



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*

Construction Industry Institute

Implementation Resource 319-2

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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.

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

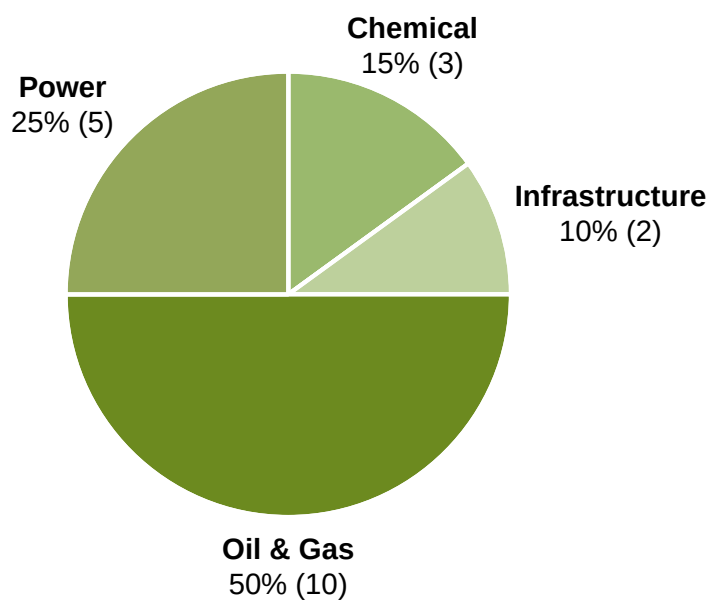


Figure 1. Number of Case Studies by Sector

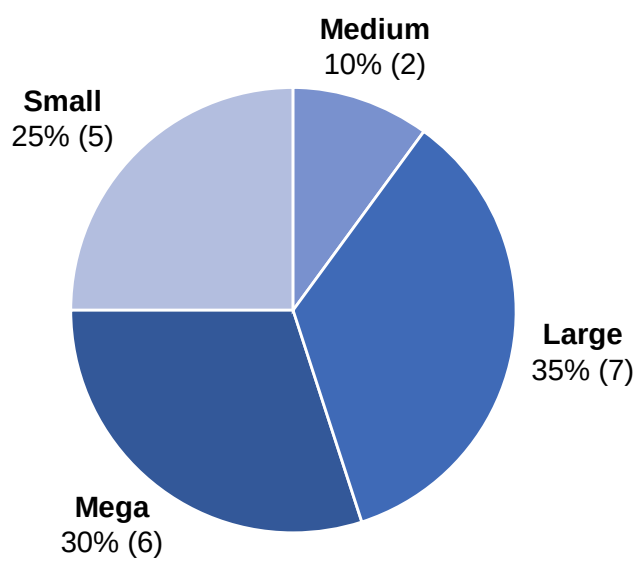


Figure 2. Number of Case Studies by Size

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.

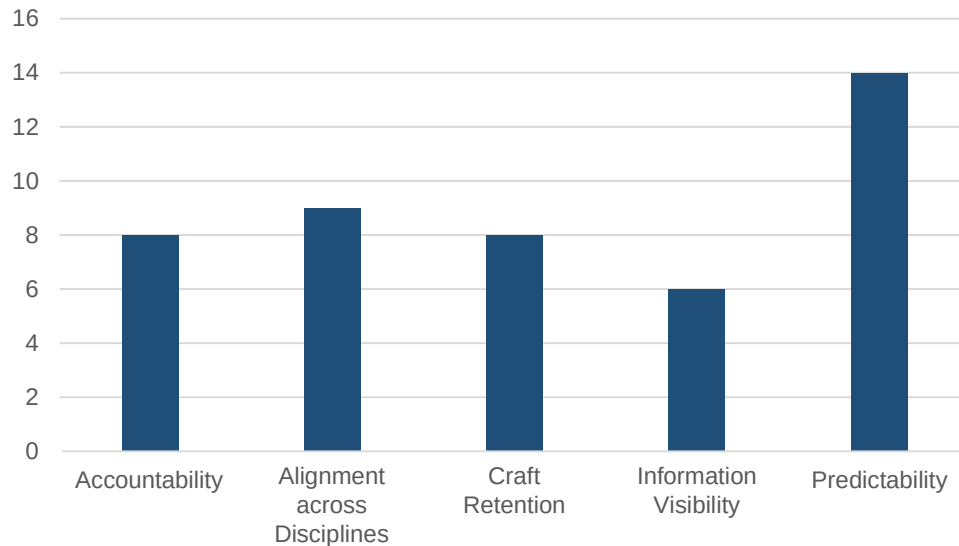


Figure 3. Top 5 Most Recurrent AWP Benefits

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 IWP's 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 IWP's
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.

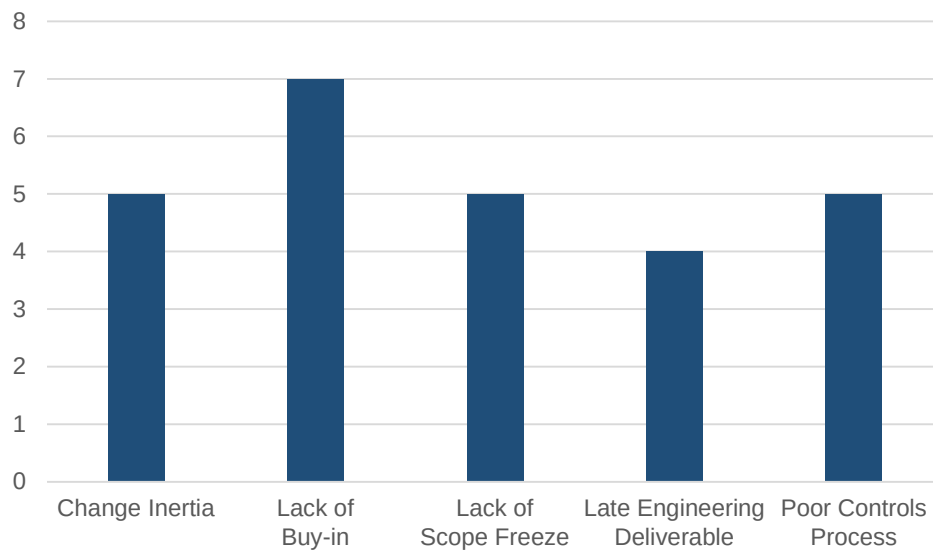


Figure 4. Top Five Most Recurrent AWP Difficulties

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 CWP). 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 then 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.

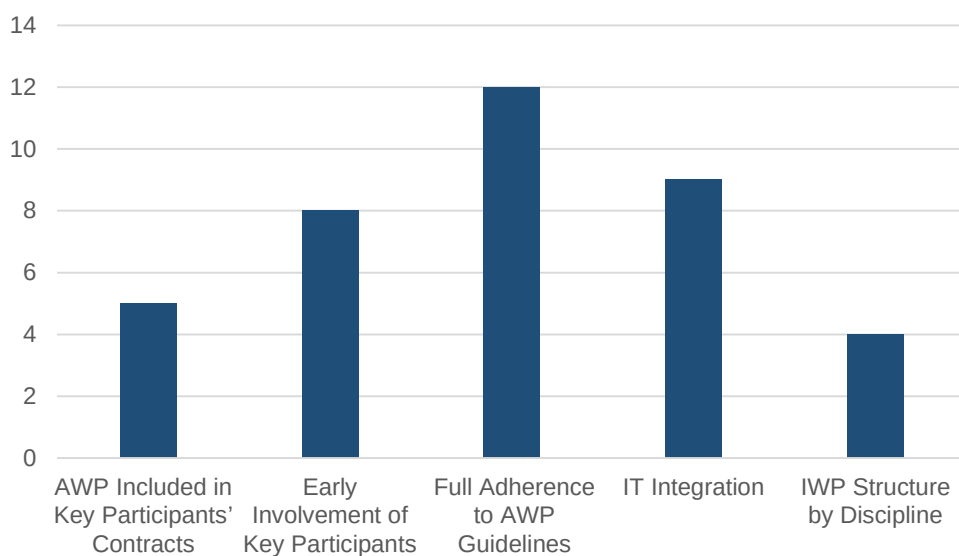


Figure 5. Top 5 AWP Lessons Learned

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 CWP and EWP. This AWP-sensitive project execution plan should be continuously refined as more details become available. Owners should perform a process with stage gates that correspond 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	Contract Type: Time and materials (T&M)
Sub-sector: Infrastructure	Project Cost: \$400 million CAD
Project Type: Sustaining mining expansion	Construction Duration: 12 months
Project Location: Alberta, Canada	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 workforce 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

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 CWP and EWP 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, CWP and EWP 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 CWP and EWP 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. CWP were divided among multiple IWP, according to the number of hours included in a single IWP shift. IWP 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 | 7. Equipment |
| 2. Scope of work | 8. Time sheets and progress |
| 3. Quality control requirements | 9. Project schedule |
| 4. Engineering documents | 10. IWP completion punch list and signoff. |
| 5. Bill of materials | |
| 6. Accessibility | |

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
- workforce 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.

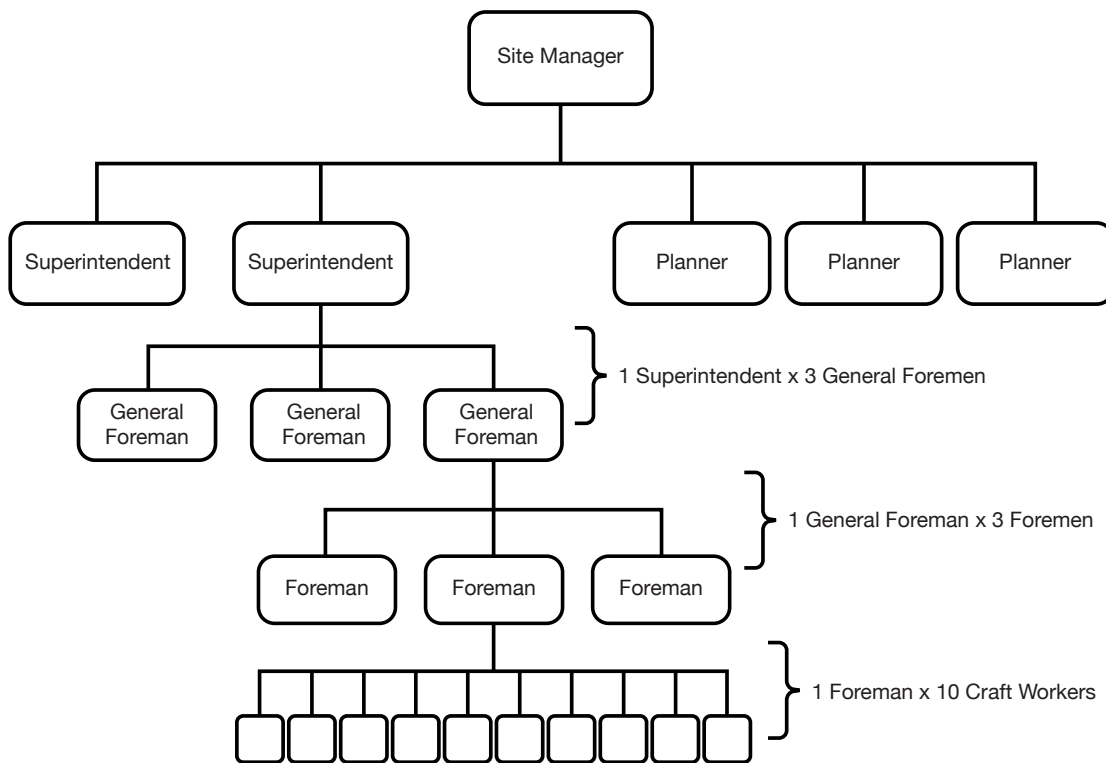


Figure 6. Case Study 5: Proportion of Field Personnel to Planning Personnel

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

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 EWP's 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	Contract Type: Time and materials (T&M)
Sub-sector: Oil and Gas	Project Cost: \$150 million CAD
Project Type: Site improvement	Construction Duration: 12 months
Project Location: Alberta, Canada	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 | 7. Equipment |
| 2. Scope of work | 8. Sub-trades |
| 3. Job cards | 9. Permits |
| 4. Quality control | 10. Engineering documents |
| 5. Materials | 11. Reporting page. |
| 6. Scaffolding | |

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.