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THE TRUE IMPACT OF LATE DELIVERABLES AT THE CONSTRUCTION SITE

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THE TRUE IMPACT OF LATE DELIVERABLES AT THE CONSTRUCTION SITE

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THESIS

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

MASTER OF SCIENCE IN ENGINEERING

THE UNIVERSITY OF TEXAS AT AUSTIN

MAY 2014

Dedication

Dedicated to all those who have taken the time to answer my questions through the years.

Acknowledgements

To all my family and friends closest to me, thank you for supporting me in my endeavors, thank you for being positive influences in my life, and thank you for putting up with me day in and day out. A person is only as strong as the foundation upon which they are built – each and every one of you has instilled in me the values of integrity, determination, and confidence. For that, I am forever indebted.

Next, I would like to thank all of the teachers, coaches, professors, and mentors who have helped and molded me through the years. Specifically, I would like to thank Dr. Fernanda Leite for her continual guidance, insight, and understanding and Dr. William J. O'Brien for his knowledge and support. Taking part in this research project with the two of you has been a spectacular opportunity and experience for which I am grateful.

I would also like to thank the Construction Industry Institute, The University of Texas at Austin, and Construction Engineering and Project Management program for providing me with support and a world-class education. And to all of the members of Research Team 300 – you have transformed my time in graduate school from an education to a learning experience. The wisdom you have bestowed upon me will not soon be forgotten – thank you.

Finally, I would like to thank the others who provided the resources and knowledge required to complete this research. This includes those from Construction Industry Institute and the Construction Users Roundtable, as well as the countless individuals who expended both time and effort to complete interviews, surveys, and questionnaires to help us develop this product. Thanks to all of you.

Abstract

THE TRUE IMPACT OF LATE DELIVERABLES AT THE CONSTRUCTION SITE

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Given that a construction site is both temporary and unique, the outcome of every construction project is dependent upon having all of the proper resources delivered to the site at the appropriate time. Although this is common knowledge in the construction industry, late deliverables to the site continue to be a major impediment to project success. In order to better understand late deliverables and their impacts on performance, the Construction Industry Institute, in collaboration with the Construction Users Roundtable, commissioned Research Team (RT) 300 to investigate how various types of late deliverables affect the cost, schedule, quality, safety, and organizational performance of industrial construction projects. Using case studies, industry surveys and questionnaires, existing literature, and internal team expertise, RT 300 developed two research thrusts: investigate how the industry understands, manages, and is affected by

late deliverables, and document and give visibility to the true risks and impacts associated with late deliverables.

When examining how late deliverables affect the construction industry, RT 300 found that (1) there is limited understanding of the full range of late deliverables and their far-reaching impacts, (2) the most common late deliverables tend to have the most severe impacts on projects, (3) project teams are typically reactionary when managing late deliverables, (4) project stakeholders have varying perceptions of the risks and impacts associated with late deliverables, and (5) proactively managing late deliverables and impacts is key for improvement in the industry. With these findings and the second research thrust in mind, RT 300 created a database tool, the Late Deliverable Risk Catalog (LDRC), to document common types of late deliverables, give visibility to the full range of impacts, and help project teams recognize risks, improve alignment, and proactively manage late deliverables and mitigate the impacts. RT 300 has also developed implementation recommendations for the LDRC, prevention recommendations for the highest risk deliverables, and lessons learned in managing late deliverables. Altogether, this research can help improve the understanding of late deliverables and resulting impacts and risks in order to improve project delivery, productivity, and predictability as well as enhance safety, quality, and organizational and individual performance.

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Chapter 1: Introduction

The Construction Industry Institute (CII) Research Team (RT) 300, a collaborative effort between CII and the Construction Users Roundtable (CURT), was chartered to define and document the full range of impacts that late deliverables to construction can have on a project. The hypothesis developed by the research team states that cost increases and schedule extensions, which are traditionally associated with late deliveries, do not completely capture the full range of impacts incurred when materials, engineering, or other required project resources do not arrive on schedule at the construction site.

A review of current industry and academic literature reveals that, while late deliverables are often cited as sources of change on project, no existing research has examined in-depth the entire spectrum of late deliverables nor traced the full range of impacts and risks they pose to the five pillars of project success (Kumaraswamy and Chan 1998; Mulholland and Christian 1999; Al-Momani 2000; Ahmed et al. 2002; Assaf and Al-Hejji 2006; Rahman, Memom and Karim 2012; Kumar 2010; Borcherding 1972; Yeo and Ning 2004; Thomas, Sanvido and Sanders 1989; Donyavi and Flanagan 2009; Ballard 1993). Previous industry and academic literature has focused primarily on two related topics: examining specific deliverables and investigating sources of change on projects. While both of these research topics have cited late deliverables as sources of significant change on projects, no previous literature examines specifically how all types of late deliverables affect projects objectives and goals.

Construction projects have multiple and often conflicting objectives that must be met for a project to be considered a success. Both the construction industry and a project's goals are dynamic in nature, and success means different things to different people at different points in a project lifecycle (Chan and Chan, 2004). Typically, time and cost performance are the predominant criteria, but these are not the only indicators of project success or failure. In construction, safety and quality risks posed by late deliverables, although less often tracked or measured, are equally important in determining the outcomes of a project. These make up the third and fourth set of objectives that must be managed appropriately for a project to succeed. A fifth set of objectives exists within the realm of the companies and individuals participating on a project. Each stakeholder, from a company involved to an individual laborer, has a set of objectives and expectations that contribute to and are derived from the project's outcomes. These measures for a company can include the profit of the project, the opening of a new market or project capability, technology innovations, and an improved reputation or relationship. For the individual stakeholders, objectives can include positive morale, productive working relationships, advancement, or recognition.

This organizational capacity, along with the aforementioned cost, schedule, quality, and safety objectives on a project, comprise the five pillars of project performance being investigated in this research. Though the goals and objectives of individual and organizational stakeholders are both abundant and dynamic, the five pillars must be collectively managed for a project to succeed. Given that a construction site is both temporary and unique, it is clear that meeting the objectives in the five project pillars is dependent upon having the proper resources delivered to the site at the appropriate time.

1.1 Purpose and Objectives

The research goal of RT 300, whose membership included experts from leading industry owners and contractors along with university academics, was to close this gap in knowledge, increase awareness to the broad range of risks from late deliverables, and focus on mechanisms for industry improvement. This was accomplished by exploring in-depth the impacts to projects of specific late deliverables and also by using more broad surveys and questionnaires to discover how the industry currently perceives and reacts to late deliverables and subsequent impacts. The final goal of RT 300 was to identify key causes and contributors, where possible, and develop means for the industry to implement and incorporate new knowledge and processes into their projects to improve performance by proactively managing late deliverables, identifying related risks, and preventing or mitigating the associated impacts. With these goals in mind, RT 300's work consisted of:

- reviewing current CII, industry and trade literature;
- conducting 54 'mini' case study questionnaires and nine in-depth case studies of projects impacted by late deliverables to construction;
- developing and documenting a comprehensive set of definitions, including types of late deliverables, categories of project impacts and project outcomes affected by late deliverables, and their relationships to one another;
- surveying over 240 industry experts to assess the relative frequency and impact severity of late delivery of each deliverable type;
- developing a relational database tool, the Late Deliverable Risk Catalog (LDRC), that ties together key findings and project risks to make them easily accessible by project teams;
- testing of the LDRC by owners and contractors to confirm its ability to help project teams easily understand impacts of late deliverables; and
- capturing a "starter list" of leading indicators and work practice recommendations that can be employed to help prevent late deliverables or to identify the potential for late delivery as early as possible.

The contents of this document include a literature review, an examination of the research methods and results, insight into several of the key findings and research products, and a collection of lessons learned and recommendations regarding late deliverables and the research products. A condensed version of this report has been prepared as CII Research Summary (RS) 300-1. Also, CII Implementation Resource (IR) 300-2 has been developed to provide instructions and implementation recommendations and accompany the research products.

1.2 RESEARCH PHASES

The first phase of the research project consisted of several data gathering techniques to identify types of late deliverables, their impacts on a project, and how the project pillars – cost, schedule, quality, safety, and organizational capacity – were affected. Using internal team knowledge, expert interviews, industry surveys and questionnaires, in-depth case studies, and a review of the existing literature, RT 300 compiled a broad list of potential late deliverables, from complex engineered equipment to design decisions to various types of human resources, and an even more extensive list of possible impacts.

In the second phase of the study, RT 300 started to identify commonalities and trends in the collected, and began to categorize the late deliverables and impacts into related groupings. As the categories were finalized, the team also began the process of cataloguing all of the data as well as identifying the commonality and severity of each category through an industry survey. Using this data, common themes were identified in the late deliverables categories, and leading indicators and preventative recommendations were developed using the combined knowledge of the research team.

The third and final phase of the research project entailed creating an industry tool, or interface, for accessing the catalogued data. The Late Deliverable Risk Catalog

(LDRC) provides for easy navigation of all of the data collected by RT 300 through the use of filters. Each individual impact description collected during the research process is identified by the type(s) of late deliverables that can cause it, the group(s) of impacts it belongs to, and the pillar(s) that are affected by the impact. Finally, the LDRC was sent out for external validation and refinement, and, with the feedback, the research team developed a set of recommendations for implementation in and potential uses for the construction industry.

1.3 RESEARCH SCOPE

The primary focus of this research is to document and give visibility to the full range of impacts of late deliverables to construction in terms of the safety, quality, schedule, cost, and organizational capacity – defined by RT 300 as the capacity or capability of individuals and/or an organization to efficiently and effectively execute work, with regard to teamwork, morale, team alignment, company alignment, relationships, and resources – on a construction project. To this end, the research team developed several scope goals and limitations to guide the research process. This study includes the full range of deliverable types that are required at the construction site beyond just material deliverables. Furthermore, the full range of impacts that can result from late deliveries, according to the research conducted by RT 300, has been included.

The late deliverable categories identified by the research team are the basis for the case studies and research products; these include physical material deliverables, information and drawing deliverables, and the human and physical resources required to complete a project. Similarly, the full range of potential impacts due to late deliverables, as shown by the team's research, has been broken down into related categories as developed by the research team. Each of these impact descriptions has also been associated with one or more of the five project pillars (cost, schedule, quality, safety, and organizational capacity) based on the knowledge collected. Defining all of these categories and pillars has also been included in the research scope in the interest of clarity, communication, and ease of implementation. Furthermore, the team has used several data gathering methods to further understand how construction professionals perceive the impacts of late deliverables, and this data has been analyzed and incorporated into the research findings.

Conversely, several limitations were applied to create a manageable scope for the research team. The range of projects studied by the team is limited to the industrial construction sector as reflective of the expertise of the research team members. The investigation into the impacts is limited to deliverables that are late to the construction site, not those to engineering firms, suppliers, etc. that may, in turn, cause late deliverables to the site. Likewise, the scope of project impacts has been limited to the impacts during the construction phase of a project, using the cost, schedule, and other requirements established at project sanction as the basis for comparisons. Consequential impacts of late deliveries extending beyond a project's construction phase (e.g. impacts due to delayed start-up or commercial operation) have also been excluded from this research effort. Finally, quantitative impacts of late deliverables have been limited to a case-specific basis, such as the in-depth case studies where quantitative data was collected. The extraordinary variety in types of late deliverables, sizes of projects, and decisions made by project teams that affect outcomes made producing generalized quantitative impacts of late deliverables infeasible and, thus, was excluded from the research scope.

1.4 REPORT STRUCTURE

This report is divided into ten chapters. Following this introduction in Chapter 1, Chapter 2 covers the research methodology and outlines and describes the processes used by the research team in this study. Chapter 3 includes a review of relevant literature, which provided a starting point for the research data collection and helped identify gaps in knowledge. This literature review describes two primary areas of previous research: investigations of a specific impact or change on projects that have cited late deliverables as one of the causes, and examinations of specific types of late deliverables. Chapter 4 provides the executive summaries of the nine case studies that were conducted to both collect information about late deliverables and provide a narrative about projects that experience late deliverables to increase understanding. As the research team collected information, categories were created and defined to organize and clarify the types of late deliverables that were included in the study, the impacts that occurred as a result, and the project pillars that were investigated by the team. These definitions are included in Chapter 5. The next two chapters outline the results of the two research thrusts. First, Chapter 6 introduces the Late Deliverables Risk Catalog, a tool developed for the industry to help navigate the data collected and incorporate the research into company processes, along with instructions and recommendations for its use. Chapter 7 provides the research findings developed to better understand late deliverables – the second research thrust. Subsequently, Chapter 8 offers lessons learned and recommendations for both research thrusts – increasing understanding of late deliverables and providing means for industry improvement. Chapter 9 covers the external validation participants and results, followed by a high-level summary of the research along with its foreseen benefits to the construction industry in Chapter 10.

Chapter 2: Methodology

Research Team 300 developed two primary research thrusts. First, the team employed a variety of research methods to understand and document the full range of potential late deliverables and the associated impacts and risks on construction projects. Secondly, RT 300 examined how the construction industry currently perceives and manages late deliverables using many of the same research methods. The methodology used for both of these parallel investigations is summarized in this chapter, and an overview of the research process, including the development of the research products, is depicted below in Figure 1. A detailed explanation of the research methodology can be found in the subsequent sections.

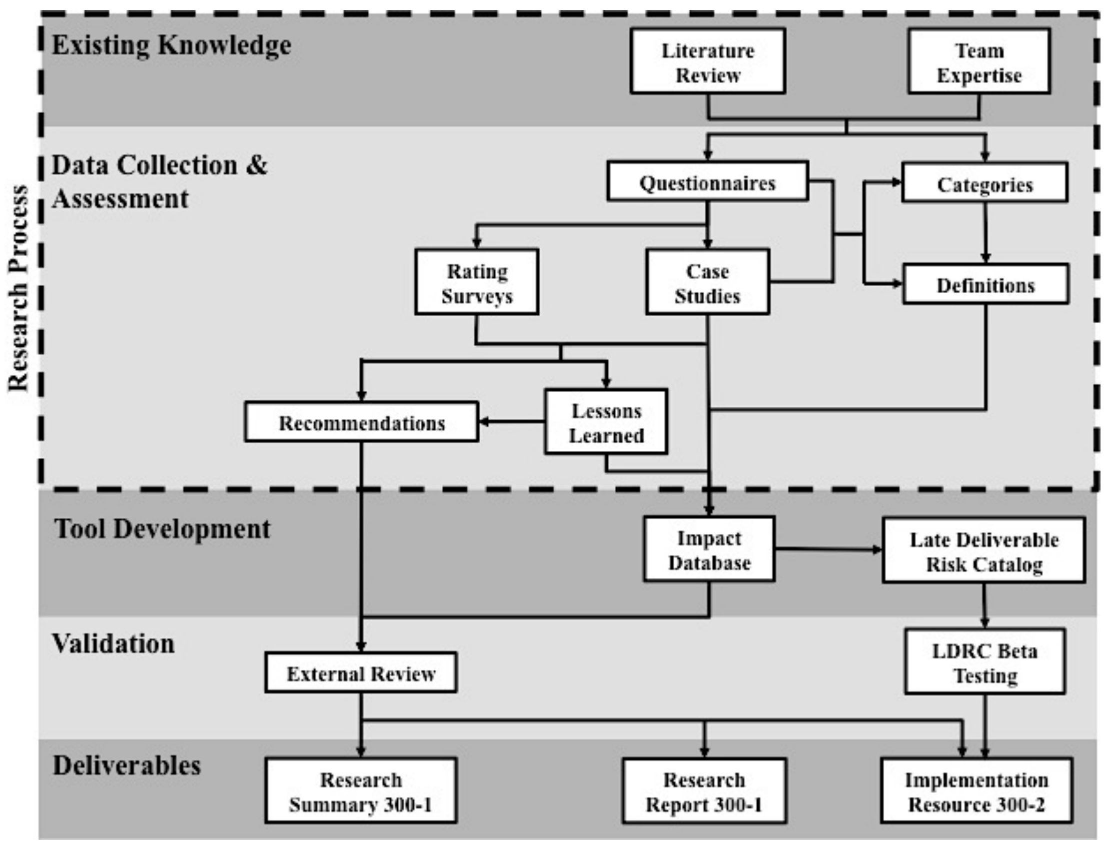


Figure 1: Research Overview

With the first research thrust in mind, the research team started with a combination of existing knowledge from industry and academic literature as well as professional expertise within the research team to begin identifying and describing the impacts of late deliverables as shown in Figure 1. Next, 'mini' case study questionnaires were developed and deployed to compile quantitative and qualitative data in order to increase the breadth of the research base. As the range of impacts and late deliverables expanded, the research team also implemented case studies to increase the depth of understanding of the topic. Each of the data collection techniques provided different information, but soon similarities and trends emerged in the data allowing the research team to categorize and define the late deliverables and impacts.

Concurrently with all of these efforts under the first focus, the team developed surveys and additional segments within the questionnaires to collect quantitative data towards the second research thrust. Altogether, the qualitative and quantitative data collected was used to develop lessons learned, prevention and implementation recommendations, and a database tool to communicate risks to project teams in the form of the Late Deliverable Risk Catalog. Finally, as shown in Figure 1, the team conducted beta testing and external validation prior to publishing the final deliverables.

2.1 EXISTING KNOWLEDGE

The research team began compiling information using knowledge from existing sources and from the combined expertise of the team members. This provided the research team a base from which to plan and create methods to extract knowledge from the construction industry as a whole. As the team noted, the information being collected was not new knowledge, but was rather "tribal knowledge" with little previous effort put into consolidating and recording how late deliverables impact construction projects.

2.1.1 Literature Review

The review of existing literature provided the research team with a starting point from which to begin creating a more comprehensive list of both late deliverables and subsequent effects. Existing CII products were reviewed along with academic and industry sources. As expected, an abundance of sources cited various types of late deliverables as reasons for all types of changes to a construction project. The impacts found in literature are far-reaching and difficult to categorize, but the effects have been documented in a range of studies covering different topics. Two primary types of studies have been previously conducted in relation to late deliverables. First, many studies investigating a specific impact or change on project have cited late deliverables as one of the causes. For example, separate studies into worker motivation and satisfaction, construction and engineering delays, cost overruns, material handling, supply chain management, and project quality performance all cited various types of late deliverables as possible causes. Second, several studies examined the impacts of a specific types of late deliverable. For example, investigations into the delivery of permits, certain types of engineered equipment, engineering and design documents, and material availability identified risks associated with each. However, no existing research has examined the full breadth and depth of the types of late deliverables and the risks they pose to construction. The full literature review can be found in Chapter 3.

2.1.2 Collective Team Expertise

Interviews and brainstorming sessions were conducted with the team members of RT 300 to further understand how late deliverables impacted projects and create a starting point from which to build the database of late deliverables and impacts. The membership of the research team had a total of 324 years of experience in the construction industry and included an equal split of owner and contractor representation, which provided insight from both perspectives on each topic discussed. The team had an average of over 23 years experience each, and Figure 2 below shows a breakdown of the experience of owners and contractors.

Figure 2: Summary of Team Experience

These interviews and brainstorming were not conducted in relation to any particular project, but rather to gather information from the many years of combined experience of the team members, who represented several different levels within their respective organizations from construction and project managers to upper management, all with expertise in construction. Using the knowledge of past late deliverables to construction sites and using expertise to predict other impacts, the research team members created "flow" charts for the purpose of capturing their thoughts on the impacts of specific late deliverables for each pillar. For example, one or more team members would create a "flow chart" by starting with one type of late deliverable and one pillar and then brainstorm specific impacts from past experience in the industry. Then, the same would be done for a different pillar with the same late deliverable, and this process was completed for most all combinations. One such chart is shown below in Figure 3 with a detailed view in Figure 4 showing thoughts captured regarding the safety impacts of late construction equipment.

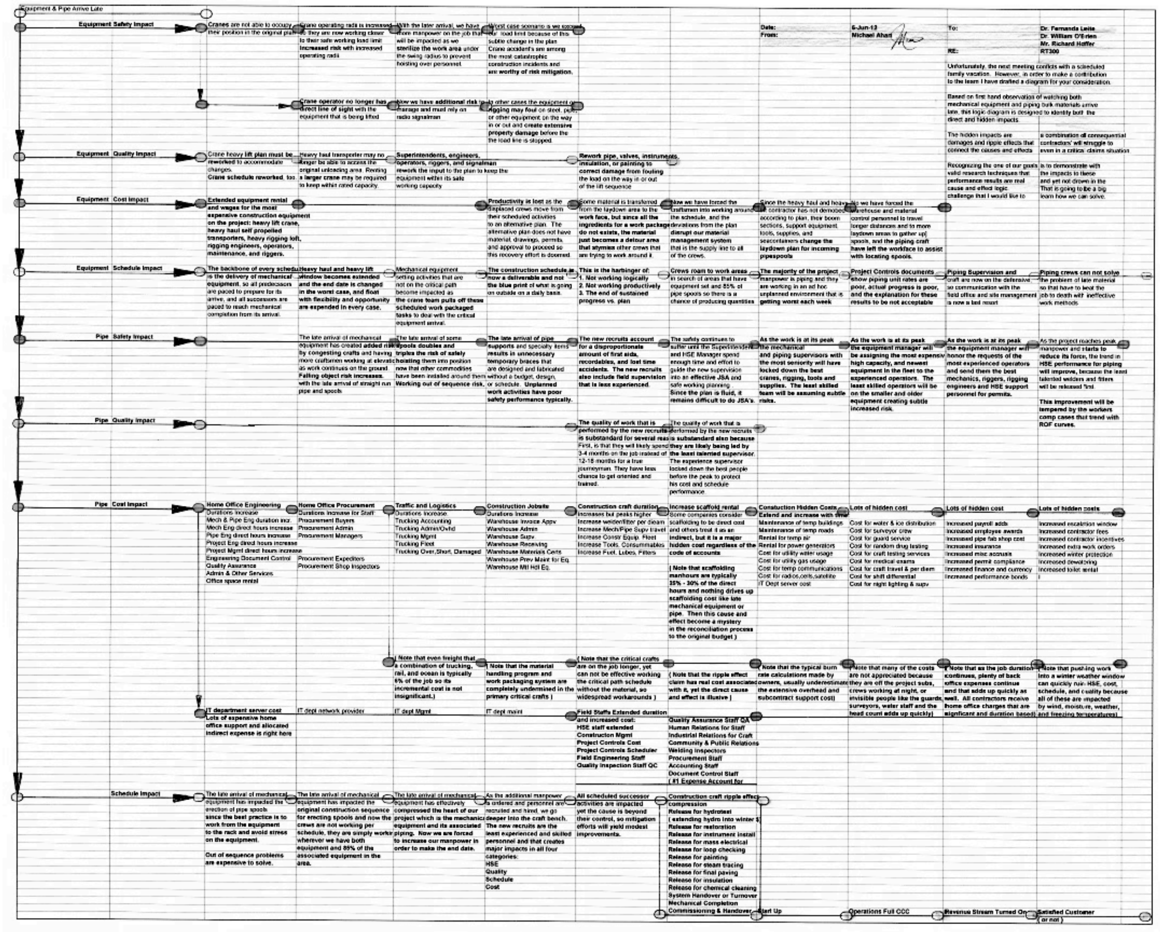


Figure 3: Brainstorming Flow Chart

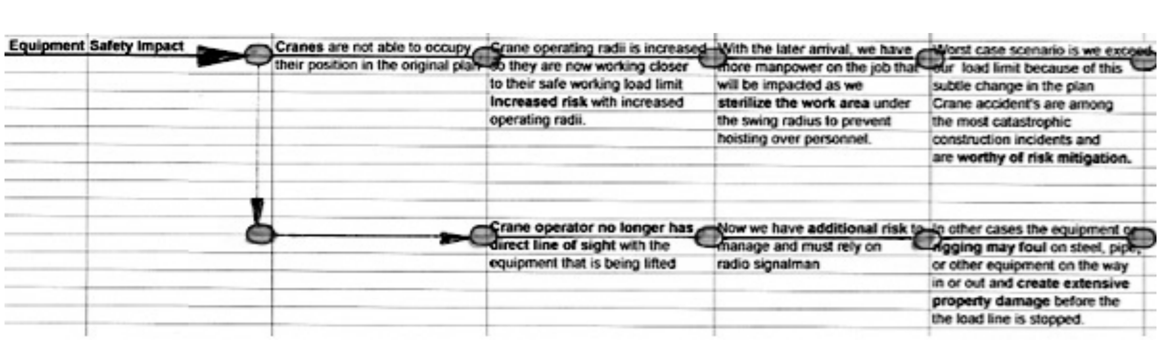


Figure 4: Detailed View of Flow Chart

Using these methods, the research team was able to synthesize a first draft of categories to encompass the list of potential late deliverables compiled thus far as part of the first research focus. The collective team expertise was also used to create a list of actual and theoretical impacts of late construction deliverables, and these impacts were then synthesized into categories of similar impacts to be refined further. The research team also compiled lessons learned, leading indicators of late deliverables, and recommendations for improving project delivery based on the results of the surveys, questionnaires, and case studies, which are included in Chapter 8.

2.2 Data Collection & Assessment

After reviewing existing literature and consolidating the team's internal experience and expertise, the research moved into the data collection and assessment phase. Within this section, each specific research tool is described, with the results of the research found in later chapters.

2.2.1 Industry Surveys & Questionnaires

A second research tool introduced for data collection was surveys and questionnaires administered to construction industry members. The surveys and questionnaires were administered in several mediums at various points in the research timeline: the first during an interactive presentation of the research project at an industry forum, the second for distribution to construction industry members for quantitative and qualitative data, and the third online and in person to rate the commonality and severity of late deliverables and impacts after the categories had been finalized. Each survey implementation is described in detail subsequently.

CURT Conference Interactive Presentation

The first round of industry surveys was completed very early in the research project at the 2012 Construction Users Roundtable (CURT) National Conference, held in November 2012, as an interactive presentation. The outline of the research project was presented with audience questions interspersed throughout. For example, questions asked how often late deliverables affected construction projects, how often each of the five pillars was impacted, what are the most common late deliverables, and how late deliverables impact planning, management efforts, and labor. With the qualitative and perception-based responses, the research team was able to further refine the research targets and to gain insight into the industry member's thoughts on late deliverables and the research effort. The feedback from this survey also assisted in the development of the 'mini' case study questionnaires. The presentation in its entirety can be found in Appendix A.

'Mini' Case Study Questionnaires

Several revisions were made to the interactive survey questions and new questions were added to create a formal questionnaire. Subsequently, the questionnaire was converted to both paper and electronic versions and distributed to CII and CURT member companies for completion by construction professionals either online or in person at the CURT Winter Member Meeting in February 2013. The questionnaire was developed by the research team to gather quantitative and qualitative data with both research focuses in mind. First, questions asked about late deliverables and consequent impacts from the respondent's past experiences. Each respondent was asked to consider a single past project when answering the questions in the survey so relationships between specific late deliverables and their subsequent impacts could be retained. Questions covered general project information such as delivery method, contract type, project sector, and overall cost as well as specific information regarding the use of front-end planning, stage-gate processes, and similar company-specific information. The survey then moved into the types of late deliverables on the project and the subsequent impacts along with how these effects were handled by the project team. Additional questions regarding contingencies, replanning, the critical path, progress monitoring, turnover, and other related topics were also included, mostly asking for yes or no responses. The entire questionnaire can be found in Appendix B. The 54 responses to the questionnaires were treated as 'mini' case studies and were used to help expand and validate the categories of late deliverables and impacts. Beyond the types of late deliverables and impacts, the 'mini' case studies were used to collect quantitative data regarding late deliverables including the most common types of late deliverables, how often contingency is adequate in compensating for late deliverables, the types of human resources most often added to projects with late deliverables, and the relative impact late deliverables have on each project pillar. This assisted the research team in collecting quantitative data for the second research focus, which will help the industry recognize where improvements can be made beyond just relating the types and impacts of late deliverables.

Rating Surveys

A third survey was distributed among CII member companies and at the 2013 CURT National Conference in November 2013 and with the purpose of ranking the various types of late deliverables and impact categories (whose development is discussed subsequently in Section 2.2.3) with respect to commonality, or frequency, and severity. This survey consisted of five questions, with the first being whether the respondent worked for an owner, contractor, or engineering company. The next four questions were based on a one to four Likert-type scale, and the respondent rated the commonality and severity of each type of late deliverable and impact from late deliverables that the team had developed. An important distinction here is that the respondents were asked to rate, rather than rank, the frequency and severity for each category, meaning that the same rating could be given for multiple categories instead of having to order them. This allowed respondents to rate each category relative to all other categories and give responses along a range capturing how strongly "affected" they were by the subject. The 240 responses to the survey provide valuable quantitative insight regarding which late deliverables are the most important and indicate which impacts due to late deliverables should be most closely monitored and mitigated. Furthermore, the results were split by company type, and this revealed several differences in how late deliverables are viewed depending on the role in a project.

Eight versions of this survey were distributed with random orders assigned to the answer choices to prevent bias in the answer choices; Appendix C contains the full version of one of the eight versions of the rating survey. The survey was designed to prevent both recency and primacy bias by randomly ordering the answer choices. Another possible bias is the thought that respondents would be more likely to remember more severe late deliverables and impacts they have experienced making the most severe seem the most frequent, or that the most frequent late deliverables are constantly troubling projects making them seem the most severe. While this may be a possibility, other forms of bias such as telescoping bias and fading affect bias may also have the reverse effect on memory. In addition, the n-value for the survey is sufficiently high to reduce the effects of individual biases. All together, these aspects work to minimize bias in the survey responses.

2.2.2 In-Depth Case Studies

The primary method for data collection was in-depth case studies of recently completed or near complete construction projects, which were selected based on several criteria. The primary criterion for the case study selection was to fulfill each late deliverable category established by the team using the other data collection strategies. Other secondary criteria were used to maintain variety in the nine case studies selected, and these, as well as the primary late deliverable categories fulfilled, are displayed in Table 1.

Each in-depth case study was comprised of several interviews with project team members at the company interviewed along with an investigation of relevant project schedules, cost breakdowns, safety reports, change orders, and other project documents. A minimum of three interviews were conducted for each case study with project team members at various hierarchical levels as well as across company divisions, which allowed for varying perspectives and areas of expertise to expand and validate the information gathered during the case study. Standardized cost and schedule data was also gathered along with any pertinent safety information (recordables, near misses, first aids) and quality documents (non-conformance reports, field change notices). This information was supplemented with project team knowledge to create a narrative surrounding each late construction deliverable and its true impacts on the project. It should also be noted that these case studies allowed RT 300 to enhance the depth of knowledge using actual impacts from previous projects in the research products.

An executive summary of each case study can be found in Chapter 4. Several lessons learned were developed for each case study and are included with each executive summary and analyzed in Chapter 8. Finally, an abbreviated transcript of the individual interviews conducted for each case study is located in Appendix D.

Table 1: In-Depth Case Study Development Criteria

	Company	Sector	Project	Location	Site	Known Late Deliverables	Late Deliverable Category Fulfilled
1	Contractor	Mining	Material Handling System	Northeast	Greenfield	Environmental Permits, Site Access	External Permits
2	Contractor	Oil & Gas	Fuel Farm	Southeast	Brownfield	Updated Specifications	Engineering Documents, Approvals & Responses
3	Owner	Oil & Gas	Offshore Platform	Asia	Greenfield	Structural Steel	Fabricated Materials
4	Contractor	Oil & Gas	Refinery	Southwest	Brownfield	Process Vessels	Engineered Equipment
5	Contractor	Power	Air Quality Control System	South	Brownfield	Crane Parts, Scope & Engineering	Construction Equipment; Engr. Documents, Approvals & Responses
6	Owner	Industrial	Processing Plant	Midwest	Brownfield	Contractor Crews, Engineering & Work Plans	Human Resources; Engr. Documents, Approvals & Responses
7	Contractor	Industrial	Processing Plant	Southwest	Greenfield	Bulks & Tagged Items, Pipe Spools, Modules	Bulk Materials; Fabricated Materials; Prefabricated Assemblies
8	Contractor	Industrial	Manufacturing Plant	Southeast	Brownfield	Underground Utilities	Utilities & Infrastructure
9	Contractor	Power	Combined Cycle Power Plant	Southwest	Brownfield	Project Execution Planning, Permits	Project Execution Planning; External Permits

2.2.3 Categories and Definitions

As the research progressed, RT 300 recognized the benefits of organizing the potential late deliverables to construction into categories. After creating an exhaustive list of potential late deliverables during the data gathering process, the team identified similar groupings of late deliverables and acknowledged that related late deliverables would have similar impacts. Therefore, the categorization of the late deliverables would simplify the study and its products without sacrificing depth in the research. After consolidating the known late deliverables into the related groups, ten encompassing late deliverable categories resulted and were then defined with examples to provide clarity and simplicity for users. While enumerating every single potential late deliverable was not feasible nor within the scope of the research project, every significant late deliverable identified during the research process fits into the ten categories listed below in Table 2 under Late Deliverable Categories. All ten categories are defined in Chapter 5.

Table 2: Late Deliverable and Impact Categories

Late Deliverable Categories	**Project Impact Categories**	
Engineering Documents, Approvals, and Responses	Scope Changes	Management/Supervisor Work
	Productivity	Personnel Turnover
Engineered Equipment	Engineering/Design Work	Procurement, Logistics, and Expediting
Fabricated Materials	Work Resequencing	Onsite Team Dynamics
External Permits	Overtime and Shift Work	Work Relocation
Prefabricated Assemblies	Critical Path Management	Onsite Material Handling
Project Execution Planning	Commissioning and Start-Up	Alternative or Additional Suppliers and Vendors
Human Resources	Rework	Liquidated Damages, Claims, and Bonuses
Utilities & Infrastructure	Craft Levels/Density	Alternative or Additional Tools and Equipment
Bulk Materials	Downtime	Offsite/Company Dynamics
Construction Equipment	Project Risk Profile Changes	Damage, Degradation, and Loss
	Indirect/Overhead Costs	Training Resources

Furthermore, RT 300 found that the impacts of late deliverables are even more numerous and diverse than the deliverables themselves. Similar to the effort to organize the potential late deliverables, RT 300 recognized that grouping the identified impacts into categories would be beneficial to understanding the research and implementing its products. After creating an extensive list of impacts identified through case studies, surveys, and interviews, the research team established 24 Project Impact Categories (also in Table 2) to encompass the recognized effects that a late deliverable can have on a project. However, it should again be mentioned that every impact on all projects cannot be cited in a single research effort. Therefore, the categories are representative of those impacts found by RT 300 but can be expanded to include information from other companies, projects, and construction sectors.

2.2.4 Lessons Learned and Recommendations

Paralleling the data collection effort, Research Team 300 also developed lessons learned and recommendations to assist the construction industry in preventing late deliverables and managing the impacts they have on projects. Many of these case study lessons learned incorporated the ideas of the project team members interviewed for each case study. Meanwhile, recommendations were developed for implementing the research into company processes and recognizing and preventing the most common late deliverables according to the data collected. Both the lessons learned and recommendations can be found in Chapter 8.

2.3 TOOL DEVELOPMENT

The development of the industry tool evolved as the research progressed; it began in earnest with the brainstorming "flow charts" depicted in Figure 3 and Figure 4. This provided a way of capturing knowledge of impacts and subsequent effects caused by specific late deliverables. However, as the list of late deliverables and impacts lengthened and the information from case studies and questionnaires expanded, this method of capturing the knowledge by hand and in Excel became insufficient. The primary concerns with this recording method were the inability to capture all of the relationships in the data and connect multiple impacts to late deliverables and vice versa. Therefore, a database was created in Microsoft Access to catalog the information using faceted classification and run as the back end of a graphical user interface.

Rather than use the query function in Microsoft Access (a program with which many are unfamiliar or do not have access to), the team decided to create a web-based interface to serve as the front end of the database. The objective was to make an intuitive and simple tool that allowed for faceted navigation of the hundreds of individual impact database entries and that would pull in both the definitions and case studies developed by the team. A web-based approach was chosen to allow for access from locations outside the office, such as in the field or with a client/owner, and so that modifications and additions, as discussed in the implementation recommendations in Chapter 8, would be updated for all users from a central database. The resulting interface was named the Late Deliverable Risk Catalog (LDRC). As shown in Figure 5, the end user will interact with the LDRC, which has been programmed to display both the case studies and definitions and communicate with the impact database. This communication between the LDRC and the database will be two ways: the LDRC will communicate to the database what selections the user has made and the database will return the query results.

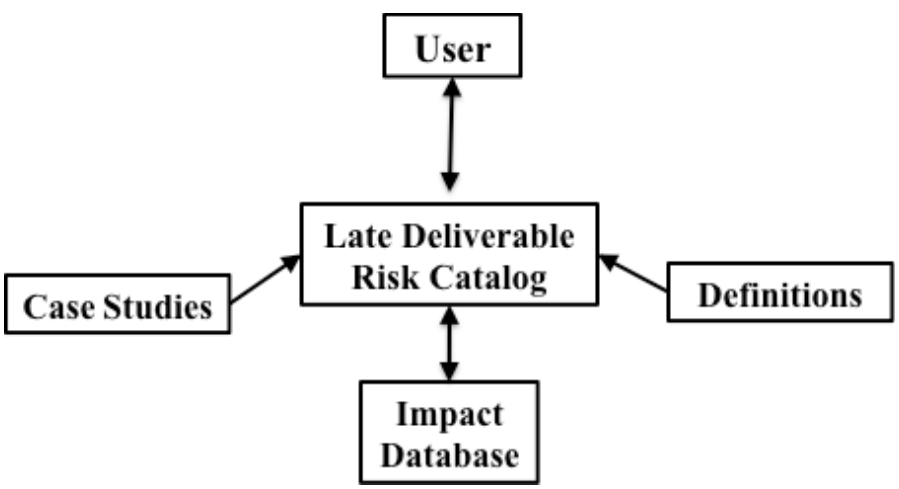


Figure 5: Late Deliverable Risk Catalog Interaction Diagram

The overarching goal for this tool is to communicate potential risks to project teams. This is accomplished by allowing industry users to quickly and easily navigate the entire list of potential impacts by narrowing down the search return based on the selections made. This will provide an individual or team with a list of potential impacts and risks that is both manageable and applicable to a certain project or situation. Chapter 6 includes detailed instructions for using the LDRC, an outline of potential uses developed by RT 300, and explanations of several example applications of the tool.

2.4 VALIDATION

After the data collection was completed and the first version of the Late Deliverable Risk Catalog and publications were created, RT 300 submitted the products to an external review. This was conducted in two phases. First, the LDRC was beta tested by several companies, and, second, experts outside the research team reviewed the Implementation Resource 300-2. This validation process was conducted to ensure there was a need in the industry for this research, the products were both understandable and applicable, and that the research and tools sufficiently addressed the gaps in industry knowledge.

2.4.1 Late Deliverable Risk Catalog Beta Testing

The beta version of the LDRC was forwarded to several project teams within CII member companies, and testers were asked for feedback regarding usability, suggestions for improvement, and possible industry applications. Overall, the testers felt there was a definite need for the tool, and the full range of late deliverables, while known through the experiences of many, had not been combined and encapsulated for the industry. They also noted that, while the list of risks seemed overwhelming, the list could be easily condensed using the filters. Suggestions for improvement that were incorporated into the tool included a tree functionality to further organize the impact descriptions as well a function to generate a report or print-out to be used or shared when offline. In addition, several possible applications of tool, such as training and knowledge sharing, were suggested and have been expounded upon in Chapter 6.

2.4.2 External Review

Prior to final submission of the research deliverables, RT 300 submitted the Implementation Resource for review to both CII and volunteers external to the research project. After reviewing the document, 30-60 minute interviews were conducted with each expert to learn how the publications could be improved and how each reviewer foresaw the Late Deliverable Risk Catalog and associated documents being used by the construction industry. A brief overview of the reviewers' backgrounds and a summary of the feedback can be found in Chapter 9, and the interview questionnaire is included in Appendix E.

2.5 RESEARCH DELIVERABLES

Research Team 300 has documented the results of this research effort in several CII publications and products. The industry and academic team members wrote these deliverables with practical application and industry use in mind. Research Summary 300-1 delivers a high-level overview of the research process with a focus on providing a comprehensive summary of the project to provide context and validity for industry users. The second published deliverable of RT 300, Implementation Resource 300-2, accompanies the Late Deliverable Risk Catalog and provides instructions and recommendations for applying the findings of the research, using the LDRC, and incorporating the products into company processes. IR 300-2, published in two volumes, also includes the full set of definitions and case studies developed by the team. The Late

Deliverable Risk Catalog is an online tool created to help project teams effectively identify impacts caused by late deliverables and how the five project pillars, cost, schedule, safety, quality, and organizational capacity, are influenced by late deliverables. Finally, Research Report 300-11 was written primarily by the academic team members to provide an in-depth look into the research methods, tools, and analysis employed throughout the research project.

Chapter 3: Literature Review

As discussed in the research methodology, Research Team 300 began by examining existing literature to begin the process of understanding late deliverables and how they can impact construction projects. This chapter begins with an overview of the existing literature followed by specific reviews of relevant literature. The final section includes a brief discussion of the findings from the literature review and how the team's research questions aim to fill the gaps in existing knowledge.

3.1 Overview

The construction industry is an integral part of a country's economy, yet it is an industry constantly plagued by poor cost, schedule, and safety performance, low profit margins, poor productivity, compromised quality, price escalation, and a lack of innovation worldwide (Yeo and Ning, 2004). Of the countless factors that lead to these performance issues, materials delivery and handling has been identified as a major concern for the industry. A significant amount of research has been conducted within the field of construction supply chain management, materials management, stakeholder relationships, and work packaging in an attempt to improve the reliability of construction material delivery and coordination on site. However, supply chain materials represent only a fraction of the late deliverables to construction sites that can adversely affect the time, cost, quality, and safety performance of the industry. Very little existing research investigates the full spectrum of resources (information, support, manpower, etc.) that must be in place for a project to succeed, and these resources are often poorly tracked throughout a project. Moreover, the broad impact of late deliverables to construction projects is even less understood.

To begin its study of late deliverables, RT 300 looked to existing industry and academic sources to begin to compile knowledge on the topic. The study of relevant literature revealed that there is great variety in potential late deliverables, and the impacts caused by each are similarly numerous and diverse. The impacts found in a literature review are far-reaching, but several effects have been well documented in a range of studies of differing topics. Previous industry and academic literature has focused primarily on two topics: investigating specific late deliverables and looking into the sources of change on projects, one of which is often late deliverables.

3.2 STUDIES OF IMPACTS

Many studies into changes on construction projects cite late deliverables as a source. The studies investigate change to all aspects of a project, including the five pillars set forth by Research Team 300: cost, schedule, safety, quality, and organizational capacity. While organizational capacity was not included in the original RT 300 charter, it quickly became clear that the fifth pillar was an important contributor to project success. As far back as 1972, studies in construction motivation revealed that crews were demotivated by a lack of materials and tools, foreman were dissatisfied with poor working arrangements such as missing essential materials and equipment, and superintendents were frustrated by delayed architectural and engineering drawings to the site (Borcherding, 1972). From this, it can be deduced that field workers at all levels are dependent upon proper resource management not only for effective work and productivity, but also for job satisfaction. While the impacts late deliverables have on construction crews are important, RT 300 recognized that this is just a fraction of the impacts to an organization as a whole. For this reason, organizational capacity was expanded to include company and team dynamics that are rarely tracked in construction projects.

Along with impacting organizational capacity, it is well known that late deliverables can lead to construction delays, and that changes to the construction schedule are huge impediments to project success. Knowing this, significant amounts of research have investigated the various causes of construction delays, and several studies have explicitly drawn the link to late deliverables. One study examining the causes of construction delays in Hong Kong attempted to enumerate and rank the most significant factors that delayed building projects using interviews of contractors, clients, and consultants. In this study, relative importance indices were assigned to each group using the feedback from industry professionals. Of the top ten factors identified as causes of delay, three of the hypothesized factors in the study can be directly associated with late informational or physical deliverables to the construction site. These factors include delays in design information (#3), delayed decisions needed in the field (#6), and ineffective resource availability and allocation (Kumaraswamy and Chan, 1998). This is just one of many studies that explicitly cite late informational and physical deliverables as major hindrances to successfully maintaining a project schedule.

Continuing on the schedule pillar, it is essential to assess risks to the construction schedule by identifying additional resources that, if not available at the right time, can delay the project. Mulholland and Christian identified 85 specific risks to project schedules, with on-time delivery of resources and one of the highest risk factors for the procurement phase (Mulholland and Christian 1999). A similar study into the causes of delay to large construction projects revealed 73 causes of delay for projects in Saudi Arabia (Assaf and Al-Hejji, 2006). Lateness and unavailability of resources made up 26 percent of the observed delay causes for the sample of projects, and Table 3 below shows the causes for delay related to late deliverables. Worth noting, every project stakeholder can cause delay through late delivery of required information, materials, or human resources. With this knowledge, RT 300 was better able to evaluate all the sources of late deliverables to begin creating an exhaustive list of late deliverables.

Table 3: Causes of Delay on Construction Projects Attributable to Deliverables

Causes of Delay	Responsible Group
Delay in progress payments by owner	Owner (Client)
Delay to furnish and deliver the site to the contractor by the owner	Owner (Client)
Late in revising and approving design documents by owner	Owner (Client)
Delay in approving shop drawings and sample materials	Owner (Client)
Slowness in decision-making process by owner	Owner (Client)
Delay in site mobilization	Contractor
Delay in performing inspection and testing by consultant	Consultant
Delay in approving major changes in the scope of work by	Consultant
Late in reviewing and approving design documents by consultant	Consultant
Delays in producing design documents	Architect or Engineer
Delay in material delivery	Material (Procurement)
Delay in manufacturing special building materials	Material (Procurement)
Late procurement of materials	Material (Procurement)
Late in selection of finishing materials due to availability	Material (Procurement)
Shortage of equipment	Equipment (Procurement)
Shortage of labor	Labor (Contractor or Sub.)
Delay in obtaining permits from municipality	External Party
Delay in providing services from utilities (such as water, electricity)	External Party
Delay in performing final inspection and certification by a third	External Party

Adapted from: Assaf, S.A. and Al-Hejji, S. (2006). "Causes of Delay in Large Construction Projects". In: International Journal of Project Management, 24, p. 349-357.

Another potential late deliverable that can cause serious delays to a construction project is permits, which can be internal or external to the project. One study found that building permit approvals are the most critical cause of delay for a selection of 380 building projects in the state of Florida. The same research found that late fabricated materials were the third most common cause of construction related delay. Perhaps more revealing is the identification of these two causes of delay as having an occurrence of greater than 50 percent in the sample of projects (Ahmed et al, 2002). A similar study of 130 residential and small commercial projects also found that late materials and equipment were a major cause of delays along with notices to proceed being later than scheduled (Al-Momani, 2000). These two studies confirmed the decision made by RT 300 to include information deliverables (permits, approvals, and responses) in the scope.

Beyond schedule the schedule pillar, cost overruns are another impact that can hamper project success. Recently, a study into the causes of construction cost overruns in Malaysia found that the late delivery of materials was the tenth most significant factor faced by contractors and the late delivery of equipment was the thirteenth most common source of cost overruns (Rahman, Memom and Karim, 2012). As shown below in Table 4, late delivery of equipment was ranked just below materials and was the highest ranked machinery related cause of cost performance issues according to the contractors interviewed. Furthermore, "late or irregular delivery or wrong types of material delivered during construction affect the utilization of other resources like manpower and machinery" and can lead "to poor productivity, time delay and cost overrun" (Rahman, Memom and Karim, 2012). Beyond the material and equipment deliverables, the study also cites labor shortages also as one of the top causes of cost overruns, which could be attributed to late human resources depending on the situation. Given that cost performance is one of the most tracked indicators of project success, it is important that the connection between these late items and cost performance is established. RT 300 used this knowledge to begin investigating the effects of late deliverables on the cost pillar.

Table 4: Ranking of Factors Affecting Project Cost According to Contractors

Rank	Factor	Mean Ranking	Category
4	Shortages of Site Workers	10.08	Manpower
10	Late Delivery of Materials	8.24	Material
11	Late Delivery of Equipment	8.20	Machinery

Adapted from: Rahman, I., Memom, A., Karim, A. (2013). "Relationship between Factors of Construction Resources Affecting Project Cost". In: Modern Applied Science, 7(1), p. 67-75.

It has also been shown that late deliverables can impact project quality along with schedule and cost performance. A study in lean construction found that the "late delivery of drawings and materials which lead to contractors pressurizing for quicker response" could cause lower quality performance on fast track projects (Kumar, 2010). The same study found that although schedule buffers can help shield contractors from late deliveries, the "shielding is expensive, in both time and money." Similarly, when management attempts to make up for delays by exerting pressure on crews to work faster, implementing overtime, and/or hiring additional crews, the short-term progress may improve but at the expense of several identifiable consequences (Ford, Lyneis and Taylor, 2007). Working faster or for longer hours increases the risk for quality errors and reduces productivity, and increasing staffing levels reduces short-term productivity while new crews are trained and long-term productivity from the inherent inefficiencies of a crowded worksite. Beyond these primary impacts, potential secondary "knock-on" impacts include out of sequence work, trade stacking, increased work to fix errors, and organizational impacts such as increased turnover and lower morale. Altogether, these changes can increase the safety risk on site.

3.3 STUDIES OF LATE DELIVERABLES

While several studies investigated specifically the impacts to the five project pillars, others focused on the studying how various types of deliverables can affect projects. While most of these studies did not focus solely on lateness, late delivery was recognized as one of the risks leading to severe impacts. The existing literature in this field focuses primarily on two general groupings of deliverables: materials and information.

To begin, several studies examined how various material deliveries can affect projects. Research into the procurement of engineered equipment, with its inherent time and schedule uncertainty, has revealed several different project impacts in comparison to late bulk materials. One study distinguished engineered equipment, in contrast to bulk materials, as major “capital equipment that will be assembled or installed to form an integral part of the constructed system or facility” (Yeo and Ning, 2004). Major engineered equipment is characterized by several risks that could provide insight into the root causes of late delivery. These risks include long lead times, incorporation of complex or specialized technology, and lack of inventory buffers. These risks are compounded by the typical location on the critical path and one-of-a-kind nature. The research continued with a survey of industrial/process, building, and civil construction projects with significant engineered equipment requirements. The responses showed that major equipment made up about 36 percent of the overall procurement costs for the projects, 50 percent of that equipment was delivered just-in-time, and around 20 percent was delivered late. Results highlighted the importance of regular communication between stakeholders, expediting late deliveries, and the importance of on time delivery to project performance (Yeo and Ning, 2004).

In recent years, significant research has been performed in the fields of construction material management and construction supply chain management. Late deliverables can have substantial impacts on materials management on the construction site. As shipments arrive out of order, material handling may increase and flexibility to accommodate changed work sequences becomes a necessity. In a case study examining a delayed shipment of steel, researchers noted the haphazard unloading of the late shipment with no regards for the construction sequence and, when construction resumed, material handling and the required time increased significantly (Thomas, Sanvido and Sanders, 1989). The storage area became crowded with steel and the condition continued for several days until the erection process was back on track. Meanwhile, the erection crews were forced to demobilize while waiting for the steel to arrive and, upon remobilization, had to work in very crowded and difficult conditions.

Donyavi and Flanagan investigated the how material delivery and availability can impact small and medium sized construction projects (2009). The most common problems with materials for the projects studied included interruption to the work schedule, rework from having the wrong or out-of-order materials, and double handling because of inadequate materials. These main problems were an effect of materials being delivered at the wrong time and the lack of information provided for materials arriving on site, among others. Additional issues that could be experienced include material deterioration during extended storage, expenses associated with crews lacking the proper materials, and lost items on or off site.

Beyond the physical construction materials required to complete a project, informational deliverables can have an equally significant impact on a project's success. Ballard of the Lean Construction Institute points out that, with the overlap of the design, procurement, and construction phases in EPC projects and lean construction, engineering has become a supplier to construction (1993). The engineering firm must provide drawings and specifications to procurement and construction teams in the same manner as external suppliers. Although these engineering deliverables are "critical inputs" to construction just like materials, one of Ballard's studies of an industrial project found that, on average, "more 30 percent of engineering deliverables were behind schedule." In addition, the average number of days beyond the scheduled delivery milestones was 56 days, but this project still finished on schedule (1993). An investigation by Ballard of the root causes of engineering delays revealed that inadequate materials, non-standardized processes, poor goal setting, and inability to understand or manage risk were common occurrences on the project. The construction phase "was usually able to absorb the late and out-of-sequence delivery of drawings and materials, but at a tremendous cost" (Ballard 1993). However, beyond cost and schedule impacts, no further pillars were investigated in relation to information deliverables.

3.4 DISCUSSION

The sources reviewed in this chapter helped Research Team 300 begin to enumerate and organize the types of late deliverables and resulting impacts, which was the first research thrust. While both emphases in literature – changes on project and types of deliverables – have contributed greatly to the knowledge surrounding late deliverables in the construction industry, no previous studies have investigated the full range of late deliverables or how they impact specific projects and the construction industry. With this gap in knowledge, RT 300 refined its research questions to address the full range of impacts from all types of late deliverables.

Refining this goal further, RT developed research focus areas to address the knowledge gap. First, the research team aimed to quantitatively and qualitatively describe the types and impacts of late deliverables using case studies and expert interviews. Furthermore, the team recognized the lack of existing knowledge regarding late deliverables from the perspective of recognition and prevention as a secondary goal. With this in mind, RT 300 developed a research methodology to identify the impacts of late deliverables to construction by consolidating industry knowledge and collecting new data.

Chapter 4: Case Studies

Included in this chapter are executive summaries for each of the nine in-depth case studies conducted by RT 300. The case studies were selected to represent each late deliverable category, and this is listed in the section headings. Each executive summary follows the same format, starting with a table indicating the late deliverable(s) and impacts experienced on the project. Following, there is a short profile of the company and project. Finally, there is a written narrative describing how the late deliverables affected the project and a listing of lessons learned and descriptions from the project team.

4.1 Case Study #1: Late External Permits

Case Study #1 examines the impact of late external permits to a construction site. A late environmental permit interrupted the construction of a mining conveyor system that crossed state lines. Presented in bold in Table 5 below are the applicable late deliverables and project impacts for this case study project.

Table 5: Case Study #1 Late Deliverables and Impacts

Late Deliverable Categories	Project Impact Categories	
Engineering Documents, Approvals, and Responses	**Scope Changes**	**Management/Supervisor Work**
	Productivity	**Personnel Turnover**
Engineered Equipment	Engineering/Design Work	Procurement, Logistics, and Expediting
Fabricated Materials	**Work Resequencing**	**Onsite Team Dynamics**
External Permits	Overtime and Shift Work	**Work Relocation**
Prefabricated Assemblies	**Critical Path Management**	**Onsite Material Handling**
Project Execution Planning	Commissioning and Start-Up	Alternative or Additional Suppliers and Vendors
Human Resources	Rework	Liquidated Damages, Claims, and Bonuses
Utilities & Infrastructure	**Craft Levels/Density**	**Alternative or Additional Tools and Equipment**
Bulk Materials	Downtime	Offsite/Company Dynamics
Construction Equipment	**Project Risk Profile Changes**	**Damage, Degradation, and Loss**
	Indirect/Overhead Costs	Training Resources

Company Profile

The general contractor in Case Study #1 provides construction, manufacturing, and engineering/design services throughout the U.S. and in several foreign markets. The general contractor, whose employees were interviewed for this case study, is a large, employee-owned corporation with projects in the mining, oil & gas, heavy civil, industrial, and manufacturing sectors.

Project Description

Case Study #1 provides an account of a 4.3-mile coal conveyer belt construction project. The project spanned two states, and moved coal from a mine across the state line to a coal power plant. The linear, greenfield worksite traversed very steep, hilly land and crossed several roadways and one large stream, and the general contractor was awarded a lump sum EPCI contract. The project was schedule driven because the conveyor system was integral to the set opening of the power plant. Table 6 below provides general cost, contract, and job information about the project in the case study. Table 7 provides general schedule information for various aspects of the project, with the baseline schedule providing a basis to identify changes in durations.

Table 6: Project Overview

Sector	Mining
Project Type	Material Handling
Construction Location	Southeast United States
Contract Type	EPCI/Lump Sum
Baseline Project Cost (TIC)	$41 million
Actual Project Cost (TIC)	$47 million
Baseline Contract Cost	N/A
Actual Contract Cost	N/A

Table 7: Project Schedule Overview

Task	Baseline Duration	Actual Duration	Difference
Total Project	30 months	40 months	+10 months
Engineering	16 months	19 months	+3 months
Procurement	12 months	19 months	+7 months
Construction	15 months	21 months	+6 months
Start-Up/Commissioning	3 months	7 months	+4 months

Late Deliverable and Impact Description

The late deliverable examined for this case study was environmental permits from one of the two state governments involved in the project. The beginning of the construction phase was contingent upon the arrival of the permits for both states, while engineering and procurement began according to the baseline schedule. The construction was scheduled to begin at the mine and proceed towards the power plant. All design, fabrication, and procurement was planned and completed in this order. However, procurement completed before the permits, which were not considered during front-end planning, were obtained from the state in which the construction was supposed to begin. Therefore, construction proceeded in the opposite direction.

Due to the delay, much of the planned work for the summer was pushed into the winter months, which were abnormally severe. This lowered project productivity, lengthened activity durations, and required extra safety precautions such as shoe spikes, space heaters, and harnesses to prevent slipping. The movement of materials to the worksite was difficult and hazardous during poor weather, and many parts of the site were inaccessible when icy. This, along with the arrival of materials before construction could begin, forced the project team to implement remote laydown areas where all materials had to be retagged for the new construction phasing. Additional cranes, trucks, and forklifts were needed for these laydown yards, and transportation to the site took extra time and money. Materials damaged due to extra handling and galvanized steel components that developed white rust from exposure had to be replaced. Rubber conveyor belts had to be stored in warehouses to prevent damage at extra cost. Limited preassembly occurred in the laydown area, but the nature of the work and the inability to transport large pieces curtailed this effort. Beyond this, the owner of the project had to fund a bond to repair the roads to and from the laydown yards that were damaged by heavy equipment and trucks.

When the delayed permits were finally released to the general contractor, work in the first state had completed and the site was nearly demobilized. When the permits were finally released, they were released in small segments rather than for the entire project site. Thus, crews were constantly relocated and split along the jobsite as new areas opened up for work. The start of the project was delayed by five months with the construction duration increased by almost 50 percent. Thus, the total project duration increased by almost one year. This prevented the management team from moving on to other projects and increased turnover among the crews, requiring additional training for new workers on site. The low productivity, inability to plan work ahead of time and see progress being made, and poor winter weather lowered crew morale and increased turnover further. Weekend work became the norm as additional shifts were needed to make up for slow progress.

Not all impacts to the project were negative. The owner and general contractor had improved relations after liquidated damages were rescinded and the change order process was streamlined. This allowed the owner and general contractor to improve communication and work together to complete the project. From an engineering perspective, the delays in permitting provided the time needed to complete the original design and make any changes required by the owner or regulatory agencies and permits were released, which reduced pressure and frustration among the engineering team.

Lessons Learned

a) Visibility is necessary for owner-acquired environmental permits during the Request for Proposal (RFP) and contract negotiation phases.

    The environmental permits were the responsibility of the owner to supply before construction work could begin on site. Had the contract included a "phase-gate process" for project authorization, this process would have allowed the owner and contractor to better control the commitment of resources dependent upon the status of owner-acquired environmental permits.

b) Project material storage and lay-down areas should be permitted and/or designed to be separate from the capital project areas.

    With the project material storage and laydown areas integral to the project site, the owner could not prepare the areas for the receipt of materials by the contractor until the receipt of permits. Once the permits were delayed, the receiving and storage of project materials became an important logistical challenge to manage because of this design. When the significance of this design was recognized, it was too late into the project to make significant design changes.

c) Interpersonal skills and the right contracting method can result in a constructive influence on how the project team manages the impacts of late deliverables.

    Soft skills are personality traits sought after in any leadership team; however, they are often not as useful without a fair contractual arrangement between parties. On this project, the soft skills of the owner's project manager along with a cost-reimbursable change order for the initial material double-handling impacts resulted in increased trust and teamwork between the project teams. Once the full impacts of the late deliverables were known, lump sum change orders were negotiated, but the baseline of these discussions was the relationships built during the initial cost reimbursable change order.

4.2 CASE STUDY #2: LATE ENGINEERING DOCUMENTS

Case Study #2 investigates the effects of late engineering documents on a construction project for a fuel farm system and how construction was impacted. The late deliverable as well as its impacts to the project are signified below in Table 8.

Table 8: Case Study #2 Late Deliverables and Impacts

Late Deliverable Categories	Project Impact Categories	
Engineering Documents, Approvals, and Responses	Scope Changes	**Management/Supervisor Work**
	Productivity	Personnel Turnover
Engineered Equipment	Engineering/Design Work	**Procurement, Logistics, and Expediting**
Fabricated Materials	Work Resequencing	Onsite Team Dynamics
External Permits	**Overtime and Shift Work**	Work Relocation
Prefabricated Assemblies	**Critical Path Management**	**Onsite Material Handling**
Project Execution Planning	Commissioning and Start-Up	Alternative or Additional Suppliers and Vendors
Human Resources	Rework	Liquidated Damages, Claims, and Bonuses
Utilities & Infrastructure	**Craft Levels/Density**	Alternative or Additional Tools and Equipment
Bulk Materials	Downtime	**Offsite/Company Dynamics**
Construction Equipment	**Project Risk Profile Changes**	**Damage, Degradation, and Loss**
	Indirect/Overhead Costs	Training Resources

Company Profile

The contractor for this project is a regional mechanical contractor with experience in the civil, oil & gas, piping, and mechanical sectors and has the ability to self-perform much of the work. For this project, the contractor was a subcontractor to a joint venture ("JV") between two large, international engineering and construction firms and also responsible to the owner's third party representative.

Project Overview

Case Study #2 looks into a fuel farm system that was constructed as a part of a larger airport development in the southeast United States. The project examined in this case study was on a brownfield site and involved the expansion of the existing fuel farm at the airport. It was a small part of the overall project for which the JV was responsible. The contractor was responsible for procurement and construction of the fuel farm using the design and specifications provided by the JV from a separate design firm. An overview of the project and schedule is shown below in Tables 9 and 10.

Table 9: Project Overview

Sector	Oil & Gas
Project Type	Transportation and Storage
Construction Location	Southeast United States
Contract Type	Lump Sum Subcontract
Baseline Project Cost (TIC)	$10 million
Actual Project Cost (TIC)	$14.5 million
Baseline Contract Cost	$6.1 million
Actual Contract Cost	$9.5 million

Table 10: Project Schedule Overview

Task	Baseline Duration	Actual Duration	Difference
Total Project	61 weeks	77 weeks	+16 weeks
Engineering	14 weeks	16 weeks	+2 weeks
Procurement	N/A	N/A	N/A
Construction	31 weeks	47 weeks	+16 weeks
Start-Up/Commissioning	8 weeks	8 weeks	0 weeks

Late Deliverable and Impact Description

The late deliverable investigated in this case study was the correct specification release to the construction teams. The designer inadvertently released the incorrect specifications to the JV, and they had been included in the Issue for Construction (IFC) documents. When the IFC was released to the contractor, the designer notified the JV of the mistake. However, the JV did not provide the correct specifications to the contractor for another 32 days. The updated specifications contained extensive additions and modifications to material and equipment that had already been purchased by the contractor under the outdated specifications. The project became schedule-driven as the fuel farm system had to be complete by a certain date as to not delay the overall project. The late specification release, combined with a prior 73-day delay for value engineering, pushed the finish date back approximately six months. The late deliverable itself directly increased the project cost by about nine percent.

When alerted to the mistake, the contractor worked to cancel and update previously placed orders for equipment and piping, and many of the items that had already arrived on site had to be stored in a warehouse. With the updated specifications, the contractor reordered the correct materials such as instruments and valves, returned items for credits lower than the original cost, and expedited new materials at additional cost. The reordering and handling process led to some damage to items as well as quality and sizing issues with materials such as underground piping.

The management team for the contractor had to revamp their entire project execution plan following the specification changes, and, in order to meet the "drop-dead" completion date, the schedule was accelerated and many activities compressed at an additional cost for labor and resources. The project manager attributed one safety incident to this acceleration. In addition, weekend work was implemented for critical path items, and the productivity of the workers decreased as planning ahead became more difficult after the delayed specification release. New workers were also added that were unfamiliar with both the safety and work practices on the site. The inability to plan ahead and the accelerated schedule also led to a drastic growth in punch list items.

One major safety and quality concern that arose from the late deliverable occurred during site preparation. The weather contingency was planned for site preparation to be completed in the winter, but this activity was pushed into the spring months. The ditches for underground piping and foundation excavations were vulnerable to collapse during heavy rainfall, and crews had to muck out the excavations several times and refill and recompact the foundations. In addition, shoring had to be used to maintain stability of the ditch sides after heavy foundations had been poured to prevent collapse during rainfall. This not only increased the safety risk profile on the project, but also accelerated the depletion of the time and budget contingencies.

As the mandatory completion date came closer, the JV and owner's rep began to allocate more resources to the fuel farm project. New safety personnel were continuously assigned to the project, which led to crews receiving mixed signals about procedures. Conversely, the addition of quality personnel and a third party assigned for testing the facility improved the project quality and was cited as a reason for project success due to the open communication and clarity provided to crews on quality expected for the work being done.

Three different project managers from the JV were assigned throughout the project, so the JV and owner received varying accounts of both the progress and the history of the project. This caused several disagreements between the contractor and JV along with crews and management and blame was passed around, so weekly meetings were set up to for the final months of the project to improve communication on the project and resolve disagreements helping to complete the project by the mandatory completion date.

Lessons Learned

a) Take time to formally review the potential impacts of a late deliverable, and then create a recovery plan that mitigates the impacts to the greatest extent possible.

Late deliverables are most often inconvenient, and many times they occur when the project is so busy no one has time to properly consider the impacts of the deliverable. At these times, it's easy to enter a reactionary mode and begin "fighting fires" as they arise. However, to maximize the chance of the project recovering from late deliverables, it would have been beneficial on this project to take a step back from the project and invest time in assessing future impacts and replanning the work.

b) Open lines of communication between project stakeholders, and, early in the project, provide means for document control and release.

In this case study, several small oversights in engineering and management created a much larger issues in the field. Creating these lines of communication and standards for document release is especially important for more complicated management structures with multiple layers of management and organizations.

4.3 CASE STUDY #3: LATE FABRICATED MATERIALS

Case Study #3 examines a project for which a shipment of structural steel and piping was hijacked en route to the construction location. Table 11 below shows late deliverables category related to this case in bold, as well as the impact categories that were a factor in this case study.

Table 11: Case Study #3 Late Deliverables and Impacts

Late Deliverable Categories	**Project Impact Categories**	
Engineering Documents, Approvals, and Responses	**Scope Changes**	**Management/Supervisor Work**
	Productivity	**Personnel Turnover**
Engineered Equipment	Engineering/Design Work	**Procurement, Logistics, and Expediting**
Fabricated Materials	**Work Resequencing**	**Onsite Team Dynamics**
External Permits	Overtime and Shift Work	**Work Relocation**
Prefabricated Assemblies	**Critical Path Management**	**Onsite Material Handling**
Project Execution Planning	**Commissioning and Start-Up**	Alternative or Additional Suppliers and Vendors
Human Resources	**Rework**	Liquidated Damages, Claims, and Bonuses
Utilities & Infrastructure	**Craft Levels/Density**	**Alternative or Additional Tools and Equipment**
Bulk Materials	**Downtime**	**Offsite/Company Dynamics**
Construction Equipment	**Project Risk Profile Changes**	**Damage, Degradation, and Loss**
	Indirect/Overhead Costs	Training Resources

Company Profile

The owner of the project examined in Case Study #3 is a large, multinational energy corporation with operations in oil and gas exploration, production, refining, and transport. The contractor hired for the project was an international corporation with experience in offshore engineering, procurement, construction, and installation (EPCI) in the oil & gas industry. The owner assigned project management staff to the project while also relying on the management teams of contracted companies.

Project Overview

Case Study #3 focuses on the construction and installation of a large oil platform in Southeast Asia. The owner awarded an EPCI contract that included a combination of reimbursable work, unit rate work, and lump sum items. The arrangement with the EPCI contractor focused on spreading the risk across multiple project aspects. The project was an expansion of an existing complex along with linking to and renovating existing facilities. Therefore, the construction site included both greenfield and brownfield segments. Tables 12 and 13 provide additional project context.

Table 12: Project Overview

Sector	Oil & Gas
Project Type	Offshore Platform
Construction Location	Southeast Asia
Contract Type	EPCI/Lump Sum
Baseline Project Cost (TIC)	$1.46 billion
Actual Project Cost (TIC)	$1.56 billion
Baseline Contract Cost	$1.22 billion
Actual Contract Cost	$1.32 billion

Table 13: Project Schedule Overview

Task	Baseline Duration	Actual Duration	Difference
Total Project	33 months	43 months	+10 months
Engineering	22 months	25 months	+3 months
Procurement	23 months	31 months	+8 months
Construction	25 months	35 months	+11 months
Start-Up/Commissioning	3 months	8 months	+5 months

Late Deliverable and Impact Description

The late deliverable examined for this case study was the structural steel for the platform and steel materials for the export pipeline, both of which were on a ship that was hijacked while in route to Asia. When the steel was hijacked, a separate second order was submitted to replace the first order at a cost of about $15 million. The original order was actually recovered and arrived to the fabrication yard prior to the second order and the owner was only able to sell the excess steel as surplus at about half the original price, in part due to the softening of the steel market during the window of the delay.

This project was supposed to be the first project in and first out of the contractor's fabrication yard. However, after the delayed steel delivery, the project was the last one in the yard and no longer a priority. This resulted in workers purposely slowing so that the work would be extended, as they would be out of work upon completion, and caused poor productivity and even some cases of sabotage in the yard. To solve this problem, more crews were added to the project and activities were overlapped in the schedule. This hurt productivity more and caused a serious quality issue and rework with the overlap of blasting and piping crews on site. The grit from the sandblasters got into the pipes and valves, and the pipes had to be removed and flushed. Many of valves were damaged in the fabrication yard and most of the damage went unnoticed until the platform had been shipped to the project site offshore. Crews attempted to repair these valves in the field but did not have the appropriate personnel so they were shipped back to land, refurbished or replaced, and reinstalled when they got back to the site, all at an estimated cost of over $10 million.

Due to the delays, much of the scheduled work was completed out of sequence leading to more delays in material delivery. There was no update to the material management plan to account for the out of sequence and accelerated work, and over 200 spools and valves were lost on the site and were reordered along with slowed production due to a lack of materials. Decks were lifted before completion and required a new crane to be used in the yard, which also increased the safety risk with more crews working at elevation than planned. When needed, many other pieces of equipment were in use in other parts of the yard because much of the work was unplanned. In addition, quality assurance became a bottleneck to the point where it interfered with progress while crews waited for approvals.

The original project execution scheduled the majority of the work to be completed on shore in the contractor's fabrication yard with minimal work needing to be done at sea. However, the late steel delivery and subsequent delays impacted the construction process in the yard and also pushed additional work to be completed offshore. This shift had several impacts on the project, which was originally planned to ship from the yard complete and require only 60 days for tie-in and startup offshore. Only the best workers were hired from the fabrication yard to work offshore, so productivity actually improved during the later parts of the project. The safety risk profile was increased offshore, but fewer workers were present so exposure to marine risk was limited. The majority of the safety issues were with third party personnel on the site, but there was one injury to a worker that was associated with the work being moved offshore.

The owner recognized that there was project team turnover for both companies and this hurt the communication of plans and risk as there was a lack of knowledge transfer when new team members were added. The relationship between the owner and the contractor deteriorated as it became evident that the fabricator had no intentions of publishing accurate reports of progress or forecasts for substantial completion. As a solution late in the project, an outside facilitator was brought in and several schedule workshops were conducted to plan future work, promote dialogue, and more effectively handle change. In the end, the project was delayed a total of 10 months cumulatively, and the final cost of the project grew approximately seven percent from the original estimate.

Lessons Learned

a) Risk identification and management efforts for materials shipping and logistics activities should consider, as appropriate, hijack/piracy and other applicable low-probability, high-impact risks. This is particularly important for long-lead, critical path materials or materials that are difficult to replace.

   In this case study, neither the owner's nor contractor's project teams had previously experienced the loss of materials due to hijacking or piracy, nor had it not been identified as a risk to the project. However, dozens of hijacking/piracy events were occurring each year during the period of this project's execution. Had the project team identified the risk of piracy, it could have been factored into the project's selection of transportation routes, contingency plans, and security plans.

b) Fully assess changes to execution plans, cost/contingency estimates, schedules, and resource availability when the project suffers a major late delivery event, including an evaluation of the consequential or knock-on impacts.

When possible, the owners and contractors should perform this assessment together to increase the transparency of changes in resource availability, job priority, and other elements of the execution environment that themselves could either amplify or dampen the impact of the late delivery. In some cases, a significant late delivery should trigger a comprehensive re-planning or "re-baselining" of the project.

c) A project's risk profile and risk management plans should be reassessed in light of any changes to the project.

In response to late steel delivery in this case study, some construction execution strategies were changed in an effort to mitigate impacts to the platform delivery schedule, and some of the key changes in risk profile (e.g. increased safety risk due to more work being taken offshore) were identified and appropriately mitigated. However, the complete impact of the late steel delivery was not comprehensively assessed, with consequential or "second order" impacts and risks fully managed, such as the contamination of valves due to the intentional overlap of valve installation and grit blasting activities. Similarly, changes in yard availability led to changes in project priority, the consequences of which were not recognized and deteriorated working relationships on site.

4.4 CASE STUDY #4: LATE ENGINEERED EQUIPMENT

A project with a delayed engineered equipment delivery is examined in Case Study #4. The impacts to the project as well as the late deliverables are presented in bold in Table 14, which follows.

Table 14: Case Study #4 Late Deliverables and Impacts

Late Deliverable Categories	Project Impact Categories	
Engineering Documents, Approvals, and Responses	**Scope Changes**	**Management/Supervisor Work**
	Productivity	Personnel Turnover
Engineered Equipment	**Engineering/Design Work**	**Procurement, Logistics, and Expediting**
Fabricated Materials	Work Resequencing	**Onsite Team Dynamics**
External Permits	Overtime and Shift Work	Work Relocation
Prefabricated Assemblies	**Critical Path Management**	**Onsite Material Handling**
Project Execution Planning	Commissioning and Start-Up	Alternative or Additional Suppliers and Vendors
Human Resources	**Rework**	Liquidated Damages, Claims, and Bonuses
Utilities & Infrastructure	Craft Levels/Density	**Alternative or Additional Tools and Equipment**
Bulk Materials	**Downtime**	**Offsite/Company Dynamics**
Construction Equipment	**Project Risk Profile Changes**	Damage, Degradation, and Loss
	Indirect/Overhead Costs	**Training Resources**

Company Profile

The EPC contractor on this project has experience in the heavy industrial sector with regional offices throughout North America and several international markets. The company has completed projects in the power generation, solar power, oil and gas, refining, metals and mining, chemicals and polymers industries, and has in-house engineering and construction services.

Project Description

Case Study #4 investigates the late delivery of two vessels to the site as a result of a change in scope by the owner and consequential delays to engineering and construction. The original plan called for four new vessels to be used, but the owner submitted a change order calling for refurbished vessels to be used. Two of these used vessels were available and delivered on time while the other two were late. Also, near the end of the project, there were additional impacts due to incorrect and late piping and pipe supports, which impacted the progress just before completion when acceleration was more difficult. Tables 15 and 16 below contain the project overview as well as an outline of the project schedule.

Table 15: Project Overview

Sector	Oil & Gas
Project Type	Refinery
Construction Location	Southwest United States
Contract Type	EPC/Lump Sum
Baseline Project Cost (TIC)	N/A
Actual Project Cost (TIC)	N/A
Baseline Contract Cost	$49 million
Actual Contract Cost	$51 million

Table 16: Project Schedule Overview

Task	Baseline Duration	Actual Duration	Difference
Total Project	25 months	28 months	+3 months
Engineering	17 months	17 months	0 months
Procurement	16 months	16 months	0 months
Construction	13 months	16 months	+3 months
Start-Up/Commissioning	1 month	1 month	0 months

Late Deliverable and Impact Description

The project consisted of the design and construction of a processing unit for the expansion of an existing refinery on a brownfield site. The project was designed in-house and underwent a formal stage-gate process. Prior to the start of construction, a delay was encountered due to the removal of an existing on-site tank, which was the owner's responsibility, and unforeseen environmental remediation required for the surrounding soils. This delayed site mobilization and shifted the start of construction back three months, but the schedule was adjusted day-for-day with the delay and the owner reimbursed the contractor for the work.

When the owner made the decision to procure a used vessel in lieu of a new vessel based on the approved data sheet, there was no procurement plan or as-built drawings to incorporate into the design and construction plans. A constructability plan had been previously completed but was altered to reflect the change, and the engineering team could not finalize the design until the actual vessels were selected and specifications known. This replanning effort was accompanied by a delay while each used vessel was located and delivered to the site.

When the vessels arrived on site and the new designs were finalized, additional time was required to prepare the vessels for installation on site. The vessels were moved to the laydown yard where a separate company refurbished the vessel and performed the required changes in preparation for installation. One of the used vessels was heavier than expected because it arrived with no exact specifications and few legible drawings. This led to additional planning time and safety concerns for its placement. The contractor was able to use a crane that was already on site in another area to lift the vessels and therefore did not have any additional costs or delays in bringing a crane to site with short notice.

The associated delays impacted the project's safety risk profile in two ways. First, with an adjacent facility completing construction and starting up, additional concern for safety arose in both the laydown areas and access points to the site and required several safety shutdowns and extra safety planning and training. Also, operation of some pumps on the site were forced to start up before the entire project was complete, creating the need for additional safety measures to be implemented, such as requirements for full personal protective equipment, air monitors, and special welding precautions. With crews working in close proximity to operating equipment, safety and quality were of great concern to the project team. However, the delay also decreased the project safety profile as the overlap in construction between the two adjacent sites decreased. This reduced the potential for collisions with equipment of the adjacent site, alleviated congestion, and there were no neighboring crews or mobile equipment to account for when critical lifts were made.

Communication and responsibility was blurred after the change in direction to procure a used vessel was made. This was attributed to a poor understanding of the schedule and engineering resources and lack of communication with the construction team on the project. For example, when the new design for the vessel supports was released for construction, the design was not usable for some of the heavier used vessels.

After the delayed installation of the vessels, some of the piping arrived on site before it was needed for installation; it was kept covered in the laydown yard to protect it from the elements. Other aspects of the piping that were supposed to be completed in the shop were moved to the project site when the project was accelerated. When the piping was ready to be installed after the vessels were in place, the pipe supports had not yet arrived on site because engineering was delayed in finishing the design. As a result, the piping was hung using temporary supports and come-alongs until the permanent supports arrived. While this method saved time and prevented further delays, it was much more difficult to install supports under pre-hung pipes, and it exposed the piping and crews to much greater risk for damage. This led to additional quality assurance staff and some rework to correct welds and field modifications.

As the construction schedule extended due to delays on the critical path, additional costs were incurred for the extended office expenses and for overtime work with crews and the project underwent normal acceleration to work around the delayed vessels. In addition, some less experienced crews were used to install some equipment. In order to receive the process guarantee from the vendor, a third party company was hired to inspect the work and fix any mistakes that were discovered. Along with this quality assurance issue for installed equipment, there were also several quality requirement changes by the owner. After the owner assigned a new quality assurance representative during the middle of the project, the owner made changes to the piping quality requirements. This created a clash between the owner and contractor, and the contractor had to repair or replace several weld caps to meet the new piping quality standards implemented on the project.

Lessons Learned

a) Evaluate the full range of impacts and risks associated with material substitutions or changes.

The decision to procure a used vessel in lieu of a new vessel was predicated on the equipment cost only and did not take into account impacts to engineering and associated changes. The assumption was made that the refurbished vessel would prove to have a lower installed cost, would improve the schedule, and would not affect the project engineering; however, this was not the case on this project.

b) Clearly define and approve any scope changes that arise in a project.

When scope change happens on a project, it is imperative that scope be clearly defined and agreed by all parties in writing, taking into consideration all aspects of the change and the effects across all disciplines, including engineering, procurement and construction. When assumptions are made regarding the condition of a used piece of equipment, including available documentation, the basis of these decisions needs to be captured.

4.5 CASE STUDY #5: LATE CONSTRUCTION EQUIPMENT

Late construction equipment is the focus of Case Study #5. This project is summarized below in Table 17, which shows both the late deliverables and the associated impacts.

Table 17: Case Study #5 Late Deliverables and Impacts

Late Deliverable Categories	Project Impact Categories	
Engineering Documents, Approvals, and Responses	**Scope Changes**	**Management/Supervisor Work**
	Productivity	Personnel Turnover
Engineered Equipment	**Engineering/Design Work**	**Procurement, Logistics, and Expediting**
Fabricated Materials	**Work Resequencing**	**Onsite Team Dynamics**
External Permits	**Overtime and Shift Work**	**Work Relocation**
Prefabricated Assemblies	**Critical Path Management**	**Onsite Material Handling**
Project Execution Planning	Commissioning and Start-Up	Alternative or Additional Suppliers and Vendors
Human Resources	Rework	**Liquidated Damages, Claims, and Bonuses**
Utilities & Infrastructure	**Craft Levels/Density**	**Alternative or Additional Tools and Equipment**
Bulk Materials	Downtime	**Offsite/Company Dynamics**
Construction Equipment	**Project Risk Profile Changes**	Damage, Degradation, and Loss
	Indirect/Overhead Costs	Training Resources

Company Profile

The company in Case Study #5 is a large, privately held contractor company in the United States with customers primarily in the process and power industries. The case study was performed within the construction branch of the company, which also has engineering and maintenance capabilities.

Project Overview

Case Study #5 provides an account of the construction of an air quality control system (AQCS) at an existing coal power plant in the Southeast United States in order to meet state emission requirements. The contract was EPC/Lump Sum with three entities in a joint venture, including the contractor and two engineering and design partners. One design partner worked primarily on the architectural design while the other completed detailed engineering. This project was necessary in order to conform to the requirements of the Clean Air Act. Table 18 and Table 19, contain an overview of the project as a whole along with the schedule durations.

Table 18: Project Overview

Sector	Power
Project Type	Air Quality Control Retrofit
Construction Location	Southeast United States
Contract Type	EPC Lump Sum
Baseline Project Cost (TIC)	$799 million
Actual Project Cost (TIC)	$827 million
Baseline Contract Cost	$799 million
Actual Contract Cost	$827 million

Table 19: Project Schedule Overview

Task	Baseline Duration	Actual Duration	Difference
Total Project	45 months	45 months	0 months
Engineering	33 months	34 months	+1 month
Procurement	31.5 months	32.5 months	+1 month
Construction	37 months	38 months	+1 month
Start-Up/Commissioning	25 months	26 months	+1 month

Late Deliverable and Impact Description

There were several late deliverables to the project, but this case study will focus on the delayed availability of two tower cranes to be used for the construction of the AQCS project. The cranes, two of the largest in the United States, had improper stress welds on the base components when they arrived on site. The erection process was approximately 80 percent complete when crews noticed several cracks in welds; this led to a full inspection. Subsequently, the crane manufacturer and crane owner sent teams to repair the faulty crane components. The management team decided to set aside space in the laydown yard for the tower cranes. However, at this early stage in the project, deliveries were steadily arriving on site, space was limited, and material management crews were forced to work around the crane. Other deliveries, particularly of process related equipment, were halted to allow time for more space to open up.

After several months in the laydown area the crane was not repaired and the laydown space was needed for deliveries, so the crane components were sent to a local machine shop to be corrected. This led to a disagreement about responsibility for shipping and repair costs. Another point of contention was the supply of manpower for the repairs, which was supplied by the contractor. These direct costs of repairs and indirect costs of the cranes' unavailability then had to be formally tracked through the project so the contractor could try to be reimbursed for those additional expenses beyond the original scope, which was very difficult and all of which could not be captured.

With the help of engineering teams, the project team took 30 to 45 days to revamp the execution plan substituting crawler cranes (at added costs) for the tower cranes. This required additional engineering and planning for lift plans and designing necessary foundations. Furthermore, several specially designed foundations for the tower cranes that had been installed were never used. The reduced capacity of the crawler cranes meant that some of the structure had to be stick-built which slowed work, created additional lifts, and changed the safety risk profile on site. Some aspects that could not be stick-built were resequenced to occur later in the project leading to many workarounds. Almost all of the lifts planned for the tower cranes were critical, and the time spent refurbishing the crane bases added scope to the work performed by the contractor and created the need to overhaul the project schedule and critical path. The schedule was formally rebaselined several times while waiting on the cranes to be repaired and returned to site.

The full inspection and refurbishment altogether took approximately four months, and the unavailability of the cranes pushed the entire work schedule to the right. In order to compensate for the lowered productivity and lagging schedule, weekend work and night shifts were implemented when both tower cranes were operating properly. Staffing for the project became difficult for the manpower necessary for the number of shifts required. Congestion was an issue on the site with many crews overlapping work that was relatively unplanned.

When the faulty welds were discovered, the manpower for the project was fully ramped up. Although the workers were never sent home and the site was never demobilized while waiting on the tower cranes, many workarounds developed and work plans with the crawler cranes were day-to-day. Coordinating crews became difficult and required additional communication between management and crews with daily meetings and additional planning sessions. Furthermore, the superintendents on the ground had difficulty tracking the work that had been completed as well as planning upcoming work with the changed.

Once the cranes were repaired, work moved forward much more smoothly even though acceleration measures were required to meet two contractual outage dates for tie-ins, which carried substantial liquidated damages. This is attributable to the ability to properly plan work in advance. However, with the changes in work sequence, numerous workarounds, and overtime work, safety management became an important aspect of the project. A catch-up mentality pervaded the site that impacted the safety risks on site. Additional shifts and night work were a necessity to meet the project schedule, and several activities that are not normally performed after dark were pushed into the night shift. One such activity performed 24 hours a day was steel erection, which is inherently much more dangerous than in daylight and altered the project's safety risk profile.

Consequently, about halfway through the project, safety professionals were added to increase the focus on safety and improve performance.

Lessons Learned

a) Critical materials and equipment should have full supplier quality surveillance plans in place to assure adherence and compliance with engineering progress, material quality, and manufacturing to code and schedule.

The delivery of critical materials and equipment, including long-lead, critical path, and unique materials or equipment, that do not meet the quality or functional requirements of a project has multiple and demonstrative impacts to a project cost and schedule. In this case study, faulty welds were not discovered until the crane components were delivered and being assembled, and these crane components were critical in that they were one-of-a-kind and essential to critical path activities. In order to avert similar scenarios, supplier quality surveillance plans should provide means for monitoring and verifying the physical conditions, fabrication methods, and assembly procedures of all suppler or vendor provided critical materials. In addition, the analysis should include associated material/equipment records to ensure the past maintenance is satisfactory and established requirements are met.

4.6 Case Study #6: Late Human Resources

Case Study #6 considers the impacts of late human resources to the construction site on a project that also experienced late engineering deliverables prior to mobilization. Both of these are presented in bold in Table 20. The project impact categories affected by these late deliverables are also indicated in Table 20.

Table 20: Case Study #6 Late Deliverables and Impacts

Late Deliverable Categories	Project Impact Categories	
Engineering Documents, Approvals, and Responses	**Scope Changes**	**Management/Supervisor Work**
	Productivity	**Personnel Turnover**
Engineered Equipment	**Engineering/Design Work**	Procurement, Logistics, and Expediting
Fabricated Materials	Work Resequencing	**Onsite Team Dynamics**
External Permits	Overtime and Shift Work	Work Relocation
Prefabricated Assemblies	**Critical Path Management**	**Onsite Material Handling**
Project Execution Planning	Commissioning and Start-Up	**Alternative or Additional Suppliers and Vendors**
Human Resources	**Rework**	Liquidated Damages, Claims, and Bonuses
Utilities & Infrastructure	**Craft Levels/Density**	Alternative or Additional Tools and Equipment
Bulk Materials	Downtime	**Offsite/Company Dynamics**
Construction Equipment	**Project Risk Profile Changes**	Damage, Degradation, and Loss
	Indirect/Overhead Costs	**Training Resources**

Company Profile

Case Study #6 was conducted with a large, American-based industrial gas company. It is a publicly traded owner company with operations around the globe. This case study was conducted with members of the U.S. construction division in charge of plant expansions, new construction, and plant commissioning

Project Overview

Case Study #6 examines the expansion project of a processing plant in the Midwestern United States as described by the owner company. The brownfield site had two existing plants, and the expansion was tied into these facilities. The engineering and design was conducted within the owner company. About 80 percent of the design was standard to the company with about 20 percent being customized to the site. The owner in this case study has both design and construction divisions for domestic and international projects. Table 21 and Table 22 show additional project and schedule information for the case study.

Table 21: Project Overview

Sector	Industrial Gas
Project Type	Processing
Construction Location	Midwest United States
Contract Type	Time and Materials
Baseline Project Cost (TIC)	$45.8 million
Actual Project Cost (TIC)	$58.6 million
Baseline Contract Cost	$11.6 million
Actual Contract Cost	$24.6 million

Table 22: Project Schedule Overview

Task	Baseline Duration	Actual Duration	Difference
Total Project	21 months	33 months	+12 months
Engineering	12 months	21 months	+9 months
Procurement	N/A	N/A	N/A
Construction	6.5 months	17.5 months	+11 months
Start-Up/Commissioning	2 months	3.5 months	+1.5 months

Late Deliverable and Impact Description

Late human resources are the focal point of this case study, which arose from the labor market conditions where the project took place. The contractor could not meet the demand of the skilled craft labor demand on the project with local labor, and, even after non-local craftspeople were brought in, the supply still fell short of demand. Along with the late ramp up of the human resources at the start of construction, there were additional issues with engineering prior to mobilization. A portion of the engineering and design was outsourced to Asia, which led to additional complications in the project.

Prior to the staffing issues on site, resource planning had occurred during the front-end loading process six to nine months before the construction began. A labor survey was completed in the local market with the contractor, and the project team concluded that there was a base of skilled labor in the region, but it would have to be supplemented with out-of-area craftspeople to meet the labor demand curve. The final resource plan developed called for approximately 50 percent travelers on the project. When execution began, the minimum craft level was not met, and as the project progressed, there was a shortage of labor every week as compared to the labor curve. The project team found that the 50 percent local labor estimate had been too high and the contractor was unable to find that percentage of local craftspeople. However, the contractor still could not find enough non-local craftspeople with the appropriate skills willing to relocate to meet the demand. After several months of continuous labor shortages and poor quality work, the general contractor was removed from the project.

The decision was made to move forward with the project being owner-managed, and the original work plan created by the contractor was carried forward. However, three of the four primary subcontractors were replaced by the owner's project team, who took additional time to orient to the project and ramp up manpower on site. A superintendent, additional quality personnel, and a full-time safety manager were added to the project from within the company. The schedule was rebaselined with the new contractor that pushed the completion date three months, and, although the project started out schedule driven with the completion date set by the business management division, there was a softening in the product market that made cost the most important factor. Thus, the project did not require drastic acceleration efforts, but many activities were compressed to accelerate the project slightly and minimize the increase in overhead and indirect costs.

In order to meet the manpower curve each week, additional per diem incentives were implemented to attract non-local labor. The additional per diem costs increased the labor rate almost eight dollars per hour for the project. Several incentives were introduced to increase retention such as 50- and 60-hour work weeks, and this also helped accelerate the work. In the end, the local labor market was so weak that the contractor had to bring in over 90 percent travelers, and the cost of labor on the project rose over 50 percent. This rise in labor costs was also a product of lower productivity on site. Although some of the existing craftspeople stayed on the project and joined the new contractor, the learning curve for new craftspeople brought on site severely hampered productivity in the first month.

One of the most significant impacts to the project was the quality of work from the original contractor and subcontractors. The level of craft turnover and the experience levels of both the craftspeople and supervision caused quality issues that resulted in high levels of rework later in the project. Also, all of the materials management had to be taken over by the owner's project team, and many materials being delivered on the original project schedule had to be stored in laydown areas on the site. This, combined with the four overlapping subcontractors on site, changed the safety profile of the project in unforeseen ways.

Along with the issues in human resources, the project experienced several problems with engineering and design. The decision was made to outsource the three-dimensional modeling, labeling, dimensioning, and final drawings to Asia. However, there was a delay of close to three months at which point the design was still incomplete, so the domestic engineering group decided to finish it. The mobilization date for construction was kept the same in an attempt to meet the market date for the plant; thus, the engineering team could not release the final design as a single package. The detailed design was instead broken down into small packages and released to the contractor on a just-in-time basis. This delay in design packages coincided with the delays caused by the staffing issues of the original contractor. The just-in-time delivery of the design packages made it difficult for the contractor to create crane lift plans, manpower curves, and other required work plans. This made the construction team very reactive, and the design packages were not released in an order that was most efficient for construction. This further slowed construction and decreased craft productivity on a project already impacted by craft unavailability.

Lessons Learned

a) When an owner implements a new "standard" or "product line" design, the owner and/or engineer must weigh the risks versus the benefits of starting construction prior to the design being complete.

   In this case study, late engineering deliverables (product line) caused phased releases of construction packages, which, in turn, increased cost and schedule of the project. Had the risks of the new design been properly assessed, the subsequent impacts to construction might have been foreseen. In turn, the owner/engineer should strive to generate complete construction packages to avoid incomplete (or "soft") planning by the construction contractor.

b) Ensure that the contractor has the ability to provide resources (both management and labor) as needed.

   The owner and/or engineer should work closely with all candidate or selected construction contractors within the geographical area to ascertain a proper expectation of available skilled trade labor in the local market. When estimating labor costs, ensure the construction contractor is accurately (perhaps somewhat conservatively) anticipating the proper percentage of "travelers" for inclusion of per diems in the cost estimate.

c) Involve all stakeholders in addressing the overall impacts of decisions regarding engineering and design.

In this case study, the decision was made to outsource part of the engineering to Asia in order to save on design costs. However, this decision was made without the input of the construction contractor. Unforeseen impacts to construction included an inability to collaborate with or control engineering, a slower response time for engineering information due to distance and communication difficulties, and less face-to-face time, which hampered teamwork and cooperation.

4.7 CASE STUDY #7: LATE BULK MATERIALS AND PREFABRICATED ASSEMBLIES

Case Study #7 included late deliverables contained within two categories, namely bulk materials and prefabricated assemblies. Both of the late deliverables are highlighted in Table 23 below. The Project Impact Categories that are discussed in this case study are also indicated in Table 23.

Table 23: Case Study #7 Late Deliverables and Impacts

Late Deliverable Categories	Project Impact Categories	
Engineering Documents, Approvals, and Responses	**Scope Changes**	**Management/Supervisor Work**
	Productivity	Personnel Turnover
Engineered Equipment	Engineering/Design Work	**Procurement, Logistics, and Expediting**
Fabricated Materials	**Work Resequencing**	**Onsite Team Dynamics**
External Permits	Overtime and Shift Work	**Work Relocation**
Prefabricated Assemblies	**Critical Path Management**	**Onsite Material Handling**
Project Execution Planning	Commissioning and Start-Up	**Alternative or Additional Suppliers and Vendors**
Human Resources	**Rework**	Liquidated Damages, Claims, and Bonuses
Utilities & Infrastructure	**Craft Levels/Density**	**Alternative or Additional Tools and Equipment**
Bulk Materials	Downtime	**Offsite/Company Dynamics**
Construction Equipment	**Project Risk Profile Changes**	**Damage, Degradation, and Loss**
	Indirect/Overhead Costs	Training Resources

Company Profile

The project team members interviewed for Case Study #7 are part of a large, U.S.-based contractor that is employee-owned. This contractor has in-house engineering, procurement, and construction services and works primarily in the chemical, oil & gas, and power industries with the ability to direct-hire most of the required craft workforce for any given project. The case study was conducted with several members of the management team responsible for the project under study.

Project Overview

Case Study #7 describes the expansion of an existing industrial process facility in the Southwestern United States. The contractor was responsible for the design and construction of three identical processing units along with the corresponding connections and tie-ins to an overall expansion program, of which the three processing units were the largest part in cost, number of procured items, and geographical areas. The owner of the project retained a separate managing contractor who was responsible for coordination, procurement, and site facilities for the entire program. Tables 24 and 25 contain basic project information as well as a detailed schedule summary for the portion of the construction completed by the contractor in Case Study #7.

Table 24: Project Overview

Sector	Oil & Gas
Project Type	Processing
Construction Location	Southwest United States
Contract Type	Cost Reimbursable
Baseline Project Cost (TIC)	N/A
Actual Project Cost (TIC)	N/A
Baseline Contract Cost	$750 million
Actual Contract Cost	$1 billion

Table 25: Project Schedule Overview

Task	Baseline Duration	Actual Duration	Difference
Total Project	36 months	60 months	+24 months
Engineering	24 months	36 months	+12 months
Procurement	12 months	18 months	+6 months
Construction	23 months	48 months	+25 months
Start-Up/Commissioning	2 months	7 months	+5 months

Late Deliverable and Impact Description

Case Study #7 concentrates on three specific categories of late deliverables to the contractor from the managing contractor: prefabricated assemblies, fabricated materials and bulk materials. For the entire expansion program, all of the construction contractors were contracted directly with the managing contractor, not the owner. The managing contractor promoted modularization for all aspects of the expansion, and, thus, all of the materials and modules had to be approved by the managing contractor. For the segment of the expansion program examined in this case study, the construction contractor requested materials from the managing contractor, the managing contractor controlled all purchasing, receiving and storage, and the construction contractors then had to request materials to be delivered from the remote laydown areas to the construction site three weeks in advance. Also under the original contract, the construction contractor could not keep any materials on their site or have any of their own laydown areas. This meant that any material delivered had to be installed the same day, meaning the contractor had to plan all work for just-in-time delivery from the managing contractor.

There were several late fabricated material deliveries to the contractor under this arrangement. First, the foundation piles were not ordered on time and arrived four months late. Consequently, the pile-driving bid was withdrawn and was let again two months later, and two pile-driving machines were required to make up lost time. Due to the pile driving being behind schedule, the work now overlapped with the pile driving on adjacent parts of the site. This caused some piles to shift on the site, which required rework and presented an additional quality risk for foundation piles. Second, after the piles were completed, the contractor moved on to installing underground piping, drains, and foundations. The contractor had placed the order for the prefabricated large-diameter insulated piping that had been previously designed. However, the managing contractor had forgotten to include the large diameter in the original budget and had to go to the owner for a change order, which delayed the delivery by six months. The pipe was then rushed in the manufacturing process that left many errors that the contractor had to both find and correct on site, which required extra time and man-hours.

The third set of late deliverables involved over 40 prefabricated modules procured by the managing contractor. These modules were to be fabricated in various module shops around the country, but several of the most important were to be assembled in a yard controlled by the managing contractor. However, although the alignment was satisfactory, the capacity of the yard was insufficient to complete the order on schedule. When the modules fell behind schedule, the managing contractor decided that instead of paying for the ships and barges that were transporting them to wait, the modules would be shipped on schedule even if they were incomplete often without packing lists and with incomplete punch lists. The late, incomplete modules had drastic effects on the original execution plan for the contractor. The added scope of finishing the modules that were shipped incomplete included determining what had not been completed and then finding and installing any incomplete parts of the module. No source inspections were allowed in the yards, so quality personnel had to be added in the field. Given that many shortcuts had been taken in the yard in an attempt to get the modules out on time, the amount of rework and repairs for damaged and incomplete items was enormous. Issues such as internal rusting to pipes during shipping and the need to refinish over 100 pipe flanges that were damaged while waiting to be installed drastically increased the number of man-hours required for completing and installing the modules. With more overlapping crews and work being performed at various heights, the safety profile of the module installation changed. There was crowding at many workfaces, a requirement for additional safety personnel and equipment, and an injury to a welder working below grade, all of which was attributable to late delivery of incomplete modules.

Finally, many of the bulk materials for the project, which were again controlled by the managing contractor, were late to crews because they could not be requested early and stored on site. The productivity issues embedded in the project with just-in-time and late delivery of materials frustrated crews as they were forced to either wait or drive to the managing contractor's laydown yard for materials, lowering productivity. The trucks that arrived on site often contained incomplete palettes with little organization and many materials were lost in the process. This created a very contentious relationship between the companies and the crews over who was responsible for the missing items, and turnover increased while morale decreased as work fell behind. Additionally, the cost impacts on the project went well beyond low productivity and additional labor. The crews did not know which bulk materials would be available each day so rework increased steadily. Theft also increased between worksites, as the contractor's bulks would disappear when other sites had material shortage or needed certain equipment, and the managing contractor left it up to the individual contractors to secure their sites.

Combined, the three categories of late deliverables had even more drastic impacts to the project. The scheduled peak manpower curve was shifted into an economic downturn when the project was scheduled to be complete, making it difficult to retain quality craft personnel who left for easier, more organized jobs. Prior to the downturn, the contractor was working under a cost reimbursable contract with the managing contractor, but was asked to renegotiate the contract. The result was a contract directly with the owner with a lump sum price for all indirects and a cost reimbursable portion for all direct labor and permanent materials. At this point, though, the contractor was given control over purchasing and materials management along with a laydown area on site. This required about $5 million in additional materials management staff and equipment addressed in a change order along with time and effort by the project management team create a recovery plan to complete the project. Additional change orders were submitted for a one-year extension in indirect costs to the final completion date and reimbursement for the 50 percent increase in direct man-hours from the original project estimate.

Lessons Learned

a) Project coordination decisions should not be taken in isolation, but with all key stakeholders in order to address a risk and mitigation plans.

   In this case study, the decision for the managing contractor to coordinate all procurement activities was made without the input of the construction contractors. By including the contractors in the planning, a more comprehensive risk assessment of the arrangement could have been compiled with the input of all parties. In addition, a mitigation plan, if created early in the project, could have provided means for transferring procurement responsibilities in case the arrangement did not work, smoothing the transition and shielding the field from additional impacts.

b) Just-in-time delivery requires a significantly higher level of control and coordination in materials management.

   If all stakeholders were aligned and recognized the requirements to make it happen on the project, the risks associated with this decision would have been better recognized so additional planning could be implemented.

4.8 CASE STUDY #8: LATE UTILITIES & INFRASTRUCTURE

Case Study #8 involved the delayed relocation of utilities and infrastructure on a project site. The late deliverables are indicated below in Table 26 along with the impact categories that were affected as a result.

Table 26: Case Study #8 Late Deliverables and Impacts

Late Deliverable Categories	**Project Impact Categories**	
Engineering Documents, Approvals, and Responses	Scope Changes	**Management/Supervisor Work**
	Productivity	Personnel Turnover
Engineered Equipment	Engineering/Design Work	Procurement, Logistics, and Expediting
Fabricated Materials	**Work Resequencing**	**Onsite Team Dynamics**
External Permits	Overtime and Shift Work	Work Relocation
Prefabricated Assemblies	**Critical Path Management**	**Onsite Material Handling**
Project Execution Planning	Commissioning and Start-Up	Alternative or Additional Suppliers and Vendors
Human Resources	Rework	Liquidated Damages, Claims, and Bonuses
Utilities & Infrastructure	**Craft Levels/Density**	**Alternative or Additional Tools and Equipment**
Bulk Materials	Downtime	**Offsite/Company Dynamics**
Construction Equipment	**Project Risk Profile Changes**	Damage, Degradation, and Loss
	Indirect/Overhead Costs	**Training Resources**

Company Profile

The project team members interviewed for Case Study #8 represented two companies. The owner's representative for the project is an international engineering, construction, and services company with offices throughout the southern United States. The owner's rep has business units in the oil & gas, process, and industrial sectors. The contractor in Case Study #8 is a large, international corporation with operations in infrastructure, oil & gas, industrial, power, and various other sectors.

Project Overview

Case Study #8 examines the impacts of the late relocation underground utility line on the construction site of a manufacturing facility in the Southeastern United States. The utilities in question ran along the easement of an existing road, and both the road and all of the utilities were to be relocated several hundred feet away to make room for the manufacturing facility expansion. The relocation of the road was the responsibility of the owner's design/build team, while the various utility companies were responsible for moving all of the underground utilities that ran along the easement. However, the demolition of the in-service public road was contingent upon the relocation of all of the utilities in the new road easement. A basic outline of the project is shown below in Table 27, and Table 28 gives an overview of the project schedule.

Table 27: Project Overview

Sector	Industrial
Project Type	Manufacturing
Construction Location	Southeast United States
Contract Type	Lump Sum & Time and Materials
Baseline Project Cost (TIC)	$55.1 million
Actual Project Cost (TIC)	$56.7 million
Baseline Contract Cost	$22.0 million
Actual Contract Cost	$23.1 million

Table 28: Project Schedule Overview

Task	Baseline Duration	Actual Duration	Difference
Total Project	15 months	21 months	+6 months
Engineering	N/A	N/A	N/A
Procurement	N/A	N/A	N/A
Construction	7 months	13 months	+6 months
Start-Up/Commissioning	N/A	N/A	N/A

Late Deliverable and Impact Description

The late deliverable examined in this case study is a utility with a main line that ran along the easement of an existing road as well as a feed line that bisected the construction site going to the existing facility. Both of these lines impeded construction when they were not relocated according to the schedule created by the contractor. The main line along the existing road could not be moved until the new line had been placed on the new easement, and the line leading into the existing manufacturing facility was a redundant feed that was essential to operations. If either line was damaged, work in the entire facility and surrounding area could have been disrupted. Also, the existing road could not be demolished in order for subsequent construction to take place until all of the utilities beneath it were safely relocated. Thus, the construction progress was contingent upon the relocation of both the main line and the redundant feed.

The project team had created the construction plan under the assumption that all of the utilities could be moved at the same time according to their work plan. However, well into the project and after the start of site work, the utility company notified the contractor of the date at which the main line would be moved, based on the services provided to other entities in the area. As the site existed, there was the road with the main line under it and a driveway to the existing factory with the redundant feed beneath. Although the utility company was able to install a temporary redundant feed replacing the feed that bisected the site, the relocation of the main line could not meet the project schedule and disrupted site preparation activities. This disruption had follow on effects for the following activities: demolition of the old road bed, tree removal, up to 12 feet of muck and fill, utility corridor construction, heavy duty paving, and various support buildings. While construction on the heavy duty paving continued per the schedule, it could not be completed until the new main utility line had been relocated, so site work moved forward with an operating road bisecting the site despite the risk involved.

The original execution plan had construction proceeding from north to south, but the orientation had to be reversed going south to north. Many of the milestone dates for site work were missed due to the unmoved utility. Many of the subcontract schedules had to be compressed at extra cost to accommodate changes. With the split in the worksite, many of the subcontractors had to bring in extra crews and equipment, which increased the labor costs. During the muck and fill operations, heavy equipment was constantly being moved across the road to each side of the site to keep each segment on schedule. Due to the disruptions in traffic and safety risk to workers and the public, the contractor eventually placed separate crews and equipment on each side of the road. This impacted costs but kept the project on schedule. Public safety also became an issue with material deliveries along the existing road that disrupted traffic. As fill material deliveries continued and construction materials started to arrive, the congestion on the road became a significant issue; flaggers and off-duty police officers were hired to direct traffic. In addition, as construction of the factory began and became a distraction to drivers, the contractor had to work with the city to add signage and place police officers along the road to prevent accidents.

New crews brought to site had to be trained in protocol for transporting equipment across the road, and the safety risk on site increased drastically with active traffic in close proximity to workers. When additional crews were added to the divided site, many of the craft workers and laborers had less experience, which lowered the quality of work and caused rework later in the project. This increased the amount of rework and created a substantial punchlist of repairs that needed to be made. All new workers also had to undergo a day of paid training to orient them to the site and safety procedures. After undergoing this training and setting up site access, many of the crews would only stay for a few weeks, which also increased the labor costs.

The existing road and utility line caused severe changes in work sequencing and craft levels after groundwork was complete, mainly by introducing numerous workarounds. Relatively small sections of the site were opened for work at one time, often spilt by the road, which resulted in lower craft productivity. This slowed construction progress and frustrated crews who could not complete the work efficiently and were constantly moved around the site. The management team spent significant amounts of time replanning the work and trying to create efficient sequences, but the partial completion of tasks and levels of rework lowered morale. In addition, the resequencing of work impacted material handling on site, as items such as electrical substations arrived on schedule but could not be installed. Space had to be leased off site to store these items, and transportation was arranged to move them to site when ready for installation.

Well after the new road was finished, the utility company relocated the main line to its permanent position, and traffic was finally moved to the new road. The contractor then proceeded with removing the existing road and completing the site work. At this point, many crews moved to this segment of the site and were working in close proximity to one another in order to expedite the remaining work items. The split site and change in the sequence of work caused significant replanning by the management team, and even resulted in a claim by the paving contractor for resequencing of work and for design changes. The claim was settled for a significant additional cost. In the end, the utility corridors, paving, and support buildings were disrupted by the delayed utility relocation.

Lessons Learned

a) Adequately identify all foreseeable external project risks and coordinate construction plan with those external stakeholders.

Risk identification at the beginning of the project should have identified all activities that were not controlled by the project team. Some may have identified the utility as a potential problem early in the project, but this was not formally communicated to the project team in this case study. In addition, there was no visibility of the problem by upper levels of management until it was too late to influence. By incorporating the external stakeholders in planning, the project team can recognize the problem, and the project team can "freeze" the plan with the utility company and communicate the importance of meeting dates.

b) Incorporate mitigation plan for utilities/infrastructure in the pre-planning risk assessment.

Given the additional risks associated with the utility lines were recognized before the project began, outlining a mitigation plan would have decreased the effort required to create workarounds later in the project. A faster reaction to a change in the utilities would have lessened the impacts in this case study.

4.9 CASE STUDY #9: LATE PROJECT EXECUTION PLANNING

Case Study #9 investigates the impacts of late project execution planning along with late permits that impacted the planning process. Table 29 lists these late deliverables as well as some of the associated impacts experienced on site.

Table 29: Case Study #9 Late Deliverables and Impacts

Late Deliverable Categories	Project Impact Categories	
Engineering Documents, Approvals, and Responses	Scope Changes	**Management/Supervisor Work**
	Productivity	Personnel Turnover
Engineered Equipment	Engineering/Design Work	**Procurement, Logistics, and Expediting**
Fabricated Materials	**Work Resequencing**	**Onsite Team Dynamics**
External Permits	Overtime and Shift Work	Work Relocation
Prefabricated Assemblies	**Critical Path Management**	**Onsite Material Handling**
Project Execution Planning	Commissioning and Start-Up	Alternative or Additional Suppliers and Vendors
Human Resources	**Rework**	Liquidated Damages, Claims, and Bonuses
Utilities & Infrastructure	**Craft Levels/Density**	Alternative or Additional Tools and Equipment
Bulk Materials	**Downtime**	Offsite/Company Dynamics
Construction Equipment	**Project Risk Profile Changes**	Damage, Degradation, and Loss
	Indirect/Overhead Costs	**Training Resources**

Company Profile

The interviews for Case Study #9 were conducted with a large, privately held contractor in the United States. The company is headquartered in the Southwestern United States, and has capabilities in the industrial, heavy civil, and various other sectors. The project team interviewed has extensive experience in the power and process industry.

Project Overview

Case Study #9 relates to a power project in the Southwestern United States. The brownfield project included the expansion of a combined cycle power plant with tie-ins to the existing generation facilities. As is standard on the contractor's projects, the project execution plan was developed prior to the bidding for the job, and included the approach to construction, a high-level schedule, milestone dates, and a procurement overview. Table 30 and Table 31 follow and show the basic outline of the project and its schedule.

Table 30: Project Overview

Sector	Power
Project Type	Power Plant Expansion
Construction Location	Southwest United States
Contract Type	EPC/Lump Sum
Baseline Project Cost (TIC)	$120 million
Actual Project Cost (TIC)	N/A
Baseline Contract Cost	$120 million
Actual Contract Cost	N/A

Table 31: Project Schedule Overview

Task	Baseline Duration	Actual Duration	Difference
Total Project	23 months	23 months	0 months
Engineering	23 months	23 months	0 months
Procurement	22 months	22 months	0 months
Construction	16 months	17 months	+1 month
Start-Up/Commissioning	17 months	17 months	0 months

Late Deliverable and Impact Description

A delayed air permit to the owner by an environmental agency altered the project execution plan as developed by the contractor. The date that the air permit would be available was unknown to the project team, and thus updating the project execution plan was difficult. After about four weeks, the permits were granted, however, the project execution plan was not fully updated to accommodate the change in mobilization date until later in the project. The combination of these late deliverables to the construction site impacted the project in many ways.

The notice to proceed for the project was contingent upon the approval of the permit, and, as such, no work could proceed on the site until it was obtained, including site work or utilities. However, the project was already mobilized and all support staff and facilities were on site. This included supervisors, foremen, and schedulers. With the date of the permit release being unknown, the project team continued refining the project execution plan, but this effort was limited by the unknown date for the notice to proceed.

Although the contractor received a day-for-day contractual extension for the delay in the air permits, several factors prevented the project team from shifting the project schedule day-for-day. The primary reason for this decision was the delivery date of the plant's generator, which was already ordered and moving through the supply chain, and would be delivered on the previously scheduled date. This was the central piece of equipment, and it had to be placed directly on its foundation. The generator could not feasibly be stored in laydown areas on or off site.

When the air permit and notice to proceed were granted, the decision was made to compress the activities leading up to the generator delivery. Excavation and underground utility work began as soon as the site was staffed, and all activities not necessary to the foundations for the generator were suspended. Meanwhile, the work was replanned and the project team attempted to update the project execution plan to reflect changes. Although the critical path did not change in the updated schedule, the work execution plan was not fully updated as work progressed to reflect the new sequencing, which led to problems later in the project. Although the activities replanned for the generator delivery were considered, a new execution plan examining how other activities were impacted was not available to the field management and crews. Some activities were postponed and others completed early, but this information and future plans was not sufficiently communicated to the field, which impacted morale on site. Beyond the field level, there was additional strain placed on the organization and upper management from the changing plans that were not reflected in the execution plan and the lack of adequate up-front planning.

The out-of-sequence work impacted the project in several additional ways. The site was very compact and became congested while accelerating the work to prepare the generator's foundations, which lowered productivity. The original project execution plan specified the locations of the cranes for lifts, including that for the generator. However, these specified areas also had a significant amount of ducts, piping, and other underground utilities that needed to be installed underneath. In order to accommodate the changes, the crane lift spaces were left open and the underground utilities were brought up to each side, to be connected later after the lifts had been made. Much of the area that had been excavated for underground utilities to be installed had to be filled in when the generator arrived on site. After the generator was set and crane moved, all of the area around the generator had to be excavated again and utilities placed.

As a result of resequencing, several safety and quality risks arose. For each lift, crews in the immediate area, which was most of the site, had to stop work. These stoppages could not be planned around the work because, due to the limited laydown space, each equipment delivery had to be placed in its final location except for in a few cases. Safety personnel were added to the project to enforce these changes. The quality risk to underground utilities increased because they were not placed continuously when leaving space for crane access. Similarly, the project ran into other logistical, staffing, and congestion issues with space needing to be occupied by more than one crew or machine. This created extra hazards, and management time was spent to create workarounds and resequence work. Similarly, some of the piping, valves, and supports had not been fabricated when needed on site to accommodate the new sequence, so, in some places, temporary pipe was installed at extra cost and labor hours, which then required rework to replace with the permanent piping or valve.

Project leadership tried to plan the work far enough ahead to coordinate deliveries as they arrived on site with the work to be performed, but when the notice to proceed had been given at the beginning of the project, the work began immediately with little time for training of the crews and replanning the work. Thus, from the beginning there was frustration among crews as look-ahead schedules were very limited. Even as the project progressed, the project team found it difficult to communicate work plans to the field without an updated schedule and execution plan.

Lessons Learned

a) Critical items, such as permits, should be reflected in the project schedule with early start and late finish dates.

If there is no confirmation for the arrival of these critical items, then the schedule should use the late finish date as a basis for the overall project and procurement schedules. This standard should be communicated to all project stakeholders, as alignment on this issue is critical.

b) Schedule changes should be communicated and understood by all key project stakeholders. Schedules are not a planning activity, but a project team tool.

In this case study, compressing portions of the schedule has unforeseen impacts on other aspects of construction. By allowing changes to be fully understood by all team members, the work can be replanned accounting for more comprehensive changes than just resequencing the schedule.

4.10 DISCUSSION

The overarching theme of these case studies is an inability of project teams to adequately identify or predict the propagation of impacts through the project lifecycle. In every case, unforeseen impacts of late deliverables affected projects far beyond the initial late deliverables. Changes to sequencing, productivity, and many other similar aspects were known to be impacted, but most project teams did not tie these effects directly back to the late deliverable until a later time. In retrospect, many of the interviewees commented that, while many of the impacts were not impossible to overcome, they had become major problems by the time they were recognized. Increasing understanding of the impacts of late deliverables as early as possible in a project, or even before a project in the case of assessing risk, is sure to mitigate at least some of the risks.

This idea of properly mitigating risks is something that can benefit projects before and after late deliverables. For example, in Case Study #8, recognizing the risks associated with an external utility company's on-time performance may have led the project team to create an alternate construction sequence. Creating this contingency prior to the delay would have improved the transition to a secondary execution plan, with a similar scenario occurring in Case Study #9. After a late deliverable event occurs, understanding late deliverables can again help mitigate future risks. In Case Study #7, an injury was attributed to the late deliverable when a welder was working below grade to complete a module. In recognizing the potential safety risks associated with a late deliverable, proper training or resources can be committed to potentially reduce the risk of injury. Similarly, quality issues not initially associated with a late deliverable need to be recognized sooner.

Another phenomenon noted during the case studies was the differences in knowledge and concerns at the various levels of an organization. As would be expected, field engineers and project executives had different areas of concern on a project trying to recover from late deliverables. However, several interviewees noted that it is difficult to understand how all of the impacts of late deliverables are interconnected, although it is recognized that they are. Along these lines, it is worth noting that all of the impact categories can impact multiple project pillars, and these are the ties that are difficult to predict and understand. As an example, in Case Study #1, the laydown areas become overcrowded as some materials arrived on time even though the work sequence had been reversed and winter weather set in. While this initially seems to be a scheduling and materials management issue, the changes also impact other project pillars. On this project, additional safety risks were introduced with an icy and crowded laydown area and icy roads to and from the project site. Furthermore, some materials had to be transported to climate-controlled facilities and others were damaged and replaced. Together, these direct and indirect costs lead to a significant increase in overall project cost. This is just one example, and there are hundreds more contained within the case studies. To that point, with the case studies being based on the interview of a limited number of project team members, there are certainly other impacts that were not known or captured. However, these case studies are the first step in recording these late deliverables and impacts and the interrelationships between them and project outcomes.

Thus, it is the hope of RT 300 that this research will improve upon this situation and allow teams to recognize late deliverables and begin to plan for, mitigate, or avoid the impacts of late deliverables before they are realized. Towards this goal, case study lessons learned were developed using input from the project team members interviewed for the case studies and the expertise of the RT 300 team members. These case studies, which are included at the end of each executive summary, range from suggestions for recognizing late deliverables to improving mitigation techniques of the impacts. A more in depth discussion of these lessons learned and their application to construction projects can be found in Chapter 8.

Chapter 5: Definitions

As referenced in the research methodology, categories were created to encompass the wide variety of possible late deliverables and impacts. In creating these categories, RT 300 recognized the importance of defining each to distinguish between each for the benefit of the final user. This chapter contains definitions for the project pillars, late deliverables categories, and project impact categories.

5.1 Project Pillars

1. **Cost** – Monetary expenditures made in relation to a project's development and execution through commissioning and start-up. These include expenses for labor (e.g., management, supervision, and craft), material, equipment, financing, services, and utilities. Also included are overhead and contractor/vendor profit in relation to completion of a project. A cost impact is a change in the amount of money spent to develop and deliver the project, having resulted from a late delivery to the construction site.
2. **Organizational Capacity** – The capacity or capability of individuals and/or an organization to efficiently and effectively execute work, with regard to teamwork, morale, team alignment, company alignment, relationships, and resources. Organizational capacity impacts resulting from late deliveries to the construction site include changes to individual and team commitment or morale (e.g., staff turnover and staffing quality), interpersonal and team dynamics (e.g., teamwork, communication, and cooperation), or relationships between and within organizations.
3. **Quality** – The applicable legal and contractual standards, codes, and specifications to which a project is to be designed and built. A quality impact is

any failure to meet or follow the defined project standards, codes, and specifications, resulting from a late delivery to the construction site. Such a deficiency could either be a defect that requires rework/repair to meet defined quality standards, or that might be accepted as a quality variance.

4. **Safety** – Protection from physical, occupational, and recognized risks and hazards, to provide a safe work environment for all personnel. Safety impacts resulting from late deliveries to the construction site include both direct safety incidents (i.e., incidents resulting in near misses or actual injury to personnel) and indirect effects such as changes to the physical/occupational risk profile, safety staffing, or safety training on site.
5. **Schedule** – An integrated Engineering, Procurement, Construction and Startup (EPCS) schedule showing the duration or calendar time, logic, and sequence of project-related activities, developed and used to guide project execution and management. A schedule impact is a change in the project's duration or in the sequence and logic of project activities, having resulted from a late delivery to the construction site.

5.2 LATE DELIVERABLE CATEGORIES

1. **Bulk Materials** – Component materials purchased in uniform lots and in quantity, for distribution as required for a project. Bulk materials are typically in stock and readily available for delivery. Examples include piping, flanges, power and instrument cable, concrete, structural fill, aggregate, loose steel, instruments, manual valves, fasteners, and gaskets.
2. **Construction Equipment** – All equipment required to perform construction operations or tasks, ranging from specialty equipment to small tools. Examples include heavy lift cranes, self-propelled module transporters, piling rigs,

scaffolding, man lifts, material handling equipment, hand tools, power tools, and welders.

3. **Engineered Equipment** – Any piece of equipment that is designed, manufactured, or customized for a specific application or requirement. Examples include pressure vessels, pumps and compressors, furnaces, control valves, turbines, generators, heat recovery steam generators, and electrical equipment, including transformers, motors, and chillers.
4. **Engineering Documents, Approvals, and Responses** – Engineering documents comprise all scope, drawings, specifications, process, bill of materials, vendor data, and data sheets as they relate to the design, procurement, manufacture, test, inspection, and construction/installation of the entire project. Engineering approval of a document constitutes engineering review and approval for function, form, or methods of achieving the engineered requirement or objective, as required in the specification. Engineering responses are answers to specific inquiries (e.g., RFI, NCR, and field memo), and render an engineering decision within the contractually prescribed time frame (typically 10-14 calendar days).
5. **External Permits** – All written approvals issued by a governing agency at the federal, state, or local levels to conduct an activity in regard to proceeding with a project or construction activity; permission to perform an action. External permits are physical items that grant an entity permission to proceed with permanent work. Examples include building, environmental, air, trade, demolition, and waste permits.
6. **Fabricated Materials** – Components of single, discrete engineered items designed, detailed, and fabricated to support the more conventional construction practice of delivery to the construction site, where all assembly is carried out.

Fabricated materials are distinguished from prefabricated assemblies by virtue of the lesser degree of assembly they require. Examples include structural steel, pipe spools, platforms, cable trays, ladders, fire protection piping, pipe supports, and plate work.

7. **Human Resources** – The personnel of a business or organization necessary to perform a construction project. This includes personnel from all organizations involved in a project. Examples include management, supervision, and labor from owners and contractors.
8. **Prefabricated Assemblies** – Components assembled in a factory or other manufacturing site, and transported to the construction site as complete assemblies or sub-assemblies. Examples include modules, skids, and power distribution centers. These assemblies are distinguished from those created through the more conventional construction practice of transporting the basic fabricated and bulk materials to the construction site, where all assembly is carried out.
9. **Project Execution Planning** – A plan that addresses scope, schedule, cost, communication, human resources, quality, safety, risk, procurement, and integration. The project execution plan is the governing document that establishes how the project will be executed, monitored, and controlled in accordance with the prime contract. The plan serves as the main communication vehicle to ensure that everyone is aware and knowledgeable of project objectives and how they will be accomplished.
10. **Utilities and Infrastructure** – A commodity or service, such as electricity, water, roads/transportation, or security that is provided to the project site (e.g., by an owner's operating organization or a public utility).

5.3 IMPACT CATEGORIES

1. **Alternative or Additional Suppliers and Vendors** – Entities contracted to perform or supply some or all of the contractual obligations as a substitute to the original plan.
2. **Alternative or Additional Tools and Equipment** – Construction tools and/or equipment provided to facilitate a work-around to the original plan.
3. **Commissioning and Start-Up** – The process by which an installed piece of equipment, system, facility, or plant (nearly complete or complete) is tested to verify that it functions in accordance with the design specifications and requirements.
4. **Company/Offsite Dynamics** – The interactions and behavioral relationships between the project team, the home office and/or functional group, owner/contractor organizations, and the community that influences the attitudes and behavior of a project team.
5. **Craft Levels/Density** – The personnel required to execute a project at optimal efficiency to meet project objectives. This includes the process of increasing or reducing the number of direct craft, and supervisors and support personnel. An excessive workforce beyond density thresholds on a project site can cause congestion that affects project execution, efficiency, schedule, safety, and cost objectives.
6. **Critical Path Management** – The original critical path is the longest logical sequence of project activities that form the contractual baseline schedule and completion date. Critical path management includes the revision of activity logic, durations, and resource loading in order to achieve the planned completion date.

7. **Damage, Degradation, and Loss –** Equipment or material on the project site that is in a state other than originally manufactured and delivered, or that cannot be found. Corrections typically require repair, replacement, or engineering approval for acceptance.
8. **Downtime** – A period during which personnel or equipment are experiencing unplanned idle time.
9. **Engineering/Design Work** – The effort required by engineering management and office engineers to develop additional designs or re-engineer completed designs in order to accommodate changes in the construction sequence, design temporary fixes, or incorporate owner or contractor modifications.
10. **Indirect/Overhead Costs** – Costs not directly involved in the construction of permanent work on the project site. These include all temporary facilities, temporary construction services, construction equipment and tools, and indirect labor and staff.
11. **Liquidated Damages, Claims, and Bonuses** – Liquidated damages are a contractual amount of compensation for a party's failure to satisfy the terms and conditions of a contract. Claims are the notification from a contracted party requesting the payment of an amount due or a time extension under the terms of the contract. Bonuses are potential payments offered to a contracted party as an incentive to improve performance beyond the base contractual requirements.
12. **Management/Supervisor Work** – The effort required by managers, field supervisors, and their direct reports to oversee all craft and construction activities, including engaging, planning, organizing, and directing resources.

13. **Onsite Material Handling –** All material control activities, including receiving, warehousing, checking, storing, protecting, maintaining, relocating, staging, and issuing of material on the construction site.
14. **Onsite Team Dynamics** – The day-to-day interactions and behavioral relationships between members of the project team (i.e., owners, contractors, and their respective functional departments).
15. **Overtime and Shift Work** – Additional work hours or shifts beyond the scheduled or established shifts planned for the project. Overtime includes the incremental hours worked beyond a normal working day or week by the same planned work crew, while additional shifts involve a different crew.
16. **Personnel Turnover** – Unplanned new or replacement personnel added to the project after construction begins, who are typically unfamiliar with project background or task-related roles and responsibilities.
17. **Productivity** – The efficiency of a person, crew, or piece of equipment in the execution of work. A production rate is the ratio of the hours worked compared to the unit of work produced, either for planned or actual work output.
18. **Procurement, Logistics, and Expediting –** The process of procuring, tracking, and, when necessary, accelerating or decelerating the supply of material and equipment in accordance with the project schedule.
19. **Project Risk Profile –** The project risk profile identifies the probability of a risk occurring and its potential impact. The profile is a ranked list of risks, type, potential impact, and probability.
20. **Rework –** The process of correcting defective, failed, or non-conforming work, prior to, during, or after inspection and testing. Rework includes all follow-on efforts, such as disassembly, repair, replacement, and reassembly.

21. **Scope Changes –** Modifications, including additions and deletions, to the original scope of work affecting the owner, contractor, subcontractors, vendors, or suppliers.
22. **Training Resources** – Resources required to support training (e.g., safety, quality, and project orientation), typically categorized as either human or physical, and the time and cost associated with those resources.
23. **Work Relocation** – A change in the planned location of work, typically to a less than optimal location, e.g. construction prefabrication or fabrication activities originally planned to be performed off site occurring at the construction site or work planned to be performed at grade occurring at elevation.
24. **Work Resequencing –**Work resequencing is a reactive work-around measure that deviates from the optimal baseline schedule sequence.

Chapter 6: Late Deliverable Risk Catalog

Research Team 300 developed the Late Deliverable Risk Catalog to enable industry professionals to easily and efficiently navigate the information collected from the first research thrust. The relational database that supports the LDRC contains all of the categories, definitions, examples, and case studies compiled by RT 300, along with hundreds of individual late deliverable impact descriptions also developed by the team. These components are inter-related within the database, and the LDRC interface provides a means for navigating, filtering, and displaying the most useful knowledge on one page. The following chapter explains the many features of the LDRC. Also included are instructions for use, several deployment recommendations, example applications of the LDRC within an organization, and an explanation of a few limitations of the LDRC.

6.1 FEATURES

The filters and categories provided in the LDRC allow the user to navigate through the inventory of various impact descriptions discovered through the research process. Each specific impact has been catalogued according to three criteria: 1) the type of late deliverable(s) that can cause each impact; 2) a categorization of similar, related impacts; and 3) the project pillars or outcomes that can be affected by the project impact. Together, these three criteria organize the data so that it can be easily navigated for specific situations or uses. These filters are found on the left side of the LDRC home page, as shown in Figure 6. One or more filters can be used, and multiple selections within each are allowed for customized searches. In addition, unchecking the box of any selection will clear it, and all selections within a category can be cleared using the "Uncheck All" button.

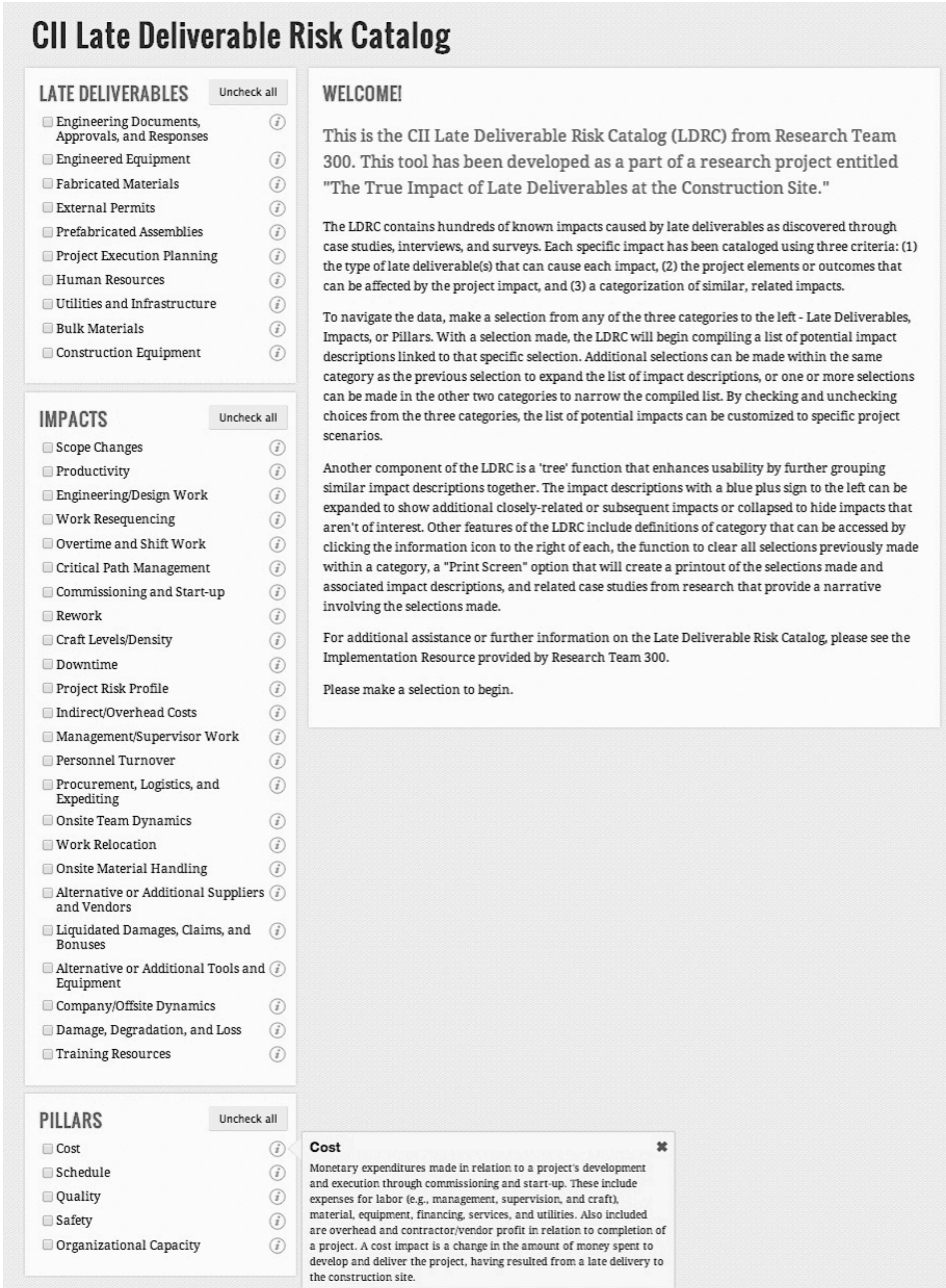


Figure 6: Late Deliverable Risk Catalog Homepage

To help users differentiate between the options within each filter, the team incorporated into the set of definitions it developed early on in the research process. (See Chapter 5 for the entire set.) A user can view these definitions within the tool by clicking the "Information" icon to the right of each option within the three filters. The definitions provide clarity for unfamiliar users, as well as consistency to prevent overlap within the LDRC filters. Figure 6 also provides an example definition selected for one of the project pillars.

The search criteria included in two of the three filters are also ordered by relative "significance," according to a risk factor developed by RT 300. As mentioned in Chapter 2, the team conducted a survey to determine the relative commonality and severity of each late deliverable type and impact category. The risk factor was calculated as the product of the average commonality and severity of each. Thus, the late deliverable category that poses the highest risk to projects, Engineering Documents, Approvals, and Responses, is listed first in the Late Deliverable filter. Similarly, the Impacts filter is also sorted by relative significance, with Scope Changes being the highest-ranked risk and Training Resources being the lowest.

After an initial selection is made from any of the three filters, the LDRC will begin compiling a list of impact descriptions the team found to be associated with the selection. The source of this list of impacts is the LDRC database, which RT 300 developed from its case studies, collective team expertise, industry surveys, and questionnaires. While the compiled list may be overwhelming at first glance, users can easily refine it to a manageable size by making additional selections in the other filters. For example, selecting only Engineering Documents, Approvals, and Responses in the Late Deliverables filter will return hundreds of responses. However, selecting one or more options under Impacts and Pillars quickly brings the search result to a manageable size. For example, by selecting only Engineering Documents, Approvals, and Responses under Late Deliverables, Onsite Material Handling under Impacts, and then only selecting Quality under Pillars, the tool will only return a few impact descriptions. Conversely, making additional selections within the same category can expand the list. If someone responsible for materials management were to use the tool, he or she could select other material related impact categories, such as Damage, Degradation, and Loss, Alternative or Additional Suppliers and Vendors, and Procurement, Logistics, and Expediting. This returns a more robust but still manageable list of potential quality impacts, as shown in the example query in Figure 7.

Also of note in Figure 7 is the Related Case Studies section located at the bottom of the screen beneath the impact descriptions. Based on the specific search criteria selected, the LDRC will list any related RT 300 case studies and provide a link to PDF files of their summaries. (See Chapter 4 to read all nine case study summaries.) The purpose of including these case study summaries in the LDRC is to provide informative narrative for the impact descriptions returned in a search. If more information is needed or wanted regarding the search results, the “full story” can be found in the related case study summaries.

Another feature of the LDRC is a 'tree' function that enhances usability by further grouping similar impact descriptions together. As visible in Figure 7 and Figure 8, a small box with a plus sign (blue in color) may appear to the left of some impact descriptions. This indicates that, under a given impact description, one or more related secondary impact descriptions are hidden within a tree structure. This tree structure can be both expanded and collapsed by clicking the blue box.

Figure 7: Example Query

Each tree structure can be expanded as needed to customize the list to specific scenarios, but it may be desirable to keep inapplicable impact descriptions hidden if they do not apply to a project or situation. For example, if a particular description involves the impacts associated with work being pushed into an unplanned season, but a project is located in a very moderate climate, then the associated impact descriptions can remain hidden to maintain a manageable and relevant list. Otherwise, the tree can be opened for a project in which extreme winter or summer weather may be a factor, as shown in Figure 8. A similar thought process is captured under each of the collapsible tree structures.

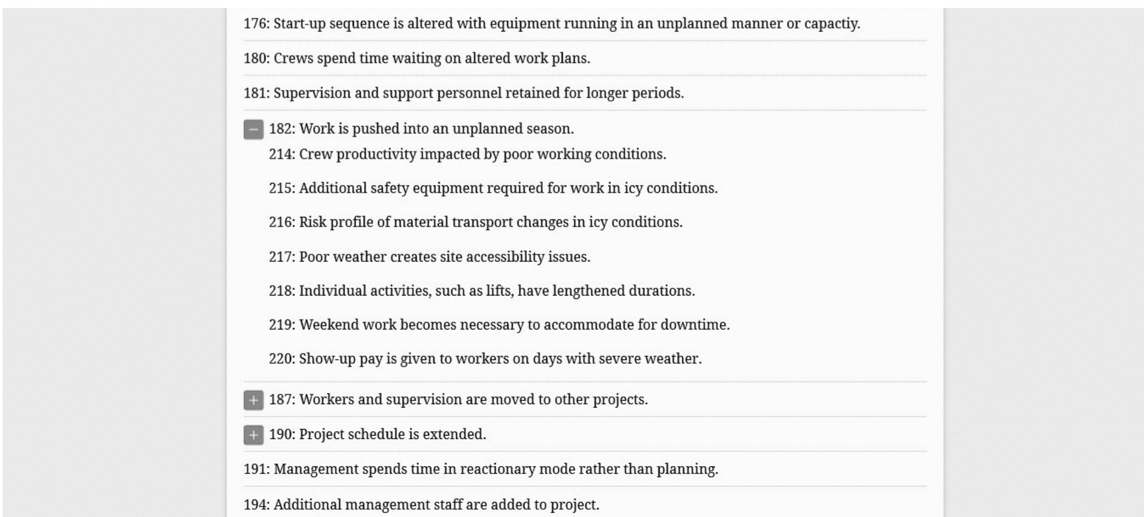


Figure 8: Tree Functionality

The final feature of the LDRC is a "Print Screen" option. This will create a printout report of the impacts associated with a specific selection. Figure 9 presents an example report drawn from the results of the example query in Figure 7. Listed at the top are the selections made to generate the list, as well as all of the associated impacts for the search criteria and related case studies. This feature provides a means of sharing the information gathered with other project team members who may not have access to the

LDRC. This printout can easily be carried to project meetings and/or the site so that teams can make proper plans to address applicable risks.

CII LATE DELIVERABLE RISK CATALOG

SELECTIONS

Late Deliverables: Engineering Documents, Approvals, and Responses,
Impacts: Procurement, Logistics, and Expediting, Onsite Material Handling, Alternative or Additional Suppliers and Vendors, Damage, Degradation, and Loss,
Pillars: Quality,

IMPACT DESCRIPTIONS

- 16: Just-in-time materials must be stored in laydown yards.
  - 18: Unfinished materials are susceptible to corrosion or deterioration.
- 48: Material management system is disrupted.
- 49: Laydown areas become overcrowded.
  - 60: Damage to materials caused by stacking in laydown yard.
  - 61: Materials in laydown yard become blocked in or more difficult to access.
- 54: Materials or equipment are shipped before completion in attempt to maintain schedule.
- 55: Punch-list items must be performed in the field in less-than-ideal conditions.
- 57: Materials or equipment are damaged from an out-of-sequence or blind lift.
- 86: Temporary pipe spools or supports are installed so work can continue in that area.
  - 87: Temporary spools or supports can be left in the system, which could lead to failure.
- 90: Improper prep and/or uncontrollable conditions increase the reject rate on site.
- 106: Extended hours or multiple shifts lead to a decrease in quality.
- 120: Delays between schedule activites can lead to damage of completed work.
- 125: Previously ordered materials are incorrect.
- 129: Materials ordered late may lead to secondary supplier/vendor for expediting needs.
- 148: Compressing commissioning and start-up can create quality control issues.
  - 161: Improper start-up and commissioning can lead to damage.
- 171: Warrantly is voided if damage occurs.
- 173: Lifecycle of engineered equipment is shortened.
- 227: Design undergoes value engineering to reduce cost/schedule.
- 229: Outstanding material orders are updated.
- 232: Some delivered materials are incorrect.
- 234: Newly ordered materials must be expedited.
  - 235: Expedited specialty materials have increased quality and sizing issues.
- 236: Laydown areas become crowded with arriving materials that can't be installed.
  - 237: Additional material handling to shift materials in laydown.
  - 239: Excess handling increases damage to materials.
- 266: Secondary suppliers and vendors are brought on to meet procurement requirements.

RELATED CASE STUDIES

1. Case Study #2: cs02.pdf

Figure 9: Example Search Report

6.2 DEPLOYMENT RECOMMENDATIONS

In creating the LDRC, the team's goal was to give project teams a user-friendly interface with the database it developed. The database incorporates all of the late deliverable impacts the team compiled through case studies, questionnaires and surveys, interviews, and collective team expertise. With the LDRC, users will be able to navigate the hundreds of impacts, to find those that are applicable to a specific project or construction scenario. RT 300 identified several potential uses of the LDRC. The uses outlined below fit in with existing CII best practices and research, and more detailed descriptions of each can be found in the related CII research products.

6.2.1 Project Risk Assessment

The LDRC may be used to identify, list, and weight potential risks associated with late deliverables. Searching the LDRC by Late Deliverables, Pillars, and Impacts will provide a list of outcomes for specific scenarios that could be used as potential risks to help populate a project's risk register or risk matrix. The user can also use the information provided on commonality and severity to help weight the potential risks; and the LDRC can serve to start discussions in developing risk avoidance and mitigation strategies and plans.

6.2.2 Dispute Prevention and Resolution

The LDRC can also be used as an interface between owner and contractor organizations or between engineering and construction groups. Senior project managers, construction managers, or engineering managers can use the tool in meetings with other project stakeholders, including business management personnel or owner's representatives and other decision-makers, to demonstrate known impacts of late deliverables. As a communication tool, the LDRC will help colleagues discuss risk and its potential effects, so that business, project-development, and commercial employees can communicate in a common language.

6.2.3 Knowledge Sharing and Transfer

The LDRC can be used to help identify the impacts of late deliverables by enumerating known effects of late deliverables, in order to train less-experienced construction, engineering, and other project-level professionals. By flagging potential impacts that may not be obvious without years of industry experience, the LDRC can help inexperienced employees develop steps to reduce or mitigate the severity of potential impacts that they otherwise would not have recognized. Project-level users of the LDRC can include project engineers, field engineers, project controls specialists, superintendents, scheduler/planner, and safety and quality personnel; and, while the tool may be especially beneficial for those with less industry experience, others may also benefit by learning from the experiences of other projects.

6.2.4 Lessons Learned

The LDRC has the potential to become a central repository for lessons learned regarding late deliverables. If an unforeseen or little-known effect caused by a late deliverable is experienced on a project, adding it to the LDRC is a simple way to catalog the knowledge for the benefit of an entire organization. By incorporating the LDRC into a lessons learned program, a company can facilitate knowledge management among its experienced employees and promote continuous improvement as an organization. By tracking changes, delays, additional costs, safety risks, and all of the other impacts caused by late deliverables to the site, the company can prevent the same mistake on multiple projects and enhance project delivery and profitability.

6.3 EXAMPLE APPLICATIONS

Research Team 300 has also developed example applications of the Late Deliverable Risk Catalog. The following sections include a description of how various levels of a company and employees of an organization can use the LDRC.

Senior Project Management

Senior project managers can use the LDRC to develop a project's risk matrix. The catalog will also give these managers an understanding of the impacts that result from missing early milestone deliverable dates in engineering, procurement, or other project functions. The LDRC can also be used as a communication tool to give upper-level or business management a better appreciation of the impacts of late deliverables. Finally, this tool can be used both in preventative and reactionary modes on a project, since it both helps predict future impacts from late deliverables, and can forensically identify the sources of change on a project.

Junior Project Engineers

The LDRC is a teaching tool that shares the benefit of years of knowledge, and can spare new project engineers the trouble of learning lessons "the hard way." Young engineers can use the LDRC to understand the wide range of possible impacts, learn how late deliverables and seemingly unrelated effects interact, and foresee potential impacts they may otherwise not have suspected. On a single platform, the tool captures industry lessons learned and expert knowledge regarding late deliverables.

Safety Supervisors/Engineers

The LDRC will also help raise awareness of the increased risk late deliverables pose to site safety. By enumerating safety impacts that do not necessarily result in a safety incident, project-level personnel can better understand how late deliverables change a project's risk profile.

Construction Site Management/Superintendents

The LDRC can support root cause analysis during the investigation of a change or safety incident. The construction and senior management teams can use it as a communication tool, to have a common language and to develop a shared perspective on late deliverable impacts.

Schedulers/Planners/Project Controls Staff

The results from an LDRC query can be used as justification for building more float for critical deliverables or unfamiliar sources into the initial schedule. The tool would also be beneficial for developing recovery plans for actual late deliverables to the jobsite. Finally, the LDRC will help forecast the impacts of known late deliverables and support "what if" analysis during recovery from a specific event.

Engineering or Procurement Management

A procurement manager could use the LDRC much like a senior project manager. It can be used as a training tool for junior procurement staff, a lessons learned repository for specific suppliers, vendors, or materials, or as a tool to raise people's awareness of the true impacts that their job functions ultimately have on projects in the field.

Executive or Business Management

The LDRC provides an unbiased industry-based reference to help prevent and resolve disputes over commercial issues or disagreements with owners/contractors and supply-chain organizations. It can also give people with less construction experience a means of understanding the range of impacts of late deliverables.

6.4 LIMITATIONS

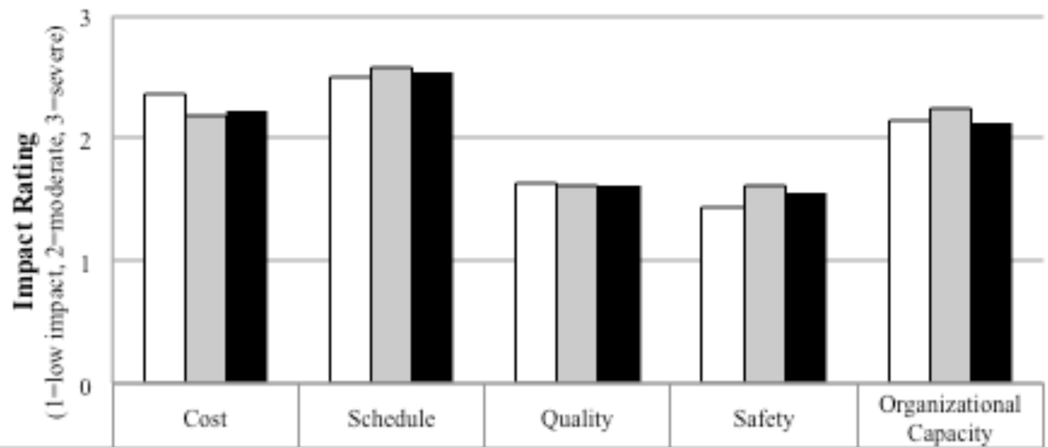
1. The LDRC is not a mitigation tool that will solve all the problems caused by late deliverables to a project. While it will help project teams identify the potential issues and the project outcomes that might be affected, it is up to the each team to develop its own plans to mitigate or prevent any problems.
2. The LDRC does not provide the actual cost increases or time delays associated with a late deliverable. Each project team will have to estimate the value/cost of any impacts on a case-dependent basis; this is because the quantitative impacts of late deliverables can be vastly different from one project to another, depending upon project size, type, complexity, and other variables.
3. Because the data used as the basis for LDRC and associated resources was collected within an 18-month period, they do not capture all possible impacts. Although RT 300 identified the most likely cases, the unique circumstances of every project can produce situations that have not occurred in the past and that cannot be foreseen through research. The intent of RT 300 is for the LDRC to be updated and maintained by individual companies to include new impacts experienced on their projects.
4. Since this research has been limited to industrial construction projects, the LDRC only addresses late deliverables to the construction site and their impacts on the construction phase in the industrial sector.

Chapter 7: Research Findings

Along with collecting the data on the impacts of late deliverables included in the Late Deliverable Risk Catalog, Research Team 300 also collected data to better understand how the construction industry currently perceives and manages late deliverables, the second research thrust. Collecting quantitative data about late deliverables allowed the team to develop prevention and implementation recommendations to help the industry become more proactive in managing late deliverables. It also helped identify and describe points of difference between owners and contractors to increase alignment and understanding in the industry.

7.1 ANALYSIS OF QUESTIONNAIRE AND SURVEY RESULTS

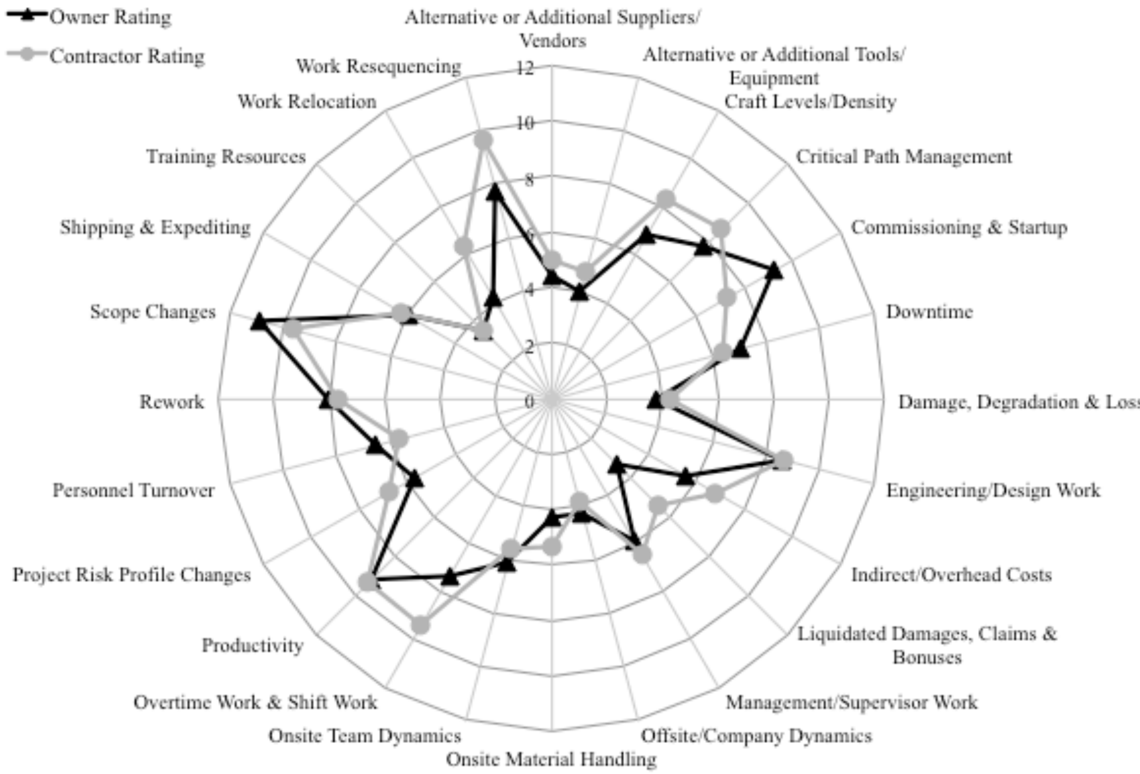
Respondents to the mini case study questionnaire, when asked to rate the impact of late deliverables to each project pillar (1=low, 2=moderate, 3=significant), identified cost and schedule as the most impacted as seen by the overall rating in Figure 10. As expected and set forth in the RT 300 research hypothesis, these two project aspects are most often tracked and closely managed on a project. However, also of note is the high rating of organizational capacity that is almost equal to cost and schedule. This confirms the research team's addition of the fifth project pillar, which was not included in the original research charter. From this, it is clear that industry professionals recognize the importance of the individuals and groups involved in a project and how they are affected by late deliverables. Conversely, RT 300 surmised in the research charter that owners and contractors would have notably different views when it comes to assessing the impacts of late deliverables. However, the data in Figure 10 shows remarkably similar averages when the results are split by organization type, which indicates an alignment between the two regarding the overall impact of late deliverables on the five pillars.



	Cost	Schedule	Quality	Safety	Organizational Capacity
Owner	2.36	2.50	1.64	1.43	2.14
Contractor	2.18	2.57	1.61	1.61	2.25
Overall	2.23	2.55	1.62	1.56	2.13

Figure 10: Project Pillar Rating

Nonetheless, when a similar question was asked in a survey using the more specific impact categories, different results emerged as seen in Figure 11. Several conclusions can be drawn from this data. First, while there are significant differences on several impact categories, impacts that are typically associated with organizational capacity have similar results. For example, Engineering/Design Work, Management/Supervisor Work, as well as Onsite Team and Offsite/Company Dynamics show remarkable similarity. Furthermore, those impacts that are most commonly measured and tracked through a project, including Rework, Personnel Turnover, Productivity, and Downtime, show correlation between owner and contractor responses. From this, it can be deduced that owners and contractors can agree upon the frequency and severity of impacts that both experience on a project or that can be quantified.



*The axis in this chart correlates to a risk factor created using the data from an industry survey. Respondents were asked to rate how commonly or frequently each impact occurred on projects due to late deliverables on a scale of 1 to 4 (1 being the least and 4 being the most). Similarly, they were asked to rate the severity of each impact category on a scale of 1 to 4. The risk factor developed and shown in this figure corresponds to the product of these two ratings.

Figure 11: Impact Category Rating

However, there is less agreement on other specific impact categories. To begin, contractors rated site-related impacts to the field consistently higher than owners, such as Work Relocation and Resequencing, Overtime and Shift Work, Critical Path Management, Alternative and Additional Tools and Equipment, and Onsite Material Handling. Meanwhile, owners showed greater concern with impacts to scope and commissioning/start-up and less with liquidated damages than contractors. While most of these differences would be expected, they are important in understanding the viewpoints of owners and contractors and helping to create a starting point for strategies to overcome late deliverables and prevent disagreements and disputes.

Referring back to Figure 10, the data shows that industry professionals consistently rated the impacts to quality and safety significantly lower relative to cost, schedule, and organizational capacity, yet the research of RT 300 found a similar number impacts in all five categories. As an example, another question posed in the mini case studies asked about which types of human resources were most often added to a project due to the late deliverable. While Figure 10 shows that respondents rated the impacts to safety lowest, the same sources identified, as shown in Figure 12, safety personnel was added on almost half of the projects, which put it at the second most common behind only schedulers and planners.

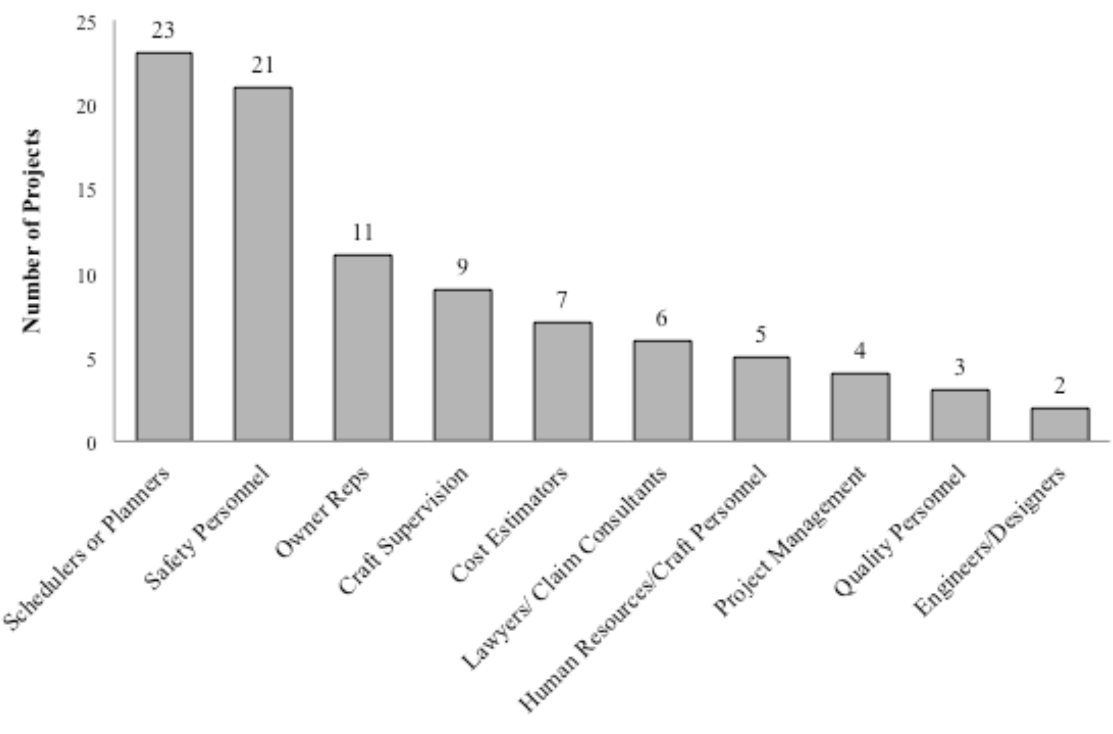


Figure 12: Most Commonly Added Human Resources

Research Team 300 reconciled this difference by recognizing that, although the safety outcomes of a project may not be impacted, changes are made to maintain a specific level of performance and meet the required objectives. For example, the late delivery of pipe spool most likely will not directly lead to an injury, which, at first thought, would mean that the safety impact is less significant than the immediate delays and schedule resequencing. However, the addition of safety personnel to monitor installation and additional safety risks to crews are both noteworthy impacts that generally are not associated with the late deliverable. Going one step further, additional safety equipment, overtime pay, or any other secondary, knock-on impacts required to make up for a late deliverable are even less often tied back to the source. Thus, while an incident may not occur on a project, the steps taken to maintain a safe project are important to monitor.

The same can be said for the quality pillar. It is understood on a project that the quality standards are set and must be met according to the project specifications. So while the quality pillar was rated second lowest by industry professional, RT 300 believes this is because the final quality on a project has met the quality standards. However, knowing the final outcome is of little benefit when examining how late deliverables affect a project throughout its lifecycle. Tracing the ripple of impacts through a project is essential to effectively managing a project and mitigating or avoiding the effects of late deliverables altogether.

Another finding from the research was drawn from the rating survey administered by RT 300; the results of one of the questions are shown below in Figure 13. At face value, the graph shows that customized, site-specific late deliverables are the most common and also have the most severe impact on project outcomes. Specifically, complicated critical-path deliverables – Engineering, Engineered Equipment, Prefabricated Assemblies, and Fabricated Materials – are some of the most pivotal to project success along with permitting, which in itself can derail a project.

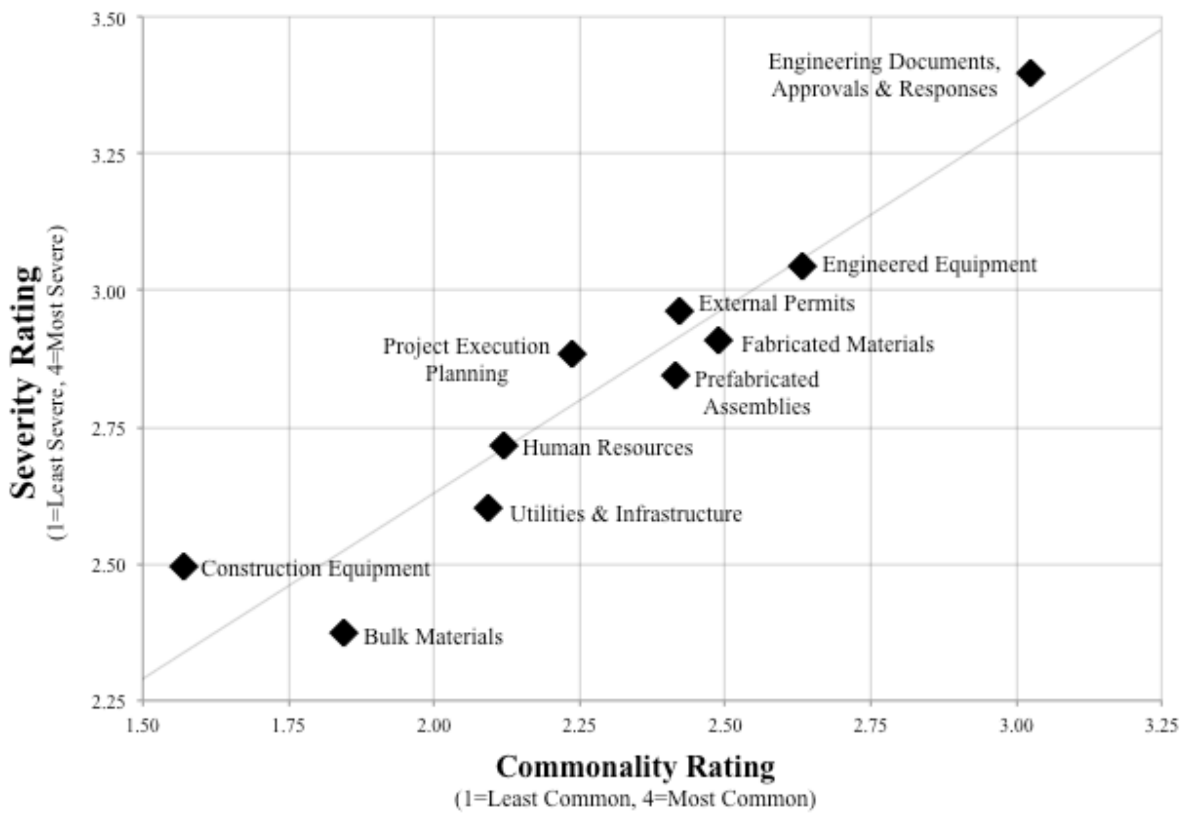


Figure 13: Severity vs. Commonality of Late Deliverables

At the other end of the spectrum are those items that can be easily procured and are readily available, in particular Construction Equipment and Bulk Materials. Thus, respondents ranked these the lowest in commonality, and the ease of replacing them keeps the severity to a minimum. In between those highest and lowest risk deliverables at are the final three categories, all with approximately equal commonality ratings. Project Execution Planning has the highest severity rating of the three, as it again is specialized for a project and is not easily replaced. Human Resources and Utilities and Infrastructure ranked lower, which are more general and can substituted on a project.

Looking at the overall trend plotted in Figure 13, a major cause of concern for the construction industry emerges; namely, the results show that the most common late deliverables are also the most severe. Typically, with a severity vs. commonality graph, the method of improvement is to make the most common the least severe and the most severe the least common (i.e. the inverse of the trend line). However, when asked only to rate the commonality and severity in separate questions, the results clearly show that the most common are the most severe as judged by the industry. It is the hope of RT 300 that by recognizing this trend, understanding the ripple effects late deliverables have on a project, and identifying the potential impacts before they occur, the points plotted in Figure 13 all move to the bottom left of the graph.

7.2 STATISTICAL ANALYSIS OF SURVEY RESULTS

While the research team analyzed the results of the survey using the figures shown in the previous section for the purpose of developing recommendations, some additional analysis was also performed to see if the differences mentioned were statistically significant. For the survey data, a paired sample t-test was performed to determine if the resulting ratings of owners and contractors was significantly different. The assumptions for the t-test include an equal variance between the two samples (homoscedasticity) and a two-sided distribution for the data. The significance level was taken as 0.05, meaning that it can be said with 95 percent confidence that the difference in the average rating between the owners and contractors is significant and real (i.e. five percent of the time the difference is caused by chance). The sample sizes from the survey are shown in Table 32.

Table 32: Survey Sample Sizes

	Total	Owner	Contractor	Other
Number of Responses	240	103	113	24

First, statistical analysis was performed on the commonality and severity ratings of the late deliverable categories. As can be seen below in Table 33 and Table 34, the overall averages as well as the averages for both contractors and owners were computed. The value shown in the fifth column corresponds to the absolute value of the difference between the owner and contractor averages. This gave the general idea as to which categories were rated differently by owners and contractors, but then the t-test was conducted to determine if this difference was, in fact, statically significant. With the parameters discussed previously, the results are shown in the final two columns of the tables.

Table 33: Late Deliverable Commonality Ratings and Statistics

Late Deliverable Commonality	Overall Average	Owner Average	Contractor Average	Difference	t-Test	Significant?
Bulk Materials	1.84	1.84	1.73	0.11	0.2908	No
Construction Equipment	**1.57**	**1.64**	**1.35**	**0.30**	**0.0048**	**Yes**
Engineering Documents, Approvals & Responses	3.03	2.98	3.11	0.13	0.3088	No
Engineered Equipment	2.63	2.50	2.71	0.21	0.0580	No
External Permits	2.42	2.35	2.42	0.07	0.6140	No
Fabricated Materials	2.49	2.47	2.52	0.05	0.6487	No
Human Resources	2.12	2.25	2.06	0.19	0.1341	No
Prefabricated Assemblies	2.42	2.30	2.47	0.17	0.1671	No
Project Execution Planning	**2.24**	**2.41**	**1.94**	**0.47**	**0.0003**	**Yes**
Utilities & Infrastructure	2.09	2.04	2.13	0.09	0.4434	No

Table 34: Late Deliverable Severity Ratings and Statistics

Late Deliverable Severity	Overall Average	Owner Average	Contractor Average	Difference	t-Test	Significant?
Bulk Materials	2.37	2.22	2.45	0.23	0.0732	No
Construction Equipment	2.50	2.44	2.48	0.04	0.7545	No
Engineering Documents, Approvals & Responses	3.40	3.38	3.43	0.05	0.6023	No
Engineered Equipment	**3.05**	**2.86**	**3.22**	**0.36**	**0.0018**	**Yes**
External Permits	2.96	2.90	2.97	0.07	0.6079	No
Fabricated Materials	2.91	2.80	2.99	0.20	0.0863	No
Human Resources	2.72	2.69	2.77	0.08	0.5453	No
Prefabricated Assemblies	2.84	2.74	2.93	0.19	0.0742	No
Project Execution Planning	2.88	2.88	2.84	0.04	0.7410	No
Utilities & Infrastructure	2.60	2.64	2.53	0.12	0.3457	No

Two categories were rated differently for their frequency: Construction Equipment and Project Execution Planning. Furthermore, there was a statistical difference in how owners and contractors rated Engineered Equipment in severity. After the t-test was performed on the individual ratings for commonality and severity, the same process was repeated for the risk factor used by RT 300, which was the product of the two ratings. In order to accomplish this, the commonality and severity of each category was multiplied for each respondent and then the statistical analysis was performed. The averages for the owner and contractor groups are shown below in Table 35.

Table 35: Late Deliverable Risk Factor and Statistics

Late Deliverable Risk Factor	Owner Average	Contractor Average	Difference	t-Test	Significant?
Bulk Materials	4.41	4.36	0.05	0.9043	No
Construction Equipment	4.20	3.51	0.69	0.0758	No
Engineering Documents, Approvals & Responses	10.40	11.06	0.66	0.2795	No
Engineered Equipment	**7.55**	**8.89**	**1.34**	**0.0112**	**Yes**
External Permits	7.25	7.50	0.25	0.6800	No
Fabricated Materials	7.24	7.67	0.43	0.4036	No
Human Resources	6.60	6.09	0.51	0.3670	No
Prefabricated Assemblies	6.58	7.39	0.82	0.1084	No
Project Execution Planning	**7.26**	**5.60**	**1.66**	**0.0025**	**Yes**
Utilities & Infrastructure	5.77	5.59	0.18	0.7133	No

These results show that there was a significant difference between owners and contractors on only two of the late deliverable categories: Engineered Equipment and Project Execution Planning. It can be deduced that the difference between owners and contractors on the commonality of late construction equipment was reduced when the risk factor was calculated by the small difference in their perception of its severity. After the t-tests were performed on the late deliverables categories, the exact same process was completed for the 24 impact categories. As can be seen in Table 36 and Table 37, five of the 24 categories showed statistical differences between the owner and contractor ratings for commonality, and nine of the 24 showed differences in severity. These two tables can be analyzed to see how owners and contractors answered differently on these two different questions rather than as a risk factor in the previous section.

Table 36: Impact Commonality Rating and Statistics

Impact Commonality	Overall Average	Owner Average	Contractor Average	Difference	t-Test	Significant?
Alternative or Additional Suppliers/Vendors	2.29	2.17	2.35	0.18	0.0828	No
Alternative or Additional Tools/Equipment	**2.19**	**2.06**	**2.32**	**0.26**	**0.0216**	**Yes**
Craft Levels/Density	2.68	2.60	2.75	0.16	0.1717	No
Critical Path Management	2.87	2.82	2.93	0.11	0.3285	No
Commissioning & Startup	**2.77**	**2.89**	**2.64**	**0.25**	**0.0431**	**Yes**
Downtime	2.51	2.54	2.44	0.11	0.3879	No
Damage, Degradation & Loss	1.88	1.81	1.91	0.10	0.3362	No
Engineering/Design Work	2.89	2.85	2.91	0.06	0.6276	No
Indirect/Overhead Costs	2.59	2.46	2.65	0.19	0.1535	No
Liquidated Damages, Claims & Bonuses	**1.99**	**1.78**	**2.09**	**0.32**	**0.0236**	**Yes**
Management/Supervisor Work	2.52	2.49	2.53	0.04	0.7584	No
Offsite/Company Dynamics	2.03	2.05	1.95	0.10	0.3963	No
Onsite Material Handling	2.24	2.14	2.27	0.13	0.2853	No
Onsite Team Dynamics	2.45	2.49	2.35	0.14	0.2729	No
Overtime Work & Shift Work	2.98	2.91	3.10	0.19	0.1071	No
Productivity	2.94	3.00	2.92	0.08	0.4597	No
Project Risk Profile Changes	2.48	2.36	2.57	0.20	0.0965	No
Personnel Turnover	2.40	2.47	2.33	0.15	0.2482	No
Rework	2.76	2.75	2.72	0.03	0.7901	No
Scope Changes	3.16	3.21	3.05	0.17	0.1771	No
Shipping & Expediting	2.52	2.54	2.52	0.02	0.8749	No
Training Resources	1.86	1.87	1.84	0.03	0.7539	No
Work Relocation	**2.24**	**1.95**	**2.45**	**0.51**	**0.0001**	**Yes**
Work Resequencing	**2.99**	**2.84**	**3.15**	**0.32**	**0.0063**	**Yes**

Table 37: Impact Severity Rating and Statistics

Impact Severity	Overall Average	Owner Average	Contractor Average	Difference	t-Test	Significant?
Alternative or Additional Suppliers/Vendors	2.08	2.02	2.11	0.09	0.3826	No
Alternative or Additional Tools/Equipment	2.00	1.93	2.03	0.10	0.3496	No
Craft Levels/Density	**2.84**	**2.62**	**3.00**	**0.38**	**0.0012**	**Yes**
Critical Path Management	2.89	2.76	2.96	0.21	0.0776	No
Commissioning & Startup	**2.98**	**3.20**	**2.78**	**0.42**	**0.0010**	**Yes**
Downtime	2.69	2.76	2.63	0.13	0.2945	No
Damage, Degradation & Loss	2.22	2.09	2.24	0.15	0.2067	No
Engineering/Design Work	3.00	3.02	2.98	0.04	0.7530	No
Indirect/Overhead Costs	**2.45**	**2.28**	**2.56**	**0.29**	**0.0210**	**Yes**
Liquidated Damages, Claims & Bonuses	**2.35**	**1.90**	**2.60**	**0.70**	**0.0000**	**Yes**
Management/Supervisor Work	2.49	2.39	2.57	0.18	0.1330	No
Offsite/Company Dynamics	2.07	2.10	1.97	0.13	0.2757	No
Onsite Material Handling	**2.19**	**1.98**	**2.36**	**0.38**	**0.0013**	**Yes**
Onsite Team Dynamics	2.44	2.44	2.39	0.05	0.6727	No
Overtime Work & Shift Work	**2.81**	**2.53**	**3.04**	**0.51**	**0.0000**	**Yes**
Productivity	3.15	3.07	3.20	0.13	0.2178	No
Project Risk Profile Changes	2.56	2.40	2.61	0.21	0.0778	No
Personnel Turnover	2.55	2.64	2.43	0.21	0.0833	No
Rework	2.91	2.92	2.83	0.09	0.4726	No
Scope Changes	**3.31**	**3.40**	**3.16**	**0.24**	**0.0315**	**Yes**
Shipping & Expediting	2.42	2.35	2.47	0.13	0.2603	No
Training Resources	1.91	1.84	1.88	0.04	0.6849	No
Work Relocation	**2.39**	**2.14**	**2.57**	**0.43**	**0.0015**	**Yes**
Work Resequencing	**2.89**	**2.72**	**3.05**	**0.32**	**0.0043**	**Yes**

Finally, the t-test was performed on the risk factors developed from the survey. As can be seen in Table 38, seven of the impact categories showed statistical differences between owners and contractors based on the 95 percent confidence level. When compared to the analysis in the previous section that was based purely on overall averages, rather than individual responses in developing the risk factor, five of these seven were cited as differences between owners and contractors. Two categories (Craft

Levels/Density and Personnel Turnover) were fairly close when averaged collectively but statistically different when tests were run on individual responses. This phenomenon is discussed further in the next section.

Table 38: Impact Risk Factor and Statistics

Impact Risk Factor	Owner Average	Contractor Average	Difference	t-Test	Significant?
Alternative or Additional Suppliers/Vendors	4.68	5.23	0.55	0.1907	No
Alternative or Additional Tools/Equipment	4.30	4.97	0.67	0.1347	No
Craft Levels/Density	**7.31**	**8.51**	1.20	**0.0348**	Yes
Critical Path Management	8.20	9.01	0.81	0.1572	No
Commissioning & Startup	**9.56**	**7.64**	1.92	**0.0019**	Yes
Downtime	7.41	6.69	0.72	0.1964	No
Damage, Degradation & Loss	4.03	4.45	0.42	0.2937	No
Engineering/Design Work	9.10	9.02	0.08	0.8923	No
Indirect/Overhead Costs	6.35	7.24	0.89	0.1425	No
Liquidated Damages, Claims & Bonuses	**4.10**	**6.08**	1.98	**0.0014**	Yes
Management/Supervisor Work	6.36	6.87	0.51	0.3544	No
Offsite/Company Dynamics	4.75	4.16	0.59	0.1844	No
Onsite Material Handling	4.77	5.69	0.92	0.0722	No
Onsite Team Dynamics	6.69	5.95	0.73	0.2033	No
Overtime Work & Shift Work	**7.76**	**9.66**	1.89	**0.0015**	Yes
Productivity	9.65	9.56	0.09	0.8729	No
Project Risk Profile Changes	6.29	7.04	0.75	0.1827	No
Personnel Turnover	**7.00**	**5.90**	1.10	**0.0451**	Yes
Rework	8.34	7.99	0.35	0.5517	No
Scope Changes	11.16	10.16	1.00	0.0977	No
Shipping & Expediting	6.35	6.44	0.08	0.8654	No
Training Resources	3.78	3.70	0.09	0.8231	No
Work Relocation	**4.64**	**6.61**	1.97	**0.0004**	Yes
Work Resequencing	**8.08**	**9.69**	1.61	**0.0038**	Yes

7.3 DISCUSSION

While the analysis of the survey results conducted by the research team was conducted using only the risk factor averages, these statistical results have been included to show the likelihood of these results being caused by statistical error. Also of note, the figures showing risk factors in the previous section were computed by finding the average of all owners' commonality ratings, then the average of all owners' severity ratings, and then multiplying these two averages together. The same was then done for contractors. However, for the purpose of a t-test, the risk factor assigned by each individual respondent was needed. Thus, first each respondents' commonality rating was multiplied by the severity rating. Then, the average of all of these risk factors was computed for the two groups. Therefore, the values shown in this section are slightly different from those in the previous due to the few survey responses that were not entirely completed (i.e. those surveys that did not answer for both the commonality and severity of any particular category were excluded from the statistical analysis, lest the assigned value would have been 0 for the risk factor). Also, the owner and contractor averages in Table 38 do not equal the product of the commonality ratings (Table 36) and severity ratings (Table 37) for the same reason. While the magnitudes are different, the overall shape of the chart is identical as seen below in Figure 14 compared to Figure 11.

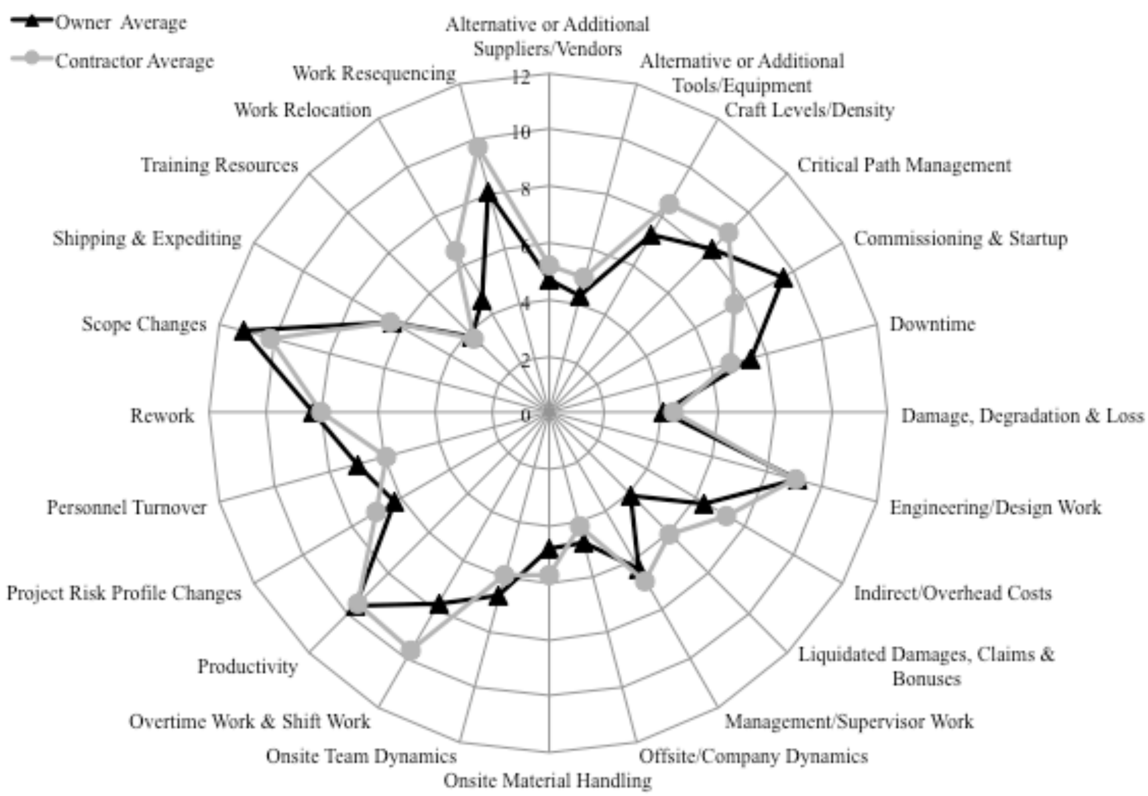


Figure 14: Risk Factor for Owners and Contractors

Chapter 8: Lessons Learned and Recommendations

While developing the case studies and analyzing the data collected from both research thrusts, Research Team 300 created a set of lessons learned from the case studies and recommendations for preventing the most common types of late deliverables. Finally, the team created a set of suggestions for fully implementing the Late Deliverable Risk Catalog into a company.

8.1 CASE STUDY LESSONS LEARNED

These lessons learned address both the prevention of late deliverables and the deployment of effective methods for minimizing their project impacts. Table 39 summarizes each of the team's nine case studies. Chapter 4 presents the entire set of case study lessons learned, as does the LDRC. In Table 39, the team presents each summary generically, so that it can be applied to any project. However, if further explanation and context are needed, the reader should refer to the detailed case study summaries in Chapter 4.

As the research team compiled and assessed these lessons learned from unrelated projects, all with different late deliverables, three common themes emerged. Each lesson learned in Table 39 is classified under one of the following three themes:

1. risk identification, evaluation, and mitigation
2. project communication and coordination
3. project planning and contingency management.

These three themes were developed by RT 300 to encompass the trends and ideas in the lessons learned, which are divided by case study so the corresponding late deliverable(s) can be identified.

Table 39: Case Study Lessons Learned

	Late Deliverable	Lessons Learned
Case Study #1	**External Permits**	a) Visibility is necessary for owner-acquired environmental permits during the Request for Proposal (RFP) and contract negotiation phases.** b) Project material storage and lay-down areas should be permitted and/or designed to be separate from the capital project areas.*** c) Interpersonal skills and the right contracting method can result in a constructive influence on how the project team manages the impacts of late deliverables.**
Case Study #2	**Engineering Documents, Approvals, and Responses**	a) Take time to formally review the potential impacts of a late deliverable then create a recovery plan that mitigates the impacts to the greatest possible extent.* b) Open lines of communication between project stakeholders, and, early in the project, provide means for document control and release.**
Case Study #3	**Fabricated Materials**	a) Risk identification and management efforts for materials shipping and logistics activities should consider, as appropriate, hijack/piracy and other applicable low-probability, high-impact risks. This is particularly important for long-lead, critical path, or materials that are difficult to replace.* b) Fully assess changes to execution plans, cost/contingency estimates, schedules, and resource availability when the project suffers a major late delivery event, including an evaluation of the consequential or knock-on impacts.*** c) A project's risk profile and risk management plans should be reassessed in light of any changes to the project.*
Case Study #4	**Engineered Equipment**	a) Evaluate the full range of impacts and risks associated with material substitutions or changes.* b) Clearly define and approve any scope changes that arise in a project.**
Case Study #5	**Construction Equipment**	a) Critical materials and equipment should have full supplier quality surveillance plans in place to assure adherence and compliance with engineering progress, material quality, and manufacturing to code and schedule.**
Case Study #6	**Human Resources Engineering Documents, Approvals, and Responses**	a) When an owner implements a new "standard" or "product line" design, the owner and/or engineer must weigh the risks versus the benefits of starting construction prior to the design being complete.* b) Ensure that the contractor has the ability to provide resources (both management and labor) as needed.* c) Involve all stakeholders in addressing the overall impacts of decisions regarding engineering and design.**
Case Study #7	**Bulk Materials Prefabricated Assemblies**	a) Project coordination decisions should not be taken in isolation, but with all key stakeholders in order to address a risk and mitigation plans.** b) Just-in-time delivery requires a significantly higher level of control and coordination in materials management.**
Case Study #8	**Utilities & Infrastructure**	a) Adequately identify all foreseeable external project risks and coordinate construction plan with those external stakeholders.* b) Incorporate mitigation plan for utilities/infrastructure in the pre-planning risk assessment.*
Case Study #9	**External Permits, Project Execution Planning**	a) Critical items, such as permits, should be reflected in the project schedule with early start and late finish dates.*** b) Schedule changes should be communicated and understood by all key project stakeholders. Schedules are not a planning activity, but a project team tool.**
***Risk Identification, Evaluation, and Mitigation **Project Communication and Coordination ***Project Planning and Contingency Management**		

It should be recognized that these themes and lessons learned address the prevention of late deliverables and/or the minimization of its impact; in short, these are methods and ideas that should all be considered before a late deliverable event occurs. In all the case studies, risks were either not considered in the original planning or were not communicated effectively to all project participants. Minimizing project impacts after the risk event has been experienced is often difficult; therefore, these projects would have benefited from a resource that enabled early identification and communication of these risks. Thus, the goal of the LDRC is to do just that—identify risks and describe their consequences so that project teams can effectively prevent late deliverables and mitigate their impacts.

8.2 LATE DELIVERABLE PREVENTION RECOMMENDATIONS

Due the great variety of possible late deliverables, RT 300 recommends a prevention-based approach for the most effective management of late deliverables. While the LDRC may make it significantly easier to identify more potential impacts of late deliverables earlier, the research team recognizes that organizations would have to commit significant resources to identifying the many causes and ripple effects on a project. Therefore, the team recommends using the LDRC in situations in which late deliverables cannot be avoided, and views avoiding late deliverables as the best solution to the problem. While avoiding the most common or severe late deliverables may seem to be common sense, data collected by RT 300 indicate otherwise. More than 240 survey respondents were asked to rate the relative commonality and severity of each category on a scale of one to four, with four being the most relative/severe. The reported average severity of each late deliverable category was plotted against the reported average commonality of each group, as shown in Figure 15.

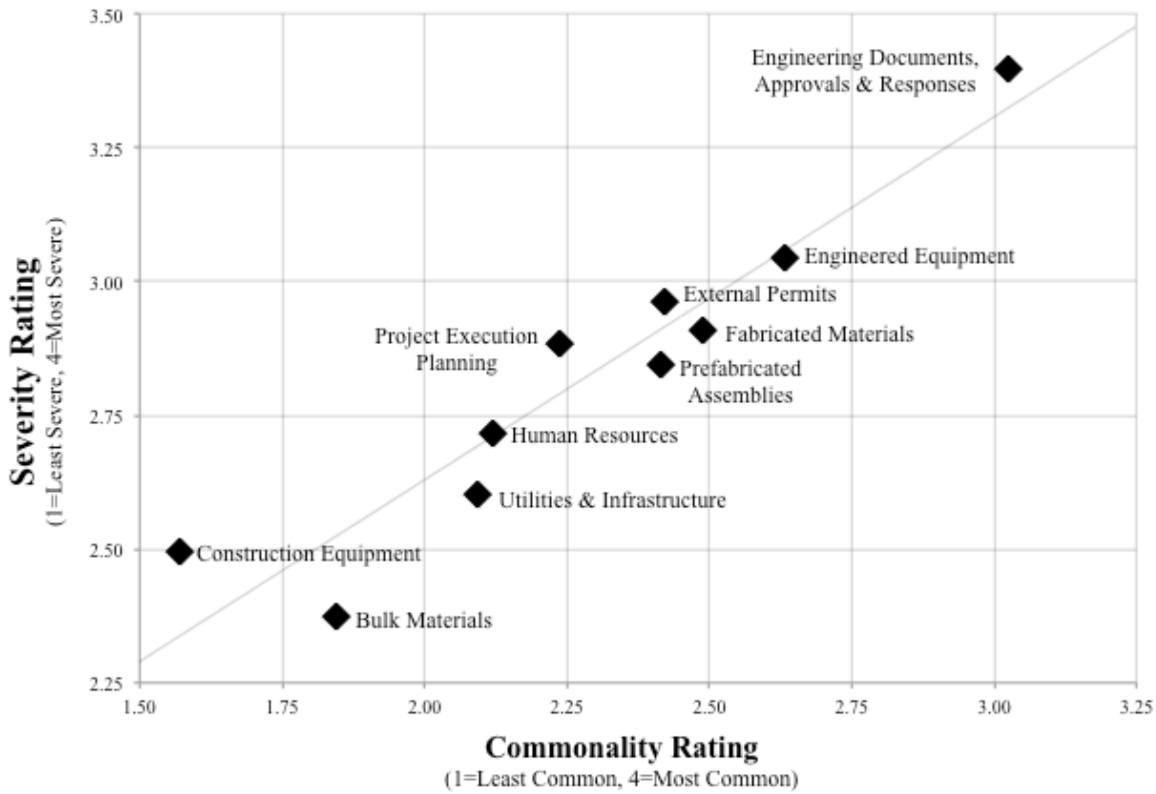


Figure 15: Severity vs. Commonality of Late Deliverable Types

To the surprise of the research team, the severity versus commonality graph showed a positive trend line, with the most severe impacts also being the most common on construction projects. Typically, organizations work to decrease the occurrence of high severity risks and/or decrease the severity of the most common risks. However, contrary to expectation, the 240 industry professionals surveyed clearly indicated that this is not the case. Fortunately, recognizing this trend creates an opportunity to improve industry performance and employ effective mitigation actions on specific targets. The knowledge of which late deliverables are most prevalent, coupled with an awareness of early indicators for these same deliverables, constitutes a force multiplier for late deliverable management. Of the ten late deliverable categories studied, the following were found to be the two most prevalent groupings, in terms of both severity and commonality:

1. engineering documents, reviews, and approvals
2. specialty equipment and materials (i.e., engineered equipment, prefabricated materials, and fabricated assemblies).

Based on the collective expertise of RT 300 team members, the following sections present the team's recommendations for pro-actively identifying and preventing these two most prevalent and detrimental late deliverable groupings. However, it is important to understand that, while these recommendations can help address some of the most common sources of problems, late deliverables may also be symptoms of other institutional issues.

8.2.1 Engineering Documents/Reviews/Approvals

The P&IDs function as a project's roadmap and set the direction for the entire project team. Thus, it is beneficial to take the time to set mutually agreed-upon dates and deadlines and to manage each of the preliminary releases to achieve an on-time IFC release. The P&IDs are critical path predecessors for the vast majority of engineering, procurement, and construction activities. If home office activities comprise approximately 10 percent of the total project costs, corrective action that includes overrunning 10 percent of the project costs is well worth it, since such action stands to protect 90 percent of the project from ripple-effect impacts. Since safety and quality are among the known project pillars to be affected, it is clear that adding resources to immediately get back on the plan is a best practice.

The second most serious problem that creates a ripple effect and can delay the delivery of engineering documents is any changes or disruptions in the plot plan. Plot plan changes create rework in every engineering discipline, and this rework stymies progress on material takeoffs and material requisitions to procurement. Therefore, late plot plan changes are an early indicator of widespread problems. Avoiding these changes forestalls the need to mitigate late deliveries along all the discipline supply lines. If the project team does not have the organizational capacity to address a plot plan change immediately by applying additional resources, it will have great difficulty coping effectively with the ripple effects. Thus, if the change cannot be avoided, resources must be added to get back on plan.

Furthermore, benchmarks and metrics at most organizations are based on the assumption that projects used an experienced workforce. The actual demographics of the workforce are currently changing at rapidly and, typically, projects require a broader mixture of experienced personnel with early-career personnel. Retirement, coupled with personnel reassignments, has recently created high turnover for many project teams. Unfortunately, because most metrics have not been adjusted, project teams are working with targets that are overly optimistic about their actual organizational capacity for engineering and design, and for approvals and responses. Early indicators for late deliverables from these functions include planned retirement, a growing backlog, the transfer of personnel to other projects, or long lead times for staffing projects. Recognizing and factoring in changing workforce demographics are important to avoiding late engineering deliverables.

Additional recommendations and best practices for preventing late engineering deliverables include the following:

- Minimize the overlap between structural steel Issue for Construction (IFC) drawings and steel fabrication activities.

- Minimize the overlap between the generation of isometrics and the actual fabrication of assemblies (e.g., spools and modules).
- Establish several periodic reviews by senior engineering management from both owner and contractor organizations during the development of supplier and contractor approval schedules.
- Identify triggers for escalating issues to senior management between reviews or in light of any other concerns.

8.2.2 Specialty Equipment and Materials

When, early in the project development process, business development and project management personnel present cost and schedule predictions that have not been vetted or scrutinized by the appropriate parties, these forecasts often become unrealistic long-term business or project objectives. A leading indicator of ensuing trouble is a sole reliance on initial internal benchmarking in lieu of consulting with suppliers and contractors. By avoiding the use of preliminary cost and schedule predictions that have not been confirmed by people in the supply chain, project teams can greatly reduce the likelihood of the late arrival of specialized and/or custom deliverables. Moreover, they can prevent many serious problems by using standard designs and proven specifications.

The standardized approach also provides a highly effective hidden benefit to projects, since it reduces the level of vendor approval work by an order of magnitude and, thus, reduces the overall lead time for deliverables. In addition, contracting with suppliers, vendors, and fabricators who have a proven “track record” and focus on lowest final cost instead of lowest initial cost can also help mitigate late deliverables. Proven providers also have an organizational maturity that eliminates broad categories of engineering approvals required during design development. However, when forced to use suppliers with known delivery deficiencies, project teams should include allowances for time and cost impacts to prevent knock-on impacts. Other effective practices for preventing the late delivery of specialty and/or custom equipment and materials include the periodic reviews by senior management to enforce specific milestones, the insertion of an expeditor/inspector and quality personnel at the supplier's facility, and the identification and communication of triggers that require management engagement.

8.3 LDRC Implementation Recommendations

While all late deliverables cannot be avoided, RT 300 hopes that companies will incorporate this research and the LDRC into their standard procedures to benefit fully from a better understanding of late deliverables. RT 300 suggests that companies adopt these research products and take the following steps to expand and integrate the LDRC:

- Add new categories of late deliverables particular to a company or industry.
- Conduct additional company-specific case studies on projects affected by late deliverables.
- Incorporate costs of specific impacts, either in dollar value or as a percentage.
- Add a new field to the tool that identifies a company contact who has previously dealt with a specific problematic situation.
- Incorporate solutions to common issues that arise or company-specific lessons learned involving impacts of certain late deliverables, suppliers, contractors or subcontractors.

Research Team 300 recognizes that fully incorporating the LDRC along with these recommended processes would take considerable time and resources. While this task will be up to the individual company, customizing the LDRC for private company use with these recommendations would allow a company both to understand late deliverables and track their impacts. Such customization would also allow the company to leverage this understanding into improved project performance in all five pillars.

Chapter 9: External Review and Validation

Eight construction industry professionals reviewed the research and provided feedback on the Late Deliverable Risk Catalog. After reading the publications, the reviewers were interviewed for 30-45 minutes using the questionnaire found in Appendix E as an outline. The construction experts interviewed had a combined 211 years of industry experience. A summary of their background information can be found below in Table 40. The primary topics covered in the interviews were the need for the research in the industry, the validity of the research background, the potential for implementation of the research and tools, an assessment of the recommendations and lessons learned, the and the documents' effectiveness of communicating all the above to the industry. Each of the subsequent segments summarizes the feedback given by the external reviewers.

Table 40: External Reviewers' Background

Title	Company	Industry
Project Director	Owner	37 years
Construction Leader	Owner	35 years
Vice President – Estimating & Controls	Contractor	32 years
Construction Operations Manager	Contractor	32 years
Engineering Manager	Owner	30 years
Construction Services Manager	Owner	22 years
Project Manager	Contractor	20 years
Project Engineer	Contractor	3 years

9.1 INDUSTRY NEED

The overall belief of the expert reviewers is that the industry readily perceives there is a problem with late deliverables but that there is little effort to investigate or record the impacts beyond the scope of a single project. This aligns with RT 300's idea that the impacts of late deliverables are "tribal knowledge" – information that is known to one group but not to others. By consolidating this knowledge, one reviewer noted that the industry needs to and could experience better risk planning that would lead to more effective project allowances and contingencies. Another considered the key to this research being a better understanding of uncertainty in construction. While the underlying effects of late deliverables may be unknown, identifying them earlier in a project is fundamental to industry improvement.

Another theme that arose in the interviews was the need for improved communication between construction groups and other project stakeholders. Being able to better disseminate information regarding late deliverables is an essential need so contractors, who are often very sensitive to changes and often have problems pushed to them in the field, can demonstrate the risks that are posed from late deliverables. Several reviewers noted that the construction side is often left to make up for problems from other parties early in the project lifecycle, and that having research that shows possible impacts will help them communicate that risk to owners. The Late Deliverable Risk Catalog can fulfill this need by assisting in risk analysis allowing all stakeholders to equitably share risk and employ the proper means of mitigation or levels of contingency.

9.2 RESEARCH PROCESS

Much of the feedback on the research process was centered on the case studies and graphs presented with data from the surveys and questionnaires. In identifying the exact process that was taken in the interviews and data collection, the reviewers knew what to expect from the research products. All reviewers agreed that the case studies were effective at communicating a specific set of problems that are tied to late deliverables. However, with the levels of uncertainty on projects, nine case studies are not sufficient to extrapolate this data to all projects. Several reviewers, although, also noted that even and “infinite” number of case studies still would not be able to capture all of this uncertainty They noted the real strength of this research and its tools are the ability to promote thought. Numerous problems experienced on a project, according to one expert, occur because people have become fixated on other pressing issues leaving other aspects subject to deviation. By putting many of these risks in one place helps the user see a bigger picture and possibly avoid the propagation of impacts. Furthermore, a couple of reviewers commented that the categories developed by RT 300 were both comprehensive and would play a significant role in improving the communication of risks more efficiently.

Two additional questions posed by reviewers involved two aspects that had not been investigated by RT 300. First, one reviewer noted that the spider graphs (showing the differences between owners and contractors on the severity/frequency of impacts) are very intuitive. In other words, most every industry professional could guess the impact categories that owners would rate higher and those contractors would be more concerned with. With this in mind, the expert wondered why the difference still exists and hopes that this graph can help increase understanding between parties. The second point raised by another expert involved the case studies, noting that many of the case studies involved similar problems and impacts caused by late deliverables. Most veteran construction professionals have experienced many of the same problems. Knowing this, the expert questioned why many of the same problems continue to plague the industry.

The final suggestion from several of the external reviewers was for further research incorporating all parties to a case study. By interviewing representatives from the owner and contractor as well as any other parties (consultants, suppliers, owner's reps, etc.), a more complete picture of the projects may be drawn. While it was noted that listing the type of company interviewed for each project was beneficial to understanding the case studies, validating the claims or at least giving multiple, differing accounts would provide more insight into the impacts to a project. Thus, in future research, incorporating both sides of a project would be beneficial.

9.3 IMPLEMENTATION

One expert noted that at the basis of any potential use of the research are two primary phases where changes can be implemented: before a late deliverable event occurs (project risk assessment, training, risk assessment, dispute prevention) and after (lessons learned, dispute resolution). The importance of this differentiation is helping to understand how these two phases interact. The goal of project management is to be proactive and manage a project ahead of the work that is happening. In order to do this with respect to late deliverables, the after (documenting and communicating known impacts) must be done prior to the before (preventing late deliverables and mitigating impacts), and this research serves as a first step in recording these risks and impacts.

Several other comments were made about the implementation of the LDRC into the construction industry practices. First, at the delivery level, the tool with help all disciplines outside construction understand how their performance echoes and multiplies into the field. This can help build teamwork by showing how everyone has a stake in the project all the way to the end. Second, the LDRC may not be used to track or predict the impact of the less frequent late deliverables. The time and effort put into understanding these impacts may not seemingly equate to the risk that these deliverables pose. However, again this tool may open the eyes of many to unforeseeable impacts of late deliverables and how isolated events can grow into much larger problems. Finally, on that note, several experts communicated that increasing the understanding of risks on a project can prevent suffering at the end. Thus, while incorporating this research for less common late deliverables may seem extraneous up front, consolidating knowledge will improve project performance in the end.

9.3.1 Project Risk Assessment

Several of the reviewers commented on the potential for the Late Deliverable Risk Catalog to improve project risk assessment early in projects. Incorporating this tool into the development of a risk profile document will expand the knowledge base by bringing in external experiences, and several external reviewers showed interest in making this change at their respective companies. Two primary reasons were given when asked how the tool would specifically help in project risk assessment. First, having all of these impacts enumerated in a single interface will prevent people from cutting corners in the risk assessment with regards to late deliverables. By taking a step back from the project itself and assessing what might happen by using the tool, teams will hopefully create a more comprehensive and, thus, accurate risk assessment. The second value added to project risk assessment is in the development of the risk matrix. With the data surrounding the frequency and severity of late deliverables, project teams will be able to be more perceptive in assessing the possibilities of late deliverables and weighting impacts in a risk matrix.

Two separate experts showed interest in introducing the LDRC to a current project. Both had projects with major engineered equipment currently in the front-end planning phases. One suggested that the project team could use the tool to explore possibilities and risks stemming from late compressors, and the second thought it would be advantageous in developing the risk matrix for a major piece of equipment. This indicates that one of the major benefits of the tool may occur before a construction begins, and that idea ties into the next deployment application – dispute prevention. Furthermore, these ideas highlight the forward-looking nature of the LDRC in risk assessment by acknowledging these risks as soon as possible.

9.3.2 Dispute Prevention and Resolution

The central theme of the feedback for this implementation recommendation was that avoiding late deliverables and preventing disputes is the key to success. However, it is known that all late deliverables simply cannot be prevented and disputes will potentially arise. Therefore, there are two specific aspects to which this research can apply: prevention of future disputes and the resolution of existing ones.

To begin, almost every external reviewer commented on the key ability of the Late Deliverable Risk Catalog to help prevent disputes in the construction industry. This assessment was based on the LDRC providing the opportunity to address changes and risks earlier to prevent disagreements later on. The tool provides a basis for communication between all stakeholders. For example, a contractor can go to a supplier or owner and communicate that previous research has shown specific risks and possibilities associated with that late deliverable. In other words, any assertions made by a party can have some basis in research and provide a staring point for negotiation. Another expert explained it a similar way, saying that the LDRC can be used to help settle future disputes before they arise. By being up front and active and showing the other parties what the risks are, the understanding of the impacts can be more fully understood before a conflict arises. In other words, starting the conversation earlier facilitates agreement later in a project if the impacts begin to propagate. Yet again, another reviewer pointed out the ability of the LDRC to increase owner understanding of the construction process, of how late deliverables affect the work in the field, and of the cumulative effect of changes. Almost every expert had a similar comment to this.

As for dispute resolution, several experts agreed that understanding what the LDRC is and is not is important in determining its applicability. The key here is the thoroughness and validity of the research. While the case studies and questionnaires were properly developed and the limitations of the LDRC were clearly communicated, several reviewers were concerned with the tool's validity with all parties – meaning that every party would have to accept the results as truth for it to be used in formal dispute resolution. While it works well for preventing disputes in saying this is what may happen, any disagreements after the fact must be fully accepted by both sides as truth. Several suggested that this could be accomplished with additional peer reviews, more case studies interviewing multiple parties, and after these changes, contracts would have to be modified to incorporate the tool.

9.3.3 Knowledge Sharing & Transfer and Lessons Learned

The feedback for the final two potential uses was very similar and centered on the ability of the Late Deliverable Risk Catalog and this research to improve communication and awareness. As mentioned several times, the impacts of late deliverables are often known; however, it often remains in the minds of experienced individuals or isolated project teams. According to most reviewers, this is where the real strength of this research lies. One reviewer noted that of the seven projects leads working in a construction group, five of them were heading projects for the first time, and by using the LDRC as a training tool, these individuals would be better able to foresee and/or mitigate the impacts of late deliverables – a skill that can only come about with many years of experience. Similarly, another reviewer suggested that new hires use the LDRC to run through scenarios of late deliverables and read the case studies to see how risks arise in seemingly unrelated areas and the effects can propagate through a project.

Another expert noted that the number of impacts found in the tool is enormous and only based on nine case studies and a group of questionnaires, saying that this in itself is a lesson learned. There is no possible way for someone to know or predict every impact of late deliverables or how it will affect the project pillars. However, one of the keys of this research and tool to the industry is increased awareness. It is important to remember that every construction project is unique, but if there is or might be a late deliverable event, the LDRC – while perhaps not telling you every possible outcome – can help stimulate the minds of the project team to think of other possible impacts.

9.4 Lessons Learned and Recommendations

The final grouping of questions posed in the external review interviews was about the lessons learned and recommendation section. Overall, the reviewers felt this was one of the most beneficial sections of the IR. For example, a couple of expert commented that they specifically want every project leader within their respective companies to read the Lessons Learned and Recommendations chapter immediately, feeling it was the most significant portion of this research next to the tool itself.

9.4.1 Case Study Lessons Learned

Several assessments were made for the case study lessons learned section. First, the three themes outlined in the section were one of the key takeaways from the chapter. Namely, these are primarily themes that tie to improved planning and communication, which are the strengths of the LDRC. Identifying these themes can help identify where mitigation and prevention of impacts can take place. Secondly, another reader felt that this section also introduced one of the simplest ways to begin incorporating the LDRC into company processes through scenario planning. Whether in new hire training or front end planning, scenario planning is a simple way to introduce the tool with other applications to follow as the tool is expanded and validity is accepted. Another reviewer pointed out that these lessons learned are a great way to narrow the focus of project team and see where the potential for improved processes lies.

9.4.2 Prevention Recommendations

Several of the reviewers felt the severity vs. commonality graph for late deliverables would be of great benefit to the industry. For the most part, this graph simply validates the perception the industry that had never been recorded. Every reviewer thinks this graph very much portrays reality and should be a huge eye opener for the industry. Furthermore, understanding the relative risk of the late deliverables can show where resources should be invested for the greatest return. Furthermore, this graph can be used as leverage when working with other parties, showing that some late deliverables can lead to significant changes and project impacts.

Three of the experts specifically commented on the prevention recommendations for engineering deliverables and specialty equipment. They all felt the suggestions were spot-on and essential to avoiding late delivery. By aligning these deliverables with front-end loading and a company's stage gate processes, the ability to track and control these deliverables is multiplied, especially when a focus can be placed on the highest risk deliverables. However, one reviewer warned not to ignore some of the lower risk late deliverables. As an example, human resources can be a huge problem based on market conditions and labor availability, so the related impacts and risks should not be ignored for any category of late deliverables.

Chapter 10: Conclusions and Contributions

The primary benefit of this work is the increased awareness in the construction industry of the full range of potential impacts and risks arising from late deliverables—which is broader than what is typically identified or measured in industry practice. This research is viewed as the first disciplined approach to investigating and documenting the array of potential late deliverables as well as tracing their respective impacts on a project. RT 300 expects that greater awareness will foster greater focus on deliverables ensuring that:

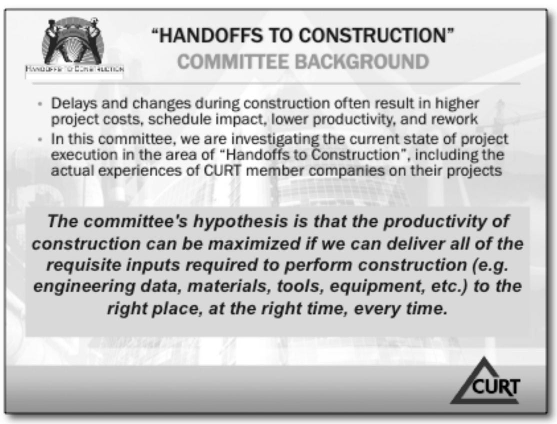
- all project functions supporting construction (e.g. engineering, procurement, contracting, logistics, business management) understand the critical importance their on-schedule performance has on overall project success;
- professionals in and outside the field will recognize and appreciate the propagation of impacts throughout a project caused by late deliverables;
- delivery dates to construction are regularly monitored and pro-actively maintained by the appropriate party; and
- earlier and more comprehensive actions are taken to mitigate the full range of risks that arise when a late delivery to construction does occur.

With the findings of this research in mind and the huge variety in possible late deliverables, the research team recommends a prevention-based approach to be most effective in managing late deliverables. While with the help of the Late Deliverable Risk Catalog and knowledge from this research it may be significantly easier to identify impacts earlier, the research team recognizes that the resources that would have to be committed to identify the many causes and ripple effects in a project is very high. Therefore, the LDRC should only be used in situations where late deliverables cannot be avoided. It is important to remember that, as discussed by several of the external reviewers, the tool is perhaps more effective as a front-end, proactive management tool rather than a reactionary one. As found in this research, is it easier to manage ahead of late deliverables and impacts rather than behind them.

Although RT 300 has limited its research to industrial projects, we expect CII member companies and others in the industry from all (or nearly all) sectors can benefit from this research. Although the data collected represents industrial projects, the processes and tools developed and outlined here can be extended and customized to include other sectors of the construction industry. Furthermore, owners, contractors, and the entire project supply chain will benefit from process changes to be more proactive when managing projects or to avoid and ameliorate the impacts of late deliverables.

Thus, the results of this research can guide CII member companies and others involved in construction projects to an improved understanding of the impacts, key causes, and likely early indicators of late deliverables. This understanding combined with prevention techniques can be used to improve project delivery, productivity, and predictability, as well as enhanced safety, quality, and organizational and individual achievement. As with all of the programs conducted by CII, the overarching goal of this research project is to help companies meet goals and expectations in all five pillars of project performance – cost, schedule, safety, quality, and organizational capacity. The research by RT 300 has clearly identified late deliverables as one of the many reasons a project may not meet one or more of these goals. However, by more fully understanding late deliverables and their impacts, altogether, this research contributes to an overall goal of the Construction Industry Institute: improving project delivery and the probability of stakeholder success for the benefit of the construction industry.

Appendix A: CURT Conference Interactive Presentation



Research Team

- Two Principal Investigators (UT Austin)
- Graduate Research Assistant (UT Austin)
- 10 Owner representatives

Praxair	Marathon Petroleum
ConocoPhillips	Ecopetrol
Bristol-Meyers Squibb	Alstom Power
Chevron	Air Products
SABIC	General Electric

- 9 Engineering & Contractor representatives

Wood Group Mustang	Zachry
WorleyParsons	S & B
Lauren	CCC Group
Robins & Morton	Bechtel

AUDIENCE QUESTION #1

Are you representing an Owner or a Contractor or a Supplier organization?

1. Owner
2. Engineering and/or Construction Contractor
3. Vendor/supplier
4. Consultant

AUDIENCE QUESTION #2

Is your company a member of the Construction Industry Institute (CII)?

1. Yes
2. No
3. Don't know

AUDIENCE QUESTION #3

If you are a CII member company, does your company use CII best practices?

1. Almost never
2. Sometimes
3. Regularly

CII RT300 Research Questions

- **What are the real impacts in terms of safety, quality, cost, schedule, and organizational capacity (morale, team alignment, company alignment, relationships, people resources, etc.) of late deliverables to a construction site?**
  - How are project outcomes affected when essential deliverables (e.g., permits, detailed engineering, construction documents, special studies, procured items and services, tagged equipment, bulks, and specialty items) arrive later than scheduled?
  - What are key contributors/causes to late deliverables?

CII RT300 Research Objectives

- Primary: document and give visibility to the magnitude of impacts of late deliverables to construction in terms of **safety**, **quality**, **schedule**, **cost**, and **organizational capacity**
- Secondary: document the types of late deliverables and key contributors to those types

AUDIENCE QUESTION #4

How often are your projects affected by late deliverables to the construction site?

1. Almost never
2. Sometimes
3. Regularly

AUDIENCE QUESTION #5

How often are your project's **SAFETY** performance affected by late deliverables to the construction site?

1. Almost Never
2. Sometimes
3. Regularly

AUDIENCE QUESTION #6

How often are your project's **COST** performance affected by late deliverables to the construction site?

1. Almost Never
2. Sometimes
3. Regularly

AUDIENCE QUESTION #7

How often are your project's **SCHEDULE** performance affected by late deliverables to the construction site?

1. Almost Never
2. Sometimes
3. Regularly

AUDIENCE QUESTION #8

How often are your project's **QUALITY** affected by late deliverables to the construction site?

1. Almost Never
2. Sometimes
3. Regularly

AUDIENCE QUESTION #9

How often are your project's **ORGANIZATIONAL CAPACITY** (morale, team alignment, people resources, project team turnover) affected by late deliverables to the construction site?

1. Almost Never
2. Sometimes
3. Regularly

Research Approach – Focus Areas

- Measure the impact of late deliverables to the construction site
  - Define measures of impacts of late deliverables for each project outcome (safety, quality, schedule, cost, and organizational capacity)
  - Quantitatively and qualitatively describe the types and impacts of late deliverables
- Identify key contributors associated with late deliverables
  - Investigate potential causes of late delivery in construction sites

AUDIENCE QUESTION #10

What is the most frequent type of late deliverable to your construction site?

1. engineering deliverables/drawings/specifications
2. late engineered equipment & fabricated materials
3. bulk materials
4. permits
5. site procedures & communications
6. people availability
7. other

AUDIENCE QUESTION #11

What is the 2nd most frequent type of late deliverable to your construction site?

1. engineering deliverables/drawings/specifications
2. late engineered equipment & fabricated materials
3. bulk materials
4. permits
5. site procedures & communications
6. people availability
7. other

AUDIENCE QUESTION #12

With what type of projects do you more frequently experience late deliverables at the construction site?(assume quality and safety drivers are givens)

1. Cost-driven
2. Schedule-driven
3. Doesn't matter, don't care

Data Collection and Scope Limitations

- Impacts during the construction phase of a project due to late deliverables
- Focus will be on industrial projects
- Data collection: case studies, expert interviews, and document analysis
- Investigate specific disciplines (e.g., piping). Focus on depth in specific disciplines rather than on breadth at the project level

Research Timeline

- Research team kicked off in May 2012
  - 4 face-to-face meetings to date
- Four completed pilot case studies
  - identified data collection challenges
- Research will be conducted over the next 15 months
  - Two sub-teams created to prepare for research:
    - Data collection formatting
    - Questionnaire/Survey creation and implementation
- 11 formal case studies already identified and planned
- Formal report-out planned for CII annual conference in July 2014
- Report-out to CURT will occur shortly after CII reporting

AUDIENCE QUESTION #13

How often do late deliverables to the construction site result in the execution of "crisis mode" (i.e. unplanned, accelerated, or compressed) work?

1. Almost Never
2. Sometimes
3. Regularly

CII The Knowledge Leader for Project Success

AUDIENCE QUESTION #14

How often do you experience poor or insufficient front end planning (aka pre-project planning, early scope definition, etc.) that results in late deliverables to the construction site?

1. Almost never
2. Sometimes
3. Almost always

CII The Knowledge Leader for Project Success

AUDIENCE QUESTION #15

How much of your time is spent in reactionary mode, rather than on proactive planning (risk & contingency planning) in response to late deliverables to the construction site?

1. Significant amount of time is reactionary
2. Some amount of time; can't avoid being reactionary
3. Relatively little time is reactionary

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Value Added

- Increase awareness within the industry regarding the range and severity of impacts of late deliverables (i.e., more than what is typically measured or assumed by most companies)
- Focus on mechanisms for improvement
- Obtain and share quantitative and objective information on the subject, including business management and other key stakeholders

CII The Knowledge Leader for Project Success

QUESTIONS?

CII The Knowledge Leader for Project Success

Appendix B: Mini Case Study Questionnaire

<u>"Late Deliverables to Construction" Case Study Questionnaire</u>

The Construction Industry Institute (CII) Research Team 300 is currently studying the impact of late deliverables to the construction site. The primary purpose of this research is to identify, describe, and where possible, quantify the effects of late physical and information deliverables to the project site. Specifically, the information gathered in this questionnaire will help the research team identify types of late deliverables and how they affect project outcomes in the construction industry.

Please complete this questionnaire <u>considering only one project</u>. All information gathered from this questionnaire will be CONFIDENTIAL to RT 300. Any information or summaries shared with the public in the final report will not contain any identifiable information about the project.

Name (optional):

Position/Title:

General Project Questions

1. To what subsector (within the industrial sector) does this project belong? (e.g. oil & gas, power, manufacturing, etc.)
   ____
2. What is the type of project site? (select one)
   - ☐ Greenfield
   - ☐ Brownfield
   - ☐ Other, please specify:____
3. What is the project delivery type? (select one)
   - ☐ EPC (i.e. engineer-procure-construct) or Design/Build
   - ☐ Design/Bid/Build
   - ☐ Construction Management (at risk)
   - ☐ Owner-Managed
   - ☐ Other, please specify: ____

4. What is the construction contract type? (select one)
    - Lump Sum
    - Unit Price
    - Cost Reimbursable
    - Other, please specify: ____

5. What is the total capital cost of this project?
    a. Total Installed Cost (TIC): ____________________________________
    b. Construction/Fabrication Cost: _________________________________

6. What is the primary driver for this project? (select one)
    - Schedule-Driven
    - Cost-Driven
    - Other, please specify: _______________________________________

7. Who set the required completion date for this project? (select one)
    - Owner Project Team
    - Project Team/Contractor's Organization
    - External Customer
    - Government/Compliance
    - Owner's Business Management
    - Other, please specify____

8. Is this project considered a "fast-track" project? (select one)
    - Yes
    - No
    - Don't Know

9. At what percent of design completion was the project mobilized for construction? (select one)
    - 0-25%
    - 25-50%
    - 50-75%
    - 75-100%

10. Was CII's Project Definition Rating Index (PDRI) or a similar sanctioning/authorization tool used to assess the project's readiness prior to project sanction/authorization?
    - Yes
    - No
    - Don't Know

11. Were all of the pre-defined deliverables (FEED Study) completed prior to project sanction/authorization?
    - Yes
    - No
    - Don't Know

12. Has this project followed a formal stage gate and/or formal authorization process?
    - Yes
    - No
    - Don't Know

Late Deliverable Questions

13. List all the major late deliverables to the site on this project. Please mark the primary late deliverable with an asterisk.

____

____

____

14. Rate the impact of late deliverables to each of the following categories. Place a number 1-3 (1=no/minimal impact, 2=moderate impact, 3=significant impact) in the blank next to each category.

___ Cost
___ Schedule
___ Quality
___ Safety
___ Organizational Capacity (morale, relationships, etc.)

15. How much of your time on this project is spent in reactionary mode rather than proactive planning? (select one)
    - None
    - Some
    - Most
    - All

Cost Specific Questions

16. Please list and describe any **COST IMPACTS** that were caused by late deliverables on the project.

____

____

____

17. Was the overall project cost adversely affected by late deliverables?
    - Yes
    - No
    - Don't Know

18. Has the planned contingency been adequate in covering late deliverables for the project?
    - Yes
    - No
    - Don't Know

19. Did late deliverables impact your ability to accurately track and report project cost?
    - Yes, please describe:____
    - No
    - Don't Know

Schedule Specific Questions

20. Please list and describe any **SCHEDULE IMPACTS** that were caused by late deliverables on the project.

    ____

    ____

    ____

21. Have late deliverables caused re-planning on the project with respect to scheduling?
    - Yes, please describe: ____
    - No

22. Did late deliverables to the construction site impact the project's critical path?
    - Yes
    - No

23. How were interrupted activities addressed in the schedule?
    - Formally
    - Informally (in the field)

24. Did late deliverables impact your ability to accurately track and report project schedule?
    - Yes, please describe:____
    - No
    - Don't Know

Quality Specific Questions

25. Please list and describe any **QUALITY IMPACTS** that were caused by late deliverables on the project.

____

____

____

26. Have late deliverables caused re-planning on the project with respect to quality?
    - ☐ Yes, please describe: ____________________________
    - ☐ No

27. Did late deliverables impact your ability to accurately monitor project quality?
    - ☐ Yes, please describe:____________________________
    - ☐ No
    - ☐ Don't Know

Safety Specific Questions

28. Please list and describe any **SAFETY IMPACTS** (either increased incident rates or increased risk) that were caused by late deliverables on the project.

____

____

____

29. Have late deliverables caused re-planning on the project with respect to safety?
    - ☐ Yes, please describe: ____________________________
    - ☐ No

30. Does your company's safety performance tracking system indicate which events were driven by late deliverables?
    - ☐ Yes
    - ☐ No
    - ☐ Don't Know

31. Did late deliverables impact your ability to accurately track and report project safety?
    - ☐ Yes, please describe:____________________________
    - ☐ No
    - ☐ Don't Know

Organizational Capacity Specific Questions

32. Please list and describe any **ORGANIZATIONAL IMPACTS** (e.g. motivation, relationships within company and with other stakeholders, etc.) that were caused by late deliverables on the project.

____

____

____

33. What percent of the core management team was with the project from start to finish or the start to present? (select one)
    - 0-25%
    - 25-50%
    - 50-75%
    - 75-100%

34. Have late deliverables caused project team turnover or change in this project? (select one)
    - Yes
    - No
    - Don't Know

35. What were the most common human resources added to the project due to late deliverables? (select all that apply)
    - Schedulers/Planners
    - Safety Personnel
    - Cost Estimators
    - Owner Reps
    - Human Resources Personnel
    - Lawyers/Claim Consultants
    - Others, please specify: ____
    - None

36. Has project team turnover or change contributed to late deliverables to the construction site? (select one)
    - Yes
    - No
    - Don't Know

37. Have late deliverables affected your willingness to work with the same owner/subcontractors/vendors/suppliers/etc. in the future?
    - I will never work with them again.
    - I will work with them again, but precautionary measures will be taken.
    - No change

- I am now more willing to work with them due to the successful resolution of past issues.

Company Specific Questions

38. What company completed this project (i.e. what company do you work for if you haven't changed employers)?

    ____

39. To which of the following categories does this company belong? (select one)
    - Owner
    - Contractor
    - Supplier/Vendor
    - Other, please specify: - ____

40. Does this company have an effective change management system that identifies changes driven by late deliverables? (select one)
    - Very Effective
    - Somewhat Effective
    - Not Effective

41. Would you be willing to answer follow-up questions by phone and/or email? If so, please provide your contact information.

____

____

Appendix C: Rating Survey

Version 1

CII RT 300 – Late Deliverables to Construction Survey

1. Which of the following best describes you?
   a. Owner
   b. Contractor
   c. Engineer
   d. Other, please specify ____________________________

2. On a scale of 1 to 4, rate the COMMONALITY or FREQUENCY of each late deliverable to construction sites, with 1 being least common and 4 being the most.

External Permits	1	2	3	4
Prefabricated Assemblies	1	2	3	4
Utilities & Infrastructure	1	2	3	4
Engineering Documents, Approvals & Responses	1	2	3	4
Fabricated Materials	1	2	3	4
Human Resources	1	2	3	4
Construction Equipment	1	2	3	4
Bulk Materials	1	2	3	4
Engineered Equipment	1	2	3	4
Project Execution Planning	1	2	3	4

3. On a scale of 1 to 4, rate the SEVERITY TO PROJECT OUTCOMES of each late deliverable to construction sites, with 1 being least severe and 4 being the most.

Engineering Documents, Approvals & Responses	1	2	3	4
Fabricated Materials	1	2	3	4
Utilities & Infrastructure	1	2	3	4
Project Execution Planning	1	2	3	4
Prefabricated Assemblies	1	2	3	4
Human Resources	1	2	3	4
External Permits	1	2	3	4
Bulk Materials	1	2	3	4
Engineered Equipment	1	2	3	4
Construction Equipment	1	2	3	4

4. On a scale of 1 to 4, rate each impact due to late deliverables by its HOW OFTEN IT IS OBSERVED ON A PROJECT, with 1 being infrequent or uncommon and 4 very frequent.

Work Relocation	1	2	3	4
Offsite/Company Dynamics	1	2	3	4
Engineering/Design Work	1	2	3	4
Alternative or Additional Tools & Equipment	1	2	3	4
Downtime	1	2	3	4
Onsite Team Dynamics	1	2	3	4
Damage, Degradation, or Loss	1	2	3	4
Alternative or Additional Suppliers/Vendors	1	2	3	4
Overtime Work & Shift Work	1	2	3	4

Rework	1	2	3	4
Craft Levels/Density	1	2	3	4
Critical Path Management	1	2	3	4
Scope Changes	1	2	3	4
Productivity	1	2	3	4
Work Resequencing	1	2	3	4
Project Risk Profile Changes	1	2	3	4
Liquidated Damages, Claims & Bonuses	1	2	3	4
Personnel Turnover	1	2	3	4
Onsite Material Handling	1	2	3	4
Management/Supervisor Work	1	2	3	4
Commissioning & Startup	1	2	3	4
Shipping or Expediting	1	2	3	4
Indirect/Overhead Costs	1	2	3	4
Training Resources	1	2	3	4

5. On a scale of 1 to 4, rate each impact's SEVERITY TO PROJECT OUTCOMES as a result of late deliverables, with 1 being not severe and 4 being very severe.

Commissioning & Startup	1	2	3	4
Work Resequencing	1	2	3	4
Rework	1	2	3	4
Onsite Material Handling	1	2	3	4
Alternative or Additional Suppliers/Vendors	1	2	3	4
Critical Path Management	1	2	3	4
Alternative or Additional Tools & Equipment	1	2	3	4
Offsite/Company Dynamics	1	2	3	4
Scope Changes	1	2	3	4
Personnel Turnover	1	2	3	4
Overtime Work & Shift Work	1	2	3	4
Onsite Team Dynamics	1	2	3	4
Project Risk Profile Changes	1	2	3	4
Craft Levels/Density	1	2	3	4
Downtime	1	2	3	4
Management/Supervisor Work	1	2	3	4
Training Resources	1	2	3	4
Shipping or Expediting	1	2	3	4
Work Relocation	1	2	3	4
Liquidated Damages, Claims & Bonuses	1	2	3	4
Productivity	1	2	3	4
Damage, Degradation, or Loss	1	2	3	4
Engineering/Design Work	1	2	3	4
Indirect/Overhead Costs	1	2	3	4

Appendix D: Case Study Interviews

Case Study #1 Interviews

The first interview was with a project executive with the contractor who manages the EPC division of the company, who has over 28 years of experience in construction with five years with the company. The second interviewee was the project manager, who has 18 years of experience with seven years in the current position. The third interviewee has been with the company for 32 years and held the title of construction manager on the project and also has a total of 38 years of experience in construction. Finally, the engineering & procurement manager was interviewed, who joined the team at approximately the midpoint of the project. This manager was employed as a subcontractor but worked closely with the contractor's project team through project completion.

Project Executive

The Project Executive expected State B to receive its environmental permits immediately, but was unsure about State A. The permitting procedure had not been included in either the pre-project planning or the front-end engineering and design processes, and the PE felt that some of the issues may have been prevented and risks mitigated if the permits had been considered.

The Project Executive felt the project was schedule driven because the conveyor system was integral to the set opening of the power plant, and it was the schedule that was most adversely affected by the late permitting. With the changes to schedule, the PE felt he spent almost all of his time in a reactionary mode for the final year of the project. This lengthening of the schedule kept the staff on this project for a longer period and prevented them from moving on to other projects. Consequently, a few managers and workers were moved from this project to another, which increased the turnover. This led into several associated cost impacts, including an increased training cost for new workers on the project that included overlapping new workers with those that were leaving to bring them up to speed on the project. This doubled the labor costs at some points in the project. In addition, the contractor had to absorb many of the additional costs the late deliverable caused for the subcontractors. The costs also increased for the owner, who had to bring on additional staff such to manage the project. However, in the eyes of the PE, the late deliverable had an overall positive effect on the relationships within Company A and with the owner. After the owner accepted that the state was delaying the project and contractor was doing what they could to move the project along, the teams came together to finish the project and minimize losses.

Project Manager

The project manager reaffirmed the absence of the permitting process during pre-project planning. The permit requests were submitted on time to both states, but State A had a more stringent review process than the "rubber stamp" procedure by State B. The cause the delays in State A was twofold: the state budget was cut so most of the department was only working three days per week, and the department required several changes to the designs, particularly in the hydraulic structures and storm water management. This led to review periods of up to 90 days for every resubmittal.

The contract was awarded in December 2009, and the project manager did not know the permits were going to be late until May 2009. When the permits were delayed, a mutually agreeable contract change order program was established, and the relationship between the two companies improved after liquidated damages were abandoned. Moving forward, the project was very reactionary after the order of construction was reversed from the plan. The work was completed in State B, and work had to stop at the border. At this point, management used the downtime to do required training hours with the crews while waiting on permits for State A. When State A finally released permits, they came in seven parts dispersed randomly throughout the project. The work had to be split and there were several times where the crews were almost demobilized while waiting for new sections to open up. Some of the downtime was used for preassembly but this was limited due to an inability to move large pieces along the worksite.

According to the project manager, the late permits most negatively affected both cost and schedule. The schedule was extended by almost a year, which contributed to a vast increase in indirect project costs. The construction period alone increased by 46 percent and started almost five months late. Materials had to be handled as many as five times as they were moved to and from laydown yards and the site. The crews tied up on this project affected the contractor's ability to execute other projects. However, the PM feels it is the responsibility of the contractor to help the owner through tough projects instead of allowing key employee turnover, and this helps improve relationships. However, the effect on the crews was more negative, as they were constantly relocated and split along the jobsite as new areas opened up. The project team made a conscience effort to make sure quality was not affected by the late permits. Galvanized steel had been specified over paint, which helped prevent damage from the excessive handling. However, this material was susceptible to white rust when exposed and many pieces had to be replaced. Rubber conveyor belts had to be stored in offsite warehouses to prevent damage from exposure, which created a significant cost impact. Additional cost impacts included a cost of living and per diem increase for workers to keep them on the project and a bond funded by the owner to repair the roads to and from the laydown yards that were damaged by heavy equipment. However, the total number of work hours for the project was less than the estimate which could possibly be attributed to a conservative estimate, improved work planning in downtime, or preassembly.

Construction Manager

The construction manager provided unique insight into how the late permits affected safety, quality, and crew morale. To begin, much of the work that was planned to be completed in the summer was pushed into the winter months, which were very severe. Although it could not be quantified, the construction manager felt that the crew efficiency went down in these times. To maintain safety on the project, shoe spikes, space heaters, and extra harnesses were provided to crew to prevent slipping. The movement of materials to the worksite was difficult and hazardous during poor weather, and many parts of the site were inaccessible when the ground was icy. Individual activities were lengthened when the weather was bad; for example, many crane lifts that were scheduled for three days took as long as two weeks while waiting for the appropriate conditions to place crane pads and make lifts.

Crew morale was low because it was difficult to see progress being made. Weekend work became the normal in order to get to 50 hours per week. Sometimes the weather was too severe to work but the workers were paid for showing up, which increased labor costs. Some crew members left the project entirely due to the bad conditions and their replacements had to be trained. However, the construction manager felt that the good communication between management and the crews promoted teamwork and kept the effects on morale at a minimum.

In addition, the remote laydown areas negatively affected the project in several ways. Additional cranes, trucks and forklifts were needed for laydown yards, which increased costs. The large laydown areas were far from the site making transportation lengthy and costly and extra material handling led to some damage to materials that had to be replaced. In addition, component warranty claims increased after equipment remained idle as the balance of the project was completed later than planned.

Engineering & Procurement Manager

From and engineering perspective, the engineering & procurement manager felt that the delays in permitting helps them complete the design and avoid paying any liquidated damages. The reduced pressure to finish the design reduced frustration among the engineering team.

For procurement, all of the materials had already been ordered when it was discovered that the permits would be late. However, the engineering & procurement manager was only responsible for getting the materials to the site. The domestically sourced materials as well as the structural steel and conveyor parts from China all arrived on time. The engineering & procurement manager did assist the laydown yard teams in retagging materials when the construction plan switched directions. The cooperation between the contractor and the engineering and procurement subcontractor improved relations.

Case Study #2 Interviews

The first interview was conducted with the project manager from the mechanical subcontractor. The second interview was with the branch manager from the subcontractor along with the chief estimator from the project. Both the project manager and the branch manager worked closely with the owner's representative for the duration of project, and their company was subcontracted by a joint venture for the fuel farm project, which was a small part of the overall program.

Project Manager

The project manager first described the position of the subcontractor as "low on the totem pole" when their subcontract was compared to other parts and the project as a whole. They had little contact with the joint venture team after they were provided with the designs and given a notice to proceed with construction after the initial delays. Communication was poor among the project stakeholders. All of the designs, specifications, and changes went through a three-part review process, each of which was performed independently by the airport authority, the private partner, and the joint venture. The root cause of the delays were twofold: the designer and joint venture did not have a standard network for verifying changes and the joint venture and owners had no formal stages for processing and approving the specifications. The correct specifications that were dated for February were found in March lost in a stack of papers on the desk of a reviewer.

In essence, the mechanical subcontractor had been working with the incorrect specifications since they were received in December when they began limited site work and procurement of certain items. More orders were placed when the IFC documents were received in February. When alerted to the mistake in March, the subcontractor worked to cancel and update previously placed orders for equipment and piping. Many of the items that had already arrived on site had to be stored in a warehouse. Using the updated specifications, they began to return the items that they could to the manufacturer for additional shipping costs and tried to get credit for the return of specialty items that had already been ordered. These credits were lower in value than the original cost of the equipment. The new materials ordered were expedited at an additional cost, and some materials, such as underground piping, were very difficult to accelerate, had even greater costs, and had some quality and sizing issues with the expedited orders. The additional material handling on site exposed crews to additional hazards as materials were moved and loaded.

Although the project started as cost-driven, the project manager explained that it shifted to schedule-driven so that the fuel farm would not delay the overall project. With this shift came associated expediting costs for the new materials that had to be ordered and the compression of many activities in the schedule at an extra cost for labor and resources. The original plan contained pieces that had been eliminated as well, and additional scope of work had been added with the updated design. The subcontractor management team at had to revamp their entire project execution plan following the specification changes, and, in order to meet the “drop-dead” November completion date; the schedule was accelerated at an additional cost for labor and resources. The project manger attributed one safety incident to this acceleration. In addition, although the work hours were not increased, the productivity of the workers decreased as planning ahead became difficult after the delayed specification release and new workers were added to the project that were unfamiliar with both the safety and work practices on the site. However, the subcontractor made sure not to work too far ahead of their planning horizon so rework was minimized for the project.

One major safety concern involved the ditches for underground piping on the site that were delayed due to the late specification and the difficulty in expediting the fabrication. This activity was supposed to be completed at the beginning of the project during the winter when less rainfall was expected. After the delays, the activity was pushed into the spring, which exposed workers to additional safety risks. Shoring had to be used to maintain stability of the ditch sides because heavy foundations had been poured within 10 feet of the sides of the ditch. Heavy rainfall in the spring season increased the probability of a soil collapse that further increased the safety risk profile.

The project manager mentioned several examples of quality risk increases on the project due to late deliverables. Along with the underground piping that was accelerated, the punch list grew drastically following the delay from the lost specification update. In addition, the joint venture assigned a third party for testing the fuel farm facility that the mechanical contractor had not worked with before. This was a point of concern for the project manager.

As the mandatory completion date came closer, the joint venture and owner's representative began to allocate more resources to the fuel farm project. Three different project managers from the Joint Venture were assigned to the project at different points in the project so the Joint Venture's eyes and ears on the site did not know the entire history of the fuel farm project. Similarly, new safety personnel were often assigned to the project so the crews received mixed signals from each. This, along with other issues for the joint venture and subcontractor, caused several disagreements between the two but, as the deadline approached, honesty, openness, and communication increased in an effort to complete the fuel farm and the issues were resolved.

Branch Manager & Estimator

The branch manager explained the change in specifications as going from a functioning design to one with "all the bells and whistles." It was at this point before the notice to proceed that the owner requested value engineering to bring down the price of the fuel farm. The project manager, estimators, and many vendors took time to complete the process, and the branch manager for the subcontractor was concerned about the final quality of the fuel farm after all of the modifications.

After the major change prior to the release of the issue for construction drawings, the project moved forward with procurement and construction. Prior to the release of the final specifications, the subcontractor was able to mobilize the site, move underground utilities, and begin limited site work to prepare for construction all during the value engineering delay in January and February. However, they were using the incorrect specifications. The branch manager felt that, when the design team made the overhaul of the specifications, they did not include the correct people from each project stakeholder in order to get input on potential changes and communicate changes to the team.

When the mistake was uncovered, the subcontractor was able to put orders on hold and modify some orders so that they would fit within the new specifications. Several supplier representatives were very helpful in this process. With their help, they were able to reorder instruments, valves, and pieces with less disruption to the project than some of the other items such as underground piping. The branch manager felt that informing the suppliers of the issues at hand was a key to project success.

Another key to the projects success was the addition of quality personnel on site by both the mechanical contractor and their two additional subcontractors for electrical and instrumentation work. One specific quality issue that arose from the late changes was due to the poor spring weather. At several points in the project, the crews had to muck out the holes that were being dug for foundations. The soil had to be removed and the refilled and recompacted several times, which used time and budget contingencies. The weather contingency had been based on another season and did not account for the amount of rain that the project experienced. In order to make up for this, weekend work was implemented for critical path items.

A key organizational impact was the relationship with the two additional subcontractors that the mechanical subcontractor hired for the project. These companies needed to move on to other jobs, but were forced to stay on the job and see the contract through. They had to increase the amount of resources and crews on the project as it accelerated and bring in the aforementioned extra quality personnel. In addition, blame was passed around between the team members, so weekly meetings were set up to for the final months of the project to clean up communication on the project and resolve disagreements.

Case Study #3 Interviews

The first interview was with the project manager for the owner company, who has worked in construction management for 35 years. A second interview was conducted with the business manager, who has spent the past 30 years working with project owner and the last 20 in the capital projects division, and a primary planner on the project who has 15 years of experience with the last 10 being in the construction division of the owner company.

Project Manager

The project manager began by explaining the how the missing steel immediately affected the project. The replacement steel was ordered at a cost of about $15 million. The original order was actually recovered and arrived to the fabrication yard prior to the second order. The owner sold the excess steel as surplus at about half the original in part due to the softening of the steel market during the window of the delay.

The project manager next explained the major changes to the execution plan the subsequent impacts to the project as it moved through the fabrication yard of the EPCI contractor. The plan was for the project to be the first one in to the fabrication yard and be completed before other projects came to the yard, but after the delay, it would up being the final project in the yard. This affected the project because the workers purposely slowed progress because they would be out of work when the fabrication was complete. This resulted in poor productivity and even sabotage by the workers that further slowed the project. The recovery plan involved hiring more workers to the yard, but this was ineffective in improving production efforts.

As the project was delayed, resources and activities were pushed further down the line than the original execution plan. This along with increased acceleration efforts increased the number of crews in the fabrication yard at any given time and led to several problems from crew stacking. The quality on the project decreased as crews worked too closely in the yard and particularly problematic was having the blasting/painting crews on the site at the same time as the piping crews. The grit from the sandblasters got into the pipes and valves, and the pipes had to be removed and flushed. Many of valves were damaged in the fabrication yard and most of the damage went unnoticed until the platform had been shipped to the project site. Crews attempted to repair these valves in the field but did not have the appropriate personnel so they were shipped back to land, refurbished or replaced, and reinstalled when they got back to the site. The project manager estimated that this rework and replacement of materials cost the project over $10 million. When the work shifted from the fabrication yard to the site also increased additional quality risks. A new quality program was introduced when the project moved offshore that required additional assurance testing that caused additional delays and increased costs and increased friction with the contractor who had its own quality program.

The original plan was to almost fully complete the platform in the fabrication yard and ship it to the site as a finished product. This would require only 60 days for crews to work at sea to tie-in the platform and start production. However, to accelerate the project and get the platform out of the fabrication yard, it was shipped incomplete to the site and required five months of work on the site to finish construction. Only the best workers were hired from the fabrication yard to work offshore, so productivity actually improved during the later parts of the project. The safety risk profile was increased offshore, but fewer workers were present so exposure to marine risk was limited. The majority of the safety issues were with third party personnel on the site, but there was one injury to a worker that was associated with the work being moved offshore. Additional safety concerns surrounded the commission process that had to begin before the project was complete. The team had to properly isolate work areas from systems that were being put online in order to mitigate the risk. Finally, the shipping and transport contract with the original company expired and a second company was hired to move the human resources and equipment back and forth to the project site. The second company had to be properly trained in regards to the owner's safety protocol.

Business Manager & Planner

The business manager pointed out that the most severe impact caused by the late steel delivery was the shift it caused in the time period for fabrication in the yard. The second order of steel was delayed as well because the mill was constrained at the time of reordering and this project was the last in line. The work on the platform for the project owner was supposed to be completed before other projects that the contractor had were to begin in the fabrication yard. With the delay to the start and a duration that stretched from three to four and a half months, the work was pushed right into the busiest period in the yard and was going to be the last project to finish. This meant that the project had less experienced supervisors and crews, which increased the safety and quality risk and slowed down progress. Also, the contractor lacked adequate oversight in the yard to keep the project moving forward.

The site was also ill prepared for the increased need for effective materials management and quality assurance. There was no update to the material management plan to account for the out of sequence and accelerated work, and over 200 spools and valves were lost on the site and were reordered. Quality assurance became a bottleneck to the point where it interfered with progress while crews waited for approvals. In addition, there were problems with the welding and heat treatment test reporting, and the subcontractor was not forthright with the results. This along with other materials had poor record keeping because the leadership was ill equipped to oversee the processes.

As work was accelerated in the yard to make up for lost time and the execution plan was changed, several issues arose. These new plans occupied the management teams and cost the project time and money. A new crane had to be brought in for lifting decks into place in the yard instead of in the field, which also increased the safety risk with more crews working at elevation than planned. The stacking of crews became inevitable, and this along with the start and stop nature of the work hampered productivity. As the work accelerated, no checks were in place to examine any inefficiency present in the work.

The business manager explained that the baseline schedule was very aggressive and the completion date may have been unrealistic. Combined with the steel delay, the contractor had to start overtime and weekend work and hire additional contract staff to increase work capacity in the yard. There was a lack of consistency in the safety training for the contract staff, which increased safety issues and near misses. As the project moved forward, management and supervision became more reactionary and planning decreased. Work fronts were opened in no particular order, and crews performed work wherever they could even if it was out of sequence. This led to extremely high rework rates from the previously mentioned sandblasting overlapping with piping as well as other aspects. The owner's management team now realizes that they should have stopped the project and looked into mitigating the risks and rebaselined the work schedule, but instead the owner allowed the contractor to push ahead with the work. Without the proper systems to handle changes and acceleration, the contractor got further off schedule.

At the crew level, the productivity continually decreased as the project came closer to ending and there were no jobs to follow up this last project in the yard. However, the owner was able to keep the best workers to take offshore, so crew morale and workmanship improved later in the project. These aspects were also improved because there were no projects competing for resources as there had been in the yard.

The relationship between the owner and contractor quickly deteriorated as it became evident that the contractor had no intentions of publishing accurate reports of progress or forecasts for substantial completion. It was evident that the contractor was trying to get as much profit out of the project as possible because they were going to be subject to liquidated damages for the additional delays beyond the hijacked steel. The owner's project management team recognized that there was project team turnover for both companies and this hurt the communication of plans and risk as there was a lack of knowledge transfer when new team members were added. As a solution late in the project, an outside facilitator was brought in and several schedule workshops were conducted to plan future work, promote dialogue, and more effectively handle change.

Case Study #4 Interviews

For this case study, interviews were conducted with the engineering manager, a field engineer, and a project controls engineer. The engineering manager has been with contractor company for seven years after spending time working with owners for several years. The project controls engineer had five years of experience and was in his first year with the company, and the field engineer was in his first year with the company at the time of the project.

Engineering Manager

The engineering manager first discussed the impacts of the late vessels to the project. The owner specified that used vessels were to replace the new vessels previously specified. This owner driven delay did not show up as a potential risk during the FEED analysis for the contractor, so many changes were required to accommodate the request.

When the owner made the change to a used vessel, there was no procurement plan or as-built drawings to incorporate into the design and construction plans. A constructability plan had been previously completed but was altered to reflect the change, and the engineering team could not finalize the design until the actual vessels were selected and its specification known. This replanning effort was accompanied by a delay while each used vessel was located and delivered to the site.

Although a detailed constructability plan had been developed during front end planning, there was a lack of communication between engineering and construction as the project was impacted by the late mobilization and subsequent late deliverables. The roles and associated responsibilities of the project team were blurred, and this hampered decision making as the project moved forward. An example of the lack of communication played out when the new design for the vessel supports was released for construction, the design was not usable for some of the heavier used vessels. Instead of going back to engineering, the design was adjusted in the field without feedback from engineering. This had the chance of leading to quality and safety issues for the project.

When the vessels arrived on site and the new designs were finalized, additional time was required to prep the vessels for installation on site. There was an additional quality concern with the used vessels and time was taken to modify them and substantially refurbish one of them. One of the used vessels was heavier than expected because it arrived with no exact specifications and few legible drawings. This led to additional planning time and safety concerns.

Along with the vessels, there were issues with piping, spools, and necessary supports being late to the project site. Extended time performing piping stress analysis and generating both spool drawings and field isometric drawings led to delayed fabrication and late delivery to the site. Following these delays, work planned to be completed in the shop had to be moved to the site causing quality concern with the piping. This unplanned shift led to the engineering department creating their own spool drawings to send to the field, a task not planned in the schedule for engineering nor one with which the engineering department had any experience in performing. With this came additional costs for quality assurance staff to maintain piping standards and a significant amount of rework for correcting welds and for modifications that had to be made in the field. In addition, the lack of synchronization between the design of the piping and the design of the supports led to higher costs for the steel supports. The engineering manager attributed this lack of organization to a poor understanding of the schedule, prioritization of engineering resources, and lack of communication with the construction team on the project. The project team spent the majority of their time in reactionary mode and did not spend time replanning and making sure all stakeholders had a firm grasp on the schedule and design as it changed.

As the schedule extended due to delays on the critical path, additional costs were incurred for the extended office expenses and for overtime work with crews. The field engineers not having the authority to make changes and keep work moving during overtime work or during additional shifts further slowed down the project. Also, the owner did not make timely decisions that were needed to keep the project moving forward. The engineering manager attributed this issue to the lack of a standard and timely RFI process with the owner. The overtime work had some associated safety concerns, but there were additional safety personnel assigned to the project and daily safety meetings were implemented. The delays also pushed the construction period to overlap with the start-up of an adjacent facility that was supposed to be start-up after Company E field construction work was nearly complete. This introduced additional risk and some stoppages as a part of a robust safety plan that was developed for the overlapping period.

With the adjacent facility starting up, additional concern for safety arose in both the laydown areas and access points to the site. Also, the contractor had to begin operation of some pumps on their site before their entire project was complete, creating the need for additional safety measures being implemented earlier than needed (including requirements for full PPEs, air monitors, and special welding precautions). With crews working in close proximity to operating equipment, safety and quality were huge concerns until the project was complete and fully functioning.

Project Controls Engineer

The project controls engineer first explained about the decision the owner made to select used vessels for shipment and refurbishment at the site. There were four used vessels. Two of the vessels arrived to the site on time and had no issues. The other two vessels had some delays in delivery and refurbishment. Although the installation was delayed for some time, the contractor maintained accessibility for vessel placement with a tighter lift window.

When the installation of the piping was well under way there were changes to the quality assurance/control personnel and program, which caused some delays to the project. The contractor had to replace several weld caps on the piping as a result of the changes in the quality standard. Progress was impacted by the startup of the adjacent unit and day-to-day plant operations. There were several evacuations ordered for the site as safety precautions. Also, additional safety personnel were brought on site to account for the extra safety risk. Any delays to the projects progress, due to the evacuations were made up in the schedule and brought the project back on track.

From the viewpoint of the project control engineer, the delay of the removal of the onsite tank decreased the safety risk in some ways because there was less work, which overlapped with the adjacent site. This reduced the potential for collisions with equipment of the adjacent site and when critical lifts were made there were no neighboring crews or mobile equipment to take into account. Less congestion on the site also made the acceleration efforts easier. The delay in the tank removal did increase some safety and quality risks as the crews worked through two winters instead of one. The contractor was also forced to use less experienced crews for some of the equipment internal installation per the project specifications to expedite the schedule and reduce costs. However to receive the process guarantee from the vendor, a third party company had to be hired to inspect the work and fix any mistakes that were discovered.

Field Engineer

The field engineer joined the project during construction mobilization and estimated that the design was released from the engineering team to construction at approximately 60 percent complete. The field engineer explained that the project was a lump sum bid, with a 3-month delay for tank removal; the schedule reflected the delayed start in order to validate any scheduling, and cost concerns. In addition to the late vessels, several smaller items were late to the site including pipe supports towards the end of the project, which impacted the progress just before completion when acceleration was more difficult.

The contingency for the project covered the cost of these small late deliverables, but the owner was responsible for the delays associated with the late vessels to the site the project underwent normal acceleration to work around the delayed vessels, and no shutdowns were necessary as crews were shifted around to keep work moving.

When the vessels arrived, they were moved to the laydown yard where a separate company refurbished the vessel that required changes in preparation for installation. The contractor was able to use a crane that was already on site in another area to lift the vessels and therefore did not have any costs or delays in bringing a crane to site with short notice. In the middle of the project the owner's quality team was replaced, this lead to a clash between the contractor and quality team. The issues were resolved after several meetings, and the contractor was able to maintain a high level of quality.

When the piping arrived on site before it was needed for installation, it was kept covered in the laydown yard to protect it from the elements. When the piping was ready to be installed after the vessels were in place, the pipe supports had not yet arrived on site because engineering was delayed in finishing the design. As a result, the piping was hung using temporary supports and come-alongs until the permanent supports arrived. While this method saved time and prevented further delays, it was much more difficult to install supports under pre-hung pipes, and it exposed the piping to much greater risk for damage. No additional safety personal were required while installing the pipe supports, any safety issues were addressed in pre-task planning and the weekly safety meeting.

Case Study #5 Interviews

Five project team members were interviewed for this case study. Two separate project managers were interviewed. The first was on the project for the first three years and had been with the contractor for about 33 years with over 40 years of experience in the industry. The second project manager had over 20 years in the construction industry and was on the project for the final year. In addition, the site superintendent for the project has over 40 years on the job. Both the project controls manager and the project construction coordinator have about 15 years of experience in their respective fields.

Project Manager and Site Superintendent

The first project manager and the site superintendent began by explaining that the crane was about 80 percent erected before the quality issue was noticed in the base. It took four months to figure out the problems with the stress welds and to correct them so the cranes could be used. The crane owner and manufacturer sent teams to correct the welds, which the project team originally planned to be done on site. However, after several months on site, crane components were sent off site to be corrected in manufacturing yards. The cost of this shipping and the repairs strained the relationship between the contractor and these companies, and the cost of lost production for the contractor was not compensated.

When the cranes' faults were discovered, the site was completely staffed up and work was ready to begin. The management team then took 30 to 45 days to revamp the project execution plan during which the crews were constantly shuffled around to find work that could be completed and the planned hiring to meet the manpower curve was halted. The engineering team was brought in to help replan the construction sequence. They began by disassembling the erected pieces of the tower cranes and moving them into the laydown area for repair. Then the process of replanning the work began using several substitute crawler cranes in lieu of the tower cranes. Additional engineering and planning for foundations and pads was required for these crawler cranes.

One of the replacement cranes was large enough for preassembly on the ground to continue and lift large segments into place. However, for other cranes the lifting capacities and radii were significantly less than the tower cranes. This impacted several lifts including some center sections of structural steel that had to be hung using a conventional rig that was much slower and also increased the safety risk profile. Other parts of the structure had to be piece-built in the air rather than assembled on the ground and lifted into place due to the reduced lifting capacity. This reduced the unit rate impacting production and also altered the safety risk profile with crews working at height and requiring more lifts. Some aspects of the AQCS that could not be piece-built were shifted back in the project until the tower cranes were available impacting the sequence of construction for both structural pieces such as trusses as well as later activities.

The original execution plan called for the two tower cranes to be used in several different locations around the project site. Each of these locations required specialized foundations that had already been installed at the beginning of the project before the issues were revealed. When the cranes were finally refurbished and ready to be installed, the work had progressed to the point where several of these foundations were not even used. As the base of the tower crane was the only component with quality issues, the upper portion of the crane was attached to the top of the assembled structure for some lifts before the base components were redelivered to the site. This required additional engineering and management resources to plan.

In the end, the unavailability of the cranes pushed the entire work schedule to the right. In order to compensate for the lowered productivity and lagging schedule, weekend work and night shifts were implemented when both tower cranes were operating properly. The decision was made not to institute night work for the crews refurbishing the crane because these were mostly comprised of manufacturer and third party workers.

Project Controls Manager

The controls manager first noted the impact the late availability of the cranes had on the critical path and project scope close to one year into the project after the foundations had been completed. The planned lifts associated with the tower cranes were mostly critical items, and the time spent refurbishing the crane bases both added scope to the work performed by the contractor and created the need to overhaul the project schedule and critical path. At additional cost, smaller cranes had to be leased and delivered to site so work could continue while the tower cranes were repaired. All of these direct costs had to be formally tracked through the project so the contractor could try to be reimbursed for those outside the original scope.

The replacement cranes could not handle the weight of some of the critical lifts for some structural trusses and ductwork. This created the need for workarounds and many changes to the project schedule. The schedule was formally rebaselined several times throughout the project both as the cranes were repaired and afterwards. With the changes in schedule and work sequence, safety management became an important aspect of the project. As mentioned, there were significant workarounds and it was difficult to project the project schedule very far into the future. This with the additional overtime after the cranes were operating impacted the workers' morale and created a "catch-up" mentality that impacted the focus on safety. About halfway through the project safety professionals were added to increase the focus on safety and improve compliance.

Although the workers were never sent home and the site was never demobilized while waiting on the tower cranes because of the workarounds developed, work plans were day-to-day and required additional communication between management and crews. After the cranes were refurbished and erected, overtime work was necessary for the crews in order to accelerate the project to meet two previously scheduled outage dates for tie-ins to the power plant later in the project. A scheduler was assigned to the project to work with the superintendent to assist in replanning to maintain these outage dates, which if missed or changed carried extensive liquidated damages.

The project controls manager also explained the impacts of a second late deliverable to the project that lead to additional, although less extensive, changes. Although the design was approximately 100 percent complete before construction began, several engineering changes came about one quarter of the way through the project. This included several architectural design changes to the buildings as well as a structural steel issue that had to be reworked. This halted fabrication and the design had to be redone to implement changes. This led to some delays that were furthered by a change in equipment selection by the owner. The primary impact of these combined changes was to the material handling on the site along with the delays leading into the tower crane issue.

Project Construction Coordinator

The project construction manager was mainly focused on replacing the lifting capacity and reach of the delayed tower cranes. The contractor was able to move a crane from another project to the site. However, the crane had been poorly maintained at the previous project and required several days to make repairs and find and replace several parts on the substitute crane. This created further downtime of the equipment and further slowed down the project that was already behind due to the unavailable tower cranes.

These repairs also impacted material handling because the substitute crane was placed in the pipe rack laydown area. This was the only area available to make the repairs, but pipe deliveries were steadily arriving at this point in the project. The crane took up a large amount of space, and material management crews were forced to work around the crane. Other deliveries, particularly of process related equipment, were halted to allow time for more space to open up.

Management was optimistic at the beginning of the tower crane repairs and believed the substitute crane would only be needed for a limited time so they replanned the work accordingly. The manufacturer of the crane along with a local machine shop worked to repair the crane base, but the contractor had to supply some manpower to help these third parties and also to erect the cranes when they were ready. They tried to capture as much as possible in the project schedule. However, the construction coordinator estimated that only about half of the changes were reflected in the official project schedule changes and rebaselines. Coordinating crews became difficult given the changing schedules, so daily meetings and regular planning sessions were implemented with two or three superintendents assigned to each craft. The construction coordinator highlighted the difficulty the superintendents had in focusing on future work and documenting the work that had been completed as well as upcoming work. This continued throughout the period when the cranes were being refurbished and it was unknown when it would be completed.

Once the crane was repaired, work moved forward much more smoothly even though acceleration measures were required to meet the outage dates. There were two 10-hour shifts seven days a week leading to work happening almost 24 hours a day. Overtime and night work were a necessity to meet the project schedule, and several activities that are not normally performed after dark were pushed into the night shift. One such activity performed 24 hours a day was steel erection, which is extremely rare for the contractor to perform during the night. Temporary lighting systems were set up, but the duration for the activity was lengthened by very low productivity in the given conditions. In addition, the safety risk profile was drastically increased for the steel erection at night.

Staffing for the project became difficult for the manpower necessary for the number of shifts required. Congestion was an issue on the site with many crews overlapping work that was relatively unplanned. Turnover was also high on the project which the construction coordinator thought could be attributable to number of other projects in the area that were moving along more smoothly.

Project Manager

The second project manager joined the project about one year before final completion. At this point in the project, the main issues on the project involved quality.

The owner's quality control professionals were very strict on standards, and this combined with a lack of quality documents and communication created an adversarial relationship between the contractor and the client. As an example, a survey concerning structural steel erection was distributed but was never returned to the site management team. Any items that needed correction that may have been uncovered and corrected proactively in the survey were never communicated to the project team. When discovered by the owner's quality team, the contractor had to go back and correct any mistakes.

The project team continued to have scheduling issues all the way to the end of the project. The schedule was rebaselined again when the new project manager joined the project to accommodate for the rework that was required and lowered productivity. Measures were taken to reengage crews and improve productivity on the project. In addition, the contractor added additional quality personnel for testing tolerances on items such as ductwork and bolts.

Case Study #6 Interviews

Three project team members were interviewed for this case study. The project manager has been in construction for over 25 years and with the company in this case study for about 10 years. The project controls engineer interviewed has been in the industry for over five years and was in his first year with the company. Finally, one of the design/product engineers from the within the design team was interviewed.

Project Manager

The project manager began by describing the resource planning that had occurred during the front-end loading process six to nine months before the construction began. A labor survey was completed in the local market, and the project team concluded that although there was a base of skilled labor in the region, it would have to be supplemented with out-of-area craftspeople to meet labor demands. The final resource plan developed called for approximately 50 percent travelers on the project. When execution began, the minimum craft level was not met, and as the project progressed, there was a continuous shortage of labor as compared to the labor curve submitted by the contractor. The project manager found that the 50 percent local labor estimate had been too high and the contractor was unable to find local craftspeople, so steps were taken to find more travelers to bring to site. However, even after searching out-of-area, the contractor still could not find craftspeople with the appropriate skills willing to relocate to meet the requirements.

In order to meet the manpower curve each week, additional per diem incentives were implemented to attract labor. The local labor market was so weak that the contractor had to bring in over 90 percent travelers. The additional per diem costs increased the labor rate almost $8 per hour for the project, and the peak manpower levels still were not met. After several months of continuous labor shortages, the general contractor was removed from the project.

The project was significantly delayed due to the lack of labor, and the owner chose to move forward with the project being owner-managed. The owner's project team replaced three of the four subcontractors, and the performance of the new subcontractors was significantly better. The owner added a superintendent, additional quality personnel, and a full-time safety manager. The safety manager was required to manage the four subcontractors working independently on a small site with an accelerated schedule. This congestion changed the project risk profile and also impacted the productivity on site.

When the decision was made by the owner to manage the project in-house, the schedule was rebaselined and that pushed the completion date three months. The completion date was based on the market date set by the business unit, so attempts were made to reduce this extension. Although some of the existing craftspeople stayed on the project when the owner took over, the learning curve for new craftspeople brought in severely hampered any acceleration attempts in the first month. After the crews were oriented to the site and project, several incentives were included such as 50 and 60 hour weeks. This not only incentivized the crews to increase retention and bring in additional travelers, but also helped accelerate the work. With this, the project team was able to bring the local to traveling craft ratio to approximately 80:20, but the extra per diem costs beyond the original estimate increased the overall project cost. Other additional costs were incurred for the increase in overheads for the schedule extension.

Several quality issues resulted from the unavailability of labor and delayed schedule. One of the most significant impacts to the project was the quality of work from the original contractor and subcontractors. The level of craft turnover and the experience levels of both the craftspeople and supervision caused quality issues that resulted in rework later in the project. Also, all of the materials management had to be taken over by the owner's project team, and many materials being delivered on the original project schedule had to be stored in laydown areas on the site.

Design Engineer

The design engineer interviewed for the case study began by explaining the engineering and design issues the project experienced that also impacted the project even though they were not considered a late deliverable. For the type of project examined in this case study, the owner used a standard design with approximately 20 percent design being customized to the site. The decision was made to outsource the 3D modeling, labeling, dimensioning, and final drawings to Asia. However, there was a significant delay of close to three months at which point the design was still incomplete so the domestic engineering group decided to finish it. The mobilization date for construction was kept the same in an attempt to meet the market date for the plant; thus, the engineering team could not release the final design as a single package. The detailed design was instead broken down into small packages and released to the contractor on a just-in-time basis.

This delay in design packages coincided with the delays caused by the staffing issues of the original contractor. The just-in-time delivery of the design packages made it difficult for the contractor to create crane lift plans, manpower curves, and other required work plans. This made the contractor very reactive, and the design packages were not released in an order that was most efficient for construction. This slowed construction further and decreased craft productivity. The cost of labor on the project was almost 50 percent more than the original estimate. Supervision costs increased with both the number of hours on site each day and with the extended project schedule. Three different field construction managers were employed while trying to bring the project back on track.

Project Controls Engineer

The project controls engineer gave further insight into the cost and schedule impacts of the late deliverables on the project. After the general contractor was removed and the project was coordinated in-house, the original work plan created by the contractor was carried forward. However, there was additional time needed to rebaseline the project and assign project level personnel to the project. Also, there was time necessary for the new subcontractors to ramp up their craft levels to have enough manpower on site. In total, the project schedule was extended three months, and, although the project started out schedule driven with the completion date set by the business management division, there was a softening in the market that made cost the most important factor. Thus, the project did not require drastic acceleration efforts to accommodate the extension. Some activities were compressed, but the demand for acceleration did not justify the cost.

Other costs from the travel reimbursement and per diem for the craftspeople brought in for the project increased the overall labor cost for the project considerably. Also, the original contract with the general contractor was time and materials. Thus, the contractor was paid for all of the installed work when they were removed from the project. Much of this work did not meet quality standards for the project and had to be redone. The owner was responsible for the cost of all this rework, which further increased the project cost.

Case Study #7 Interviews

The three project team members interviewed for this case study included two senior construction managers and the project materials manager. Both construction managers have over 40 years in the construction industry and over 30 with the contractor in this case study. The materials manager has been with the contractor for about 20 years with over 15 years of construction experience prior to that.

Construction Manager 1

The first construction manager began by describing the contractual arrangements between the owner, the managing contractor, and the contractor with whom he was employed. The contract between the managing contractor and the contractor on this case study was modeled upon the contract between the owner and the managing contractor. Originally the contractor was only signed on to do the design with the managing contractor in charge of both procurement and construction. After engineering was complete and the contractor revised a flawed constructability plan by the managing contractor, the owner and managing contractor decided to have the contractor complete construction as well. However, procurement was still to be managed by the managing contractor, and all materials had to be requested by the contractors and ordered by the managing contractor.

The portion of the project under the responsibility of the contractor was over 15 acres making it the largest segment of the site; all of the other portions of the project were significantly smaller. Thus, a great majority of the materials being controlled by the managing contractor were for this piece of the expansion. There were several late material deliveries to the contractor under this arrangement. First, the foundation piles were not ordered on time and arrived four months late. Consequently, the pile-driving bid was withdrawn and had to be let again 2 months later, and although one pile-driving machine was called for in the original execution plan, machines were required to make up lost time. Due to the pile driving being behind schedule, the work now overlapped with the pile driving on adjacent parts of the site. This caused some piles to shift on the site, which required rework and presented an additional risk to the quality of the foundation piles.

After the piles were completed, the contractor moved on to installing underground piping, drains, and foundations. At this time, the second set of late deliverables from the managing contractor emerged. The contractor had placed the order for the prefabricated large-diameter insulated piping that it had previously designed. The managing contractor had forgotten to include the large diameter in the original budget and had to go to the owner for a change order, which delayed the delivery by six months. The pipe was then rushed in the manufacturing process that left many errors that the contractor had to both find and correct on site, which required extra time and man-hours.

The third set of late deliverables involved over 40 prefabricated modules designed by the contractor to be procured by the managing contractor. These modules were to be fabricated in various module shops around the country, but several of the most important were to be assembled in a yard controlled by the managing contractor. Thus, the alignment with the module shop was sufficient, but there were concerns by the construction manager of the capacity of the shop to complete the modules on the aggressive schedule required to meet the project schedule. The contractor requested additional module yards be employed to but was denied, and it soon became evident that many of the modules were going to be delivered just in time. This did not allow the contractor time to properly inspect and prepare the modules for installation, and the contractor was not allowed to place quality personnel in the yard to perform inspections before the modules were shipped. As the shops came under pressure to ship the modules to the site to meet the project schedule, they began taking shortcuts. They began shipping incomplete modules and crates of uninstalled loose materials (about 10 times more than planned). These crates did not contain packing lists and only sometimes included incomplete punch lists, and none of this could be monitored because the contractor's employees were not allows in the module yard. In addition, the modules being shipped incomplete had many quality issues including internal rust that had to be repaired on site along with the final preassembly. The crates of materials shipped with the modules were often incomplete and or damaged, and the contractor had to go the managing contractor in order to procure the correct materials. In the end, the last module was installed about 15 months late.

The fourth set of late deliverables included all of the bulk materials for the project, which were again controlled by the managing contractor. The original materials management plan called for a 3-week notice for materials to be prepared by the managing contractor and delivered to the contractor on site. In addition, the contractor was not allowed to keep any laydown areas on the actual site where construction was taking place. This meant that any material delivered had to be installed the same day, meaning the contractor had to plan all work for just-in-time delivery. The productivity issues embedded in the project with just-in-time and late delivery of materials frustrated crews as they were forced to either wait or drive to the managing contractor's laydown yard for materials. The trucks that arrived on site often contained incomplete palettes and many materials were lost in the process. This created a very contentious relationship between the companies and crews over who was responsible for the missing items. After the contractor was given control over materials management and several weeks were spent implementing the contractor's material management processes, the productivity improved and the work continued more smoothly according to the construction manager.

One of the most drastic impacts of all of these late deliverables involved shifting the peak of the scheduled manpower into an economic downturn when instead the great majority of the work was scheduled to be complete. The owner and managing contractor requested that the contractor cut costs, so the contractor cut costs by 30 percent by reducing staff and craft labor as well as other overhead costs. Prior to the downturn, the contractor was working under a cost reimbursable contract with the managing contractor, but was asked to renegotiate the contract. The result was a contract directly with the owner with a lump sum price for all indirects and a cost reimbursable portion for all direct labor and permanent materials. Also, the managing contractor relinquished control over material management, and the contractor created its own laydown yard offsite. This required about $5 million in additional staff and equipment, which was addressed in a change order. A second change order was required to cover the indirect costs of the one-year project extension. The contractor's staff spent time creating a recovery plan to complete the work under the new circumstances and keep the retained craft labor working so they would not move on to another project. The final cost of the project grew by about 33 percent not including the overhead and profit of the managing contractor from the beginning of construction to completion. In addition, the direct man-hours for the contractor ballooned by about 50 percent over the course of the project. This was a result of low productivity and the unavailability of materials at the site when necessary.

Construction Manager 2 and Materials Manager

The second construction manager and materials manager, who joined the project after materials management was turned over to the contractor by the managing contractor, focused mainly on describing the impacts of the late prefabricated assemblies and the inefficient materials management system of the managing contractor. The managing contractor controlled all purchasing, storage, and delivery of materials to the contractor's site within the overall expansion project. As part of the process, the contractor requisitioned the materials warehouse and laydown yards three weeks in advance for materials to be delivered to their site. The trucks that arrived on site from the managing contractor had little organization, were not labeled correctly, and had the materials for multiple crews contained on the same palette. Without knowing where materials were or if they would arrive on site, the work of the contractor slowed significantly.

The prefabricated modules being constructed in module shops were well behind schedule as well, so the managing contractor decided that instead of paying for the ships and barges that were transporting them to wait, the modules would be shipped on the scheduled even if they were incomplete. This continued for the first few of the 40 modules, but with the economic slowdown, the shipping schedule eventually had to be slowed as well. The late modules had drastic effects on the original execution plan for the contractor, who had designed the assemblies for constructability under the direction of the managing contractor. The added scope of finishing the modules that were shipped incomplete included finding and installing any incomplete parts of the module, testing the piping, welds, electronics, and insulation, and then reworking any of the portions that did not meet the specifications. This added a huge number of man-hours to the project that, in the end, had to be paid for by the owner. However, the contractor had to cover the cost of additional quality personnel in the field to monitor the welds that were being performed outdoors instead of in the module shop. The lift plans on the site were also altered, as was the constructability plan as the order of delivery and preparedness for installation was constantly changing.

The cost impacts on the project went well beyond low productivity and additional labor. Days or weeks were spent trying to find missing materials at additional cost, and lost materials were repurchased. This lengthened the process even more because most items would have to be rebid. Transportation costs increased as crews went back and forth to the remote laydown areas looking for materials. Also, the crews did not know which materials would be available each day so rework increased steadily, which under the lump sum portion of the contract was the contractor's responsibility. Theft also increased between worksites, as the contractor's bulks would disappear when other sites had material shortage or needed certain equipment, and the managing contractor left it up to the individual contractors to secure their sites.

The safety risk profile of the site changed as work on the modules and their installation created the need to work at height to complete the modules after installation and the overlapping of crews that were working on the modules at the same time to prepare it for installation. Safety equipment was required for the crews working at height and for the welders working in the field. Not only did the extra man-hours on site introduce additional safety risk, there was a particular safety incident caused by the late and incomplete modules. On several of the modules, most of the drain piping was incomplete when it arrived on site, and to maintain the schedule, the modules were set in place. Welders were then required to work below grade to complete the drain piping, and one welder was injured while getting out of the void under the module.

The quality of the project was also impacted by the delays in the schedule from late materials. Over 1000 pipe flanges had to be refinished after rusting while waiting to be installed on site. Each flange had to resurfaced and inspected by quality personnel before they could be installed. In an attempt to save money, the managing contractor eliminated source inspections on the modules, so there was no quality check until the material was already on site. This meant that pieces of the assemblies were often left out and items, such as tools and extra pieces, were found in the modules. Several critical valves had not been tested so they had to be removed, tested, and reinstalled.

Turnover on the site was drastic according to the construction manager, and securing quality craft workers was extremely difficult as the project fell behind. The labor issues exacerbated the material issues as planning was limited and many of the craft workers were either off searching for materials or had not shown up on site that day. The morale on site became a big issue for the contractor. All parties, including the owner, managing contractor, and contractor, became frustrated on the project and butted rather than trying to solve the issues. The owner and managing contractor had high turnover at top-level project management positions, and this turnover brought changes in processes that made it even more difficult for the contractors who spent all of their time either adapting to new processes or troubleshooting existing problems.

When control of materials was turned over to the contractor following the contract renegotiation, a specialized team of materials management experts was assigned to the project. In addition, the owner and managing contractor decided to also give the contractor authority to purchase the indirect materials and consumables under the lump sum portion of the new contract. This team set up an electronic materials management system, and once it was operating after a period of about one month, productivity improved drastically. However, the full scope of work was still unknown with all of the incomplete items and rework, so tracking progress was very difficult for the project team. A few months later, the purchasing of bulk permanent materials was also turned over to the contractor.

Case Study #8 Interviews

Three interviews were conducted for this case study with various project team members. First, the owner's rep project manager and the contractor's project manager were interviewed. The owner's rep project manager has about 10 years of experience in the construction industry. The contractor's project manager, who was in charge of site work and logistics for the project, has been in construction for over 20 years and with his current employer for eight years. The third interview was conducted with a project engineer for electrical systems, who has worked in construction for almost 40 years.

Project Managers

The two project managers from the project were interviewed together for this case study. They began by explaining the amount of site work necessary for the project and how it was impacted by the unmoved utility. The site as it existed was adjacent to the existing facility but was all wooded except for the existing road that ran through it. There was also a driveway that provided access for employees and deliveries to the existing plant. Thus, the first step was to relocate the driveway and redundant feed line that ran beneath it. The driveway was relocated to the edge of the construction site, and the utility company hung a temporary redundant feed along a fence that surrounded the construction site next to the new driveway and tied into the main feed. However, although the contractor could now move forward with removing the existing driveway, the utility that needed to be housed in conduit and buried underground was exposed above ground and in one place elevated over the driveway. This presented many hazards not only to the feed to the facility, but also to crews on site and vehicles using the driveway. Crews had to be notified of the exposed cable and their danger and trained to keep all machinery and equipment away from the fence. Flaggers had to be hired to monitor the fence line and check the height of delivery vehicles passing under the elevated cable.

Although the temporary redundant feed was moved by the utility company, the main line that ran along the existing road was not moved according to the plan created by the contractor. This impeded the enormous site prep effort by the contractor, which included up to 12 feet of muck and fill after the removal of all the trees, the construction of the new road, signals, and parking areas, and the coordination of the relocation of all the utilities. Although construction on the new road continued with the schedule, it could not be completed until the new main utility line had been relocated, and thus traffic had to remain on the existing road through the construction site. Thus, site work moved forward with an operating road bisecting the site.

The project managers next described the many impacts from this situation. During the muck and fill operations, heavy equipment was constantly being moved across the road to each side of the site to keep each segment on schedule. Crews had to be trained in protocol for transporting equipment across the road, and the safety risk on site increased drastically with active traffic in close proximity to workers. Due to the disruptions in traffic and safety risk to workers, the contractor eventually placed separate crews and equipment on each side of the road, which impacted costs but kept the project on schedule. Public safety also became an issue with material deliveries along the existing road that disrupted traffic. As fill material deliveries continued and construction materials started to arrive, the congestion on the road became a significant issue, and flaggers and off-duty police officers had to be hired to direct traffic. In addition, as construction of the factory began and became a distraction to drivers, the contractor had to work with the city to add signage and place police officers along the road to prevent accidents.

Well after the new road was finished, the utility company relocated the main line to its permanent position and the temporary feed line underground, and traffic was finally moved to the new road. The contractor then proceeded with removing the existing road and completing the site work. At this point, the contractor had to remove the existing road and muck and fill below, and thus many crews were working in close proximity to one another. The split in the site and change in the sequence of work had caused significant replanning by the management team, and even resulted in a claim by one of the contractors for resequencing of work and design changes that was settled. However, in the end, only paving was disrupted by the delayed utility relocation, and construction of the factory continued as planned.

Project Engineer

The project engineer first gave some additional background on the underground utility that impacted the project. The project team had created the construction plan under the assumption that all of the utilities could be moved at the same time according to their work plan. However, well into the project and after the start of site work, the utility company notified the contractor of the date at which the main line would be moved, based on the services provided to other entities in the area.

The original execution plan had construction proceeding from north to south, but the orientation had to be reversed going south to north. Many of the milestone dates for sitework were missed due to the unmoved utility. With the split in the worksite, many of the subcontractors had to bring in extra crews, which increased the labor costs, and many of the subcontract schedules had to be compressed at extra cost to accommodate changes.

The unmoved road and utility line caused severe changes in work sequencing and craft levels after groundwork was complete, mainly by introducing numerous workarounds. Relatively small sections of the site were opened for work at one time, which resulted in lower craft productivity for electrical tasks such as running conduit and pulling wire. The road also disrupted these activities as work could continue on either side but not be connected. This slowed construction progress and frustrated crews who could not complete the work efficiently and were constantly moved around the site. The management team spent significant amounts of time replanning the work and trying to create efficient sequences, but the partial completion of tasks hampered progress. This along with rework for installed work that did not line up perfectly or did not match updated work plans lowered morale on site. In addition, the resequencing of work impacted material handling on site, as items such as electrical substations arrived on schedule but could not be installed. Space had to be leased off site to store these items, and transportation had to be arranged to move them to site when ready for installation.

The project engineer also explained additional issues that arose on site with new crews brought to site. When additional crews were added to the divided site, many of the craft workers and laborers had less experience, which lowered the quality of work. This increased the amount of rework and created a substantial punchlist of repairs that needed to be made. All new workers also had to undergo a day of paid training to orient them to the site and safety procedures. After undergoing this training and setting up site access, many of the crews would only stay for a few weeks, which also increased the labor costs.

Case Study #9 Interviews

Case Study #9 included interviews of four project team members from the contractor company. The first two interviews were with project executives, both of whom have over 25 years of experience in the construction industry. The third interview was conducted with the project's construction coordinator who has been with the contractor for eight years. Finally, a project controls manager with around 15 years of experience was interviewed.

Project Executives

The project executives first explained the immediate impacts of the delayed air permits. The notice to proceed for the project was contingent upon the approval of the permit, and, as such, no work could proceed on the site until it was obtained, including site work or utilities. However, the project was already mobilized and all support staff and facilities were on site. This included supervisors, foremen, and schedulers. With the date of the permit release being unknown, the project team continued refining the project execution plan, but this effort was limited by the unknown date for the notice to proceed.

Although the contractor received a day-for-day contractual extension for the delay in the air permits, several factors prevented the project team from shifting the project schedule day-for-day. The primary reason for this decision was the delivery date of the plant's generator, which was already ordered and moving through the supply chain, and would be delivered on the previously scheduled date. This was the central piece of equipment, and it had to be placed directly on its foundation. The generator could not feasibly be stored in laydown areas on or off site.

When the air permit and notice to proceed were granted, the decision was made to compress the activities leading up to the generator delivery. Excavation and underground utility work began as soon as the site was staffed, and all activities not necessary to the foundations for the generator were suspended. Meanwhile, the work was replanned and the project team attempted to update the project execution plan to reflect changes. Although the critical path did not change in the updated schedule, the work execution plan was not fully updated as work progressed, which led to problems later in the project.

While the intent of the changes was to compress the activities in front of the generator delivery, the change amounted to delivering the generator earlier than arranged in the execution plan. Because the planning leading up to the generator was not sufficient, many unexpected costs arose as the project proceeded. In addition, although the activities replanned for the generator delivery were considered, a new execution plan examining how other activities were impacted was not available to the field management and crews. Some activities were postponed and others completed early, but this information and future plans was not sufficiently communicated to the field, which impacted morale on site. Beyond the field level, there was additional strain placed on the organization and upper management from the changing plans that were not reflected in the execution plan and the lack of adequate up-front planning.

The out-of-sequence work impacted the project in several additional ways. The site was very compact and became congested while accelerating the work to prepare the generator's foundations. The original project execution plan specified the locations of the cranes for lifts, including that for the generator. However, these specified areas also had a significant amount of ducts, piping, and other underground utilities that needed to be installed underneath. In order to accommodate the changes, the crane lift spaces were left open and the underground utilities were brought up to each side, to be connected later after the lifts had been made. The quality risk to these underground utilities increased because they were not placed continuously. Similarly, the project ran into other logistical, staffing, and congestion issues with space needing to be occupied by more than one crew or machine. This created extra hazards, and management time was spent to create workarounds and resequence work.

Construction Coordinator

The construction coordinator first described the immediate impacts from the delays. First, much of the area that had been excavated for underground utilities to be installed had to be filled in when the generator arrived on site. After the generator was set and crane moved, all of the area around the generator had to be excavated again and utilities placed. Before and after this, the small site presented numerous access issues for crews and equipment as trades stacked up on site. It was not until the generator and other modules were set and the structural steel was erected that the stress analysis on piping could be completed and the design of the supports and valves could be finalized. As a result, subsequent structural steel and piping was delayed. In some places, temporary pipe was installed for extra costs and required extra time to place and remove before permanent piping was installed. Similarly, material handling increased on site as items were handled two and three times while making room on site and installing items out of order.

Project leadership tried to plan the work far enough ahead to coordinate deliveries as they arrived on site, but when the notice to proceed had been given, the project ramped up staffing levels and began work immediately, which left little time for training of the crews and further planning the work. Thus, from the beginning there was frustration among crews, and look-ahead periods for crews were very limited which slowed progress. The management team also found it difficult to communicate work plans to crews without an updated project execution plan.

Project Controls Manager

The controls manager attributed additional difficulties in the compressed activities leading up to the arrival of the generators on poor weather during that period. With the compressed schedule and poor weather, the congestion on the small site became a hamper on productivity. In addition, the small site limited the amount of equipment that could be used. No additional crews could be added beyond the original execution plan due to the constricted space, and all manpower was focused on completing the activities for the generator placement. However, the rest of the project fell behind schedule.

As congestion became an issue on site, safety personnel were added to the project. As an example of safety issues on site, the controls manager described the coordination of lift plans. The lift plan could not be changed from the original execution plan and had not been updated with the new work sequence. Thus, for each lift, crews working in large portions of the site had to stop work for each lift. These stoppages could not be planned around the work because, due to the limited laydown space, each equipment delivery had to be placed in its final location except for in a few cases.

Appendix E: External Validation Questionnaire

This questionnaire has been created by CII Research Team 300 to help you organize your thoughts and provide an outline for an interview regarding Implementation Resource (IR) 300-2. These questions do not need to be formally written out, but rather will serve as a guide for the phone interview. Please review the questions before you read IR 300-2 and refer back to them as you read to help you understand the type of feedback our team is looking for.

Thank you for taking the time to review our product.

Overall Document

- Is the report well organized and easy to read?
- Is the level of detail within the report appropriate?
- Is there any information that you were expecting to find that was missing?
- Is any part of the report extraneous or confusing?

Introduction

- Is the gap in knowledge in the industry clear from the information presented? Is there a need in the industry for this research product?

Research Background

- Has the research process been outlined in a logical way?
- Does the research process as described give you confidence in the validity of the research?

Implementation

- Are the features of the LDRC clearly outlined and described?
- Do you think the LDRC would be easily implemented into your company's processes? How would you use this product?
- Are the deployment recommendations and example applications applicable to both your company and the industry as a whole?
- Will the limitations constrain the tool's use in the industry?

- How can the LDRC be used to prevent and resolve disputes and claims? Do you foresee the tool being effective for dispute resolution? What improvements could be made to improve it effectiveness for dispute resolution?

Learned Lessons & Recommendations

- Will the lessons learned and recommendations be beneficial to the industry?
- Are the LDRC implementation recommendations something that your company would consider implementing?

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Vita

William Ryan Barry was born and raised in Texarkana, Texas. After graduating from Pleasant Grove High School, Will attended Texas A&M University, College Station where he majored in Civil Engineering and was an Athletic and Academic All-American in track and field. A proud member of the Texas A&M Class of 2012, Will was granted a research position with the Construction Industry Institute at the University of Texas at Austin. He enrolled in the Construction Engineering and Project Management, studying under the guidance of Dr. Fernanda Leite and Dr. William J. O'Brien and earning a Master of Science in Engineering degree in May 2014.

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