DD.2 – Finalize Drawings & Construction Specs.	0.9	1.0
D.DD.10 – Coordinate Vendor/Engineering Interface	0.9	1.0

Respondent's Comments: Supplier is involved and can assist with design and review. Reduce activities as indicated.

Phase 8 – Work Packages

Respondent's Comments: No change to this phase.

Phase 9 – Preliminary Construction

Activity	Time Factor	Cost Factor
C.PW.8 – Develop Materials Management Plan	0.9	1.0
C.EX.14 – Document QA/QC	0.85	1.0

Respondent's Comments: Working with all three players simplifies these activities.

Phase 10 – Field Construction

Activity	Time Factor	Cost Factor
C.EX.2 – Execute Labor Management & Construction	0.9	0.9
C.EX.3 – Monitor Schedule Status/Maintain Schedule	0.9	0.95
MM.FD.4 – Vendor Inspection	0.5	1.0
C.EX.12 – Inspect & Test Equipment	0.5	1.0
SU.SP.1 – Prepare Start-Up Procedures	0.5	1.0

Respondent's Comments: Involving major equipment suppliers in installation and start-up should significantly reduce time required for MM.FD.4, C.EX.12, and SU.SP.1. Savings could be as much as 50%. Actual construction time and cost may also be slightly reduced.

Phase 11 – Start-Up

Activity	Time Factor	Cost Factor
SU.SP.3 – Train Personnel	0.5	1.0
SU.SP.6 – Obtain Spare Parts	0.5	1.0
SU.SP.7 – Review Operations & Maint. Manuals	0.5	1.0
SU.CO.1 – Commission Major Systems	0.5	1.0
SU.PCO.1 – Identify Warranty Items	0.5	1.0
SU.CO.6 – Complete Punchlist for Commission	0.5	1.0
SU.PCO.2 – Complete Final Punchlist	0.5	1.0

Respondent's Comments: Items indicated should be reduced considerably if major suppliers are used during installation and start-up. The amount of reduction will be a function of what percentage of the project is represented by major equipment. When major equipment is a large part of the project, savings could be substantial.

Phase 12 – Documentation

Respondent's Comments: No change to this phase.

APPENDIX E

CHANGES TO THE BASELINE MODEL FOR THE DUPONT FLOW MODEL

This appendix contains the details of the changes made to the baseline model to reflect the way in which DuPont procures compressed air equipment and systems.

Addition and Elimination of Activities

Added Activity:

Activity Code	Activity Name	Time	Cost
PPP.CS.6	Select Major Suppliers	75% of PPP.CS.4	75% of PPP.CS.4

Eliminated Activities:

Activity Code	Activity Name	Reason
MM.SPE.6	Coordinate Vendor Design	Early supplier involvement & cooperative relationship eliminate need
D.DCE.1	Estimate Installation Cost	Incorporated into supplier's scope of supply
D.DD.10	Coordinate Vendor/Engineering Interface	Early supplier involvement & cooperative relationship eliminate need

Changes in Logic for Existing Activities

Activity Code	Activity Name	New Predecessors	Reason
PPP.SD.5	Detail Work Breakdown Structure	PPP.TP.2	Project is broken into systems early
PPP.PP.1	Develop Preliminary Design Criteria	PPP.SD.4	Supplier involvement allows earlier completion
D.FS.3	Define Major Equip. & Material Specifications	PPP.PP.1	Supplier involvement allows earlier completion
D.FS.6	Acquire Permits & Approval	PPP.PP.1	Supplier involvement allows earlier completion
MM.STE.6	Release Data Sheet	MM.STE.1	Suppliers need data sheets to provide scope of supply
MM.STE & MM.SPE	Standard & Special Equip. Activities	PPP.M3	Supplier involvement allows earlier completion
SU.SP.1	Prepare Start-Up Procedures	C.EX.14	Construction need not begin to start

Changes in Time and Cost for Existing Activities

Activity Code	Reason	Time Factor	Cost Factor
MM.SPE.2 & MM.STE.2	No bid process	.25	.25
MM.SPE.3 & MM.STE.3	No bid process	.50	.50
MM.SPE.4 & MM.STE.4	No bid process	.25	.25
D.DCE.4	Included in scope of supply	.75	.75
D.DCE.6	Included in scope of supply	.70	.70
D.DD.9	Cooperation reduces review	.70	.70
MM.SPE.7 & MM.STE.7	Cooperation reduces hand-offs	.50	.50
MM.BC.2 & MM.FI.2	No bid process	.25	.25
MM.BC.3 & MM.FI.3	No bid process	.50	.50
MM.BC.4 & MM.FI.4	No bid process	.25	.25
D.DD.6	Cooperation reduces changes & review	.50	.50
C.EX.8	Cooperation reduces changes & review	.50	.50

APPENDIX F

CASE STUDY 1 CHANGES TO THE BASELINE MODEL

This appendix contains the details of the changes made to the baseline model to reflect the actual conditions in Case Study 1.

Addition of Activities

Added Activities:

Activity Code	Activity Name	Time	Cost
PPP.CS.6	Involve EPC Contractor	Like PPP.BP.9	Like PPP.BP.9
PPP.CS.7	Select Machine Supplier	50% of PPP.CS.4	None
PPP.CS.8	Select Control Valve Supplier	Like D.FS.3	Like D.FS.3
PPP.CS.9	Select SS Piping Supplier	Like D.FS.3	Like D.FS.3
PPP.CS.10	Select Bulk Electrics Supplier	Like D.FS.3	Like D.FS.3
PPP.CS.11	Select Bulk Valves Supplier	Like D.FS.3	Like D.FS.3

Changes in Time and Cost for Existing Activities

Changes:

Activity Code	Reason	Time Factor	Cost Factor
MM.SPE.1	Due to SS piping	0.75	0.80
MM.SPE.2	Due to SS piping	0.75	0.80
MM.SPE.3	Due to SS piping	0.75	0.80
MM.SPE.4	Due to SS piping	0.75	0.80
MM.SPE.5	Due to SS piping	0.75	0.80
MM.SPE.6	Due to SS piping	0.75	0.80
MM.STE.1	Due to control valves	0.90	0.90
MM.STE.2	Due to control valves	0.90	0.90
MM.STE.3	Due to control valves	0.90	0.90
MM.STE.4	Due to control valves	0.90	0.90
MM.STE.5	Due to control valves	0.90	0.90
MM.BC.1	Due to valves & electric	0.90	0.90
MM.BC.2	Due to valves & electric	0.90	0.90
MM.BC.3	Due to valves & electric	0.90	0.90
MM.BC.4	Due to valves & electric	0.90	0.90
PPP.PP.1	Machine supplier able to perform this on single technology	0.75	0.50
PPP.PP.3	Machine supplier contributed to reduced estimating time and scope	0.75	0.50
D.DD.1	Use generic supplier drawings on machine and control valves to compress this	0.75	0.75
D.DD.4	Generic drawings shortened this	0.85	0.85
D.DD.5	Generic drawings shortened this	0.85	0.85
D.DD.6	Simplified	0.85	0.85
MM.S3	Bulk electrical & bulk valves assisted with quantity take-off and shortened this	0.80	0.80
MM.S.4	Bulk supply decision shortened this	0.80	0.80
MM.FEM.1	Bulk supplies, particularly electrical, shortened this	0.85	0.85

APPENDIX G

CASE STUDY 2 CHANGES TO THE BASELINE MODEL

This appendix contains the details of the changes made to the baseline model to reflect the actual conditions in Case Study 2.

Addition and Elimination of Activities

Added Activities:

Activity Code	Activity Name	Time	Cost
PPP.CS.6	Select Core Equipment Supplier	50% of PPP.CS.4	50% of PPP.CS.4
MM.SPE.10	Issue P.O. for Core Equipment	80% of MM.SPE.2	80% of MM.SPE.2

Eliminated Activities:

Activity Code	Activity Name	Reason
PPP.TP.3	Obtain Patents & Licenses	Not applicable

Changes in Time and Cost for Existing Activities

Activity Code	Reason	Time Factor	Cost Factor
MM.STE.1	Reduced # of suppliers	.50	.50
MM.STE.2	Reduced # of suppliers	.50	.50
MM.STE.3	Reduced # of suppliers	.50	.50
MM.STE.4	Reduced # of suppliers	.50	.50
MM.STE.5	Reduced # of suppliers	.50	.50

Changes in Logic for Existing Activities

Activity Code	Activity Name	New Predecessor	Reason
D.FS.7	Conduct Site Evaluation	PPP.CS.5, PPP.CS.1	Early supplier involvement
PPP.TP.4	Establish Security & Secrecy Agreement	D.FS.7, PP.PPP.7, PPP.CS.3, PPP.CS.2	Must occur in parallel with selection of EPC contractor
D.FS.3	Define Major Equipment and Materials Specs.	PPP.TP.1	Early supplier involvement permits
MM.STE.1-5 MM.STE.1-6	Standard & Specialized Equip. Activities	D.FS.3	Can begin upon completion of specifications
D.M3	Detail Integrated Project Schedule Complete	D.M2	Early supplier involvement
D.DS.4	Detail Start-Up Schedule	D.M1	Can begin upon completion of scope definition
SU.SP.1	Prepare Start-Up Procedures	D.DS.4	Early supplier involvement
D.DS.1, D.DS.2, D.DS.3, D.PWP.1	Scheduling Activities	D.M1	Early supplier involvement

APPENDIX H

CASE STUDY 3 CHANGES TO THE BASELINE MODEL

This appendix contains the details of the changes made to the baseline model to reflect the actual conditions in Case Study 3.

Addition of Activities

Added Activities:

Activity Code	Activity Description	Time	Cost
PPP.CS.6	Select EPC Contractor	Like PPP.CS.4	Like PPP.CS.4
PPP.CS.7	Select MPE Supplier	Like PPP.CS.4	Like PPP.CS.4

Changes in Time and Cost for Existing Activities

Changes:

Activity Code	Reason	Time Factor	Cost Factor
PPP.CS.1	Selections done prior to funding	.1	.1
PPP.CS.2	Selections done prior to funding	.1	0
PPP.CS.3	Selections done prior to funding	.1	0
PPP.CS.4	Selections done prior to funding	.1	0
PPP.PP.7	Selections done prior to funding	.5	.5
PPP.TP.3	Not required due to pre-selection	0	0
PPP.TP.4	Not required due to pre-selection	0	0
D.FS.3	Not required	0	0
MM.SPE.1	Major item completed	.5	.5
MM.SPE.2	Major item completed	.5	.5
MM.SPE.3	Major item completed	.5	.5
MM.SPE.4	Major item completed	.5	.5
MM.SPE.5	Major item completed	.5	.5
MM.SPE.6	Major item completed	.5	.5
D.DD.1	Drawings expedited by MPE supplier	.5	.75
D.DD.4	Drawings expedited by MPE supplier	.75	.75
D.DD.6	Drawings expedited by MPE supplier	.75	.75
D.DD.2	Drawings expedited by MPE supplier	.75	.75

APPENDIX I

CASE STUDY 4 CHANGES TO THE BASELINE MODEL

This appendix contains the details of the changes made to the baseline model to reflect the actual conditions in Case Study 4.

Addition and Elimination of Activities

Added Activities:

Activity Code	Activity Name	Time	Cost
PPP.CS.6	Appoint bottle line contractor	Like PPP.CS.4	0
PPP.CS.7	Appoint steel fabricator	Like PPP.CS.4	0

Eliminated Activities:

Activity Code	Activity Name
PPP.CS.5	Develop Labor Strategy
PPP.CS.3	Review Potential EPC Contractor Bidders
PPP.CS.4	Select EPC Contractor Team
PPP.TP.3	Obtain Patent and Licenses

Changes in Logic for Existing Activities

Activity Code	Activity Name	New Predecessor
MM.SPE.1	Specify Specialized Equipment	PPP.M4
MM.BC.1	Specify Materials	PPP.M4
D.PWP.2	Prepare Material Requisitions	PPP.M4

Changes in Time and Cost for Existing Activities

Changes:

Activity Code	Time Factor	Cost Factor
PPP.TP.1	0.50	0.25
PPP.PP.3	0.75	0.75
MM.SPE.1	0.50	0.50
MM.SPE.2	0.50	0.50
MM.SPE.3	0.50	0.50
MM.SPE.4	0.50	0.50
MM.SPE.5	0.50	0.50
MM.SPE.6	0.50	0.50
MM.BC.1	0.75	0.75
MM.BC.2	0.75	0.75
MM.BC.3	0.75	0.75
MM.BC.4	0.75	0.75
MM.FI.1	0.75	0.75
MM.FI.2	0.75	0.75
MM.FI.3	0.75	0.75
MM.FI.4	0.75	0.75
D.DD.3	0.75	0.75
D.PWP.2	0.75	0.75
D.DD.1	0.75	0.75
D.DD.10	0.75	0.75
D.DD.4	0.75	0.75
D.DD.5	0.75	0.75
D.DD.6	0.75	0.75
SU.SP.2	0.50	0.50
SU.SP.3	0.50	0.50
SU.SP.6	0.50	0.50
SU.SP.7	0.50	0.50
SU.CO.1	0.50	0.50
SU.CO.4	0.50	0.50
C.DM.1	0.50	0.50
SU.PCO.3	0.50	0.50

APPENDIX J

RT 111 PROJECT COMPETENCIES AND DEFINITIONS

Pages 215 through 217 contain the core competencies and definitions established by CII RT 111 (CII 1996b).

Alliance/Partnering: Utilizing long-term relationships with two or more organizations for the purpose of achieving business objectives.

Benchmarking/Metrics: Benchmarking is the process of assessing and establishing standards to achieve excellence in performance; metrics is the process of measuring progress of project performance against established standards.

Business Development: Conversion of owner business needs into project goals.

Commissioning/Start-Up/Performance Testing: Front-line development, management, and coordination of operations and/or contract personnel to proceed toward and proved commercial operation.

Conceptual Cost Estimating: Preparation of estimate at various stages of scope development for purposes of project option selection.

Constructability: Incorporating construction knowledge and experience into project development and execution.

Construction Management: Management oversight of field construction operations and start-up.

Convert Research to Project/Scale Up: Defining project requirements based on new or improved products or processes.

Definitive Cost Estimating: Preparation of estimates for purposes of procurement and project control.

Detail Design: Completion of design drawings and material and equipment specifications.

Environmental/Permits: Ensuring compliance with environmental laws and regulations, filing permit applications, and site assessments.

Field Quality Control: Conduction inspections required to achieve the specified level of quality.

Financial Approval: Development op appropriation requests, risk analysis for corporate strategy, and project funding approval and decision-making at owner level.

Legal/Contract Administration: Contract negotiation and interpretation to include change order management and dispute resolution.

Lessons Learned: Knowledge gained through the collection and analysis of experiences, successful or otherwise, to be applied to future projects for purpose of improving performance.

Maintenance & Operability: Incorporating input from maintenance and operations personnel during project development and detail design phases.

Preliminary Design/Scope Development: Conceptual preparation of overall project design and scope.

Process/Conceptual Design: Process definition and feasibility analysis congruent with overall project objectives, including owner proprietary process know-how.

Procurement: Corporate procurement buying strategy, contractual arrangements, and vendor inspections.

Project Controls: Identification and reporting of actual and potential cost and schedule deviation.

Project Management: Management and coordination of project development and execution.

Project Management Oversight: Leadership of owner effort of project development and execution including decision-making authority.

Project Planning/Scheduling: Determination of project development and execution strategies such as contracting plan and materials management plan.

Risk Management: Assessment, analysis, planning and control of risks on a project.

Safety: Ensuring or supporting compliance with operating facility and OSHA regulations and requirements including construction safety.

Setting Project Goals, Objectives, & Priorities: Establishing key project requirements and prioritizing these requirements to meet the business development needs for the project.

Team Building: A project-focused process that builds and develops shared goals, interdependence, trust, and commitment and accountability among project team members.

Technical Expertise: Specific equipment, systems, or technological specialization.

Total Quality Management: A continuous work process improvement methodology provided during project development and execution.

Vita

Stephanie Magrogan received a Bachelor of Science in Civil Engineering from Virginia Tech in May 1995. Upon graduation, she continued studies at Virginia Tech leading to the degrees of Master of Business Administration in December 1997 and Master of Science in Civil Engineering in January 1998. Her goals are to pursue a career as a technical analyst and eventually work as a technical consultant.