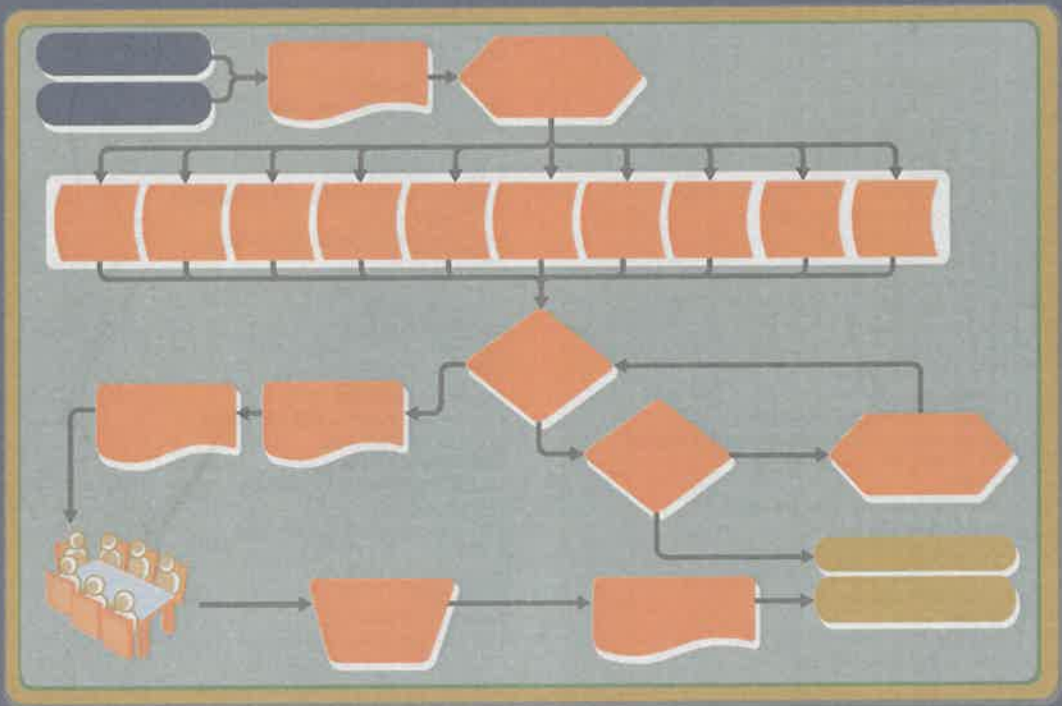
Validating Advanced Work Packaging as a Best Practice

A Game Changer



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Implementation Resource 319-2

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Validating Advanced Work Packaging as a Best Practice: A Game Changer

Research Team 319, Making the Case for Advanced Work Packaging as a Standard (Best) Practice

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Contents

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Introduction

Overview

Established by CII to validate the exploratory findings of Research Team (RT) 272, RT 319, Making the Case for Advanced Work Packaging as a Standard (Best) Practice, investigated the applicability of Advanced Work Packaging (AWP) across industrial construction sectors and on different-sized projects, to illustrate actual AWP implementation efforts and details. This research extends the previous findings on AWP implementation documented in Implementation Resource (IR) 272-2 (2013). This three-volume resource provided an extended AWP model, along with definitions, procedures, contracting guidelines, job role descriptions, checklists, case studies, and templates. All three volumes are a necessary pre-read for this document, which presents 13 new case studies and three new expert interviews. Incorporating the RT 272 research, RT 319 analyzed a total of 20 case studies and 25 expert interviews, to identify the most updated and effective methods of AWP implementation.

Scope and Objectives

The primary research objective was to explore detailed aspects of AWP implementation as they varied by construction sector and project size. This involved several secondary objectives:

1. Demonstrate the applicability of the AWP framework on projects of different sizes (from small to mega-projects), and across different industrial sectors (e.g., power, oil and gas, and infrastructure).
2. Provide further evidence of the “ancillary” benefits of AWP that are not measured quantitatively and require qualitative investigation, e.g., predictability, accountability, and alignment.
3. Examine specific implementation challenges in detail and determine how they can be overcome. Implementing AWP is a resource-intensive process that can face significant change resistance. Analyzing the difficulties projects have adopting it can raise awareness of its most challenging aspects.
4. Document lessons learned from various implementation efforts to help practitioners handle the learning curve during AWP adoption. Capturing these lessons learned is fundamental to helping construction managers succeed on future projects.

The RT 319 research methodology was based on multiple case studies and expert interviews in the industrial construction sector.

Reading Guide

This implementation resource is composed of four main sections. Following this introductory chapter, Chapter 2 describes in detail the most recurrent AWP benefits, difficulties, and lessons learned. Chapter 3 provides the write-ups of the multiple case studies, describing the characteristics, AWP procedures, and level of performance of each project. Finally, Chapter 4 presents summaries of the expert interviews, which focus on specific aspects of AWP implementation.

2

Findings

Case Studies Characteristics

RT 319 performed multiple case studies in the industrial construction sector, exploring AWP benefits, difficulties, lessons learned, and project performance. The research team chose a case study methodology because it would allow for an in-depth understanding of AWP within its implementation context. The objective was to explore the different methods of implementing work packaging in the construction industry and to get data on AWP implementation at the project level. The team analyzed a total of 20 industrial projects implementing AWP for this study. Seven of the 20 were the case studies performed by RT 272 in its AWP research. The remaining 13 case studies were collected by RT 319. Table 1 provides the details of each case study, providing the scope, size, duration, location, and type of organization represented by each interviewee. (See IR 272-2, *Advanced Work Packaging,* for more detail on the development of the first seven case studies.)

The research team identified industrial construction companies for its project case studies from the CII membership and from the audiences attending international AWP-related conferences. The unit of analysis of the case studies was the single project. The final sample included small, medium, large, and mega-projects from various industrial construction sectors (e.g., chemical, oil and gas, power generation, and infrastructure) in the United States and Canada. Data collection involved primary sources of data by means of direct face-to-face and telephone interviews, all performed between 2012 and 2015. To triangulate data sources and, thereby, to increase the reliability of the findings, the team asked multiple informants from each project to answer the interview questionnaire. The interviewees sample included experienced and senior-level managers from various functional departments (e.g., construction managers, engineering directors, and planners) and from companies with different positions within the supply chain (e.g., owner, contractor, and engineering organizations). To obtain a heterogeneous sample, the team selected managers who were employed in several business departments and involved in different parts of the AWP implementation process. Figures 1 and 2 break down the project sample by industrial sector and size, respectively.

Table 1. Characteristics of Multiple Case Studies

Project ID	Scope	Size	Duration (months)	Location	Interviewees
CS1	Power	$600 million	25	U.S.	Construction Manager (C) Planner (O) Planner (E)
CS2	Power	$350 million	27	U.S.	Project Manager (O) Vice-President of Operations (C)
CS3.1	Oil & Gas	$50 million	4	U.S.	Engineering Director (E) Project Manager (C) Superintendent (C)
CS3.2	Oil & Gas	$50 million	4	U.S.	Engineering Director (E) Project Manager (C) Superintendent (C)
CS3.3	Oil & Gas	$50 million	4	U.S.	Engineering Director (E) Project Manager (C) Superintendent (C)
CS3.4	Oil & Gas	$50 million	4	U.S.	Engineering Director (E) Project Manager (C) Superintendent (C)
CS4	Chemical	$700 million	29	Canada	Construction Manager (O) Project Manager (C)
CS5	Infrastructure	$400 million	12	Canada	Construction Manager (O) Planning Director (O) Operations Director (C) Foreman (C) Planner (E)
CS6	Oil & Gas	$150 million	12	Canada	Operations Manager (O) Planner (O) Planner (C) Buyer (C)
CS7	Chemical	$800 million	76	Canada	Construction Manager (O) Construction Director (C) Planner (C) Superintendent (C) Engineering Manager (E)
CS8	Infrastructure	$1 billion	18	Canada	Site Manager (C) Construction Manager (C)
CS9	Power	$30 million	9	Canada	Construction Manager(C) Project Manager (O)
CS10	Oil & Gas	$30 million	6	U.S.	Construction Manager (O) Modularization Manager (C)
CS11	Power	$2 million	8	U.S.	Quality Director (O) Construction Manager (O) Superintendent (O)
CS12	Oil & Gas	$1.2 billion	24	Canada	Project Quality Manager (O) Project Manager (C) Project Scheduler (C)
CS13	Power	$300 million	60	U.S.	Quality Director (O) Construction Manager (C)
CS14	Oil & Gas	$8 billion	42	Canada	Project Manager (O) Planner (C)
CS15	Oil & Gas	$1 billion	30	Canada	Project Manager (O) Lean Implementation Lead
CS16	Chemical	$650 million	36	U.S.	AWP Manager Automation Integrator
CS17	Oil & Gas	$300 million	24	U.S.	AWP Manager Automation Integrator

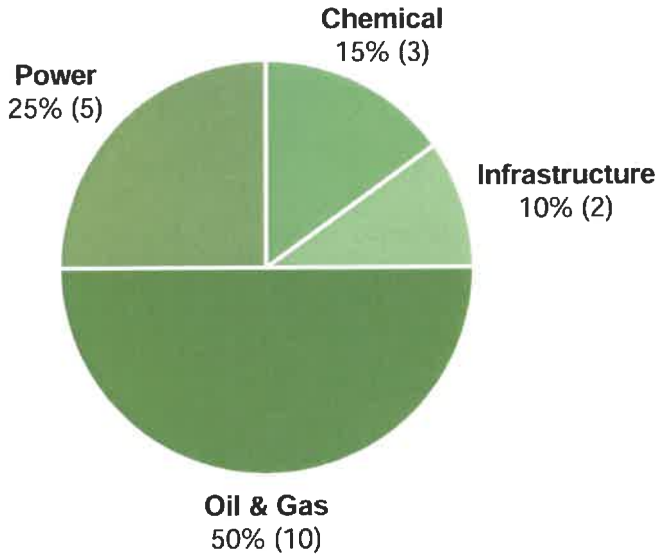

Figure 1. Number of Case Studies by Sector

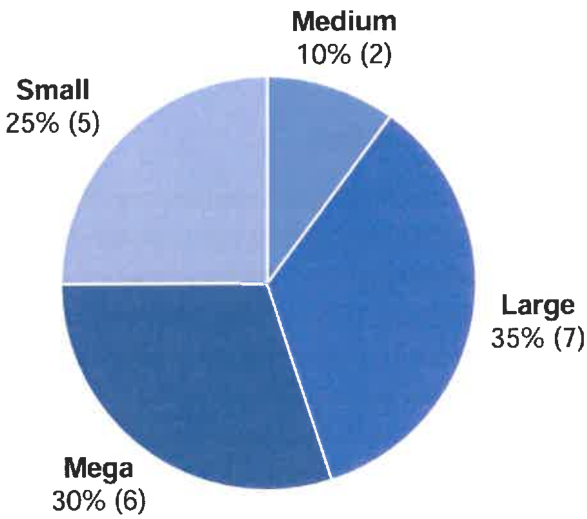

Figure 2. Number of Case Studies by Size

To increase findings reliability, the research team developed a semi-structured questionnaire to guide the interviews. The team chose the semi-structured interview format to give form to the interviews, while also allowing for probing. The questionnaire covered seven main areas:

1. Project background
2. Previous planning experience
3. AWP process
4. Materials management
5. Organizational implication
6. Project performance
7. AWP benefits, difficulties, and lessons learned.

The average duration of each interview was approximately 60 minutes. Data analysis was performed both within- and cross-cases, developing a case study database with the transcript of the interviews. To enhance the reliability of research, each case study report was sent back for confirmation to the various companies. The following sections will report the results of the multiple case study analysis and, specifically, will focus on section 6 "project performance" and section 7 "AWP benefits, difficulties, and lessons learned". (Appendix A provides the complete case study questionnaire.)

Expert Interviews Characteristics

The research team conducted six expert interviews to investigate specific processes related to AWP implementation, and to gain insights into emergent and advanced AWP traits in the industrial construction sector. The initial three interviews were conducted by RT 272, and the remaining three by RT 319. Table 2 lists the company type, sector, expert role, and focus of each interview. The expert interviewees occupied managerial positions within big EPC and owner companies operating in various industrial construction sectors, including power, oil and gas, and buildings. These experts' respective organizations have designated them as the most knowledgeable on AWP procedures and implementation.

The multiple perceptions of participants concerning the AWP topic were collected and triangulated against the findings from the case study analysis. Data and information were collected through face-to-face and phone interviews, as well as from secondary sources, such as internal reports and other corporate resources. The average interview duration was 55 minutes. The interview sessions were taped, transcribed, and coded. Data were analyzed and checked for patterns and relevant comments/revisions.

Table 2. Characteristics of Expert Interviews

Expert ID	Company Type	Sector	Expert Role	Focus of the Interview
Expert 1	EPC	Commercial Building	Construction Manager	Front End and Detailed Engineering for AWP
Expert 2	EPC	Various Industrial	Project Engineering Supervisor	Detailed Engineering for AWP
Expert 3	Owner	Industrial and Commercial	Project Manager	Integration between Lean Construction and AWP
Expert 4	Owner	Oil & Gas	Supply Chain Manager	Logistics and Materials Management for AWP
Expert 5	Owner	Commercial Building	Project Manager	AWP Application in the Modular Building Sector
Expert 6	EPC	Oil & Gas	AWP Champion	Automation of AWP Process to Manage Multiple Projects

AWP and Project Performance

The case study analysis showed a strong relationship between AWP assessment and higher project performance, compared to traditional planning and execution processes. Table 3 presents the findings from the analysis of the 13 new case studies with regards to productivity, cost, schedule, safety, quality, and predictability performance. In general, each case study revealed significant improvements across each dimension. The magnitude of these improvements increased according to the maturity and sophistication of the AWP approach. (Research Report (RR) 319-11, *Transforming the Industry: Making the Case for Advanced Work Packaging as a Standard (Best) Practice*, presents the results for each performance dimension in technical detail, and Research Summary 319-1, *Making the Case for Advanced Work Packaging as a Standard (Best) Practice*, presents a less-detailed yet thorough discussion of these findings.)

AWP Benefits, Difficulties, and Lessons Learned

The case studies also identified additional benefits, challenges, and lessons learned with regards to AWP implementation. Table 4 lists these additional findings from all 20 case studies. The following paragraphs describes only the most recurrent benefits, difficulties, and lessons learned related to AWP. (See the case study write-ups in Chapter 3 for in-depth discussions of each item.)

Table 3. Performance of Case Studies

ID	Project Performance					
	Productivity	**Cost**	**Schedule**	**Safety**	**Quality**	**Predictability**
CS5	25% better than estimates	10% reduced TIC	On schedule (same project without AWP was 3 months late)	0 lost time incident (same project without AWP had 12 accidents)	Reworks below company average	Completely positive with fully respected estimates
CS6	15% better than estimates	6% reduced TIC	Minor delay due to scope creep	0 lost time incident (TRIR below company performance)	Reworks below company average	Moderately positive, with small continuous changes to estimates
CS7	5% better than estimates	Under budget (millions USD in savings)	Minor delay due to late engineering deliverables	0 lost time incident	Target quality standard were not met	Not satisfying, with major sporadic changes to estimates
CS8	25% better than estimates	10% reduced TIC	Four months ahead of schedule	0 lost time incident (sporadic near misses)	Field reworks lower than estimates	Completely positive with fully respected estimates
CS9	n/a	n/a	On schedule	0 lost time incidents (TRIR below company performance)	Rework below company average	Moderately positive, with small continuous changes to estimates
CS10	>25% better than estimates	10% reduced TIC	On schedule	0 lost time incidents	Reworks below company average	Mostly positive, with small sporadic changes and modifications
CS11	>10% better than previous similar projects	On budget (previous similar projects were 4 times over budget)	On schedule	0 lost time incidents	Really high quality (in line with estimates)	Completely positive with fully respected estimates

Table 3. Performance of Case Studies *(continued)*

ID	Project Performance					
	Productivity	**Cost**	**Schedule**	**Safety**	**Quality**	**Predictability**
CS12	<10% better than estimates	40% increased TIC (20% below budget with approved scope changes)	Six months of delay due to late engineering deliverables	0 lost time incident (TRIR below company performance)	Reworks higher than company average	Not satisfying, with major sporadic changes to estimates
CS13	In line with estimates	Under budget (millions USD in savings)	On schedule	0 lost time incident	Field reworks lower than estimates	Moderately positive with small continuous changes to estimates
CS14	n/a	n/a	n/a	n/a	n/a	n/a
CS15	12% better than estimates	Under budget (millions USD in savings)	Minor delay	0 lost time incident (TRIR below company average)	Reworks comparable to company average	Mostly positive, with small sporadic changes and modifications
CS16	Better than estimates	On budget	Minor delay due to transportation constraints	TRIR 10 times below company average	Field reworks lower than estimates	Moderately positive with small continuous changes to estimates
CS17	25% better than estimates	15% reduced TIC	One month ahead of schedule	0 lost time incident (TRIR 20 times below company average)	Reworks and RFIs substantially below company's average	Mostly positive, with small sporadic changes and modifications

Table 4. AWP Benefits, Difficulties, and Lessons Learned

ID	Benefits	Difficulties	Lessons Learned
CS1	Improved Constructability Cleaner Jobsite Reduced Material Loss Reduced Paperwork Identification of Recovery Schedule Measure	Late AWP Implementation Unmanageable IWP Size Materials Management System Glitches Lack of Buy-in	Proper Implementation Timeline Effective IWP Size Intelligent Numbering System 3D Model Visualization Completion Sequence of IWPs Materials Management Systems Model Dump and Spool Numbers
CS2	Reduced Impact of Uncertainty Increased Predictability Collaboration among Project Participants Quick Decision Making Information Visibility Accurate Reporting Alignment across Disciplines Improved Commissioning and Turnover Improved Customer Satisfaction	Change Inertia	Operations Planning Collaboration between Engineering and Construction Define AWP Roles and Responsibilities IWPs Non-compliance Tracking
CS3.1	Craft Retention Alignment across Disciplines Increased Predictability	Lack of Buy-in Paper IWP Management System	IWP Development Support IT Integration Full Adherence to AWP Procedures (Constraint Analysis) Integration between IWP and Engineering
CS3.2	Craft Retention Alignment across Disciplines Increased Predictability	Lack of Buy-in Paper IWP Management System	IWP Development Support IT Integration Full Adherence to AWP Procedures (Constraint Analysis) Integration between IWP and Engineering
CS3.3	Craft Retention Alignment across Disciplines Increased Predictability	Lack of Buy-in Paper IWP Management System	IWP Development Support IT Integration Full Adherence to AWP Procedures (Constraint Analysis) Integration between IWP and Engineering

Table 4. AWP Benefits, Difficulties, and Lessons Learned *(continued)*

ID	Benefits	Difficulties	Lessons Learned
CS3.4	Craft Retention Alignment across Disciplines Increased Predictability	Lack of Buy-in Paper IWP Management System	IWP Development Support IT Integration Full Adherence to AWP Procedures (Constraint Analysis) Integration between IWP and Engineering
CS4	Collaboration among Project Participants Accurate Reporting Improved Customer Satisfaction	Unstructured AWP Process	Early involvement of key participant Achieve Better Procurement Integration Design IWPs for Turnover Effective IWP Size Centralized AWP Management Group
CS5	Accountability Improved Constructability Faster Engineering Process Cost Baseline Development Workforce Empowerment Information Visibility Measurability Ready for Operations Repeatability Transferable Know-how Workforce Retention Improved Financial Availability Promotion of Proactive Team Culture	Alignment of Procurement and AWP Poor Controls Process IWP Backlog Level Lack of Buy-in Change Inertia	IWP Structure by Discipline IT Integration AWP Pushed by the Risk-taker Focus on Schedule Continuous Effort

Table 4. AWP Benefits, Difficulties, and Lessons Learned *(continued)*

ID	Benefits	Difficulties	Lessons Learned
CS6	Systemic Thinking Recovery Schedule Measures Increased Predictability Workforce Retention Leveled Performance of Contractors Performance Benchmarking Cleaner Jobsite More Time for High Value Activities Identification of Critical Management Areas	Alignment of Procurement and AWP IT Integration Integration between CWP and EWP Poor Controls Process Lack of Scope Freeze	IWP Structure by Disciplines Consulting Integrate with Lean Construction Principles
CS7	Accountability Increased Predictability Ready for Operations Increased Engineering Productivity during Ramp-up Cleaner Jobsite	Poor Controls Process Lack of Experience Late Involvement of Main Contractor Lack of Buy-in Late Engineering Deliverables	IWP Structure by Discipline AWP Included in Key Participants' Contracts Assessment of Project Participants' Prequalification Full Adherence to AWP Procedures (Constraint Analysis) IT Integration
CS8	Reduced Impact of Uncertainty Improved Constructability Promotion of Proactive Team Culture Supervisors spent more time supervising Workforce Retention Increased Predictability Information Visibility Process Improvement Performance Benchmarking Workforce Empowerment	Shortage of Skilled Workforce Planners Change Inertia Lack of Scope Freeze Late Engineering Deliverables	Full Adherence to AWP Procedures (Constraint Analysis) Early Involvement of Key Project Participants Integrate with Operations
CS9	Accountability Reduced Impact of Uncertainty Streamline Construction Processes Increased Predictability	Lack of Buy-in	Full Adherence to AWP Procedures (Constraint Analysis) Early Involvement of Key Project Participants

Table 4. AWP Benefits, Difficulties, and Lessons Learned *(continued)*

ID	Benefits	Difficulties	Lessons Learned
CS10	Accountability Increased Predictability Identification of Recovery Schedule Measure Scope Clarity Workforce Empowerment Supervisors Spend More Time Supervising Support for Modularization Strategy	Change Inertia Lack of Scope Freeze	Full Adherence to AWP Procedures (Constraint Analysis) Standardization of Construction Approaches Early Involvement of Key Project Participants AWP Included in Key Participants' Contracts Steep Learning Curve
CS11	Increased Predictability Reduced Impact of Uncertainty Repeatability for Future Projects Management of Multiple Projects Collaboration among Project Participants Alignment across Disciplines	Poor Controls Process Lack of Scope Freeze Late Engineering Deliverables	Early Involvement of Key Project Participants
CS12	Definition of Realistic Budget Accountability Improved Commissioning and Turnover Information Visibility	Lack of Scope Freeze Poor Controls Process Late Engineering Deliverables Functional Silos Lack of Inter-organizational Coordination Fragmented Procurement Process Lack of IWP Backlog	AWP Included in Key Participants' Contracts Early Involvement of Key Project Participants Full Adherence to AWP Procedures (Constraint Analysis) Allocate Resources upfront to Identify Control Metrics and Responsibilities
CS13	Scope Clarity Accountability System Optimization Reduced Design Changes Shorter Learning Curve Incorporate Feedbacks and Lessons Learned	Limited Time Window to Develop IWPs Change Inertia	Selection of Expert Contractors for AWP Early Involvement of Key Project Participants AWP Included in Key Participants' Contracts Steep Learning Curve

Table 4. AWP Benefits, Difficulties, and Lessons Learned *(continued)*

ID	Benefits	Difficulties	Lessons Learned
CS14	Scope Clarity Accountability Increased Predictability Adequate Field Mobilization	Change Inertia Poor Controls Process Lack of Buy-in Late Engineering Deliverables	Full Adherence to AWP Procedures (Constraint Analysis) Assessment of Project Participants' Prequalification AWP Included in Key Participants' Contracts
CS15	Predictability Alignment across Disciplines Support for Modularization Strategy Accountability Workforce Retention Incorporate Feedbacks and Lessons Learned High Scalability Reduced Impact of Uncertainty	Alignment of Procurement and AWP Lack of Buy-in	IT Integration IWP Structure by Discipline Perform Both Formal and Informal Audits Integrate with Lean Construction Principles Foster Alignment between AWP and Control Process
CS16	Information Visibility Alignment across Disciplines High Scalability Quick Decision Making	Change Inertia	IT Integration Early Involvement of Planners Full Adherence to AWP Procedures (Constraint Analysis)
CS17	Information Visibility Alignment across Disciplines High Scalability Improved Customer Satisfaction Reduced Impact of Uncertainty	Late Engineering Deliverables	IT Integration Align Performance Measurement with AWP Deliverables

AWP Benefits

The analysis of multiple case studies indicated a total of 45 "ancillary" benefits related to AWP implementation. Table 5 gives a complete list of these reported benefits.

Table 5. Full List of AWP Benefits

AWP Benefits	
Accountability	More Time for High Value Activities
Accurate Reporting	Performance Benchmarking
Adequate Field Mobilization	Promotion of Proactive Team Culture
Alignment across Disciplines	Process Improvement
Cleaner Jobsite	Quick Decision Making
Collaboration among Project Participants	Ready for Operations
Cost Baseline Development	Recovery Schedule Measures
Definition of Realistic Budget	Reduced Design Changes
Faster Engineering Process	Reduced Impact of Uncertainty
High Scalability	Reduced Material Loss
Identification of Critical Management Areas	Reduced Paperwork
Identification of Recovery Schedule Measure	Repeatability for Future Projects
Improved Commissioning and Turnover	Scope Clarity
Improved Constructability	Shorter Learning Curve
Improved Construction Measurability	Streamline Construction Process
Improved Customer Satisfaction	Supervisors Spend More Time Supervising
Improved Financial Availability	Support for Modularization Strategy
Incorporate Feedbacks and Lessons Learned	System Optimization
Increased Engineering Productivity during Ramp-up	Systemic Thinking
Increased Predictability	Transferable Know-how
Information Visibility	Workforce Empowerment
Leveled Performance of Contractors	Workforce Retention
Management of Multiple Projects	

The five most frequent "ancillary" AWP benefits found across the case studies are as follows: improved accountability; better alignment between disciplines; higher craft retention; increased information visibility; and improved construction predictability. (See Figure 3.) Each benefit is discussed in the following paragraphs.

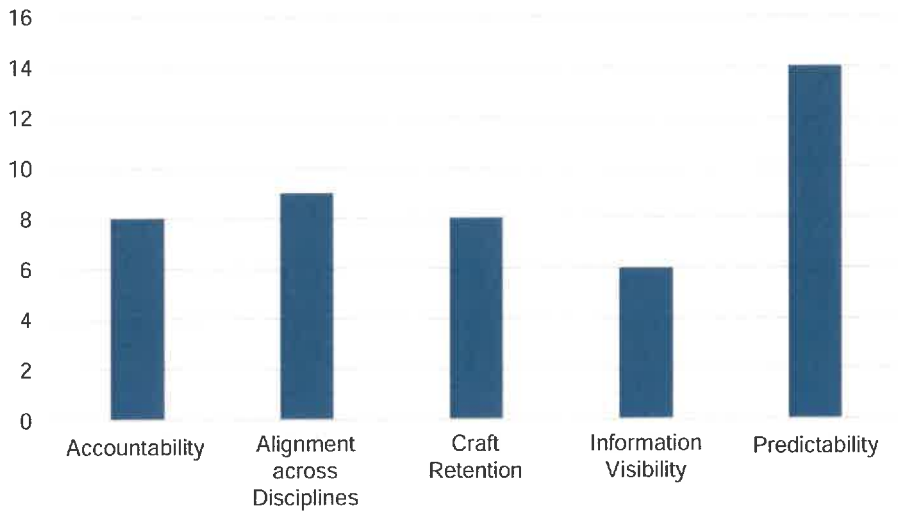

Figure 3. Top 5 Most Recurrent AWP Benefits

Accountability. AWP allows construction personnel to develop, review, and correct project plans, taking ownership of scope execution by signing each IWP before the beginning of field activities. The construction team has a primary role in the planning process by supporting the definition of the path of construction. During project execution, general contractors take ownership of construction activities, and the completion of each package is assigned to a specific foreman or superintendent. The fact that construction representatives are required to approve the same IWPs that they will execute in the future is critical to achieving accountability. This process increases commitment during project execution, empowering the crews to deliver the scope of each package in a reliable manner. IWP quality is checked after the completion of each IWP, to ensure the continuous flow of activities, especially during the transitions between different crews.

Alignment across Disciplines. The involvement of construction representatives, starting in the initial planning phase, improves the validity of project plans. As a project progresses, its early plans are iteratively refined by the various functions and departments, so that potential mistakes are fixed as soon as possible. Various owners reported better collaboration, both between construction and engineering, as well as between different construction disciplines (e.g., between electrical and mechanical). To foster alignment, IWPs are developed by dedicated and experienced AWP planners, who effectively combine construction and engineering perspectives into a final package, reducing confrontations across the different departments and establishing trust-worthy behaviors. Structuring IWPs by discipline also improved implementers' ability to identify clear interdependencies and to sequence between the different crews, minimizing responsibility gaps.

Craft Retention. AWP was credited with lowering employee turnover rates among craft personnel, with interviewees citing three main factors. First, the extensive training activities performed on AWP topics resulted in higher workforce engagement. Second, the development of a safe and organized construction environment enhanced workers satisfaction. Enhanced satisfaction was perceived across multiple hierarchical levels, from the construction manager to craftsmen. Third, the early involvement of constructors increased their level of engagement and commitment to meeting project objectives through proactive participation. AWP eases the supervisor's role during construction execution; instead of reactively addressing continuous emergencies due to missing materials, equipment, and specifications, field supervisors on projects that implement AWP spend a higher proportion of their time with crews. Superintendents reported that they had more time to focus on field activities and prevent potential problems.

Information Visibility. Interviewees noted that AWP supports the establishment of shared and agreed-upon communication rules among project participants. The objective is to generate a responsive and prompt information flow to sustain project activities; and this approach to communications should ensure the transfer of information, both internally and externally, for each organization involved in the project. The case studies indicated that AWP increased the level of transparency and visibility throughout the planning and execution processes. AWP allows the planning and construction teams to work on the latest versions of the packages, ensuring the clear resolution of package requirements (e.g., missing drawings). AWP planners are able to identify specific constraints to be solved prior to the issuance of IWPs to the field and the start of construction activities. The project management team should ensure that data are stored and retrieved in a unique database.

Predictability. Because projects implementing AWP have highly reliable project estimates and consistent execution of packages, they are highly predictable. After packages are developed from robust and shared estimates, several project participants iteratively review them for accuracy. The packages are issued to the field only when they are constraint-free and ready to be executed by a specific construction crew. Higher predictability means less uncertainty, since, with AWP, any effects of uncertainty are identified as early as possible and are limited to one work package at a time. Also, crews have alternative construction plans to execute, if necessary. The continuous monitoring of a manageable amount of activities fosters the quick identification of schedule recovery measures. Thus, the working capacity can be redirected to the other IWPs that make up the backlog for each active crew. The enhanced robustness of estimates also allows both owners and contractors to develop reliable cost and productivity baselines for future projects. The implementation of the AWP methodology is perceived as an effective way to identify a reliable baseline of cost to plan and to monitor construction activities.

AWP Difficulties

The analysis of multiple case studies identified a total of 20 difficulties faced by practitioners during AWP implementation. (See Table 6.)

Table 6. Full List of AWP Difficulties

AWP Difficulties	
Alignment of Procurement and AWP	Late AWP Implementation
Change Inertia	Late Engineering Deliverables
Fragmented Procurement Process	Late Involvement of Main Contractor
Functional Silos	Limited Time Window to Develop IWPs
IWP Backlog Level	Materials Management System Glitches
Lack of Buy-in	Paper IWP Management System
Lack of Experience	Poor Controls Process
Lack of Inter-organizational Coordination	Poor IT Integration
Lack of IWP Backlog	Shortage of Skilled Workforce Planners
Lack of Scope Freeze	Unmanageable IWP Size

The research team isolated the top five most frequent AWP difficulties: Change Inertia; Lack of Buy-in; Lack of Scope Freeze; Late Engineering Deliverables; and Poor Controls Process. (See Figure 4.) The following paragraphs discuss each of these difficulties.

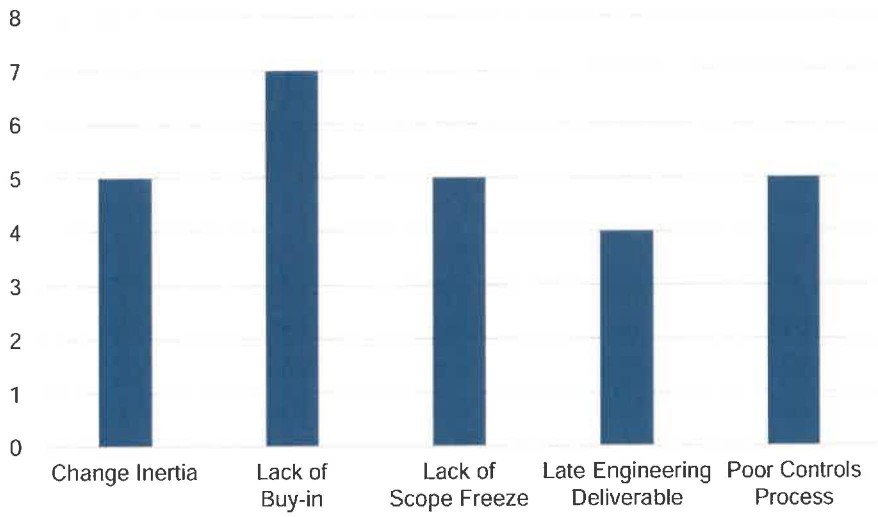

Figure 4. Top Five Most Recurrent AWP Difficulties

Change Inertia. The case study interviewees reported that construction personnel frequently oppose AWP implementation during the initial implementation stages. Specifically, frontline personnel can perceive AWP as a threat to operations, because the increased attention to planning can be interpreted as "micro-managing" field activities. When foremen have to re-allocate part of their tool time for AWP-related planning activities, this re-allocation is often perceived as a loss in productivity. In reality, though, measured productivity increases can reach 25 percent. Also the engineering team can put up initial opposition because engineering personnel are not used to providing their deliverables in alignment with the construction sequence (in this case, with CWPs). Change resistance consistently decreased after the initial achievement of performance improvements in predictability, productivity, and safety. The general contractors started to take ownership of the AWP process by actively proposing new procedures and by performing the planning process independently. Project managers can justify the need to adopt AWP through a four-step process: 1) showing evidence of poor performance and of scarce customer satisfaction with traditional processes; 2) providing evidence of how AWP represents a suitable solution to specific problems; 3) raising awareness about future AWP-related changes and of their impacts on project roles and responsibilities; and 4) identifying key-users and involving them during initial adoption.

Lack of Buy-in. The case studies showed that owner buy-in is one of the most critical of successful AWP implementation. Indeed, buy-in and commitment were shown as fundamental to reducing change resistance and introducing the necessary prerequisites of a mature AWP adoption. During initial implementation, buy-in from the top management of all stakeholders is particularly important. Without the commitment and willingness to change traditional construction practices, internal barriers could become insurmountable barriers. Lack of buy-in can appear in multiple ways, such as the unwillingness to allocate adequate resources up front or the lack of AWP training for inexperienced personnel. The experts reported that the most difficult part of achieving owner buy-in is that, although it is crucial to have it during the initial planning stage, it is usually only obtained after the owners observe construction performance improvements during project execution. The owner should demonstrate a considerable commitment to and control over AWP implementation through the development of processes, definitions, procedures. Owners should be actively involved until the development of the Level-3 schedule and delegate the execution of the detailed plan to contractors. After that, the owner should play a continuous coordination and control role on package definition and execution.

Lack of Scope Freeze. The case studies indicated that unexpected scope changes often increase the amount of rework and expose the project to overschedule risk. Unexpected change can be caused either by external and uncontrollable phenomenon, or by the owner's inability to provide a reliable scope specification. The latter can and has to be avoided through an iterative and continuous evaluation of plans, beginning in the initial project stages. Sometimes early design changes affecting modular activities can require major scope modifications, which can than cause extensive rework and delay. Such changes frustrate the construction personnel who have to re-schedule or re-perform field activities, and this leads to lower morale and less productivity. Changes during the detailed design phase also absorb the attention of the project management team members, distracting them from activities that add higher value, such as coordination and constraint minimization. Although AWP reduces the impact of changes by limiting it to a specific set of packages rather than the whole sequence of activities, any scope change results in unpredictable AWP implementation and should be minimized as much as possible with clear owner direction and coordination.

Late Engineering Deliverables. Late delivery of engineering deliverables was found to be a major challenge to achieving a mature AWP implementation. Engineering deliverables are generally understood as posing the highest risk of disrupting the planning effort to define constraint-free IWPs. The owner should allocate adequate time and resources to the early development of engineering estimates in order to meet schedule requirements. Insufficient engineering details should be formulated as quickly as possible, to avoid the generation of a vicious circle that hampers project performance. When this happens, the late issuance of engineering deliverables typically generates RFIs or causes quality errors that have to be fixed and measured by the planning team at a higher cost during project execution. This extra documentation absorbs the attention of the engineering personnel, who are not able to reduce the delay, thus generating additional RFIs, and so on. Late engineering deliverables can also reflect an insufficient design lead time, which requires the postponement of mobilization and the further deployment of engineering resources. Since premature field mobilization is counterproductive and related to unsatisfactory performance, late deliverables should be prevented rather than ignored. In some cases, design decisions are delayed without any changes to the final delivery date. This delay results in a compression of construction activities, which are then performed in fast-track mode. This shift to fast-tracking then decreases productivity. To improve engineering punctuality, documentation always has to be updated to reduce the amount of planning errors, and the delivery objectives should be reliable and continuously monitored to identify modifications to the original plans as early as possible.

Poor Controls Process. Both AWP processes and deliverables have to be consistently controlled during the various project life cycle stages. Various case study project participants reported the difficulty of aligning the control process with AWP. Because the control process can lack responsiveness, the project management team often faces difficulties in determining when delays will occur and what their potential impact on construction operations will be. An unresponsive control process could hamper the timely identification of specific countermeasures. Owners have to ensure the alignment between the control process and AWP deliverables (e.g., CWP/EWP completion). The upfront definition of AWP-related metrics allows for the identification of areas needing improvement and sources of delay, before they can affect field operations. A poor control process can also result from lack of dedicated personnel to implement control procedures. The planning process should ensure that an adequate number of trained supervisors and controllers be appropriately assigned.

AWP Lessons Learned

Table 7. Full List of AWP Lessons Learned

AWP Lessons Learned	
3D Model Visualization	Full Adherence to AWP Procedures (Constraint Analysis)
Achieve Better Procurement Integration	Integration between IWP and Engineering
Allocate Resources upfront to Identify Control Metrics and Responsibilities	Integrate with Lean Construction Principles
Assessment of Project Participants' Prequalification	Integrate with Operations
AWP Included in Key Participants' Contracts	Intelligent Numbering System
AWP Pushed by the Risk-taker	IT Integration
Centralized AWP Management Group	IWP Development Support
Collaboration between Engineering and Construction	IWP Structure by Discipline
Completion Sequence of IWPs	IWPs Non-compliance Tracking
Consulting	Materials Management Systems
Continuous Effort	Model Dump and Spool Numbers
Define AWP Roles and Responsibilities	Perform Both Formal and Informal Audits
Design IWPs for Turnover	Proper Implementation Timeline
Early Involvement of Key Project Participants	Selection of Expert Contractors for AWP
Effective IWP Size	Standardization of Construction Approaches
Focus on Schedule	Steep Learning Curve

The top five most frequently occurring AWP lessons learned are as follows: 1) Include AWP in contracts; 2) Involve key project participants early on in the project; 3) Fully adhere and commit to prescribed guidelines and procedures; 4) Use IT integration; and 5) Structure IWPs by discipline. (See Figure 5.) These difficulties are described in the following paragraphs.

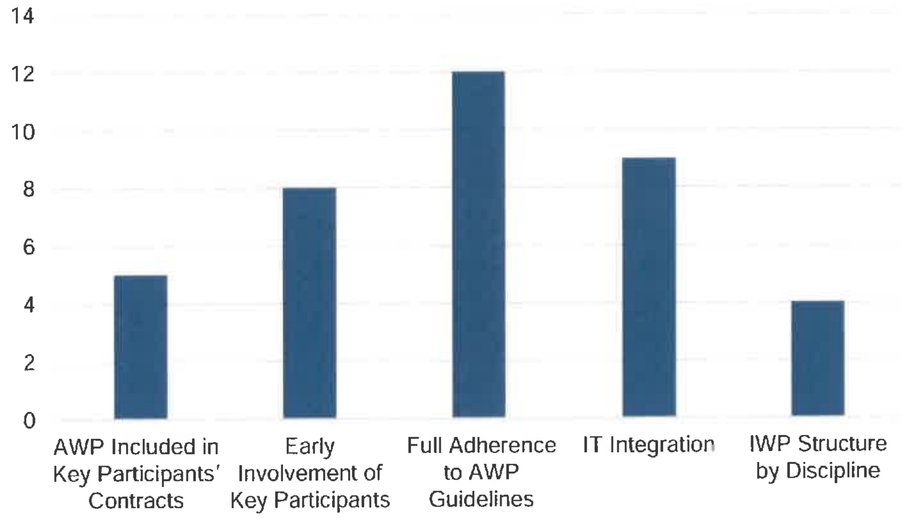

Figure 5. Top 5 AWP Lessons Learned

AWP Included in Key Participants' Contracts. The agreement on the terms of use of AWP should be defined at the very beginning of the project. Therefore, contracts should include detailed description of prequalification requirements and should clearly mention the use of the methodology. The formalization of requirements within each stakeholder contract reduces initial change inertia and any potential opportunistic behaviors. The payment schedule should be modified to be coherent with AWP deliverables, such as payments that correspond to CWP completion, to EWP issuance to the field, and to IWP turnover. Coherency with AWP deliverables is necessary to incentivize the engineering and construction disciplines to adopt AWP and to drop traditional planning practices. Project roles and responsibilities should be updated and defined within contracts. Responsibility gaps can be identified with the support of specific matrix and flowcharts, and they should be minimized as early as possible during preliminary planning.

Early Involvement of Key Project Participants. The early involvement of both the engineering and construction disciplines is necessary to achieving effective alignment and communication, starting in the initial project phases. The early involvement of construction representatives results in the improvement of initial estimates that include constructability principles. Early involvement reduces the number of scope changes and increases the reliability of plans, since it ensures that they are developed with the support of all main disciplines. It can be promoted through both formal and informal means, e.g., dedicated meetings, rewards, and rules. The case studies indicate that the performance of participants not involved in the planning stage do not meet expectations.

The main struggles in this respect include lack of commitment and understanding of AWP, difficult adaptation of procedures, and disagreement on plans and estimates. Every main participant should be involved early on in the project, even if at different levels of engagement.

Full Adherence to AWP Procedures (Constraint Analysis). The case studies showed that effective AWP implementation requires consistent definition and observance of procedures and guidelines. Systematic work packaging procedures and the definition of responsibilities should be defined and agreed upon by each project participant, beginning at early project definition. AWP should not be implemented mid-stream or without adequate preparation, which includes the commitment of additional resources such as a dedicated AWP team. Having a dedicated team can ensure the success of the work packaging process to produce the best work structure and constructability plans for the project. In the preliminary planning phase, the owner identifies the basis of the methodology through the definition of procedures and the training of personnel. The objective is to set the basis for a detailed project execution plan, which includes the list of CWPs and EWPs. This AWP-sensitive project execution plan should be continuously refined as more details become available. Owners should perform a process with stage gates that correspondence to different planning milestones, in order to validate feasibility studies and initial estimates before moving to the next phases. It is fundamental that procedures are tailored to project characteristics and to the requirements of the project management team. As a rule of thumb, the project management team should standardize the 80 percent of AWP procedures and leave a 20 percent of "flexibility" to managers in order to explore new implementation possibilities.

IT Integration. Even if AWP does not require implementation of IT systems, the case studies demonstrate that the adoption of an IT platform fosters and supports AWP execution, especially on big and complex projects. Specifically, the IT platform should allow integrated data-sharing from the different project functions. The objective is to foster the development of the various AWP deliverables through continuously updated project information and with a responsive control process. During the planning stage, a unique electronic data repository can be fundamental to managing the large volume of project information. Hence, AWP receives inputs from and exchanges data with different project team members from all project disciplines, across multiple interfaces. IT integration can be extended to field activities through the use of tablets or other devices that allow the immediate retrieval of most updated information about the content of work packages. Potential improvements can be the reduction of information lead time, the integration with 3D and 4D schedules, and a faster and more precise control process.

Work packages can be integrated with the CAD systems and then assembled in only a few minutes. Project teams can use commercially available software to support AWP implementation; this software integrates project data with existing proprietary systems. The performance improvements in productivity, cost savings, and reduced mistakes will offset the investment necessary to implement such an IT system, especially when its implementation is systematic and comports with the organization's capabilities. Since construction or engineering organizations can lack personnel skilled enough to properly use these systems, owners should plan and deploy training processes before adopting the tools.

IWP Structure by Discipline. Some of the case studies reported that the size of IWPs should not be the same for all project disciplines and should instead vary, depending on the scope of works. Such an adaptation of project procedure should be limited to the IWP development process. In some cases, the activities with higher repeatability do not require a detailed decomposition until the daily or weekly level. The adaptation of the AWP process to the different procedure requirements can reduce opposition to AWP, which is often perceived as time wasting and ineffective. Different construction disciplines may require different deployments of AWP procedures. Especially for civil works, the principle of "one crew, one shift" for IWP design can be difficult to implement for contractors who are working on several projects simultaneously. A common solution is to develop packages with a higher number of construction hours (up to twice as many), depending on the repetitiveness of the disciplines. In any case, the control process should not be diluted and should be capable to identify deviations from plans as early as possible.

Summary of Findings

This chapter presented the case study finding, which are summarized as follows:

- AWP can be applied to projects of different sizes (from small to mega-projects) across different industrial sectors (e.g., power, oil and gas, infrastructure). The research team conducted case studies and expert interviews to show how projects with different characteristics have comparable results and implementation characteristics.
- AWP is related to substantial performance improvements, when consistently applied. Reported project performance evinces similar patterns: up to 25-percent productivity improvements; up to 10-percent cost savings; improved schedule adherence; and increased construction quality and predictability. RS 319-1 and RR 319-11 provide detailed discussions of these AWP performance improvements.

- The case study interviewees reported many additional benefits, challenges, and lessons learned related to AWP implementation. The variety of the most recurrent elements reflects the wide impact of AWP on construction practices, organizational roles, and planning processes.
- The detailed documentation of specific implementation challenges can help practitioners prevent them by allocating the proper level of resources to address the most challenging ones. In a similar manner, documenting lessons learned can improve how AWP implementers handle the learning curve, by highlighting critical AWP facilitators.

3

Case Studies

This chapter provides the complete write-up of the RT 319 case studies. Since the RT 319 research builds on and extends the case studies of RT 272, these write-ups adopt the format and terms of those case studies. Also, their numbering begins where the previous write-ups left off: after Case Study 4.

Case Study 5

Project Characteristics

Sector: Industrial

Sub-sector: Infrastructure

Project Type: Sustaining mining expansion

Project Location: Alberta, Canada

Contract Type: Time and materials (T&M)

Project Cost: $400 million CAD

Construction Duration: 12 months

Construction Hours: approximately one million

Project Description

Between 2010 and 2012, Company A (the owner) progressed mining activities into new zones by hauling construction-grade waste material to in-pit dykes and removing non-construction-grade waste externally. This case study focused on the projects performed during 2012, which included the completion of two dykes and the partial development of a dedicated disposal area. Project activities involved a massive quantity of civil and piping works. The owner mainly operated with three engineering companies and four contractors (piping, electrical, paving, civil works) through time-and-materials contracts.

The labor market was characterized by low supply, and environmental and sustainability regulations compelled the owner to implement a set of processes on a strict time line. In addition to these contingent and critical challenges, unexpected natural events threatened the project and imposed drastic changes in the construction plan to mitigate their possible disruptive effects on industrial operations. Weather was also a critical contingency to consider. During the winter season, the construction site faces sub-zero temperatures, which decrease workface productivity and increase safety risks.

From a methodological perspective, this case study had two characteristics that allowed for the measurement of the impact of AWP methodology:

- The various projects that Company A started during the last decade had similar characteristics in terms of scope work and construction disciplines. Therefore, performance differences between pre-AWP and post-AWP projects can be ascribed to AWP implementation.
- Company A owns another site in the same region, where AWP has not been implemented. Both sites are similar in size and face similar environmental contingencies. The impact of AWP on project performance can be compared between projects executed within the same period, all things being equal (i.e., same owner, same contractors, and same project characteristics).

Prior Construction Experience

Previous owner-led projects were mainly driven by engineering, at the expense of constructability principles. The construction sequence had to adapt to the engineering release sequence of documents, which occasionally involved improper site turnover during project execution. Cost and time overruns hampered the major parts of projects, which required a great amount of rework activities.

From a contractual perspective, previous projects were based on E-P-C contracts with main contractors. The industry has a tendency to include overestimates in its planning. Project organizations also reported a systematic lack of transparency, which hinders their ability to detect inefficiencies or to identify realistic performance baselines as benchmarks for future projects.

From a planning perspective, the owner did not provide consistent upfront planning to project execution and felt a lack of control over site operations. Contractors submitted a large number of RFIs, opposing the sequence and the feasibility of operations. These RFIs occasioned time- and cost-consuming negotiations and operational changes. The planned value of activities was not available to the workforce with the sufficient level of detail. The project team had only defined the schedule at the macro-level, using unsophisticated paper-based supports. The lack of transparency and the poor definition of details resulted in schedule overruns and had required reactive measures.

From a materials management perspective, the owner faced a major challenge related to the absence of constraint analysis, especially with respect to materials procurement. BOMs had not been developed, and that had generated higher supply costs and occasional schedule delays, due to late and unpredictable activity definition. The absence of BOMs implied that the materials management was delegated to contractors. The owner did not have control of the procurement process and could not prevent supply disruptions.

From an information management perspective, document control lead time was one to two weeks. This created a major problem for the planning process, since information lead time is often longer than the construction lead time at the activity level. This discrepancy then hampers project execution. When the project experienced unexpected events, the unresponsiveness of the information flow created a bottleneck that occasionally forced management to bypass procedure to avoid construction delays. A poor communication exchange—characterized by arms-length relationships between the owner and the contractors—plagued project execution.

AWP Implementation

In January 2011, Company A initiated a plan to implement AWP. This plan covered twenty major areas, all of which were assigned priority levels in three stages, according to the effort they required and their impacts on project performance. (See Table 8.) In the first stage, the owner identified the basis of the methodology within the definition of procedures, the obtainment of standards, and the training of project managers/construction supervisors. The objective was to define detailed project schedule and cost, reliable earned value management (EVM) analysis, and accurate progress reporting. In the second stage, particular emphasis was placed on managing information flow in order to include an optimal path of construction, to develop a progress database, and to identify the correct numbers of backlog IWPs. The third and final stage involved the alignment of outbound/inbound logistical activities with project execution. This stage also included materials management, equipment and scaffolding coordination, and the evolution of the control phase to a digitalized level through online document control.

The plan constituted a guide to prioritizing the various management areas involved in complex industrial projects. A simultaneous effort in every area would not have been feasible and sustainable. Organizational resources were allocated on the basis of a logical implementation sequence, which was necessary to achieve performance improvements in the short term without sacrificing long-term vision. At the time of the interview, Company A had completed the second implementation stage and was approaching the third stage.

Table 8. AWP Implementation Areas

Area	Effort Required	Positive Impact
Stage 1		
Area	**Effort Required**	**Positive Impact**
1. Procedures	Low	High
2a. Standard for Workface Planner	Low	High
2b. Standard for IWP	Low	Mid
2c. Standard for Constraint Removal	Very High	Very High
3. AWP Champion	Low	High
4. Contract Language	Low	High
5. Project Schedule	High	High
6. Earned Value Management	High	High
7. Cost Codes	Low	High
8. Progress Reporting	Mid	Mid
9. AWP Training	Low	High
10. Construction Supervisor Training	Low	High
Stage 2		
Area	**Effort Required**	**Positive Impact**
11. Audits	Low	Mid
12. Backlog	Very High	Very High
13. Progress Database	Mid	High
14. Information Management	Low	High
15. Path of Construction	Mid	High
16. Project Management Training	High	High
Stage 3		
Area	**Effort Required**	**Positive Impact**
17. Equipment Coordinator	Low	High
18. Scaffold Coordinator	Low	High
19. Online Document Control	Very High	Very High
20. Procurement and Materials Management	Very High	Ultra High

AWP Procedure

Initially, the CWPs and EWPs were developed by the owner and engineering firms respectively. The role of the AWP team was to integrate the two plans, and achieved this integration by considering constructability principles from the very beginning of the design process. At the time of the interview, constructors were involved after planning Level 2 definition; but for future projects, their involvement would begin earlier, to include the generation of issued-for-review drawings. Both owner and contractors agreed to anticipate this participation to improve constructability and reduce future RFI generation.

At Level 2 schedule development, CWPs and EWPs were subjected to constraint minimization. For example, the sequence of site turnover was defined at this point. Also, major procurement and equipment requirements were identified and evaluated, since they influence all subsequent construction decisions.

After Level 2 schedule development, the integration between CWPs and EWPs made it evident that they had different paths, due to the scope and the complexity of construction activities. For easier activities, such as piping, the boundary definition was not critical: a single CWP included a single EWP. For more complicated activities, the boundary definition was driven by constructability principles, and each CWP included a set of EWPs.

After Level 3 schedule development, the detailed planning was mainly managed by contractor personnel, particularly including the following: superintendents, materials coordinators, and workface planners. The role of the owner's AWP personnel was oriented toward the support of detailed planning process. CWPs were divided among multiple IWPs, according to the number of hours included in a single IWP shift. IWPs were sized on the "one crew, one shift" principle. A shift included 10 days and approximately 2,000 working hours.

Contents of IWPs

IWPs included 10 main chapters:

1. Safety procedures
2. Scope of work
3. Quality control requirements
4. Engineering documents
5. Bill of materials
6. Accessibility
7. Equipment
8. Time sheets and progress
9. Project schedule
10. IWP completion punch list and signoff.

A typical IWP consisted of almost 100 pages. Contractors found the information content to be too extensive, and preferred to eliminate redundancies within the progress and safety sections. This preference was mainly ascribed to the paper-based IWP support, which did not facilitate the readability or the portability of the package.

Issuance of IWPs

IWPs were completed three weeks before the construction start date. Procurement and equipment availability were checked as early as eight weeks before the construction phase. The backlog level of IWPs was approximately four for each contractor. One week before the construction date, paper-based versions of the IWPs were issued to the superintendent that developed their detailed design, in order to check and approve their IWP documentation. After the approval, electronic versions of the IWPs (produced with PDF editing software) were also sent to the owner for review.

One day before the construction start date, the paper-based IWPs were then issued to the foremen responsible of daily operations. Face-to-face meetings between planners and superintendents/foremen took place during the IWP issuance, in order to highlight the scope of work and quality requirements. Superintendents showed an increased level of buy-in for the AWP procedure. They were pulling the release sequence of IWPs in accordance with the general construction plan. The role of planners consisted mainly in controlling the correctness of the work sequence and ensuring the release of all documents in a timely manner.

Progressing IWPs

IWPs were controlled by the foremen and owner's representatives. They controlled the progress of each IWP on a daily basis at Level 6 planning, by checking the percentage of work completed, the size of the crew, and the material/equipment included within the IWP. On one side, contractors' foremen and planners controlled the progressing of works through scorecards, also on a daily basis. On the other side, owner's representatives were equipped with tablet devices and checked the progress of the IWP every day at 10 a.m., to identify possible constraints, and—before the end of the shift—to control work developments. Meetings between contractors and owner representatives were organized every week to highlight main criticalities and solve occasional constraints.

Controlling the progress of IWPs included the recording of problems and errors during execution. An error procedure was started every time a problem originated at the construction site. The error procedure allowed the project team to investigate the root causes of the delay and to develop adequate corrective actions. This allowed the team to improve future IWPs that contained similar activities. Through a risk management approach, the variance and the tolerance of activities with major problems (e.g., the piling for this specific site) were incorporated, and *ad hoc* procedures were developed to minimize the risk of repeating the same errors.

During the initial phase of AWP implementation, Company A developed stringent control procedures that had a counterproductive effect on field productivity, since they delayed the construction process with too many bureaucratic control points. At the time of the interview, the level of bureaucracy had been decreased, and both owner and contractor reported that it had been a temporary and necessary evolution process to ensure the correct implementation of the new methodology since the initial phase of implementation.

Materials Management

The definition of a detailed BOM was one of the greatest challenge for the organization. It considered procurement from the beginning of CWP development, with a particular focus on major long lead materials and major equipment. Customized and long lead materials were identified between six and 12 months before the construction date.

For the first time, engineering and the construction departments jointly developed BOMs up to the detailed level. At Level 2 schedule development, the procurement department and all contractor (in case of outsourcing) were informed about major procurement decisions. The general rule differentiating insourcing and outsourcing a specific supply depended on the delivery lead time and on the criticality of materials:

- In cases of lead times longer than eight weeks, the owner purchases all materials after the preparation and the approval of an IFR.
- If the lead time is shorter than eight weeks and the material is not on the critical path, contractor are allowed to purchase the material. They are qualified to make these purchases because they have deep knowledge of the supply market and can pool the requirements from different projects.
- If the lead time is shorter than eight weeks and the material is on the critical path, the owner usually has the responsibility of the procurement process.

The objective level of inventory backlog was set at eight weeks. As each IWP was issued three weeks before the construction date, the procurement department had five weeks to check and prepare the materials. All materials and equipment constraints had to be removed during this time interval. Finally, materials were bagged and tagged three weeks in advance at the site.

Organizational Implications

The AWP team included the following personnel:

- AWP champion from the owner company
- construction manager from the owner company
- superintendents from the contractor companies
- workface planners from both the owner and the contractor companies
- engineering coordinator.

Under the guidance of the AWP champion, two AWP training sessions were executed before the definition of the construction plan. The objective of the training was to align the knowledge of all participants and to implement a change management process effectively, starting at the beginning. At Level 2 schedule development, the AWP team met for interaction planning sessions to remove constraints and to achieve a final agreement on the plan. During all the sessions, the facilitating role of the AWP champion was necessary to mediate contrasting opinions and positions.

Figure 6 shows the proportion of field personnel to planning personnel of the main contractor that performed civil and piping works, with an average of 300 workers on site. In summary, each superintendent was responsible for 90 craft workers, and a planner was necessary for every 60 craft workers. Due to the relative complexity of construction activities, this proportion can be considered an upper level of the planner/craft worker ratio.

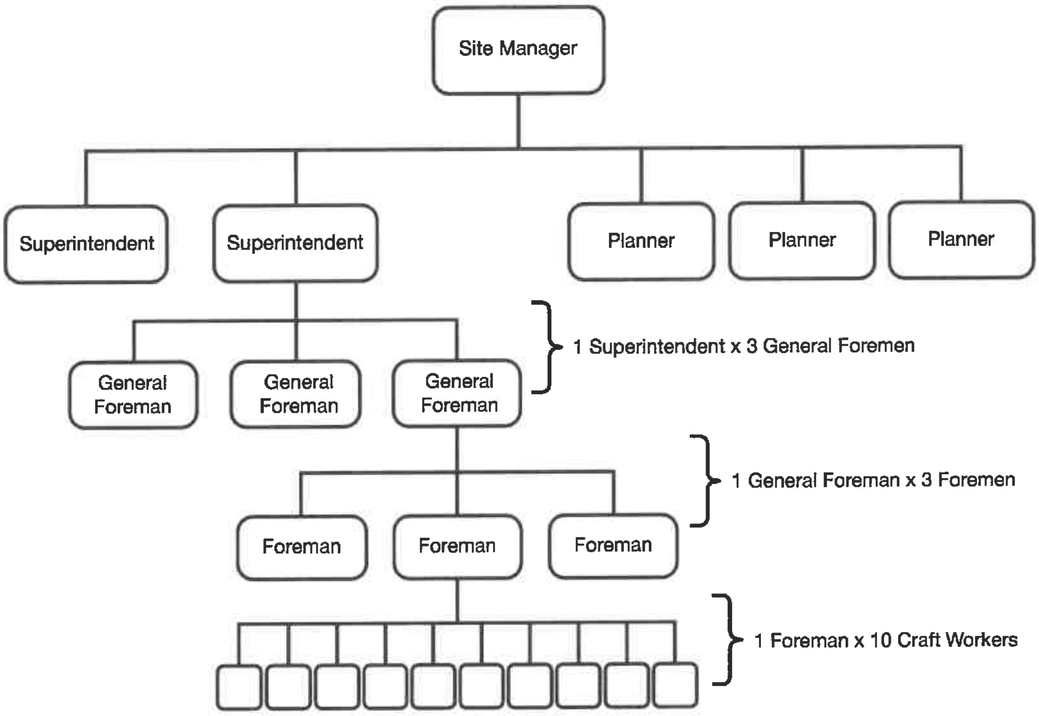

Figure 6. Case Study 5: Proportion of Field Personnel to Planning Personnel

Project Performance

As shown in the Project Description section, this case study project allowed for two comparisons that shed light on the impact of AWP methodology on project performance. First, the research team was able to compare previous performance on the same site before AWP implementation. Then, the team was able to perform another analysis by comparing current performance on another site at which AWP had not been implemented. The results presented in this section stress the impact of AWP from both a quantitative and a qualitative perspective.

Safety Performance

After one million work hours, the company recorded zero safety incidents in 2012. This result became particularly significant when compared with the trend of the other site where AWP was not implemented. On that site, the project team recorded one recordable injury every month. The structure of IWP constrains the workforce to focus on a single area, reducing aimless and dangerous movements around the site. Also, materials and equipment have to be cleared away from the working area after each shift; a cleaner jobsite is also a safer jobsite.

Management also used AWP to influence the workforce psychologically, by highlighting safety rules and procedures at the very first chapter of each IWP. Superintendents and foremen got used to thinking about safety at the beginning of all construction activities. Various mitigation risk measures were also proposed to minimize different categories of safety risks.

Schedule Performance

During the period considered for the case study, all projects were concluded on schedule. This trend represented a drastic improvement when compared with the continuous schedule overruns that occurred during the pre-AWP period at the site. When the research team compared the performance of the AWP site with that of the non-AWP site, one finding stood out: the schedule performance of an 18-month-long electrical project executed on both sites. These projects had the same scope, no particular contingencies occurred during their execution, and the same contractor was assigned to them. At the time of the interviews, the project on the AWP site was completed on time, while the project on the non-AWP site still required three months of work.

Cost Performance

The owner completed the AWP projects, saving 10 percent of planned budget and surpassing estimated productivity by 25 percent. The typical trend for projects without AWP implementation was systematic budget overruns. When AWP was in effect, the budget definition itself was based on a more precise and accurate estimate. Also, the contractors increased their profit after AWP implementation. Compared to other projects of similar size and scope at the other owner's site, the profit for the AWP site was approximately three times higher (a 300-percent increase).

Quality Performance

Construction quality was improved, and the amount of rework decreased on the AWP site. The contractors and the owner were able to implement the same quality assurance program. This was a fundamental step toward effective collaboration that was made possible by the definition of the expected quality standards within each IWP. The sequential release of IWPs allowed the project team to mitigate the effect of delays and errors by decoupling the variability of activities. This meant that each IWP only dealt with variations caused by the preceding IWP. The daily control of project activities allowed for the prompt identification of recovery schedule measures. This management of uncertainty minimized disruptions to the critical construction path.

AWP Benefits, Difficulties, and Lessons Learned

Owner and contractors personnel realized significant benefits and also faced relevant difficulties through the implementation of AWP methodology. Mostly important, they provided a set of valuable lessons learned that will be used to improve the planning processes during future project execution. Table 9 provides an overview of major AWP benefits, difficulties and lessons learned.

Table 9. Case Study 5: Benefits, Difficulties, and Lessons Learned

AWP Benefits
Accountability
Improved Constructability
RFI Reduction
Faster Engineering Process
Cost Baseline Development
Empowerment of Workforce
Information Visibility
Measurability
Readiness for Operations
Repeatability
Transferable Know-how
Craft Retention
Financial Availability
Promotion of Proactive Team Culture
AWP Difficulties
Alignment of Procurement and AWP
Poor Controls Process
IWP Backlog Level
Lack of Buy-in
Change Management Support
AWP Lessons Learned
IWP Structure by Disciplines
IT Integration
AWP Pushed by the Risk-taker
Focus on Schedule
Continuous Effort

AWP Benefits

Accountability. The AWP methodology forced the contractors to provide accurate estimates of schedule and cost for each IWP. Through this requirement, they became accountable for construction activities: they are able to edit, negotiate, and correct the construction plans, but, before the activities start, they have to agree upon and sign each IWP. In exchange, they receive a detailed and feasible construction schedule (correlated with a detailed BOM) and complete ready-to-go documentation.

Improved Constructability. The early involvement of construction representatives, starting in the initial planning phase allowed for constructability input throughout the entire project sequence.

RFI Reduction. The implementation of AWP enabled a 30-percent reduction of the number of RFIs from the contractor, compared to similar projects without AWP. Also, the proportion of RFIs shifted from the execution to the planning phase, when their impact on project cost and schedule is substantially lower.

Faster Engineering Process. Not only did early involvement improve project execution, but its impact was also felt during the engineering process. The primary example was the experience of the main contractor, who was responsible for nearly 40 percent of project scope. This organization's experience and knowledge of site conditions reduced the time required to develop Level 2 EWPs by months.

Cost Baseline Development. Initially perceived as a major constraint for project execution, the relationship between engineering and construction was transformed after AWP implementation into a win-win cooperation that led to mutual improved performance. With AWP, the value of planning activities is shared among the owner and the contractors, since it allows them to deploy control data to improve their knowledge of activity cost and duration.

Workforce Retention. The AWP-based standardization of activities required the development of standard procedures and documents. Since the document guidelines minimized errors, critical activities that were usually handled by superintendents could be delegated to foremen. This shift enhanced worker retention on the AWP site.

Information Visibility. AWP requires the establishment of mutual agreements, objectives, and rules among project participants. Project activities are sustained by a responsive and prompt information flow that is regulated by procedures. The entire construction process is characterized by increased transparency and visibility.

Measurability. The owner was able to standardize the deliveries coming from different construction disciplines and from different contractors. This permitted the use of the same measurement base for the whole set of construction activities. The added dimension of earned value management in the planning phase shifted the role of owner representatives from a control/directive to a governance/support role on field activities, ultimately giving more control and responsibility on daily operations to contractors.

Readiness for Operations. The detailed definition of the work scope and early involvement during the planning phase ensure that superintendents are ready for operation at the construction date. Superintendents were able to focus on field activities, since all job information was included *ex-ante* within each IWP. They did not have to waste time looking for documents and/or materials.

Repeatability. The detailed measurements of activities set the basis for benchmark definition for future similar project activities. The implementation of AWP methodology was perceived as an effective way to identify a reliable baseline of cost for construction activities. The performance of contractors is measured with increased precision and they provide the owner with useful data for partner selection on future projects. Contractors themselves were working on multiple projects at the same time and were able to collect lessons learned from the project with AWP and implement them on their other projects.

Transferable Know-how. The content of IWPs is conceived to be complete and self-explanatory. This wealth of information decreases the project's dependency on the single superintendent/foreman to proceed with the construction process. One contractor reported that, when a foreman did not show up one day, the daily activities were delegated to another foreman who was working on another project. The complete documentation within the IWP allowed the substitute foreman to complete the construction activities without delays or interruption.

Craft Retention. The inter-organizational mobility of skilled crews represented a major problem for contractor companies. The extensive training activities of AWP resulted in higher workforce commitment, and thus improved craft retention. The development of a safe and organized site environment enhanced worker satisfaction.

Financial Availability. Especially for small-to-medium enterprises, the accurate determination of budget allowed for the execution of cash flow analyses that reflected the variability of construction activities. This ability improved financial stability, since it helped identify the need for extra resources before problems arose.

Promotion of Proactive Team Culture. Contractors were involved from the beginning of the schedule development process. This made them feel as though they were part of the team, increasing their commitment to the project and encouraging them playing a proactive role during project execution. With this approach, all relevant stakeholders work together as a team to resolve problems. Even when they have different perspectives, they become more oriented toward the same final objective. This team approach reduces local optimizations that undermine final project success.

AWP Difficulties

Change Management Support. AWP implementation faces much push-back from contractors, who initially perceive this methodology as over-controlling and as interfering with their activities. An effective change management process is fundamental to resolving and minimizing disputes among project participants, and it ensures the team building progression that is necessary to achieve AWP benefits. Contractors report that, in addition to having major difficulty obtaining skilled planners during the initial implementation of the methodology, they are also burdened by the subsequent upfront investment required to hire the new personnel. Especially in a low supply market, the hiring process can be long and unavailing. The owner should support contractors during the transition process by clarifying the final objectives of AWP implementation from the beginning. This includes indicating the additional number of resources required and providing training activities.

Poor Controls Process. A great challenge for AWP is its management of indirect costs that are still perceived as difficult to control. Indirect activities are continuously repeated during project execution and, from a project life cycle perspective, constitute a relevant source of project cost. Indirect activities could be converted into a set of support IWPs that would allow for measurement of the impact of each indirect task. This measurement could highlight and justify hidden costs and prevent manipulations that could distort the real performance of construction activities.

IWP Backlog Level. Establishing the correct level of backlog IWPs is a difficult and critical activity that requires experience and knowledge across project areas. At the preliminary implementation stage of AWP, the objective was to avoid any project disruption, and the backlog level was set to a security level of 4 on the critical path.

Lack of Buy-in. AWP buy-in from top management is fundamental for all the stakeholders involved. Without the commitment to changing traditional construction practices, internal barriers could become insurmountable obstacles.

Alignment of Procurement and AWP. The alignment of procurement with the structure of IWPs has been identified as the main area in need of development for AWP. The objective is to define the various sourcing responsibilities according to the capabilities and the economies of scale achievable by the various organizations involved. Ideally, the owner would take responsibility for the whole procurement process, in order to avoid the additional mark-up applied by the contractor; but, this effort requires expertise, deep understanding of construction BOMs, and a drastic change of budget allocation strategy. For example, the procurement of commodity materials should be centralized for all the owner's projects, in order to pool the requirements and reduce the risk of unavailability. For the owner, this approach would require a shift from the allocation of budget to single projects to the definition of a common budget for multiple projects.

AWP Lessons Learned

Continuous Effort. Because the introduction of an innovative methodology requires implementers to spend considerable time and effort consolidating and improving practices and processes, the frequent job rotation policy of the owner organization hampers the stability of the AWP team. Also, AWP is not a standalone system and it requires continuous control and improvement to deliver full benefits. At the time of the interview, a new AWP team had been organized, and the contractors reported a decline in performance in terms of increased RFIs and reduced constructability.

Focus on Schedule. With respect to reducing project direct costs, owners and contractors should instead focus on reducing schedule overruns. The reduction of costs will be achieved as a consequence of a reliable schedule definition.

AWP Pushed by the Risk-taker. As the risk-taker on the project, the owner is the main driver of AWP implementation. The push to implement the AWP methodology is initially more effective when it is propagated from the final risk-taker to the progressive upstream levels of the supply chain.

IT Integration. The evolution of AWP will involve a major integration of IT tools. For contractors, the use of tablets on site will further reduce information lead time and will allow workers to exploit the power of 3D drawings. It will also improve the control process by making major details available.

IWP Structure by Disciplines. Different construction disciplines may require different deployments of AWP procedures. Especially for piping and civil works, the principle of "one crew, one shift" for the design of IWPs was difficult to implement for contractors that were working on several projects simultaneously. The crews changed their composition every day, depending on multiple contingencies, such as weather, permits, and worksite conditions. Contractors tried to modify the structure of IWPs by structuring them per working area and scope of work instead of per timeline. With this approach, IWPs could include up to 4,000 work hours, two times the size initially defined. This scope enlargement was beneficial to the foremen and was limited to civil and piping works. Eventually, this scope enlargement posed no problems at the procurement and control levels.

Case Study 6

Project Characteristics

Sector: Industrial
Sub-sector: Oil and Gas
Project Type: Site improvement
Project Location: Alberta, Canada

Contract Type: Time and materials (T&M)
Project Cost: $150 million CAD
Construction Duration: 12 months
Construction Hours: 400,000

Project Description

Having operated in the region for decades, the owner recently initiated significant changes to its tailing management plan to effect a sensible reduction of mine fine tailings and a consequent eventual reduction of the required fluid tailing. From the beginning of 2011 until the end of 2012, the owner executed a series of projects related to the development of mining technologies. The projects included the construction of drying fields and infrastructure that were considered critical to the continuity of industrial activity. Major crafts working on the projects, included piping, electrical, and civil works. The owner operated with engineering companies and four other contractors through time-and-materials contracts.

Main contingencies affecting the site included severe weather conditions and governmental policies and regulations, especially concerning environmental issues. While the technological changes that necessitated the projects were driven by the desire for increased production efficiency, they were also motivated by the necessity to adequately follow governmental directives. This case study aimed to measure the impact of AWP by comparing the performance of the projects during the AWP implementation period (in 2012) with their pre-AWP performance (in 2011). These projects had similar characteristics in terms of craft, scope, and duration. Also, they were performed on the same site by the same project participants.

Prior Construction Experience

Before 2010, since the drying technology itself was not stable, the scope of the infrastructure projects was poorly defined. Project execution was unpredictable and it was undermined by budget and time overruns. The owner tolerated the expensive trend of construction activities, but schedule delays represented a serious threat to the continuation of its industrial activities.

The established field culture still insisted on keeping the workforce busy without any focused direction. Although the objective was to maximize their utilization, this practice had the opposite effect: field productivity did not increase, and the lack of detailed planning generated reworks and reactive measures to accelerate the construction schedule. In 2010, Company B began implementing a lean construction environment to obtain more predictable project outcomes. The lean principles, such as continuous improvement and waste removal, prepared project stakeholders to execute projects with improved efficiency. For example, the construction team conducted various SMED training sessions with the support of internal consultants. In order to operationalize the lean concepts in the context of industrial projects, Company B decided to hire an external consultant to help implement the AWP methodology. The high profile of the projects meant that they needed more predictable execution, and the management team recognized the need for increased planning capabilities.

AWP Implementation

In 2011, the construction team—composed of the construction manager (the AWP Champion), planners, engineering coordinators, contractors' superintendents, schedulers and planners—provided their front end requirements to the consultancy company. The team developed *ad hoc* procedures for each participant, to support AWP. Initially, it was most critical to get buy-in from the contractors and to select the most suitable candidates for the AWP implementation. Subsequently, AWP procedures were distributed and supported by intensive coaching sessions. As a result, the contractors adapted their processes to incorporate AWP guidelines.

In 2012, construction projects started the effective implementation of AWP methodology. A system of earned valued management was introduced at the Level 5 planning development. Concurrently, project constraints were identified in advance, thanks to the support of widespread communication between participants. This early identification of constraints made the project ready for execution sooner. Moreover, the AWP implementation stabilized the working environment, starting at the initial phase. Once execution was underway, it became evident that materials management was the area most in need of improvement.

AWP Procedure

The input for each project was provided by the engineering team that immediately prepares a general CWP. Site turnover was considered from the outset, insofar as constructability principles were integrated with the engineering aspect in order to prevent scope creep. The construction team then revised and approved the CWP, and proceeded with the breakdown of the project by discipline up to Level 3 planning. The owner's management team noted that the scope of work was too generally defined at the beginning, and that the team had not dedicated enough time to upfront engineering to allow for a proper integration of EWPs and CWPs.

After Level 3 planning, the break-down of CWPs was the responsibility of the contractors, who further detailed the construction plan by defining the materials and the size of the crews up to Level 5 planning. The owner asked the contractors to respect the schedule boundaries identified at a Level 3, but the owner had not been involved in the subsequent detailed planning process. The size of an IWP included a shift of 10-20 working days, depending on the construction discipline. Each IWP included approximately 4,000 work hours. Company B paid particular attention to limiting the scope of IWPs in order to shield the working activities from uncertainty and to maintain a steady level of control on them.

Contents of IWPs

IWPs included the following chapters:

1. Safety procedures
2. Scope of work
3. Job cards
4. Quality control
5. Materials
6. Scaffolding
7. Equipment
8. Sub-trades
9. Permits
10. Engineering documents
11. Reporting page.

Each IWP consisted of almost 100 pages. The contractor who performed civil and mechanical crafts perceived an excessive level of information within the single IWPs. The high complexity level of the drawings was not helpful to the foremen, who expected simple directives, especially for repetitive civil works like excavation.

Issuance of IWPs

Since the development and design of IWPs was delegated to the various contractors, they each established different procedures for issuing them to the field assumed different procedures. In general, superintendents received each IWP approximately one to two weeks before the construction date, but the arrival of the packages was subject to variation.

Progressing IWPs

The progressing of IWPs was controlled on a daily basis, with the responsibility being delegated to the foremen. The foremen report to the planners and superintendents, and to the owner representatives, who update the schedule and verify IWP quality.

Materials Management

Procurement and inbound logistics represented the most critical management areas for the owner. After the identification of the items with long lead times (e.g., pumps and valves), the owner's procurement department was responsible for purchasing materials as soon as possible. The objective was to minimize the cost and the risk of disruptions by pooling materials requirements. The objective for the backlog inventory was to cover three months of construction activities.

In case of materials with shorter lead times, any decision was postponed until after the Level 2 planning. To track the necessary materials and equipment, a database was created and maintained from the planning to the installation stages. The database was based on a collection of spreadsheets that allowed for the tracking of incoming and onsite materials. However, contractors were still having problems with materials management. For example, required materials for every IWP were not checked in advance, and that resulted in missing components during operations, especially for commodity materials such as bolts.

Organizational Implications

A contractor responsible for piping and mechanical works employed an average of 80 workers onsite. Figure 7 shows this contractor's organizational hierarchy. The following proportions were developed between the operations and the planning roles:

- One superintendent was responsible for almost 80 craft workers.
- One planner was employed for every 60 craft workers.

For this case, although the owner and the contractors agreed on the 1:60 proportion of planners to craft, the project eventually employed a planner for every 40 craft workers.

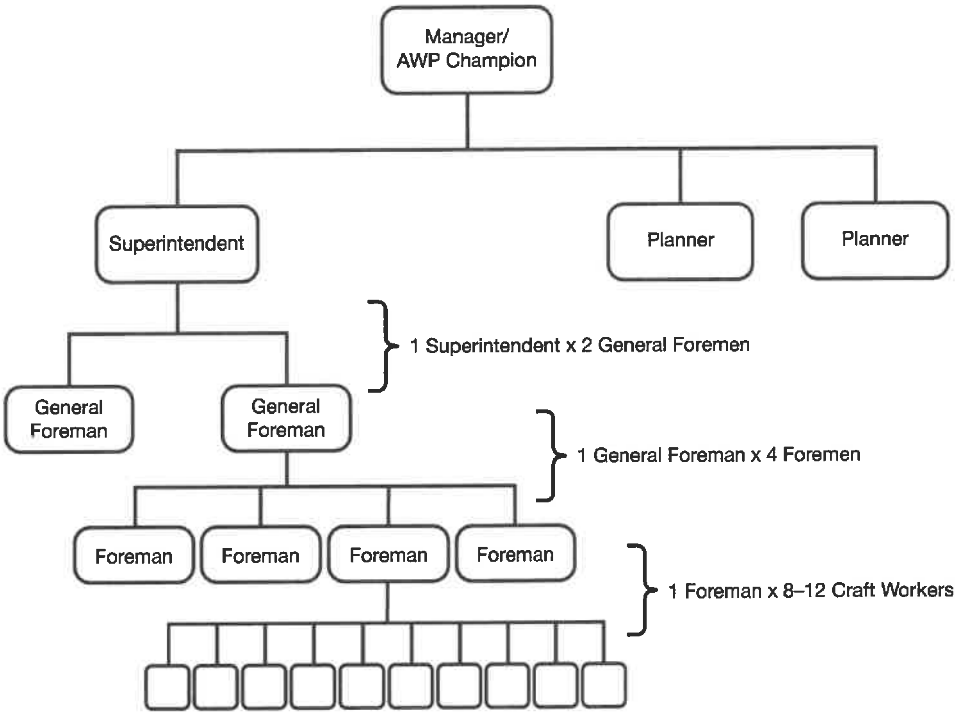

Figure 7. Case Study 6: Proportion of Field Personnel to Planning Personnel

Project Performance

As highlighted in the Project Description section, the present case study assessed the impact of AWP implementation by comparing the performance during the case study period (in 2012) with the performance on the same site before AWP implementation (in 2011). The projects that were compared had similar scope and involved the same project participants. The results discussed below aim to stress the impact of AWP from both a quantitative and a qualitative perspective.

Safety Performance

In 2012, the project's total recordable incident rate was zero. During this period, safety procedures were included in each IWP, standardized for similar construction activities, and shared among all contractors. The construction activities included in each IWP limit the movements of craft workers to a single construction area, thereby minimizing unnecessary travel around the site. Also, pursuing a "clean jobsite" is one of the principles of lean construction. It was integrated with the AWP methodology and made the removal of materials mandatory after each working shift, thus reducing the risk of accidents.

Schedule Performance

All projects performed during 2012 were delivered on schedule. The only exception was a project that exceeded the planned schedule by seven days due to scope creep. The pre-AWP trend was overall project delay, starting from initial construction activity, as a consequence of the lack of planning.

Cost Performance

The project's overall cost savings was $11.5 million CAD, equivalent to 6.3 percent of total installed cost. The definition of the budget itself was improved by taking into account the hourly cost of activity. This savings represents a counter-trend result if compared to pre-AWP project cost performance, which entailed systematic budget overruns.

Improved Productivity. Because craft workers remained focused only on one area until its conclusion, the field productivity naturally increased. In 2012, the owner recorded a 30-percent increase for the volume of construction activities compared to a 20-percent increase of working hours recorded in 2011. Using a simple proportion that normalizes the amount of working hours, RT 319 calculated a 15-percent increase in field productivity from the end of 2011 to the end of 2012, the year the project implemented AWP. (Figure 4 presents the details of specific construction activities.) The main units of productivity measurement across the crafts include the following: inches welded (inches), pipe installed (meters), valves (number), injectors (number), mixer (number), header (number), cells (number), piles (number), ADA-constructed (square meters), volume of material hauled (cubic meters).

Quality Performance

The project's quality improvement was not measured through a quantitative indicator, but a civil works contractor reported that the amount of rework decreased after AWP implementation. Each IWP was checked before completion by contractors' and owner's inspectors.

AWP Benefits, Difficulties, and Lessons Learned

Owner and contractor personnel realized significant benefits and also faced certain difficulties throughout the AWP implementation. Mostly importantly, these difficulties provided a set of valuable lessons learned that will be used to improve the planning processes of future project execution. Table 10 provides an overview of major AWP benefits, difficulties and lessons learned.

Table 10. Case Study 6: AWP Benefits, Difficulties, and Lessons Learned

AWP Benefits
Systemic Thinking
Recovery Schedule Measures
Predictability
Identification of Critical Management Areas
More Time for High-value Activities
Cleaner Jobsite
Performance Benchmarking
Workforce Retention
Leveled Performance of Contractors
AWP Difficulties
Alignment of Procurement and AWP
IT Integration
Integration between CWP and EWP
Poor Controls Process
Lack of Scope Freeze
AWP Lessons Learned
IWP Structure by Disciplines
Consulting
Integrate with Lean Construction Principles

AWP Benefits

Systemic Thinking. AWP was perceived as a methodology that allowed systemic thinking, by forcing project participants to consider the elements of project execution not as discrete entities, but as components of a general management system. This system is based on the principle of continuous improvement by repeating a "Plan, Do, Check, Act" model for each project. (See Figure 8.)

Recovery Schedule Measures. The fact that construction activities were controlled every day made possible to identify and minimize the impact of any delay in a timely manner. This early warning system prevented a significant number of supply and operation disruptions. Because the sequential release of IWPs had the effect of decoupling the variability of activities—with each IWP dealing only with the variations caused by the preceding IWP—it mitigated the effects of delays and errors.

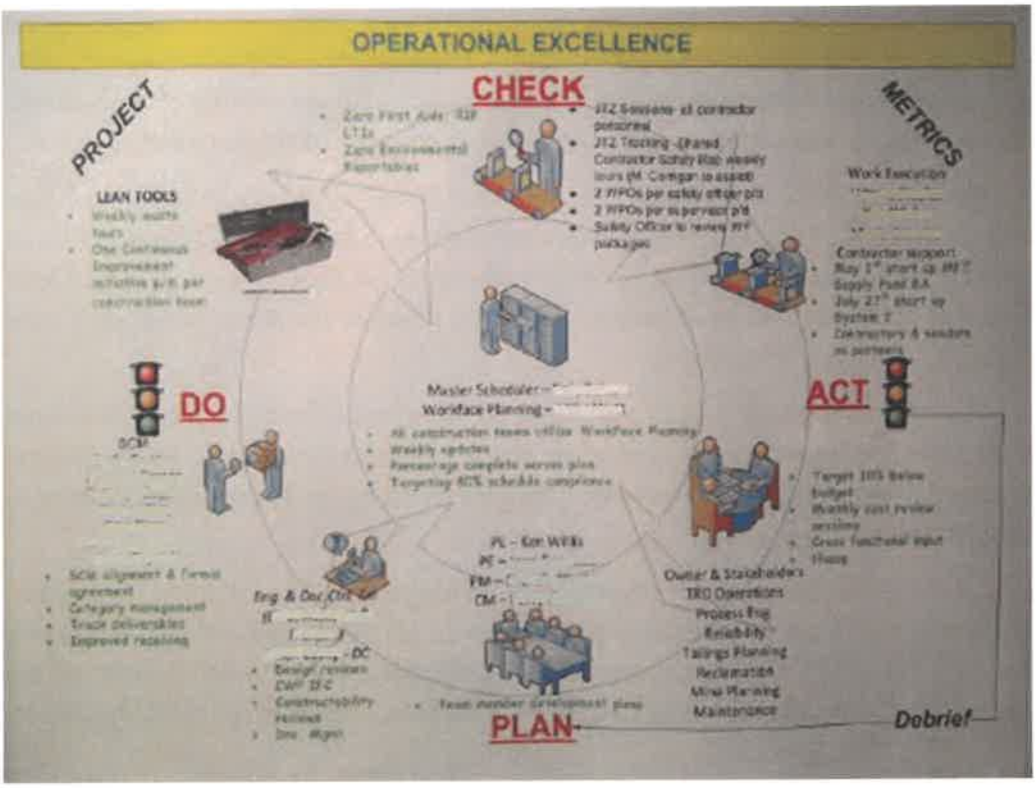

Figure 8. "Plan, Do, Check, Act" Model

Predictability. AWP implementation provided increased project outcome predictability across a broad range of contractors. The initial definition of reliable IWP-based work estimates established a trustworthy sequence of activity throughout project execution. Especially for the civil works, the increased predictability allowed for improved work performance and enable better limits on the effects of uncertain events on the construction schedule.

Identification of Critical Management Areas. AWP allowed for the stabilization of the construction schedule and the identification of the management areas that required a greater level of integration with other project functions, especially materials management. This recognition emerged during the constraints minimization phase at the very beginning of the planning stage and resulted in more effective and focused measures to cope with inefficiencies.

More Time for High-value Activities. The reduction of reactive construction activities allowed construction team members to focus their attention on high-value activities, e.g., the identification of better procurement alternatives to extend suppliers' portfolios or the provision of training sessions on continuous improvement initiatives.

Cleaner Jobsite. In accordance with lean principles, maintaining a clean jobsite is a fundamental driver of safety and work performance. The owner organized weekly audits and inspections on site to verify that all work areas had been cleared of all materials after each shift. These audits used scorecards to evaluate all the contractors.

Performance Benchmarking. The estimates developed for this project will be used as a baseline for future projects. These estimates must be validated and modified on future projects, and thus constitute benchmarks for similar activities on these projects. These benchmarks that could help to isolate the effect of specific contingencies from a risk management perspective.

Workforce Retention. The interviews to the member of the construction team highlighted the higher morale and effort of the working environment. The enhanced satisfaction was perceived at all hierarchical levels, from the construction manager to the craftsmen.

Leveled Performance of Contractors. While the success of previous projects depended mostly on the outstanding performance of certain contractors (superstars), the implementation of AWP brought an over-performing performance level for all the contractors. This higher and leveled performance also reduced the uncertainty of projects.

AWP Difficulties

Alignment of Procurement and AWP. Procurement was an area that the owner perceived as an obstacle to operations. The main contractors did not buy into procurement-related AWP procedures, and failed to check on the presence of materials enough in advance to enable corrective action. On the other side, the owner organization felt that it had poor control over in-bound logistical activities. It was common that materials needed on site were not traceable in the warehouses. The contractors and owner alike perceived a general lack of integration with vendors. However, the development of the materials tracking database allowed the owner to have a better perspective on its many projects. For example, a surplus of valves from another project was used to satisfy an unexpected requirement on an unrelated piping project. This transfer of material allowed the company to avoid an additional purchase that would have delayed construction operations. Also, economies of scale among multiple projects were successfully introduced.

IT Integration. Information technology tools were poorly implemented among the contractor, all of whom lacked enough skilled workers to introduce and use these systems properly. During the planning phase, this lack of resources caused a level of specification that could go no further than Level 4 in detail. The lack of IT support also resulted in less prompt communication across owner, contractor, and vendor organizations.

Integration between CWPs and EWPs. Constructability principles were integrated after the Level 1 planning, and the owner reported that the front end engineering design (FEED) was driving the planning process. The initial plan was organized by discipline, and the development of CWPs included a resource-intensive translation process by area that could be attenuated by improving the integration of EWPs.

Poor Controls Process. Since contractors were completely responsible for the schedule development after Level 3 planning, the owner's lack of control during detailed planning activities was perceived as leading to a subsequent loss of control on daily operations. At the time of the interview, the owner did not have enough dedicated resources to follow the detailed planning process. The company recognized that few additional human resources could substantially improve its control of detailed planning, at least at the supervisory level.

Lack of Scope Freeze. The owner reported its willingness to improve the initial scope definition process, since poor definition had caused scope creep and design changes. A clear strategic commitment is fundamental, since proper scope definition at the initial phase of project design is critical to achieving project success and to fostering AWP implementation among project participants.

AWP Lessons Learned

IWP Structure by Discipline. Contractors and owners adapted the size and the content of IWPs according to the various construction disciplines. For civil works, the size of an IWP was typically double that of an IWP for mechanical work. This adaptation gave contractors increased manageability, enabling them to increase the scale of repetitive activities, thus intensively exploiting possible economies of scale.

Consulting. For this case study, the mediating role of a consulting firm was fundamental to obtaining objective alignment among project participants. Since AWP expertise was not present in-house at a sufficient level, the project needed the support of an independent third-party to facilitate the implementation of the new procedures. This third-party consultant was effective at leading and making the change management process more palatable.

Integrate with Lean Construction Principles. The earlier introduction of the lean principles of efficiency and waste minimization fostered the AWP implementation. Some lean principles, such as "partnership of trust" and "pulled schedule," were in perfect harmony with AWP methodology. The increased communication required by AWP and the methodology's orientation towards common objectives for all project participants enabled the project to achieve predictable outcomes with mutual benefits. Contractors' foremen started demanding the release of IWPs without being pushed by planners and superintendents, which smoothed the flow of operations. The lean principle of "continuous improvement" supported the execution phase, since it entailed leveraging the expertise of contractor to enhance the AWP procedures.

Case Study 7

Project Characteristics

Sector: Industrial
Sub-sector: Chemical
Project Type: Gas plant expansion
Project Location: Canada
Contract Type: Cost reimbursement – fixed fee
Project Cost: $800 million CAD (estimated)
Construction Duration: 76 months (estimated)
Construction Hours: 1.7 million (estimated)

Project Description

The project includes the expansion of two gas plants that will have a capacity of 900 to 1,100 million tons of plastic per year. This case study focused on the FEED and detailed engineering (DE) phase related to the first plant, which has an expected completion date of October 2016, and a TIC of $815 million CAD. The project estimates that it will require 1.7 million direct construction hours, and these will become 2.2 million hours when indirect work hours (onsite and offsite) are taken into account. The core of operations will involve three main areas: polymerization, catalysis, and finishing. In addition, the project includes the construction of a train track to provide additional access to the existing facility. Then, the project scope included the construction of various power distribution substations fitting into the plant area, together with a cooling water tower. The project site is mainly greenfield, but it also comprises a partial brownfield renovation. Outside the core of the project are the rebound areas (e.g., for pumping systems, potable water, and steam), which are necessary for providing sufficient support capacity for the operations of the new plants. The project's major crafts included the following (sorted by amount of work hours): earth-works, piping, electrical and instrumentation, steel erection, concrete pouring, power generation, and vessel construction.

The owner selected one main contractor—through a cost reimbursement contract with a fixed fee—to execute the project. Most importantly, the subcontractors included steel erection and insulation. For example, for a three-story building, the main contractor brought in a building erector under a design-bid-build contract. Insulation represented another sub-contracted critical activity, and was expected to require more than 100,000 work hours. Finally, other smaller contractors were enrolled for maintenance and service operations, e.g., the construction of roads, piling activities, and the maintenance of the field in case of adverse weather conditions.

The project evolved with the following timeline: project definition and FEED had been performed for 30 months; then, DE was performed for 12 months; and the construction phase is expected to take 33 months. Since the project was in the initial stage of the construction phase when the case study was completed, the measurement of the project's performance is partial and incomplete. So, the objective was to analyze the FEED and the DE phases, highlighting the AWP-related benefits, challenges, and lessons learned, as reported by the main project participants. Specifically, the case study involved several interviews with the top management of the owner, main contractor, and engineering organizations.

Prior Construction Experience

The main contractor had been successfully implementing the workface planning methodology for a decade. The novelty of this project for this contractor was in the increased level of detail of the planning activities. The owner had implemented AWP on a previous project, but it had been limited to the commissioning and turnover process. Because this implementation was considered successful in terms of clear scope breakdown and detailed identification of tasks, the company decided to adopt the methodology for new projects with the support of an experienced contractor. The project was also the first mega-project undertaken by the owner. Finally, the engineering company was not familiar with the AWP methodology, none of its strategic suppliers had ever participated in the construction of a mega-project.

AWP Implementation

During initial project definition, the owner engaged the engineering company and a construction consultancy company to give constructability input to the scope definition process. For example, the initial project definition was oriented toward reducing the amount of indirect costs (e.g., scaffolding), by installing more walkways. The output was the Level 1 schedule definition, which also included a modularization plan. The contractor was involved at the end of the FEED phase in order to ensure the correctness of estimates related to schedule and budget. However, the exclusion of the contractor from the FEED phase allowed for various alterations to the original plans. In particular, the contractor updated the modularization plan and intensively modified the budget estimates.

In terms of data management, the project appeared fragmented across the different functional areas, with a variety of proprietary tools being used and limited sharing of information. The engineering developed Level 5 drawings using internal software, which did not allow for extensive integration with other participants. The drawings were shared in the PDF format with the owner and the contractors. Materials management was divided between the engineering (the buyer of major equipment and materials) and the contractor (the final user of the materials), with poor integration points. Another tool was used to coordinate schedule and cost control. Finally, another specific tool was installed for the management of turnover and commissioning.

AWP Procedure

A pre-construction team was established four months before the construction start date. After the FEED phase, the owner engaged the main contractor and the engineering company in identifying related field and equipment requirements. Four construction representatives (one construction manager, one engineering manager, and two superintendents) were involved to ensure that constructability principles were included in the path of construction. The output of this phase was a defined construction sequence that all project players agreed on and that was formalized through a release plan for CWPs and EWPs. The final number of CWPs was around 200, and each one included, on average, 90,000 construction hours. The CWP definition started with the piling, proceeded to the foundations, and ended with the structural steel. The material requirements were in the same sequence, so as to support the modular fabrication. The engineering sequence was aligned with the path of construction, and roughly 40 percent of engineering was developed prior to project execution.

Identifying the CWPs required the project team to break down the project scope by sub-area, e.g., water treatment or power generation. The engineering company provided specifications and drawings from the EWPs, and these were included and fitted into the various CWPs. The projects analyzed in this case study did not present particular criticalities for the integration of the different sub-areas, which were mostly interconnected by pipelines.

On the owner side, the definition of packages was coordinated up to the Level 3 schedule. After the DE phase, the definition of IWPs was completely delegated to the main contractor, who used an SQL-based estimation platform to estimate the duration and the work hour required for construction activities. The duration of activity was calculated through a set of cost codes, along with a final percentage of construction time allocated for buffers. These codes and buffers corresponded to different types of activity and were evaluated by the experienced planners and superintendents.

Contents of IWPs

The owner required that each IWP be developed according to the "one crew, one shift" principle, with a single shift comprising approximately 1,000 work hours (equivalent to 10-15 days of work). The generation of IWPs was delegated to the main contractor.

Each IWP was produced by one planner, one superintendent, two general foremen, and one engineering coordinator. The IWPs were structured to minimize the load of information on the frontline personnel. The content was usually contained within 10 pages and it included the following:

1. Bill of materials
2. Scope of the package, including budget and schedule
3. Drawings and isometrics, including model shots for visualizing the activities
4. Special equipment and required materials.

Issuance of IWPs

The owner required the issuance of each IWP six weeks in advance of the construction start date. This lead time was required to maintain a certain level of backlog and to provide a threshold for ensuring the presence of all materials on site. Prior to issuance, a check for completeness was executed, to make sure that the IWPs were ready for operation by the construction date. IWPs are stored electronically in a central database and issued to the field on a paper-based support. The check for completeness of packages was considered particularly important by the main contractor, since any missing information would make execution difficult. The project manager reported that for a previous project, the IWPs were issued even if all the constraints had not been solved (e.g., missing materials or drawings). During construction execution, field superintendents acknowledged that some information or materials were missing, and they were forced to switch to other IWPs while waiting for the RFI to be resolved. This interruption of the IWP sequence hampered construction productivity.

Progressing IWPs

To identify any divergences from the original plan, the contractor performed a daily progress of IWPs in meetings with crews at the end of each shift. The contractor reported the execution of IWPs to the owner on a biweekly basis. The owner's representatives reported that the designated control personnel were not sufficient—in terms of both size and expertise—to cope adequately with the monitoring process. The company, thus, felt a loss of control on operational activities.

This procedure was also used to estimate the duration of activities executed by subcontractors. In particular, the main contractor assigned its own personnel to support the estimation and the control of activities for the subcontractors that performed critical activities. A typical example is insulation, an extensive subcontracting activity that is fundamental to a completed turnover and that requires continuous control.

The main contractor had a consultation unit that, every week, controlled the gap between estimates and actual performance. This unit analyzed the data to determine the additional resources needed to cope with the delay and to separate anecdotal evidence from the real causes of delays. The contractor reported that this unit produced a high-level analysis and did not actually provide enough details to investigate theses real causes.

Materials Management

Since there is a high demand for design-build components in the gas industry, the engineering company purchased the major part of equipment through the preferred pool of suppliers it had provided. The project team had used a 3D model of the project at the beginning of FEED, to identify major components and equipment. The contractor purchased and provided other materials, such as structural steel and consumables.

The owner had a team that checked the coherence of the design directly with the vendors. The presence of materials was checked six weeks before the construction date, following the BOMs provided within the single IWPs. This time buffer was considered excessive but also very useful for an initial AWP implementation; it was especially helpful for resolving potential quality issues of shipped materials. In particular, modular components and pre-fabricated items were reported as having persistent quality problems on site. These quality issues required additional work to prevent construction delays.

Engineering personnel and main contractor representatives reported that materials tracking was not perfectly synchronized and organized. The information exchange between the materials buyer (i.e., the engineering company) and the end-user of the materials (i.e., the main contractor) was not fully integrated, so that some information was often missing or duplicated. This resulted in late communication of occasional delays that influenced the entire procurement chain. For instance, the late communication of delays in the provision of electrical components severely affected the contractor, who in turn had to change its delivery plans with the piping pre-fabricator. The contractor invested significant amounts of time and labor into allocating materials by IWP, bagging and tagging the required items at the site in advance of construction start.

Organizational Implications

The owner and the engineering company did not appoint specific AWP-related positions for this project, such as AWP champions or AWP planners. The responsibilities of an AWP planner were instead spread across various other roles, such as buyer and scheduler. On the other side, the contractor had specific planner positions, established to promote collaboration on building the packages with the frontline personnel.

Before project execution, the owner provided detailed training on AWP procedures for the construction team and for the controllers, to ensure an adequate level of knowledge about AWP procedures and the processes. Since this training proved to be insufficient, the owner conducted a second intensive training program, this time involving the engineering company to improve alignment among project participants. In both cases, the training consisted of one-day intensive courses, which cost around $60,000.

Figure 9 depicts the ratio of field to planning personnel for the main contractor. The following relationships emerged:

- Each superintendent was responsible for 200 craft workers. In detail, a superintendent managed two general foremen, who oversaw five foremen, who in turn managed 10 craft workers.
- Between two and five planners supported each superintendent. The number varied by construction discipline. For example, the lower boundary was for piping, and the higher boundary was for electrical instrumentation.

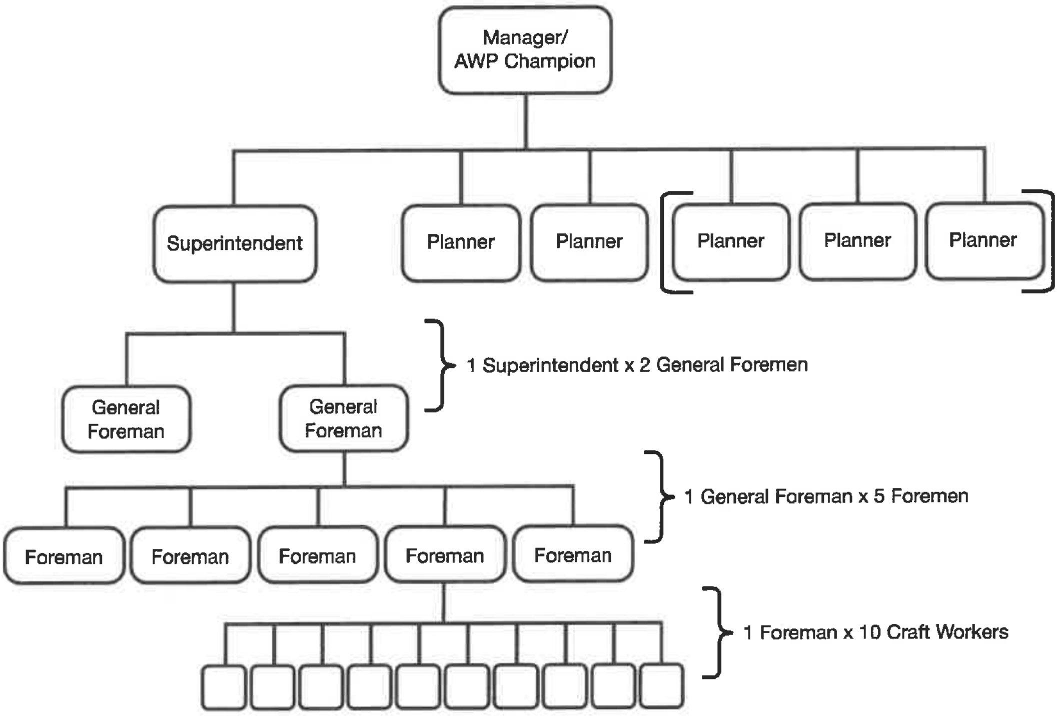

Figure 9. Case Study 7: Proportion of Field Personnel to Planning Personnel

Project Performance

Safety Performance

The project experienced zero recordable injuries at the time of the interview. The main reason given for the improved safety performance was the early identification of potential construction risks during the initial planning stage, which involved all key project participants.

Cost Performance

The detailed engineering and the initial part of the construction stage were on budget. In comparison to estimates, TIC was slightly better than planned (approximately one percent).While the productivity of detailed engineering was not satisfactory, initial field activities were a few percentage points (around five percent) better than estimates. In particular, the waiting time due to missing materials have been avoided.

Schedule Performance

The project experienced some delays because of the insufficient capacity of the engineering company. However, initial field activities were completed before estimates and this trend suggested that it would be possible to absorb these delays.

Quality Performance

During the first part of the project, the unsatisfactory quality of the engineering deliverables affected construction execution. In particular, the definition of electrical interfaces was poor, and some items (e.g., control panels) had not even been designed when they were required for IWP definition. The owner lost control over the detailed engineering process and was, thus, not able to control and cope in advance with errors. In terms of rework, the first part of construction activities did not pose any significant problems, even when the targeted quality performance was not met. For example, the welding reject rate was 3.5 percent instead of the planned 2.5 percent.

AWP Benefits, Difficulties, and Lessons Learned

Owner, engineering, and main contractor personnel noted several benefits and challenges in adopting the AWP methodology. Most importantly, they provided a set of valuable lessons learned that could be used to improve the planning processes of future projects. Table 11 provides an overview of the project's major AWP benefits, difficulties, and lessons learned.

Table 11. Case Study 7: AWP Benefits, Difficulties, and Lessons Learned

AWP Benefits
Accountability
Predictability
Readiness for Operations
Increased Engineering Productivity during Ramp-up
Cleaner Jobsite
AWP Difficulties
Poor Controls Process
Lack of Experience
Late Involvement of Key Project Participants
Lack of Buy-in
Late Engineering Deliverables
AWP Lessons Learned
IWP Structure by Disciplines
AWP Included in Key Participants' Contracts
Assessment of Project Participants' Prequalification
Adherence to AWP Guidelines
IT Integration

AWP Benefits

Accountability. The superintendents participate in the definition of the IWPs that they will execute. As such, they become accountable for construction activities: they are able to edit, negotiate, and correct the construction plans, but, before the activities start, they must agree and sign each IWP.

Predictability. The definition and approval of reliable project plans and estimates were perceived to be beneficial to the morale of the whole construction team. In addition, the FEED and DE phases involved the definition of procedures to reduce the potential execution impacts of project uncertainties, e.g., severe weather conditions and difficult field conditions. The estimates were respected and perceived as reliable, especially in comparison to estimates formulated on previous projects performed by the owner.

Readiness for Operations. The issuance of complete packages to the field (with materials, drawings, and other necessary contents) ensured that superintendents were ready for operation when construction starts.

Improved Engineering Productivity during Ramp-up. The engineering company reported that AWP was particularly beneficial during ramp-up periods, since it could drive focused owner and contractor information management on project packages and thereby minimize delays. During ramp-up, when productivity functionally decreases, the engineering company reported a decrease of performance down to 60 percent of estimates for previous projects. With the introduction of AWP, the productivity decrease was limited to 85 percent of estimates.

Cleaner Jobsite. The contractor removed all materials at the end of each shift, thus reducing potential safety hazards and increasing item availability. This policy had positive effects on the morale and productivity of the crews.

AWP Difficulties

Poor Controls Process. The measurement of engineering performance should have been included within the planning and control system to ensure the effective release of documents to the contractor. The delay of design drawings prompted construction compression measures, thus increasing managerial complexity and construction indirect costs.

Lack of Experience. The owner did not have previous experience with AWP, and this first implementation encountered difficulties during the planning phase. When highly experienced construction personnel were not available to support the construction team, the lack of supervision stood out in certain management areas (e.g., procurement and civil works). The engineering company was not used to dealing with mega-projects, and this affected the selection of minor contractors. Hence, the engineering company selected the fabricators with whom they had had long-term relationships, but these choices did not take into consideration that these companies had never dealt with such large projects. As such, the fabricators underestimated the requirements and had to cope by subcontracting major part of operations, which resulted in increased managerial complexity and in a jeopardized AWP implementation.

Late Involvement of Key Project Participants. The initial construction team did not include the main contractor until the end of the FEED phase. Despite the fact that the team had been sure to include constructability principles from the beginning of project definition, the path of construction had to be revisited by the construction team before the DE phase. Moreover, early involvement would have provided increased alignment for the adoption of AWP procedures. It would also have prevented various confrontations that occurred when engineering deliverables had to be developed to adapt to the construction sequence.

Lack of Buy-in. Despite the fact that the top management of the contractor company had already experienced and sponsored AWP implementation, some crews were not familiar with these concepts and opposed the detailed definition of IWPs prior to the start of construction activities. Also, the engineering firm put up initial opposition, particularly because the engineering personnel were not used to providing deliverables by area (in this case, by CWPs).

Late Engineering Deliverables. The general contractor and the owner reported that many EWPs had been delayed. Late and incomplete deliverables affected construction activities by delaying field mobilization and by generating a large number of RFIs.

AWP Lessons Learned

IWP Structure by Discipline. The size of the IWPs should not be the same for all project activities, but should instead vary according to the scope of works. The main contractor perceived the high repeatability of construction activities as inconsistent with the required level of specifications. Because this contractor's personnel had to re-write the same IWP again and again, they considered the procedure to be a waste of time and thus opposed it.

AWP Included in Key Participants' Contracts. In terms of contract management, the owner reported that, with improved AWP knowledge, it would be possible to implement less risky contract types with contractors than the actual cost reimbursement contract. Anyway, the cost reimbursement with fixed fee type contract empowered the contractor, who had had significant experience with work packaging and, ultimately, was the final user of the methodology in the field.

Assessment of Project Participants' Prequalification. Had the project pre-selected its main project participants on the basis of AWP capabilities, it would surely have avoided the major difficulties it encountered. In particular, the owner and the engineering company reported that the late involvement of the contractor resulted in a construction team that was not aligned, starting at the beginning of project definition. Differences between project participants should be minimized, to ensure that AWP principles are accepted down to the crew level. The determination of minimal AWP experience for each crew should have been performed in order to ensure high project performance in all the major construction disciplines.

Adherence to AWP Guidelines. The improvement between the first and the second implementation of the AWP methodology was encouraging to the owner, who reported a willingness to implement AWP on future projects. Taking a continuous improvement approach, the owner wanted to increase future pre-planning efforts and to pre-select project participants on the basis of capability and experience. On this project, AWP had provided substantial value when the prescribed guidelines and procedures were fully implemented. The lesson learned was that a partial implementation does not permit an aligned definition of aligned deliverables between engineering and construction personnel.

IT Integration. Another improvement that was recommended by the engineering company on this project involved the introduction of advanced IT tools to support AWP execution. In particular, an integrated platform for the sharing of data from the different functional areas is the natural evolution of the IT system, which will be able to foster the division of scope within IWPs and provide a responsive control process during project execution.

Case Study 8

Project Characteristics

Sector: Industrial
Sub-sector: Infrastructure
Project Type: Relocation
Project Location: Canada

Contract Type: Lump Sum
Project Cost: $1 billion CAD
Construction Duration: 18 months
Construction Hours: Four million

Project Description

In 2013, the CM contractor performed a mega-project that involved the relocation of two existing plants to a new strategic pit. The relocations and rebuilds were necessary to support advances in mine development and to dispose of consolidated tailings. The existing facilities mainly consist of three trains that transport sands to two primary separation cells (PSCs). The main concern of the project was maintaining standard levels of production as two of the three trains (and related refinery equipment) were relocated. The high risk of losing even one of the working trains—mainly due to the extreme working conditions—further increased the necessity of pursuing construction operations as effectively as possible. Hence, during the relocation of one train, the temporary shutdown of another train would decrease the production capacity by 50 percent, thus hampering the profitability of the project owner. The project was therefore extremely schedule-driven, since the relocation window was minimized as much as possible in order to mitigate production losses. It was also extremely schedule-constrained, since there was a hard back-end delivery date driven by a tailings pour.

Each train worked with five major pieces of equipment movements including the crusher, the surge bin feed conveyor, the surge facility, the mix box feed conveyor, and the slurry preparation tower. All 10 of these major components required the use of self-propelled modular transporters (SPMTs) for their relocated, since each weighed thousands of tons and were higher than a 10-story building. The main relocation effort required various ancillary construction activities: structural; mechanical; electrical; piping; instrumentation; and civil (e.g., removal and salvage of reclamation materials, overburden removal in advance of oil sands ore recovery, ecological restoration of altered mine site areas, and construction of two large mechanical stabilized earth walls). In addition, the owner saw the project as a key opportunity to perform an extensive set of maintenance activities on the major equipment and on the transportation infrastructure. The construction team cooperated with the maintenance department, as it pushed to maximize the amount of maintenance activities performed during the relocation process.

The project definition phase started in February of 2008 and the project development phase began in January of 2010. The intensive planning activities were finalized for executing a complete relocation within the shortest lead time. Starting from planning for an initial project duration of 180 days, the construction team introduced aggressive measures (e.g., ramp-up production) and finally proposed a 130-day project execution. In particular, the project was divided into two major 65-day periods, each corresponding to the relocation of one of the two trains. To meet this ambitious deadline, the plan was to schedule two continuous 12-hour shifts throughout the 130-day duration. As with other projects conducted in the Alberta region, the weather was noted as the major productivity risk factor.

Seven major contractors were utilized to develop the project scope. In addition, thirty minor contractors were employed for ancillary services such as site cleaning, worker housing, busing, logistics, and equipment refueling. The contractors were carefully selected on the basis of their level of expertise and planning capabilities (e.g., adherence to AWP methodology). At peak, onsite field effort required 1,150 workers, 80 percent of whom performed direct work.

From a methodological perspective, this case study presents an excellent example of AWP implementation under critical schedule requirements. Also, the uniqueness, the complexity, and the size of the project constitute three additional elements of uncertainty that challenge the robustness of the methodology when adopted with an extremely high level of detail. Data were collected from primary sources (seven direct face-to-face interviews) and secondary sources (reports and IWP documentation). In addition, multiple project participants were interviewed (the CM contractors and three major subcontractors), to triangulate the data and to provide a multi-faceted perspective on this implementation of AWP methodology.

Prior Construction Experience

During the last decade, the CM contractor implemented the concept of scope breakdown through the provision of "job cards," which included a detailed set of daily activities—derived from a robust schedule—and related engineering drawings. Throughout that period, the concept of "job cards" extended to the procurement function, taking into account site materials, equipment, and ancillary site services. As a natural progression, the company adopted the AWP methodology for the execution of the relocation project. The main difference between the previous planning experience and this AWP implementation was the increased effort in the initial project phase to reach consensus on a robust schedule definition. However, because the novelty of the project hampered the use of standard scheduling methods, the planning team had to involve experienced construction people, to compensate for the lack of proven norms and techniques. The CM contractor keeps internal records of the various projects performed around the world, as basis for formulating specific construction estimates for the various construction disciplines. Because this project was so unique, the contractor was unable to use this bank of information to produce estimates for it. Instead, the construction team relied mostly on the experience of its own members.

The pool of contractors had a variegated experience implementing the AWP methodology. On the one side, two mechanical-electrical-construction (MEC) contractors reported that their previous planning process entailed providing field personnel with design deliverables, which were translated into construction deliverables similar to IWPs. However, these deliverables had a low level of detail (i.e., its scope, schedule definition, and resource requirements were broad). The first MEC contractor explained that the detail and frequency of control activities were superficial and discontinuous. The construction manager of the second MEC contractor reported experiencing long information lead times during project execution, with continuous, time-consuming feedback loops between engineering and construction. On the other side, an insulating-cladding (IC) contractor was not familiar at all with AWP methodology. The project control manager stated that the company's previous planning procedure involved a similar scope breakdown process that lacked formalization and documentation. In particular, the package format was incomplete and inconsistent with field operations (e.g., was missing drawings and specification). This meant that the plans were unreliable and ultimately caused budget and schedule overruns. The main problem was the limited involvement of the execution construction personnel in upfront project definition, which, because of the numerous gaps in the package data, resulted in continuous RFI generation.

AWP Implementation

The criticality of pursuing schedule adherence required a punctual and complete definition of the project into daily construction shifts. In 2008, Company D began project definition by including an early design contractor on the construction team. Project definition required intensive coordination with the major contractors and suppliers involved, in order to minimize project risk and align project objectives. The CM contractor's construction manager identified AWP as the optimal methodology for achieving an agreed-upon and realistic project plan—one that could solve production constraints in accordance with the various supply chain participants. At that point in the project, getting all project stakeholders to accept the AWP methodology was essential. In order to promote accountability among the project participants, the construction team also included the contractors' AWP champions throughout the project life cycle.

The project team used a 4D modeling tool to create a simulation of the entire project that depicted how the relocation was to take place. The 4D model provided a detailed view of project activities (e.g., interactions between cranes and SPMTs), mainly for educational and interface analysis purposes, before project execution began. Besides that, the owner relied on a proprietary customized IT suite that included the Project Completion System (PCS) and that was integrated with other planning software (e.g., Primavera or Skyline), to allow reviews and approvals in near real time with field operations.

AWP Procedure

Since 2010, the owner had set up a FEED construction team. At the beginning of the planning process, a total of 150 CWPs at the sub-system level had been identified. These were later reduced to 35 CWPs at the major system level. For this particular project, CWPs were structured by discipline—like EWPs—and not by area. The output of this phase was a Level 2 schedule.

Major contractors had one year to develop, revise, and agree on the detailed construction sequence with the owner. Since the project's main concern was the relocation of major equipment, constructability was considered essential. Indeed, the construction resources on the team were as large as the engineering resources. Afterwards, the necessary materials and equipment requirements were planned in accordance with project estimates, with the levels of productivity characterizing the various jobs taken into account. The output of this phase was the definition of a Level 3 schedule.

The owner demonstrated considerable commitment to and control over AWP implementation by proposing the methodology, the systems, the procedures, and the guidance to the various project members. Hence, the owner was actively involved up to the development of the Level-3 schedule; subsequently, it delegated the execution of the detailed plan to the contractors, in accordance with their assigned scope. After that, the owner took on a constant coordination and control role (i.e., the number of supervisors was large enough to control the execution of each IWP on each shift).

The subject matter experts (SMEs) engaged by the owner and working with the CM contractors' superintendents developed comprehensive "method statements" for each major piece of equipment. The document included a detailed scope statement and strategy, along with a specific job hazard analysis (JHA) and an inspection and test plan (ITP), both created specifically for this project's scope. The workface planners utilized the method statement as the parent document for the development of job cards (IWPs).This led to the final output of the planning process, which was a detailed shift-by-shift Level 6 schedule of IWPs, articulating the successors and dependencies of the construction sequence for equipment relocations and reconnections. The IWPs were then checked for consistency and content through a bottom-up approach by the field supervisors.

The packages were planned to be completed in single 12-hour shifts. Actually, each shift contained 10 working hours and had a two-hour time buffer. As the crews were composed by 10 to 15 persons, an IWP contained from 100 to 150 working hours. In order to establish a non-stop sequence of activities, the construction team organized production on two shifts per day.

Contents of IWPs

A typical IWP included the following main sections:

1. Safety procedures
2. Summary – table of contents
3. Scope of work
4. Sequence of activities
5. Quality control and permits
6. Bill of materials
7. Sub-trades
8. Equipment
9. Engineering documents
10. Completion punch list.

Each IWP was three to five pages long. Three of the contractors reported feeling overwhelmed by the volume of information within a single IWP, adding that it hampered the supervisors' ability to perform accurate final checks.

Issuance of IWPs

The final revision of the IWP was sent electronically to the contractor's superintendent and workface planner after the final approval of the construction team. The various contractors printed the electronic IWP and issued it to the field. In this case study, the consolidated version of the IWP was sent to the various contractors before the initial execution date, so to perform a final check for schedule and resource consistency. The CM contractor required the superintendents to revise and sign the final versions of the IWPs at least two weeks before the starting date. A backlog of IWPs was maintained by each contractor in order to absorb potential delays due to unforeseen circumstances.

Progressing IWPs

Major activities appeared in the project schedule, and the daily IWPs were tracked on Skyline and Excel, that showed a daily list of the packages scheduled for execution. Each contractor's superintendent controlled the progressing of site activities on an hourly basis and communicated the data to the workface planner and to the CM contractor's superintendents in charge of updating the project schedule through the IT suite. For the control process, the CM contractor defined specific procedures and designated the monitoring of each IWP to a specific superintendent. Meetings between the owner and other contractors' representatives were organized at the end of each shift, every 12 hours. Given the tight schedule requirements, the focus of the meetings was on eventual delays and possible alternative solutions for minimizing the impact of unexpected contingencies.

Materials Management

Materials management did not pose a significant challenge on this project. The relocation activities made extensive use of consumable materials (e.g., fittings and fasteners), which were simply bagged and tagged to the field two weeks before the starting date. Materials requirement had been identified from the content of the various EWPs, which were translated into BOMs. Contractors developed their own purchase orders after Level 3 schedule definition. As materials were quite standard and had a limited stockage value, the various contractors purchased them in advance; although, all long lead items were procured by the FEED/detailed design engineering contractor. The materials management aspects of the project were covered entirely by the AWP procedure in a dedicated section of the IWP. The IT system adopted by the CM contractor allowed material requirements to be electronically stored and constantly updated and synchronized with construction operations.

Organizational Implications

The construction team was composed of the following organizations:

- construction managers of the owner
- subject matter experts of the owner
- CM contractors' construction managers
- AWP champions of various companies

The contractors allocated different resources to the planning teams, in accordance with their knowledge of AWP methodology. In general, the companies with higher AWP-related expertise were able to use fewer workface planners (WPs) (e.g., the owner had one WP per 100 craft workers, and the IC had one WP per 50 craft workers). The number of WPs needed also varied by construction discipline. Repetitive and predictable work required fewer workface planners (e.g., relocation activities required on average one WP per 80 craft workers, while construction activities required on average one WP per 60 craft workers).

On the selection of workface planners, the CM contractor's project manager highlighted the importance of selecting people with high levels of construction experience. In this case, the CM contractor employed planners with prior experience as field supervisors. The IC contractor had no previous experience with AWP and reported thinking that the planners' expertise was not adequate to manage correctly the release sequence of IWPs during project execution and that caused delays and an unfair distribution of workloads between the crews.

Figure 10 shows the composition of the entire project during the peak period:

- 889 craft workers
- 15 workface planners
- 60 foremen
- 10 superintendents.

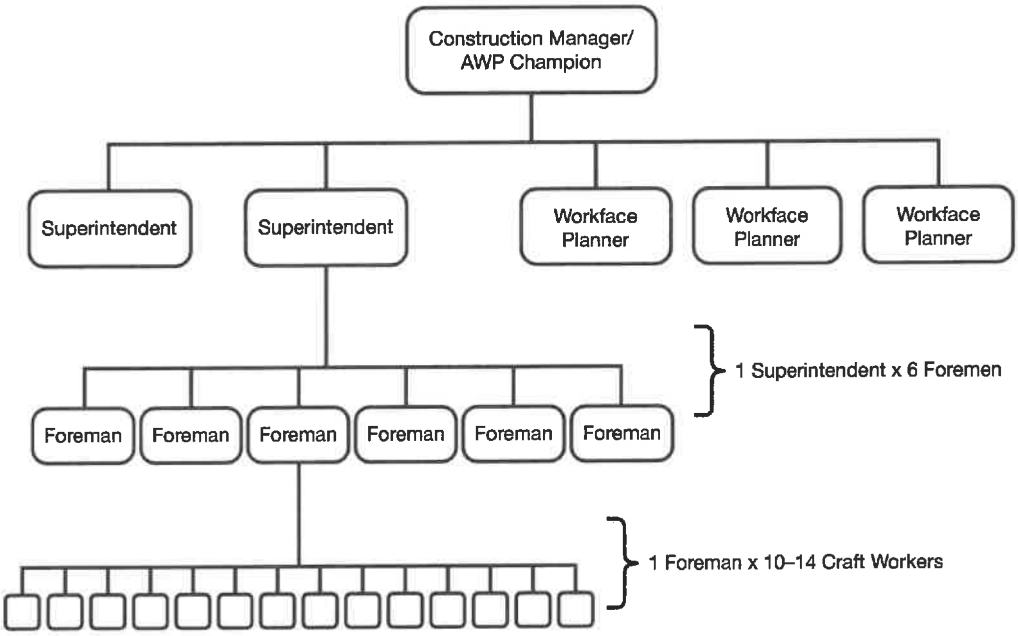

Figure 10. Case Study 8: Proportion of Field Personnel to Planning Personnel

Project Performance

The section aims to assess the impact of the AWP methodology on project execution through quantitative and qualitative indicators. The implementation of AWP drove the successful completion of the project, the high levels of risk due to project size and schedule pressure notwithstanding. Unfortunately, the uniqueness of the project did not allow the research team to verify the inverse relationship (i.e., that not implementing AWP results in poor project performance). For example, the research team was unable to compare this project's performance with that of other projects that did not implement the methodology. However, the results (with AWP) were compared with the average results achieved by project participants in the past (without AWP), to determine how AWP influenced construction procedures and operational performance.

Safety Performance

The novelty, complexity, and long shift duration of construction activities resulted in a high level of safety risk for the workforce. To mitigate this risk, each IWP contained a special section that considered the various risk factors involved within the single package. The section included both general prevention norms as well as specific field-level risk, such as the use of scaffolding and other known risks. The highest level of safety is required in order to execute a fast-tracked project flawlessly.

The project achieved better safety records (TRIR = 0.58) when compared to the average of other projects performed in the same geographical area. Zero lost time injuries happened after four million working hours. The CM contractor's construction manager emphasized the positive impact of AWP on safety performance and also on the attitude of the workforce toward safety. The project director of an MEC contractor said that the major safety benefit was the awareness level that the crew achieved after only a few hours of work. Being in the same working zone for a prolonged period of time fostered employees' confidence about recognizing the potential hazards and about the preventive measures to take. The IC contractor also achieved an excellent safety performance, a rate that was better than company's historical norm. In particular, the project control manager noted how the early delivery of IWPs had allowed the crews to take more time to focus on safety.

Schedule Performance

The financial risk to the owner in the case of late delivery accounted for the criticality of schedule adherence to this project. Final schedule performance surpassed original estimates, and the construction team did not have to use the schedule reserves (20 percent of total) that had been established between the two relocation efforts. The project team delivered the project four months ahead of schedule, without ever succumbing to the pressure to exceed maximum working capacity. This excellent schedule performance was due to the team's realistic and construction-oriented planning. The construction team considered AWP a best practice for project planning and execution, especially on projects with strict schedule deadlines or when operations entail a high level of novelty in terms of contingent site conditions and project scope.

Cost Performance

In spite of the schedule-driven orientation of the project, Company D sought to execute the project in the most capital-efficient manner possible; this decision was motivated by the parent company's perception of the funds needed for the relocation as detracting from the value of site resources. In the end, the project did not absorb additional resources and was completed saving more than 10 percent of planned TIC. Both owner and contractors reported that field productivity was approximately 25 percent higher than the average for projects performed without AWP.

Quality Performance

In terms of field rework, the CM contractor representatives noted that the relocation phase did not incur significant changes, while the construction phase had many small changes (total scope changes corresponded to 25 percent of total). An MEC contractor stated that its percentage of scope change was between 10 and 30 percent. In particular, changes and rework were concentrated in the delivery of work fronts, with major impacts at the execution access points. The CI contractor reported many small project changes (ranging from minor to 15 percent) and a field rework rate that came in at below five percent and that progressively diminished during project execution.

AWP Benefits, Difficulties, and Lessons Learned

Besides showing the striking performance improvements achieved by the construction team, this case study evinces a set of additional and valuable benefits that clearly improved project execution. Identifying such benefits and examining the difficulties associated with implementing AWP is crucial to analyzing (and understanding) the methodology and providing guidance for other managers. To these ends, the research team asked the study participants to describe the lessons learned from their AWP implementations. Table 12 provides an overview of major AWP benefits, difficulties, and lessons learned.

Table 12. Case Study 8: AWP Benefits, Difficulties, and Lessons Learned

AWP Benefits
Reduced Impact of Uncertainty
FEED Included Constructability Principles
Promotion of Proactive Team Culture
Supervisors Spent More Time Supervising
Increased Craft Retention
Increased Predictability
Improved Information Visibility
RFIs Shifted to the Planning Phase
Process Improvement
Performance Benchmarking
Increased Workforce Empowerment
AWP Difficulties
Shortage of Skilled Workface Planners
Change Inertia
Lack of Scope Freeze
Delayed Documentation from Engineering
AWP Lessons Learned
Full Adherence to AWP Procedures (Constraint Analysis)
Early Involvement of Key Project Participants
Integrate with Operations

AWP Benefits

Reduced Impact of Uncertainty. An MEC superintendent reported that construction activities were conducted with excellent clarity, with thorough explanations of work scope and expectations. In particular, AWP provided significant added value for supporting trades, providing easier take-over, incorporating the contingencies, and mitigating the project risk.

FEED Included Constructability Principles. The owner acknowledged better collaboration between the project disciplines—especially construction and engineering—but also among different construction sub-disciplines. The IC and MEC contractor reported that AWP allowed the different disciplines to communicate intensively to reach agreement on the definition of the working sequence. The increased collaboration among construction sub-disciplines (e.g., between mechanical and electrical) was particularly useful during construction activities.

Promotion of Proactive Team Culture. The early involvement of engineering and construction representatives from various contractors helped shape a proactive team culture. This open atmosphere emerged from and was strengthened by the mutual sharing of know-how of both departments, especially during the constraint minimization process.

Supervisors Spent More Time Supervising. Superintendents reported that they had more time to focus on field activities and, thus, were actively able to develop preventive solutions to potential problems.

Increased Craft Retention. Contractors noted that the rate of personnel turnover decreased during project execution. Superintendents stressed the criticality of craft retention for a labor market such as Alberta. The interviewees saw higher morale in the working environment and closer alignment between the crews and the planning team.

Increased Predictability. Despite the fact that the project had unique characteristics, the construction professionals on site were able to work collaboratively to define a trustworthy and robust working sequence. The final outcome of the planning process was a set of IWPs that provided detailed scope decomposition with high construction predictability.

Improved Information Visibility. The MEC contractors reported that AWP reduced the impact of personnel turnover during project execution. Because the packages are designed to be complete and ready for use by each superintendent, they make delegation easier and facilitate internal and external transfer of information (e.g., for reporting or RFI management).

RFIs Shifted to the Planning Phase. Since engineering was not promptly generating drawings, and some unexpected variations were faced on site, the CI contractor faced more RFIs than expected. However, most of the responses to the RFIs (70 percent) were generated during the planning process. This ability to handle them early meant that they did not hamper field activities.

Process Improvement. The IC contractor noted that after few weeks of training, field workers notably improved construction operations by following AWP procedures. This was due to the fact that the sequence of activities and the scope of work had been assimilated by the superintendents in advance, and the packages had been defined by skilled people with construction background.

Performance Benchmarking. Since the owner will require other massive relocations in the following years, the construction team performed a detailed analysis of the root causes of construction problems. To this end, the causes for IWP non-compliance and delay were thoughtfully investigated after project execution.

Increased Workforce Empowerment. Because they got involved at the initial stages of planning, construction personnel had a major influence over the development of the entire project. During project execution, having this higher level of knowledge about project activities allowed the project team to promptly re-allocate resources to minimize the impact of changes.

AWP Difficulties

Shortage of Skilled Workface Planners. The IC contractor indicated that the major difficulty of successfully implementing AWP was the increased upfront resource requirements during the planning process (i.e., it required three times the number of planners needed on a previous project of similar size).

Change Inertia. Contractors also noted that their lack of skilled construction people on the workface planning team, especially at the beginning of the process, hampered the effectiveness of the project planning. However, as a project control manager of an MEC contractor pointed out, the success of the project hinged greatly on overcoming this initial barrier and, thus, required a strong commitment during the early planning process and the involvement of all project participants from the beginning. After initially resisting the process—especially given the limited flexibility of superintendents—the entire organization has now accepted the AWP process.

Lack of Scope Freeze. Although the project team implemented AWP procedures with extreme accuracy on the relocation, it experienced some scope creep on the new construction. This scope creep happened mostly during turnover, which increased the amount of rework needed and exposed the project to schedule risk.

Late Engineering Deliverables. In certain cases, IWPs had not been updated to their latest versions, and there were incomplete engineering drawings. Since the superintendents did not want to be accountable for unauthorized operations, the construction process faced some delays.

AWP Lessons Learned

Full Adherence to AWP Procedures (Constraint Analysis). The various contractors agreed that they would have benefited from a defined explanation of the AWP process and of related procedures at the very beginning of their work with the owner. The lack of initial training necessitated an additional unilateral effort by the contractors that would have been easily avoided, had an improved communication process been established at the outset. Since the initial construction team faced some changes during the planning process—mainly due to reassignments and replacements—these transitions would have been easier if knowledge support on AWP process and procedures had been available.

Early Involvement of Key Project Participants. The minor contractors that were not involved in the planning process had significant difficulty adapting their procedures to the AWP methodology. The CM contractor faced a high execution risk in not having engaged with every contractor from the beginning of construction activities, since even crews performing ancillary activities can create operations bottlenecks if they are not informed in advance. The CM contractor recognized that all contractors should be involved, no matter their levels of engagement. To accomplish this total involvement, the IC contractor proposed that the procedures should be customized according to the characteristics of the receiver, reflecting the peculiarities and the different responsibilities of the various roles.

Integrate with Operations. As mentioned in the Project Description section above, the construction team worked alongside the maintenance department during the relocation, with requirements that did not exactly match the established project sequence. Given the tight project schedule, the construction team required complete visibility on the repair activities. This meant that, to work within the AWP framework, the maintenance department had to deliver its detailed plan of activities. The project was complemented by a collection of services that adopted the same planning methodology in order to achieve the project goal and meet the project deadline. Interestingly, this project proposed a scenario in which the operations and management (O&M) department adapted its scheduling methodology to the one embraced by the construction department, and not the other way around.

Case Study 9

Project Characteristics

Sector: Industrial

Sub-sector: Power/hydro-electric

Project Type: Refurbishment and extension

Project Location: Canada

Contract Type: Fixed price

Project Cost: $30 million CAD

Construction Duration: Eight months

Construction Hours: 90,000

Project Description

The project involved the expansion of an existing hydro-electric power generation facility in Canada. To define the scope of work, the owner engaged experienced construction consultants during project concept definition to establish the initial path of construction and determine constructability constraints. After initial demolition, the major part of the project involved electrical-mechanical activities. Two main general contractors (GCs) executed the project: the first one focused on the construction of the turbine and generator; the second one was responsible for the balance of plant (BOP) portion of the project. These GCs were selected through a bidding process, and were awarded a fixed-price contract. The project included the refurbishment of existing facilities. Since it was equally cost- and schedule-driven, no intensive compression techniques and cost-cutting measures were undertaken.

The project's unique design was the most critical factor for the owner, and it required focused planning attention. Also, it was important to keep a second unit in operation at the same power house. The owner project team decided to adopt AWP to execute a rigorous detailed planning process in alignment with construction deliverables, in order to achieve the desired level of productivity and safety. Another critical issue was the simultaneous coordination of two main GCs onsite. The decision to adopt AWP was also driven by the BOP GC's limited experience on hydro-electric projects and by the need to develop integrated plans with clear divisions of responsibilities and duties, while maintaining high levels of productivity and control on field operations on such a small jobsite.

Prior Construction Experience

Generally, an owner's decision to use AWP depends on project scope and GC expertise. For projects that can re-use previous design specifications, the owner typically does not implement AWP. Conversely, when the design has consistently novel elements, and the construction requires high levels of specification detail, AWP allows a systematic drill-down of each work package, clarifying complex interdependencies between distinct construction disciplines.

The other key project participants, the engineering company and the GCs, were not familiar with AWP methodology. The owner set up intensive training sessions to clarify project roles and procedures, and to prevent any negative schedule impacts on the detailed engineering process.

AWP Implementation

AWP Procedure

The owner developed the initial sequence and scope of work together with construction and engineering consultants. During FEED (which, on this project, absorbed approximately 10 percent of TIC) the project is first divided into systems and then into CWPs. For example, a "service water system" is a single system comprising a single CWP, while a "cooling water" system is a major system that is divided into multiple CWPs. At 30-percent design completion on this project, a few of the contractors were involved in developing exploratory quotes to generate budget estimates. These companies also provided constructability input that supported engineering during the planning process. The definition of CWPs and EWPs was driven by the largest portion of the project (generator and turbine construction), and the BOP packages were released all at once to the GCs at 80- to 90-percent design completion. The GCs reviewed the constructability of the plans to reach 100-percent agreement on construction sequences and estimates. This early involvement in the planning incentivized them to provide all their RFIs before construction activities began. Ultimately, the GCs translated each CWP into a set of IWPs for field execution, taking into account the completion dates and the estimated resources needed in terms of frontline personnel, equipment, and materials.

Once this part of the IWP development process was complete, the owner performed a final review and approved the content of all IWPs, ensuring that safety concerns and a complete scope of work were taken into account and included within the packages. Also, the owner used procedural requirements and of predefined guidelines (derived from Construction Owners Association of Alberta Best Practices) to make sure that AWP expectations were included in the GCs' contracts. Moreover, the incentive and payment structures were aligned with AWP deliverables, so that GCs were rewarded after CWP/IWP completion for their adherence to schedule and quality requirements.

To foster a seamless communication process, project stakeholders made intensive use of the project's information-sharing platform. This platform allowed for data-synchronization and data-conversion across various formats. The owner, together with engineering and the GCs, defined what information they required and identified the interface points between the departments.

Contents of IWPs

IWPs included fewer than 1,000 construction work hours for every discipline. The typical IWP included the following elements:

1. Safety procedures
2. Scope of work
3. Interdependence of IWPs
4. Workforce/labor
5. Material free-issued by the owner
6. Quality control requirements
7. Check list
8. Scaffolding, lifts, and specialty tools
9. Engineering documents
10. Materials forecast
11. Waste management
12. Rigging and crane usage
13. Lessons learned.

Issuance of IWPs

The project team was sure to maintain a backlog of IWPs, to be prepared to temporarily re-assign frontline personnel to other activities in the event of unexpected accelerations or decelerations in project execution. For example, during the turbine scope of work inside the generator building, the two GCs performed sequential activities. If the first GC were to face delays, the second one (the BOP GC) would be ready to switch to support the execution of the delayed IWPs. The owner required the packages to be issued to the field two weeks prior to the beginning of construction activities. The owner considered this lead time was considered adequate, due to the comparatively small size of this specific project.

Progressing IWPs

The project controls process was developed in accordance with AWP deliverables, starting in the FEED phase. Structured at the CWP/IWP level, the controls metrics were gathered bi-weekly at the actual level of IWP completion and compared to estimates. However, the owner reported that project controls mainly involved tracking CWP/EWP execution, rather than IWP execution.

Owner representatives performed quality inspections and signed off on each CWP/IWP after completion. If any IWPs failed the quality test, they were held back, their payment withheld, and their completion re-scheduled.

Materials Management

Procurement was driven by the engineering company, which provided the specifications for the various systems. The owner was responsible for the purchase of large items, such as specialty materials and equipment. The procurement of small items and commodity materials was delegated to the GCs.

Long-lead items were identified during the FEED stage, to trigger the beginning of the procurement process. Suppliers were identified during detailed engineering and had either been recommended by the engineering company or included in the owner's pool of preferred suppliers. These preferred supplier relationships were characterized by long-term agreements and pre-approved design solutions. The definition of specifications became protracted, extending into the detailed engineering stage. At this stage, all required materials were identified and included into CWPs; this clarified the estimated delivery date and determined which participants were responsible for different purchases. This planning for the procurement of long-lead materials was to ensure their availability on site with a time buffer of about two months. The delivery of other materials was required within two weeks prior to the execution of field activities. Once they had arrived on site, the materials were bagged and tagged in accordance with IWP requirements.

Organizational Implications

The GCs and the engineering company were required to add specific professional roles to cope with AWP adoption. Such roles included an increased number of planners, on both the construction and the engineering side, all of whom were responsible for the definition and control of packages. These professionals from both the owner and GC companies received AWP training specific to their project roles. Other specific roles prescribed by AWP guidelines (e.g., the AWP champion) were not included; those responsibilities were assigned to other roles already filled in the organization (e.g., the project manager). In retrospect, the owner would have put an AWP champion in place as a full-time position.

Project Performance

Safety Performance

The project had zero lost time safety accidents. The owner reported that the project was systematically planned around the safety dimension, starting with preliminary planning. Throughout the project, AWP reinforced the project's safety culture, focusing foremen and crews on safety activities and providing achievable construction objectives that did not require overrun measures.

Cost Performance

The project did not meet initial cost estimates, due to scope changes made during detailed engineering. However, because of the fixed-price contract, the owner could not determine the difference between approved budget and effective project cost at the AWP level. In terms of productivity, the owner reported that tool time was higher in comparison with traditional projects without AWP. This outcome was particularly significant, due to the productivity-hampering space constraints of the project.

Schedule Performance

The BOP scope of work was delivered on schedule. Despite an initial delay in field mobilization caused by the late completion of a previous project on the site, the GCs met intermediate and final milestones without intensive recourse to extra shifts. The project management team perceived the delayed field mobilization as beneficial, since it allowed field activities to start with adequately detailed engineering specifications.

Quality Performance

The owner reported that project quality was average in comparison with previous projects. Rework was necessary on between five and 10 percent of construction activities. Major difficulties were reported for the electrical discipline, due to both change requests and to actual engineering deficiencies.

AWP Benefits, Difficulties, and Lessons Learned

Besides the above-mentioned project performance improvements, the present case study also found a set of additional AWP-related benefits, challenges, and lessons learned. (See Table 13.)

Table 13. Case Study 9: AWP Benefits, Difficulties, and Lessons Learned

AWP Benefits
Accountability
Reduced Impact of Uncertainty
Streamlined Construction Process
Increased Predictability
AWP Difficulties
Lack of Buy-in
AWP Lessons Learned
Full Adherence to AWP Procedures (Constraint Analysis)
Early Involvement of Key Project Participants

AWP Benefits

Accountability. The agreement on the final version of IWPs by foremen and superintendents resulted in increased commitment to perform construction activities in accordance with plans.

Reduced Impact of Uncertainty. The inclusion of a backlog for IWPs allowed switching construction crews across different tasks in case certain constraints could not be solved for planned IWPs. GCs were then able to re-allocate the crews on different activities without reducing field productivity through waiting and waste of time.

Streamlined Construction Process. The IWP development process allowed streamlining construction activities when multiple contractors were operating onsite at the same time through a clear subdivision of work and responsibilities, which resulted in orderly working and inventory areas.

Increased Predictability. Engineering deliverables were almost completed when delivered to the GCs. Plans were then reviewed and modified in case of errors, misalignment with the preferred construction sequence, and missing details. Although these packages were constraint-free and included agreed-upon specifications to be performed within realistic targets, greater emphasis on constructability would have been beneficial.

AWP Difficulties

Lack of Buy-in. The owner reported that a higher involvement during the control of estimates would have improved the reliability of IWPs. Achieving full commitment on AWP procedures was identified as a fundamental element to obtain a shorter learning curve and the related immediate AWP benefits.

AWP Lessons Learned

Full Adherence to AWP Procedures (Constraint Analysis). Instead of implementing the methodology starting at the initial project development stage, the project only gradually implemented AWP during FEED and detailed engineering. This later implementation caused the project to lose some of the typical benefits related to early adoption (e.g., the focus on constraints minimization). Also, the owner reported that the schedule controls process should have been more systematic and aligned with IWP execution. This would have further reinforced the adoption of project guidelines and showed the commitment of the owner to AWP adoption.

Early Involvement of Key Project Participants. Had the engineering company had the input of construction managers during the initial planning definition, it would have been able to make more reliable estimates and to meet the schedule deadlines of the planning process. The owner reported that the project would have had better integration and would have been able to adhere to estimates, had the GCs been involved in the process at least by 50-percent engineering completion, instead of at 80- to 90-percent completion.

Case Study 10

Project Characteristics

Sector: Industrial

Sub-sector: Oil and gas

Project Type: Water treatment – modular

Project Location: Northwestern U.S.

Contract Type: Lump-sum

Project Cost: $30 million USD

Construction Duration: Six months

Construction Hours: 16,000

Project Description

This case study focuses on the construction of water treatment facility modules in the U.S. for a larger oil and gas project in Alberta, Canada. The extraction site was expanding its steam-assisted gravity drainage (SAGD) activities and required new building facilities to support the de-oiling process and warm lime softener operations. RT 319 investigated this project because of its application of AWP on a modular project. Moreover, this case study assesses the first pilot implementation of the methodology for the general contractor (GC). Thus, the investigation can highlight the dynamics that occur within an organization during its initial adoption of AWP adoption.

This modular project was executed by the GC, who received the drawings and specifications from an external engineering company. The project involved the fabrication of four main modules, which were provided by an internal production facility (piping) and by an external subcontractor (steel). The fabricated materials were shipped to various assembly facilities in the northwestern U.S., where the various pieces of equipment (mainly electrical, piping, steel, and insulation) were installed and the modules were brought together. The modules were then sent to the site in Alberta as components of the water treatment facility. The owner selected the GC for its experience performing modular projects and chose a lump-sum contract strategy.

The project did not have a dominant business driver, and all the cost, schedule, and quality dimensions were considered important. The project made extensive use of offsite fabrication—outsourcing the production of certain construction modules—in order to reduce cost and time. However, to link the modules on the field properly and, thus, to achieve the benefits of modularization, the project adhered to strict quality requirements.

Previous Workface Planning Efforts

The general contractor specializes mainly in executing modular projects that mainly involve the steel, insulation, electrical, and mechanical disciplines. The GC noted that, compared to previous projects on which the owners simply provided partial specifications about the scope and the sequence of work, the owner's involvement in the detailed definition of work-packaging on this project significantly improved its predictability. The company felt that it needed major input from the construction side during FEED, and that the output of the planning stage should have been closer to the executable construction work. The inclusion of constructability principles in the engineering plans is a key element for modular projects and was the main motivation for implementing AWP on the project. Indeed, the methodology was chosen for its ability to incorporate constructability principles, beginning at the initial project development stages. This early input enables project teams to align the different disciplines, ensuring that the scope and sequences of construction are agreed-upon and understood by the different project players. Another motivation for AWP adoption on this project was the necessity to create a reliable and updated connection between the schedule and the execution of construction activities. Typically, construction personnel have limited access to estimates and planning deliverables, and this creates misalignment with subsequent lack of accountability for the execution of field activities.

AWP Implementation

AWP adoption was driven by the owner, who wanted to be more involved in the detailed planning and to have access to the detail of each construction package. The project players designated an AWP champion, who was mainly responsible for project control, schedule development, and oversight of the project team. His purpose was to achieve consistent performance between different projects.

Besides designating an AWP champion, the GC assigned four other senior managers to participate (with different levels of involvement) in the definition of AWP guidelines and procedures. In particular, these roles included a fabrication operations manager, a project control manager, a facility coordinator, and a project manager. The safety manager was also involved, but at a subsequent stage. The team defined the planning and operations gap, and provided an AWP format aimed at filling this gap. By making this significant top-management commitment, the GC showed its support for the adoption of the methodology.

The various project departments and functions communicated through a Web-based data repository. (Most of the information was also accessible from mobile devices, in case field personnel needed to consult databases or procedures.) Using this system, the different project teams provided the most up-to-date documentation and information and, thus, avoided any long information lead time that would hamper the planning process.

AWP Procedure

The GC, together with the owner, provided initial project definition, highlighting project strategy, scope, and key milestones. The engineering company participated at a later stage, and this resulted in a difficult alignment and extensive design changes during operations. By means of the EWPs, the engineering company provided the specifications to the GC at Level 3 schedule detail. The various EWPs were first grouped by discipline for the modules and then delivered to the GC, who reviewed and approved them. On the basis of this documentation, the GC developed the detailed construction plans, which resulted in the definition of IWPs. The project team reported a strong commitment to sharing and agreeing on construction estimates. The definition of the detailed budget was based on the Level 3 schedule, which included the details on module content and material deliverables. This information enabled the team to develop work packaging deliverables with an intermediate level of granularity, similar to that of the CWPs, which included four to six weeks of work for approximately 2,500 work hours.

At this stage, the path of construction had been carefully reviewed by the GC, who provided additional information on the modalities of assembly. The GC also put particular emphasis on including job safety analysis into construction plans and sequencing; the intent was to minimize specific safety constraints by including pre-test modular analysis and jobsite hazard analysis. After the CWPs were developed, the various superintendents signed and agreed upon the plans.

The whole project was pre-tested through 3D models by the GC, to assess the construction sequences and the feasibility of interdependences before the delivery of the IFC drawings. These simulations allowed the GC to examine module specifications at various levels of detail, to support the definition of the IWPs and their related bills of materials, which occurred after all engineering deliverables were provided. Because the fabrication activities for the modules reduced much of the uncertainty that building them in the field would have introduced, all IWPs were completely defined prior to construction execution.

Contents of IWPs

The IWPs on this project were designed to take fewer than 300 working hours and a no more than one week to complete—conditions that were considered ideal to achieve the required level of detail to support field activities. Each package was given a serial ID number, and its content was defined according to the requirements of frontline personnel in the various disciplines. A typical IWP included the following:

1. Safety procedures
2. Scope of work
3. Sequence of activities
4. Materials and equipment
5. Engineering documents (e.g., 3D model shots and P&IDs)
6. Interdependencies with other IWPs.

Issuance of IWPs

Hard copies of the IWPs were sent to the general foremen responsible for execution of the packages two weeks prior the start date. The use of hard copies was enforced by the GC, who noticed that the superintendents and foremen would abandon the electronic IWPs and would replace them with alternative and unauthorized planning resources. Intensive training was also provided to support the use of electronic platforms and to ease this transition for the frontline personnel.

Progressing IWPs

To align the project's control process with the AWP deliverables, management tracked site activities on a weekly basis, with a focus on the amount of resources (work hours and materials) utilized to execute each task. The planners used this information to verify adherence to project plans and to react promptly to any deviations. An IT tool kept track of package execution, alerting management to any delays and identifying their causes.

Since quality control is so critical for modular projects, the output of each IWP was compared to its specifications. Before an IWP could be considered complete, the quality and control (Q&C) crews had to sign off the package and return it to the planning department. Once the planners received it from the Q&C crews, they updated the project schedule. This process ensured the proper transition between different disciplines and crews onsite.

Materials Management

Identified at the Level 3 schedule, the bill of materials accommodated the time needed for the delivery of the items required by each IWP. For this project, materials procurement was divided between the GC and the owner. The former was responsible for piping and fittings. The latter purchased valves and electric components, providing them to the GC in accordance with the delivery dates of the IWP schedule. After the materials were received at the onsite warehouse, they were grouped by IWP. The bill of materials was checked for consistency for each package, and the required items were bagged and tagged two weeks before the execution of the IWP. The GC decided against just-in-time deliveries and opted for the bi-weekly buffer, to shield the project from unexpected contingencies. The Q&C personnel inspected all the equipment and the materials after their arrival. The Q&C also checked to make sure that delivered materials corresponded to the engineering drawings and the specifications.

Organizational Implications

The GC defined the role of the planner by extending the typical duties of field supervisors, asking them to support the subdivision of CWPs into IWPs and to control package execution. The planners were also part of the project team that defined the bill of materials and grouped the drawings and specifications by IWP. The site manager, together with the superintendents, defined the interdependencies between IWPs, determining the duration of each package and the amount of work hours required to complete its scope of work.

The following proportions between the operations and the planning roles emerged (see also Figure 11):

- One superintendent was responsible for almost 40 craft-persons.
- One planner (field supervisor) was employed for every superintendent.

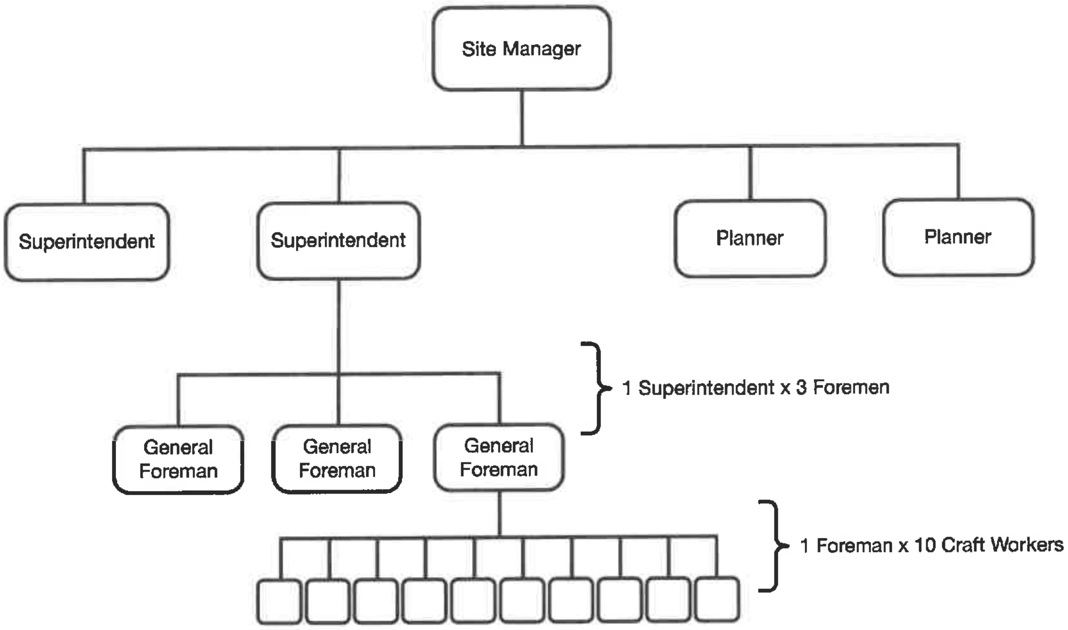

Figure 11. Case Study 10: Organizational Structure

Project Performance

Safety

Safety performance was aligned with the historical performance of the GC, who achieves rates consistently below national average. From this perspective, AWP implementation did not affect the portion of the project involving modularization. This was not surprising, since the installation of modules is typically characterized by accident-free performance.

Cost Performance

Although the project began with a labor estimate of 24,000 assembly work hours, it only required 16,000. This savings corresponded to a 33-percent decrease and a nearly 10-percent reduction on total TIC. In comparison to previous water treatment projects completed by the GC, this project was the one most successful. It stood out particularly, given that the project scope faced 15-20-percent engineering changes. Such changes can be particularly critical for modular projects, which require early design freeze to be successful. Because management created contingency plans, the project had enough flexibility to avoid the danger these changes posed to project duration and quality.

In terms of productivity, offsite fabrication activities showed an increase of productivity, mainly due to the reduction of change orders (less than five percent). On site, the smooth execution of regular assembly activities was evidence that the waiting time for missing materials and specifications had been almost eliminated (around 33 percent).

Schedule

The project schedule was negatively affected by the extensive scope changes, since they forced project management to shut down field activities for a few days in order to redefine the sequencing of activities and re-align the path of construction. Despite this delay, the project was completed in accordance with the planned deadline.

Quality

The contingency reserves were not used up, and the amount of rework was lower than on previous similar projects. AWP supported project quality by systematically highlighting the interdependencies between modules and by minimizing the risk of inconsistent planning. The engineering changes were a source of RFI generation for this project. However, the amount of RFIs shifted from construction to the planning stage, where they have a minor impact on project cost and schedule.

AWP Benefits, Difficulties, and Lessons Learned

The interviewees noted several improvements and challenges in relation to AWP implementation. Their comments are discussed below in terms of the major AWP benefits, difficulties, and lessons learned. (See Table 14.)

Table 14. Case Study 10: AWP Benefits, Difficulties, and Lessons Learned

AWP Benefits
Improved Accountability *Enhanced Project Predictability* *Faster Communication and Recovery* *Scope Clarity* *More Time for Supervisor Supervision* *Support for Modularization Strategy*
AWP Difficulties
Change Inertia *Lack of Scope Freeze*
AWP Lessons Learned
Full Adherence to AWP Procedures (Constraint Analysis) *Standardization of Construction Approaches* *Subcontractor Involvement* *Inclusion of AWP in Key Participant Contracts* *Steep Learning Curve*

AWP Benefits

Improved Operations Accountability. The GFs and superintendents signed and agreed on the scope and sequencing of the various packages. The quality checks after the completion of each IWP ensured the proper transition between different crews from distinct disciplines. It also forestalled the search for other crews to blame for previous quality errors (actual or imagined) and prevented expensive rework.

Enhanced Project Predictability. The GC reported that the planning process was more detailed and precise than it was before. Every IWP was related to specific budget and resource estimates, allowing the systematic drill-down into activities and the development of reliable high-level plans at both the schedule and cost performance level.

Faster Communication and Recovery. Each deviation from plan can be promptly identified and communicated to the owner and to suppliers/subcontractors. The intensive control process at the single package level and the various lines of communications that are open across project stakeholders result in a reduced information lead-time and in a more reliable connection between the schedule and the actual construction process.

Scope Clarity. Frontline personnel understood the project's path forward. The superintendents and the foremen reported feeling empowered by the early agreement, saying that the early involvement provided them an overall vision of the project. This empowered field-level leadership generated enthusiasm among the crews. Moreover, because the improved scope clarity increased the crews' awareness of the impact of changes on the chain of activities, they were less likely to make unauthorized deviations from approved plans.

More Time for Supervisor Supervision. The site manager reported that AWP greatly eased supervisors' burdens during construction execution. Instead of reactively addressing continuous emergencies due to missing materials, equipment, and specifications, the systematic planning and development of the IWPs allowed supervisors to focus intensively on field activities. The improved supervision was extremely beneficial for the quality of construction activities, since it meant that potential issues were more likely to be promptly identified and addressed.

Support for Modularization Strategy. The early and reliable development of work packages is a pre-requisite for successful modularization projects. The enhanced reliability of module specifications (based as they were on the early packages) allowed project management to increase the amount of offsite fabrication activities for the project. This reduced the amount of construction activities with their attendant risks (e.g., due to weather and site conditions). Also, the offsite relocation of construction activities is closely related to efficiency improvements and to reduced safety hazards.

AWP Difficulties

Change Inertia. Frontline personnel perceived AWP as a threat to operations. The crews initially rejected the methodology, perceiving the increased attention to planning as "micro-managing" the execution of activities. At the supervisory level, the change management process was carefully managed to minimize resistance and get the approval of key users. However, after this initial period of inertia, the methodology was fully accepted and considered a positive new approach to the safe and systematic execution of activities.

Lack of Scope Freeze. The owner made several scope changes that hampered the reliability of estimates. The implementation of AWP requires early design freeze, especially for modular projects. The risk of making changes later is that it can frustrate construction management and crews that have to re-schedule construction activities.

AWP Lessons Learned

Full Adherence to AWP Procedures (Constraint Analysis). The project team reported that AWP implementation required the full commitment of top management and that implementing AWP after a project has begun limits its benefits and increases change inertia. Top-management commitment does not mean that the procedures have to adhere strictly to those prescribed. Indeed, a certain level of flexibility is preferable, as long as the whole organization is aligned in the same direction. To ensure the integrity of the process and to demonstrate management's commitment to full adoption of the guidelines, audit procedures should be developed to measure implementation and satisfaction.

Standardization of Construction Approaches. The systematic application of AWP to multiple projects will promote best construction practices that will become the standard for project execution. It will become routine to use AWP to include multiple constructability options, enhance construction productivity, and increase the reliability of estimates. Also, the use of AWP will allow for the early capture of safety knowledge and its systematic inclusion into project plans.

Subcontractor Involvement. A future development will be to define procedures for guiding and controlling work package execution by subcontractors. Since, on this project, the information-sharing process with them was not formalized or aligned with the development of the work packaging deliverables, they did not provide adequate input to engineering and GC. Moreover, although the subcontractors performed modular activities, they were not involved in AWP execution and had no incentivize to follow prescribed guidelines.

Inclusion of AWP in Key Participant Contracts. The project team sees the inclusion of AWP expectations and guidelines in contracts as the next evolution of its implementation of AWP. The owner expressed a desire to make field activities more visible and to include specific contractual norms that would enhance the visibility of the contractor's system. The GC was planning to implement a system with this kind of visibility on a project it expected to begin soon after the completion of the project under study.

Steep Learning Curve. After seeing the success of this project, the GC decided to implement AWP for other modular projects. Various senior managers reported that the methodology was successfully adopted at all organizational levels, improving the company's ability to develop reliable and complete work packages in adherence to AWP guidelines. The learning curve effect quickly resulted in increased accuracy of estimates and improved project predictability.

Case Study 11

Project Characteristics

Sector: Industrial
Sub-sector: Power
Project Type: Co-generation
Project Location: United States

Contract Type: Cost reimbursable
Project Cost: $2 million USD
Construction Duration: Eight months
Construction Hours: 10,000

Project Description

The scope of this project involved the design and execution of four co-generation systems to support nuclear plant operations. The 48-month duration was long for such a small project, but throughout the entire project, the periodic need to isolate parts of the interconnected subsystems limited actual execution time on each one. That is, since the project team could only work on one subsystem at a time, construction on each of the systems required the temporary shutdown of parts of their linked equipment as the worked progressed. To maximize productivity during these brief execution windows and reduce their impacts on site performance, this project made extensive use of pre-fabricated activities outside the field. Main disciplines involved in the project included excavation, welding, and mechanical (assembling of valves).

The project management team included personnel from the owner organization (the nuclear site operator), the project management company (the group responsible for the planning and execution of this project), and the general contractor (a construction company prequalified to design and implement activities on nuclear sites). This case study examines the uniqueness of AWP on a small project in the nuclear sector, where the emphasis is on the quality and predictability of construction activities, rather than on cost performance. Because the site's stringent procedures and strict regulatory environment require continuous control of the construction process, the project team chose to implement AWP to formulate predictable and detailed project plans.

Prior Construction Experience

The owner struggled during the initial planning and execution activities, causing costs to exceed the estimated budget significantly. In particular, the owner faced major design changes and poorly synchronized deliveries of major equipment and materials on site. As a result of these difficulties, the construction of the first subsystem was unsuccessful from both the cost and schedule perspectives. In the wake of this failure, the management of the project was assigned to another energy company (the project management company). This replacement organization was charged with developing a consistent final design and meeting all regulatory requirements.

AWP Implementation

AWP Procedure

The planning process was developed around nuclear regulations and had to adhere precisely to the owner's internal processes. Project planning included four main stages: 1) the definition of a conceptual design plan; 2) a detailed engineering stage; 3) an implementation/installation stage; and 4) a final closeout. For this project, the project management company got involved during the detailed engineering stage, reviewing the design deliverables, determining the sequencing of activities, and managing potential design modifications.

The project's conceptual design was performed by the owner and the general contractor. During this stage, they defined the scope of work and made decisions on the allocation of financial resources. The detailed engineering process was mainly performed by the general contractor, who had been prequalified to perform the process in accordance with owner requirements. Because of the project's limited scope, the GC diverged from AWP guidelines during detailed engineering, developing packages that did not differentiate between CWPs and EWPs. The outcome of the detailed engineering stage was a set of engineering design packages—high-level packages that include the design of engineering systems, procurement requirements, regulatory analyses, construction sequences, and commissioning and testing plans.

The owner also defined procedures to modify these engineering design packages, requiring that any changes be assembled into a revised package for review and approval. Subsequently, new packages would be distributed to the engineering team, who would update the schedule and allocate the resources in accordance with the modified scope. These high-level packages were broken down into elementary installation work packages, called work orders, and delivered daily to the construction team. Work orders differentiated between off site, on site, and turnover activities. Each work order had dedicated schedule, sequencing, and integration plans.

Dedicated planners (representing the contractor or the project management company) developed the work orders (equivalent to IWPs), using their relevant construction experience to ensure consistency across the various packages. The planners were first involved during the early detailed engineering process, so that they could contribute by providing constructability principles and reach alignment with the project management team. The outcome was an integrated project schedule at a level of granularity that defined the single tasks in the field. Particular attention was given to achieving a streamlined flow of activities across the various projects performed on site. The scope of the project was performed simultaneously with other construction activities, and the work packages were fundamental to defining precise scope boundaries and sequencing.

Contents of IWPs

Every implementation package had a unique identification number and included the following information:

1. Safety procedures
2. Risk management plan
3. Scope of work
4. List of activities, starting and completion date
5. Quality standard
6. Responsibility matrix drawings and sketches
7. Materials and equipment
8. Instructions and procedures
9. Control activities.

The work orders were grouped by discipline and did not have a fixed size in terms of work hours. For example, a welding work order typically involved more repetitive activities and could exceed one day in duration, while an electrical work order was more specific and had a duration of a few hours. In general, the rule of thumb was to limit a work order to 12 hours of work per crew. Again, the high level of detail was aimed at obtaining the maximum level of control on field activities.

Issuance of IWPs

The work orders were completed between three and four months before field execution. This early development of highly detailed planning was required by the owner, who had to approve the plans and ensure their consistency with regulatory specifications. After the issuance of the work orders, the construction superintendents checked their content in order to eliminate any chance of misunderstanding of to fill any potential sequencing or design gaps. Once they had signed off on a package, they became accountable for its execution. These implementation packages were distributed and retained in both paper and electronic versions.

Progressing IWPs

Project control procedures were defined during early project definition stages, and conducted at the work-order level through daily meetings and electronic reporting. At the end of each shift, owner and project manager representatives performed a quality check, ensuring that activities were on schedule and that documentation was properly maintained. This process ensured that the working crews were aware of the construction plans and sequencing at any given time. Project control status was also updated electronically at the task level, so that detailed information on field activities was updated online every 12 hours.

In accordance with regulations, quality inspectors monitored all the activities included in the scope of each work order package, ensuring that all required documentation was complete and that the appropriate parties had signed off on each one. These quality inspectors would return any incomplete work packages to the designated planners. The planner would then work with the construction company to re-schedule the activities. The outcomes of field activities were synthesized every month during high-level meetings, at which management would discuss project performance and address potential challenges.

Materials Management

The supply chain function of the project management company was mainly responsible for the procurement of materials. The general contractor provided support for this effort by offering consulting services when the project required customized and complex parts. Starting in the early planning stage, supply chain representatives first defined materials with long-lead time requirements. Given the strict supplier and material certification requirements on the project, these supply chain personnel needed a deep understanding of any materials availability issues that might have led to modifications to the initial design and/or contractual requirements.

Each engineering design package included a detailed bill of materials. This information was part of the project scope and accounted for vendor lead times and capabilities. The design was completed during the planning process, 12 months before the start of field operations. One month later—11 months before field operations—the planners used design specifications and consulted with the various suppliers to identify every long-lead item needed on the project. Purchase orders were issued at this stage and were subsequently controlled by project management. The material was shipped to the site six to eight weeks before the construction start date. This early delivery minimized the impact of unexpected delays and allowed for the quality inspection activities, which were performed by the GC and project management personnel.

Organizational Implications

The project management team identified organizational representatives of the various project stakeholders during the conceptual design stage. Key participants included engineering and craft installation leads, project controls personnel, and plant representatives knowledgeable about the project scope, schedule, and budget. Project roles, responsibilities, and reporting relations were defined and assigned during detailed engineering. In particular, human resource management was responsible for assessing the following aspects:

- organizational planning—when and how human resources are brought onto the project.
- agendas for meetings—weekly/bi-weekly core team and stakeholder meetings
- resource requirements—for both engineering and craft activities
- schedule status updates—to ensure the timely completion of packages.

Project Performance

Safety Performance

The project had zero recordable incidents and a few near misses. Each package included safety procedures and a risk management plan, so that each crew was aware of its surroundings. The sporadic near misses were recorded and incorporated into safety procedures.

Cost Performance

The cost for the work on the first subsystem were four time higher than the estimated cost. This budget overrun was due to an incorrect initial estimate rather than to poor construction performance. Once the project management company got involved, it reviewed all the estimates and reloaded the resources to achieve the project scope. Because the project team correctly implemented the work packaging procedures, it achieved a substantial increase of field productivity (around 10 percent) for the second subsystem and, thus, was able to execute this part of the project on budget. The simultaneous execution of the project with other onsite activities provided an opportunity for crews to share common equipment. By thus maximizing equipment utilization, the project achieved consistent savings during construction.

Schedule Performance

During the work on the first to subsystems, classification changes of major mechanical components caused consistent delays. By the time work started on the third subsystem, the project—originally started as a fast track project—had absorbed the delays and construction reverted to regular in-process operations. The project's detailed control procedures supported the effective allocation of resources to accelerate field activity. Ultimately, the implementation was successful, and the project was completed on schedule.

Quality Performance

Construction was performed in accordance with the highest quality standards and nuclear regulations. The use of work packages allowed for a detailed control process on field activities, since each package had a defined scope, specifications, and quality requirements. After construction had already started, a vendor noted a major design modification involving the size and weight of valves. This change created a potential safety hazard for operators, and the project management team had to perform extensive redesign and excavation rework to cope with the modified valves.

AWP Benefits, Difficulties, and Lessons Learned

The project management team reported gaining significant "ancillary" benefits through the implementation of the AWP methodology. The interviewees also explained that their awareness of challenges and valuable lessons learned will help them improve their planning processes on future projects. Table 15 provides an overview of what they listed as the main AWP-related benefits, difficulties, and lessons learned on this project.

Table 15. Case Study 11: AWP Benefits, Difficulties, and Lessons Learned

AWP Benefits
Predictability
Reduced Impact of Uncertainty
Repeatability
Management of Multiple Projects
Long-term Collaboration among Project Participants
Alignment across Disciplines
AWP Difficulties
Poor Controls Process
Lack of Scope Freeze
Late Engineering Deliverables
AWP Lessons Learned
AWP Included in Key Participants' Contracts
Early Involvement of Key Project Participants

AWP Benefits

Predictability. AWP allowed the detailed definition of project scope at the task level. To ensure that the estimates for each package were realistic and achievable, the planners obtained input from construction personnel.

Reduced Impact of Uncertainty. Each implementation package included a risk response plan that isolated the impact of its particular uncertainties. When a package was jeopardized, management was able to draw on the backlog of packages to shift the affected working crew to other activities while restoring the package's operability.

Repeatability. In spite of the uniqueness of each project, AWP can introduce a process stability that allows for a faster and more systematic definition of project plans. Planning and implementation errors are discussed during meetings and are then incorporated into project procedures to avoid future mistakes.

Management of Multiple Projects. The clear identification of project scope and boundaries allowed the project team to perform multiple projects on site (e.g., maintenance, testing, expansion, and quality assurance) without responsibility gaps or overlapping.

Long-term Collaboration among Project Participants. Because the GC had a long-term working relationship with the owner, the companies were familiar with project procedures and with the owner's work culture.

Alignment across Disciplines. Despite its small size, the project involved the continuous coordination of multiple construction disciplines on site. The development of implementation packages by discipline allowed the project team to establish clear interdependencies and sequencing between the crews.

AWP Difficulties

Poor Controls Process. The design misspecification of long-lead materials by one of the vendors resulted in consistent delays on site. The limited window for construction activities required immediate project deployment, and these material delays hampered project execution. The controls process did not allow for the identification of these delays with sufficient lead time to propose specific countermeasures. The controls process had to be aligned with AWP procedures.

Lack of Scope Freeze. The project faced many changes during the detailed design stage, and the need for continuous modifications to baselines and estimates distracted the management team from value-added activities during project execution.

Late Engineering Deliverables. The owner should have allocated more resources to the early development of engineering estimates in order to meet schedule requirements. In some cases, even though design decisions were delayed, final delivery dates remained unchanged. This resulted either in a compression of construction activities or in the initiation of fast track activities that could have been avoided.

AWP Lessons Learned

AWP Included in Key Participants' Contracts. The owner reported that the inclusion of AWP procedures into contractual agreements was necessary to achieving commitments from the contractors. The general contractor had a long-standing relationship with the owner. Because of their shared history, the realignment of project procedures in accordance with AWP guidelines was not a major challenge.

Early Involvement of Key Project Participants. The consistently high number of scope changes was due to the project management company not having been involved starting at the initial project stages. The cost of changing plans during construction was several times more costly than performing more accurate estimates during conceptual design.

Case Study 12

Project Characteristics

Sector: Industrial
Sub-sector: Oil and gas
Project Type: Plant construction
Project Location: Canada
Contract Type: Lump-sum
Project Cost: $1.2 billion CAD
Construction Duration: 24 months
Construction Hours: 1.4 million

Project Description

This case study examines the construction of a three-phase steam-assisted-gravity-drainage (SAGD) plant supported by a co-generated train power system in Canada. The main field disciplines involved civil foundations, structural, piping, mechanical, and electric. The project also involved a large amount of pre-fabrication and modularization activities, running in parallel to field activities. The project management team was composed of the owner, the engineering company, the general contractor, and two minor contractors for civil and paling works. These project parties considered the project highly challenging because of its stringent delivery deadlines and complexity (it required high synchronization between field and prefabrication activities).

This project serves as an interesting example of challenging integration between key project participants. The project team adopted AWP guidelines consistently during the detailed engineering and construction phases, but in a less systematic manner during the preliminary planning, or FEED stage.

Prior Construction Experience

Neither the owner nor the engineering company had ever implemented AWP before this project. The owner selected an AWP implementation team to develop planning, execution, controls procedures, contractual requirements, and the training process. The general contractor had considerable experience in implementing AWP in the oil and gas industry. At the outset, the company had established internal procedures, a training process, and dedicated roles (e.g., AWP champion, AWP planner), so that it was able to support other key project participants implementing the methodology.

AWP Implementation

AWP Procedure

During preliminary planning, the owner and the engineering company defined the Level 1 schedule. This project plan was handed over to the general contractor that became involved at 30-percent design completion. High-level AWP guidelines were included in contracts with key project participants in order to achieve alignment and commitment to implementing the methodology.

During the detailed engineering stage, the project management team developed a set of CWPs by incorporating the constructability input of the general contractor; however, the team produced these packages without modifying the initial construction path and scope defined during preliminary planning. The general contractor was not involved in a systematic manner in the definition of design solutions, and was instead negotiating and ultimately agreeing on pre-determined plans and sequencing. A general contractor representative was charged with supporting each engineering team. At the Level 2 schedule, the project management team defined the deadlines for the development, issuance, and review of CWPs and EWPs.

Subsequently, the project management team identified the workforce requirements in terms of AWP planners, superintendents, foremen, crews, and supporting staff. Because these requirements were directly related to the CWP and EWP release schedule, the workloads were specified by discipline throughout the construction phase. Prefabrication activities were divided into six CWPs that did not require subdivision into EWPs because of operational characteristics. The prefabrication activities had a sufficient amount of floating schedule to allow for sequencing operations by discipline across the construction areas. This sequencing permitted the general contractor to maximize the learning curve of the various systems, reducing startup times and, thus, increasing efficiency.

Field activities were divided into five main CWPs by area, and each CWP was further divided into EWPs by system. The sequence and the completeness of engineering deliverables were particularly critical to this project because of the necessity of achieving early synchronization between field and pre-fabrication activities. After their issuance, CWPs had to be approved by the GC, who translated the scope of work into estimates by interrelating three different levels of analysis: budget, schedule, and earned value management (EVM). Budget estimates were performed by area (from the CWPs). Schedule estimates were measured through time-sheets and quantity surveys. EVM estimates were performed by system (from the EWPs) and measured through scorecards, in accordance with the specific rules of credit. A comparison of these three levels ensured the consistency of the estimates across the various dimensions and highlighted major constraints to be solved.

All the information was stored in a project database, which allowed for analysis of the required data across several dimensions (e.g., by system, vendor, and/or time-frame). The GC managed the database internally. Other participants had limited visibility of the stored information, which the GC periodically updated as the design process progressed.

After the definition of the Level 3 schedule, the GC was responsible for breaking down CWPs into IWPs, assigning AWP planners, schedulers, and superintendents to work jointly on this effort. The AWP planners had considerable construction experience and mediated the relationships between the schedulers and superintendents, maintaining control over schedule, budget, and EVM estimates, to achieve the scope of the packages. The foremen were responsible for checking the resolution of all constraints before beginning package execution. Particular attention was paid to including detailed system turnover considerations into the IWPs. The owner was not actively involved during the IWP development process, but instead implemented a bottom-up controls process on scope completeness.

Contents of IWPs

Each IWP comprised between 1,000 and 2,000 construction work hours, focusing on a single area and system per single crew. Typically, an IWP allotted five days for field activities and included the following information:

1. Safety procedures
2. Scope of work
3. Engineering documents
4. Interdependencies
5. Materials
6. Equipment and specialty tools
7. Quality requirements.

Issuance of IWPs

Project procedures required that IWPs be issued to the field six weeks before the start date of construction activities. This lead time was higher for pre-fabrication IWPs (10 weeks), to force the project management team to freeze the design at the module fabrication yard. However, the GC was unable to meet the issuance deadlines consistently and, for certain disciplines, the packages were completed almost in a just-in-time fashion. This delayed issuance compressed reduced the available review time superintendents needed to ensure that all constraints were properly resolved.

Progressing IWPs

Each package included a final quality check to be performed by the responsible foreman or superintendent and by the appropriate owner quality surveyor. Upon successful completion, the appropriate party would sign off on each package. In cases of unsuccessful completion, packages could require immediate rework, be sent back for constraint resolution, or design changes. Any updates of the various IWPs were translated into the EVM system in accordance with the specific rules of credit. The project management team systematically captured the lessons learned in dedicated panel sessions during regularly scheduled meetings.

Materials Management

During the preliminary design stage, the owner and the engineering company identified long-lead items and pieces of major equipment for the project, especially cranes. The GC was not involved in providing constructability guidance at this stage, but was responsible for the purchase of most materials. The engineering company provided the bill of materials (BOM), and the GC identified a set of suppliers to perform a bidding process. Generating purchase orders required final permission from the owner.

The delayed design specifications significantly impeded the procurement process, with the missing details making it difficult to complete the BOM. It was possible to generate purchase orders from the 4D model specifications, since they provided the required-at-site dates for the various material codes. Materials tracking was supported by an RFID system, which reduced the number of lost and missing codes and decreased the time spent in locating materials. The RFID system was integrated into the schedule management system, so that materials were systematically bagged and tagged by IWP.

Organizational Implications

The project management team conducted initial training sessions for the various project participants to align AWP-related objectives, terms, and procedures. The GC developed a specific training program and an *ad hoc* project responsibility matrix for AWP implementation. This matrix was perceived as an invaluable tool for guiding the training process when any professional roles were lacking the necessary skills and capabilities.

Project Performance

Safety

The project had zero recordable incidents after more than one million construction hours. The project control manager reported that AWP allowed the project team to include safety considerations starting from the beginning of the detailed engineering stage. Furthermore, it fostered a safety mentality on site by highlighting safety requirements at the IWP level and by focusing the activities in a specific construction area.

Cost

Overall, the project cost increased by approximately 40 percent. Scope changes were found to be the main source of this cost increase. The 40-percent increase varied dramatically depending on the different construction disciplines. When small changes occurred, construction costs were lower than planned, but this was not the case for the most of the disciplines (e.g., instrumentation costs were four times higher than planned). Considering the approved scope changes, the actual project cost was between 0.8 and 0.9 of the planned project cost. Despite project execution being hampered by scope changes, field productivity was 10 percent higher than estimated.

Schedule

Since the construction stage initially had a nine-month delay, and three months of that delay were absorbed by the high performance of the GC, the overall project faced a six-month schedule delay. The project was characterized by constant engineering delays. Such delays disproportionately affected construction activities. For example, concrete pouring was planned for the summer season but, because of engineering delays, it was postponed until the winter season. Once it was underway, the colder conditions made it take 20 percent longer.

Quality

Prefabrication activities faced constant engineering changes that twice affected the operations sequencing: the first time, it was because of the engineering delay; and the second time, it was because of the reduced time for reviewing engineering deliverables in the field. The GC reported a large share of incomplete IWPs, saying that the late response time to subsequent RFIs hampered the operational flow. In certain cases, the RFIs were answered after the systems were already completed, and this caused some rework, especially for civil and instrumentation activities. The performance difference between prefabrication (constraint-free) and field activities (unresolved RFIs) is evidence of how counterproductive it can be to start operations for packages with unresolved constraints. The GC had to balance the risk of rework for unfrozen specifications against the loss of efficiency resulting from delayed specifications.

AWP Benefits, Difficulties, and Lessons Learned

The project management team reported various AWP-related benefits during project planning and execution. The interviewees also mentioned a set of challenges and of valuable lessons learned that they thought would provide useful feedback for future projects. Table 16 provides an overview of the main benefits, difficulties and lessons learned related to this AWP implementation.

Table 16. Case Study 12: AWP Benefits, Difficulties, and Lessons Learned

AWP Benefits
Clear Operational Accountability
Improved Commissioning and Turnover
Information Visibility
AWP Difficulties
Lack of Scope Freeze
Poor Controls Process
Late Engineering Deliverables
Functional Silos
Lack of Inter-organizational Coordination
Fragmented Procurement Process
Lack of IWP Backlog
AWP Lessons Learned
AWP Included in Key Participant Contracts on AWP Deliverables
Early Involvement of Key Project Participants
Full Adherence to AWP Procedures (Constraint Analysis)
Allocate Resources upfront to Identify Control Metrics and Responsibilities

AWP Benefits

Clear Operational Accountability. The early identification of roles and responsibilities eliminated management gaps during the planning process. During project execution, the GC took ownership of construction activities and assigned the completion of each package to a specific foreman or superintendent.

Improved Commissioning and Turnover. System turnover activities were defined during the detailed engineering stage and included in the IWPs. Comparing this project to its previous projects, the GC reported a consistent improvement with respect to meeting turnover (and payment) milestones. This improvement was attributed to an improved specification of the process during the planning stage. The early definition of turnover activities was performed more efficiently and effectively, because the engineering company was fully engaged at the detailed engineering stage. This early planning meant that the system details were completely available when needed. This availability reduced rework and made any rework activities needed more effective.

Information Visibility. The GC reported that AWP allowed for the retrieval of the most up-to-date estimates and plans. The planning team had visibility on missing drawings that were required for EWP release. AWP planners were also able to identify specific constraints to be solved prior to issuance of IWPs to the field and before start of construction activities.

AWP Difficulties

Lack of Scope Freeze. The project experienced constant scope changes during the planning and execution stages. These major changes hampered the implementation of the AWP methodology, even as the project management team reported that AWP reduced the impact of scope changes by limiting their impacts to specific packages, rather than the whole sequence of activities.

Poor Controls Process. The project management team faced difficulties in measuring the number of delays and their impacts on construction operations. The upfront definition of AWP-related metrics would have allowed for proactive project controls that would have identified sources of delays before they affected field operations (e.g., CWP and EWP completion).

Late Engineering Deliverables. The delay of engineering deliverables was a major challenge for the project. In addition, engineering deliverables were frequently issued as incomplete to the GC. These incomplete deliverables prompted RFIs that obstructed the design process and, thus, hampered the planning flow toward the definition of constraint-free IWPs.

Functional Silos. The owner and the engineering company faced functional silos across the various offices that were specialized by discipline. Although the offices were formally committed to implementing the same procedures, they were, in practice, adopting customized planning processes, characterized by poor information-sharing across the different units. These different procedural approaches increased the complexity of coordination and reporting throughout project planning and execution.

Lack of Inter-organizational Coordination. Besides functional silos within the single organizations, project execution was affected by a lack of coordination among key project participants, in particular between the GC and the engineering company. One of the main causes lay in the different contractual incentives for the project parties and in the lack of information-sharing during construction execution. This lack of integration negatively affected the predictability of estimates and resulted in delayed IWP issuance and execution.

Fragmented Procurement Process. The procurement process was characterized by significant delays for both long-lead items and short-term materials. The high process fragmentation was indicated as the main cause of poor performance. The engineering company issued design specifications and the bills of materials to the GC, who then pre-selected a list of suppliers and performed a bidding process. While the GC was responsible for the procurement of materials, the owner had to grant permission for the generation of any purchase orders. Thus, the GC was responsible for a process over which it had little control. A streamlined procurement process, with centralized control, would have reduced the amount of material delays.

Lack of IWP Backlog. The GC was not able to develop a consistent backlog of IWPs for the various disciplines involved. In particular, prefabrication activities had a lack of back-up plans for when design and materials delays occurred.

AWP Lessons Learned

AWP Included in Key Participants' Contracts. The different contractual terms between the engineering company and the contractors resulted in a more difficult integration and alignment of objectives. Each contract should be aligned to support the AWP strategy.

Early Involvement of Key Project Participants. The GC engaged with the owner in a months-long negotiation over contractual terms. This was not followed by a change in the project delivery date, which required constant recourse to overtime.

Full Adherence to AWP Procedures (Constraint Analysis). The project manager for pre-fabrication reported that different disciplines implemented different AWP procedures. For example, not all engineering offices were breaking down EWPs by discipline. This resulted in non-homogeneous planning deliverables, such that EWPs could include a different number of disciplines and require completely different planning efforts during the detailed engineering stage. A centralized corroboration of standard procedures by the owner would have minimized the number of engineering bottlenecks.

Allocate Resources upfront to Identify Control Metrics and Responsibilities. The owner reported that, during the initial planning stages, not enough attention was paid to defining controls metrics in alignment with AWP deliverables. Because of this imperfect alignment of the controls process with AWP processes, the buy-in of the engineering company was reduced.

Case Study 13

Project Characteristics

Sector: Industrial

Sub-sector: Power/coal

Project Type: Plant renovation

Project Location: United States

Contract Type: Mixed lump sum/ cost reimbursable

Project Cost: $300 million USD

Construction Duration: 60 months

Construction Hours: One million

Project Description

This project involved the construction of 10 environmental control systems to reduce the carbon emission of four coal power plants. Each plant was composed of a dry sorbent injection (DSI) system, an activated carbon injection (ACI) system, and a trans-shipment facility to connect the power plants with raw materials warehouses by rail. The four plants were similar but not identical; each had an element of uniqueness in terms of its typology and the amount of construction activities required for its final delivery.

Besides the erection of the DSI, ACI, and trans-shipment systems, major project disciplines included demolition, development of roads and rails, bulk materials (and related storage), piping, electrical, and structural steel. The project team constructed the four subsystems serially, to prevent any power shutdowns. This allowed the team to incorporate valuable feedback and lessons learned as project execution progressed from one subsystem to the next.

When the research team conducted the case study interviews, project design had been entirely completed and construction was at 40-percent completion. The originality of the project lay in its technological complexity: the technology adopted for it had never been implemented on a project of this size, and the execution required intensive coordination between the main project participants.

Prior Construction Experience

The project was the first AWP implementation effort by the owner and the project management company. Their choice of adopting AWP was a consequence of the high implementation risk related to the project. The project management team was committed to ensuring continuous controls on field activities.

The EPC company—the party responsible for project execution—already had some AWP experience. In particular, this company had already implemented the portion of the methodology focused on field activities. For this project, the core project management team extended AWP implementation into earlier project phases, starting at detailed engineering.

AWP Implementation

AWP Procedure

After obtaining financial approval for the project, the owner involved the project management company during the conceptual design stage. The project management company performed the initial testing and simulation of the systems in order to prove the feasibility of the technology. The outcome of conceptual design was a Level 1 schedule that enabled the selection of the general contractor (an EPC company) and the technology provider through a competitive bidding process.

At the beginning of detailed engineering, the general contractor (GC) participated in the development of budget and schedule estimates, the definition and alignment of AWP procedures, and the identification of high-level project milestones. During this stage, the project management team divided the project scope into major systems, providing a schedule and a sequence for each one. High-level packages were identified by system, so that the final output of detailed engineering was a set of EWPs (produced without the development of CWPs by area). For each of the four power plants, approximately 80 EWPs were identified.

The definition of EWPs was not completed in advance for the whole project, but rather progressed in accordance with construction execution. EWPs were typically completed six months before the construction start date. This early definition allowed the project management team to address potential uncertainties that might arise during project implementation.

In terms of project controls, the detailed engineering process followed a stage-gate check at 30-percent, 60-percent, and 90-percent design completion. To ensure continuous alignment among project participants, the team reviewed the scope, estimates, and design of the various EWPs provided by the EPC company. EWPs were also aligned with the work breakdown structure (WBS) of the project, which provided an additional level of alignment among project parties.

The EPC company was then responsible for breaking down the scope of each EWP into IWPs. As construction crew deliverables, the IWPs were developed by EPC planners and superintendents so that construction personnel would be aware of planned field activities. These packages were broken down by discipline (e.g., electrical, structural steel, piping, and cables). In addition to the typical implementation packages, the EPC company also provided detailed control and startup packages for the most critical activities, such as valve execution.

Contents of IWPs

IWPs were defined at the Level 5 schedule and precisely defined required resources in terms of workforce, materials, equipment. The typical content of an IWP included the following elements:

1. Safety procedures.
2. Scope of work
3. Engineering documents
4. Checklists
5. Equipment and specialty tools
6. Materials
7. Quality requirements.

The superintendents received a hard copy of each package for field utilization. The electronic version was retained by the AWP planners and by the project management company to use for updating field progress. The control and startup packages included system specifications and tolerances, as well as maintenance procedures to support the owner during operations.

Issuance of IWPs

The EPC company completed the IWPs at least eight weeks before the start of construction activities. The project management company reviewed the packages before their issuance to the field. Potential modifications to them were discussed in advance to ensure agreement on scope, procurement, quality requirements, interdependencies, and sequencing of activities. The final packages were issued to the field superintendents no earlier than two weeks before the start of construction. The superintendents and general foremen signed off on each package to signal personal accountability for its execution. To ensure that construction crews could be efficiently relocated in cases of unexpected events on site, the EPC company maintained a backlog of IWPs for superintendents to use to shift their crews to other parts of the project in such instances.

Progressing IWPs

After completion, IWPs were inspected by both the EPC superintendents and quality inspectors. This control was performed on a weekly basis and the results were reported directly to the project management team. When the superintendents and inspectors signed off on each package, it would trigger the issuance of subsequent work packages. The control process included the retention of feedback from field activities; this feedback was stored within the project database to improve the execution of subsequent systems.

Materials Management

Material procurement followed two main processes:

- For technology purchases (power plant components), a standalone contract with the technology provider was in place. This company had been integrated with the EPC to ensure the alignment of onsite materials delivery with construction execution.
- The project management company and the GC were responsible for all other materials required for building and assembling the plant components (depending on the availability, cost, and quality of their respective supply pools).

Materials were scheduled to arrive on site two weeks before the start of construction. Specialty items and long-lead equipment require more lead time.

Organizational Implications

The project management company held a set of informal meetings with the EPC, to define a common AWP strategy before entering the contractual agreement. The meetings addressed the project's procedures, roles and responsibilities, contractual incentives, controls processes, and training activities. The EPC developed specific AWP-related organizational roles. In particular, the company defined the roles of AWP champion and of AWP planner. The former was responsible for the company's adherence to and alignment with AWP procedures. The latter developed the IWPs and served as the interface between engineering and construction disciplines during the detailed planning and construction stages.

Figure 12 illustrates the following ratios of personnel playing different professional roles on the jobsite:

- One superintendent from the project management company supervised the activities of two EPC superintendents.
- One superintendent from the EPC company was responsible for approximately 30 craft workers.
- One AWP planner was paired with each superintendent.

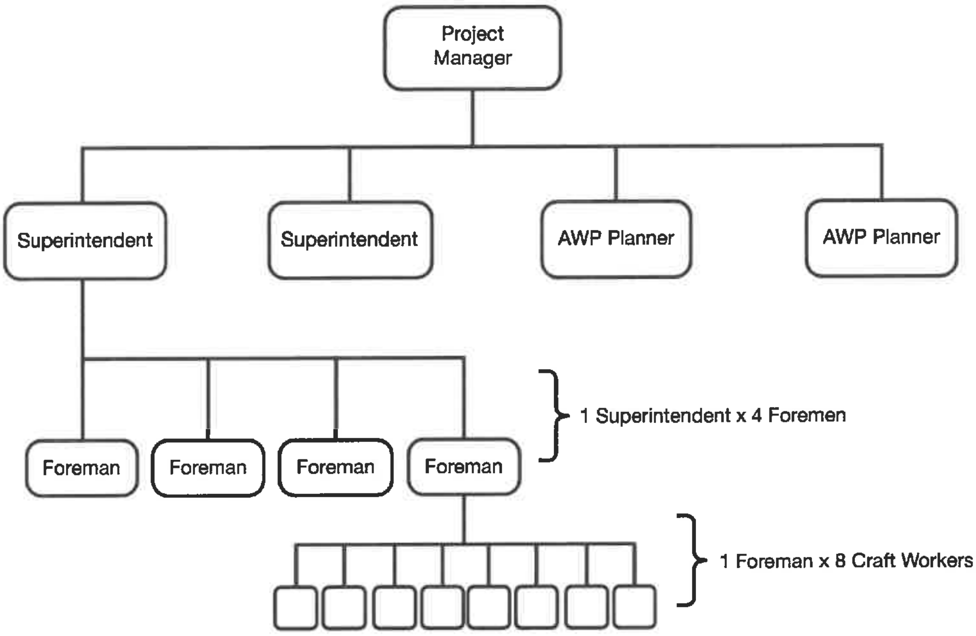

Figure 12. Case Study 13: Organizational Structure

Project Performance

Safety Performance

After 400,000 work hours, the project experienced zero recordable incidents. The adoption of AWP allowed the EPC to mandate that the same team had to perform a single work package. With such a singular focus on each package, workers became more attuned to their surroundings on the site and aware of the scope of the work at hand at any given time. The sporadic near misses that occurred were documented and shared by the safety team during weekly and monthly meetings. This attention to these events enabled the planners to incorporate the lessons learned into similar packages yet to be executed.

Cost Performance

The project was under budget, with a total CPI of 1.23. When the project management team examined the estimates from an AWP perspective, it was able to identify considerable cost savings opportunities. For example, more than $5 million were saved by reducing the scope of two EWPs. These savings were shared between the project management company and the EPC in order to foster cost optimization behavior. Field productivity was aligned to estimates for the activities of the first two power plants. The project management team identified several productivity improvement opportunities for to implement during subsequent construction activities.

Schedule Performance

Overall, the project was on schedule, with a total SPI of 1.02. Some disciplines performed particularly well, such as the demolition of standing facilities. Other disciplines experienced delays, such as the late start on the construction of the trans-shipment facilities, due to late permit releases.

Quality Performance

The project did not require substantial rework activities. Field activities followed high-level standards, and a small percentage of IWPs (less than five percent) required rework. The project did have a problem with the quality of its engineering drawings, having had a high number of RFIs on 10 percent of the drawings. The disciplines that generated a major number of RFIs were electrical, mechanical, and civil. The main problem was the short lead time available for review and approval of the drawings contained in the work packages.

AWP Benefits, Difficulties, and Lessons Learned

The project management team reported significant "ancillary" benefits during the implementation of the AWP methodology. The interviewees also noted challenges and valuable lessons learned that they planned to use to improve their planning processes on future projects. Table 17 presents these AWP-related benefits, difficulties, and lessons learned.

Table 17. Case Study 13: AWP Benefits, Difficulties, and Lessons Learned

AWP Benefits
Scope Clarity
Accountability
System Optimization
Reduced Design Changes
Shorter Learning Curve
Incorporate Feedbacks and Lessons Learned
AWP Difficulties
Limited Time Window to Develop IWPs
Culture Change
AWP Lessons Learned
Selection of Experienced Contractors for AWP
Early Involvement of Key Project Participants
AWP Included in Key Participants' Contracts

AWP Benefits

Scope Clarity. Interviewees reported that, in comparison with previous projects, this project's scope was clearly defined and adequately detailed. The use of EWPs supported the identification of specific characteristics and boundaries across the systems.

Accountability. The issuance of IWPs to construction personnel constituted a fundamental step toward obtaining accountability and commitment from the EPC. The requirement that superintendents review and sign off on the various packages increased their involvement in project execution. Their increased involvement, in turn, empowered the crews to deliver the scope of each package in a detailed manner.

System Optimization. Defining packages before the start of construction activities enabled the project management team to identify a number of opportunities for cost and schedule reduction. The team reported that the discussion and review of each package was fundamental to de-scoping and re-configuring construction activities, as needed.

Reduced Design Changes. The project management team reported that, compared to previous projects, this project benefited from its considerable design stability. The systematic engineering process ensured the attainment of frozen designs for major systems. This stability was particularly positive for long-lead material procurement and for the planning of workforce requirements.

Shorter Learning Curve. After the execution of the first power plant, the project management team reported increased efficiency of package definition and execution. These productivity improvements were perceived across the different construction disciplines, all of which experienced a steep AWP learning curve.

Incorporation of Feedback and Lessons Learned. The project management team paid particular attention to collecting and discussing the mistakes made and opportunities missed during project execution. By taking these elements into account in the project's planning as it progressed, the project was able to absorb delays and improve project performance.

AWP Difficulties

Limited Time Window to Develop IWPs. The EPC company had defined IWPs eight weeks in advance of construction starts. However, after the packages had been defined, they had to be reviewed and approved by the project management company. Since this review process typically took between four to six weeks, the EPC would receive the final approved version of the IWPs only two weeks before the start date. This lead time was not found to be sufficient for solving any RFIs that surfaced and for getting all materials bagged and tagged in their respective IWPs in advance. The project management company proposed reviewing IWPs together with the EPC company on future projects, in order to obtain final and agreed-upon versions of the packages with a longer lead times.

Culture Change. The owner and the project management company did not have previous experience implementing AWP. The adoption of the methodology necessitated training programs and generated some initial resistance, especially from more experienced personnel. During project execution, this push-back consistently decreased, and the project achieved high-level performance. This reduction of push-back was mainly attributable to management's unflagging commitment to effective AWP implementation.

AWP Lessons Learned

Selection of Expert Contractors for AWP. The contractor on this project was already familiar with AWP procedures and supported the owner during the implementation process. AWP is effective when specific guidelines are in place, and the support of an expert player drastically enhanced the ability of other project participants to learn the methodology.

Early Involvement of Key Project Participants. While construction experts provided input during the development of the EWPs and CWPs, they did weigh in on the IWPs. Thus, these were issued to the field a few weeks before the starting date, without the support of the construction superintendents. As a result, the field personnel pushed back by issuing more than the usual number of RFIs and by being less accountable. Had the IWPs been developed in collaboration with field superintendents, it would have reduced confrontations on the project and enhanced alignment between engineering and construction.

AWP Included in Key Participants' Contracts. The project management representatives reported that more specification of AWP guidelines within project contracts would have fostered the implementation of the methodology. The lack of specification was especially noticeable in the controls process, because the quality requirements included within the IWPs were not reflected in the individual contracts. This meant that the EPC was not perfectly aligned with the project management team.

Case Study 14

Project Characteristics

Sector: Industrial

Sub-sector: Oil and gas

Project Type: Plant construction

Project Location: Canada

Contract Type: Mixed lump sum/ cost reimbursable

Project Cost: $8 billion CAD

Construction Duration: 42 months

Construction Hours: Eight million

Project Description

This study was of a mega-project that involved the construction of an oil & gas (O&G) plant in Canada, with a TIC of $8 billion CAD, a total of eight million construction hours, and an expected 42-month construction duration. Major disciplines involved in the project included an extensive use of modularization, earth-works, piping, and mechanical activities. During the data collection process, project engineering was at 60-percent completion, and construction was at 20-percent completion. The owner decided to implement AWP methodology, starting at the preliminary planning phase, to organize the project with the support of other project participants. The project engaged eight different general contractors (GCs) to perform different disciplines, all with different contractual arrangements (e.g., lump-sum, cost reimbursable) and project delivery strategies (e.g., E-PC, EP-C, EPC, EPCM).

On a project of this size, the technical complexity posed a significant risk. Another major risk element was the managerial complexity faced by the project owner, a new joint venture of various O&G operators, none of whom had much experience in mega-project execution. (Thus, this case study does not include a section on previous planning experience.) The project's managerial complexity was increase by the need to replace three GCs during the initial planning stage, due to limited integration and difficult collaboration. This replacement led to immediate delays.

AWP Implementation

AWP Procedure

After selecting key project participants (including GCs, engineering companies, and vendors for long-lead materials and equipment), the owner defined and communicated the AWP strategy. The strategy then necessitated a set of formalized documents and procedures to be included in the various contracts. Procedures had been discussed, negotiated, and agreed-upon during various kickoff meetings, ensuring a certain level of flexibility in the different contracts and delivery strategies. This formal communication process was fundamental to obtaining a shared project vision, as well as establishing common and consistent AWP definitions and procedures.

The project was initially divided into 10 major units, which, in turn, were divided into approximately 10 construction work areas (CWAs) for a total of 100 CWAs. The scope of work of each CWA was included within the corresponding GC contract. Table 18 presents the contract types and delivery strategies of the 10 units.

Table 18. Case Study 14 Characteristics

Unit	Contract	Delivery Strategy
1	Cost Reimbursable	EP-C
2	Cost Reimbursable	EPC
3	Cost Reimbursable	EPC
4	Lump Sum/ Cost Reimbursable (module)	EPCM
5	Lump Sum	EPC
6	Lump Sum	EPC
7	Lump Sum	EPC
8	Cost Reimbursable	EP-C
9	Cost Reimbursable	EP-C
10	Cost Reimbursable	EP-C

Subsequently, each CWA was further divided into groups of EWPs. The criterion for dividing CWAs was the function of CWA location: if onsite, EWPs were identified by discipline; if offsite, EWPs were identified by module in a cross-disciplinary manner. There were five main disciplines involved: electrical, mechanical, piping, steel, and tracing. Particular attention was paid to align onsite to offsite modular activities, since the achievement of an effective synchronization was critical to achieving the benefits of modularization. Initially, the CWAs were divided up into 5,000 EWPs, an amount considered unmanageable by the owner. After going through a process with the GCs to reduce it, the final tally was 1800 EWPs. A typical EWP had the following contents:

1. Safety procedures
2. Scope of work
3. Equipment and specialty tools
4. Construction hours
5. BOMs
6. Documents
7. Scaffolding.

The owner reviewed all proposed packages to ensure that they adhered to guidelines (e.g., construction hour limits) and were complete. The GCs checked the EWPs, reviewed them and eventually signed off on them. Although AWP requires that EWPs be released 12 weeks before field activities begin, this rule was not strictly enforced by the owner. Thus, EWPs were actually released from six to eight weeks prior to the start of construction activities. This shorter lead time (LT) gave the project team less time to review and modify the estimates.

EWPs included scaffolding, construction hours, equipment, and specialty tools. There was no distinction between EWPs and CWPs for this project. The project management team did not use CWPs because it did not want to introduce another AWP deliverable that could have further complicated AWP adoption. The GCs ended up being entirely responsible for grouping the EWPs, which they did by construction area rather than by CWP. This process was not regulated by a standard procedure and was perceived as confusing by both the owner and the GCs. Indeed, the owner project manager reported that having had CWPs would have prevented a lot of the time-consuming confusion surrounding the grouping of the EWPs.

Contents of IWPs

Some disciplines, such as modularization, did not develop IWPs. Instead, they used the larger EWPs, which had been defined at a Level 4 schedule and allowed for managing construction without additional information. The GCs were responsible for developing the IWP packages, which included startup and commissioning work for the various systems. Overall, the project generated between 5,000 and 6,000 IWPs. The content of the various IWPs was generally different across the disciplines and varied in terms of procedures for the GCs. IWPs were developed specifically for the turnover and commissioning phase, with approximately 2,000 turnover and commissioning packages (TCPs) per unit. P&IDs were populated with TCP numbers and were also integrated with the 3D model and the Level 3 schedule.

Issuance of IWPs

Ideally, IWPs were sent to the field a few weeks before the beginning of construction activities. Packages were issued after superintendent or foreman approval and, most importantly, once all constraints had been solved. The owner reported that, in certain cases, late engineering and procurement specifications resulted in delayed IWP definition.

Progressing IWPs

After IWP issuance, the planning, execution, and control activities were delegated to the various GCs. The owner saw to it that field construction adhered to schedule, budget, and quality requirements. For modularization activities, the activities were progressed at the EWP level, while, for construction activities, the control level varied by discipline and could be performed at either the EWP or IWP level.

Materials Management

After initially implementing a central warehouse management logic, the owner realized it was not manageable and introduced more decentralization at the unit level. The decision to establish a central warehouse was motivated by the project's use of a single material management system. As the GCs took over the planning process, and after the Level 3 schedule had been developed, the materials management system was unable to stay up to date on inventory and field requirements. This was due to inconsistent updating and poor integration between the GCs schedule and the owner's central system. As a consequence, the central system was only partially used, and the project management team dropped this implementation to perform materials management at the unit level. The GCs were responsible for the procurement and logistics of materials on site. Long-lead materials deliveries were often delayed, and, because the central system was not up to date, the owner was unaware of the extent of these delays.

Organizational Implications

The owner established dedicated AWP roles and responsibilities, the most important of which was the AWP champion. This person was responsible for driving the initial AWP implementation, assigning responsibilities, and ensuring that project participants adhered to the prescribed procedures. The AWP champion was supported by eight "senior" AWP planners. These planners were specifically selected to coordinate AWP implementation within the GC organizations. They had extensive construction experience and were familiar with the AWP methodology. Each planner was specialized in a different discipline (e.g., electrical, mechanical, automation, piping, modularization yard, and quality control) and was fundamental to helping the various project managers develop and refine the packages during the initial planning stages.

The GCs of both onsite and offsite units incorporated the roles of AWP champion and AWP planner. The ratios between AWP planners and people in other workforce roles (e.g., foreman or supervisor) had not been established in advance and varied by discipline across the GC organizations. The owner performed various audits on AWP adoption, beginning at the FEED stage. A collaborative approach was taken, to foster GCs comments and to obtain real alignment. The audits had four main areas of concern: 1) organization (definition of roles and responsibilities for AWP); 2) process (use of prescribed documentation, guidelines, and procedures); 3) technology (the planning systems used and how they are integrated with each other without any loss of desired functionalities); 4) and reporting (metrics and frequency of reporting). The audits covered a wide population and were divided by division or department. This meant that different questions were asked of personnel in engineering and procurement, automation, fabrication, and construction.

Project Performance

At the time of data collection for this case study, the project had not been completed. Specifically, engineering completion was at around 80 percent, modularization was at around 50-percent complete, and construction was at approximately 20-percent complete. Performance dimensions were more indicative than conclusive, and they are not included in this case study. Overall, it is worth noting that, during FEED, the project management team faced various design and scope changes. Also, the owner had to review and modify the GCs' initial estimates extensively. This process delayed the construction timeline by approximately 10 months.

AWP Benefits, Difficulties, and Lessons Learned

Besides the above-mentioned project performance improvements, this case study documented a set of additional AWP-related benefits, challenges, and lessons learned. (See Table 19.)

Table 19. Case Study 14: AWP Benefits, Difficulties, and Lessons Learned

AWP Benefits
Scope Clarity
Accountability
Predictability
Adequate Field Mobilization
AWP Difficulties
Change Inertia
Poor Control Alignment
Lack of Buy-in
Late Engineering Deliverables
AWP Lessons Learned
Full Adherence to AWP Procedures (Constraint Analysis)
Assessment of Project Participants' Prequalification
AWP Included in Key Participants' Contracts

AWP Benefits

Scope Clarity. The use of AWP prevented overlaps and gaps in project scope. Every portion of the project scope was clearly assigned to a specific GC, resulting in clear responsibility for assignments and a shared overall vision of the project.

Accountability. The issuance and definition of CWPs/EWPs to construction personnel was a fundamental step toward obtaining accountability and commitment from the various GCs. Superintendents and foremen reviewed, modified, and eventually signed off on the various packages before the beginning of construction activities. This process increased their commitment and empowered their crews to deliver the scope of each package to the last detail, in accordance with original plans and estimates.

Predictability. AWP allowed for the detailed and reliable definition of project scope at the task level. The owner reported high levels of project predictability when the GCs collaborated on the detailed definition of work packaging. Because all project participants defined and agreed on the ambitious but achievable targets in the packages, they were able to solve all major construction constraints.

Adequate Field Mobilization. Field mobilization was delayed due to insufficient engineering specifications. This was a direct outcome of AWP adoption, which—departing from the traditional planning rationale to start earlier—prescribed the identification and resolution of major constraints before field mobilization. Delaying field mobilization in this way is considered the best choice for avoiding poor performance during execution.

AWP Difficulties

Change Inertia. The owner reported that the inexperienced GCs on the project initially pushed back against the AWP implementation, and instead wanted to implement different procedures and codifications. The lack of discipline this caused during the early planning stage resulted in delays that were not reflected by a change of project end-date. For two project units, the new contractors coming in were awarded fast-track contracts and were unable to develop rigorous AWP-aligned plans (from a 40-percent design completion to less than five percent).

Poor Control Alignment. During the execution of the project's earthworks, certain GCs only used AWP on paper and for documentation purposes. After defining EWPs, the GCs did not further break down the project scope. As a result, they experienced constant delays during operations. This also negatively affected the consistency of the quality control process, since it was not aligned between GCs and the owner. Initially performing monthly controls, the owner found this interval was too long and decided to effect weekly controls. A formalized feedback analysis process was introduced only after the beginning of construction activities; but, had the project defined and systematized its control activities at the outset, it would have reduced its initial poor performance.

Lack of Buy-in. The owner's entire senior management team changed during the DE phase. This shake-up was followed by numerous modifications for planning and construction procedures, which jeopardized the AWP implementation. As the project progressed, the owner reported a weakened commitment by top-management. When a project face such AWP-related planning and leadership challenges, it can get caught in a vicious cycle—since a limited AWP implementation cannot provide full expected benefits. If the AWP performance is perceived as limited, the project team might mistakenly decide to reduce the use of AWP on future projects. On this project, the owner concluded that more involvement during the definition and control of planning estimates would have improved the consistency of the AWP implementation. In any case, despite the lack of buy-in during DE, the FEED phase was characterized by high integration across the different disciplines and project participants, with consistent construction input. This early integration of the construction perspective enabled an optimized scope definition that supported subsequent stages.

Late Engineering Deliverables. The owner reported that, because late engineering deliverables upset the entire planning sequence (from procurement definition to construction field), field mobilization was delayed. The owner reported that a major control on engineering productivity would have prevented or at least reduced the final extent of the delay. It was particularly undesirable because of its ripple effects on other disciplines, such as module fabrication and field construction—areas with less available time for review and refinement of estimates.

AWP Lessons Learned

Full Adherence to AWP Procedures (Constraint Analysis). After the owner reinforced the use of AWP procedures, the project's construction processes, particularly, piling and foundation, were performed better; and, more importantly, project management could foresee incipient problems and could define appropriate corrective action. The owner emphasized that adherence to prescribed procedures was critical to achieving consistent adoption and minimizing planning and execution errors. Moreover, according to the owner, had the project begun with strong audit procedures to measure adoption of and satisfaction with AWP procedures, the implementation would have been more successful.

Assessment of Project Participants' Prequalification. GCs on this project were not were not prequalified on the basis of their AWP capabilities. The owner reported that such a prequalification process would have prevented the major change inertia issues that slowed down detailed engineering and construction for certain GCs. In particular, the objective of prequalification should have been aimed at identifying and minimizing AWP-related knowledge and experience gaps among project participants.

AWP Included in Key Participants' Contracts. The inclusion of AWP requirements in the various contracts for the key project participants was fundamental to achieving early integration and immediate commitment. Even as adherence to AWP dwindled on the owner side, most of the general contractors were still actively implementing the methodology because of the enhanced execution performance. These general contractors were already familiar with AWP concepts. The project participants who were unfamiliar with AWP only implemented the methodology at the bureaucratic level, providing plans and results as dictated by AWP, but without real implementation in the field. The inclusion of AWP guidelines in the contracts was also aimed at aligning the payment and controls system with AWP deliverables. The GCs were incentivized to complete the various packages by adhering to the initial guidelines, since their performance was measured by CWP/EWP completion.

Case Study 15

Project Characteristics

Sector: Industrial
Sub-sector: Oil and gas
Project Type: Plant expansion
Project Location: Canada

Contract Type: Time and materials
Project Cost: $1 billion USD
Construction Duration: 30 months
Construction Hours: 2.7 million

Project Description

This project involved the construction of a carbon capture and storage (CSS) system to cut CO_2 emissions from the oil extraction process. The project was budgeted at $1 billion USD for approximately 2.7 million construction hours and a 30-month construction duration. The project had both brownfield and a greenfield sections, and included the upgrade of an extraction facility. This upgrade was aimed at enabling the capture of carbon dioxide from the existing site, transporting it, and permanently storing it deep underground, to prevent it from dispersing into the atmosphere.

The project presented various interconnection challenges, since it had to ensure continued site operability during construction. The owner stressed the project's technological complexity, given that this engineering solution had never been implemented on such a large scale. Another element of its complexity came from the considerable recourse to modularization and pre-fabrication activities. More than 70 interlocking modules had been identified, produced off site, and then shipped and assembled on site. Because of the size of the modules, transporting them posed a major challenge that required intensive space optimization design solutions. This optimization involved leveraging the principles used in offshore plant construction.

The project consisted of three main stages:

- offsite modularization (utilities and offsite tie-ins)
- pipeline
- onsite assembly (modifications on current facilities, assembly, and stick-building).

After obtaining all permissions and clearances from governmental and other stakeholder bodies, the owner selected a major EPC company for project execution—awarding it a unit price contract for the first stage, and a time and materials contract for the second and third stages. This company was contracted to provide construction management services during the pre-FEED, FEED, and execution phases during the third stage (i.e., perform project management, project controls, and information management services under an EP-CM delivery strategy).

The preliminary planning, or FEED, phase for this project was critical to achieving integrated and coordinated deliverables on site. It was necessary to manage several design and space constraints to enable effective module transportation and installation. Also, because the optimization logics differed between the module fabrication yard and the construction site, aligning the module delivery sequence with the construction sequence was critical.

The project management team established high safety, cost, and quality performance as project drivers, with a safety performance target of zero lost time incidents as its most important goal. Cost was the second main dimension, since the project was not a cash flow generator for the owner. Lastly, had the project avoided schedule overruns, it would have achieved its quality goals of maintaining fitness for purpose and zero defects. Various project configurations were modeled and prioritized in accordance with the expected performance outcomes. Once the project's strategy and objectives had been formulated, they were shared among key project participants to establish a shared vision. To reach the levels of planning integration and estimate reliability needed to realize this vision, the owner selected AWP in a joint agreement with the EPC .

AWP Implementation

AWP procedures were included in the contract with the EPC company for the execution of the onsite assembly stage. The appropriate guidelines and procedures were prepared by the EPC, and then reviewed and approved by the owner. The contract specified major project milestones and served as a basis for audits throughout the various project phases.

The project scope was initially broken down by construction work areas (CWAs), which constituted the building blocks for the path of construction. Each CWA was then divided by discipline to define the boundaries of multiple EWPs. Because the general contractor responsible for project execution considered this CWA-level breakdown sufficient, no CWPs were not developed. To establish consistent alignment, all major disciplines were involved before the detailed engineering phase. At Level 2 schedule definition, the project management team (composed of representatives from the owner, engineering and construction disciplines) finalized the path of construction and completed the initial development and sequencing of EWPs. EWPs were developed up to a Level 3 schedule and included vendor requirements. These requirements were translated and formalized into procurement work packages (PWPs), which mirrored the EWP sequence, which, in turn, was aligned to the CWA sequence. The construction sequence included considerations for the commissioning process, although startup operations were performed and managed by a separate division of owner and EPC personnel.

The EPC developed the IWPs at the Level 4 schedule and was responsible for their management, which involved updating and aligning them with the master schedule. The IWPs were mostly assembled manually by the various planners and then, to ensure their completeness and correctness, approved by the HSE, quality control, and construction representatives. An IWP backlog was continuously developed and maintained, to have a "Plan B" ready at a moment's notice for every discipline involved. This backlog contained constraint-free packages that any remobilizing crew could begin implementing within three working days. The dimension of the backlog varied by discipline, depending on the complexity and duration of construction activities.

AWP adoption was monitored through both formal and informal audits. These were based on checklists recommended by CII and the Construction Owners Association of Alberta (COAA). The audit process involved formal reviews that tracked project milestones, along with informal reviews that gathered more detailed input from the construction crews on a daily basis.

Contents of IWPs

IWPs included the following information:

1. Materials
2. Specialty tools and equipment
3. Engineering documents
4. Interrelationship with other IWPs
5. Quality requirements
6. Safety analysis
7. Permissions

The size of IWPs varied, depending on the scope of the activities. For instance, a single package could include more than one week of work, if it were executed by a single foreman and if it involved repetitive activities within a single discipline.

Issuance of IWPs

A constraint management process ensured that IWPs were ready for operations before issuance to the field. Following were the main constraints: alignment with the path of construction; conflict resolution with other IWPs; completion of materials, drawings, and scaffolding; trades availability; training and qualification requirements; quality standard and documentation; safety planning; and permits and agreements. IWPs were issued to the field anywhere between three and 10 days before the beginning of construction. This interval was shorter than the three weeks recommended by the CII/COAA guidelines, because the project management team wanted to focus the foremen's efforts on current construction activities. Each assigned foreman reviewed and agreed to the content of each IWP by signing off on the package.

Control of IWPs

The owner controlled the execution of CWAs/EWPs and did not track IWP execution. The EPC took care of rolling up IWP data, to monitor the progress at a higher level of granularity. Construction activities were monitored in alignment with IWP execution. To progress field activities, the EPC used a set of pre-defined key performance indicators (KPIs) that included the following:

- **Total number of IWPs for the project (actual to plan)**: This KPI measures potential deviations from estimates.
- **Number of completed IWPs to total IWPs**: This KPI is measured at the beginning of the project to indicate total construction completion, and then on a weekly basis to track the construction trend.
- **Number of IWPs issued to the field**: This KPI is measured in comparison to the total number of planned IWPs, to find the percentage of planning completion and to determine an absolute number for tracking the extent of the work in progress.
- **Number of IWPs that require constraint resolution**: This KPI identifies IWPs with issues related to access to work, materials, equipment, and other constraints.
- **Number of IWPs signed off on by HSE, quality control, and construction**: This KPI counts the number of packages in the system and tracks their status.
- **Number of IWPs returning as incomplete**: This KPI highlights the reason for the IWP incompleteness, such as missing materials or engineering drawings.
- **Size of IWP backlog by discipline**: This KPI identifies potential backlog deficiencies that could indicate either a lack of planning personnel or an excess of construction workers.

The project management team used these KPIs to reinforce AWP principles that required all planning constraints to be properly resolved before the start of construction activities. The team also paired the control process for IWPs with a comprehensive collection of lessons learned that it had captured in workshops and through feedback from foremen and AWP planners. For this particular project, more than 100 lessons learned had been collected and stored in a repository. In this repository, each lesson learned had an identification number, a title, a description, an appropriate countermeasure, and the name of the person who reported the lessons learned. The lessons learned were stored for the future development of packages, and the repository was centralized within the owner organization to give other project management teams access to the information.

Materials Management

Materials requirements were packaged into PWPs and aligned with EWPs. Long-lead materials were treated as critical components and issued to the field a few weeks before the construction date. Critical materials were purchased out of sequence to build a buffer in case of delivery delays.

Bulk items were procured through preferred suppliers and were not assigned to specific CWAs. The purchasing logic followed the pooling principle, which, although convenient from an economic perspective, did not perfectly mirror the construction sequence. The owner recommended more alignment between procurement requirements and construction packages—suggesting that the project should shift its procurement rationale away from considering purchase cost alone and toward considering the total cost of ownership (including the cost of missing material). The project management team reported that materials deliveries could have been improved by getting closer to a just-in-time (JIT) philosophy, which would have reduced inventory and ownership costs. The need for this potential improvement notwithstanding, there were no construction delays due to lost or missing materials. Indeed, the performance of the procurement team fostered a stable flow of field activities.

Organizational Implications

The AWP planner manager identified the specific roles and responsibilities related to AWP implementation and hired planners specifically for AWP implementation. As a rule of thumb, each discipline was assigned a dedicated AWP planner who had received specific professional training from an external company. The number of planners assigned to a discipline could vary depending on its complexity and size within the project (e.g., the electrical/instrumentation discipline had two dedicated planners). Also personnel in other AWP-related organizational roles received training on AWP guidelines, processes, and expectations (e.g., superintendents, foremen, and schedulers).

The ratio of AWP planners to general foremen was approximately 1:4. This ratio was lower than company's average because of the high level of modularization on this project. This meant that onsite activities were mostly focused on managing the interconnections between the modules rather than on performing the whole project scope in the field.

Project Performance

Safety Performance

The project recorded zero lost time incidents and only a few first-aids and minor injuries. Compared to a recently completed project that was similar in terms of scope, complexity, and size, this project registered significantly better safety statistics. This improvement was attributable to the generally increased focus on safety—starting at the initial planning phase—as well as to the more systematic safety considerations included in each package.

Cost Performance

The project was delivered under budget, with more than $20 million in savings. The owner reported that the project achieved a substantial 12-percent increase in productivity, compared to a recently completed project of similar scope, complexity, and size. This productivity increase was measured for the overall project. The disciplines implementing AWP consistently out-performed those without AWP. The improvement was mainly related to the enhanced deployment of craft, who had less down time because they could execute constraint-free activities. The increased productivity was also related to the crews' enhanced familiarity with the construction areas in which they worked, which was a consequence of better workforce retention and the focus of each IWP on the same construction area.

Schedule Performance

In spite of experiencing some delays during the final construction stages, the project was delivered three months ahead of schedule. Although the project was not schedule-driven, previous intermediate schedule milestones were met.

Quality Performance

The project faced some change orders in the field, but had a significantly lower number in comparison to previous similar projects. In terms of rework, the performance of this project was better than previous projects (less than one percent rather than three percent). A system to keep track of revised drawings had been put in place to ensure that the latest versions of packages were the ones issued and executed. However, the project's use of paper-based IWPs did not support an immediate updating process.

AWP Benefits, Difficulties, and Lessons Learned

This case study found significant "ancillary" benefits related to AWP implementation. The interviewees also noted challenges and valuable lessons learned that they will use to improve the planning processes on future projects. Table 18 presents the complete set of these benefits, difficulties, and lessons learned.

Table 18. Case Study 15: Benefits, Difficulties, and Lessons Learned

AWP Benefits
Predictability
Alignment across Disciplines
Support for Modularization Strategy
Accountability
Workforce Retention
Incorporation of Feedback and Lessons Learned
High Scalability
Reduced Impact of Uncertainty
AWP Difficulties
Alignment of Procurement and AWP
Lack of Buy-in
AWP Lessons Learned
IT Integration
IWP Structure by Discipline
Performance of Both Formal and Informal Audits
Integrate with Lean Construction Principles

AWP Benefits

Predictability. The owner reported that AWP supports the definition of reliable cost and schedule estimates, improves project predictability, helps meet safety target, and ensures the achievement of expected project value.

Alignment across Disciplines. The construction team participated in the initial planning phase with the engineering and procurement representatives and, because this early involvement supported the definition of the path of construction, it improved the consistency of the plans. Constructability could have been further improved had additional disciplines been included as early as possible—especially those representing a high share of TIC, such as scaffolding. Nonetheless, scaffolding considerations were included during the detailed engineering phase through a matrix that identified the most appropriate means of access for the various construction areas.

Support of Modularization Strategy. Having a modularization strategy can provide performance improvements (e.g., reduced work hour exposure in the field), if it is linked to highly detailed and reliable planning that synchronizes multiple offsite production facilities. For example, module installation was performed by a 600-ton heavy-lift crane, the efficiency of which depended on the sequence and timing of module arrival on site. AWP was essential to achieving the cost savings from modularization.

Accountability. Construction personnel took ownership of field execution activities by participating in the planning phase and by signing off on the packages. Overall, foremen had increased visibility on the project and were committed to adhering to the deadlines because they had discussed each package with the planning team.

Workforce Retention. The high engagement of construction personnel, along with the project's higher safety performance and the reduced disruption during operations, elicited higher crew satisfaction. This resulted in reduced workforce attrition and turnover, in comparison to the company average.

Incorporation of Feedback and Lessons Learned. The project management team developed a detailed and comprehensive feedback process that it deployed on a daily basis and then reviewed once a week. Every craft member filled out a checklist to indicate any construction problems experienced, giving the causes of the problems (e.g., conflicting activities, access to work area, missing equipment, or other issues). The most recurrent and impactful causes of problems were identified to determine whether the delays were acceptable and to define potential countermeasures, if necessary. The impact of each countermeasure was then evaluated and reviewed with the crafts in every discipline involved. This collaborative review process supported the implementation of compelling and agreed-upon countermeasures.

High Scalability. The owner expects to be able to use AWP to plan and execute all its project on a global scale, from small projects to mega-projects. The AWP process the owner adopted is extremely scalable because it was based on the core principles of AWP, such as executing only constraint-free operations, and defining a path of construction during the initial project stages, to guide the subsequent detailed planning and execution activities.

Reduced Impact of Uncertainty. The breakdown of work into elementary packages reduced the impact of disruptions on any single construction unit. This impact was minimized by the availability of an IWP backlog that allowed the remobilization of crews within a few working days.

AWP Difficulties

Alignment of Procurement and AWP. Materials were bagged and tagged in alignment with IWP requirements. The integration of procurement and AWP could have been further improved had a procurement team been dedicated to the identification, preparation, and delivery of materials, without the involvement of construction personnel. This would have further increased the percentage of tool time and thus had a positive impact on productivity.

Change Inertia. Construction personnel did not show consistent engagement during the initial phases of AWP implementation because of the changes to the traditional construction process. This change inertia decreased after the project management team involved construction personnel in the planning and training processes, and after performance improvements were apparent. Also, to stress the necessity of adhering to prescribed guidelines and procedures, the owner demonstrated significant top-management commitment to AWP implementation.

AWP Lessons Learned

IT Integration. The IWP development and management processes were managed mostly manually. To improve the productivity and reliability of the planning process, the project team will introduce an additional management layer for real-time materials tracking on future projects. The IT system will integrate 4D and 5D planning technologies to develop packages digitally. The owner reported that the definition of electronic IWPs will be critical to allowing quick updates when drawings or specifications are revised and when the issuance of paper-based packages should be postponed as long as possible.

IWP Structure by Discipline. The project did not adopt the "one crew, one shift" principle to determine the scale of IWPs, but rather adapted IWP size depending on the repetitiveness of the discipline and on the party responsible for execution. For example, if a welding process involved three weeks of field activities and was assigned to a single foreman, a single IWP would include the whole scope of work.

Performance of Both Formal and Informal Audits. The owner comprehensively monitored AWP implementation through a mixture of formal and informal audits. The formal audits were based on recommended AWP checklists to ensure process adherence. These were integrated with more frequent and more detailed informal audits that identified potential deviations and root causes of deviations, in a timely manner.

Integrate with Lean Construction Principles. The owner's lean construction subject matter expert reported that AWP fosters the implementation of lean construction principles (e.g., pull planning and execution, and clean jobsites, among others). Starting at the initial project stages, AWP introduces a systematic planning approach that is essential to adopting the lean philosophy in the field in an orderly manner without upstream disruptions.

Case Study 16

Project Characteristics

Sector: Industrial
Sub-sector: Chemical
Project Type: Plant expansion
Project Location: United States
Contract Type: Time and materials
Project Cost: $600 million USD
Construction Duration: 36 months
Construction Hours: Six million

Project Description

This project involved a brownfield expansion of a chemical production site, mainly requiring steel erection and pipe rack construction within an existing facility. The project was considered particularly complex because of the limited available laydown areas, the necessity of continuing operations on other lines, and the constrained construction operability. Managed in the U.S. by the EPC and executed overseas by a subcontractor, the project required global coordination of multiple participants. To address this main managerial complexity, the EPC had to synchronize the activities of six different fabricators with the overseas subcontractor's production schedule. The transportation of major materials and modules was a critical consideration because of the long lead-time they needed and the uncertainty of their passage through customs. For the EPC, this project constituted a turning point towards the consistent multi-project application of AWP using advanced automation tools. The project presents an interesting example of high-level integration of different project participants located in different geographical regions.

AWP Implementation

Project scope was initially broken down into CWPs at a Level 2 schedule and then divided into EWPs by process. This preliminary planning began more than 12 months prior to field mobilization. The engineering systems used decoupling points—such as valves for piping—to delineate the various systems going into EWPs as they crossed multiple CWPs. Engineering plans included estimates of required labor resources, materials, and equipment. EWPs were aligned with the WBS at a Level 3 schedule and then assigned to subcontractors through lump-sum bids.

At the beginning of detailed engineering, consistent training on AWP procedures and guidelines was provided to the engineering, procurement, planning, and controls departments, in order to clarify definitions, procedures, and expectations. For this particular project, subcontractors were responsible for developing IWPs in accordance with schedule deadlines and quality requirements specified within the bids. Subcontractors were fully integrated with the EPC company, so that they use the same planning and automation tools. The EPC supported the subcontractors by providing training and access to its IT tools.

Contents of IWPs

A typical IWP included the following information:

1. Safety procedures
2. Scope of work
3. Engineering documents
4. Quality requirements
5. Progressing documentation.

Issuance of IWPs

IWPs were developed electronically 90 days before the construction start date. Once ready, they were sent to the field for superintendent review and approval. After approval, the final versions of the IWPs were issued four weeks before the beginning of construction activities. These final versions were distributed only after all major constraints had been solved. The complete availability of materials and engineering specifications was verified before issuance. For example, if the required materials of an IWP were not 100-percent available on site, the superintendents could decide either to postpone or accept the specific package, depending on the construction sequence and the scheduled materials delivery (which could occur within the four weeks of lead time).

The planning system monitored the number of IWPs in the system, so that no more than a certain number of IWPs could be developed and issued at any given time. This pull mechanism was aimed at stabilizing the execution flow to prevent the accumulation of package buffers that could be misaligned with field activities. The EPC implemented a visualization application that was integrated with the IWPs. For future project execution, the superintendents will be able to use tablets to visualize the areas surrounding the work detailed in IWPs and study construction details in real time. This virtual support will enable users to magnify drawings to see complicated details.

Control of IWPs

The project controls system allowed users to visualize the status of each package in the system. Each package had a unique identification number, and project plans were aligned with AWP deliverables. Project progress could be visualized at different levels of granularity, from the single package to the whole CWP or construction discipline.

The subcontractors would update the progress status of the IWPs and upload the data on the controls system, which the owner and the EPC could access remotely. The system provided a set of dashboards and performance indicators to show variances and criticalities. The dashboards clearly indicated whether the planning or execution processes were on schedule, whether minor constraint resolution was required, and whether re-planning or additional resources were needed to absorb delays. All this information was stored in a unique database and shared among key project participants. Different pieces of information had different update cycles. For example, installation progress was updated bi-monthly, while engineering information was updated weekly.

Materials Management

Procurement responsibility was divided among project participants: subcontractors purchased all bulk materials; the EPC purchased the tag-line items; and the owner was responsible for specialty equipment. All procurement information was updated into the AWP system and linked to engineering specifications. Each item was tracked through the system, which notified project personnel of any criticalities caused by missing information or unexpected delays.

Organizational Implications

The project's high level of automation allowed the EPC to assign a single AWP planner to multiple projects at the same time. The AWP manager continuously trained planners to prepare them to work on multiple disciplines on the same project. Specifically, AWP planners were able to clear constraints during package development, check materials status, validate the schedule, and check schedule progress. Generally, an AWP planner was expected to be able to manage activities worth $100 million. Planners developed IWPs on the basis of the company's previous performance, discussing the outcome with foremen and superintendents through an iterative and collaborative process.

Project Performance

Safety Performance

The project improved its safety performance significantly, in comparison with the company average. The EPC reported that, after AWP adoption, the average TRIR dropped from 3.7 to 0.3. AWP supports the improvement of safety performance by including safety—starting at the preliminary planning stages—such that safety considerations are fundamental to developing the path of construction.

Cost Performance

The planning process realized consistent savings, since it was 88 percent less expensive than the company's average and required 75 percent less full time equivalent (FTE) staff members, thanks to the process automation tools implemented. Overall, the planning process cost one percent of TIC. Quantitative data on productivity were not available for this project, even though the EPC noted that the project performed better than the company's average projects.

Schedule Performance

The project was delivered with minor delays related to fabrication deferrals and materials transportation halts at customs. The EPC reported that AWP helped reduce the impact of fabrication delays by supporting the prompt identification of these delays and the subsequent definition of appropriate countermeasures. The planning process benefited from automation improvements that enabled planners to create electronic IWPs in approximately 30 minutes. This represented a substantial reduction, compared to the average of eight hours on previous projects.

Quality Performance

Quality performance on this project was better than the company average. IWPs included detailed quality requirements, with the objective of achieving a punch list with zero items. The inclusion of quality requirements was checked before IWP issuance, and the foremen were committed to meeting quality objectives.

AWP Benefits, Difficulties, and Lessons Learned

This case study found significant "ancillary" benefits related to AWP implementation. The interviewees also noted a set of challenges and valuable lessons learned that they will use to improve the planning processes on future projects. Table 19 provides an overview of these major AWP-related benefits, difficulties and lessons learned.

Table 19. Case Study 16: Benefits, Difficulties, and Lessons Learned

AWP Benefits
Information Visibility
Alignment across Disciplines
High Scalability
Quick Decision-making
AWP Difficulties
Change Inertia
AWP Lessons Learned
IT Integration
Early Involvement of Planners
Full Adherence to AWP Procedures (Constraint Analysis)

AWP Benefits

Information Visibility. Project information was collected and shared within a unique database, allowing integrated planning with comprehensive supply chain visibility. Information was updated on a daily basis and was used to minimize communication gaps among project participants. Both the construction and engineering departments improved their productivity and reduced rework, thanks to this higher information visibility. The EPC gave an example of how the integrated database increased the effectiveness of its proprietary design tool for piping. The traditional planning process involves managing status by color coding the various lines. This process is prone to human error and is rarely seamlessly integrated across the planning and the design departments. Thus, if a new line was color-coded by mistake, the designer would never provide the accurate information for this new item. Such mistakes would cause delays or even rework for the construction, engineering, and procurement departments. The use of an integrated database provided made this process more visible by performing variance analysis and preventing erroneous duplication of data.

Alignment across Disciplines. The EPC was able to integrate the engineering, procurement, and construction disciplines into the final schedule. Engineering specifications were integrated into the fabricators' systems, which followed the materials until their delivery to the field, where the modules were assembled as described by the IWPs. The schedules from engineering, fabricators, and subcontractors were constantly reviewed and aligned, to maximize field productivity. AWP implementation allowed the project team members to break traditional functional silos, highlighting the various information requirements and fostering the controls process with a multi-project perspective.

High Scalability. AWP procedures are designed to be scalable and applicable to projects of any size. The EPC consistently implemented AWP across projects from different sectors (e.g., power, chemical, and oil and gas), replicating the same systems across the projects with minimal adaptation effort in terms of tools, procedures, and capabilities.

Quick Decision-making. The project's high information visibility improved the decision-making process. Potential problems and misalignments were promptly identified, such that the impact of uncertain events was reduced before any dangerous ripple effects were set in motion.

AWP Difficulties

Change Inertia. The EPC reported that the major difficulties during initial AWP implementation included adherence to AWP process guidelines by the various departments. A major change was required by the engineering department, which had to change its specification development process substantially to adapt to the AWP construction requirements. Breaking down engineering specifications by EWPs was perceived as challenging and required specific training. This training had to consistently explain the reasons and potential benefits of the required process modification. This change management process required a significant amount of time and involved some inefficiencies, before effecting the consistent integration and alignment fostered by AWP.

AWP Lessons Learned

IT Integration. The use of advanced automation tools was necessary to implementing AWP across multiple projects and in geographically dispersed companies. IT integration was not limited to the planning and controls process, but also involved all supply chain interactions, from procurement to training. Many of the IT applications were based on license-free tools, which, because their use meant reduced upfront and operational expenditures, fostered AWP adoption among subcontractors and vendors. The EPC developed a set of tools for future implementation that would allow packages to be integrated with 4D and 5D scheduling tools. These tools also gave superintendents and foremen real-time access to packages with interactive capabilities.

Early Involvement of Planners. In contrast to traditional planning practices, the AWP planning approach involves the planners earlier in the project, so that they can put information together to perform a preliminary check of estimates. On this project, planners were involved at a Level 3 schedule, and the EPC noted that, had they been involved even earlier, it could have improved the quality and reliability of the planning process through closer alignment and better focus on constructability.

Full Adherence to AWP Procedures (Constraint Analysis). AWP should not be implemented mid-stream or without adequate preparation and training. This requires the commitment of additional resources such as a dedicated AWP team. Partial AWP adoption only allows for a fraction of the potential performance improvements. The EPC reported that, to achieve full adherence to AWP implementation (and, thus, to obtain all its benefits), it sought full commitment to AWP at various levels of the corporate hierarchy. Specifically, commitment should initially come from the owner, but it also must be internalized by craft workers, who are the final users of the methodology.

Case Study 17

Project Characteristics

Sector: Industrial
Sub-sector: Oil and gas
Project Type: Plant expansion
Project Location: United States
Contract Type: Time and materials
Project Cost: $360 million USD
Construction Duration: 24 months
Construction Hours: Two million

Project Description

This project involved the expansion of an existing oil and gas facility in the U.S. Specifically, its scope was to increase processing capacity, and its complexity lay in its need for global coordination of multiple participants. This project represented a turning point for the EPC in its use of advanced automation tools to apply AWP consistently on a number of projects at the same time.

AWP Implementation

Project scope was initially broken down into CWPs at a Level 2 schedule, and then divided into EWPs by process. This preliminary planning phase began more than nine months prior to field mobilization. The engineering systems used decoupling points—such as valves for piping—to delineate the systems going into EWPs as they crossed multiple CWPs. Engineering plans included estimates of required labor resources, materials, and equipment. EWPs were aligned with the WBS at a Level 3 schedule and then assigned to subcontractors through lump-sum bids. EWPs were developed by discipline. Engineering collaborated with the construction and procurement departments to provide aligned specifications.

AWP involved all main project disciplines, which included civil foundations. Foundations were planned individually, allowing for an easier break-down process. The planning team adopted a laser scanning technology with data point-cloud capability to obtain 3D scanning visualization for effective brownfield project planning.

Contents of IWPs

A typical IWP included the following information:

1. Safety procedures
2. Scope of work
3. Engineering documents
4. Quality requirements
5. Progressing documentation.

Issuance of IWPs

AWP guidelines require that IWPs be developed electronically 90 days before the construction start date. Once developed, they are sent to the field, where superintendents review and approve them. After approval, the final versions of IWPs are issued to the superintendents or general foremen. These final versions are distributed only if all major constraints have been resolved. Hence, materials and engineering specification availability is verified before issuance.

This project's planning system allowed for monitoring of the number of IWPs in the system at any given time. This ensured that no more than a certain number of IWPs could be developed and were in circulation. This pull mechanism was aimed at stabilizing the execution flow, to prevent the creation of package buffers that could be misaligned from field activities.

Control of IWPs

The owner monitored the resolution of all constraints prior to field mobilization. The project's planning system tracked the status of each package, providing updates on the completion of each item. The project management team conducted weekly meetings of construction and planning representatives to discuss and approve current and upcoming packages.

Materials Management

The EPC was able to establish an integrated and accessible production schedule with the project's steel and pipe fabricators. The project team pursued integration, starting at the beginning of the project, by integrating AWP guidelines and deliverables into contracts. Production updates were shared among fabricators and project participants, allowing for continuous monitoring of delivery dates. The system tracked each item, alerting users of criticalities caused by missing information gaps or unexpected delays.

Organizational Implications

The planning process involved two planners, who both leveraged the high automation level of the EPC. The first planner was involved during the early Level 3 schedule planning (three months prior field mobilization). The second became engaged at the beginning of field mobilization to support the development of the increasing IWP volume. The planners integrated engineering, construction, and planning control deliverables remotely from offsite stations.

Project Performance

Safety Performance

The project's safety performance consistently improved in comparison with the company's average performance. Zero lost time incidents were recorded, and the TRIR was approximately 0.12—an improvement over the company average of 3.7 on previous projects. AWP supports the improvement of safety performance by addressing safety concerns as early as the preliminary planning stage, such that safety considerations are fundamental to developing the path of construction. The EPC's safety department defined the project's health and safety analysis (HSA) plans for the various portions of the construction scope.

Cost Performance

Productivity was approximately 25 percent better than estimated, and, at completion, the project came in approximately 15 percent under budget. Savings were achieved not only through increased field productivity but also through a less expensive planning process. Savings opportunities identified during detailed engineering reduced scope overlaps and precisely defined the minimum number of personnel required.

Schedule Performance

The project was delivered one month ahead of schedule. The EPC reported a high level of satisfaction over this result, especially considering that the project faced various construction halts due to unexpected inclement weather conditions.

Quality Performance

Quality performance was better than the company average. IWPs include detailed quality requirements, with the objective of eliminating the need for a punch list. The quality requirements included are checked before IWP issuance, and the foremen are committed to meeting these quality objectives.

AWP Benefits, Difficulties, and Lessons Learned

This case study found significant "ancillary" AWP-related benefits. The interviewees noted challenges and valuable lessons learned for improving the planning processes on future projects. Table 20 provides an overview of these major AWP benefits, difficulties, and lessons learned.

Table 20. Case Study 17: Benefits, Difficulties, and Lessons Learned

AWP Benefits
Information Visibility *Alignment across Disciplines* *High Scalability* *Improved Customer Satisfaction* *Reduced Impact of Uncertainty* *Predictability*
AWP Difficulties
Late Engineering Deliverables
AWP Lessons Learned
IT Integration *Alignment of Performance Measurement with AWP Deliverables*

AWP Benefits

Information Visibility. Relevant project status information was collected and shared within a single database, allowing for integrated planning with comprehensive supply chain visibility. Information was updated on a daily basis and was used to minimize communication gaps among project participants. For example, each engineering item was assigned a specific status indicating whether it had been issued and received by other participants (i.e., by fabricators or AWP planners). Data consistency was checked across the various companies and departments, so that, if a certain number of ISOs were issued by engineering, the same number should be received by procurement, fabricators, and others. The planning and controls teams developed a number of dashboards to track changes in status and highlight potential criticalities. All project participants and departments perceived benefits from this increased information visibility.

Alignment across Disciplines. The EPC was able to integrate the engineering, procurement, and construction disciplines into the final schedule. Engineering specifications were integrated into the fabricators' systems, and the module materials were tracked up to their delivery to the field, where crews assembled the modules as described in the IWPs. To maximize field productivity, the schedules from engineering, fabricators, and subcontractors were constantly reviewed and aligned.

High Scalability. AWP procedures are designed to be scalable and applicable to projects of any size. The EPC consistently implements AWP across projects from different sectors (e.g., power, chemical, and oil and gas), replicating the same systems across the projects with minimal adaptation needed in terms of tools, procedures, and capabilities.

Improved Customer Satisfaction. The EPC reported that the owner was highly satisfied with the AWP implementation, particularly its requirement of readiness for field mobilization through systematic planning and updated status information.

Reduced Impact of Uncertainty. AWP provided for a faster decision-making process in cases of unexpected events (e.g., fabrication delays). The EPC reported that AWP reduced the ripple effect of such events on project execution, by promptly identifying the source of the problem. The continuous monitoring process allowed the project team to identify and, in some cases, anticipate, misalignment from original estimates. This early awareness fostered effective re-planning.

Predictability. The estimates for this project were perceived as more reliable than those for previous projects performed by the EPC. The final set of IWPs provided detailed and compelling scope breakdowns with high construction predictability.

AWP Difficulties

Late Engineering Deliverables. The definition of EWPs faced some delays, mainly due to changes made in the delivery process for engineering specifications. The engineering department was not used to decoupling the systems by construction areas and had never done this to create deliverables for construction. This inexperience caused some delays during the detailed engineering phase. However, the EPC reported that the increased productivity during construction execution absorbed these delays. Also, these delays occurred at the beginning of the detailed engineering stage, and their frequency decreased as the engineering department became more familiar with AWP procedures.

AWP Lessons Learned

IT Integration. Using advanced automation tools was necessary to implementing AWP across multiple projects and among geographically dispersed companies. IT integration was not limited to the planning and controls processes, but also involved all supply chain interactions, from procurement to training. The EPC developed and shared suites to integrate the work packages with 4D and 5D scheduling tools. These applications also enabled superintendents and foremen to use tablets to visualize and interact with packages in real time. By basing most of these IT applications on license-free tools, the EPC minimized upfront and operational expenditures.

Align Performance Measurement with AWP Deliverables. To increase the information content of the controls system, performance measurements should be made in accordance with main AWP deliverables such as CWPs, EWPs, and IWPs. With AWP, the controls process is fundamental to ensuring compliance with the systematic early planning and critical to efficient and effective construction. Thus, consolidating the controls process and aligning it with a project's planning and construction processes are paramount to project success.

4

Expert Interviews

This chapter summarizes three expert interviews conducted by RT 319. These summaries adopt the terminology of the three expert interviews conducted and summarized by RT 272, extending that team's numbering of the interviews. Thus, these summaries present the findings of the fourth, fifth, and sixth CII interviews of AWP experts.

Expert Interview 4

Characteristics

This interview focused on the deployment of AWP from a supply chain management (SCM) perspective, which looks at the in-bound flow of materials to a project. It includes the upstream management of materials, from the release of the purchase order (PO) to the delivery and onsite storage of materials to the pick-up of materials for construction. The expert was a supply chain manager of an owner company in the oil and gas sector. The company was executing various medium and large projects involving the construction and development of oil and gas plants across North America.

At the time of the interview, the company had recently introduced AWP methodology as a best practice for achieving a structured planning process. Also, previous projects had experienced poor communications and limited data visibility, with delayed and inconsistent information updates (e.g., duplication of data across multiple databases). Moreover, the logistics process was limited to a single-project focus, which blocked opportunities for risk pooling and economies of scale. These ineffective and inefficient systems complicated the decision-making process during the planning and controls processes. The company paid particular attention to integrating AWP with vendors of long-lead materials and equipment, leveraging SCM principles across multiple projects. The interview addressed the company's construction of a $500 million steam-assisted gravity drainage facility in Canada. The project was particularly interesting because it involved the supply chain integration of more than 20 different contractors (some performing onsite and offsite prefabrication) over a 42-month duration, for more than four million construction hours. The project management team chose to implement the SCM system to support the planning process in accordance with AWP guidelines. RT 319 selected the project logistics lead as the expert to interview—an individual who had already headed several initiatives to use external logistical support to improve materials traceability on projects, for more successful AWP implementations.

Focus: Supply Chain Management for AWP

The owner implemented a traceability system to give the various project participants full materials visibility. The system was owned and managed by a third-party company that adapted procurement procedures to follow owner requirements and AWP guidelines. It used both top-down and bottom-up approaches to identifying and tracking materials requirements. In the top-down approach, procurement was performed and updated as the engineering process progressed, so that materials releases were detailed according to EWP specifications. In the bottom-up approach, the contractors provided all additional supplies to the owner (in terms of free-issues, reimbursables, accessories, and other items) for inclusion in material requirements. Compared to requirements developed during traditional planning—which takes a predominantly top-down approach—these requirements constituted a more comprehensive and reliable list of actual field needs. Contractors and engineering companies received adequate training to use the materials system during the initial project stages.

The system was constantly updated and integrated into the systems of the various project participants. Having updated information allowed for immediate materials 3D listing and reporting that could be parametrized and integrated into EWPs. The system was also used to develop IWPs quickly and then control their implementation. After the IWPs were created with the 3D system, their materials were bagged and tagged according to construction requirements. Once issued to the field with the IWPs, the materials were monitored through RFID or bar-coding tracking. This integration of AWP procedures with materials tracking was fundamental to ensuring materials visibility. Previously, the owner had no visibility of materials after issuance to the work front. This resulted in substantial material losses and subsequent re-purchasing. The new, integrated tracking system gave multiple project participants materials visibility up to the moment of installation of the materials on site.

The management of cable provides a good example of how this AWP-governed process improved materials management on this project. Cables were managed during the planning process through a mixed push-pull mechanism: IWPs were developed top-down in a push mode until the release of the PO; they were then issued in a pull mode to the contractors in accordance with field requirements. With AWP, IWPs perforce have no installation constraints, and cables are automatically bagged and tagged before their issuance to the field. RFID tags placed on the spools of cables allowed for immediate field traceability.

Results

The AWP traceability system increased field productivity, since, by reducing the waiting time for unavailable materials, it enabled contractors to operate at full capacity. For example, before system implementation, crews typically spent two to three hours per day on materials issues. After implementation, materials-related lost time was reduced to 20 minutes per day.

The materials system also improved the project cash flows, by decreasing re-procurement and material losses. Construction delays due to late materials were minimized, and the supply chain department was able to support construction effectively on fast-track projects. Other benefits related to the adoption of the system included the following:

- **Increased crane efficiency**: By reducing idle time, the improved materials coordination resulted in better crane optimization. This higher efficiency realized savings equivalent to 12 hours per month per crane.
- **Higher expediting efficiency**: With better access to up-to-date information, expeditors performed more efficiently.
- **Improved safety**: The traceability of materials through RFID tags minimized the risk exposure during materials pick-up and issuance to the work front.
- **Reduced storage capacity requirements:** With more materials visibility, planning for materials storage became more precise.

The inclusion of a third-party logistics company added a tier to the SCM system, and thus increased management cost. The cost to implement the system was approximately one percent of project TIC, which was consistently outweighed by cost savings for the owner (in terms of reduced inventory and equipment costs) and for the contractors (in terms of higher productivity and safety improvement).

Lessons Learned

The expert stressed the importance of creating a central database to provide a unique and ever-updated source of data, from any vendor and any offsite location. Because the database allows every project participant to operate with full visibility, it fosters the use of mixed pull-push management mechanisms. In this instance, the achievement of real-time visibility improved the overall planning process; AWP planners and schedulers were able to identify potential issues before field activities began. This early trouble-shooting supported the decision-making process for activity re-sequencing and materials expediting.

The system fostered horizontal and vertical materials integration among project participants. Horizontal because it was integrated across different disciplines (e.g., by system, area, and IWP). Vertical because it was integrated among project participants with different levels of granularity (e.g., by material code, IWP, and vendor). According to the expert, the system also supported schedule development and control responsively. Because all materials constraints had been solved prior to construction execution, a higher percentage of IWPs were ready for operations and were not affected by delays.

Future developments of the system will be aimed at achieving a full scalable system with major upfront integration. One of the main objectives will be to begin material coordination in the initial stages of preliminary planning. This earlier integration will support the identification of long-lead items and major equipment. Once identified, they will be tied to project plans in a consistent and integrated manner with the main vendors.

Expert Interview 5

Characteristics

This interview focused on the application of AWP principles in the modular building sector. Specifically, AWP was implemented on a renovation of the owner's corporate headquarters in North America. The project involved 30 floors of the building and was performed floor by floor in 12 weeks at a cost of less than $2 million per floor). The floors all had a common basic layout that could be customized, depending on the number and types of rooms required (e.g., conference rooms or offices). The owner decided to implement AWP during project execution in response to a lack of coordination that was evident during the construction on the first few floors. The owner imposed AWP on the two GCs to replace their more *ad hoc* approach to planning with a more systematic and sophisticated planning process.

The expert interviewed was the project manager and AWP champion of the owner company. RT 319 selected this individual because this project constituted an original application of AWP concepts in the construction sector. Indeed, AWP was used on the project as means of making the traditional planning process more sophisticated. The owner instituted the change to AWP to ensure that the proper planning was performed, controlled, and owned by the GCs.

Focus: AWP for Modular Building

The owner collaborated with an architecture firm to define the major part of the project's design. After GC selection, the owner included AWP guidelines within the contractors' and subcontractors' contracts. The GCs were first involved on the project during the detailed planning process.

The detailed design of each floor was performed one month before construction activities began, to incorporate the specific needs of the corporate teams using the floor. Due to the limited size of the project, each floor represented a single CWP. EWPs were not included, since the design for each floor was composed of variations of standard modules. Contrary to AWP guidelines, the contractors did not have dedicated AWP planners, and the IWPs were directly assembled by the foremen for the various disciplines. Even the smallest crews (e.g., two to three electricians) had to adhere to AWP guidelines and solve IWP constraints before performing construction activities. IWPs comprised a day's worth of construction work per crew. The relatively small size of the packages was a consequence of the short duration of activities per discipline.

Before being issued them to the field before execution, owner representatives revised and controlled the IWPs. Before beginning work on an IWP, the two GCs would go through a checklist to ensure that all activities were properly sequenced, that all drawings and quality checks were included, and that all required materials were indicated. The foremen briefed the crews every day, describing the scope of activities and providing details on safety and any special tools to be used.

Owner representatives performed the controls process for IWP execution as a weekly routine. The owner's foremen provided feedback and performance reports for the closeout for each IWP. AWP procedures required that lessons learned at the IWP level be incorporated, to improve operations on the subsequent floors. Once collected, this information was used as a guide for project execution.

Results

The expert reported that construction activities were more predictable compared to the initial floors executed without AWP. The improved predictability was a direct consequence of the more systematic planning process. This process included the integrated sequencing of activities and the early identification of construction needs.

Other performance improvements were seen in immediate reductions of construction changes and unproductive time. AWP fostered the integration among the GCs and the different crews. Since there were no halts for missing materials, the waiting time due to poor coordination between crews was minimized.

AWP was also used as a means to reduce the lock-in effect, wherein an owner is constrained to keep contractors on the job, in spite of poor performance. Having a repository of packages and plans in place allows owners to switch contractors more easily, because know-how and procedures are quickly transferable.

Lessons Learned

AWP guidelines should be adapted according to the scope and the size of a project. On this project, AWP guidelines were modified as a function of the level of construction complexity and sophistication required. The owner demonstrated full commitment to implementing the AWP planning approach in collaboration with the GCs, and was always willing to adapt the procedures and to provide training and consultation. Also, the early definition of floor design forced the owner to freeze the design in advance. This represented a major improvement for the owner, who had to commit to a final design and avoid late changes that would hamper the reliability of the plans.

AWP fostered a process optimization mentality, even for small crews and construction activities that are typically unstructured. As someone used to implementing AWP for large and mega-projects in the power sector, the expert interviewee reported the great predictability benefits of implementing a systematic planning approach even for such small (floor-by-floor) projects.

During the initial implementation, the owner faced some change inertia from the contractors concerning the time required to develop the packages. Foremen had to re-allocate part of their tool time for planning activities, and this re-allocation was perceived as less productive. This change inertia faded when the crews found that predictability, productivity (as a reduction of wasted time), and customer satisfaction were actually increasing. The GCs started to take ownership of the AWP process by actively proposing new procedures and by performing the planning process independently.

Expert Interview 6

Characteristics

This interview took a corporate perspective on how the automation aspect of the AWP process improves the management of multiple projects. The expert was the AWP champion of a big EPC company operating in the industrial construction sector. The company mainly undertook projects in the oil and gas, power, and manufacturing (e.g., pharmaceutical) sectors. The company was able to automate the AWP process across multiple projects, managing more than $2 billion worth of work. The project management team took a standard and structured approach to developing the automation system, to ensure that it applied AWP equally to medium, large, and mega-projects. It was mainly used for civil works (e.g., foundations) and the piping, electrical, and mechanical disciplines. The research team selected this expert as an interviewee because of his visibility on the entire AWP implementation process, from preliminary planning to turnover. He was also considered a good source of data because he was accountable for the success of the implementation, managing the resources and assigning AWP responsibilities within the company.

Focus: AWP Automation across Multiple Projects

The AWP process began during FEED, at Level 2 planning. The AWP champion was mainly involved at this stage to ensure that procedures and integration mechanisms were effectively integrated into the project strategy. The AWP champion collaborated with the engineering and construction managers to identify CWPs and the subsequent EWP sequence. The project management team identified and sequenced the main planning deliverables according to constructability principles.

AWP planners were involved during detailed engineering, at Level 4 planning. The EWPs were at an advanced level of completion (50-60 percent), and the planners made certain that they were complete and that there were no gaps in the project scope. As a rule of thumb, the company allocated a single AWP planner for every $100 million worth of project scope. Planners were placed off site and continuously exchanged information with engineering and construction representatives to integrate and align project plans.

AWP planners were trained to develop reliable estimates for all project disciplines. Thus trained, these planners could deliver and control metrics for the piping, steel, electrical, mechanical, and foundations disciplines. Another reason for giving the planners this multi-disciplinary training was the need to prevent any of them from "locking in" to a given discipline and, thus, possibly shoring up any functional silos on the project. A multi-disciplinary AWP planner can integrate the perspectives of different superintendents and develop a plan that is discussed and ultimately approved.

EWPs were broken down into IWPs following the "one crew, one shift" principle, with a typical IWP requiring 1,500 work hours. Each IWP was assembled, issued, and stored in an electronic format, to allow for quick updates and modification. To provide the estimates, AWP planners had the support of the controls department, which delivered cost and productivity ratios for the various disciplines.

IWPs were issued to the responsible foremen three weeks before the construction start date. The foremen reviewed the package, discussed the contents with the planner, and signed off on the packages, taking responsibility for their execution. To reduce the tendency of accelerating field activities by pooling disciplines together, foremen could not receive new IWPs until they had returned a completed one. This process allowed for a stable flow of activities for every discipline.

The company maintained a backlog of IWPs that was equivalent to eight to 12 weeks of activities (approximately four to six IWPs) to re-allocate crews in cases of unexpected production halts and to absorb the effect of disruptions. IWPs in the backlog were constraint-free and ready for operations. In cases of unexpected problems with an IWP, the foreman would communicate the nature of the problem to the planner. If the problem involved a major planning deficiency (e.g., inconsistency with other packages), the IWP would be halted, and the foreman would receive a backlog package for construction. If the problem was only a minor inconsistency (e.g., the resolution of an RFI), the information was provided without halting construction.

Results

The company had full visibility on the planning process. The automated system allowed the project management team to develop multiple planning deliverables (e.g., drawings for a certain area or equipment/materials purchased per vendor or per arrival date) at different levels of granularity. The system was used intensively to ensure the completeness of planning items, as well as to achieve real-time reporting.

One of the major advantages of the automation system was that it required a very limited amount of dedicated resources. The total cost reduction for planning was 25 percent. The planning process also reached an unprecedented level of productivity, with IWPs that could be assembled in fewer than 10 minutes. (Before the automation system was implemented, the normal requirement was one hour.) Ultimately, the savings realized from using the system outpaced the fixed cost for implementing it.

Lessons Learned

The technological platform was a fundamental enabler of the successful AWP automation. The adoption of the platform was an incremental process that required training and commitment. The main difficulty was establishing an awareness of the tool's full potential and convincing the various functions involved of the benefit they stood to gain. This technology adoption began within the organization's boundaries and later extended to include external project parties. To integrate the system with the vendors' systems, the team had to define specific information requirements (e.g., data format, detail level, and deadlines), so that it was possible to include vendor data within the EWPs.

Early owner buy-in was the most critical aspect of successfully implementing AWP. The expert interviewee reported that the most difficult part of achieving owner buy-in was that, while it was argued for on the basis of results (i.e., improved construction performance), it had to be obtained before any results had been obtained (i.e., during the initial planning stage). The automation system allowed the owner to replicate the AWP implementation process on every project, and the main implementation barrier was the owner's willingness to align procedures and information exchange requirements.

Appendix: Questionnaire

Project Background and Company General Characteristics

1. Please describe your position within the company as well as your experience: ______________________________
____

2. Please describe your experience with work packaging: ______________
____

3. What is the main contract type of your projects? (Check all that apply)
   - ☐ Lump Sum
   - ☐ Unit Price
   - ☐ Cost Plus
   - ☐ Others: ______________

4. What are your typical project drivers?
   - ☐ Cost
   - ☐ Quality
   - ☐ Time to market (schedule)
   - ☐ Others: ______________

5. What is the project delivery type?
   - ☐ EPC (i.e., engineer-procure-construct) or Design/Build
   - ☐ EP-CM (i.e., EP with management of prime constructors/suppliers)
   - ☐ Design/Bid/Build or Construction Only
   - ☐ Construction Management (at risk)
   - ☐ Owner-managed

6. What is the Construction contract type? (Check all that apply)
   - ☐ Lump Sum
   - ☐ Unit Price
   - ☐ Cost Reimbursable
   - ☐ Other, specify: ______________________

7. Are there multiple prime general contractors?
   - □ Yes How many? _____
   - □ No

8. What is the expected capital cost of this project?
   - □ Total installed cost (TIC): _____

9. What are the expected total on-site field effort work hours?
   - □ Direct work hours: _____
   - □ Indirect work hours: _____

10. Which crafts are subject to work packaging? ______________________________
    ____

11. What are the expected ratios for general foremen, foremen, planners, and crew?
    - □ General foremen to foremen: _____
    - □ Foremen to planners: _____
    - □ Foremen to crew: _____
    - □ Planners to crew: _____

12. Which crafts are subject to Advanced Work Packaging (e.g., piping)? _____
    ____

13. Did work packaging drive the use of advanced tools and technology? _____
    ____

14. Before utilizing this current form of work packaging, what was used for planning? ____
    ____

15. What opportunities for work packaging improvement have been identified?
    ____

16. What were the key difficulties associated with work packaging implementation? ____
    ____

17. What cultural changes were made due to work packaging implementation?
    ____

AWP Process – Preliminary Planning

18. Please describe your work packaging process during FEED (e.g., what is a EWP and a CWP, relationships between EWPs and CWPs, level of planning details before starting detailed engineering) ______________________

____

19. Please describe your CWP/ EWP boundary development process. Who does the EWP boundaries development? Do EWPs correlate to CWPs in content and sequence?______________________

____

20. Are path of construction meetings attended by appropriate stakeholders?

____

21. Are roles and responsibilities defined and updated for all stakeholders? ____

____

22. Are documented audit protocols developed and frequently implemented to measure AWP process validity?______________________

____

23. Do early scope definition documents include construction sequencing phases and turnover implications to support the construction of packages?

____

24. Are the CWP/EWP/IWP schedule and release plans developed during FEED? ______________________

____

25. Does the AWP plan include long-lead items assessment and considerations for site logistics/support services? ______________________

____

26. Does experienced construction personnel approve the schedule, scope, sequence and timing of EWPs/CWPs?______________________

____

27. Please describe your EWPs progress monitoring process. ____________

____

AWP Process – Detailed Design

28. Please describe your process of developing the detailed engineering documents? ______________________________

    ____

29. Who is involved in developing the detailed engineering documents? _______

    ____

30. Is a Level 2 schedule developed, prior to the start of detailed engineering, for all construction and engineering work packages (CWPs/EWPs) to support the construction plan? ______________________________

    ____

    - If no, how is engineering data delivered to site? (Are people responsible for arranging engineering data and repackaging it to support the workface? Is this a formal process or is it performed in an *ad hoc* manner?)

31. Please describe any existing updating process of EWPs and CWPs: _______

    ____

32. Is the construction side involved in the detailed engineering process?

    □ Yes

    □ No

    - If yes, please explain how: ______________________________

      ____

33. How do you tie procurement into your EWP planning? ________________

    ____

34. How do you make sure that procurement and engineering are consistent with the installation sequence? ______________________________

    ____

AWP Process – Construction

35. Please describe by whom and how installation work packages (IWP) are defined ______________________________
____

36. Is a written procedure in place to regulate IWP management? ____________
____

37. Are IWPs retained in electronic format and not issued in hard-copy format until they are required by construction operations? ____________
____

38. How much in advance are IWPs issued to field? Are they approved by contractors? ______________________________
____

39. Are materials bagged and tagged by IWP? ____________
____

40. What does an IWP contain?
    - □ Scope
    - □ Drawings
    - □ Materials
    - □ Safety and risk response plan
    - □ Interdependencies with other IWPs
    - □ Scaffolding
    - □ Turnover and commissioning
    - □ Equipment and specialty tools
    - □ Quality controls
    - □ Others: ____________

41. Is a backlog of IWPs in place to minimize the impact of unforeseen circumstances? ______________________________
____

42. Are audits and lessons learned captured for future use? ____________
____

43. Please describe your IWP control process (frequency, sign-off, management of late starts, performance measurement) ____________
____

Organization and Work Packaging Functional Capabilities

44. Does the company enforce work packaging practices or does the project team determine its application? ____
    ____

45. Do you have a champion for the new work packaging process? Please describe his/her responsibilities.
    □ Yes
    □ No

46. Do you have a work packaging planner? Please describe the relationship between the Engineering manager and the work packaging planner: ______
    ____

47. Are there any new positions that were created specifically for the current work packaging process (e.g., data-integration coordinator, audit manager)?
    □ Yes
    □ No
    - If yes, please describe: ______________________________
      ____

48. Is a training matrix established with regard to AWP strategy? ____________
    ____

49. Is a data integration plan utilized to ensure compatibility between systems?
    ____

50. Are the CWP/EWP release plans developed and issued to all project stakeholders? ______________________________________
    ____

51. Are vendor's data mapped for each EWP and included within purchase orders? ____
    ____

52. What cultural changes resulted from the new work packaging process implementation? Is a change management process defined for jeopardized activities? ______________________________________
    ____

Contracts

53. What is the contract's role in enhancing the work packaging process for engineering and contractors? ______________________________

54. Are data format/requirement/maintenance defined and agreed within contracts? ______________________________

55. Are the various project participants prequalified and aligned? ______________________________

56. Do cost and payment milestones reflect the AWP plan? ______________________________

57. Are specific AWP expectations included within participants' contracts? ______________________________

58. Are AWP requirements written into every construction/engineering and procurement contract including formatting, level of detail and frequency? ______________________________

59. What contract language do you recommend for enhancing work packaging procedures? ______________________________

60. Perceived needs and recommendations to be addressed in contracts for work packaging process improvement? ______________________________

Project Performance – Benefits – Challenges – Lessons Learned

61. Safety performance:
    a. at project completion
        - □ Better than recent company historical norm
        - □ Close to recent company historical norm
        - □ Worse than recent company historical norm
        - □ Don't know
    b. Please justify: ______________________________

62. Quality performance:
    a. at project completion
        - □ Better than plan
        - □ Close to plan
        - □ Worse than plan
        - □ Don't know
    b. Please justify: ______________________________

63. Cost performance:
    a. at project completion
        - □ Better than plan
        - □ Close to plan
        - □ Worse than plan
        - □ Don't know
    b. Please justify: ______________________________

64. Schedule performance against original plan (e.g., meeting intermediate milestones, conformance to scheduled work)
    a. at project completion
        - □ Better than plan
        - □ Close to plan
        - □ Worse than plan
        - □ Don't know
    b. Please justify: ______________________________

65. Schedule performance against project delivery date:
    a. at project completion
        - □ Better than plan
        - □ Close to plan
        - □ Worse than plan
        - □ Don't know
    b. Were aggressive measures taken to meet the project delivery date?
       Please explain: ______________________________

66. Field productivity:
    a. at project completion
        - □ Better than plan
        - □ Close to plan
        - □ Worse than plan
        - □ Don't know
    b. Please justify: ______________________________

67. Field rework:
    a. at project completion
        - □ Better than plan
        - □ Close to plan
        - □ Worse than plan
        - □ Don't know
    b. What was the percent of rework seen on this job? ____________

68. Request for information (RFI) frequency:
    a. at project completion
        - □ Fewer than expected
        - □ As expected
        - □ More than expected
        - □ Don't know
    b. What percentages of RFIs were generated from field labor vs. the planning department?
       Percentage of RFIs generated by field labor: ____
       Percentage of RFIs generated by planning: ____

69. Additional benefits/challenges:
    a. Alignment between engineering, procurement and construction
    b. Workforce satisfaction/craft retention
    c. Predictability
    d. Availability of materials
    e. Constructability
    f. Disruptions of operations (speed of decision making, impact of changes)
    g. Others: ______________________________

70. What are the lessons learned from the AWP implementation process? _____
    ____

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