



Construction Industry Institute®

Identifying Drivers, Leading Indicators, and Impacts of Premature Starts to Construction: A Quantitative and Qualitative Approach

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IDENTIFYING DRIVERS, LEADING INDICATORS, AND
IMPACTS OF PREMATURE STARTS TO CONSTRUCTION:
A QUANTITATIVE AND QUALITATIVE APPROACH

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

Under the Guidance of
CII Research Team 323
Finding Leading Indicators to Prevent Premature Starts,
and Assuring Uninterrupted Construction

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Executive Summary

Nearly every project in the Architecture, Engineering, and Construction (AEC) industry has at least one stakeholder who perceives a benefit from an early start to construction. As a result, project teams face pressure to begin construction, whether or not they are in fact ready. In order to begin early mobilization, engineering design drawings are then rushed and assumptions left unmitigated, resulting in inaccurate plans and, often, unrealistic schedules. The construction phase of the project is then impeded by costly interruptions and holds. When these interruptions occur, project teams often react by spending more money and crashing schedules even further in order to make up for the interruptions, causing additional strain on all project stakeholders. Hence, there is a need in the industry to understand what drives a premature start, their potential impacts, and to determine what the leading indicators that signal a premature start are. The purpose of this report is to describe the process used to identify and document leading indicators, drivers, and impacts of premature starts to construction and to present a tool developed based on the findings of this research that can be used in industry that can alert project teams of potential interruptions.

To prevent these impacts and interruptions, the Construction Industry Institute (CII) commissioned Research Team (RT) 323 to gain a better understanding of what constitutes a premature start to construction and what factors drive a premature start. The main objective of RT 323 was to first define what is a premature start, determine what drives a premature start, understand what impacts occur as a result, and lastly, to investigate if there are any leading indicators, or red flags, that could serve as early warning signs that the construction phase of a project is mobilizing prematurely.

In order to develop a basis of analysis, RT 323 defined a premature start as ***a decision, by at least one party, to start construction with at least one risk that exceeds an acceptable tolerance to a party and which can result in an interruption to construction.*** Two research thrusts were carried out in order to develop both a qualitative and quantitative understanding of premature starts to construction. The first research thrust focused on identifying drivers, leading indicators, and impacts associated with premature starts through case studies and review of literature. The second research thrust focused on quantifying discoveries made in research thrust one by conducting a survey with respondents who represent the construction industry. RT 323 developed a Microsoft

Excel-based tool called the Premature Start Impact Analysis (PSIA) that incorporates the research findings into an interactive tool that can be used in the industry by various members of a project team through all phases of construction. The primary purpose of the PSIA is to identify potential impacts based on leading indicators and drivers reported by the user. The tool then guides the user towards reference material and data compiled by RT 323, such as case studies and survey results. The development process of the PSIA and deployment recommendations are described in detail in Implementation Resource 323-2.

This research adds value by: (1) identifying leading indicators to signal a premature start, and (2) documenting drivers and impacts of premature starts to construction. RT 323 envisions that such findings will be incorporated into project risk assessment and overall planning, and will facilitate communication between stakeholders. The results of this research will guide CII member companies and others involved in construction projects to an improved understanding of the impacts, key causes, and early indicators that together can be used to improve project delivery, productivity, and predictability, as well as enhanced safety, quality, and organizational and individual achievement. The overall goal of RT 323 is that this research contributes to the improvement of project delivery and stakeholder success for the benefit of the construction industry.

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1. Introduction

The Construction Industry Institute (CII) Research Team (RT) 323 was chartered to investigate premature starts to construction and to document drivers, leading indicators, and impacts that can occur as a result. Early efforts of RT 323 involved defining what constitutes a premature start to construction. In order to develop a basis of analysis, RT 323 defined a premature start as ***a decision, by at least one party, to start construction with at least one risk that exceeds an acceptable tolerance to a party and which can result in an interruption to construction.***

With this definition, RT 323 hypothesized that various impacts occur as a direct result of a premature start. Furthermore, RT 323 postulated that there existed drivers that influence a premature start and leading indicators that could signal a premature start. This motivated the team to determine to what extent is the commonality of these drivers and leading indicators, and how severe are the impacts. RT 323 proposed that having this information prior to mobilization could warn a project team that the construction phase is beginning too soon and construction interruptions and negative outcomes are likely to occur.

Even though there are numerous planning tools and templates, projects still experience costly stops or holds. Moreover, since at least one stakeholder on virtually every project benefits from a premature start to construction, project teams nearly always feel pressure to begin construction—whether or not they are in fact ready. When a project starts construction prematurely, the result is frequently that it experiences an interruption to construction at least once. Complicating matters, when projects experience these stops and starts, project teams often seem to react rather than take a proactive management approach.

Research in this area is dated and generally more focused on project readiness, effects of field rework, project change management, cost/schedule controls than on actual investigation of premature starts. The focus throughout past research has been to improve pre-project planning techniques and enhance coordination between stakeholders in order to prevent these various impacts (Laufer 1991; Gibson and Dumont 1995; Walewski, Gibson and Dudley 2003). However, very little research exists that investigates drivers and impacts of premature starts to construction and what are early warning signs. New research is needed to better document premature starts and their impacts. This information could then be used to alert project stakeholders at all levels of an

organization. It was with this need in mind that the Construction Industry Institute (CII) commissioned Research Team (RT) 323. First, a review of past literature was carried out to understand what has been discussed regarding construction interruptions and what the outcomes are followed by two research thrusts explained in section 1.2 of this chapter.

1.1 Purpose and Objective

The purpose of the research was to identify and document drivers and impacts of premature starts to construction to establish whether there are leading indicators to signal a premature start to avoid unintended construction interruptions. The objectives of this research involve the following: (1) identify leading indicators that signal a potential premature start, and (2) document drivers and impacts of premature starts to construction. Contents of deliverables will cover the following areas:

1. Identify leading indicators associated with premature starts.
2. Describe the drivers and impacts of premature starts.

After performing these stages of research, RT 323 developed a Microsoft Excel-based tool called the Premature Start Impact Analysis (PSIA) that incorporates the research findings into an interactive tool that can be used in the industry by various team members throughout the project lifecycle. The primary purpose of the PSIA is to identify potential impacts based on leading indicators and drivers related to premature starts. The tool then guides the user towards reference material and data validation compiled by RT 323, such as case studies and additional survey data. This information is presented in the PSIA in conjunction with the anticipated impacts in order to alert the user of the quantified impact data discovered by RT 323. The development process of the PSIA and deployment recommendations are described in detail in Implementation Resource 323-2. The outcome of this research will guide CII members and others involved on construction projects to an improved understanding of the drivers, impacts, and leading indicators of premature starts that can be used to improve project delivery.

1.2 Research Scope

The primary scope of this research involved reviewing past literature as well as conducting survey and case study based research. Review of literature served as a basis for how the research questions were developed and initial drivers, leading indicators and impacts were identified. Because RT 323 was composed of members involved with a wide range of project definitions, the

primary research focus was on project types within the expertise of the research team. Industry sector expertise ranges from heavy industrial to governmental agencies and is made up of both owners and contractors. Given that industrial construction projects are usually complex and involve several stakeholders, project management teams deal with a high degree of uncertainty and risk. Therefore, RT 323 focused primarily on industrial construction projects. The scope was limited to the impacts incurred during the construction phase of a project due to a premature start, drivers and leading indicators prior to the premature start.

Two research thrusts were carried out in order to develop both a qualitative and quantitative understanding of premature starts to construction. The first research thrust focused on defining and documenting drivers and leading indicators associated with premature starts. This thrust aimed at identifying any leading indicators that could signal a premature start to help prevent construction interruptions. Impact data collected from case studies was compared to the baseline scope, schedule, and cost of that particular project. Research scope of the case studies looked at impacts incurred during the construction phase of a project due to a premature start. The second research thrust focused on quantifying discoveries made in research thrust one by conducting a survey. The team chose to analyze drivers, impacts, and leading indicators in terms of commonality, or the frequency of an occurrence on a construction project. Construction impacts related to premature starts were observed in terms of commonality and severity. Survey results were then partitioned by owner and contractor to determine whether or not premature start perceptions differed from one project entity to another.

The main focus area of the research approach is limited to drivers, impacts, and leading indicators. The primary goal of documenting drivers and impacts was to quantitatively and qualitatively describe the types and impacts of premature starts illustrated via in-depth case studies. Identification of leading indicators was also limited to case studies and literature review but was extended through internal team validation. The leading indicators were identified through case studies and literature, as described in the Research Methodology section. Special efforts were taken to ensure that the case studies were readable and accessible to a broad industry audience.

1.3 Research Structure

This report is divided into nine chapters that cover every aspect of the research done by RT 323. Chapter 2 describes the research methodology and explains the research structuring process and data collection approach. Chapter 3 will review past academic journals and scholarly articles that served as points of departure for crafting the research questions and for identifying gaps in knowledge. Chapter 4 contains in-depth case studies conducted by RT 323. Each case contains a description of the project and how the project outcome fits the definition of a premature start to construction and its pertinence to RT 323. After reviewing each case study, the research team began defining and categorizing key terminology. These terms and definitions are found in Chapter 5. Chapter 6 includes the research findings discovered by RT 323. Chapter 7 introduces the Premature Start Impact Analysis (PSIA) tool, and discusses how it can be used in industry as a means of detecting a premature start to construction. This chapter will discuss the tool development process, features, example applications and deployment recommendations of the PSIA. Chapter 8 will be a collective review of the lessons learned by RT 323 throughout the research project. The ninth and final chapter concludes this research report by reviewing the initial research objective and discussing how the research approach and results fit that objective.

2. Methodology

The research implemented by RT 323 consisted of review of existing literature, in-depth case study analysis, and survey-based research. Prior to executing the data collection phase of this project, RT 323 reviewed several research papers and looked within the make-up of RT 323 to extract as much information as possible. The essential question addressed by this research was: ***“What are the leading indicators to signal a premature start to avoid unintended construction interruptions?”*** In order to answer this question, RT 323 proposed two intermediate questions that explore the underlying cause and effect of premature starts to construction. These two questions were:

1. What are the factors that drive a premature start to the construction phase?
2. What are the types and impacts of interruptions related to premature starts?

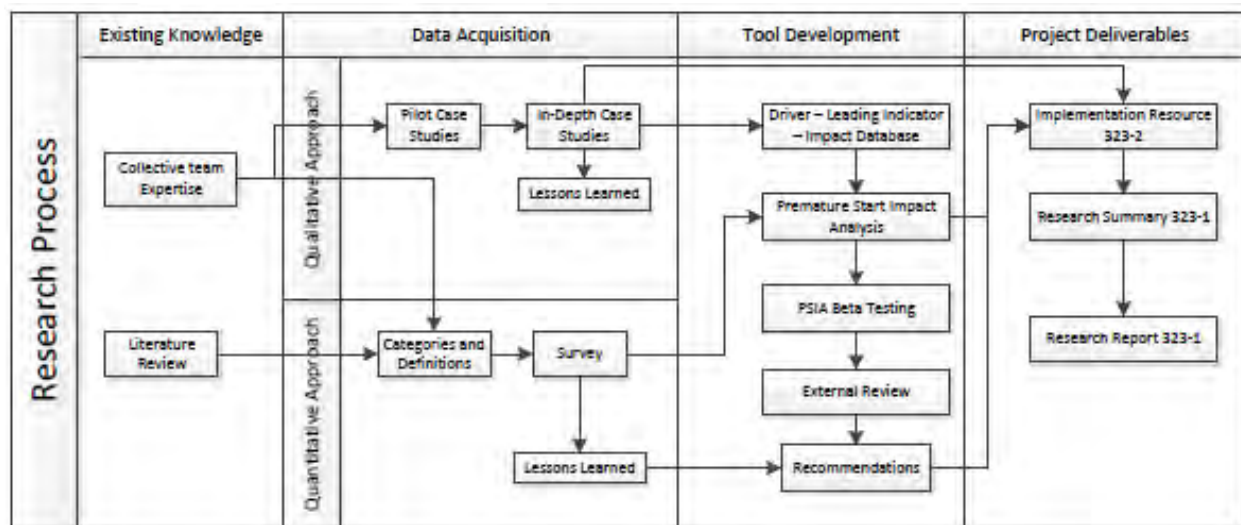


Figure 2-1: Diagram of Research Process

To answer these questions, the research approach was broken down into two separate thrusts in order to develop both a qualitative and quantitative understanding of premature starts to construction. The qualitative thrust includes pilot case studies, in-depth case studies, interviews of professionals on the project, and documentation of lessons learned. The quantitative thrust involved a survey of industry professions in various AEC disciplines.

Throughout the research phase of this project, the research team chose to leverage as much information from past research and from within the collective expertise of RT 323 participating members. Figure 2-1 outlines the research process take by RT 323.

2.1 Existing Knowledge

This section includes a detailed description of existing knowledge reviewed for this research report. Because of the diverse nature of the research team, RT 323 derived much of its knowledge base from members within the team; some of whom have over twenty years of construction industry experience. This section will provide an overview of collective team expertise and also describe the process of reviewing past studies and journal articles.

2.1.1 Collective Team Expertise

RT 323 members came from various industry sectors with project definitions ranging from the oil and gas industry to historical site renovations. The team held several brainstorming sessions prior to conducting surveys and case studies in order to develop comprehensive criteria for classifying a premature start. Many RT 323 members already had a risk register of potential leading indicators and drivers from their organizations, which helped inspire the categorical framework utilized by this research project. The team also included individuals from organizations heavily involved with software and graphical user interface development. Team members with this background helped design a straightforward working environment for the PSIA so that the user experience can be as seamless and as data rich as possible.

2.1.2 Literature Review

The literature review served as a point of departure for how the research question was developed and what the study should focus on. Due to the limited research discussion surrounding premature starts to construction, broad research topics such as front end planning, effects of rework, risk assessment, and work packaging were investigated. To serve as a means of analyzing a premature start in terms of what drives it and what are some early warning signs, RT 323 searched for past studies that focused on documenting and surveying multiple factors related to a certain outcome in order to serve as a means of measuring current project status.

2.2 Data Acquisition

The research team determined that two research thrusts would be needed in order to develop a qualitative and quantitative understanding of premature starts to construction. The first research thrust focused on identifying drivers and leading indicators associated with premature starts. This thrust aimed at identifying if there were any leading indicators that could signal a premature start to help manage/prevent these construction interruptions, through case studies, related data, and literature review. Leading indicators can help communicate to major project stakeholders the severity of the potential outcome of a premature start to a project, illustrated through documented cases. The primary research strategy of thrust one was case study research. The research team followed a two-step analysis for the case studies. First was intra-case analysis which focused on a description of a single project with a documented premature start, impacts, drivers, and potential leading indicators. Second was cross-case analysis, which consisted of a section cut of common information across all cases to identify commonalities and patterns in drivers, impacts and leading indicators. For each case, the research team identified key drivers that led to the premature start, the main interruption, and the impacts of that interruption to construction. The ultimate objective was to find leading indicators through understanding drivers – moving from post-mortem analysis to proactive/leading indicator identification.

2.2.1 Qualitative Research Approach

The first research thrust focused on identifying drivers and leading indicators associated with premature starts through case study based research. The purpose of research thrust one was to gain a qualitative understanding of premature starts to construction by implementing a research strategy known as “theory building case studies” (de Vaus 2001). This strategy involves first hypothesizing about a certain outcome and selecting cases that further develop the proposition. De Vaus explains that “(i)n the theory building model, we begin with only a question and perhaps a basic proposition, look at real cases and end up with a more specific theory or set of propositions as a result of examining actual cases.” According to de Vaus, “analysis of each case would aim to highlight differences between cases where it did and did not work” (de Vaus 2001). This type of analysis would also involve looking at commonalities of each case and formulating various propositions. It is with this that RT 323 chose to pursue a qualitative approach to researching premature starts by theory building case studies.

To accomplish this, research thrust one involved pilot case study submissions from past projects completed by member of RT 323 that faced construction interruption. After each pilot case study satisfied the definition of a premature start to construction, select pilot cases studies were expanded upon as in-depth case studies. The following sections will describe in detail the process taken to develop a well-defined and qualitative understanding of premature starts to construction.

Pilot Case Studies

Case studies were completed in a three step process. First, a pilot case study was submitted and reviewed by the research team in order to determine if the case was in fact a premature start. Members of RT 323 received a questionnaire asking about basic project information and what were some interruptions and impacts faced by the project team. Each case study underwent a vetting process to see if the pilot case study was in fact a premature start according to the definition derived by RT323. In order to qualify a project as a premature start, the project had to: (1) have faced at least one instance where the construction phase was interrupted, and (2) have a risk tolerance for a single party exceeds acceptability prior to mobilization. If the pilot case study satisfied those two items, it would move on to become an in-depth case study.

In-Depth Case Studies

If a pilot case study was deemed in fact a premature start, an interview with a project member (project manager, project engineer, or supervisor) was conducted with a member of project team to collect detailed information such as company profile, project overview, cost and schedule information. The last step was to develop a write-up describing what were the drivers of the premature start, what leading indicators or red flags were available to the project team during construction, what impacts occurred as a result, and what were the lessons learned. Information gathered from the case studies were logged into a table and reviewed by the research team to determine commonality amongst completed case studies.

2.2.2 Quantitative Research Approach

The second research thrust aimed at documenting the impacts of premature starts to construction and quantifying the commonality of these documented drivers and leading indicators, as well as commonality and severity of impacts. This thrust aimed at describing the types and

impacts of premature starts, illustrated through survey data. The research team collected data through a survey, administered to both CII member companies (through RT 323 direct contacts), as well as the Construction Users Roundtable (CURT) membership during the 2015 CURT National Conference. The objective was to support a quantitative description of the impacts of premature starts to construction.

Survey

The survey consisted of eight questions. The first two questions were intended to classify the respondents into owners and contractors with a breakdown of industry sector. The purpose of this was to see if there was any difference in perception of the data between groups. The next four questions employed a 5-point Likert scale. The research team produced four versions of the survey to minimize the effect of recency and primacy bias. Recency and primacy bias refers to a survey respondent's recollection dependence on the order of list items (Knoedler et al., 1999). The respondents' memory of earlier test items is best while recollection of middle and later list items worsens. Randomization of survey list items across multiple survey samples reduces the bias over the entirety of the survey results. The next four questions in the survey addressed drivers, leading indicators (red flags), commonality of impacts, and severity of impacts. The final two questions of the survey covered the respondent's most recent project experience in terms of cost and schedule growth, and captured approximate project value for their most recent project relevant to this topic. The research team also asked for those who would be willing to participate in a follow up interview.

3. Literature Review

3.1 Overview

Review of literature served as a point of departure for how the research questions were developed, and how drivers, leading indicators and impacts were identified. Due to the limited research surrounding premature starts to construction, broad research topics such as front end planning, effects of rework, risk assessment, and work packaging were investigated.

3.2 Studies on Project Drivers

A speedy time-to-market with minimal field rework clearly has extensive business value. Although this may be true, construction delays in the industry continue to plague the global construction market and are becoming a typical characteristic of the construction project lifecycle (Sambasivan and Soon 2007; Sweis et al. 2008). To understand these current industry challenges, one paper investigated factors that extend a project lifecycle and the frequency of each (Zidane et al. 2015). What the research uncovered was that the top five causes of delay, referred to as “time-thieves,” are “management and coordination,” “quality issues and errors,” “administration and bureaucracy,” “decision issues” and “waiting.” It was noted that some of these factors were more important to owners rather than contractors. Survey results indicated that the “(t)he two first were important to all parties, of the three others were more important for contractors and subcontractors less to the clients and sponsors.” Indication, or a red flag warning system, of the potential factors for occurrence prior to them actually becoming problematic was not extensively researched in the study.

When an organization experiences an interruption, project teams react by spending additional capital on increased labor and speedier engineering documentation delivery in order to get the project back on track. This behavior often times has an adverse effect and creates confusion, low quality drawings, and additional interruptions. One study investigating complex industrial projects claims that they are subject to unique types of risk (Li, Taylor, Ford 2011). The article claims “(o)ne such risk is the combination of rework and increased project scope that can push a project from a behavior mode of progress towards completion, past a tipping point, and into a behavior mode of falling further and further behind.” A tipping point was considered to be a threshold condition that, when crossed, internally threatens the success of a project (Sterman

2000). The goal of the study was to determine a method of monitoring those tipping points by understanding their dynamics. Understanding of tipping point characteristics would then allow project teams to handle issues with a proactive approach rather than being surprised and forced to react. The study created models and simulated various project situations. An example of what Sterman (2000) discovered was that certain well intended project control actions, such as overtime, pushed the project over the tipping point and into various problems. A sensitivity analysis was done to understand the extent of the negative project impact. Although this study covered actions taken during the construction phase of a project, the research did not evaluate actions made prior to construction mobilization.

According to a study investigating cost-influencing factors on construction projects, cost overruns are a common problem in the construction industry (Cheng 2013). The study claims that it is customary in the construction industry for contracts to bid low in order to win the job, therefore, without controlling certain cost-influencing factors of the project, construction companies will not be able to effectively control cost expenditures. The purpose of the study was to investigate what those cost-influencing are and how they could be monitored and controlled throughout the construction lifecycle of a project. The study concluded that there were sixteen factors that showed a significant degree of influence over project costs. These sixteen factors are shown in Table 3-1 along with their severity index and rank.

Table 3-1: Ranking of the key cost-influencing factors (Cheng 2013)

Factor	SI (severity index)	Rank
Clearly define the scope of project in the contract	94.78	1
Cost control	94.78	1
Contract dispute (unclear drawings or guidelines/regulations)	93.04	2
High fluctuation in commodity	89.57	3
The gap between the construction plan and the reality is too great	89.57	3
Material shortage or supply delay	89.57	3
Time management	88.7	4
Practical experience	87.83	5
Modifications to the scope of construction	86.96	6
The level of demand on quality	86.96	6
Project team (coordination capability and the understanding of operational procedure)	86.96	6
Project valuation does not match the collected payment	86.09	7
Procurement contract	85.22	8
Geology, topography	84.35	9
Climate factor	82.61	10
Natural disaster	80	11

These factors were determined through surveys using the Kawakita Jiro (KJ) method and the Modified Delphi method (MDM) with two groups and two rounds of data collection. The paper argues that “(i)f construction companies can effectively control these key factors and formulate prevention strategies, it is possible not only to avoid cost overrun(s), but also to increase the overall profits for the project.” Impacts outside of cost-overruns were not looked at in this study. Although cost overruns are a chronic problem across most projects in the construction industry (Doloi 2011), there are a multitude of impacts other than cost overruns that need to be evaluated.

Another study investigated the implementation of various innovative and non-traditional practices and determined ten drivers that play a role in determining the use of these practices within an organization (Vanegas et al. 1998). The purpose of this study was to analyze the practices of reducing engineering cost and capital cost, and still achieve business objectives. The main objectives were to evaluate different techniques, identify innovative or non-traditional practices,

and define the drivers that determine the use of these practices. The report contains 10 of the practices, and explains what are the benefits and risks for the company by adopting them.

Another research project utilizing the driver-impact research framework is CII RT 300 that addressed the impact of late deliverables to a construction project (Barry and Leite 2014; Barry and Leite 2015; Barry et al. 2015). The process of determining the impact of late deliverables began with developing a comprehensive list of indicators through expert interviews, in-depth case studies and industry surveys. These studies set the framework in which RT 323 would ultimately use to investigate drivers and leading indicators that signal a premature start. RT 300 also developed a tool called the Late Deliverables Risk Catalog (LDRC) designed to allow users to check late deliverables such as “engineering equipment” or “external permits.” The tool then takes these inputs and returns potential project impacts while also directing the user towards case studies that supports the output. The tool utilizes a tree-like structure with collapsible categories that allows a user to track specific details that pertain to the project being evaluated. The LDRC was developed mainly for use by industrial sector construction projects. The intent of the LDRC was not to mitigate problems caused by late deliverables but instead help project teams identify potential issues prior to their occurrence (Barry and Leite 2014).

3.3 Studies on Negative Project Outcomes

Early inspiration of investigating drivers, leading indicators and impacts to premature starts to construction as a means of predicting project success or failure was found in a study by CII RT 153, whose objectives were to determine major causes of rework, how to efficiently categorize and record factors, determine impacts on cost and schedule, and identify practices to minimize the occurrence of rework (Rogge et al. 2001). RT 153 created a list (shown in Table 3-2) of potential predictors of field rework using past projects as a benchmark and then conducted a survey to quantify and evaluate the relationship of each predictor. What they discovered was that certain predictors had a stronger influence to field rework than others.

Table 3-2: Field Rework Causes and Relationships (Rogge et al. 2001)

Field Rework Index (FRI) Variable	Orig. Quest No.	FRI-EZ Quest. No.	Relationship with Field Rework Rating (r- squared)	Significance Level
Owner alignment	2	1	0.19	.00
Design rework	31	15	0.16	.00
Constructability commitment	33	16	0.16	.00
Interdisciplinary design coordination	23	10	0.13	.00
Degree of project execution planning	8	4	0.12	.00
Design firm's qualifications	13	7	0.08	.00
Field verification	20	9	0.08	.00
Expected craft worker availability	38	17	0.08	.00
Expected construction overtime	39	18	0.07	.00
Engineering overtime	30	14	0.06	.00
Design leadership changes	19	8	0.05	.01
Design schedule compression	29	13	0.04	.01
Vendor prequalification	26	11	0.03	.02
Vendor information	28	12	0.03	.02

What the results from RT 153 indicate was that relationships between the various items in the left column of Table 3-2 can be linked to negative construction outcomes; in this case, field rework. This provided a starting platform for RT 323 to begin looking for similarly influencing factors that could contribute to negative construction impacts that are not necessary limited to rework. RT 323 chose to expand the scope and include negative outcomes such as schedule delays and cost overruns.

Delay and disruption claims continue to be an area of uncertainty and a potential area for dispute in the construction process (Critchlow et al. 2005). It is without doubt that researching potential causes of construction interruptions and developing methods of interruption avoidance can improve project team awareness and provide a proactive management approach to eliminating disputes, litigation and claims. According to one study that looks at delay and disruption claim avoidance, “(d)isruption costs are essentially production related and, as such, are difficult to prove” (Aibinu 2009). What the research suggests is that delay claims often stem from the construction phase of a project and, as a result, are difficult to investigate because a contractor has limited means

of proving owner-driven delay that has negatively impacted construction-worker output (Aibinu 2009). One cause of delays was identified as owner directed changes (Aibinu 2009). Owner directed changes were discovered to be potential “delay events that could give rise to extension of time claims” because they disrupt the contractor’s work pace leading to overall schedule slippage.

Owner directed change can also negatively impact labor productivity. According to Ibbs (1994), change is defined as any addition, deletion, or revision to the general scope of a contract (1994). Ibbs (2012) argues that when additions or deletions in scope of work occur, the result is typically rework, schedule resequencing, schedule delay, and possibly schedule suspension; each of which impact labor productivity (Ibbs 2012). With this it becomes clear that change to project scope should be minimized. One study in dispute avoidance and mitigation looks at project benchmarking of a contractors performance (LaBarre and El-adaway 2013). The research looked at various reasons for claims in construction including safety issues, design errors, changes, and delay. The study went on to survey 40 construction contractors who did work for the U.S. Army Corps of Engineers regarding various performance measures. The result of the research was a benchmarking model that could provide contractors a means of mitigating problems and issues that would have otherwise caused litigation and claims (LaBarre and El-adaway 2013). The research was limited strictly to contractor performance and did not review actions by project owners or other stakeholders.

According to another study, rework has become one of the most common concerns on construction projects (Hwang, Zhao, Goh 2014). This research focused mainly on client-related rework and found that rework occurs due to changes, defects, and omissions. The research concluded that the client, rather than the contractor, contributed most to rework. One recommendation from the study suggests that developing a risk-register or knowledge transfer system of specific measures could support the decision-making process to control the occurrence of rework. The scope this research was also limited to projects based in Singapore.

Walewski et al. (2003) suggest that there are various risk factors that influence construction cost and schedule performance from project conception to completion (Walewski, Gibson and Dudley 2003). Some of these factors are inherent to organizations that are solely responsible for managing them, whereas others are closely related to the political, cultural, economic, and operational environments of the project’s location. With this, it becomes clear that the search for

factors that influence a projects outcome are not limited to owner driven schedules, but also factors such as time to market, seasonal and weather constraints, and financial obligations.

Regarding time to market, one study researched time to market as a project driver and looked at associated implications (Mahmound-Jouini, Midlerm and Garel 2004). The goal of the study was to understand management of time on Engineer-Procure-Construct (EPC) projects from a time-to-delivery perspective. What the research found was that concurrent engineering reduces time to market and has the potential to speed-up projects. Mahmound-Jouini et al. (2004) warned however, that “(o)ne might think that in order to reduce the delay of the project decisions must be made as quickly as possible.” Additionally, “at the beginning of the project, understanding is too low a level and it serves no purpose to make hasty decisions.” The paper states that “there is a risk of getting off on the wrong track, possibly resulting in costly and time-consuming modifications” (Mahmound-Jouini, Midlerm and Garel 2004). The decision to mobilize field craft and heavy equipment and begin construction is a single decision that arguably has the most financial and legal implication of the entire project. The extent of those risks and what could be some indicators of those risks occurring was not looked at in the study.

3.4 Studies on Negative Project Outcome Avoidance and Practices

Through reviewing past literature, RT 323 discovered many studies that researched and developed some form of risk assessment or conflict avoidance tool that can be applied to any project of carrying scope. These include items such as the Project Definition Risk Assessment (PDRI), the Late Deliverables Risk Catalog (LDRC), the International Project Risk Assessment (IPRA), and the Flash Track tool (Gibson and Dumont 1995; Barry et al. 2015; Walewski, Gibson, and Dudley 2003; Austin, de la Garza, Pishdad-Bozorgi 2015). These tools were developed by incorporating findings from research that targeted specific aspects within the construction industry such as stakeholder alignment, front-end planning, and constructability. This section will review each of these industry practices and tools to gain a better understanding of what negative project outcome avoidance techniques already exist and what knowledge gaps could be closed.

The PDRI was developed by the CII Front End Planning Research Team 113 and the Project Definition Rating Index (PDRI) for Industrial Projects Research Team 153 (Gibson and Dumont 1995; Gibson 1997). The Front End Planning Research Team was commissioned to

develop project tools that support both owners and contractors during the pre-project planning stages of a construction project. The PDRI is an Excel-based tool that serves as a checklist and allows users, typically all stakeholders on a given project, to rate various project category elements. Research Team 113 also researched and defined standardized construction terminology to incorporate into the PDRI in order to better facilitate communication between all project stakeholders.

The categories and elements in the PDRI cover a broad range of pre-project items such as “Equipment Scope,” “Site Information” and “Business Objectives” (Gibson and Dumont 1995). The user of this tool is asked to score 70 weighted elements. A low score for a category indicates the item is well defined while a high score indicates the item is poorly defined. The total score of a project is out of 1000 points. The research showed that successful projects scored less than 200 (Gibson and Dumont 1995). It is recommended that scores for each element are to be determined by a group of project team members with a neutral facilitator to lead the scoring process (Gibson and Dumont 1995).

One valuable feature of the PDRI is that each element is weighted according to relative importance based on industry perception. During the research phase of developing the PDRI, two workshops, involving 54 project managers and estimators from the construction industry, were held so that each element could be weighted (Gibson and Dumont 1995). These weighted elements then underwent a validation process which involved surveying company representatives on 23 projects. The purpose of this was to correlate PDRI scores with actual project success. Each company representative was asked to refer back to the pre-design and pre-construction phase and determine how well each element from the PDRI was defined at that time. The research team then developed a method to determine project success based the relationship between pre-project planning efforts and project success (Gibson and Dumont 1997). What was discovered was a positive correlation between low PDRI scores and high project success.

During the development and validation of the PDRI, the research team found that project team members and stakeholders often had conflicting criteria for determining project success (Gibson and Dumont 1997). One of the biggest discoveries made by developing the PDRI was not simply being able to give a project a score out of 1000, but also allowing all project teams to understand and effectively communicate to all parties the overall project objective (Gibson and

Dumont 1995). This prompted the need for an additional research team to investigate factors that affect project team alignment and how it impacts project success (Gibson and Dumont 1997).

In an effort to establish standardized industry terminology, the Front End Planning Research Team originally defined alignment as “the condition where appropriate project participants are working within acceptable tolerances to develop and meet a uniformly defined and understood set of project objectives” (Gibson and Dumont 1997). Under the guidance of the Front End Planning Research, CII published a follow-up research report called “Team Alignment During Pre-Project Planning of Capital Facilities” (Griffith and Gibson 1997). Using workshops, surveys and telephone interviews, a list of 66 issues involving project team alignment were discovered. These issues fell into separate categories such as “execution process” issues, “tools,” “information,” and “company culture” (Griffith and Gibson 1997). From the list of 66 issues, 10 were deemed critical based on survey rankings and actual project data. The top three critical alignment issues are “proper staffing of pre-project planning team with representatives from all significant project stakeholders,” “develop and support effective team leadership,” and “identify and communicate to all pre-project team members the priorities between the project’s costs, schedule, and required features” (Griffith and Gibson 1997). Using sample projects, the research team utilized the project success index versus PDRI score developed by the Front End Planning research team and did a regression analysis with 20 sample projects in order to understand if there was a correlation between a PDRI score, alignment, and project success. The research uncovered a positive relationship between alignment and project success. What this allowed project teams to do is measure the degree of alignment attained on projects prior to design and construction (Gibson and Dumont 1997). One limitation was mentioned in the study and that is that the sample projects that were used to validate the alignment versus project success were all large industrial projects.

Another study reviewed is on the topic of Constructability. CII initiated a taskforce to determine which constructability practices are being used in the construction industry and to qualitatively describe its benefits through documented cases. Constructability refers to the “optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives” (O’Connor and Tatum 1986). The objective of the taskforce was to determine how constructability is currently applied based on past project characteristics. The second part of the investigation looked at how constructability concepts apply

to both design and construction phases of a project. The goal was to then lump these characteristics into a program that can be implemented to allow for constructability concepts to be applied to any given project. To determine these key aspects of constructability, seven projects were reviewed and constructability characteristics that apply to both construction and design were recorded.

Through cross-case analysis, the task force determined that four common characteristics were emphasized by projects who utilize a constructability program. The number one characteristic is that “(o)wner and contractor (design and construction) managers are committed to the cost effectiveness of the whole project. They recognize the high cost influence of early project decisions” (O’Connor and Tatum 1986). Another common characteristic is that designers are receptive to input from construction teams and often times request feedback and evaluate recommendations objectively. The research team summarized all of these characteristics and compiled key ingredients required for a successful constructability program. This included clear communication of constructability commitment, encourage teamwork, assign a single point-person to lead the program, and start constructability as soon as possible (O’Connor and Tatum 1986).

Another research project that produced a tool is CII Research Team 311 that looked at fast track projects in order to determine what industry practices are essential to attain an even faster successful project delivery, known as “flash track project” (Austin, de la Garza, Pishdad-Bozorgi 2015). The research team, recognizing the emergence and prevalence of flash track construction projects, looked at how these projects could be delivered efficiently by developing a complete understanding of every aspect of flash track projects and creating a tool that obtains inputs regarding organizational capacity and contract selection to planning and execution.

The research first identified flash track practices by reviewing literature and interviewing personnel on EPC flash track projects (Austin, de la Garza, Pishdad-Bozorgi 2015). From the research, 66 practices were identified and later ranked using Analytical Hierarchy Process. The ranks of each practice was determined by recruiting 64 individual industry experts who had to meet minimum criteria in order to participate. This included a minimum of fifteen years of experience in the EPC or AEC industry, five years in a project leadership role, five years fast track project experience, and prior experience in at least two phases of a project’s life cycle (Austin, de la Garza, Pishdad-Bozorgi 2015). RT 311 then incorporated the results into an Excel-based tool

that helps users assess the readiness of the project team prior to beginning a flash track project. The tool also recommends strategies based on the users input to increase the likelihood of successful project delivery.

The final research study reviewed that developed a research implementation tool is from the CII Risk Management Integration Team (RT 181). The goal of the team was to review and integrate risk management documentation into a tool called the Integrated Project Risk Assessment (IPRA) (Walewski, Gibson, and Dudley 2003). The development of this tool is based heavily on the same process utilized by the Front End Planning Research Team that developed the PDRI. The main difference is that the PDRI is meant to be used during the pre-planning stages of a project lifecycle while the IPRA is designed to be used during all stages of a project lifecycle. Expert interviews from 26 upper mid- to upper-level management personnel were conducted from 26 organizations made up of contractors and owners (Walewski, Gibson, and Dudley 2003).

Focus groups were then implemented during the research process to weight each element. These expert interviews resulted in 82 risk elements grouped into 14 categories representing the entire project life cycle from business plan evaluation to production and operation. The IPRA also differs from the PDRI in that the user of the IPRA must include a two-step input per element process rather than issuing a single value for each item. This two-step process requests that the user provide a “likelihood” and “impact” score of each risk element. To serve as a validation process, RT 181 conducted workshops with industry professionals who used the IPRA in conjunction with past projects to see if project success was correlated. The research stated that one limitation to the study is that these projects were volunteered and could be biased towards successful projects while not fully incorporating unsuccessful projects in the validation process. The time taken to complete the IPRA with test subjects was one to four hours.

3.5 Discussion

These studies inspired RT 323 to structure the research in a driver-leading indicator framework. Because of the implication of incomplete engineering documentation and abundance of field rework as a result, RT 323 chose to look at engineering documentation as a potential leading indicator to signal a premature start. After reviewing multiple sources, it became evident that drivers affect a project outcome and contain one or more indicators that take place prior to the

influencing factor. Throughout the literature review, it became a main goal of RT 323 to determine exactly what those leading indicators are, how they are defined within the context of the construction industry, as well as how they can be quantified. RT 323 also chose to develop a tool that incorporates the research findings into a user-friendly excel-based environment. The goal was to also allow users to have quick and easy access to survey data, case studies, and terminology developed by RT 323. This was chosen as an objective so that projects teams can gain awareness and avoidance of beginning construction prematurely.

4. Case Studies

This section contains each in-depth case study. The case studies vary in project scope, schedule, and budget. Project definition for these case studies include projects related to infrastructure development, government funded renovations, and oil and gas midstream facilities. Average baseline project cost for these case studies range from \$2.4 million to \$208 million (average: \$64.2 million; median: \$44.2 million). These results from research thrust one serve as the framework for the creating the survey conducted in the quantitative research thrust.

The case study research also served as an opportunity for the research team to collect terminology from each scenario and to compare it to other scenarios of similar outcomes. First the team identified key components that qualified the case as a premature start to construction and categorized and defined each. This approach helped further qualify each aspect of a premature start to construction. Definitions of each category can be found in Chapter 5.

Two rounds of pilot case study place. Each pilot case study answered eight basic question regarding project scope, cost, schedule, and interruption(s) that took place on the project. Twenty pilot case studies were collected from the two rounds of submissions. These pilot case studies were the starting point for the in-depth case studies, given that they satisfied the definition of a premature start. After performing the first several in-depth case studies, the team planned subsequent in-depth case studies. Of the twenty pilot case studies, eight became in-depth case studies. For research thrust one, the team followed a two-step case study analysis process as follows:

- Intra-case analysis: description of a single project with a documented premature start, impacts, drivers, potential leading indicators;
- Cross-case analysis: section cut of common information across all cases to identify commonalities and patterns in drivers, impacts and leading indicators.

For each case, RT 323 identified key drivers that led to the premature start, the main interruption, and the impacts of that interruption to construction. See Table 4-1 for a list of pilot and in-depth case studies.

Table 4-1: Pilot Case Study Summary

Pilot Case Study #	Description	Owner / Contractor	Industry Sector	Project Cost \$	Premature Start (yes/no)	In-depth Case Study (yes/no)	Case Study #	Driver
1	Renewable Energy Project	Contractor	Heavy Industrial	\$240M	yes	yes	1	Owner Mandated Overly Aggressive Schedule, Time to Market, Capital Availability
2	AFB Late Deliverable	Contractor	Buildings	\$11M	no	no		
3	Chemical Plant Refurbish	Contractor	Heavy Industrial	\$100M	yes	yes	2	Owner Mandated Overly Aggressive Schedule, Owner Perceived Benefit For Early Start
4	Copper Mine	Contractor	Heavy Industrial	\$2.5B	no	no		
5	New Sports Facility	Owner	Buildings	\$25M	no	no		
6	New Helium Plant	Owner	Heavy Industrial	\$115M	no	no		
7	Franchise Utility Ductbank	Contractor	Infrastructure	\$3.7M	yes	yes	4	Owner Mandated Overly Aggressive Schedule, Owner Perceived Benefit For Early Start, Time to Market, Regulatory Compliance
8	Power Transmission Line Extension and Reconductor	Contractor	Infrastructure	\$1.4M	yes	no		
9	New Fuel Gathering Site	Owner	Heavy Industrial	\$41.3M	yes	yes	5	Owner Mandated Overly Aggressive Schedule, Owner Perceived Benefit For Early Start, Time to Market
10	Midstream Facility Upgrade	Owner	Heavy Industrial	\$14.1M	no	no		
11	Water Recycling Network	Owner	Infrastructure	\$9.2M	yes	no		
12	New Natural Gas Station	Owner	Heavy Industrial	\$7.2M	yes	no		
13	New Heavy Gauge Line	Owner	Infrastructure	\$126M	no	no		
14	Tank Refurbishment Project	Owner	Heavy Industrial	\$4.3M	yes	yes	3	Owner Mandated Overly Aggressive Schedule, Time to Market, Regulatory Compliance, Capital Availability
15	Brownfield Manufacturing Expansion	Owner	Heavy Industrial	\$250M	no	no		
16	Historic Renovation	Owner	Buildings	\$19.9M	yes	yes	7	Owner Mandated Overly Aggressive Schedule, Owner Perceived Benefit For Early Start, Time to Market, Regulatory Compliance, Capital Availability
17	Offshore Pipeline Install	Contractor	Heavy Industrial	\$100M	no	no		
18	Install New Furnaces	Contractor	Heavy Industrial	\$150M	yes	yes	6	Owner Mandated Overly Aggressive Schedule, Owner Perceived Benefit For Early Start, Time to Market, Contractor Eager to Get Started, Contractor Perceived Benefit for Early Start
19	Natural Gas Pipeline Install	Owner	Heavy Industrial	\$50.5M	yes	yes	8	Owner Mandated Overly Aggressive Schedule, Owner Perceived Benefit For Early Start, Time to Market, Seasonal/Weather Constraints, Contractor Eager to Get Started, Contractor Perceived Benefit for Early Start, Contractor Mobilization in Order to Start Billing
20	Arctic Oil and Gas Production	Owner	Heavy Industrial	\$123.8M				

The twenty pilot case studies reflect the diversity of the construction projects and include cases with varying levels of project definition. Each case also identifies with various industry sectors, such as oil and gas to government renovation project. The pilot case studies that fit the definition of a premature start to construction are highlighted in grey in Table 4-1 and list basic project attributes. These in-depth case studies are found below in the following sub-sections.

4.1 Case Study 1: Cost and Schedule Driven Premature Start

This case study investigates the effects of having a government grant issued on the basis of the completion of certain construction milestones and how it drove the construction of a renewable energy plant. It will look at how time to market and an aggressive owner schedule also influenced a premature start to construction and discuss various impacts of that premature start in

the project outcome. Table 4-2 identifies (asterisked and highlighted in yellow) precisely which premature start drivers, leading indicators and impacts occurred in this case.

Table 4-2: Case Study 1 Premature Start Drivers, Leading Indicators, and Impacts

Premature Start Drivers	Leading Indicators	Project Impacts
*Owner Mandated Overly Aggressive Schedule	*Engineering Documentation Not Complete	*Cost Overruns
Owner Perceived Benefit For Early Start	*Late Design Deliverables	*Overtime / Unplanned Work
*Time to Market	Unrealistic Schedule	*Schedule Slippage
Seasonal / Weather Constraints	Material Not Available	*Out of Sequence Work
*Regulatory Compliance	*Vendor Information Unavailable Prior to Design	*Rework
*Capital Availability	Unmitigated Assumptions	Poor Productivity
Contractor Eager to Get Started	Unclear Project Objectives	*Facility Start-up / Production Delay
Contractor Perceived Benefit for Early Start	Lack of Regulatory License / Permits	Scope Not Identified
Contractor Mobilization in Order to Start Billing	Unsupportive Management	Relationship / Reputational Damage
	Contract Terms in Place That Incentivizes Mobilization	*Poor Morale
		*Safety Exposure
		Litigation / Claims
		*Failure to Attract / Maintain Craft

Company Profile

The company involved in this case is a design-build contracting company specializing in the design and construction of industrial facilities such as power plants, oil, gas and chemical facilities, and other manufacturing facilities. The project investigated in this case study is a renewable energy power plant located in the northeastern region of the United States.

Project Overview

The project delivery type was Design/Build with a contract type of lump sum. Funding for this project was supplemented by an American Recovery and Reinvestment Act (ARRA) government grant which was to be awarded to the contractor upon the completion of specified construction milestones. The first milestone that needed to be achieved in order to qualify for the grant was the installation of a specified percentage of building foundations. After the end of the fiscal year, the grant money would have expired and would no longer be available to the contractor.

Thus, a sense of urgency was placed on completing the grant milestones which led to interruptions to the construction phase of this project. In order to achieve this milestone, the equipment foundation design process was accelerated and since the detailed equipment data sheets from the project vendors were not yet available, conservative assumptions were made for equipment loading. As a result, the foundation design was ultimately completed with less information than is typical or ideal and led to many construction interruptions, involving both the contractor and the subcontractor.

Table 4-3: Project summary of cost and schedule

Sector	Power
Project Type	Renewable Energy Power Plant
Construction Location	New England, US
Contract Type	Lump Sum
Baseline Project Cost (TIC)	\$208 million
Actual Project Cost (TIC)	\$240 million
Total Project Baseline Duration	24 months
Total Project Actual Duration	27 months

The premature start risk identified in this project was the acceleration of the design process and subsequent start of construction for the equipment foundations. This task is considered a risk because detailed equipment data sheets necessary for comprehensive foundation designs were not yet available from the equipment vendors when the foundation design started. The decision to start construction, despite the aforementioned risk, was driven primarily by a government grant which was to be issued to the contractor upon the completion of certain construction milestones.

Driver(s)

Throughout the course of this project two main drivers were identified; one being the grant tied to certain construction milestones and other being the time to market push by the contractor and owner, who both were owners in the power plant. As described earlier in this case study each of these drivers caused interruptions in the construction phase. The second driver identified in the project is directly related to time to market. Being a co-investor in the project, the contractor shared risk with the owner in the sense that they both perceived a benefit with an early start-up so that revenues from power generation could commence as soon as possible. Because the contractor

shared partial stake in the operation of the plant, a larger emphasis was placed on getting the plant producing power which required an aggressive schedule. In summary, the drivers identified in this case were:

- Owner Mandated Overly Aggressive Schedule
- Time to Market
- Regulatory Compliance
- Capital Availability

Impact(s)

One impact of the accelerated foundation design process that caused interruptions in the construction phase was fluctuations in manpower for the concrete subcontractor. As soon as a foundation design for a piece of equipment was released for construction, the foundation contractor increased manpower and completed the work. Once that foundation was installed, the contractor reduced manpower and waited for the next set of foundation drawings to be released. These fluctuations in manpower had significant cost impacts as well as trade labor frustration, as steady work was not available. Key personnel on the subcontractor team were lost due to the start/stop nature of the foundation installation.

Another interruption to construction as a result of the accelerated foundation designs was added rework. More than typical amounts of rework were reported as being required as a result of the early and accelerated foundation designs. Excessive rework increased worker safety exposure due to overtime and shift work in order to meet milestones. Stacked resources also contributed to increased dangerous work zones. More than typical amounts of rework, poor productivity, and an overly conservative concrete design affected the overall quality of the project. Cost and schedule outcomes include not being able to competitively negotiate price because of growing pressure to start construction; total installed cost (TIC) was \$240 million (\$32 million more than the contract cost). Also, although all construction milestones were met, overall construction did not meet production date. The impacts of these interruptions are summarized below.

- Cost Overruns
- Out of Sequence Work
- Overtime/Unplanned Work
- Schedule Slippage

- Rework
- Poor Productivity
- Scope Not Identified
- Facility Start-up/Production Delay
- Relationship/Reputational Damage
- Poor Morale
- Litigation/Claims
- Safety Exposure
- Failure to Attract/Maintain Craft

Leading Indicator(s)

Leading indicators act as early warning sign that have potential to alert the project team of potential problems and issues. This section will cover warning signs that were pointed out by members of the project team that could have provided some foresight that construction interruptions were imminent. Signing and closing of the contract occurred three months later than expected; contributing to major deliverables arriving late. Another key indicator was lack of vendor information and procurement schedule prior to commencing design. As a result, engineering documents were not complete and lacked detail. Foundation engineers were not sure where tie-in-points were going to be; as a result, assumptions were made. When vendor information was available and assumptions were deemed incorrect, rework of pipe installation had to occur. Leading indicators identified on this project include the following:

- Engineering Documentation Not Complete
- Late Design Deliverables
- Vendor Information Unavailable Prior to Design

Lessons Learned

This section will address the various lessons learned from the project outcomes and provide strategies to address each issue.

a. Importance of Schedule Integration between Engineering, Procurement & Construction.

In order to prevent the ramp up / ramp down of manpower for the concrete installation contractor, the Engineer-Procure-Construct (EPC) Contractor could have taken a step back

to regroup. The EPC team could have put together an execution schedule that grouped portions of the foundations into design packages (e.g., 50% of the foundations). That design package could then be released for construction and allowed the Civil Contractor to work steadily. The second design package could have been released at the time the first set of foundations was completed to allow additional steady, uninterrupted work for the Civil Contractor. This could have potentially reduced costs, improved morale, and maintained a predictable overall project schedule.

b. Conduct a detailed risk analysis on front end costs vs. potential benefits.

In this project, the completion of the commercial agreement occurred three months after the date that it was originally planned. However, the end date of the project did not change. In retrospect, the EPC Contractor and Owner could have jointly moved forward with detailed design during the time period that the commercial agreement was in negotiation. The risk (and associated sunk costs) of moving forward with the detailed design was much lower than then risk (and associated sunk costs) of compressing the EPC schedule for the overall project. The team could have conducted a risk analysis at this point in the project and have potentially saved the project from cost and schedule impacts.

c. Front end evaluation of available resources and their allocation to the project.

During FEED, the EPC team could have performed a more detailed analysis of available resources and the plan for allocation of those resources to the project. For this project, there were resource shortages that were not discovered until those shortages were impacting cost and schedule.

4.2 Case Study 2: Owner Driven Construction through Overly Aggressive Schedule

This case study investigates the effects of having an owner mandated aggressive schedule and how it drove the construction of a \$55 million dollar chemical plant. It will also look at how an owner's perceived benefit for early start-up influenced a premature start to construction and discuss various impacts of that premature start in the project outcome. Table 4-4 identifies (asterisked and highlighted in yellow) precisely which premature start drivers, leading indicators and impacts occurred in this case.

Table 4-4: Case Study 2 Premature Start Drivers, Leading Indicators, and Impacts

Premature Start Drivers	Leading Indicators	Project Impacts
*Owner Mandated Overly Aggressive Schedule	*Engineering Documentation Not Complete	*Cost Overruns
*Owner Perceived Benefit For Early Start	*Late Design Deliverables	*Overtime / Unplanned Work
Time to Market	*Unrealistic Schedule	*Schedule Slippage
Seasonal / Weather Constraints	*Material Not Available	*Out of Sequence Work
Regulatory Compliance	*Vendor Information Unavailable Prior to Design	*Rework
Capital Availability	Unmitigated Assumptions	*Poor Productivity
Contractor Eager to Get Started	Unclear Project Objectives	*Facility Start-up / Production Delay
Contractor Perceived Benefit for Early Start	Lack of Regulatory License / Permits	*Scope Not Identified
Contractor Mobilization in Order to Start Billing	*Unsupportive Management	*Relationship / Reputational Damage
	Contract Terms in Place That Incentivizes Mobilization	Poor Morale
		*Safety Exposure
		Litigation / Claims
		Failure to Attract / Maintain Craft

Company Profile

The company responsible for construction on this project is a large Engineering-Design-Construction (EPC) Contractor located in North America. The Contractor has extensive experience in oil and gas, infrastructure, power, and industrial markets and is one of the largest providers of engineering, construction, and technical services in the world.

Project Overview

This case study looks at a brownfield project belonging to the heavy industrial subsector. The project delivery type was EP-C where the Owner was responsible for the engineering and procurement while the Construction Contractor was responsible only for the construction. The contract type was cost reimbursable. This Construction Contractor had no prior business relationship with this particular client and was currently facing an aggressive Owner mandated schedule to complete construction by July 2013. After accepting the terms of the contract the contracting company mobilized for construction. The Construction Contractor then encountered several issues with engineering design, fabrication and equipment, and material delivery.

Significant design errors became prevalent and materials were arriving out of sequence and contained deficiencies. An overall critical path in the schedule could not be determined by the Construction Contractor and many of the Owner mandated construction sequences were considered disruptive and contradictory to typical flow of construction.

The status of engineering and procurement was unclear before the contract was awarded to the Construction Contractor; however, it was assumed to be sufficient per Owner information. During construction, the Owner did not provide items such as materials purchasing order information to the Construction Contractor. The Construction Contractor did not know when materials and equipment would be arriving to the construction site for installation. Initially, the Construction Contractor maintained a low level of craft to align with available engineering and procurement information. Because of the lack of material and equipment delivery information from the Owner, the Construction Contractor did an independent review of engineering and procurement phases to better understand what was needed to continue construction. After these reviews were conducted and several design and fabrication errors became apparent, it became clear to the Construction Contractor that there were scope definition issues and additional resources would be required in order to meet the Owner's completion date of July 2013. Several schedule revisions including additional craft resources and double shifting were provided to the client by the Construction Contractor that ultimately set a projected completion date of December 2013, well beyond the intended completion date desired by the Owner. The Owner did not accept the December completion forecast and directed the new completion date to be in September 2013. Table 4-5 summarizes the various cost and schedule implications due to the aggressive schedule and project team reacting address the heavy burden of meeting the Owner's scope requirements.