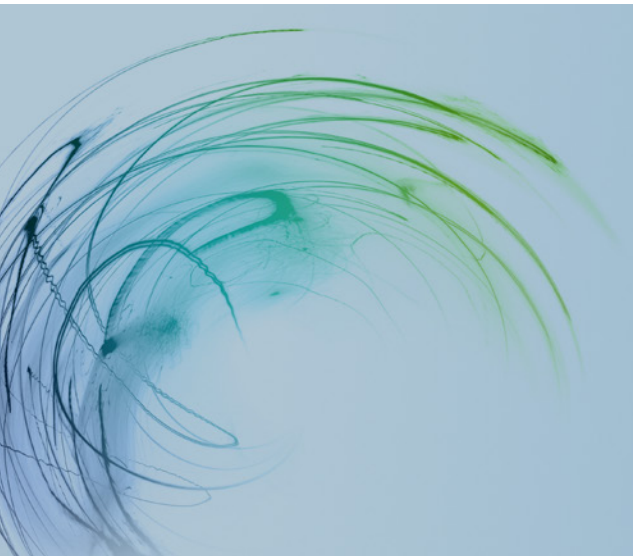
Final Report 344

Improved Integration of the Supply Chain in Materials Planning and Work Packaging

Part I: Visibility



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Improved Integration of the Supply Chain in Materials Planning and Work Packaging
Part I: Visibility

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in Materials Planning and Work Packaging

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Executive Summary

Materials are the life blood of projects. If materials don't flow smoothly from specification to fabrication to site installation, project performance will be poor. All too often, even well planned and executed projects face disruptions to materials flow. Indeed, late or missing materials are a common occurrence on almost every project. While there are many challenges, a fundamental problem is lack of visibility of materials status in the supply chain. Being able to see where materials are and subsequent ability to accurately forecast delivery dates enables effective work in the field and supports timely corrective action. While most projects have some sort of materials tracking tools, the experience of the research team and a survey of 218 industry professionals reveal that there are numerous opportunities to improve. A significant percentage (27%) report materials visibility is less than adequate on site, and visibility worsens upstream away from the site. The net result is poor productivity, costly expediting, and out of sequence work with all the consequent challenges to project alignment, safety, and quality.

It is the considered opinion of Research Team 344 that enhancing materials visibility is among the greatest opportunities for improvement available to capital projects. Fortunately, improving materials visibility can be tied to other productivity and quality enhancement efforts, such as Advanced Work Packaging. Indeed, almost all project improvement efforts can benefit from heightened supply chain visibility. We note that the streamlined and responsive supply chain transformations in other industries have been enabled by better materials visibility.

The research findings provide concrete starting points from which firms and projects can take action. This volume provides detailed definitions of desired visibility across common decisions during execution. A complement of enablers is also provided to enhance the benefit of increased visibility. The definitions represent the broad input of the research team, including owner, designer, contractor, supplier and technology perspectives. Projects and firms are encouraged to use the visibility definitions and enablers to audit their own capabilities and prioritize actions for improvement. To support such assessment, firms can score themselves against averages collected by the research team. Definitions can also support contracting for desired information and provide input into information systems for materials tracking.

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Chapter 1
Introduction

This research was chartered by CII, which gave the following essential questions to Research Team (RT-344): “What are the new tools, practices, and documentable benefits improving supply chain visibility, advanced work packaging, and risk mitigation? Further, as part of enhanced supply chain visibility, can project material and equipment inventories (and associated inventory costs) be optimized? Specifically, can an analytical process be devised to select the optimal balance between just-in-time and just-in-case delivery strategies for various types of project materials and equipment without jeopardizing project schedules?” These questions are expansive in scope and seek to document the current state of practice and understand the opportunities to improve materials availability without unduly increasing stocks of materials. Central to the essential questions is visibility of materials in the supply chain, so visibility became the central focus of the research team.

Visibility is seen by many as a key enabler for improvements to supply chain performance (Bartlett et. al, 2007; Young et. al, 2010; Heaney 2013). Without being able to see progress of materials fabrication and logistics, it is difficult to effectively plan project production in a timely manner or alter plans to fit the availability of materials and resources. As noted by the industry members of RT-344, visibility is not just for larger items – it is for all items, so projects can daily move from ”success to success” rather than “die by a thousand cuts.” Indeed, the survey results related in this study speak to the need for the improved visibility of all types of materials on projects, both on-site and off-site (particularly off-site, but there remains broad opportunity for improvement). The findings of this RT-344 research further demonstrate that visibility on many dimensions remains uneven across firms in terms of access to and trustworthiness of information. This presents a significant challenge to project success, but also an offers important opportunity for improvement.

A principal challenge that retards materials visibility is that various project participants have different perspectives about what visibility is needed. These perspectives stem from their various roles in projects and vary both across and within firms. There is not a definition of visibility shared by the industry. As such, we adopt Tohamy’s (2003) definition of supply chain visibility as *“capturing and analyzing supply chain data that informs decision, mitigates risk, and improves processes.”* The research team members felt this definition captures the need to not just see materials status but to have information that supports actionable decisions.

While Tohamy's (2003) definition is motivating, it does not provide detail about the numerous items that require visibility to make actionable decisions. RT-344 undertook significant work to develop detailed and shared definitions of what visibility is needed for important and common decisions on projects. The team limited its scope to tactical decisions from detailed design through construction execution. The team'Í members understood the importance of early, strategic decisions (such as major supplier selection), but desired a more defined starting point for establishing detailed investigation. Clear definition of visibility during the operational phase of a project will also provide useful information for early planning.

This report details survey and case study data that demonstrate both the challenges and opportunities for improved visibility in the supply chain. This work provides context and background to RT-344's extensive work on defining desired visibility and associated enablers to help firms successfully implement improvements on their projects. The definitions of visibility are a basis for the industry to improve – the team recommends adopting its definitions across the industry for internal use, for defining contractual requirements for sharing information, and as a basis for implementation in tools. A self-assessment of performance on visibility items and on enablers shows that the industry has significant room for improvement. That said, while this speaks to poor current performance, the research provides a path forward for improvement.

The Business Case for Supply Chain Improvement through Visibility

Although the need for supply chain integration is widespread and well recognized, it is not straightforward and is considered an elusive goal (Briscoe and Dainty, 2005). While integration is broad, specific to this study, improved integration of the supply chain in materials planning and work packaging has potential to improve project performance. Numerous project, industry, and academic studies have examined the influence of ineffective materials management in the capital projects supply chain and on-site. Some of the relevant findings from case studies and publications that highlight the importance of this research initiative are summarized as follows:

- Materials play a vital role in the successful delivery of construction projects. "Over-runs stem from a lack of control and visibility of materials, personnel, and equipment." (CII RS240-1, 2008).
- Fifty to 60% of the total project cost constitutes the cost of construction materials, and materials management accounts for 80% of the project schedule (Ibn-Homaid 2002; Stukhart and Bell 1986; Caldas et al. 2004; Kerridge 1987).
- Modern productivity thinking, such as Lean Construction and Advanced Work Packaging (AWP) (CII IR272-2, 2013), places emphasis on the flow of materials to assure productive construction. Much current work within the AWP community focuses on defining and improving Procurement Work Packages (PWPs).

- There is limited up-to-date visibility regarding status and location of materials. 63% of the average craft laborer's time is spent off tools. A significant portion (49%) of this non-productive direct labor time can be attributed to waiting on materials and/or instructions (13%), for tools and equipment (19%), and travel (17%) (CII RT252-2a, 2010).
- Storing a majority of the materials in advance in large laydown yards on the construction site also does not guarantee a highly productive environment. Craft workers spend substantial amounts of their working time searching for components due to insufficient status and location information. Bell and Stukhart (1987) found that foremen lost 20% of their working time to searching for materials, and an additional 10% due to tracking purchase orders and expediting activities.
- On power plant projects, it was found that approximately 28% of craft workers' time was either idle or non-productive due to the unavailability or non-readiness of the right materials and tools at the moment they are needed (Borcherding and Sebastian, 1980). Readiness issues of materials at the moment of installation increase craft labor hours between 16% and 18% (CII 1986; Thomas et al. 1989).
- In general, daily productivity is reduced due to material management deficiencies such as running out of materials, improper storage, double handling, sporadic and out-of-sequence deliveries, inefficient methods, poor housekeeping, and other inefficiencies (Thomas and Smith, 1992).
- Many projects continue to utilize manual or semi-automated methods for materials management (Kasim, 2008). Inefficiencies due to these methods lead to waste and surplus materials, schedule delays, and lack of up-to-date information regarding the status of materials (Navon and Berkovich, 2006).

The findings above point to the multiple aspects of how more materials management affects productivity and these examples are but part of a large literature. There is a well-documented need for improvement. A theme central to making progress is improving the visibility of materials status and location in the supply chain. Put simply, without the ability to know the status of materials, it is difficult to plan and difficult to assign effective work to the field. Better visibility is prerequisite to progress and is seen by the research team as a core enabler of improvements to capital project performance. Heaney (2013) points out "increasing visibility is a critical strategy for enterprises aimed at reducing costs and improving operational performance" and "before a company can reduce inventory or landed cost, it needs visibility into them."

The centrality of visibility as a focus for improvement is substantiated by the research team's survey of firms in the capital projects industry. In response to the question, "Would better supply chain visibility materially change how you do business?," almost two-thirds of 218 respondents replied in the affirmative and another 31 percent selected

"maybe." (See Figure 1.1.) Only five percent did not think supply chain visibility would change the way they do business. Incidentally, these results mirror a study conducted by the Aberdeen Group (Heaney 2013) in which 63 percent of respondents from 149 companies, mostly with global supply chains, indicated supply chain visibility as a "high priority for improvement," with an additional 28% rating it as a "medium priority."

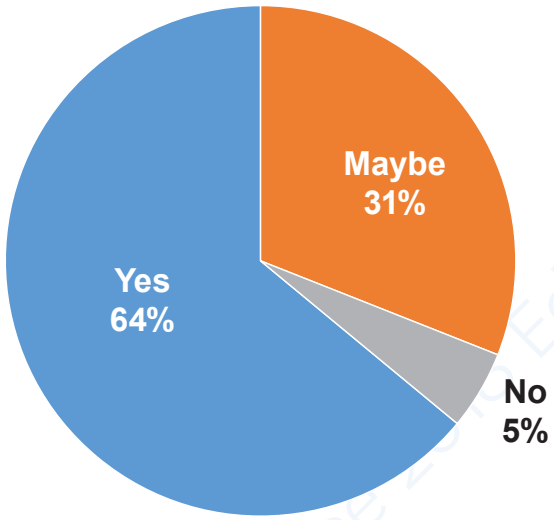


Figure 1.1. Responses to the Survey Question: "Would Better Supply Chain Visibility Materially Change How You Do Business?" (n=176)

Reader's Guide

This report is laid out as follows. Chapter 2 details the research methodology behind the RT-344 research. Those seeking a detailed understanding of the research approach should review Chapter 2 in its entirety; others may choose to skip or skim the chapter. Chapters 3 and 4 present the research findings. Chapter 3 documents the current state of visibility in the industry by reporting on case studies of success as well as a detailed survey regarding current challenges and anticipated benefits. Chapter 4 presents the team's findings regarding definitions of visibility, associated enablers, and assessment against those definitions and enablers. As the definitions are extensive, a full listing of each is presented in the appendices. Readers are encouraged to use the definitions and assessment measures as a way to self-assess their projects/firm to identify targeted improvements. Chapter 5 presents the overall conclusions and recommendations of the research team.

Chapter 2
Methodology

In service of the essential questions, Construction Industry Institute established RT-344 in June 2016 with a goal to better understand visibility and the relation to materials management, including support for work packaging and for inventory management. The team conducted research and documented the findings through several face-to-face meetings, web meetings, conference calls, and emails in addition to various data collection efforts. RT-344 was composed of representatives from owners, service providers (including contractors, suppliers, engineers, and technology providers), and academics.

During its initial phase, the research team conducted a literature review, identified and reviewed success cases and initial assessments of the challenges to and costs of poor visibility, conducted a state of the industry survey, and defined objectives for the research in support of the initial direction CII gave the team. This resulted in a specific proposal the team presented to CII in October 2016, and which CII accepted for full funding. Over the period between October 2016 and June 2018, the research team conducted research in two separate thrusts, with the first thrust becoming the subject of this volume. A second volume will present the work of the second thrust.

2.1 Research Objectives, Thrusts, and Questions

The research team early on in its deliberations focused on supply chain visibility as the key enabler for improvement of materials flow on projects. As such, the primary purpose of the research was to have methods to improve capital project performance through enhanced visibility across the supply chain. This research accomplished its primary purpose through the following specific objectives:

1. Documenting current performance to understand opportunities and costs of existing practices;
2. Defining supply chain visibility for capital projects that reflects the needs of participations as well as their commercial constraints to sharing information;
3. Developing a decision making framework at the operational/tactical level to better allocate production and inventory across the supply chain as well as respond to changes in a proactive manner; and,
4. Define the three prior objectives in manner that supports implementation on projects, including provisions for contracts.

Given the scope of the research, the approach was divided into two thrusts; Thrust 1 and Thrust 2. The first addresses current conditions and the need for improved visibility to better define opportunities for advancement. The second thrust posits improved visibility on projects and examines how to use that visibility to improve decision making and hence project outcomes. These two thrusts respond to the essential questions posed by CII at the start of the project and each thrust has two research questions (RQs). Figure 2.1 shows how this study's methodology was shaped by pursuing the following two thrusts:

Thrust 1: Enhancing Supply Chain Visibility. Essential question: What are the new tools, practices, and documentable benefits improving supply chain visibility, advanced work packaging, and risk mitigation?

RQ1: What are current technologies and novel practices, and their associated benefits and challenges, supporting the capital projects supply chain (particularly with regard to AWP and risk mitigation)?

RQ2: What does improved visibility mean for different stakeholders?

Thrust 2: Enhancing Supply Chain Decision Making. Essential question: Further, as part of enhanced supply chain visibility, can project material and equipment inventories (and associated inventory costs) be optimized? Specifically, can an analytical process be devised to select the optimal balance between just-in-time and just-in-case delivery strategies for various types of project materials and equipment without jeopardizing project schedules?

RQ3: Assuming improved visibility, what is a decision making framework for planning and managing the position of inventory and production capabilities that strikes the right balance between efficiency and responsiveness for managing project risks and schedule?

RQ4: As a use of the RQ3 framework, what insight can be given into overall potential for reducing inventory stocks in the industry?

2.2 Scope of the Research

To limit scope and ensure success of the research, the team considered the following points as starting points and key limitations:

1. To focus on capital projects and not include considerations for maintenance and turnaround projects (such projects will likely benefit from improved visibility, but they will not be the principal focus)
2. To use AWP as an organizing framework for improving capital projects productivity across the lifecycle from planning to execution through startup.

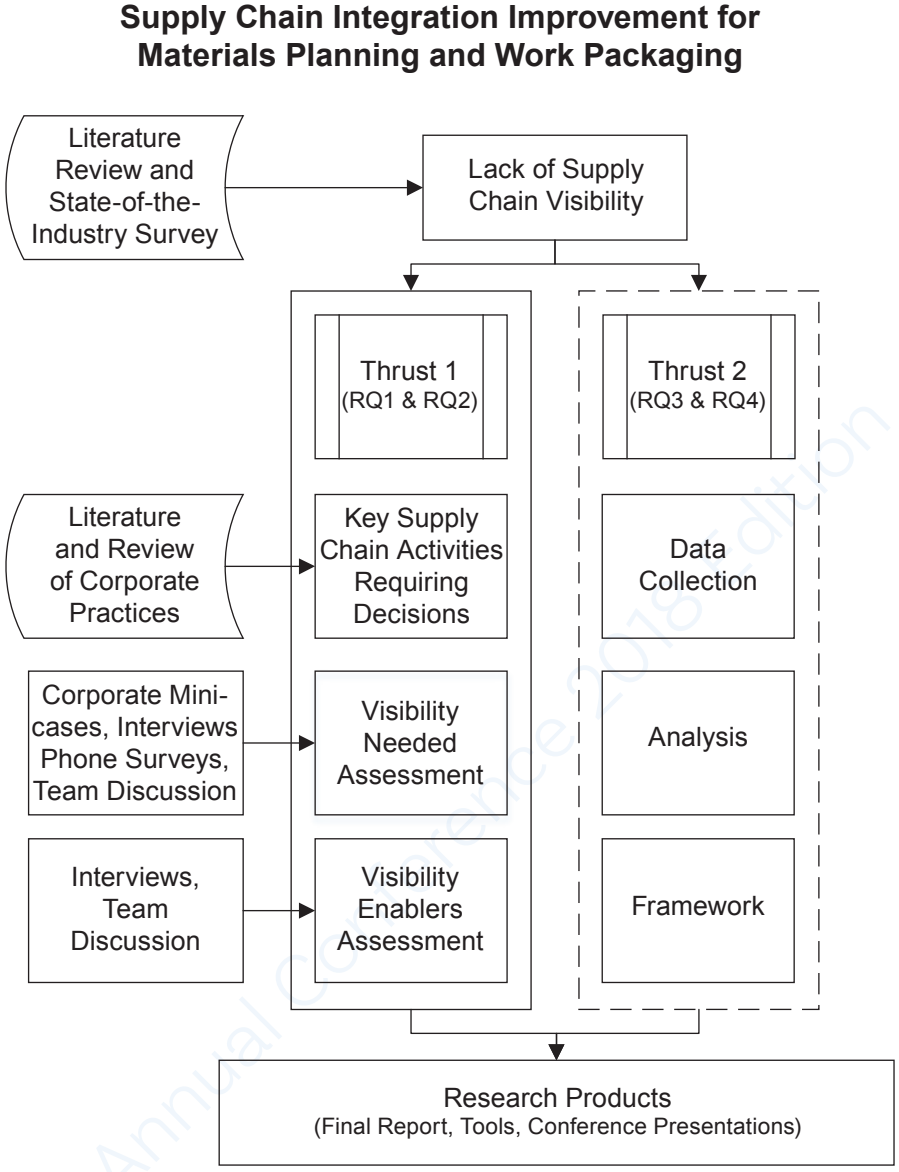


Figure 2.1. RT-344 Study Methodology

3. A principal focus on visibility will be the off-site supply chain to site, as existing technologies and processes for site logistics can enhance site visibility.
4. Decision-making frameworks will focus on tactical/operational decisions rather than strategic sourcing. Therefore, it is assumed that the decisions are made at detailed design, procurement and supply chain, and construction phases. (Early decisions, while important, will be a subject for future research.)

This report focuses on scope of the research of Thrust 1. Thrust 2 and its corresponding research questions will be addressed in a subsequent report.

2.3 Specific Methodology

Figure 2.1 shows the methodology RT-344 applied to conduct this research. Framing discussions included literature review and a state of the industry survey to investigate the current status of supply chain visibility and assess and benefits and barriers. Case studies of success from the literature as well as contributions of the team contributed to framing the subsequent research scope as well as answering the first research question regarding technologies and practices around improved visibility. Chapter 3 that follows presents a concise summary of the cases around practices and technologies as well as principal challenges and benefits from the state of the industry survey. As much of the technologies have been reported elsewhere, the review is not meant to be comprehensive but rather contain key learnings that support the research question.

As this report only contains findings and contributions in service of the Thrust 1: Enhancing Supply Chain Visibility, the following discussion pertains to the left column of Figure 2.1. The subsequent report will review methodology for Thrust 2.

Research question 2, "What does improved visibility mean for different stakeholders?" is deceptively simple. In fact the question is multifaceted and the research team undertook a comprehensive review of understanding the current state of visibility as well as defining and assessing an ideal state for visibility. Principal research approach was structured elicitation of team knowledge to identify challenges and define desired visibility. This was supported by specific documentation of cases as well as examples of current visibility in detail by review of existing tools. In service of the team's adopted definition of supply chain visibility as *"capturing and analyzing supply chain data that informs decision, mitigates risk, and improves processes"* (Tohamy 2003), the team started with identifying key supply chain activities that require decisions. These were arrived at by a Delphi style process to review, refine, and achieve consensus using the collected perspectives and experience of the team. These activities are depicted as the first box and supporting input of the left column in Figure 2.1.

Using these key activities as a starting point, the team undertook definition of visibility needed items. This activity was intensive and was the focus of multiple team meetings and team calls between meetings. Input to the deliberations of the team included multiple mini-cases that detailed examples of problems from lack of visibility and discussion and generalization of these cases by the team. Deliberations were conducted in a Delphi style, with repeated review and refinement to develop consensus in the team. It is important to note that the deliberations reflected the viewpoints of owners, designers, constructors, and suppliers and that the resulting definitions are meant to support all the main stakeholders. In some cases, there may be commercial

concerns that limit sharing of information, but the resulting identification and definition of visibility needed for each of the key activities is meant by the research team to be definitions that can be broadly shared and supported by the industry. Principal input and findings are detailed in Chapter 4 and the appendices. Also supporting deliberation but not presented in this report were reviews of information present in existing visibility tools used by contractors and in those support by major software vendors. Details about the information in these tools were collected through phone and web interviews and supporting screen shots. Summary of the data collected was reviewed by the team as part of their deliberations and hence is reflected in the final definitions.

In a parallel process, the team also undertook identification and definition of enablers that support effective processing of visibility information. These undertook the same rigor and refinement that was undertaken to support the definition of visibility needed items. Enablers were also identified around key supply chain activities supporting decisions in the tactical phases of the project (detailed design, procurement, and construction).

After defining visibility needed items and enablers, the research team undertook further assessment by scoring the level of implementation and the importance of each. This detailed assessment was conducted within the team and also supplemented by a few outside reviews from CII member companies. These external assessments represented a form of external review, as well as additional input to the team. The scoring is detailed in Chapter 4, and detailed results appear in the appendices. This report contains a summary of the results; additional data supporting the research findings will be reported in the forthcoming doctoral dissertation of Vineeth Dharmapalan, the principal student on the project.

Chapter 3
Current State of Visibility

This chapter reviews case studies of successful efforts to improve visibility using technology as well as a survey documenting the current state of visibility. Principal findings demonstrate the capability for existing technologies – even basic ones – to provide improved visibility. However, survey results indicate that there is definite need for visibility improvements across the supply chain. Opportunities for improvement exist on-site, but in general the further from site, the more the need for better visibility.

3.1. Case Studies – New Technologies for Visibility

Studies have identified the need, recommended the use, and empirically demonstrated the positive impacts of automation and integration technologies on materials management. The utilization of auto identification, locating and tracking technologies upstream at the manufacturing facilities have the potential to increase visibility throughout the supply chain (CII RS240-1, 2008) by providing near real-time, better, and timely information on shipping, receiving, and inventory (Caldas et al. 2006; Nasir et al. 2010; Song et al. 2006). RT 240 assessed the impact of material identification and locating technology on labor and construction productivity using a series of field trials. Recently, O'Brien et al. (2017) examined seven industrial projects and documented the lessons learned from recent applications of novel processes and technologies for materials management on capital projects. The reader is encouraged to refer to CII RS 240-1 (2008) and the Fiatech report by O'Brien et al. (2017) where the respective research studies are presented in detail. In contrast to these case studies of more advanced technologies, Ontario Power Generation (OPG) demonstrated their in-house procurement tool used for a nuclear refurbishment project that utilizes straightforward technologies for data management. The tool is designed to provide OPG visibility of purchase order (PO) status tied to the project schedule. These cases provide an overview of current technologies and demonstrate the potential of current technologies in service of Research Thrust 1 outlined in the previous chapter.

Fiatech – Integrated Materials Management (IMM) Case Studies

The goal of this Fiatech research project (O'Brien et al. (2017)) was to thoroughly document the drivers, benefits, and challenges to provide lessons learned and guide future development of supporting technologies and work processes for IMM. Data was collected through interviews with project personnel as well as collection of contemporary project data.

Project Details

Table 3.1 shows a summary of the characteristics of the seven projects that were selected for the current study. The project names were coded P1 through P7 for confidentiality reasons. Altogether, there were five oil and gas projects: P2, P3, and P4 within the exploration and production division; P5 and P6 within the refinery and distribution division. Project P1 belonged to the power sector and P7 belonged to mining and metals sector. The construction period of these projects ranged between 2005 and 2017, and the baseline cost between $300 million and $6 billion.

Technologies Utilized

The projects studied utilized combinations of barcodes, RFID tags, GPS, mobile devices, gate readers, vehicle mounted readers to locate and track materials and web-based server application were used at different locations in the supply chain, as the materials advanced from fabrication though installation. The solutions provided near real-time status and location information of materials to the project teams.

Drivers for Solution Implementation

Principal goals for technology implementations were to provide materials status and location to minimize time spent looking for materials in the lay down yards and increasing timely and accurate delivery of materials to the work front. Specific drivers for implementation varied across projects studied. Specific project drivers identified in the study are shown in Table 3.2.

Table 3.2. Implementation Drivers

Drivers	Project						
	P1	P2	P3	P4	P5	P6	P7
Low visibility	✔	✔	✔	✔	✔	✔	✔
Productivity improvement		✔	✔	✔	✔	✔	✔
Prior use		✔	✔	✔	✔	✔	✔
Supply chain complexity			✔		✔		
Inadequate supply chain decision making and inventory planning		✔					✔
Contractual requirements			✔	✔			

It is important to note that the need to improve visibility in the supply chain or on the project site was the common driver on all seven projects. For example, the owners In P2 and P7 wanted visibility into the procurement data for the materials bought on the projects in order to track costs that the EPC and contractors were spending on behalf of the owners.

Table 3.1. Summary of Projects Studied for Automated Material Location and Tracking Technologies

Feature	Project						
	P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**
Project type	Brownfield	Green field, Brownfield	Greenfield	Greenfield	Brownfield	Greenfield	Greenfield
Sector	Power	Oil and gas	Oil and gas	Oil and gas	Oil and gas	Oil and gas	Mining and metals
Scope	Two coal-fired, steam turbine generating units	Central processing, field facilities with nine wall pads	Ore preparation plant, extraction, tailing, and froth treatment facilities	a module facility; fabricates and constructs topsides -offshore semi-submersible platforms	Liquefaction facilities on existing LNG terminal	Petrochemical project – ethylene plant constructed to produce medical-grade plastics.	cement plant expansion project
Output	1230 MW	90,000 barrels per day	180,000 barrels per day	80,000 barrels per day	5.25 million tons per annum	1.6 million tons of ethylene per year	3300 tons of cement per day
Location	USA	Canada	Canada	USA	USA	USA	Canada
Delivery type	EPC	EPC	EPC	EPC	EPC	EP-C	Owner- managed
Contract type	Lump sum	Time and material	Cost plus	Item rate	Lump sum	Lump sum	Cost plus
Champion	Contractor	Contractor	Owner	Contractor	Contractor	Contractor	Owner
Baseline Cost (TIC)	$1–2 billion	$4–5 billion	$2–3 billion	$5–6 billion	$2–3 billion	$1–2 billion	$300–500 million
Baseline Duration	4 years	3.5 years	30 months	3 years	4 years	3 years	28 months

Large laydown yards with inventory build-up due to economic downturn and unforeseen conditions made materials locating using traditional methods unproductive. In order to improve the productivity of finding materials and reduce impact on cost and schedule, auto identification and locating technology was used on the projects.

The technology was implemented on previous projects through the same solution provider. The knowledge of benefits and experience with the system facilitated the adoption process on some of the projects.

Project P3 had a complex supply chain with multiple fabrication facilities in Asia, a staging yard, four modular yards and the project in North America. Also in P5, there were two project laydown facilities (in one state of the United States) and two off-site fabrication laydown facilities (in another state of the United States). The complexity of the supply chain and subsequent challenge of maintaining the logistic operations between the facilities drove the implementation of the track and trace technology.

P2 had an inventory pile up due to economic downturn and laydown yards were inadequate. In P7, on-site laydown yards were far off from the project site and scattered due to inexperience of the project team. The lack of decision making and inventory planning led to the implementation of technology on P2 and P7.

Two of the projects had the owner specify the use of technology for materials management through contracts. The contractual obligation drove the implementation and compliance on the projects.

Observed Benefits

The projects studied demonstrated the following significant benefits from implementation:

- **Efficient material transactions** – A significant improvement in the material receiving, locating, issuing times, and confidence regarding material availability was observed. Reductions in loss of materials, rework, misplacement, unnecessary searching, re-procurement, and error reporting were also reported.
- **Improved visibility** – The solutions enhanced materials visibility in the supply chain and/or at the jobsite by providing near real-time status and location information of materials at the different supply chain nodes depending on the deployment of solution.

- **Digitized information sharing** – The solution replaced the manual process using clipboards for generating packing lists, shipments, conducting inspections, reporting inventory and progress to electronic form that can be easily shared.
- **Productive meetings** – The meetings between owners and contractors were more productive since the solution made the materials management process more transparent. The focus of the meetings shifted to resolving issues and not on the data in the reports.
- **Improved safety** – The solutions reduced the exposure of the crew to hazardous work environments since the identification and locating process is more efficient and more accurate.

Observed Challenges

The following challenges were observed to caused implementation problems:

- **Changes** – Changes on mega projects (personnel/team change, execution plan) affect the materials management function. This is not unique to the solution implementation but can exacerbate other challenges to successful implementation.
- **Data integration and management** – The integration of solution with the EPC/ Owner procurement systems was a major challenge observed on some of the case studies.
- **Organizational and sociological** – One of the common challenges observed by the technology champions across the case studies was a reluctance among upper management and/or hesitance of crews in the field to embrace the technology.
- **Technology and process** – Hardware, software (internet, GPS connectivity), and process-related (scoping, tagging) issues were observed on some projects.

These challenges are not unique to the materials tracking and locating solutions, and they indicate the need for careful planning that comes with implementing any new technology.

Ontario Power Generation Case Study

The cases reviewed above concern materials tracking for materials in fabrication, transit, and installation. As a complement to these, the Ontario Power Generation (OPG) case study is focuses on visibility prior to ordering materials.

Project Details

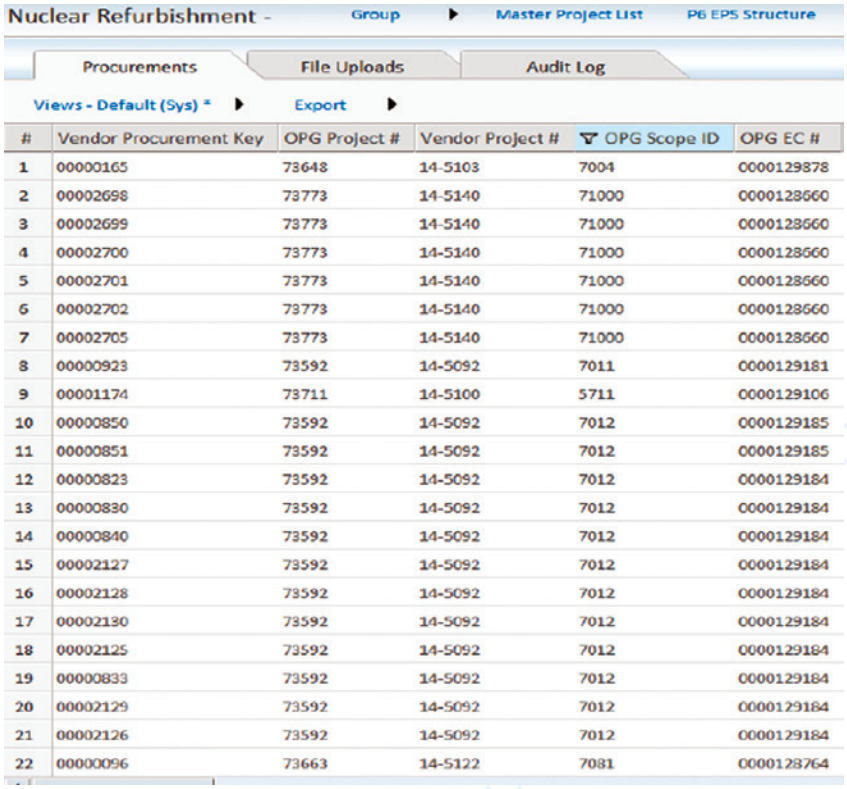
OPG's Darlington nuclear generating station has been producing about 20% of Ontario's electricity since the early 1990s. At the time of this project, the four-unit facility is undergoing a mid-life refurbishment. The scope of the project consists of the replacement of feeder pipes, end fittings, pressure tubes, and calandria tubes due to the aging concern of the pipes. The cost of replacing the pipes and conducting the balance of plant activity of the four units is estimated at $12.8 billion CD and the project is scheduled to last 10 years, though it may be possible to reduce the schedule by overlapping the last three units of the total four reactor units that need to be installed.

Problem

Previous project experience on nuclear refurbishment indicated that materials were one of if not the greatest risk. Part shortages, late deliveries, quality issues pushed the schedule and resulted in non-performance on projects. The owner had no visibility of procurement of parts through EPC vendors. As such, on this project a key was to drive procurement of parts early so to avoid shortages during the project.

Solution and Process

An integrated tool was developed to reduce risk and ensure a single process to manage supply chain activities. The data in the tool gives proactive information about procurement status to assure timely orders and, as necessary, inform decisions about corrective actions. The tool is used to track procurement for the refurbishment projects and was developed 2015. Figure 3.1 depicts a screen shot of the data management function of the tool. It has three tabs: procurement, file uploads, and audit log. The procurement tracking tool supports all the EPC firms that are working on multiple projects across the nuclear refurbishment portfolio. It required collaboration with the EPC firms to develop the process and required functionality. These are EPC firms who regularly work with OPG and have agreed to share information using the tool. As an administrator, the owner (OPG) has access to view all the EPC data. A particular EPC can view only its projects and associated orders.



#	Vendor Procurement Key	OPG Project #	Vendor Project #	OPG Scope ID	OPG EC #
1	00000165	73648	14-5103	7004	0000129878
2	00002698	73773	14-5140	71000	0000128660
3	00002699	73773	14-5140	71000	0000128660
4	00002700	73773	14-5140	71000	0000128660
5	00002701	73773	14-5140	71000	0000128660
6	00002702	73773	14-5140	71000	0000128660
7	00002705	73773	14-5140	71000	0000128660
8	00000923	73592	14-5092	7011	0000129181
9	00001174	73711	14-5100	5711	0000129106
10	00000850	73592	14-5092	7012	0000129185
11	00000851	73592	14-5092	7012	0000129185
12	00000823	73592	14-5092	7012	0000129184
13	00000830	73592	14-5092	7012	0000129184
14	00000840	73592	14-5092	7012	0000129184
15	00002127	73592	14-5092	7012	0000129184
16	00002128	73592	14-5092	7012	0000129184
17	00002130	73592	14-5092	7012	0000129184
18	00002125	73592	14-5092	7012	0000129184
19	00000833	73592	14-5092	7012	0000129184
20	00002129	73592	14-5092	7012	0000129184
21	00002126	73592	14-5092	7012	0000129184
22	00000096	73663	14-5122	7081	0000128764

Figure 3.1. OPG Procurement Tracking Tool

The procurement tab tracks information such as vendor, project number, vendor project number, catalog, supplier names, POs issued and accepted, vendor PO number, line item, and quantity. It also has the execution need date and it is tied to the P6 schedule. The P6 schedule (Level 2) is integrated with the tool and the tool updates simultaneously as the schedule gets updated. By linking procurement status to schedule, OPG is able to assess procurement status across several functions: projected requisition date, actual issues of purchase requisition, purchase order planned and actual, expected delivery date, actual delivery date, and quantities accepted.

The second tab, file upload, gives the option to upload a file from the desktop. For example, if an EPC is procuring 7000 items for OPG, it would be able to upload using a file in few minutes rather than manually type in the information for each item. OPG requires the EPC to upload the information once a week based on most recent information from buyers and material coordinators. However, the EPCs are uploading almost every day thereby providing daily updates.

Figure 3.2 depicts a screen shot from a graphical report based on status data in the tool. The procurement tool tracks items at the line level and hence tracks thousands of items. However, these items are grouped in project or program bundles. For example, Shutdown Layout (SDLU) is a bundle that has all the shutdown projects. In the figure, the metrics are evaluated and displayed at the bundle level (high level). However, the tool can also display at detailed level (lowest level) as desired, thereby providing rollup and drill down functionality. The information can also be filtered by EPC firm.

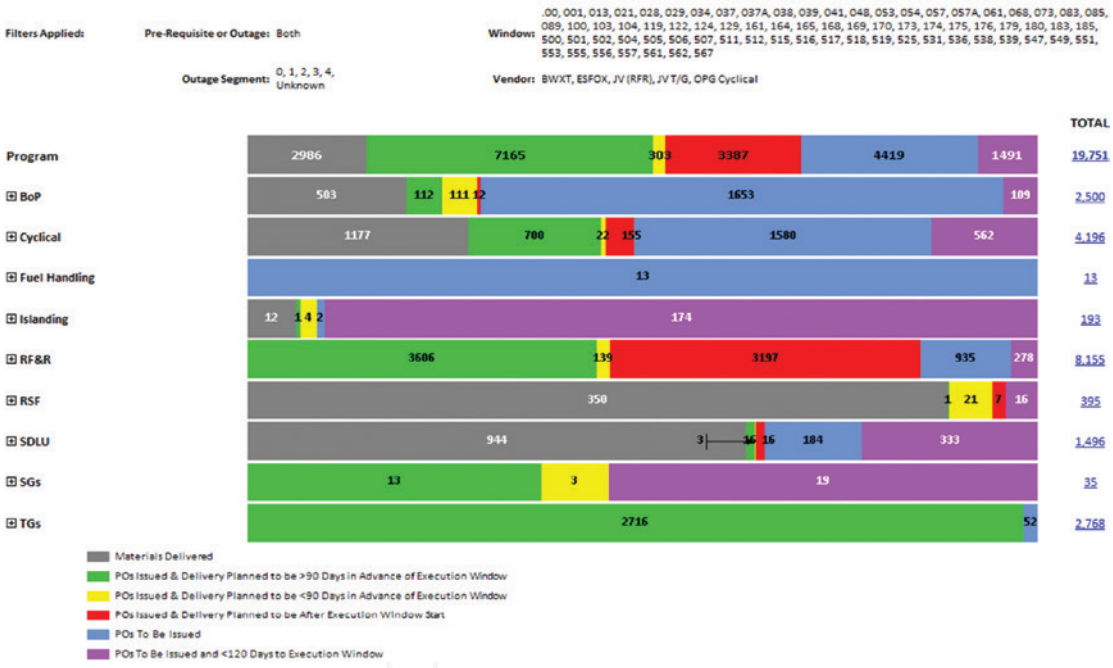


Figure 3.2. Procurement Status from Procurement Tracking Tool

In the tool, the indicators indicate the following delivery information about different classes of materials:

- POs have been issued and delivery is planned more than 90 days in advance of execution
- POs have been issued and delivery is planned less than 90 days in advance of execution
- POs have been issued and delivery is planned after execution window start
- POs to be issued
- POs to be issued less than 120 days before the execution window.

Status is based the execution date that is tied to the P6 schedule. As the tool is integrated with the schedule, updating occurs automatically with schedule changes. Status is depicted by color; in Figure 3.2, the red bars indicate POs that are issues, but delivery is expected after the execution start. These are areas for corrective action. Other colors show status against execution, and these colors can focus actions. Drilldown capabilities quickly allow users to examine specific items that are problematic.

Benefits

The team observed the following benefits with use of the tool:

- During meetings, when parts status is discussed, the owner is able to focus on the specific actions related to getting those parts and not be distracted by other issues.
- There is full alignment about the data and metrics. The focus is on the issue and not on the data, since the data has been taken care of.
- The tool is used by top management as well as the site team of owner and EPCs. The project manager and the president of the company have access to the same information.

Challenges

Currently, there are few challenges beyond the initial implementation. A limitation of the tool is that is limited to data from the EPC firms. Expansion into the first tier of suppliers has not been explored, but may be desirable to increase data availability and quality, particularly regarding status of deliveries after orders have been placed. At the moment, the EPC firms must use an approved supplier list for the nuclear site; as such, expansion may be possible due to the supplier relationship with the owner. At the moment, the tool is used exclusively on the nuclear refurbishment projects underway. There is a goal to take the tool across all types of projects.

3.2. Survey

To investigate visibility in the capital projects supply chain and assess its importance, the research team developed a survey to gain a better understanding of the current state of visibility by stakeholder, material type, and supply chain stage. The survey also included questions on benefits of improved visibility, barriers to visibility improvement, and overall importance of visibility for business transformation. The survey can be found in Appendix E. The survey was conducted in the Qualtrics tool (www.qualtrics.com) received 218 self-selected responses from CII and Fiatech members. Of the 218 respondents, all though not all respondents responded to every question. The number of respondents (n) to any given question is shown in the figure. Figure 3.3 shows the breakdown of 170 respondents who reported their stakeholder category. E&C, EPC, and EPCM were included in contractor category, EP and E&P were considered to fall in the Designer/Engineer category, and Fabricator and Software Solution Provider were incorporated into the Supplier/Vendor category. While the survey sample was not random, this figure demonstrates ample industry representation in all stakeholder categories. Although the contractor category accounted for a higher number of respondents than any other category, the imbalance likely reflects industry conditions in which contractors assume many supply chain management responsibilities.

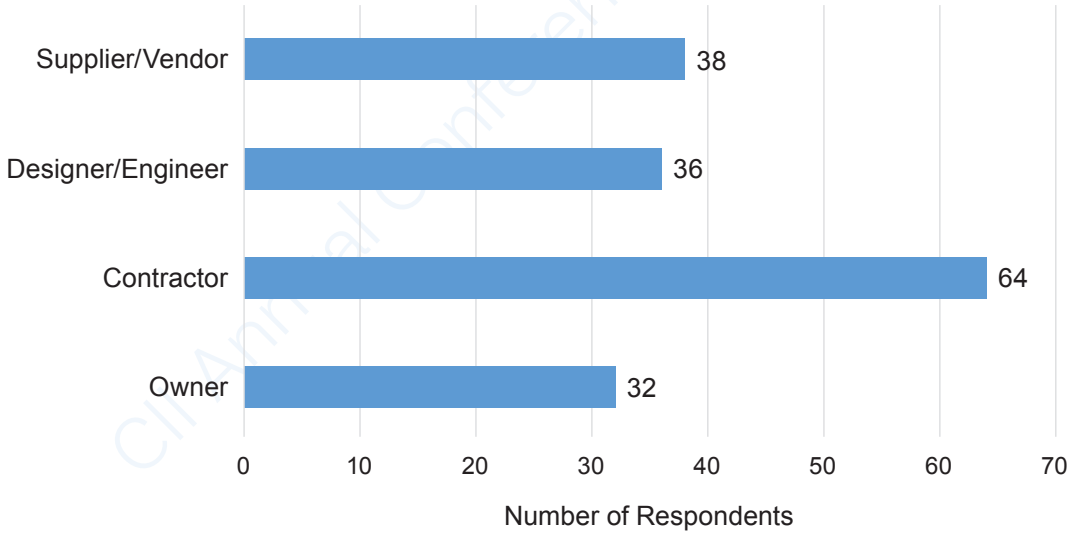


Figure 3.3. Number of Survey Respondents by Stakeholder Categories (n=170)

Respondents also reported other demographic information. The mean, minimum, and maximum years of experience were 21.6, 1, and 50, respectively. Figure 3.4 illustrates that respondents were predominantly from the industrial sector. (The “Other” category included respondents from manufacturing and government organizations.)

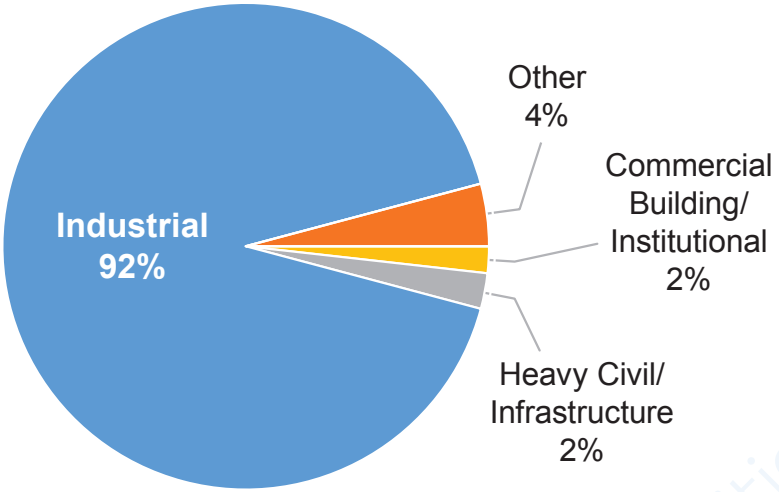


Figure 3.4. Construction Sector of Respondent's Business Unit (n=169)

Importance of High Supply Chain Visibility

Figure 3.5 demonstrates the importance of supply chain visibility. In response to the question "Would better supply chain visibility materially change how you do business?," almost two thirds of 176 respondents replied in the affirmative and another thirty-one percent selected maybe. Only five percent did not think supply chain visibility would change the way they do business. Incidentally, these results mirror a study conducted by the Aberdeen Group (Heaney 2013) in which 63 percent of respondents from 149 companies, mostly with global supply chains, indicated supply chain visibility as a "high priority for improvement" with an additional 28% rating it as a "medium priority."

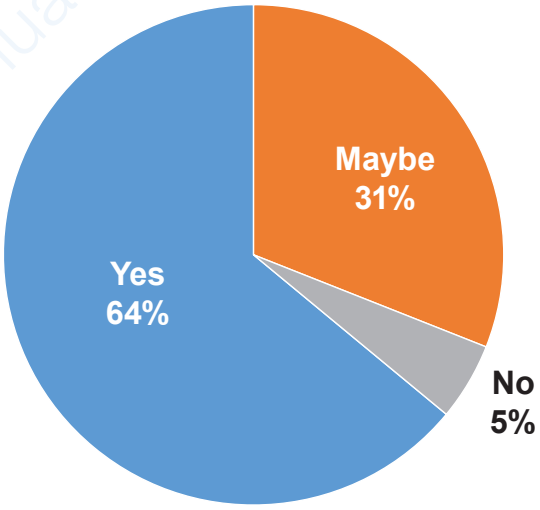


Figure 3.5. Responses to the Survey Question: "Would Better Supply Chain Visibility Materially Change How You Do Business?" (n=176)

Figure 3.6 breaks down the responses in Figure 3.5 by stakeholder. It is quite evident that the importance of visibility differ across stakeholders. In fact, a Chi-square technique for testing the differences between the stakeholder samples yields a statistically significant result with a p-value = 0.0381. Owners value visibility the most because ultimately they bear the costs and risks associated with the outcome of the project. (This is clearly the case for reimbursable work; however, in lump sum work the contractor will bear risk but this is expected to be priced into the work so the owner must pay for the risk.) In addition, they are downstream in the capital projects supply chain where visibility is most critical. Contractors also place a high importance on visibility because they are often the most responsible for project coordination and often bear the risk of timely project completion.

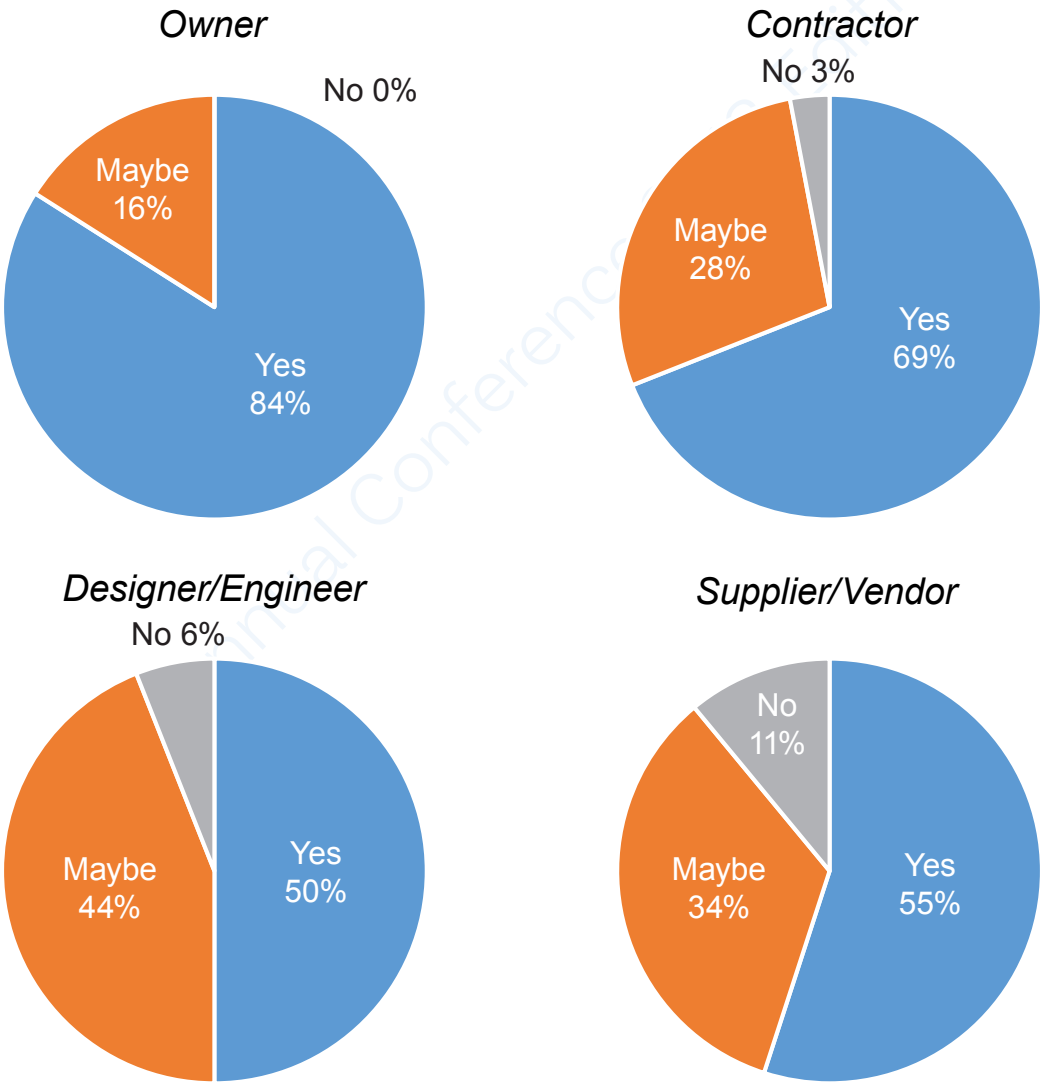


Figure 3.6. Responses to the Survey Question: "Would Better Supply Chain Visibility Materially Change How You Do Business?" by Stakeholder (n=176)

Level of Visibility in the Supply Chain

An important issue explored by the survey was how visibility compared across different stages of the capital projects supply chain from on-site to second tier suppliers. To assess the level of visibility by supply chain stage, the survey included the question, "What is your current level of visibility regarding location information about materials in the Supply Chain?" Table 3.3 contains the six possible responses. Since the primary aim was to determine the extent to which visibility was inadequate in the supply chain, the research team decided to consolidate the responses into two categories: "None," "Low," and "Fair" into a "Less Than Adequate "category and the rest of the response levels into an "Adequate or Better" category. The subsequent analysis will focus on these two categories.

Table 3.3: Possible Response Levels to the Survey Question: "What is Your Current Level of Visibility Regarding Location Information about Materials in the Supply Chain?"

Response Level	Description
None	(No additional description given)
Low	Access to little amount (<10%), frequently incorrect, and "updated only when asked" information
Fair	Access to fair amount (30%), sometimes incorrect, weekly to "once in three week" updated information
Adequate	Access to adequate amount (50%), occasionally incorrect, "daily updated" information
High	Access to good amount (70%), rarely incorrect, "hourly updated" information
Extremely High	Access to all (>90%), accurate, and real-time information

Figure 3.7 illustrates a few important findings. First, significant visibility inadequacy exists at all stages of the supply chain (all percentages are significantly different from zero with p-values < 0.05), even at the on-site workface. Second, relative to on-site visibility respondents believe there is an even greater problem with visibility at off-site at lay-down yards/warehouses, fabrication shops, tier-1 and -2 suppliers, kitting sites, ports and barge sites, and transporting/shipping. The results also suggest that the farther away from the on-site work-face, the greater the visibility inadequacy, with off-site (tier-2 suppliers) being ranked highest. A Chi-square test of the equality of the percentages in Figure 3.7 establishes that they are significantly different (p-value < 0.0001). Pairwise comparisons tests of offsite activities with the onsite activities bolster the strength of these findings. In particular, a greater percentage of respondents view visibility for off-site (tier-2 suppliers), port and barges, kitting sites,

and off-site (fabrication shops) as more inadequate than for on-site project lay-down yard/warehouse and on-site (work-face) (all p-values < 0.005). In addition, more respondents view off-site (tier-1 supplier) and off-site project lay-down yard/warehouse visibility as more inadequate than for on-site (workface) (both p-values < 0.05). Lastly, the inadequacy percentage associated off-site (tier-2 suppliers) is significantly greater than that associated with transportation/shipping (p-value = 0.0017).

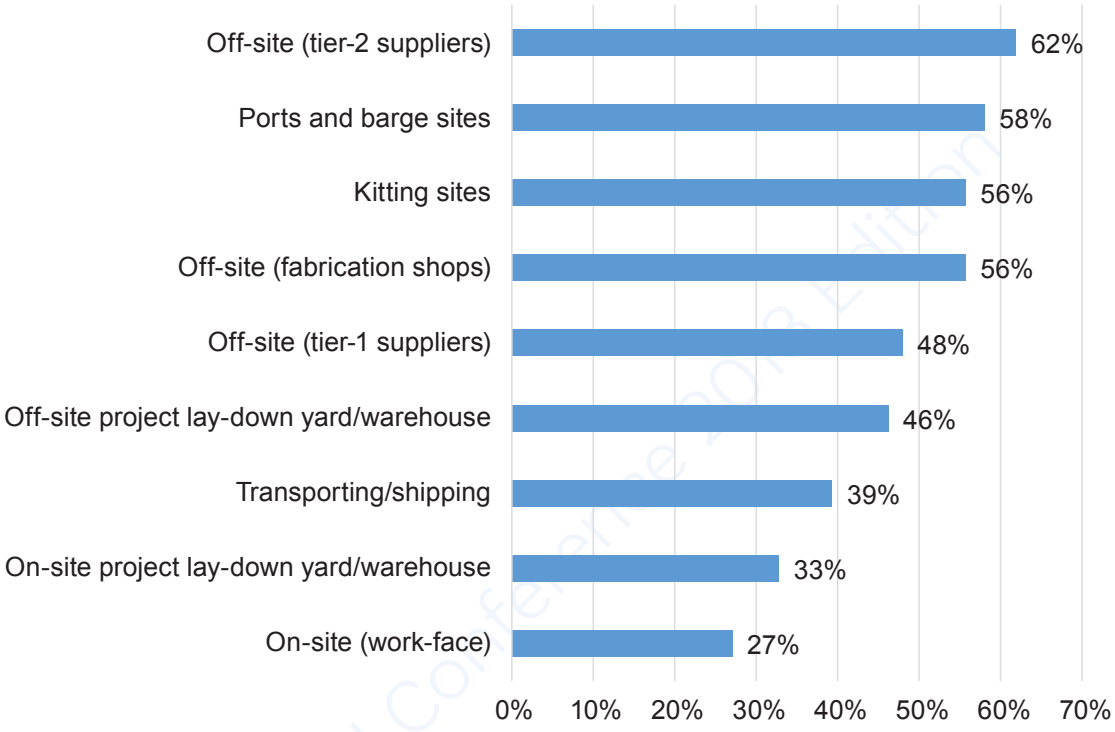


Figure 3.7. Percentage of All Stakeholders Rating Visibility as Less than Adequate by Supply Chain Stage (n=170)

While it was not possible to establish statistical differences when the results in Figure 3.7 were broken out by stakeholder due to smaller sample sizes, the data do suggest some interesting patterns. Relative to other stakeholders, suppliers tend to have the most adequate visibility into off-site (fabrication shops, tier-1 suppliers, tier-2 suppliers), offsite project lay-down yard/warehouse, and transporting/shipping. The opposite is true for owners and designers/engineers. One possible explanation for this finding is that since some suppliers also work with other sectors (e.g., manufacturing), they have attained higher levels of supply chain maturity. Owners and suppliers report less visibility into onsite project lay-down yard/warehouse and on-site (work-face) than do contractors and designers. This result probably reflects the fact that contractors tend to take the primary responsibility for on-site operations. All the stakeholders tend to consistently rate visibility kitting sites and ports and barge sites as less than

adequate. Lack of visibility at ports and barge sites may be related to international shipments that face uncertainty in customs clearance. Furthermore, since third-party logistics providers often handle materials through ports and kitting facilities, visibility at these supply chain stages can be lost to other stakeholders.

Benefits of Improved Visibility

Survey respondents were asked to rate the benefits of improved visibility on the following four point scale: no benefit, minor benefit, moderate benefit, and major benefit. To simplify the analysis, the research team combined the no and minor benefits rating into one category, and moderate and major benefits into another. Figure 3.8 shows that a majority of the respondents (75% or greater) selected all options provided as moderate to major benefits of improved visibility. These findings are statistically significant at the 5% level. The importance of all these benefits demonstrates the great potential for improved visibility in the capital projects supply chains.

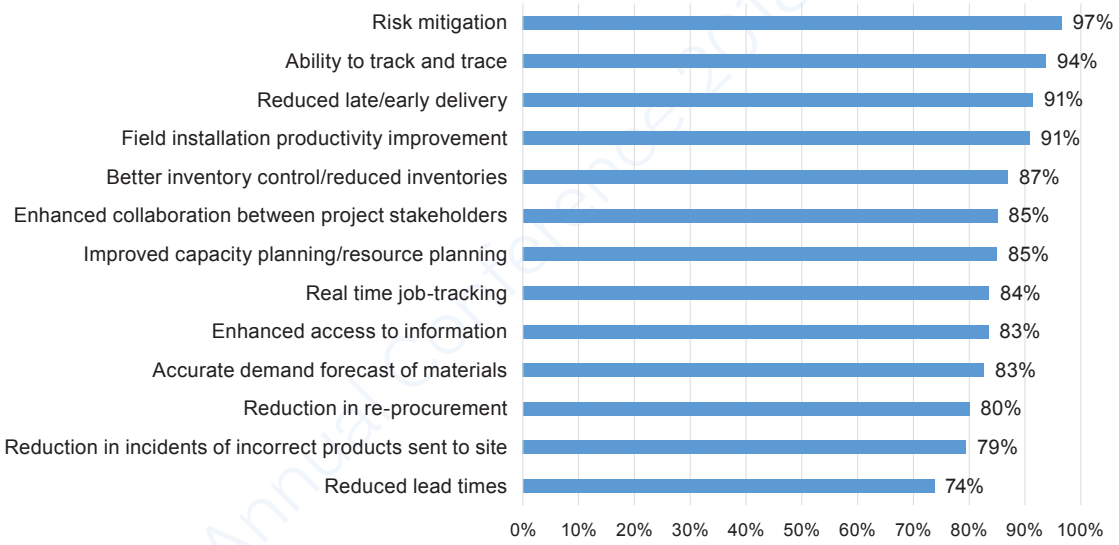


Figure 3.8. Percentage of Respondents Selecting Moderate to Major Benefits of Improved Visibility (All Stakeholders) (n=175)

The research team focused on the four top ranked benefits for all stakeholders (Figure 3.8) and by individual stakeholders (Figure 3.9). The industry members of the team suggested the following thoughts concerning these benefits: Considering all stakeholders, risk mitigation tops the list, which may be expected because the purpose of visibility is to provide better information reducing uncertainty and risk throughout the supply chain. Additionally, risk mitigation is a broad concept and in a sense, the other benefits refer to specific strategies to mitigate risk. The ability to track and trace is another great benefit of improved visibility because it can lead to better

project planning and execution. As the OPG case in Section 3.1 illustrates, visibility is highly valued because it enables stakeholders to monitor delivery status and manage exceptions in a timely fashion. This type of capability increases the likelihood of on-time deliveries crucial for successful materials management and project execution, which explains why survey respondents ranked reduced early/late delivery as one of the top benefits of improved visibility. Field installation productivity improvement likely ranks high because it has been shown under this initiative in the context of AWP that the craft waste less time waiting for deliverables.

When considered from an individual stakeholder perspective in Figure 3.9, risk mitigation and reduced early/late delivery appear at or near the top of everyone's benefits ranking. Contractors, designers/engineers, and suppliers see track and trace as one of the major benefits because they are often most responsible for materials movement in the supply chain. The research team found it surprising that contractors did not rank field installation productivity improvement higher. However, as it turns out, contractors still considered this an important benefit, ranking it sixth with a percentage of 89%. That better inventory control/reduced inventories shows up near the top of the benefits for contractors supports the main thesis of this project: the importance of materials management. Arguably, on most capital projects, contractors are the stakeholder most responsible for good materials management.

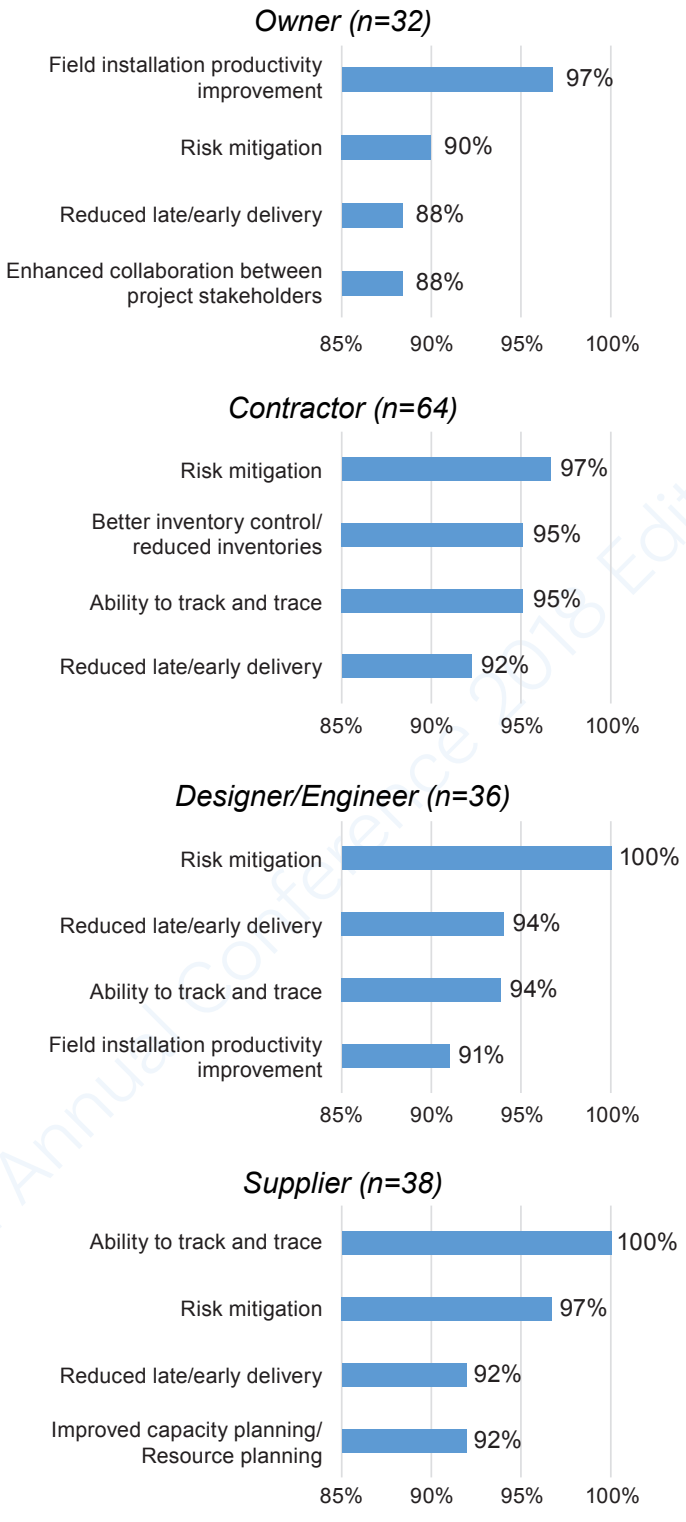


Figure 3.9. Top Four Benefits of Improved Visibility by Stakeholder

Barriers to Visibility Improvement

Survey respondents were asked to rate several criteria as whether or not they were barriers to visibility improvement using a four point scale (not a barrier, somewhat of a barrier, moderate barrier, and extreme barrier). Similar to the benefits of improved visibility, the research team decided to combine the first two ratings levels into one category and the remaining two into another in order to simplify the analysis. Figure 3.10 shows the percentage of respondents rating each criteria as moderate to extreme barriers to visibility improvement. All are considered significant barriers (significance level 0.05). Once again, the research team chose focus on the top four.

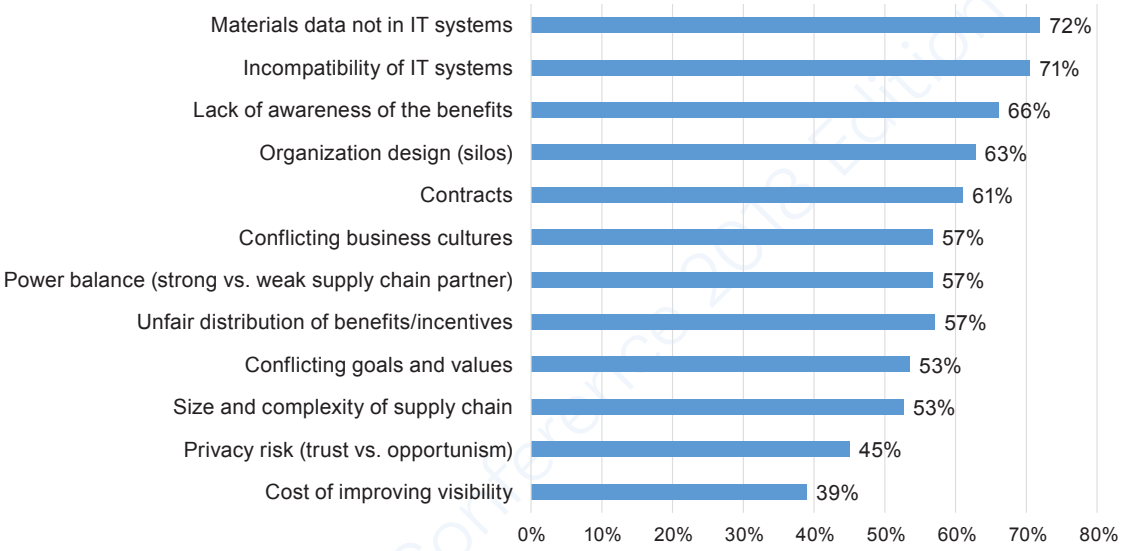


Figure 3.10. Percentage of Respondents Rating Each Criterion as Moderate to Extreme Barriers to Visibility Improvement (All Stakeholders) (n=171)

Topping the list are two IT systems issues. The first issue speaks to lack of availability of materials data in IT systems. The second has to do with fragmentation of IT systems.

Hence, even if quality data is available in one stakeholder's IT system, it may not be accessible to another. When these results were analyzed by the research team, several more issues emerged from the discussion:

- Initiatives such as AWP are making all stakeholders more aware of IT problems and it is crucial that they be addressed in order for such initiatives to move forward and be successful.
- Lack of industry standards IT systems (e.g., API standards) perpetuates fragmentation and incompatibility of IT systems.
- Misaligned incentives are a problem. Stakeholders must be properly incented to enter data accurately and adopt industry standards in order to share it electronically.
- Contracts should stipulate the needed visibility and capabilities to provide data updates.
- Limited connectivity is often a problem on many job sites, and not just at remote locations, making information sharing difficult.

Data are often locked behind firewalls. Cloud computing is enabling more secure connectivity, but has not been widely adopted due to some of the aforementioned issues.

The next two barriers in Figure 3.10, lack of awareness of benefits and organization design (silos), are more organizational than IT issues. However, stakeholders freely recognize that the two issues go hand-in-hand and are negatively reinforcing. IT fragmentation often results from organizational silos and on a large industrial construction project, many silos exist because there are so many stakeholders involved, especially when one includes the supply chain. Even within an individual stakeholder silos are common. When the data is broken down by stakeholder (see Figure 3.11), these findings are reinforced.

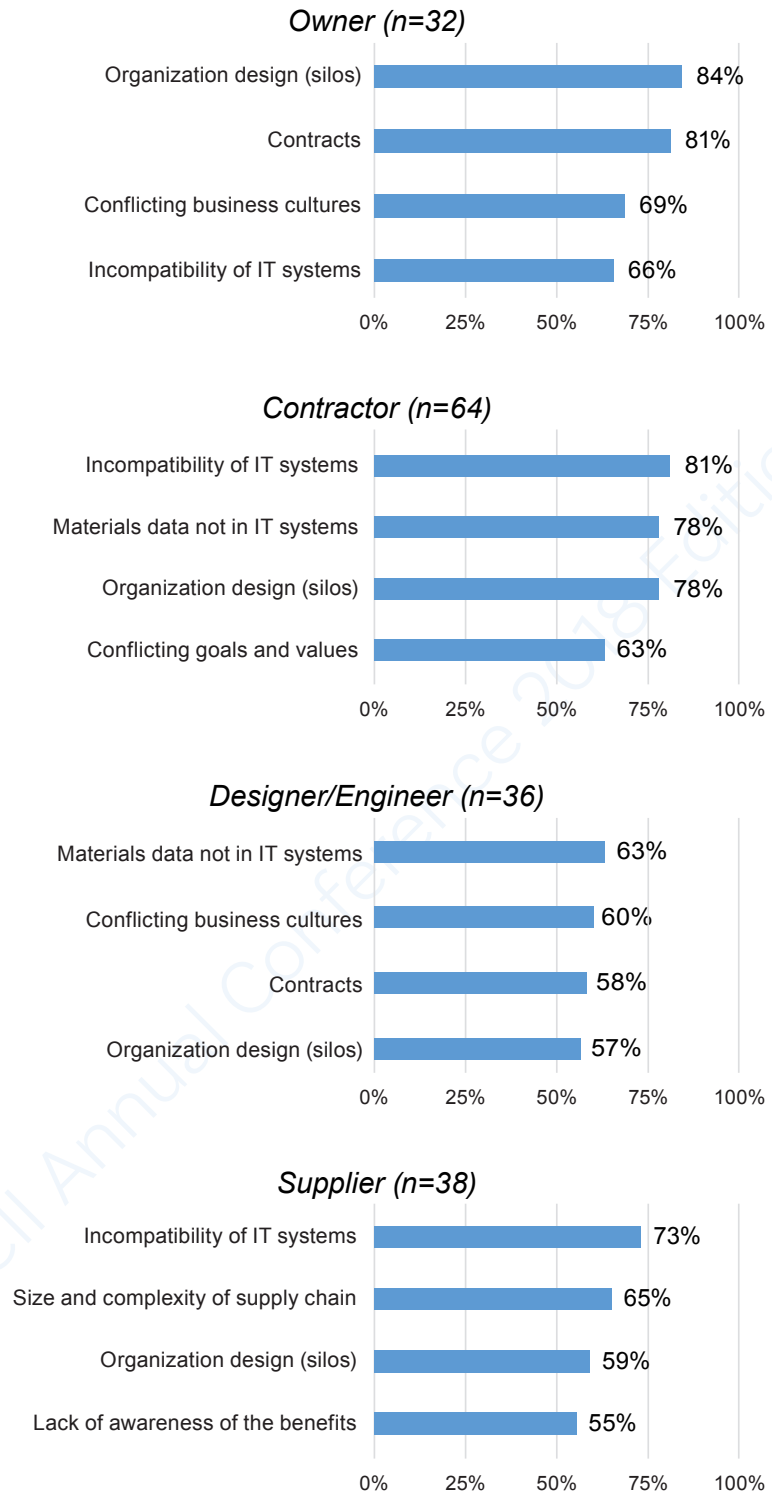


Figure 3.11. Top Four Barriers to Visibility Improvement by Stakeholder

Summary of Findings

Importance of Visibility

- Improved visibility is important to all stakeholders in the capital projects supply chain.
- Owners value visibility higher than the other stakeholders because they bear more risk and costs associated with the project outcomes.
- Contractors place a high value on visibility because they assume the primary responsibility of project coordination and bear the risk of timely project completion.

Level of the Supply Chain Visibility

- There exists significant visibility inadequacy at all stages of the supply chain.
- Off-site visibility is more inadequate than on-site visibility.
- The farther away from the on-site work-face, the greater the visibility inadequacy.

Benefits to Improved Visibility

- For the 13 benefits listed on the survey, all were considered as moderate to major benefits by at least 75% of respondents, indicating great potential gains for improved visibility.
- For all stakeholders, the top four benefits include:
    1. Risk mitigation
    2. Field installation productivity improvement
    3. Better inventory control/reduced inventories.
    4. Ability to track and trace.

Barriers to Improved Visibility

- Of the 12 barriers listed on the survey, all were considered as moderate to extreme barriers to visibility improvement, indicating that the industry faces significant challenges to improved visibility.
- The top two barriers were IT systems issues: lack of availability of materials data and systems incompatibility.
- The third and four barriers highest ranked barrier were organizational issues: lack of awareness of benefits and organization silos.
- There was consensus amongst the research team these IT systems and organization issues are negatively reinforcing (e.g., organizational silos make overcoming IT systems incompatibility much less likely).

Chapter 4
Visibility Definitions and Assessment

As described in Chapter 3, there is need to improve supply chain visibility. However, visibility on its own will not necessarily improve project performance. Consider again Tohamy's (2003) definition of visibility as "capturing and analyzing supply chain data that informs decisions, mitigates risk, and improves processes." Hence, visibility of information is a prerequisite to more opportune decisions, improved processes, and hence the ability to manage risk, especially in regards to materials management in the supply chain. This chapter presents detailed definitions of visibility that support key decisions, enablers that help firms make better use of visibility, and assessments of the level of implementation of both visibility and enablers.

4.1. Visibility Definitions

4.1.1. Supply Chain Activities Requiring Decisions

To effectively manage the construction supply chain for a project, it is imperative to fully understand the key supply chain activities that require decisions. Azambuja and O'Brien (2008) identified a spectrum of supply chain decisions from strategic to operational level that span from pre-project planning through construction. These supply chain decisions from literature were used as a starting point for the RT-344 study to document the key supply chain activities that require decisions. Initially, the team identified more than 30 key activities from opportunity framing through construction. Through a Delphi-style process, RT-344 reduced the number of key activities to 10 by combining like activities, focusing on the most important decisions, and limiting scope to tactical rather than strategic decisions at the front end of projects. The final list of key supply chain activities requiring decisions organized by phase timing – from detailed design through construction are represented in Table 4.1. While there are important activities in the early stages of the project that require visibility, the team chose to focus first on tactical and operational decisions during execution. If the industry can have better visibility during execution, these conditions should also support early decisions such as provisions for strategic sourcing.

Table 4.1. Key Supply Activities Support Decisions during Execution

Phases	Key Supply Chain Activities (KSCA) Requiring Decisions	KSCA Codes
Detailed Design	Detailing the construction sequence to get materials on site	DD1
	Reviewing long lead items and need dates	DD2
	Identify materials and equipment requiring higher visibility	DD3
	Establish supplier quality surveillance program and plan	DD4
	Use of catalog vs. custom	DD5
Procurement and Supply Chain	Order long lead time products	PSC1
	Supplier selection	PSC2
	Expediting decisions considering overall project picture	PSC3
	Order commodities and bulk	PSC4
Construction	Adjustment in schedule and/or supply chain to accommodate materials flow disruption	C1

4.1.2. Visibility Needed Items and Definitions

The RT-344 team identified the visibility needed within each of the 10 key supply chain activities requiring decisions (KSCA). As a starting point for deliberations, the team members contributed case studies around each of the activities to help identify specific examples and conditions that required visibility. Each of these case studies was reviewed in a team meeting and discussed by the team as a starting point for identifying desired visibility for each KSCA. As the case studies were specific instances, discussion was guided to generalize the case to more fully cover the challenges posed by lack of visibility and the desired visibility for each KSCA. The resulting list of visibility needed items was developed to include perspectives from owner, engineer, procurement, contractor, supplier, and technology provider perspectives (reflecting the full breadth of the team experience). After initial definition, the elements of the list were reviewed and refined multiple times by the research team in a Delphi-style manner. Also supporting team deliberations were reviews of information currently provided in EPC materials tracking tools and in current materials tracking software (contributed by the team members). To provide context for the definitions presented below, Table 4.2 gives an overview of the case studies, including context, specific problem (from lack of current visibility), desired visibility, and anticipated benefits. Each case is cross-indexed to the KSCA it relates to (often more than one).

Table 4.2. Case Studies Supporting Visibility Needed for Key Supply Activities Requiring Decisions

KSCA	Stakeholder Viewpoint	Project Context	Problem	Information Visibility Needed	Benefits
DD1, PSC1	EPC	Petrochemical project in the gulf coast of USA. Total procurement spend: over 200 million on national and international. Commodities included fabricated equipment, piping, structural steel (long lead items). Material needed to be ordered according to the project schedule agreed with the client and engineering progress.	Detailed construction schedule was not ready; initial required-on-site (ROS) dates were estimated to drive bids and purchase orders (POs) of long lead items; Additional labor costs in purchasing and expediting due to renegotiation with suppliers to revise POs as per schedule became more defined	Early information about construction work packages (CWP) and required-on-site (ROS) dates; transparency in production schedule and progress at suppliers	Prevent rework in purchase orders (POs); transparency during rescheduling minimizes expediting fees, improves cooperation, successful project delivery
DD2, PSC1, PSC3	Owner	Pipeline integrity program (6 inch to 36 inch pipeline and valves) for PSIG natural gas service. Valves were sourced internationally from a pre-qualified supplier list for pipes fabricated within USA. Fabrication and installation driven by outage dates.	Uncertainty in need dates due to non-defined outage dates; long lead times of valves challenged the fabrication of pipes and installation schedule; changed valve source (more expensive) for specific valves due to altered need dates; original valve supplier failed to deliver as promise	Defined outage information; detailed vendor reports; status and progress of valves in production, logistics and inventory	Valve order and deliveries could have been tied tightly to the pipe fabrication schedule; detailed vendor reports would find problems early and research cheaper alternate sourcing during production and logistics; reduced expediting impacts
DD3, DD4	EPC	Alloy fabrication for 970 MW combined cycle power plant in Canada. Supplier was a Canadian fabricator whose scope involved fabrication and supply of pipe spools post weld heat treatment as per specifications. Third party Inspection was required and no Chinese material was allowed	Large number of non-conformance identified at job-site due to material supply from China; schedule deviations and subsequent quality issues to make up schedule by supplier	Actual status and progress information from supplier including quality checks early on	Proactively catch problems and react; improved visibility on quality and schedule

Table 4.2. Case Studies Supporting Visibility Needed for Key Supply Activities Requiring Decisions *(continued)*

KSCA	Stakeholder Viewpoint	Project Context	Problem	Information Visibility Needed	Benefits
PSC2	EPC	Final commissioning phase for an offshore production unit. A change in schedule made a non-critical equipment into a critical package. The previous order was ineffective to meet the requirements. The project technical team did not consult with the supply chain team (which had the global visibility of pre-approved and pre-qualified vendors) and engaged with non-qualified supplier.	Non-compliance of vendor prequalification during selection process; engaged vendor without going through the process due to lack of internal visibility (silo problem) within the organization; non-involvement of supply chain, and accelerating order placement without pre-qualification	Internal collaboration and visibility: access to database of approved vendors; reach out to supply chain organization at the earliest possible; inform changes upfront by working in partnership; use list of approved vendors first.	Ensures material quality early on due to approved suppliers; internal visibility (within organization) supports external visibility
DD5	Supplier	Custom colored couplings required by client in Asia for 2400 MV power plant project for pulverized coal piping	Schedule constraints since piping system was installed and was waiting on couplings; style and quantity of couplings was shared by the EPC with supplier but not specialty paint information in spite of it specified by the owner; increased lead times due late information of custom work	Project and paint specs shared earlier from EPC's engineering team	Supplier would have shared realistic lead times that would have facilitated construction and more accurate pricing information; reduced expediting and expensive fabrication efforts

Table 4.2. Case Studies Supporting Visibility Needed for Key Supply Activities Requiring Decisions *(continued)*

KSCA	Stakeholder Viewpoint	Project Context	Problem	Information Visibility Needed	Benefits
PSC4	Supplier	Chemical Facility Expansion in Gulf Coast. European. European engineering and design firm with some procurement scope. U.S.-based contractor had a lump sum procurement and construction contract with client. Grating fasteners initially furnished had substantial installation time, high failure and rework rates. New grating fastener system was required and introduced to mitigate the problems.	Quantity breakdowns and corresponding required-on-site (ROS) dates of new fasteners were not provided to supplier. Material stock for the product in the US was zero when first PO and ROS date were finally provided to supplier. Quantity requested in the PO was the full order amount – 200,000 fasteners. Required special production runs and airfreight of product from Europe.	Updated construction schedule information – facilitates better material planning and deliveries; Improve level of detail and accuracy of component/material specifications – eliminate ambiguous descriptions of "commodity" items	Eliminates unnecessary production and expediting fees
C1	EPC	Time and material contract – approximately 200 million. Milestone dates with incentives and liquidating damages. Extremely schedule sensitive project since it was one phase of a multi-phase project. Material flow process was controlled by the owner. The decision was made by management to bulk issue all materials to the field to expedite the start of a project, meet schedule and early milestones	Bulk and inefficient distribution of materials to the field resulted in unaccountability and loss of materials. The productivity on the field was impacted as workers were spending time searching for materials.	Status, location, ownership of materials that were bulk issued	Reduces loss of materials and subsequent reprocurement; improves time on tools and project performance

The research team identified 79 visibility needed items across the 10 key supply chain activities requiring decisions (KSCA). A sample of these is shown in Table 4.3, which lists the 13 visibility needed items and respective definitions that support the KSCA DD1 "Detailing the construction sequence to get materials to site." Based on its review of the case studies and deliberations, the team contends that the visibility needed items represent the ideal set for effective support of decisions for DD1. This set represents the multiple perspectives of team members. It is understood that the desired information is generally not fully available today (this is explored in more detail below).

Table 4.3. Visibility Needed Items and Definitions for DD1

Detailed Design	
DD1. Detailing the construction sequence to get materials on site	
Ability to accelerate or decelerate	
Visibility Needed	**Definition**
Upstream constraints	Visibility into constraints in fabrication yard release dates, modular yard schedule, fabrication yard and tier-2 supplier contractual milestones.
Site constraints	Visibility into site constraints such as area release dates, logistics limitations, readiness reviews.
Construction sequence/ path of construction	General plan for construction sequencing, including work areas that supports plan for CWPs/IWPs.
Current supplier lead times for early planning	Current windows between ordering and delivery for components. May include subtiers of suppliers (upstream) for clarity.
Supplier ability to accelerate	Ability of a supplier to add capacity by adding shift or additional or alternate resources to production. This supplements availability based on production windows.
Design dependencies	Identification of dependencies and constraints to design; e.g., vendor data, owner inputs, internal dependencies between systems.
EWP completion	Status and progress of engineering deliverables associated with each EWP.
BOM quantities by CWP/IWP	Detailed bill of material quantities including systems and associated assemblies, components, sub-components, consumables as per CWP and IWP.
System interface points and boundaries	Clear delineation of boundary points in design (by CWP, EWP).
Regional resource availability	Understanding of regional availability (key constraints) of labor and limited resources (e.g., specialized equipment) that may limit resources available to the project
Materials handling costs off site	Costs for materials handling, including storage costs off-site.
Materials handling costs on-site	Costs for materials handling, including storage, re-handling, and maintenance costs on-site.
Logistics availability windows	Shipping window/logistics constraint; e.g., limited availability of heavy lift capability

The full set of visibility needed items and associated definitions for the 10 KSCA is given in Appendix A. Several of the visibility needed items are repeated across the 10 KSCA, however, there are 79 unique ones in total. To provide some context regarding what information is contained in the visibility needed items, the words comprising the items were put into a word cloud generator and displayed graphically. This is shown in Figure 4.1; size of words is roughly proportional to the frequency to which they appear in the list of visibility needed items.

Figure 4.1. Word Cloud of Visibility Needed Items

4.2. Enablers

For each of the key supply chain activities requiring decisions (KSCA), the research team future identified a set of enablers. Supporting Tohamy's (2003) definition as "*capturing and analyzing supply chain data that informs decision, mitigates risk, and improves processes,"* enablers represent organizational competencies to process and make use of the information provided by visibility into the supply chain. The enablers, 76 in all across the 10 KSCA, were developed together with the visibility needed items and represent the same collected perspectives and experience of the team and have been similarly reviewed against the sample cases and through iterative review and refinement by the research team.

Table 4.4 lists the enablers for KSCA DD1 “detailing the construction sequence to get materials to site.” It should be noted that enablers are multi-faceted, incorporating personnel, process, technology, resources and actions. It is also important to note that there is no one-to-one correspondence between the visibility enablers and visibility needed items; the visibility needed items were used as a reference to generate the visibility enablers. As with the visibility needed items, some enablers apply to multiple KSCA. The full list of enablers and associated definitions are provided in Appendix B. Figure 4.2 presents a word cloud of the words in the enablers where size of the word is roughly proportional to the frequency. Figure 4.2 provides some context and quick understanding of what is included in the enablers.

Figure 4.2. Word Cloud of Enablers

4.3 Assessment

4.3.1. Visibility Needed Ratings

To better understand the current state of visibility in the industry, the research team scored each of the 79 visibility needed items for ease of access, accuracy and trustworthiness of the data, and importance. From the survey results in chapter 3, it is broadly understood that visibility is lacking in the industry, particularly into the supply chain. However, there is not a detailed understanding of where visibility is lacking. Rating the 79 visibility items provides such a detailed assessment. Table 4.5 shows the three ratings categories along with scoring levels and definitions.

Table 4.4. Visibility Enablers and Definitions for DD1

Detailed Design	
DD1. Detailing the construction sequence to get materials on site	
Ability to accelerate or decelerate	
Visibility Enabler	**Definition**
Qualified supplier and specialty contractor list	Prequalified supplier and specialty contractor list, grouped by component type or trade/discipline, based on firms' past delivery and quality performance, which can be used for supplier selection and ordering process. Includes suppliers with framework agreements.
Material responsibility matrix	Clearly defined ownership of material processes through a detailed, project-specific Material Responsibility Matrix (MRM). A process to review and update the MRM over the life of the project is recommended. The MRM should be aligned with the AWP implementation on the project.
Risk register	A detailed and dynamic description of significant project risks that is continuously assessed in terms of likelihood and impact on project performance. Typically includes appropriate mitigation and strategies.
Complete specifications available to all stakeholders	Consistent, complete, and accurate project specifications (and catalog) that is available to all the stakeholders (e.g., owner, engineer, contractor, and supplier).
AWP process implementation	Clear definition of project scope in work packages (e.g., CWP, EWP, PWP, and IWP) to facilitate supply chain processes.
Detailed understanding of the scope and sequence (agreement/buy-in by all stakeholders)	Clearly defined project scope (including sequence) agreed by all stakeholders. Implemented through clear planning and definition of project (e.g., AWP planning processes). Detailed definition of scope and sequence in project contracts (and RFPs) is recommended.
Early technical and commercial requirements to/from supplier	Communication of special requirements (e.g., national sourcing requirements, special QA/QC, specific materials, and MTR) with the supplier and receiving lead time and cost information based on the requirements. May include submittal information, particularly around dimensional information.
Early involvement/ onboarding of suppliers for alignment and interdependency identification and planning	Have a process for increasing supplier engagement early in the project; may be part of alignment and/or AWP procedures. Focus on bi-directional communication (i.e., consult/partner with suppliers). Early identification of interdependencies is a significant goal of early involvement/on-boarding.
Information specification in contracts	Contractual definition of desired information and its format to facilitate sharing of supplier design information into project information systems (design tools).
Data exchange specification and process	Process and definitions for standardized supplier data exchange (i.e., materials handling and design data).
Contractual requirements for suppliers to describe composition of shipments	Include contractual requirements for suppliers to identify the what, and how of shipments to facilitate materials tracking and management. Particularly important for ship loose, multiple parts per shipment, and pre-engineered systems.

Table 4.5. Visibility Rating Categories and Levels

Ease of Access	Score
No access or very limited access	1
Considerable effort to access	2
Limited effort to access	3
No effort to access; automated	4

Accuracy/Trustworthiness	Score
Consistently unreliable	1
Incorrect information is common	2
Incorrect information is uncommon	3
Consistently reliable	4

Importance	Score
Low	1
Medium	2
High	3
Critical	4

Following the scoring shown in Table 4.5, each team member scored each of the visibility needed items from the perspective of their firm/business unit. The team also recruited other CII member companies they were familiar with to also assess their visibility. Including team members, there were 23 firms that undertook the assessment. Assessment generally took at least an hour to go through. The numbers include a mix of owners, EPC, and supplier firms. There were no observable trends in the numbers that showed differences between firm types. Appendix C provides the average score for each of the visibility ratings. Simply, the average importance scores indicate that all almost all the visibility needed items score highly on importance, although there is some variability in assessment.

Most interesting in terms of ratings is the range of ratings for ease of access and accuracy/trustworthiness of the information. The range of responses is shown in Figure 4.3; this figure does not focus on a single item but rather shows the range for each of the 79 visibility needed items (each row represents one item). This figure is color coded where responses from 1 to 4 are shown for ease of access in blue where a darker shade indicates more responses and white indicates no responses. Similarly, the red coloring shows responses to accuracy and trustworthiness from 1 to 4 per Table 4.5.

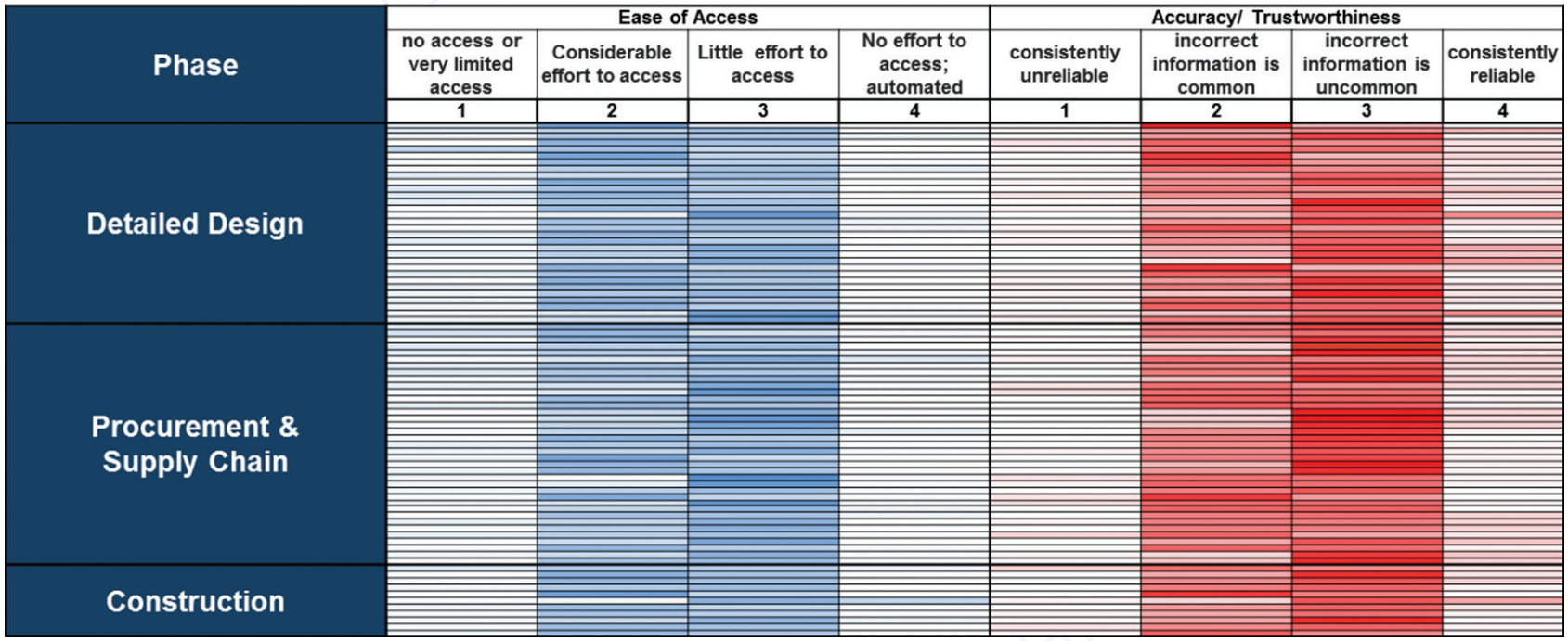


Figure 4.3. Range of responses to ease of access and accuracy/trustworthiness for visibility needed items. (Color intensity shows relative number of responses; darker represents more responses)

As can be seen from the figure, most responses cluster in the middle, showing the industry has some level of access and some level of trust in the visibility information it has. There is very little information that requires no effort to access and relatively little information that the industry deems to be consistently reliable. Across almost every row, there is a significant portion of respondents that indicate that the information takes considerable effort to access (or no access). Similarly, there are a significant portion of respondents that indicate that incorrect information is uncommon or consistently unreliable. In total, this poses a considerable challenge for projects – the picture adds detail to the contention that visibility is a challenge on projects. Beyond focusing on any specific item, the research team indicated that Figure 4.3 provides a clear indication of the considerable challenges to visibility and the opportunity that improvements may provide.

4.3.2. Enabler Ratings

The identified visibility enablers for the 10 key supply chain activities requiring decisions were also assessed from detailed design through construction. Each enabler was assessed in terms of the ability to impact project (on a ten-point scale) and how often the enabler was competently executed on project (on a six-point scale). Table 4.6 shows the two rating categories along with the respective levels and definitions. The gradations for scoring shown by the team are somewhat finer than that chosen for the visibility assessments. This is largely due to the chosen metrics. In particular, the frequency of competent execution follows the path set by CII IR310-2 (2015), where six degrees of gradation was found to meaningfully describe rated of occurrence. Similarly, a 10 point scale across five indicator numbers provides useful distinction between medium and high impact enablers.

Table 4.6. Visibility Enabler Categories and Levels

Ability to Impact Project	Score
Limited importance/limited impact	1
Moderate importance/moderate impact	4
Important/high impact	6
Very important/major impact	8
Critical/extremely high impact	10

Frequency of Competent Execution	Score
Very rare	1
Rare	2
Occasional	3
Frequent	4
Common	5
Very Common	6

Appendix D provides averages for the scores on each of the 76 enablers. As with the visibility needed items, in general the enablers are seen as having at least moderate impact and most are important. Frequency of competent execution scores are most telling, with an average score between 3 and 4 or between occasional and frequent. This spread is shown in Figure 4.4, which depicts the range for each of the 76 enablers (each row represents one item). This figure is color coded where responses from 1 to 6 are shown for frequency of competent execution in purple where a darker shade indicates more responses and white indicates no responses.

As can be seen in Figure 4.4, while most of the responses range between 3 and 4 there is a wide spread across almost all rows. There are significant number of responses in categories 2 (rare) and 5 (common) and a few in 1 (very rare) and 6 (very common). This speaks to considerable opportunities for the industry to improve. As enablers are considered to be capabilities to make better use of supply chain visibility, a reasonable conclusion is that the industry is not well positioned to make use of better visibility on projects. It is unclear if the limited execution of enablers restricts visibility or if limited visibility restricts investment in enablers. Perhaps there is self-reinforcing lack of investment in by the industry. In any case, the challenge remains for the industry to improve and jointly invest in both visibility needed items and enablers to process the information.

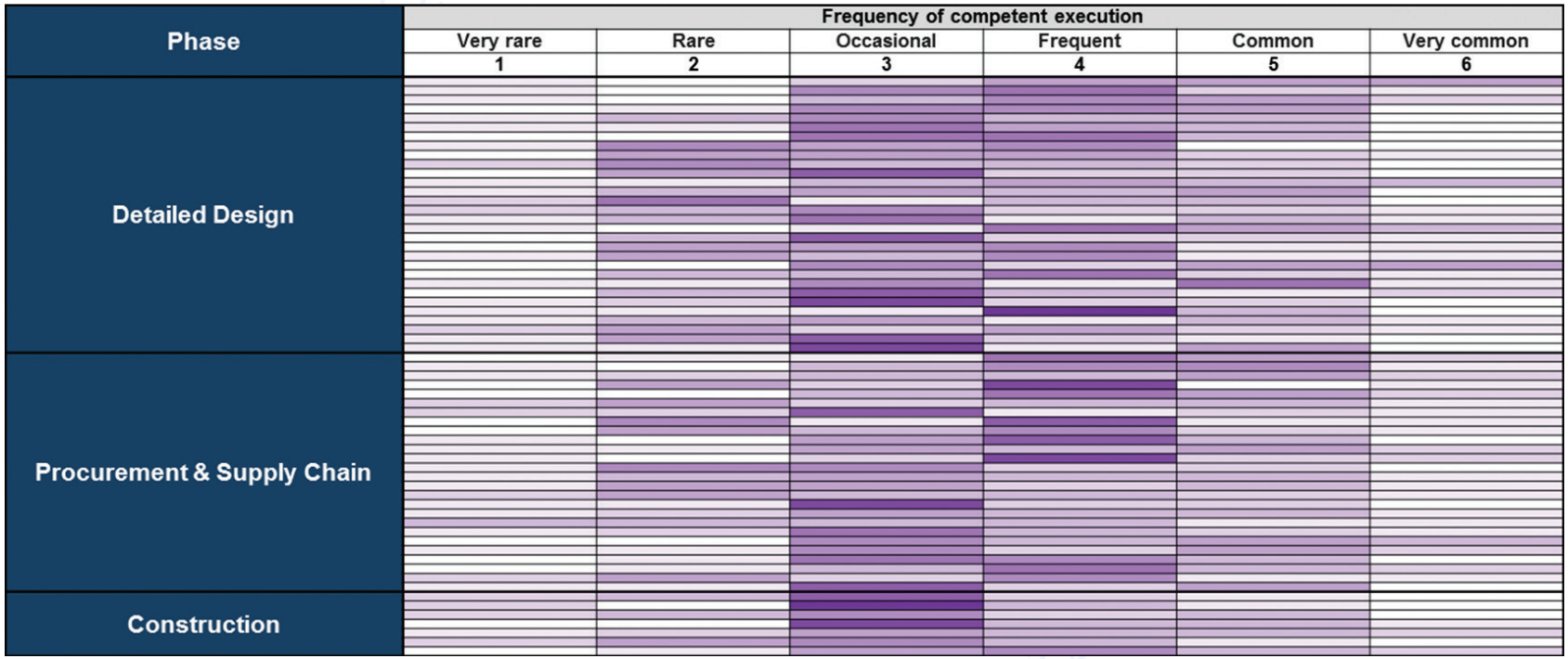


Figure 4.4. Range of responses to frequency of competent execution of enablers.
(Color intensity shows relative number of responses; darker represents more responses)

4.3.3. Self-Assessment

Appendix E provides score sheets by which firms can score their visibility and enabler performance. These can be compared to the averages given in Appendices C and D. There are two specific benefits of completing the assessment. First, self-assessment provides a basis for useful discussion inside the firm about actual visibility and capabilities at a detailed level. Firms that have undertaken the assessment – particularly those that performed the assessment with a group – found the exercise to stimulate useful discussion and self-reflection. Most firms rarely have the opportunity to undertake such an assessment at the level of detail of this report. Second, as we have found, firms have very different capabilities. The spread of responses in Figures 4.3 and 4.4 indicate this. As such, starting points for improvement vary considerably across the firm. A self-assessment exercise provides a useful starting point from which a firm can catalog and prioritize actions for improvement.

4.4 Summary

The research findings in this chapter provide a substantive basis by which the industry and individual firms and projects can improve. Principal findings are:

- 79 visibility needed items across 10 key supply chain activities (KSCA) requiring decisions have been defined. These define the desired state of visibility supporting this 10 KSCA. As such, there are multiple uses for these definitions, not least as a basis for contractual requisition of information. These definitions will also support development of information systems to provide information.
- 76 enablers have been identified across the 10 KSCA. These represent organizational capabilities to process information from supply chain visibility. Implementation of enablers is key to achieving benefits from improved visibility.
- Assessment of visibility needed items and enablers shows general poor performance by the industry, as well as wide spread of competencies. Low abilities to access or trust information and low frequency of competent execution of enablers supports observations of low visibility and its impacts on productivity and performance. These assessments speak to a call to action for the industry to improve.
- Self-assessment using the lists of visibility needed items and enablers provides a path forward by which firms can understand their needs and prioritize actions to improve.

Chapter 5
Conclusions and Recommendations

Conclusions

The principal conclusion of this volume is that the industry needs to take action to enhance supply chain visibility to improve materials management on project. Survey data and detailed assessment indicate that the industry is performing poorly on multiple measures. Ease of access to information and accuracy of received information shows considerable variance across 79 visibility needed items, with overall averages lower than desirable. Similarly, the industry shows both a wide spread and low average performance across 76 enablers that support good decision making. These detailed assessments add further detail to survey results where a preponderance of respondents indicate that current visibility is less than adequate, particularly as one moves further away from site.

While lack of visibility is costly, the research also supports a number of benefits that stem from improved visibility – risk mitigation and productivity improvement among others. Case studies demonstrate that improvement to visibility is achievable; these cases also demonstrate that tangible benefits stem from such improvements. While the research does indicate that there are barriers to implementation, the case research and definitions and assessments provided in this volume provide a path forward for firms and projects seeking to improve.

Recommendations

An overall recommendation is that firms and projects immediately undertake steps to improve visibility on their projects. The definitions and assessments reviewed in Chapter 4 and presented in detail in the Appendices in particular provide detailed starting points for improvement. Overall, the research team recommends a three pronged approach to improve:

1. Self-assess
2. Close the gaps
3. Align with other efforts

These steps are discussed in greater detail below.

As visibility is multifaceted and firms have different needs and competencies, it is difficult to provide a singular recommendation for improvement. As such, a first step is necessarily to self-assess. The score sheet attached as Appendix E provides firms a basic tool from which they can score their performance on visibility needed items as well as enablers. This assessment may best be performed by a group to foster useful discussion. Score results can be compared with the averages presented in Appendices C and D to help firms gauge their performance against others. However, relative scores are not as important as using the assessment as basis for identifying and prioritizing areas for improvement. The detailed assessments can help a firm or project understand needs and make a path forward.

Based on assessment and priorities for improvement, the second recommendation is to take action to close the gaps. The detailed definitions of visibility needed items (Appendix A), and to a lesser extent, the definitions of enablers (Appendix B), provide a basis from which to improve. Definitions of visibility needed items are intended to serve multiple stakeholders and can be a common and shared basis for implementation by the industry. Definitions can support contractual requests for information as well as implementation in software tools. Similarly, the set of visibility items for each of the key supply chains reviewed in Chapter 4 provides a goal or definition of ideal visibility. As such, the sets of definitions are starting points for focused improvement. Enablers supporting key decisions also are indicative of what organizational competencies can best support and utilize improved visibility. As such, they are an important complement to the visibility definitions and support meaningful improvements.

Advances to visibility likely not trivial. The barriers reviewed in Chapter 3 indicate several issues – technological, organizational, and contractual. It is likely detailed assessment by firms may find some easy opportunities such as making more consistent use of existing systems and adding clarity to requests for information. However, sustained advances will take effort. As such, the third recommendation is that firms should link efforts in improving visibility with other efforts. Productivity improvement initiatives such as Advanced Work Packaging or related efforts like Lean by necessity require materials visibility. As such, the findings of this volume directly support these efforts. Other efforts in Front End Planning can benefit from the definitions and enablers defined in this volume, and efforts to improve digitalization – efforts in automation and integration – can directly be supported by the visibility definitions. More broadly, the research team anecdotally recognizes a trend in the industry to add capabilities in procurement to foster true supply chain professionals for the industry. The definitions and findings of this research support such efforts to grow responsible and proactive project personnel.

Improving visibility to better support the smooth and timely flow of materials to site represents one of the largest opportunities the industry has to improve. Better involvement of the supply chain on projects is perhaps the most understudied area of the industry and more investment here will pay dividends for projects and ultimately business outcomes. Visibility is a key enabler supporting supply chain transformation in other industries. Ninety-five (95) percent of respondents to the team's survey indicated that improvement supply chain visibility could make a material change to their business. Thus, the team closes with a call-to-action – there is no better time than now to start or enhance visibility improvement efforts.

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Appendix A

Visibility Needed and Definitions

Detailed Design	
DD1. Detailing the construction sequence to get materials on site	
Ability to accelerate or decelerate	
Visibility Needed	**Definition**
Upstream constraints	Visibility into constraints in fabrication yard release dates, modular yard schedule, fabrication yard and tier-2 supplier contractual milestones.
Site constraints	Visibility into site constraints such as area release dates, logistics limitations, readiness reviews.
Construction sequence/ path of construction	General plan for construction sequencing, including work areas that supports plan for CWPs/IWPs.
Current supplier lead times for early planning	Current windows between ordering and delivery for components. May include subtiers of suppliers (upstream) for clarity.
Supplier ability to accelerate	Ability of a supplier to add capacity by adding shift or additional or alternate resources to production. This supplements availability based on production windows.
Design dependencies	Identification of dependencies and constraints to design; e.g., vendor data, owner inputs, internal dependencies between systems.
EWP completion	Status and progress of engineering deliverables associated with each EWP.
BOM quantities by CWP/IWP	Detailed bill of material quantities including systems and associated assemblies, components, sub-components, consumables as per CWP and IWP.
System interface points and boundaries	Clear delineation of boundary points in design (by CWP, EWP).
Regional resource availability	Understanding of regional availability (key constraints) of labor and limited resources (e.g., specialized equipment) that may limit resources available to the project
Materials handling costs off site	Costs for materials handling, including storage costs off-site.
Materials handling costs on-site	Costs for materials handling, including storage, re-handling, and maintenance costs on-site.
Logistics availability windows	Shipping window/logistics constraint; e.g., limited availability of heavy lift capability

Detailed Design	
DD2. Reviewing long lead items and need dates	
Determination of engineering sequence' compatibility with the schedule	
Visibility Needed	**Definition**
Identification of critical components/long lead time items	Critical/long-lead components are identified through a review of RAS dates against PO lead times; such components require early ordering to assure timely delivery to site. Critical/long-lead components set key procurement dates and may require extra monitoring. Critical components may also be identified as ones that have specific site installation dates that come from contractual milestones or key constraints such as limited availability of installation/expertise providers, weather windows, etc.
Installation/expertise provider availability	Dates that specialized expertise (such as installation or technical monitoring) are available. Such availability may limit construction windows.
Design deliverable dates by EWP	The agreed completion dates of engineering work packages.
Current supplier lead times for early planning	Current windows between ordering and delivery for components. May include subtiers of suppliers (upstream) for clarity.
Design dependencies	Identification of dependencies and constraints to design; e.g., vendor data, owner inputs, internal dependencies between systems.

Detailed Design	
DD3. Identify materials and equipment requiring higher visibility	
Depends on the nature of the material, confidence in delivery, and the position of the item in the critical path	
Visibility Needed	**Definition**
Identification of critical components/long lead time items	Critical/long-lead components are identified through a review of RAS dates against PO lead times; such components require early ordering to assure timely delivery to site. Critical/long-lead components set key procurement dates and may require extra monitoring. Critical components may also be identified as ones that have specific site installation dates that come from contractual milestones or key constraints such as limited availability of installation/expertise providers, weather windows, etc.
Installation/expertise provider availability	Dates that specialized expertise (such as installation or technical monitoring) are available. Such availability may limit construction windows.
Materials that require special handling	Identity of materials that require special handling, such as over-size/ overweight, and or that have special storage, special resources for delivery (e.g., cranes), or related requirements.
Shipment quantities and composition – engineered materials, major equipment packages	Visibility into shipment quantities as well as how suppliers (and sub suppliers) ship materials (e.g., major equipment, packages of equipment including sub-assemblies and parts. Also, loose components, spares, etc. of equipment that is designed and shipped by vendor)
Design dependencies	Identification of dependencies and constraints to design; e.g., vendor data, owner inputs, internal dependencies between systems.
Supplier delivery performance history for ordering	History of on-time performance for suppliers, used to screen qualified suppliers before placing an order.
Supplier quality history for ordering	History of quality (ability to meet specifications) for suppliers, used to screen qualified suppliers before placing an order.

Detailed Design	
DD4. Establish supplier quality surveillance program and plan	
Visibility Needed	**Definition**
Detailed supplier progress reports	The report provides status and progress of the delivery including forecasted delivery dates, constraints, associated document status, engineering issues, fabrication, sub-supplier progress, packing/ transport, look ahead activities and inspections planned, status of deviations (technical queries, supplier variation requests, NCRs), pictures, schedule, quality performance that affects schedule.
Supplier production schedule	Supplier production plan and schedule(including incremental milestones) – constraints; cutting, welding, fit up, inspection etc.
Supplier delivery performance history for ordering	History of on-time performance for suppliers, used to screen qualified suppliers before placing an order.

Detailed Design	
DD5. Use of catalog vs. custom	
Visibility Needed	**Definition**
Visibility into what is catalog (standard)	Ability to identify catalog components that should be readily available compared to custom
Current supplier lead times for early planning	Current windows between ordering and delivery for components. May include subtiers of suppliers (upstream) for clarity.

Procurement and Supply Chain	
PSC1. Order long lead time products	
Visibility Needed	**Definition**
Logistics availability windows	Shipping window/logistics constraint; e.g., limited availability of heavy lift capability
Supplier production windows for ordering/ monitoring	Availability of production capacity time (low volume production – window has start/end dates) for the supplier to produce components.
Current utilization for ordering/monitoring	Availability of production capacity as a fraction of utilization for volume production.
Supplier capabilities for ordering	Key limitations of supplier's ability to produce, such as limits to size of parts they can handle (e.g., ability to galvanize)
Work breakdown structure including EWP, PWP, CWP, IWP	The division of the project into different work packages, including engineering, procurement, and construction.
ROS/RAS dates	The date needed on site (or laydown/receiving yard) derived from the construction needed date plus the time needed to receive materials (including testing or assurance). May include a buffer between construction need date and date need to deliver to site (e.g., regulations may require a buffer).

Procurement and Supply Chain	
PSC2. Supplier selection	
(Selection of subcontracts and suppliers, including location consideration)	
Visibility Needed	**Definition**
Logistics availability windows	Shipping window/logistics constraint; e.g., limited availability of heavy lift capability
Supplier production windows for ordering/ monitoring	Availability of production capacity time (low volume production – window has start/end dates) for the supplier to produce components.
Current utilization for ordering/monitoring	Availability of production capacity as a fraction of utilization for volume production.
Construction need date	Installation date for materials on-site based on current information (path of construction, schedule level of detail)
ROS/RAS dates	The date needed on site (or laydown/receiving yard) derived from the construction needed date plus the time needed to receive materials (including testing or assurance). May include a buffer between construction need date and date need to deliver to site (e.g., regulations may require a buffer).

Procurement and Supply Chain	
PSC3. Expediting decisions considering overall project picture	
Visibility Needed	**Definition**
Logistics availability windows	Shipping window/logistics constraint; e.g., limited availability of heavy lift capability
Construction need date	Installation date for materials on-site based on current information (Path of construction, schedule level of detail)
ROS/RAS dates	The date needed on site (or laydown/receiving yard) derived from the construction needed date plus the time needed to receive materials (including testing or assurance). May include a buffer between construction need date and date need to deliver to site (e.g., regulations may require a buffer).
Detailed supplier progress reports	The report provides status and progress of the delivery including forecasted delivery dates, constraints, associated document status, engineering issues, fabrication, sub-supplier progress, packing/ transport, look ahead activities and inspections planned, status of deviations (technical queries, supplier variation requests, NCRs), pictures, schedule, quality performance that affects schedule.
Supplier production schedule	Supplier production plan and schedule(including incremental milestones) – constraints; cutting, welding, fit up, inspection etc.
Materials that require special handling	Identity of materials that require special handling, such as over-size/ overweight, and or that have special storage, special resources for delivery (e.g., cranes), or related requirements.
Engineering progress	Visibility into status of engineering deliverables (% complete) and engineering milestones.
EWP Completion	Status and progress of engineering deliverables associated with each EWP.
Supplier capabilities for ordering	Key limitations of supplier's ability to produce, such as limits to size of parts they can handle (e.g., ability to galvanize).
Supplier quality history for ordering	History of quality (ability to meet specifications) for suppliers, used to screen qualified suppliers before placing an order.
Supplier delivery performance history for ordering	History of on-time performance for suppliers, used to screen qualified suppliers before placing an order.
Materials handling costs off site	Costs for materials handling, including storage costs off-site.
Materials handling costs on-site	Costs for materials handling, including storage, re-handling, and maintenance costs on-site.
Finished goods inventory levels off-site	Stock level of finished goods off-site at various supply chain nodes.
Finished goods inventory levels on-site	Stock level of finished goods on the construction site.
Logistics constraints	Identification of constraints and availability on delivery of certain items (especially oversize/overweight). Example is regulations that limit delivery times or number per day.

Procurement and Supply Chain	
PSC4. Order commodities and bulk	
(supplier data, inspection, and acceptance plan – do bulks match specifications)	
Visibility Needed	**Definition**
Supply chain's ability to hold inventory/delay deliveries	Ability of a supplier or logistics yard to hold additional inventory or delay deliveries. This can relieve the pressure on site storage needs. May be contractual.
IWP readiness including design, materials, labor, equipment etc.	Visibility into IWP readiness to assure they are constraint free.
Visibility into status and location of materials in the supply chain (at the tag level)	Near real time transactional information (status and location) of physical material as it traverses through different supply chain nodes as appropriately planned for the project (includes desired upstream nodes such as fabrication shops and second-tier suppliers; specification of extent of tracking is part of project planning). Must include BOM information for parent-child assemblies. Tags may need to be assigned upon receiving if common parts are shipped in quantity (bag and tag).
Warehouse space availability over time	Allocation of warehouse space over time according to planned deliveries and installation of materials on-site that releases space.
Client milestones	The dates set by client for key activities (e.g., start dates, turnaround windows, and required completions).
Availability level/options of alternate supply source for common parts/ consumables	Alternate supply of common parts that can substitute for parts that are ordered (i.e., can substitute an alternate if the desired is unavailable)
EWP Completion	Status and progress of engineering deliverables associated with each EWP.
Line breaks/piece marks	Visibility into fabricator information that affects design such as breaks between spools, piece marks for structural steel
BOM quantities by CWP/ IWP	Detailed bill of material quantities including systems and associated assemblies, components, sub-components, consumables as per CWP and IWP.
Site resource availability	Resources assigned/available to site over time (resource pool)
Resource allocation	Allocation of resources to specific activities (over time) by IWP/detailed schedule

Procurement and Supply Chain	
PSC4. Order commodities and bulk	
(supplier data, inspection, and acceptance plan – do bulks match specifications)	
Visibility Needed	**Definition**
Supply chain's ability to hold inventory/delay deliveries	Ability of a supplier or logistics yard to hold additional inventory or delay deliveries. This can relieve the pressure on site storage needs. May be contractual.
IWP readiness including design, materials, labor, equipment etc.	Visibility into IWP readiness to assure they are constraint free.
Visibility into status and location of materials in the supply chain (at the tag level)	Near real time transactional information (status and location) of physical material as it traverses through different supply chain nodes as appropriately planned for the project (includes desired upstream nodes such as fabrication shops and second-tier suppliers; specification of extent of tracking is part of project planning). Must include BOM information for parent-child assemblies. Tags may need to be assigned upon receiving if common parts are shipped in quantity (bag and tag).
Warehouse space availability over time	Allocation of warehouse space over time according to planned deliveries and installation of materials on-site that releases space.
Client milestones	The dates set by client for key activities (e.g., start dates, turnaround windows, and required completions).
Availability level/options of alternate supply source for common parts/ consumables	Alternate supply of common parts that can substitute for parts that are ordered (i.e., can substitute an alternate if the desired is unavailable)
EWP Completion	Status and progress of engineering deliverables associated with each EWP.
Line breaks/piece marks	Visibility into fabricator information that affects design such as breaks between spools, piece marks for structural steel
BOM quantities by CWP/ IWP	Detailed bill of material quantities including systems and associated assemblies, components, sub-components, consumables as per CWP and IWP.
Site resource availability	Resources assigned/available to site over time (resource pool)
Resource allocation	Allocation of resources to specific activities (over time) by IWP/detailed schedule

Construction	
C. Adjustment in schedule and/or supply chain to accommodate materials flow disruption	
Visibility Needed	**Definition**
Supply chain's ability to hold inventory/delay deliveries	Ability of a supplier or logistics yard to hold additional inventory or delay deliveries. This can relieve the pressure on site storage needs. May be contractual.
IWP readiness including design, materials, labor, equipment etc.	Visibility into IWP readiness to assure they are constraint free.
Visibility into status and location of materials in the supply chain (at the tag level)	Near real time transactional information (status and location) of physical material as it traverses through different supply chain nodes as appropriately planned for the project (includes desired upstream nodes such as fabrication shops and second-tier suppliers; specification of extent of tracking is part of project planning). Must include BOM information for parent-child assemblies. Tags may need to be assigned upon receiving if common parts are shipped in quantity (bag and tag).
Warehouse space availability over time	Allocation of warehouse space over time according to planned deliveries and installation of materials on-site that releases space.
Client milestones	The dates set by client for key activities (e.g., start dates, turnaround windows, and required completions).
Availability level/options of alternate supply source for common parts/ consumables	Alternate supply of common parts that can substitute for parts that are ordered (i.e., can substitute an alternate if the desired is unavailable)
EWP Completion	Status and progress of engineering deliverables associated with each EWP.
Line breaks/piece marks	Visibility into fabricator information that affects design such as breaks between spools, piece marks for structural steel
BOM quantities by CWP/ IWP	Detailed bill of material quantities including systems and associated assemblies, components, sub-components, consumables as per CWP and IWP.
Site resource availability	Resources assigned/available to site over time (resource pool)
Resource allocation	Allocation of resources to specific activities (over time) by IWP/detailed schedule

Appendix B

Visibility Enablers and Definitions

Detailed Design	
DD1. Detailing the construction sequence to get materials on site	
Ability to accelerate or decelerate	
Visibility Enabler	**Definition**
Qualified supplier and specialty contractor list	Prequalified supplier and specialty contractor list, grouped by component type or trade/discipline, based on firms' past delivery and quality performance, which can be used for supplier selection and ordering process. Includes suppliers with framework agreements.
Material responsibility matrix	Clearly defined ownership of material processes through a detailed, project-specific Material Responsibility Matrix (MRM). A process to review and update the MRM over the life of the project is recommended. The MRM should be aligned with the AWP implementation on the project.
Risk register	A detailed and dynamic description of significant project risks that is continuously assessed in terms of likelihood and impact on project performance. Typically includes appropriate mitigation and strategies.
Complete specifications available to all stakeholders	Consistent, complete, and accurate project specifications (and catalog) that is available to all the stakeholders (e.g., owner, engineer, contractor, and supplier).
AWP process implementation	Clear definition of project scope in work packages (e.g., CWP, EWP, PWP, and IWP) to facilitate supply chain processes.
Detailed understanding of the scope and sequence (agreement/buy-in by all stakeholders)	Clearly defined project scope (including sequence) agreed by all stakeholders. Implemented through clear planning and definition of project (e.g., AWP planning processes). Detailed definition of scope and sequence in project contracts (and RFPs) is recommended.
Early technical and commercial requirements to/from supplier	Communication of special requirements (e.g., national sourcing requirements, special QA/QC, specific materials, and MTR) with the supplier and receiving lead time and cost information based on the requirements. May include submittal information, particularly around dimensional information.
Early involvement/ onboarding of suppliers for alignment and interdependency identification and planning	Have a process for increasing supplier engagement early in the project; may be part of alignment and/or AWP procedures. Focus on bi-directional communication (i.e., consult/partner with suppliers). Early identification of interdependencies is a significant goal of early involvement/on-boarding.
Information specification in contracts	Contractual definition of desired information and its format to facilitate sharing of supplier design information into project information systems (design tools).
Data exchange specification and process	Process and definitions for standardized supplier data exchange (i.e., materials handling and design data).
Contractual requirements for suppliers to describe composition of shipments	Include contractual requirements for suppliers to identify the what, and how of shipments to facilitate materials tracking and management. Particularly important for ship loose, multiple parts per shipment, and pre-engineered systems.

Detailed Design	
DD2. Reviewing long lead items and need dates	
Determination of engineering sequence' compatibility with the schedule	
Visibility Enabler	**Definition**
Integrated project schedule	A combined schedule including design, procurement, and execution activities along with key milestone dates. The schedule follows the path of construction and includes the sequence for CWP execution. The integrated project schedule reflects input from all stakeholders (including suppliers) to ensure feasibility and buy-in. The integrated project schedule is updated over time.
Information specification in contracts	Contractual definition of desired information and its format to facilitate sharing of supplier design information into project information systems (design tools).
Data exchange specification and process	Process and definitions for standardized supplier data exchange (i.e., materials handling and design data).
Early involvement/ onboarding of suppliers for alignment and interdependency identification and planning	Have a process for increasing supplier engagement early in the project; may be part of alignment and/or AWP procedures. Focus on bi-directional communication (i.e., consult/partner with suppliers). Early identification of interdependencies is a significant goal of early involvement/on-boarding.
Market intelligence report	Intelligence report reflecting current and forecasted market capacity availability to facilitate preordering and long lead item planning (including reservation of production windows) and to identify potential project risks.

Detailed Design	
DD3. Identify materials and equipment requiring higher visibility	
Depends on the nature of the material, confidence in delivery, and position of the item in the critical path	
Visibility Enabler	**Definition**
Detailed inspection and testing plans	Project specific supplier/component level plans to assure quality. Degree of observation will vary by component and supplier certification/past performance. May include concerns about counterfeit or prohibited materials. Development of the plan helps identify materials needing higher visibility.
Risk register	A detailed and dynamic description of significant project risks that is continuously assessed in terms of likelihood and impact on project performance. Typically includes appropriate mitigation and strategies.
Cost estimate	Cost estimate using validated prices (where possible) to augment historical data. Use of a cost estimate to identify "big ticket" items that merit additional visibility.
Special handling/logistic needs	Identity of materials requiring special handling or logistics that may require higher visibility.

Detailed Design	
DD4. Establish supplier quality surveillance program and plan	
Visibility Enabler	**Definition**
Level or Degree of Inspection	Assigning critically ratings based on the type of equipment that needs to be inspected (i.e., static equipment, rotating equipment, electrical and instrumentation).
Review of Supplier's Quality Plan and Inspection Test Package	Confirm alignment to the order expectations.
Establishment of Proper witness Points	Ensuring the number of witness Points are in aligned to meeting the committed delivery dates.
Dissemination of quality performance issues to detailed planners	Timely dissemination of Non-conformance reports and similar production issues to appropriate stakeholders (including detailed planners such as workface planners/senior site supervision) to incorporate known issues into site sequence and inspections plans.
Information specification in contracts	Contractual definition of desired information and its format to facilitate sharing of supplier design information into project information systems (design tools).
Data exchange specification and process	Process and definitions for standardized supplier data exchange (i.e., materials handling and design data).
Establishment of a Non-Conformance Report (NCR) Process	Ensuring all non-conformance issues are captured and the proper stakeholders are identified. Have a defined supplier inspection process that enables capturing supply issues at the fabricator as opposed to on site when it may be too late to correct.

Detailed Design	
DD5. Use of catalog vs. custom	
Visibility Enabler	**Definition**
Framework Agreements	A corporate or business level, time-bound collaborative agreement between parties – typically contractor and supplier or owner and supplier (may be tri-party) – that mutually benefits the parties through improved trust, early involvement, speed of procurement, and cost efficiency. May be called master service agreements, strategic alliances, commodity contracts, or master pricing agreements. Framework agreements may apply to both customized and standardized products and services.
Integrated Project Schedule	A combined schedule including design, procurement, and execution activities along with key milestone dates. The schedule follows the path of construction and includes the sequence for CWP execution. The integrated project schedule reflects input from all stakeholders (including suppliers) to ensure feasibility and buy-in. The integrated project schedule is updated over time.
Operating and maintenance strategy	Clear communication (such as in RFP) of owner O&M strategy and specifications that affects component and part selection. Preference for standardized components my affect choice of catalog vs. custom, although preferences must be balanced against capital efficiency and operating production priorities.
Schedule impact and cost estimating capabilities supporting alternates selection	Ability to estimate full costs and benefit of alternates, including direct costs, O&M costs, schedule implications, and associated benefits (such as earlier project completion/earlier revenue generation).
Recognition of regulatory and compliance constraints.	Clear guidance on regulatory and compliance constraints, including country of origin restrictions that may affect choice of alternates.
Life cycle costing analysis	From an owner's perspective, ability to quantify costs and benefits during construction, O&M, and disposition to support a complete life-cycle cost evaluation of alternates.
Data exchange specification and process	Process and definitions for standardized supplier data exchange (i.e., materials handling and design data).
Early involvement/ onboarding of suppliers for alignment and interdependency identification and planning	Have a process for increasing supplier engagement early in the project; may be part of alignment and/or AWP procedures. Focus on bi-directional communication (i.e., consult/partner with suppliers). Early identification of interdependencies is a significant goal of early involvement/on-boarding.
Standardization strategy	Plan for choosing standards for materials and equipment on the project. Will include owners O&M preferences; availability of framework agreements and supplier capabilities may be additional considerations for capital efficiency. Standardization strategies may include limitations on equipment/material variety (designed for one and used for many; e.g.: compressed air valves used in many locations of a plant.).

Procurement and Supply Chain	
PSC1. Order long lead time products	
Visibility Enabler	**Definition**
Qualified supplier and specialty contractor list	Prequalified supplier and specialty contractor list, grouped by component type or trade/discipline, based on firms' past delivery and quality performance, which can be used for supplier selection and ordering process. Includes suppliers with framework agreements.
Aligned stakeholder team	Aligning the stakeholder team in identifying longer lead items so that those items receive higher visibility in the ordering process
Integrated project schedule	A combined schedule including design, procurement, and execution activities along with key milestone dates. The schedule follows the path of construction and includes the sequence for CWP execution. The integrated project schedule reflects input from all stakeholders (including suppliers) to ensure feasibility and buy-in. The integrated project schedule is updated over time.
Project controls capabilities around forecasting supply chain impacts	Organizational capabilities to understand supply chain lead times/shop loads and calculate the impact of design completion dates and other schedule changes on key milestones (e.g., ability to forecast ripple effects of design changes/delays on meeting delivery dates.) Forecasts may include cost and quality impacts as well as schedule.
Established material requisition and expediting process	A mature requisition and expediting process including communication across internal silos; includes a material responsibility matrix (MRM).
Data exchange specification and process	Process and definitions for standardized supplier data exchange (i.e., materials handling and design data).
Early involvement/ onboarding of suppliers for alignment and interdependency identification and planning	Have a process for increasing supplier engagement early in the project; may be part of alignment and/or AWP procedures. Focus on bi-directional communication (i.e., consult/partner with suppliers). Early identification of interdependencies is a significant goal of early involvement/on-boarding.
Capability to track design status of long-lead items	Ability to track the readiness to purchase long-lead items by monitoring design status, such as EWP completion.

Procurement and Supply Chain	
PSC2. Supplier selection	
Selection of subcontracts and suppliers, including location consideration	
Visibility Enabler	**Definition**
Established BOM and PWPs	Capability to establish a BOM and PWPs early in procurement phase to consider sourcing needs and implications for supplier location and capacities. Early BOM may stem from technical standards/reference plant designs in design tools.
Material responsibility matrix	Clearly defined ownership of material processes through a detailed, project-specific Material Responsibility Matrix (MRM). A process to review and update the MRM over the life of the project is recommended. The MRM should be aligned with the AWP implementation on the project.
Integrated Project schedule	A combined schedule including design, procurement, and execution activities along with key milestone dates. The schedule follows the path of construction and includes the sequence for CWP execution. The integrated project schedule reflects input from all stakeholders (including suppliers) to ensure feasibility and buy-in. The integrated project schedule is updated over time.
Qualified supplier and specialty contractor list	Prequalified supplier and specialty contractor list, grouped by component type or trade/discipline, based on firms' past delivery and quality performance, which can be used for supplier selection and ordering process. Includes suppliers with framework agreements.
Market intelligence report	Intelligence report reflecting current and forecasted market capacity availability to facilitate preordering and long lead item planning (including reservation of production windows) and to identify potential project risks.
Data exchange specification and process	Process and definitions for standardized supplier data exchange (i.e., materials handling and design data).
Early involvement/ onboarding of suppliers for alignment and interdependency identification and planning	Have a process for increasing supplier engagement early in the project; may be part of alignment and/or AWP procedures. Focus on bi-directional communication (i.e., consult/partner with suppliers). Early identification of interdependencies is a significant goal of early involvement/on-boarding.
Supplier shop visibility	Knowledge of visibility provided by suppliers into their shop loads and related production/shipping capabilities, commitments, and constraints. Suppliers that can readily supply such visibility may be preferred over those that can/will not share such information.

Procurement and Supply Chain	
PSC3. Expediting decisions considering overall project picture	
Visibility Enabler	**Definition**
Material track and trace tool providing status and location information material tracker/ traceability reporting and look ahead reporting	Traceability tool that enables knowing the source, location, and status of materials through their entire lifecycle from fabrication through installation
Risk register	A detailed and dynamic description of significant project risks that is continuously assessed in terms of likelihood and impact on project performance. Typically includes appropriate mitigation and strategies.
Integrated project schedule and critical path management dates and CWP quantities	A combined schedule including design, procurement, and execution activities along with key milestone dates. The schedule follows the path of construction and includes the sequence for CWP execution. The integrated project schedule reflects input from all stakeholders (including suppliers) to ensure feasibility and buy-in. The integrated project schedule is updated over time.
Supplier level contingency plan	Planning in response to potential problems identified in supplier progress reports, problems due to late orders, etc. Understanding of supplier internal contingency plans (such as availability of alternate shops). Plan for alternate sourcing or site sequencing should primary supplier be unable to meet schedule/quality requirements.
Procedures for schedule communication with supplier	Consistent and frequent dialogue regarding site need dates and supplier production status since site progress and sequence can change. Implies adjusting need dates in partnership with supplier. Site need dates may reflect acceleration or deceleration of schedule. Discussion must be aligned with contractual terms and conditions.
Information specification in contracts	Contractual definition of desired information and its format to facilitate sharing of supplier design information into project information systems (design tools).
Data exchange specification and process	Process and definitions for standardized supplier data exchange (i.e., materials handling and design data).
Continuous supplier performance evaluation	Supplier evaluation over life of the order on a periodic basis (e.g., quarterly, monthly) to identify issues early on and prevent or mitigate quality, cost, or schedule issues.

Procurement and Supply Chain	
PSC4. Order commodities and bulk	
(supplier data, inspection, and acceptance plan – do bulks match specifications)	
Visibility Enabler	**Definition**
Look ahead reporting	Reporting capability (typically at the IWP level) that forecasts demand in the coming weeks (3 to 6 weeks) so as to rearrange sequencing if necessary and provide warnings so adjustments can be made in case of delays
Integrated site warehouse demand, delivery, and warehouse space capability	Capability to integrate the warehouse demand, delivery, and warehouse space and forecast space utilization over time. Assures bulk material storage capability matched delivery and demand schedule.
Project storage and logistic plan	A storage and logistic plan that accounts for projected demand and supply over project duration; ensures adequate laydown and warehouse storage and reduces material rehandling.
Established Material requisition and expediting process	A mature requisition and expediting process including communication across internal silos; includes a material responsibility matrix (MRM).
Integrated project schedule	A combined schedule including design, procurement, and execution activities along with key milestone dates. The schedule follows the path of construction and includes the sequence for CWP execution. The integrated project schedule reflects input from all stakeholders (including suppliers) to ensure feasibility and buy-in. The integrated project schedule is updated over time.
Standardized specifications and design packages	Established set of “for construction” owner/contractor design drawings and specifications utilizing standard materials
Qualified supplier and specialty contractor list	Prequalified supplier and specialty contractor list, grouped by component type or trade/discipline, based on firms’ past delivery and quality performance, which can be used for supplier selection and ordering process. Includes suppliers with framework agreements.
Data exchange specification and process	Process and definitions for standardized supplier data exchange (i.e., materials handling and design data).
Market intelligence report	Intelligence report reflecting current and forecasted market capacity availability to facilitate preordering and long lead item planning (including reservation of production windows) and to identify potential project risks.

Construction	
C. Adjustment in schedule and/or supply chain to accommodate materials flow disruption	
Visibility Enabler	**Definition**
Material track and trace tool providing status and location information material tracker/ traceability reporting and look ahead reporting	Traceability tool that enables knowing the source, location, and status of materials through their entire lifecycle from fabrication through installation
Recovery/ alternate sequence planning capability	Having personnel with the required capability to plan for acceleration, deceleration, or alternates due to loss, late materials, etc. The goal is to keep production on site to facilitate meeting milestone dates. Procedures, tools and systems support decision making with information and analysis (e.g., trial allocation to reflect materials availability for alternate sequence).
Ability/ tool to perform trial allocations	Match current and projected inventory to production at the IWP level to assure materials are available to support planned production.
Knowledge of market and labor constraints	Ability to forecast labor availability (and related constraints) in region to support acceleration/deceleration decisions; may support decisions to move work off-site if labor is not available or expensive.
Job-site inventory management	Capability to integrate the warehouse demand, delivery, and warehouse space and forecast space utilization over time. Assures bulk material storage capability matched delivery and demand schedule.
Data exchange specification and process	Process and definitions for standardized supplier data exchange (i.e., materials handling and design data).
Look ahead reporting	Reporting capability (typically at the IWP level) that forecasts demand in the coming weeks (3 to 6 weeks) so as to rearrange sequencing if necessary and provide warnings so adjustments can be made in case of delays

Appendix C

Average Scores for Each Visibility Rating

Detailed Design			
DD1. Detailing the construction sequence to get materials on site			
Ability to accelerate or decelerate			
Visibility Needed	**Average Ratings**		
	Ease of Access	**Accuracy/Trustworthiness**	**Importance**
Upstream Constraints	2.04	2.24	2.91
Site constraints	2.30	2.81	3.09
Construction sequence/ Path of construction	2.50	2.71	3.57
Current supplier lead times for early planning	2.43	2.43	3.13
Supplier ability to accelerate	1.96	2.59	2.18
Design dependencies	2.26	2.50	3.00
EWP Completion	2.41	2.52	3.04
BOM quantities by CWP/IWP	2.68	2.52	3.23
System interface points and boundaries	2.33	2.79	2.86
Regional resource availability	2.30	2.65	2.61
Materials handling costs off site	2.22	2.76	2.22
Materials handling costs on-site	2.13	2.57	2.39
Logistics availability windows	2.30	2.91	3.00

Detailed Design			
DD2. Reviewing long lead items and need dates			
Determination of engineering sequence' compatibility with the schedule			
Visibility Needed	**Average Ratings**		
	Ease of Access	**Accuracy/Trustworthiness**	**Importance**
Identification of critical components/long lead time items	2.87	3.18	3.83
Installation/expertise provider availability	2.57	2.77	2.61
Design deliverable dates by EWP	2.59	2.38	3.17
Current supplier lead times for early planning	2.57	2.64	3.17
Design dependencies	2.22	2.57	3.13

Detailed Design			
DD3. Identify materials and equipment requiring higher visibility			
Depends on the nature of the material, confidence in delivery, and position of the item in the critical path			
Visibility Needed	**Average Ratings**		
	Ease of Access	**Accuracy/Trustworthiness**	**Importance**
Identification of critical components/long lead time items	2.65	3.04	3.74
Installation/expertise provider availability	2.39	2.91	2.52
Materials that require special handling	2.61	3.23	2.78
Shipment quantities and composition – engineered materials, major equipment packages	2.36	2.50	2.73
Design dependencies	2.22	2.64	3.09
Supplier delivery performance history for ordering	2.30	2.48	2.61
Supplier quality history for ordering	2.35	2.65	2.87

Detailed Design			
DD4. Establish supplier quality surveillance program and plan			
Depends on the nature of the material, confidence in delivery, and position of the item in the critical path			
Visibility Needed	**Average Ratings**		
	Ease of Access	**Accuracy/Trustworthiness**	**Importance**
Detailed supplier progress reports	2.30	2.57	3.13
Supplier production schedule	2.35	2.57	3.00
Supplier delivery performance history for ordering	2.26	2.61	2.65
Supplier quality history for ordering	2.43	2.83	2.87

Detailed Design			
DD5. Use of catalog vs. custom			
Visibility Needed	**Average Ratings**		
	Ease of Access	**Accuracy/Trustworthiness**	**Importance**
Visibility into what is catalog (standard)	2.83	3.09	2.61
Current supplier lead times for early planning	2.61	2.57	2.78

Procurement and Supply Chain			
PSC1. Order long lead time products			
Visibility Needed	**Average Ratings**		
	Ease of Access	**Accuracy/Trustworthiness**	**Importance**
Logistics availability windows	2.30	2.95	2.74
Supplier production windows for ordering/ monitoring	2.22	2.74	2.96
Current utilization for ordering/monitoring	2.09	2.73	2.65
Supplier capabilities for ordering	2.39	2.68	2.87
Work breakdown structure including EWP, PWP, CWP, IWP	2.32	2.95	2.87
ROS/RAS dates	2.91	2.61	3.61

Procurement and Supply Chain			
PSC2. Supplier selection			
(Selection of subcontracts and suppliers, including location consideration)			
Visibility Needed	**Average Ratings**		
	Ease of Access	**Accuracy/Trustworthiness**	**Importance**
Logistics availability windows	2.57	2.95	2.74
Supplier production windows for ordering/ monitoring	2.35	2.78	2.74
Current utilization for ordering/monitoring	2.30	2.70	2.74
Construction need date	2.57	2.52	3.39
ROS/RAS dates	2.78	2.43	3.30

Procurement and Supply Chain			
PSC3. Expediting decisions considering overall project picture			
Visibility Needed	**Average Ratings**		
	Ease of Access	**Accuracy/Trustworthiness**	**Importance**
Detailed supplier progress reports	2.43	2.57	3.30
Supplier production schedule	2.26	2.57	3.17
Materials that require special handling	2.65	3.00	2.70
Logistics constraints	2.83	2.96	3.17
Logistics availability windows	2.61	2.95	2.83
Finished goods inventory levels on-site	2.74	2.70	2.78
Finished goods inventory levels off-site	2.39	2.61	2.78
Materials handling costs off site	2.35	2.68	2.43
Materials handling costs on-site	2.57	2.59	2.65
Supplier delivery performance history for ordering	2.17	2.65	2.78
Supplier quality history for ordering	2.39	2.83	2.78
Supplier capabilities for ordering	2.30	2.74	2.78
ROS/RAS dates	2.83	2.43	3.61
Construction need date	2.74	2.48	3.57
EWP Completion	2.50	2.57	3.17
Engineering progress	2.35	2.22	3.17

Procurement and Supply Chain			
PSC4. Order commodities and bulk			
(supplier data, inspection, and acceptance plan – do bulks match specifications)			
Visibility Needed	**Average Ratings**		
	Ease of Access	**Accuracy/Trustworthiness**	**Importance**
ROS/RAS dates	2.65	2.43	3.22
BOM quantities by CWP/IWP	2.68	2.50	3.39
Shipment quantities and composition – bulks (gaskets, pipes, bolts etc.)	2.64	2.73	2.68
Materials handling costs off site	2.43	2.64	2.22
Materials handling costs on-site	2.55	2.71	2.41
Warehouse space availability over time	2.41	2.32	2.68
Delivery rates for bulks	2.64	2.91	2.32
Regional inventories of common/commodity items	2.41	2.55	2.32
Expediting costs related to transport/logistics	2.59	2.95	2.18
Availability level/options of alternate supply source for common parts/consumables	2.59	2.95	2.00

Construction			
C. Adjustment in schedule and/or supply chain to accommodate materials flow disruption			
Visibility Needed	**Average Ratings**		
	Ease of Access	**Accuracy/Trustworthiness**	**Importance**
Warehouse space availability over time	2.35	2.95	2.00
Availability level/options of alternate supply source for common parts/consumables	2.43	2.39	2.61
Supply chain's ability to hold inventory/delay deliveries	2.39	2.83	2.48
IWP readiness including design, materials, labor, equipment etc.	2.41	2.78	2.57
Visibility into status and location of materials in the supply chain (at the tag level)	2.30	2.62	3.17
Client milestones	3.13	2.39	3.22
EWP Completion	2.33	3.05	3.39
Line breaks/piece marks	2.37	2.75	3.09
BOM quantities by CWP/IWP	2.71	2.61	2.75
Site resource availability	2.41	2.71	3.14
Resource allocation	2.32	2.50	3.05

Appendix D

Average Scores for Each Visibility Enabler

Detailed Design		
DD1. Detailing the construction sequence to get materials on site		
Ability to accelerate or decelerate		
Visibility Enabler	**Average Ratings**	
	Ability to Impact Project	**Frequency of Competent Execution**
Qualified supplier and specialty contractor list	6.75	4.44
Material responsibility matrix	7.94	3.75
Risk register	7.00	4.19
Complete specifications available to all stakeholders	7.75	3.88
AWP process implementation	8.50	3.25
Detailed understanding of the scope and sequence (agreement/buy-in by all stakeholders)	8.75	3.44
Early technical and commercial requirements to/ from supplier	7.88	3.81
Early involvement/onboarding of suppliers for alignment and interdependency identification and planning	7.25	2.88
Information specification in contracts	7.19	3.38
Data exchange specification and process	6.44	2.81
Contractual requirements for suppliers to describe composition of shipments	6.94	3.25

Detailed Design		
DD2. Reviewing long lead items and need dates		
Determination of engineering sequence' compatibility with the schedule		
Visibility Enabler	**Average Ratings**	
	Ability to Impact Project	**Frequency of Competent Execution**
Integrated project schedule	9.13	4.06
Information specification in contracts	6.69	3.50
Data exchange specification and process	6.06	2.88
Early involvement/onboarding of suppliers for alignment and interdependency identification and planning	7.75	3.19
Market intelligence report	6.63	3.38

Detailed Design		
DD3. Identify materials and equipment requiring higher visibility		
Depends on the nature of the material, confidence in delivery, and position of the item in the critical path		
Visibility Enabler	**Average Ratings**	
	Ability to Impact Project	**Frequency of Competent Execution**
Detailed inspection and testing plans	7.00	4.38
Risk register	7.50	4.25
Cost estimate	7.50	4.40
Special handling/logistic needs	7.25	4.13

Detailed Design		
DD4. Establish supplier quality surveillance program and plan		
Visibility Enabler	**Average Ratings**	
	Ability to Impact Project	**Frequency of Competent Execution**
Level or Degree of Inspection	7.13	4.19
Review of Supplier's Quality Plan and Inspection Test Package	7.13	4.19
Establishment of Proper witness Points	6.69	4.06
Dissemination of quality performance issues to detailed planners	8.00	3.50
Information specification in contracts	6.38	3.44
Data exchange specification and process	5.75	3.31
Establishment of a Non-Conformance Report (NCR) Process	7.50	4.50

Detailed Design		
DD5. Use of catalog vs. custom		
Visibility Enabler	**Average Ratings**	
	Ability to Impact Project	**Frequency of Competent Execution**
Framework Agreements	6.88	3.63
Integrated Project Schedule	8.25	3.81
Operating and maintenance strategy	7.47	3.47
Schedule impact and cost estimating capabilities supporting alternates selection	6.38	3.19
Recognition of regulatory and compliance constraints.	6.44	3.88
Life cycle costing analysis	6.31	3.43
Data exchange specification and process	5.69	3.25
Early involvement/onboarding of suppliers for alignment and interdependency identification and planning	6.88	2.88
Standardization strategy	7.13	3.44

Procurement and Supply Chain		
PSC1. Order long lead time products		
Visibility Enabler	**Average Ratings**	
	Ability to Impact Project	**Frequency of Competent Execution**
Qualified supplier and specialty contractor list	7.47	4.33
Aligned stakeholder team	7.50	4.06
Integrated project schedule	8.88	3.81
Project controls capabilities around forecasting supply chain impacts	7.88	3.50
Established material requisition and expediting process	8.13	4.31
Data exchange specification and process	6.25	3.25
Early involvement/onboarding of suppliers for alignment and interdependency identification and planning	7.25	3.19
Capability to track design status of long-lead items	8.38	3.44

Procurement and Supply Chain		
PSC2. Supplier selection		
Selection of subcontracts and suppliers, including location consideration		
Visibility Enabler	**Average Ratings**	
	Ability to Impact Project	**Frequency of Competent Execution**
Established BOM and PWPs	7.63	3.50
Material responsibility matrix	7.19	3.75
Integrated Project schedule	8.88	3.94
Qualified supplier and specialty contractor list	7.00	4.06
Market intelligence report	6.00	3.44
Data exchange specification and process	5.88	3.00
Early involvement/onboarding of suppliers for alignment and interdependency identification and planning	7.00	3.00
Supplier shop visibility	7.50	3.13

Procurement and Supply Chain		
PSC3. Expediting decisions considering overall project picture		
Visibility Enabler	**Average Ratings**	
	Ability to Impact Project	**Frequency of Competent Execution**
Material track and trace tool providing status and location information material tracker/ traceability reporting and look ahead reporting	7.88	3.31
Risk register	6.69	4.13
Integrated project schedule and critical path management dates and CWP quantities	8.88	3.81
Supplier level contingency plan	6.63	2.94
Procedures for schedule communication with supplier	7.38	3.56
Information specification in contracts	6.88	3.38
Data exchange specification and process	5.88	3.13
Continuous supplier performance evaluation	6.63	3.27

Procurement and Supply Chain		
PSC4. Order commodities and bulk		
(supplier data, inspection, and acceptance plan – do bulks match specifications)		
Visibility Enabler	**Average Ratings**	
	Ability to Impact Project	**Frequency of Competent Execution**
Look ahead reporting	8.27	3.60
Integrated site warehouse demand, delivery, and warehouse space capability	7.07	2.93
Project storage and logistic plan	7.13	3.38
Established Material requisition and expediting process	7.00	4.38
Integrated project schedule	7.88	3.88
Standardized specifications and design packages	7.13	3.69
Qualified supplier and specialty contractor list	6.75	4.19
Data exchange specification and process	6.13	3.19
Market intelligence report	5.81	3.56

Construction		
C. Adjustment in schedule and/or supply chain to accommodate materials flow disruption		
Visibility Enabler	**Average Ratings**	
	Ability to Impact Project	**Frequency of Competent Execution**
Material track and trace tool providing status and location information material tracker/ traceability reporting and look ahead reporting	8.50	2.81
Recovery/ alternate sequence planning capability	8.13	3.06
Ability/ tool to perform trial allocations	8.00	3.13
Knowledge of market and labor constraints	6.75	3.88
Job-site inventory management	7.00	3.75
Data exchange specification and process	6.13	2.81
Look ahead reporting	8.50	4.06

Appendix E: Visibility and Enabler Performance Score Sheets

Phase	Key Supply Chain Activities Requiring Decisions	Visibility Needed	Ease of Access **1**: No access or very limited **2**: Considerable effort to access **3**: Little effort to access **4**: No effort to access	Accuracy/Trustworthiness **1**: Consistently unreliable **2**: Incorrect information is common **3**: Incorrect information is uncommon **4**: Consistently reliable	Importance **1**: Low **2**: Medium **3**: High **4**: Critical
Detailed Design	**Detailing the construction sequence to get materials on site**	Upstream Constraints (constraints in module, mod yard schedule, fab yard, tier 2 suppliers contractual milestones)			
		Site constraints			
		Construction sequence/ Path of construction			
		Current supplier lead times (including sub-tiers as needed) for early planning			
		Supplier ability to accelerate by adding capacity or using alternate production resources			
		Design dependencies			
		EWP Completion			
		BOM quantities by CWP/IWP			
		System interface points and boundaries (by CWP, EWP)			
		Regional resource availability (key constraints)			
		Materials handling costs off site			
		Materials handling costs on-site, including storing, re-handling and maintenance			
		Logistics availability windows			

Phase	Key Supply Chain Activities Requiring Decisions	Visibility Needed	Ease of Access 1: No access or very limited 2: Considerable effort to access 3: Little effort to access 4: No effort to access	Accuracy/Trustworthiness 1: Consistently unreliable 2: Incorrect information is common 3: Incorrect information is uncommon 4: Consistently reliable	Importance 1: Low 2: Medium 3: High 4: Critical
Detailed Design	**Reviewing long lead items and need dates (to determine engineering sequence compatibility with schedule)**	Current supplier lead times (including sub-tiers as needed) for early planning			
		Identification of critical components/long lead time items			
		Installation/expertise provider availability			
		Design deliverable dates by EWP			
		Design dependencies			
	Identify materials and equipment requiring higher visibility	Design dependencies			
		Identification of critical components/long lead time items			
		Installation/expertise provider availability			
		Materials that require special handling			
		Shipment quantities and composition (major equipment, packages of equipment including sub-assemblies and parts, ship loose etc.)			
		Supplier delivery performance history for ordering			
		Supplier quality history for ordering			

Phase	Key Supply Chain Activities Requiring Decisions	Visibility Needed	Ease of Access **1**: No access or very limited **2**: Considerable effort to access **3**: Little effort to access **4**: No effort to access	Accuracy/Trustworthiness **1**: Consistently unreliable **2**: Incorrect information is common **3**: Incorrect information is uncommon **4**: Consistently reliable	Importance **1**: Low **2**: Medium **3**: High **4**: Critical
Detailed Design	**Establish supplier quality surveillance program and plan**	Supplier delivery performance history for ordering			
		supplier quality history for ordering			
		Detailed supplier progress reports (*consider logistics)			
		Supplier production schedule (including incremental milestones)			
	Use of catalog vs. custom	Visibility into what is catalog (standard)			
		Current supplier lead times (including sub-tiers as needed) for early planning			
Procurement and Supply Chain	**Order long lead time products**	Supplier production windows (low volume production) for ordering/monitoring			
		Current utilization (volume production) for ordering/ monitoring			
		Supplier capabilities for ordering			
		Logistics availability windows			
		Work breakdown structure including EWP, PWP, CWP, IWP			
		ROS/RAS dates			

Phase	Key Supply Chain Activities Requiring Decisions	Visibility Needed	Ease of Access 1: No access or very limited 2: Considerable effort to access 3: Little effort to access 4: No effort to access	Accuracy/Trustworthiness 1: Consistently unreliable 2: Incorrect information is common 3: Incorrect information is uncommon 4: Consistently reliable	Importance 1: Low 2: Medium 3: High 4: Critical
Procurement and Supply Chain	**Supplier selection (selection of subcontracts and suppliers, including location consideration)**	Supplier production windows (low volume production) for ordering/monitoring			
		Current utilization (volume production) for ordering/ monitoring			
		Logistics availability windows			
		Construction need date			
		ROS/RAS dates			
	Expediting decisions considering overall project picture	Detailed supplier progress reports (*consider logistics)			
		Supplier production schedule (including incremental milestones)			
		Materials that require special handling			
		Logistics constraints (especially for oversize/ overweight items)			
		Logistics availability windows			
		Finished goods inventory levels on-site			
		Finished goods inventory levels off-site			
		Materials handling costs off site			
		Materials handling costs on-site, including storing, re-handling and maintenance			
		Supplier delivery performance history for ordering			

Phase	Key Supply Chain Activities Requiring Decisions	Visibility Needed	Ease of Access **1**: No access or very limited **2**: Considerable effort to access **3**: Little effort to access **4**: No effort to access	Accuracy/Trustworthiness **1**: Consistently unreliable **2**: Incorrect information is common **3**: Incorrect information is uncommon **4**: Consistently reliable	Importance **1**: Low **2**: Medium **3**: High **4**: Critical
Procurement and Supply Chain	**Expediting decisions considering overall project picture**	Supplier quality history for ordering			
		Supplier capabilities for ordering			
		ROS/RAS dates			
		Construction need date			
		EWP Completion			
		Engineering progress			
	Order commodities and bulk	ROS/RAS dates			
		BOM quantities by CWP/IWP			
		Shipment quantities and composition of bulks (gaskets, pipes, bolts etc.)			
		Materials handling costs off site			
		Materials handling costs on-site, including storing, re-handling and maintenance			
		Warehouse space availability over time			
		Delivery rates for bulks			
		Regional inventories of common/commodity items			
		Expediting costs related to transport/logistics			
		Availability level/options of alternate supply source for common parts/consumables			

Phase	Key Supply Chain Activities Requiring Decisions	Visibility Needed	Ease of Access **1**: No access or very limited **2**: Considerable effort to access **3**: Little effort to access **4**: No effort to access	Accuracy/Trustworthiness **1**: Consistently unreliable **2**: Incorrect information is common **3**: Incorrect information is uncommon **4**: Consistently reliable	Importance **1**: Low **2**: Medium **3**: High **4**: Critical
Construction	**Adjustment in schedule and/ or supply chain to accommodate materials flow disruption**	Warehouse space availability over time			
		Availability level/options of alternate supply source for common parts/consumables			
		Supply chain's ability to hold inventory/delay deliveries			
		IWP readiness including design, materials, labor, equipment etc.			
		Visibility into status and location of materials in the supply chain (at the tag level)			
		Client milestones			
		EWP Completion			
		Line breaks/piece marks			
		BOM quantities by CWP/IWP			
		Site resource availability			
		Resource allocation			

Phases	Key Supply Chain Activities Requiring Decisions	Enabler	Ability to impact project **1**: Extremely low impact **2**: Low impact; **3**: Moderate impact; **4**: Significant impact **5**: High impact **6**: Extremely high impact	Frequency of competent execution **1**: Very rare; **2**: Rare; **3**: Occiasional; **4**: Frequent; **5**: Common; **6**: Very common
Detailed Design	**Detailing the construction sequence to get materials on site**	Qualified supplier and specialty contractor list		
		Material Responsibility matrix		
		Risk register		
		Complete specifications available to all stakeholders		
		AWP process implementation		
		Detailed understanding of the scope and sequence (agreement/buy-in by all stakeholders)		
		Early technical and commercial requirements to/from supplier		
		Early involvement/onboarding of suppliers for alignment and interdependency identification and planning		
		Information specification in contracts		
		Data exchange specification and process		
		Contractual requirements for suppliers to describe composition of shipments		
	Reviewing long lead items and need dates(to determine engineering sequence compatibility with schedule)	Integrated project schedule		
		Information specification in contracts		
		Data exchange specification and process		
		Early involvement/onboarding of suppliers for alignment and interdependency identification and planning		
		Market intelligence report		

Phases	Key Supply Chain Activities Requiring Decisions	Enabler	Ability to impact project **1**: Extremely low impact **2**: Low impact; **3**: Moderate impact; **4**: Significant impact **5**: High impact **6**: Extremely high impact	Frequency of competent execution **1**: Very rare; **2**: Rare; **3**: Occiasional; **4**: Frequent; **5**: Common; **6**: Very common
Detailed Design	**Identify materials and equipment requiring higher visibility**	Detailed inspection and testing plans		
		Risk register		
		Cost estimate		
		Special handling/logistic needs		
	Establish supplier quality surveillance program and plan	Level or Degree of Inspection		
		Review of Supplier's Quality Plan and Inspection Test Package		
		Establishment of Proper witness Points		
		Dissemination of quality performance issues to detailed planner		
		Information specification in contracts		
		Data exchange specification and process		
		Establishment of a Non Conformance Report (NCR) Process		
	Use of catalog vs. custom	Framework Agreements		
		Integrated Project Schedule		
		Operating and maintenance strategy		
		Schedule impact and cost estimating capabilities supporting alternates selection		
		Recognition of regulatory and compliance constraints		
		Life cycle costing analysis		
		Data exchange specification and process		
		Early involvement/onboarding of suppliers for alignment and interdependency identification and planning		
		Standardization strategy		

Phases	Key Supply Chain Activities Requiring Decisions	Enabler	Ability to impact project **1**: Extremely low impact **2**: Low impact; **3**: Moderate impact; **4**: Significant impact **5**: High impact **6**: Extremely high impact	Frequency of competent execution **1**: Very rare; **2**: Rare; **3**: Occiasional; **4**: Frequent; **5**: Common; **6**: Very common
Procurement and Supply Chain	**Order long lead time products**	Qualified supplier and specialty contractor list		
		Aligned stakeholder tea		
		Integrated project schedule		
		Project controls capabilities around forecasting supply chain impacts		
		Established material requisition and expediting process		
		Data exchange specification and process		
		Early involvement/onboarding of suppliers for alignment and interdependency identification and planning		
		Capability to track design status of long-lead items		
	Supplier selection (Selection of subcontracts and suppliers, including location consideration)	Established BOM and PWPs		
		Material responsibility matrix		
		Integrated Project schedule		
		Qualified supplier and specialty contractor list		
		Market intelligence report		
		Data exchange specification and process		
		Early involvement/onboarding of suppliers for alignment and interdependency identification and planning		
		Supplier shop visibility		

Phases	Key Supply Chain Activities Requiring Decisions	Enabler	Ability to impact project **1**: Extremely low impact **2**: Low impact; **3**: Moderate impact; **4**: Significant impact **5**: High impact **6**: Extremely high impact	Frequency of competent execution **1**: Very rare; **2**: Rare; **3**: Occiasional; **4**: Frequent; **5**: Common; **6**: Very common
Procurement and Supply Chain	**Expediting decisions considering overall project picture**	Material track and trace tool providing status and location information material tracker/traceability reporting and look ahead reporting		
		Risk register		
		Integrated project schedule and critical path management dates and CWP quantities		
		Supplier level contingency plan		
		Procedures for schedule communication with supplier		
		Information specification in contracts		
		Data exchange specification and process		
		Continuous supplier performance evaluation		
	Order commodities and bulk	Look ahead reporting		
		Integrated site warehouse demand, delivery, and warehouse space capability		
		Project storage and logistic plan		
		Established Material requisition and expediting process		
		Integrated project schedule		
		Standardized specifications and design packages		
		Qualified supplier and specialty contractor list		
		Data exchange specification and process		
		Market intelligence report		

Phases	Key Supply Chain Activities Requiring Decisions	Enabler	Ability to impact project 1: Extremely low impact 2: Low impact; 3: Moderate impact; 4: Significant impact 5: High impact 6: Extremely high impact	Frequency of competent execution 1: Very rare; 2: Rare; 3: Occiasional; 4: Frequent; 5: Common; 6: Very common
Construction	Adjustment in schedule and/ or supply chain to accommodate materials flow disruption	Material track and trace tool providing status and location information material tracker/traceability reporting and look ahead reporting		
		Recovery/ alternate sequence planning capability		
		Ability/ tool to perform trial allocations		
		Knowledge of market and labor constraints		
		Job-site inventory management		
		Data exchange specification and process		
		Look ahead reporting		

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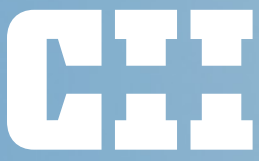

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