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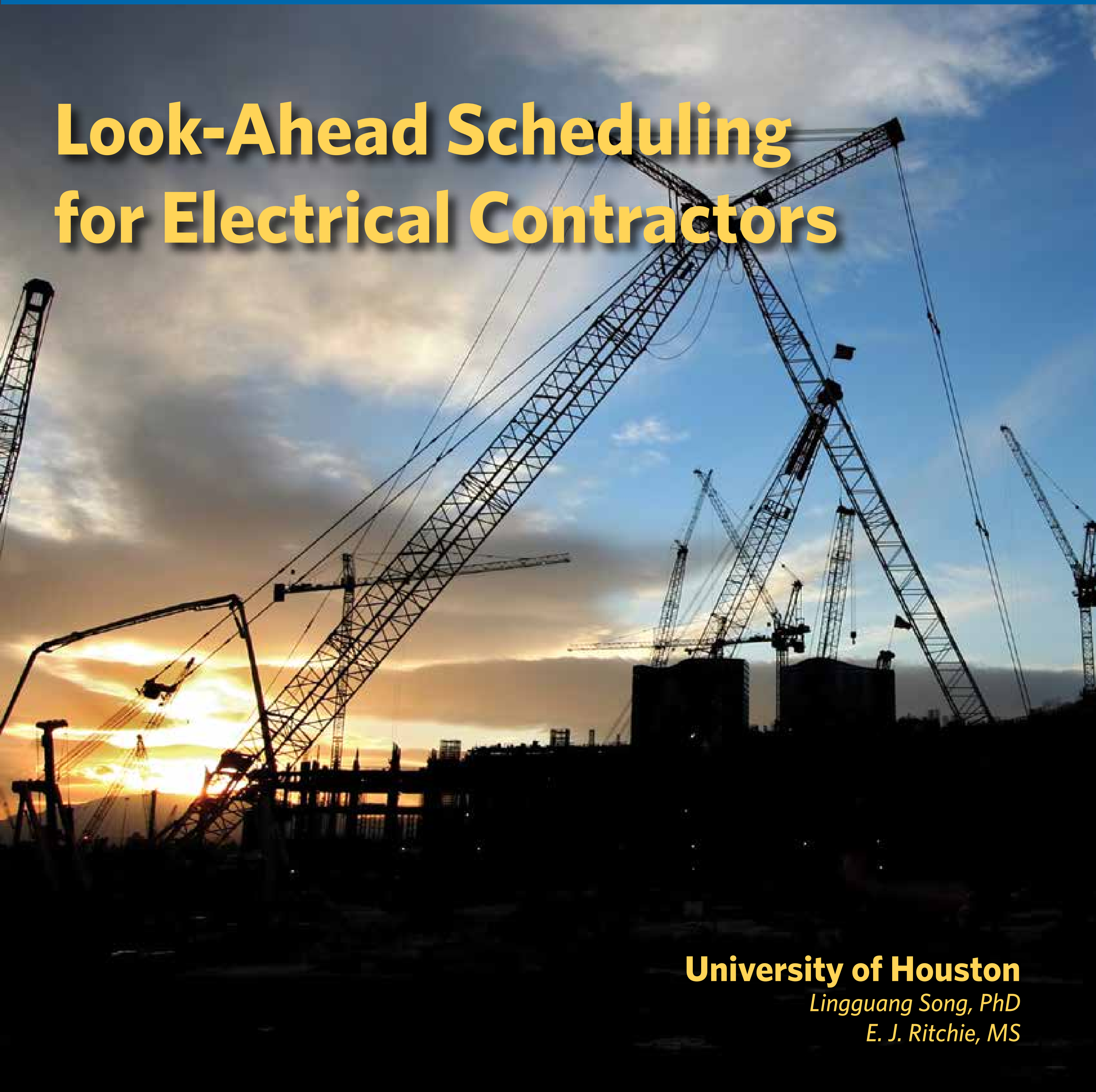

University of Houston

Lingguang Song, PhD

E. J. Ritchie, MS

ELECTRI International

The Foundation for Electrical Construction, Inc.

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Table of Contents

Executive Summary

Productivity in the construction industry has lagged and continues to lag other industries. Construction subcontractors and, in particular, electrical contractors, are at high risk of subpar productivity performance and schedule delays due to many unique challenges in the field. More often than not, this subpar performance is a planning issue.

Published short-term planning methods, such as Workface Planning, Enhanced Work Packaging, and Last Planner®, which have demonstrated success in other fields of construction, can be used to improve productivity in electrical contracting. In this study, we designed a "best practice" tailored to electrical contracting by combining elements of these methods into an effective field-friendly best practice model. The model was designed on the basis of a literature review and a survey of, and interviews with, electrical contractors.

The literature review focused on key elements of emerging and proven methods in construction look-ahead scheduling. General project-management methods were also reviewed to include elements that might potentially be useful.

The survey was designed to identify electrical contractors' current practices, solicit opinions of best practices to identify gaps between current practices and best practices, and identify the most significant causes of delay so that the best practice could be designed to be most effective in improving project performance. The sixty respondents to the survey represented a broad geographic sample within the U.S. and worked on a wide range of project types. They are mainly managers or owners of medium- to large-sized companies. The survey showed look-ahead scheduling to be widely practiced, although the methods, level of detail, and persons responsible varied by contractor.

A comparison between the survey results and proven planning methods showed several areas of potential improvement. The important elements of these methods were combined into a four-step process designed to be most effective for electrical contractors. The planning steps are:

1. A collaboratively planned, multi-week schedule based on work packages tailored to field operations
2. A weekly work plan including only work packages made fully ready and committed to by the foreman
3. A daily plan providing clear assignments to each worker and serving as the basis for record keeping for process improvement
4. Tracking scheduling effectiveness and performing root cause analysis to eliminate recurring delays and improve schedule reliability.

The best practice model was tested in a case study in a water-treatment plant construction project. Feedback and lessons learned from this pilot study are presented in Chapter 5.

This report describes the research and rationale for the best practice, as well as a detailed description of the method. Readers interested in a concise treatment should refer to the Implementation Guide in Appendix C.

Introduction

1.1 Look-Ahead Scheduling

The coordination of construction projects is a complex task. Electrical contractors are at particularly high risk of subpar productivity performance and schedule delays because of the many unique challenges in the field, such as delayed preceding trades, out-of-sequence work, frequent schedule acceleration, symbiotic work, resource and space constraints, and various other interruptions. More often than not, this subpar performance is a planning issue, not a labor issue. Given the complex and uncertain nature of electrical field operations, planning should be moved closer to the workface and focused on effective look-ahead scheduling (e.g., 3-week, weekly, and daily planning) that dynamically re-plans around constraints at a more detailed crew level during construction execution.

Look-ahead scheduling, also called short-interval or short-term scheduling, is not new. Processes to ensure that everything is in place to begin work have historically been practiced both formally and informally and are described, typically briefly, in classic construction management books. The following is a description from *Construction Project Management: A Practical Guide to Field Construction Management* (Sears et. al 2008):

> … a short-term schedule is needed to focus detailed attention on the specific activities scheduled over the coming weeks. Frequently, this type of schedule concentrates on the next four to six weeks of the project. Here again, short-term schedules are closely linked to the baseline and updated schedules. In this way, the project team is able to add detail to the project plan while assuring that the macro planning contained in the baseline schedule is fully supported.

Despite this common practice, delays, rework, and added expense often result from inadequate look-ahead scheduling. The best practice recommended here is intended to increase efficiency and to reduce delays and cost by combining the features of published look-ahead scheduling methods that are most effective and most applicable to electrical contractors.

1.2 Current Practice

Despite its importance, very little study has been conducted so far on understanding and improving electrical contractors' look-ahead scheduling practice. The current industry approach to look-ahead scheduling uses (1) a contract-level master schedule to set and communicate project phase milestones among owner, engineer, and contractor; (2) project-level multi-week schedules for project manager and trade superintendents to plan work in the present and coming month; and (3) crew-level weekly and daily planning conducted by superintendents and foremen to resolve design and field-work coordination issues.

Look-ahead scheduling in electrical construction projects has commonly been performed by the field superintendent or craft foreman. Planning tools used include checklists, Gantt charts, and handwritten schedules or their spreadsheet equivalents. These methods are reasonably successful, although the performance of individual foremen varies. A study by Horman et al. (2006) proposed an updated planning process with a focus on improving work sequencing through better involvement of foremen and careful management of pre-requisite activities and requirements.

Over the past ten years, there have been exciting research and development (R&D) efforts in the area of look-ahead scheduling, primarily originating from the industrial construction sector and conducted by industry organizations. Of particular significance and recognition is the work done by the Construction Owners Association of Alberta (COAA), the Construction Industry Institute (CII), and the Lean Construction Institute (LCI), which resulted in three correlated look-ahead scheduling methodologies: WorkFace Planning (WFP), Enhanced Work Packaging (EWP), and Last Planner ® (LP) respectively. The success and lessons learned from these documented and validated practices provide valuable inputs in identifying and defining a look-ahead scheduling best practice model that is suitable for electrical contractors.

1.3 Problem Statement and Significance

Look-ahead schedules are detailed plans that facilitate organizing activities at the crew level. Typically, they are for periods of one to three weeks and provide means of coordinating such resources as time, materials, equipment, workers, and information. The basic elements of identifying the work and resources required, constraints, and dependencies are fundamental to any project. Furthermore, all common planning models recognize a hierarchy in the breakdown of the work schedule from larger to smaller components. In a large project, it is not practical for the master schedule to include detailed planning of individual crew assignments. Look-ahead scheduling fills this gap and is a critical element in ensuring satisfactory construction performance.

Numerous studies report that craft workers spend less than 50% of their time on the job in direct work. The reasons for this are varied. Thomas and Oloufa (2008) identified the following 10 categories as the most significant causes of labor inefficiency:

1. Congestion
2. Out-of-sequence work
3. Adverse weather
4. Inadequate supervision
5. Work performed while the facility is in operation
6. Lack of information
7. Lack of equipment
8. Lack of tools
9. Lack of materials
10. Rework

Six of these—congestion, out-of-sequence-work, and lack of information, equipment, tools, or materials—can result from inefficiency in planning. Despite the publication of numerous recommended construction planning methods, labor productivity has remained stagnant and has even declined relative to other industries. Improved planning methods have the potential to increase productivity, thereby reducing cost, saving time, and increasing profitability.

Scheduling issues are particularly important for electrical contractors because electrical work is highly specialized and technical in nature. In the field, electrical contractors face even more unique operating challenges in areas such as coordination, schedule acceleration, symbiotic work, various uncertainties and interruptions, as well as resource and space constraints which expose them to high risk (Horman et al. 2006). Although electrical contractors are typically involved in pre-construction planning to coordinate with other trades, the resulted master schedule only identifies high-level work packages and the overall project execution strategy and milestones. During field execution, electrical work that is driven by other trades working before them is frequently challenged by out-of-sequence work, congestion problems, uncertainties, and other resource constraints that are difficult to predict in the pre-construction stage through a fixed definite master schedule.

Several newly proposed methods of look-ahead scheduling mentioned previously aim to foster more efficient accomplishment of the work by addressing crew-level planning. They have elements in common with one another and with historical planning methods, although they vary in terminology, the mechanics of procedures, and in some cases, the time horizons. With limited exceptions, these methods have not been applied specifically to electrical contracting projects. Therefore, this study is to address the following issues:

1. What are the productivity issues faced by electrical contractors, their underlying causes, and the corrective actions taken so far in terms of planning and scheduling?
2. What are the better or best principles/practices of look-ahead scheduling recognized by electrical construction practitioners?
3. What are the recognized best or innovative scheduling practices and principles outside of the electrical construction sector? What is their applicability in terms of work type, project size, and prerequisite requirements?
4. How can we refine and adapt the best practices identified above for electrical contractors' use? How do factors such as the current scheduling practice in electrical construction affect the decision?
5. How can this enhanced look-ahead scheduling model be packaged in a user-friendly way for effective field implementation?

1.4 Objectives and Scope

The objectives of this study can be summarized as follows:

- To identify the current look-ahead scheduling practices of electrical contractors.
- To identify the most effective look-ahead scheduling methods in the construction industry.
- To combine these methods into a recommended best practice that can improve project schedule performance.

More specifically, this model reflects the best practices identified in other construction sectors (e.g. WFP, EWP, and LP), refined and adapted to meet the unique needs of electrical contractors. Particular deliverables include the following:

1. Research reports—*Providing theoretical background and technical knowledge*

- Current look-ahead scheduling practices and issues in electrical construction
- Best practices identified in other sectors and their effectiveness and applicability

2. A best practice look-ahead scheduling model for electrical contractors

- Implementation resources—*Making solutions practical and accessible to contractors*
- Field implementation procedure and guidelines
- Templates and checklists associated with the proposed model

The best practice model is most applicable to medium- and large-scale projects, but the basic principles are applicable to projects of any size.

1.5 Research Method

This research was funded by a grant from ELECTRI International. Design and analysis of the survey and best practice model design were done by a research team at the University of Houston. The research methodology had two main goals: (1) defining the look-ahead scheduling best-practice model for electrical contractors, and (2) implementing and validating the model for practical field implementation. The basis for the best practice model was a comprehensive literature review and a Web-based survey. The model was validated in a field pilot study.

The research was done in six stages:

1. Review of pertinent literature
2. Pre-survey interviews
3. Survey of existing practices
4. Post-survey interviews
5. Best-practice design
6. Field pilot study

The literature review focused on identifying challenges unique to electrical contractors (ECs) and components of proven, effective scheduling methods that could be adapted to form a successful best-practice look-ahead method specifically designed for ECs. This information guided the design of the survey of existing practices and was the basis for the best practice.

Pre-survey interviews were used to validate the results of the literature review and to refine the survey questions.

The survey of existing practices was designed to identify current practices in the industry, ECs' opinions of what their practices should be, and issues that affect their schedule performance. This information was used to identify areas in which current practice is working well and areas where it could be improved. The analysis of the gap between current practices and ideal practices was important in the selection of planning methods for the best practice. ECs' opinions of the expected effectiveness of components of various scheduling methods influenced the best practice design.

Post-survey interviews were useful in clarifying the survey results and adding detail to the understanding of current practices.

The best practice model is the product of the research, incorporating the results of the steps above. It incorporates particular consideration of past lessons learned and the uniqueness of electrical construction projects (e.g., symbiotic work, frequent schedule acceleration, contracting environment, etc.). This best-practice model identifies and defines work packaging method, constraint tracking and removal strategies, and team organization and communication protocols.

The proposed best-practice model was tested in a pilot case study of an expansion project at a water-booster pump station. The project includes installation of a new 4,160-V service, a 600hp pump and related switchgear, and upgraded process instrumentation throughout the pump station. The case study was used to evaluate the effectiveness of the best practice and provide feedback.

1.6 Report Structure

Chapter 2 describes the published information on scheduling issues of electrical contractors and the planning methods used for look-ahead scheduling in the construction industry. The benefits of a customized method for ECs and choice of elements comprising the best practice are discussed.

Chapter 3 describes the design of the industry survey, the survey method, and the pertinent results. The impact of information from the survey in the best-practice design is discussed.

Chapter 4 describes the best practice, the primary product of this report. It is a tailored selection of components of other planning methods that will be most effective in improving schedule performance under ECs' unique working conditions.

Chapter 5 describes the use of the best practice in a field pilot study and lessons learned.

Chapter 6 describes conclusions and recommendations for use of the best practice.

Appendices A through C contain the Implementation Guide, and the FIWP checklist, which is a concise description of our recommended best practice, as well as an example FIWP document. The Implementation Guide is a self-contained document that includes detailed procedural instructions, useful forms, and checklists.

Unique Challenges and Current Scheduling Practices

This chapter describes factors unique to electrical contractors' field operations and briefly describes look-ahead scheduling methods that may be of value in the recommended best practice based on a comprehensive literature review. It focuses on key elements of both emerging and proven methods in construction look-ahead scheduling. These methods evolve in use and may be described differently by different authors and by the same authors at different times.

2.1 Introduction

The literature on project planning and scheduling is extensive. Over 1,000 sources were reviewed for this study, including books, peer-reviewed papers, trade journal articles, product-marketing literature, construction firm websites, owners' websites, trade organization websites, masters theses, Ph.D. dissertations, and government publications. Only a small fraction of the sources specifically addressed electrical contractors or their scheduling needs.

A portion of the literature review focused on electrical contracting field practices and scheduling methods. This might be considered background information, which was not directly pertinent to the best-practice design, but it was necessary in order to place planning methods in proper context and contribute to a practical design.

Several general project-management methods were reviewed, a few of which incorporate look-ahead scheduling in enough detail to have been potentially useful. They are sometimes mentioned as alternatives to the look-ahead scheduling methods.

2.2 Unique Challenges of Field Operations in Electrical Construction

The literature on construction productivity issues is extensive. Authors commenting on causes of productivity loss often cite scores of potential causes, which are typically divided into a smaller group of categories. The categorization by Thomas and Oloufa (2008) was described previously, but their classification is not comprehensive—training, absenteeism, and worker qualifications are examples of other factors. Dai et al. (2009) identified 83 factors at the craft-worker level, which they classified into 10 groups called latent factors. Other causes occur at the owner, architect, and construction-manager levels and are largely beyond the control of the electrical contractor. This study focuses on those causes most likely to be considered by electrical contractors during look-ahead scheduling.

2.2.1 Uncertainty

Electrical contractors, along with other trade contractors, face numerous sources of uncertainty, which include the business climate, payment issues, clarity of contract documents, liability and responsibility questions, changes in the scope of work, managerial ability and attitude of the general contractor, quality and timing of preceding work, cooperation among trades, availability of skilled personnel, weather, material or equipment delivery delays, unexpected conditions, estimating errors, price changes in materials, and the necessity to maintain relationships in order to secure future work. However, many of these issues cannot be addressed by look-ahead scheduling and are best handled through contract negotiations and other parts of the business process. The focus of this study is on those areas in which look-ahead scheduling can improve productivity performance, such as uncertainties related to pre-requisite work status and resource supplies.

2.2.2 Technical and Quality Requirements

The electrical scope of work is regularly the most technical work on a project. Electrical design documents are schematic in nature and require an educated, experienced subcontractor to complete the work. Technical and quality requirements of electrical construction can be summarized as follows (Horman et al. 2006):

1. Electrical machinery, components, and systems are among the most technically sophisticated in the building. Much of the work of electrical contractors is with sensitive and sophisticated systems whose installation and eventual operation has very little tolerance for misalignment, construction variations, and other problems. These factors require a higher level coordination and scheduling to ensure the availability of the right skilled workers, tools, drawings, and proper working conditions for quality work.
2. The sequence of work is quite important for efficient electrical construction. There are rigid requirements dictated by the physical installation of the system.
3. Electrical systems and electrical work demand close coordination with other systems and other work, particularly structural, mechanical, communications, and interior finish systems. These systems must often be fit into constrained spaces.
4. Electrical work requires experienced selection, purchase, and delivery of the right kinds of electrical apparatus, appliances, equipment, and materials, including their correct assembly and proper installation. This makes the purchasing and delivery of materials particularly critical to the electrical contractor. Incorrect or damaged items may not be able to be quickly replaced, resulting in delay of subsequent work, out-of-sequence work, and other inefficient practices.

2.2.3 Subcontractor status

The electrical contractor is typically a subcontractor, and, except in integrated project-delivery methods such as design-build, has limited ability to influence the design or the master schedule that is typically created by a general contractor. The lack of a direct contractual relationship between the electrical contractor and other subcontractors (e.g., HVAC, plumbing) further challenges the field coordination as discussed in Section 2.2.4.

2.2.4 Interaction with other trades and coordination issues

Electrical contractors are not usually the main drivers of a project and exercise nominal influence in the early organization of the project. Also, they are expected to be flexible in the event of conflicts in physical elements, space constraints, and schedule, as well as in schedule compression. Electrical contractors often have to fit their work to the sequence set in early project planning. This can typically result in out-of-sequence work and space congestion/ stacking of trades that interrupt performance, require rescheduling of workers and material deliveries, and incur extra costs.

2.2.5 Schedule compression and related issues

In the later phases of the project, electrical activities often become critical-path items for the project schedule. If the project is behind schedule, electrical contractors must often use acceleration techniques such as over-manning, overtime, shift work, and out-of-sequence work, as mentioned above. Stacking of trades, congestion problems, and interference with other trades may occur. Look-ahead scheduling can be particularly helpful in eliminating the need for or reducing the effects of these inefficient practices.

2.2.6 Skilled labor shortage

Incorrectly installed electrical products and systems may expose the public to potential hazards. In order to protect public safety most states and localities require that electrical installations comply with the National Electrical Code, that electrical products be "listed" by nationally recognized safety-testing organizations, and that electricians be qualified and licensed. The long training period and cyclic nature of the construction industry contribute to periodic or local shortages of qualified personnel.

2.3 Existing Look-ahead Scheduling Best Practices

2.3.1 Introduction

The planning methods discussed in this section include a spectrum of published methods that were considered to be potentially useful in designing the recommended best practice. Most are general project-management techniques—i.e., they are not specifically designed for look-ahead scheduling. The discussion summarizes the primary features of each, insofar as it is pertinent to the design of the recommended best practice. The key elements of the best practice were selected primarily from Last Planner and Workface Planning.

2.3.2 Last Planner

Last Planner (Ballard 1994), a trademark of the Lean Construction Institute (LCI), is a lean-production-based project planning methodology that integrates a multiple-level planning framework that includes master scheduling, look-ahead scheduling, and weekly work planning to improve the reliability of work flow.

Fundamental assumptions. Unit-level performance may be improved by proper definition of work assignments, meaning that the work is clearly defined, the scope is appropriate to the crew, all constraints are satisfied, and the work is done in the right sequence. A six-week look-ahead cycle is used to create a backlog of weekly work plans that allow for alternate crew assignments if an assignment is not possible. A measurement mechanism, Percent Plan Complete (PPC), is incorporated and analyzed with run charts, a method common to Agile Construction, which is discussed later in this section.

Primary tools. The six-week look-ahead schedule (LAS) and weekly work plan are designed to identify constraints and assure that they are satisfied before weekly work assignments are released. The person responsible for scheduling is usually a foreman or superintendent rather than a dedicated planner. The look-ahead schedule is updated weekly, and production planning meetings are held weekly. Also, daily progress monitoring is mentioned in some Last Planner publications. Two key elements in Last Planner are (1) work is not released until all constraints are satisfied, and (2) commitment must be obtained from the crew to accomplish the work.

Unique elements. Look-ahead scheduling is done by field personnel, and collaboration at the early engineering design stage is recommended though not required. Look-ahead scheduling is more specifically addressed in Last Planner than in other methods presented later in this report.

Applicability. This method is directly targeted at short-term scheduling and does not require project-level implementation. Its constraint tracking and removal process, and the involvement of field personnel, are valuable scheduling concepts incorporated into our best practice.

Comments. When compared with techniques that are presented below, Last Planner is most relevant to electrical construction due to Last Planner's primary focus on field-level planning. For example, Workface Planning and Enhanced Work Packaging, which are discussed later, are explicitly tied to project-level planning, while the primary focus of Last Planner is on field-level planning.

2.3.3 Workface Planning

Workface Planning (COAA 2013) is a Best Practice of the Construction Owners Association of Alberta (COAA) intended to improve productivity in large industrial projects (Ryan 2009). According to COAA, the goal is "getting the right things to the right people and the right place at the right time." The method is based on the earlier concept of the work breakdown structure and includes three breakdown levels: the Engineering Work Package, the Construction Work Package, and the Field-Installation Work Package (FIWP), which is a package that defines an execution plan for a one- to two-week scope of work for a single crew. The method was developed on oil and gas mega-projects but is represented to be scalable to project size.

Fundamental assumptions. Safety, productivity of construction workers, and predictability of task duration may be improved by detailed planning of work in small work packages, including identification of all prerequisites, and by not beginning work until prerequisites are satisfied. The breakdown of work in earlier phases of planning should be designed to facilitate definition of FIWPs. These are the same as assumptions for the closely related Enhanced Work Packaging described later. FIWPs are typically one to two week's work for a single crew. Workface Planning additionally provides for the preparation of alternate FIWPs that can be available in case previously scheduled FIWPs are delayed.

Primary tool. The FIWP describes the work to be done, including all necessary elements such as construction documents, materials, tools, equipment, sequence of work, approvals, persons responsible, and site constraints. A dedicated workface planner who is knowledgeable in the applicable trade has the primary responsibility for designing the FIWP. In a typical industrial construction project, the work package is ideally issued four weeks before work is scheduled, and once work has begun the progress is monitored daily. Workface Planning includes ancillary tools such as installation checklists and a Workface Planning Scorecard to facilitate implementation of the method.

Unique elements. Workface Planning is required in the contract, and a dedicated workface planner is required. The look-ahead scheduling procedure is rigidly defined.

Applicability. This tool is targeted at short-term scheduling, but early stage contractor involvement in the design stage is impractical for electrical contractors involved in typical design-bid-build contracts. The elements of satisfying constraints and maintaining alternate work packages are common to Last Planner and some other look-ahead methods.

Comments. Workface Planning (WFP) is very detailed and includes rigid schedule requirements. It was developed for use on mega-projects and contains some elements, such as dedicated material, equipment, and tool coordinators, that may not be applicable on smaller projects. Although the FIWP is applicable at the crew level, WFP requires implementation throughout the entire construction process from design through construction. A few comments in the literature refer to scaling the method for different size projects, but published examples all seem to be for large projects.

2.3.4 Enhanced Work Packaging

Enhanced Work Packaging (EWP) is a method originated by Research Team 272 of the Construction Industry Institute (CII 2011). The team's charter was to review existing work-packaging practices and recommend a best-practice implementation. The CII team was aware of COAA's Workface Planning and viewed EWP as a refinement and extension of WFP. Some differences from WFP result from modifying WFP to allow application to a broader range of project types. A joint venture between CII and COAA to merge the two methods is currently in progress.

Fundamental assumptions. Similar to WFP, safety, productivity of construction workers, and predictability of task duration may be improved by detailed planning of work in small packages, including identification of all prerequisites, and not beginning work until prerequisites are satisfied. The packages are typically one week's work for a single crew.

Primary tool. The Installation Work Package (IWP) is a plan that describes the work to be done, including all necessary elements such as construction documents, materials, tools, equipment, sequence of work, approvals, persons responsible, and site constraints. A dedicated workface planner who is knowledgeable in the applicable trade has the primary responsibility for designing the IWP. The work package is ideally issued 1-2 weeks before work is scheduled, and once work has begun the progress is monitored daily. CII has defined ancillary tools such as example checklists and an EWP Scorecard to facilitate implementation of the method.

Unique elements. A dedicated workface planner is required. This method is more general and flexible than WFP, and it places greater emphasis on checklists than either WFP or Last Planner. CII states that improvement can be achieved with partial implementation of the method.

Applicability. The intended purpose of this tool is the short-term scheduling that is the focus of our study, although it includes involvement in early phase planning in the same fashion as WFP. Emphasis on work-package design was incorporated into our recommended best practice.

Comments. Enhanced Work Packaging is partially based on WFP and bears many similarities. The WFP literature focuses on process industrial projects, and therefore the longer recommended time intervals and larger work-package content of WFP are appropriate to projects of that nature. Enhanced Work Packaging is more general.

2.3.5 Other Scheduling Methods

A number of project-management methods were reviewed in less detail. These were not used in the best practice except as noted.

Agile Construction

This method is offered as a National Electrical Contractors Association (NECA) course by Dr. Perry Daneshgari. It is a project-level or company-level method that relies heavily on statistical process control and productivity monitoring, but it also includes use of short-interval schedules, including 3-week and 3-day look-aheads. Although look-ahead methods receive relatively brief coverage, the use of run charts for productivity tracking and examples of reporting forms are useful. Run-chart analysis is an important element in our recommended best practice.

Electrical Work Sequencing

Horman et. al. (2006) discussed a sequence-planning method for electrical contractors that included productivity tracking and three-week, two-week, and weekly schedules. The framework of this method is similar to that of Last Planner and our recommended best practice, although it tracks productivity rather than schedule performance, does not delegate responsibility for look-ahead scheduling to a particular individual, and is less detailed than our recommended best practice. It was not directly used in our design.

Project-Level Methods

Several project-level methods were reviewed but were not significant in our design of the best practice because they did not provide the level of detail needed.

Lean construction, also called simply LEAN, is a loosely defined term for a group of process-improvement methods based on production methods at Toyota Motor Corporation. One implementation, the Lean Project Delivery System (LPDS), is a trademark of the Lean Construction Institute, which has published extensively on the method and related subjects. The LPDS incorporates Last Planner, which is described above.

Prince2 is a project-level management method developed by the U.K. government that is popular in the U.K., Europe, and Australia. The work package definition includes constraints, interfaces, resources, and “the mechanism to ensure that completed work will meet expectations on all levels.” Unlike the look-ahead methods above, the Prince2 work package definition does not include a specific time frame.

Integrated project delivery (IPD) is a term used generically in the industry to describe a collaborative construction model incorporating early involvement of key players (owner, architect, and constructor) and shared decision making. Versions of IPD are promoted by the American Institute of Architects (AIA), ConsensusDOCS (an industry coalition), and others.

Quality methods, such as Total Quality Management, Six Sigma, and LEAN, are process-improvement methods. As the name suggests, they focus on improving product quality and consistency, but they typically include elements targeted at productivity improvement as well. Broadly speaking, they may be viewed as a toolbox of methods from which selected tools can be used as applicable to a particular situation. Portions of these methods are sometimes recommended for construction productivity improvement.

The Critical-Path Method (CPM) is well known, widely used, and is often required by contract. The master schedule, from which the activities (FIWPs) of the look-ahead schedule are extracted, is normally a CPM schedule.

Critical Chain Project Management (CCPM) is a critical-path method that varies from CPM mainly in assigning median expected task durations and use of time buffers to manage task overruns. It also enables scheduling of multiple projects.

The Theory of Constraints (TOC) is basis of CCPM. It has been used in manufacturing processes, but it is more of a problem-resolution process than a project-management or scheduling method. The TOC is useful in problem analysis but is not part of our recommended method.

2.3.6 Additional Considerations

Several other issues, such as scalability and the use of technological aids and productivity-measurement techniques, which might have affected the recommended look-ahead scheduling model, were investigated. Except as noted elsewhere, these issues were outside the scope of the study.

Scalability

Issues of scalability to project size have been discussed elsewhere in the literature review. Scalability to company size may also be a factor, but this was not found to have been discussed in the literature.

Technology

Software, wireless devices, and other applications of technology may contribute to crew-level productivity improvement. A limited investigation of programs advertising Last Planner or WFP capability, as well as other software applicable to look-ahead scheduling, was performed in the literature-review process, but determining the merit of particular software packages was not within the scope of this study.

Productivity Measurement

Productivity measurement techniques include direct measures such as value per time unit or labor unit, quantity per time unit or labor unit, percent over or under budget, and percent ahead of or behind schedule, as well as indirect measures such as percent idle time and percent rework. Some review of this subject was included in the literature review, but it was not a primary focus. This study intended to find a quantitative way to measure the effectiveness and reliability of the look-ahead scheduling process. Percent Plan Complete (PPC) as introduced in Last Planner was deemed adequate for the best practice and is the only productivity measure recommended for the purpose of measuring the reliability of look-ahead schedules. Contractors will no doubt continue to use other measures to evaluate other aspects of project performance.

Impact of Human Factors

The production-scheduling literature addressing manufacturing operations includes the analysis of the impact of human factors on scheduling processes and results. These factors include such things as the personality and rules of thumb of the scheduler, the scheduler's ability to gather information informally and to anticipate problems, and the practice of maintaining several concurrent mental versions of the schedule. There may be valuable insights to be gained from further investigation of this aspect of scheduling.

2.4 Discussion

The literature review identified historical productivity issues in construction, the numerous unique challenges facing electrical contractors, and various recommended practices that have been shown to improve scheduling performance and productivity. This information was used to help design the survey described in the next chapter and, with the survey results, to tailor the best practice to the specific need of electrical contractors.

Survey Design and Analysis

The survey had three primary goals:

1. Identify ECs' current practices, including differences related to project or company size, type of work, and geographic area.
2. Solicit ECs' opinions of best practices to identify potential areas for improvement.
3. Identify the most significant causes of delays so that the best practice could be designed to be most effective in improving schedule performance.

Information from the survey influenced selection of elements chosen from the planning methods described in the literature review.

3.1 Survey of Existing Practices

3.1.1 Survey Design

Preliminary survey design was based on six previously published surveys, the intent and subject of which were similar to the subject survey. Additional questions were added based on issues in electrical planning identified in the literature review. Survey design principles from Smart Survey Design (2012) and The Question Bank Factsheets (2012) were followed in question wording and design. The initial draft was prepared by the authors and subsequently modified in a joint session of the research team. The survey was again modified based on inputs from expert reviewers as described under pre-survey interviews below.

3.1.2 Pre-Survey Interviews

In order to focus the survey questions on issues of interest to ECs and accurately reflect actual planning practices, a series of interviews were conducted with industry experts. Six industry experts reviewed the draft of the survey and were interviewed in person or by telephone during the fall of 2012. Suggestions were minimal and consisted primarily of clarifications and the addition of answer options.

3.1.3 Data Collection

The result of the design was a 36-question survey that primarily addressed look-ahead scheduling procedures currently in use but also included opinions on effectiveness and the potential for improvement.

Survey data collection began in December 2012. The survey was conducted online on SurveyMonkey. Although participation was solicited by e-mail, the survey was open, and no validation of the respondent was required. Requests to publicize the survey were sent by e-mail to 121 NECA chapters, 59 Independent Electrical Contractors chapters, and the International Brotherhood of Electrical Workers (IBEW) international office. The survey was open until March 2013, by which time 60 responses had been received. The respondents represented a geographically diverse sample and included owners or employees of both union and open shops. The majority of respondents were owners or managers of medium and large firms.

3.1.4 Survey Results

Look-ahead scheduling was found to be widely practiced, and characteristics of current practices were documented. The survey found that some elements of published best scheduling practices were not typically used. Possible improvement methods identified in the survey questions were strongly supported. Respondents sometimes skipped questions, but this is not noted in the discussion unless the response rate was below 75% or was otherwise pertinent to the analysis.

Characteristics of Respondents

Respondents were predominantly owners or senior managers of medium and large electrical contracting firms, with 44 of 60 respondents (73.3%) falling into this category. Over 85% of respondents had more than 15 years of experience. More than half of the firms surveyed had over 100 employees, approximately 70% had over 50 employees, and 93% employed more than 10. This is a reversal of the industry composition: according to the 2012 Electrical Contractor Magazine survey, 74% of firms employ fewer than 10. Forty-two percent had annual revenue over $25 million. The firms worked in a broad range of projects across the board, including new construction, additions, retrofitting, and maintenance, and the work was concentrated in commercial, industrial, and institutional projects, with less emphasis on residential projects, as shown in **Figure 1** below.

Figure 1. Project type

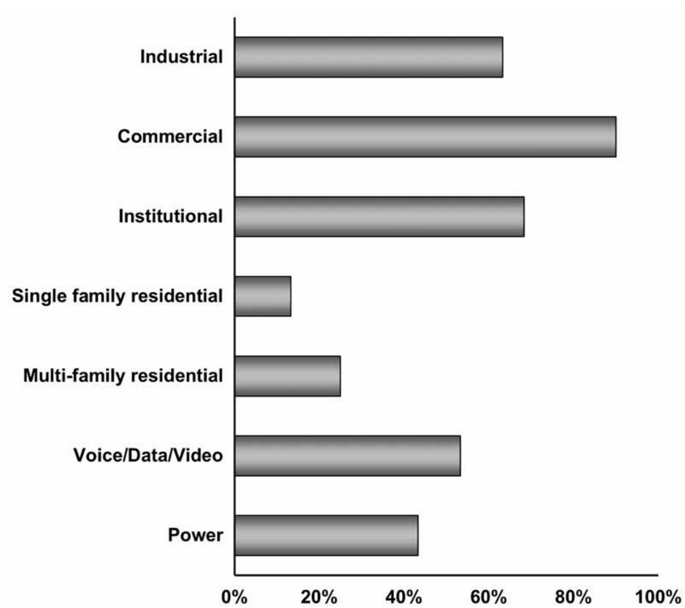
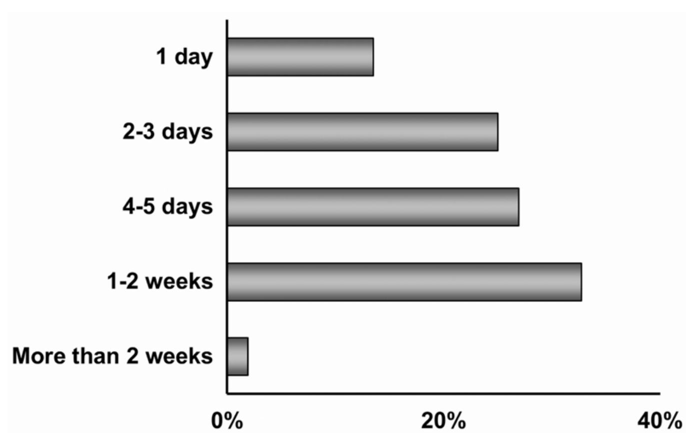


Figure 2. Average task duration



Sixty-two percent of the respondents worked for union shops. The responses were reasonably geographically diverse. The South, defined in accordance with the National Electrical Contractors Association (NECA) region boundary, was slightly over-represented, with 55% of responses; according to the 2007 U.S. Census Bureau survey, this region includes 38% of industry employees.

Current Look-Ahead Scheduling Practices

Forty-five of 60 respondents (75%) used some form of look-ahead schedule: monthly, multi-week, or weekly schedules. Sixty-five percent also used a daily schedule or task plan, and over 85% used schedules of two or more different durations. The most commonly used schedules included a master schedule along with one or more detailed short-term schedules, including monthly, multi-week, and weekly schedules having responses of 28%, 40%, and 42%, respectively. The most common look-ahead period was two weeks. Five percent used the project master schedule only. The relatively low usage of multi-week schedules suggests potential for improvement.

The majority of task durations ranged from one day to two weeks, as shown in **Figure 2.** Task duration is likely related to project size, but that question was not included in the survey.

Seventy-three percent of look-ahead schedules were updated weekly, and 25% percent of these were also updated daily.

The form in which the schedule was presented varied widely. Paper daily schedules were most common, being used by over 50% of respondents. Gantt charts, calendar charts, daily schedules, and task forms were used in roughly equal proportions. Paper forms were used 65% of the time, but schedules were sometimes presented in both paper and electronic formats. In the less-frequent circumstances in which CPM charts were employed, electronic forms predominated. Project planning software was used for look-ahead scheduling by 42% of respondents reporting (60% response rate), and respondents often used more than one program. Primavera was most common, with 29% of respondents reporting use of one or more versions. Microsoft Project was second in reported usage at 19%.

Among companies using a look-ahead schedule, the primary responsibility for preparing the schedule variously rested with the project manager, superintendent, or foreman (31%, 31%, and 25%, respectively). Less than 8% of companies used a dedicated scheduler as defined in WFP. The project manager and foreman were involved in defining the schedule in 80% or more of the companies. Other personnel were involved less frequently, as shown in **Figure 3** *(next page)*. Job titles were not consistent among companies, so distributions by job titles should be considered approximate.

Over 80% of respondents reported being involved in the general contractor's scheduling effort at least part of the time. This response did not vary greatly with the size of the electrical contracting firm. When involved in the GC's scheduling, over 85% of respondents indicated being able to influence the master schedule to at least some degree. The indicated degree of influence is shown in **Figure 4** *(next page)*.

Smaller companies (fewer than 50 employees) reported less ability to influence the GC's schedule, with no small company reporting high influence. A comparison by company size is shown in **Figure 5** *(next page)*. Greater involvement of the electrical contractor in the master scheduling may be appropriate.

Look-ahead schedules are used primarily to ensure adequate supplies of labor, materials, and equipment, and to coordinate work, as shown in **Figure 6** *(next page)*. Using the schedule to include a back-up plan and to measure performance are relatively uncommon, being done by only 27% and 37% of respondents, respectively. This is another area of potential improvement, although in a later question 73% of respondents indicated having a back-up plan at least part of the time.

Emphasis in task plans focuses on labor, equipment, and the scope of the work; other aspects are less often defined, as shown in **Figure 7**. This is more pronounced in smaller companies. Respondents did indicate use of a process to check for readiness of all elements approximately 80% of the time. This check is most often the responsibility of the foreman, although the superintendent or project manager may be used. Some issues noted as significant in a later question, such as other subcontractors being behind schedule and incorrect drawings, were often not included in the task plan, although larger companies did give more attention to prerequisite work. Inclusion of all requirements in the plan is another area of potential improvement.

Figure 3. Individuals involved in look-ahead schedule definition

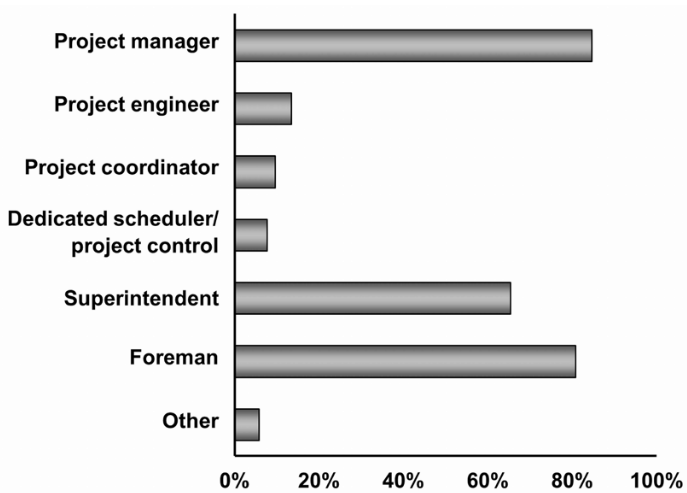


Figure 4. Ability to influence master schedule

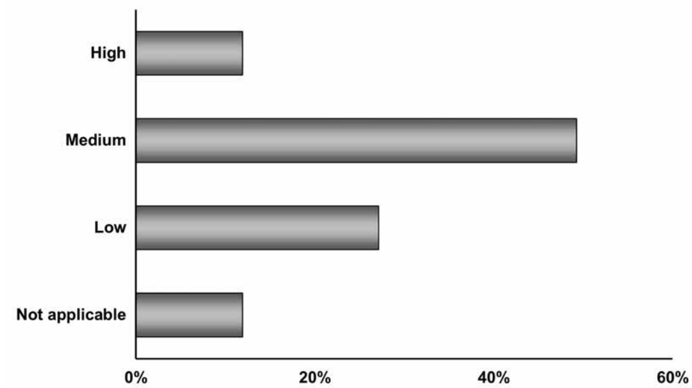


Figure 5. Ability to influence master schedule by company size

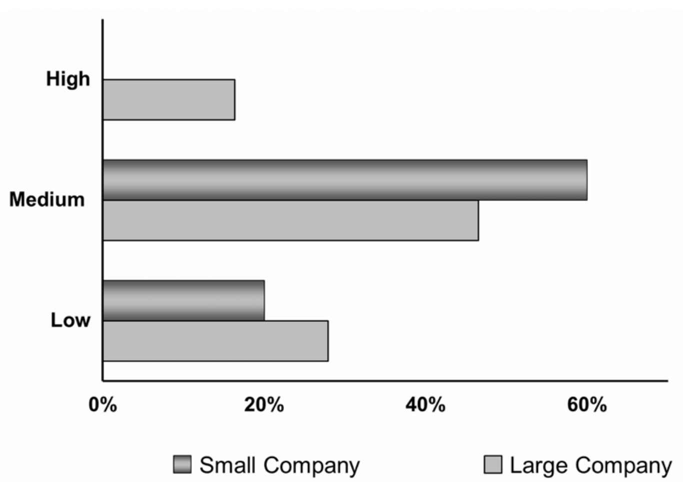


Figure 6. Main purposes of look-ahead schedule

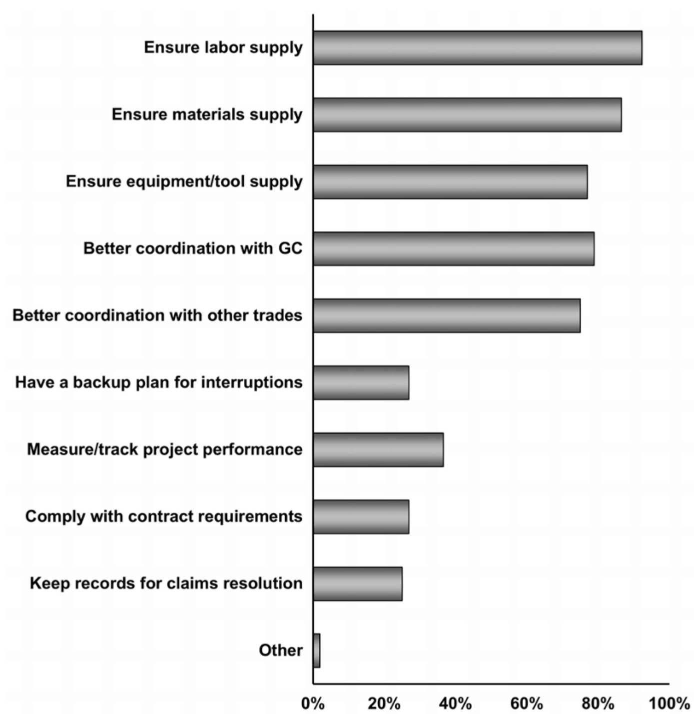
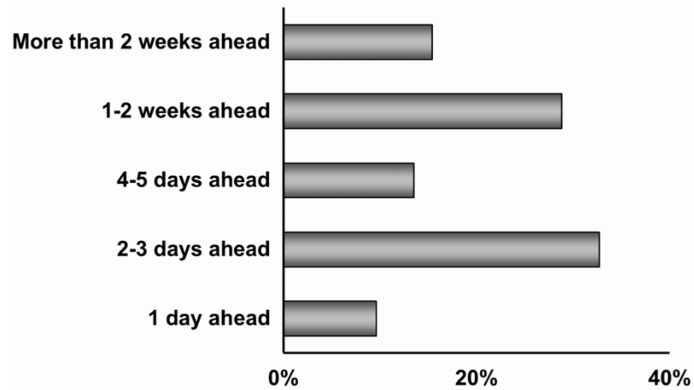


Figure 7. Elements included in task plan

Figure 8. Task notice to foreman



The amount of notice of upcoming work given to foremen varies widely, as shown in **Figure 8.** This may be a function of the scope of the task or project, but that was not addressed in the survey questions. Smaller companies generally gave longer advance notice.

Eighty-seven percent of respondents who answered the pertinent question (47 respondents) indicated that their personal opinion of the schedule varied from the officially published schedule at least part of the time. Respondents were also more than three times as likely to expect the actual time to be longer than scheduled rather than shorter (54% vs. 15%)—a phenomenon that has been reported in the production literature but was not found in the review of the construction management literature. It merits further research.

Trade Coordination

Sixty-one percent of respondents reported sharing their look-ahead schedule with the GC; 40% reported sharing it with other trade contractors. Verification that necessary prerequisites had been completed was done by personal inspection, regular trade contractor meetings, and direct contact, with reported percentages being 73%, 65%, and 46%, respectively.

Performance Measurement and Sources of Delay

All but one respondent indicated that they used at least one measure of performance, and slightly over 50% reported using two or more measures. Planned vs. actual duration was used by 65% of respondents.

Current practices were rated primarily neutral or effective in a roughly normal distribution, as shown in **Figure 9** *(next page).*

The sources of construction delay that have been typically identified in the literature were all reported as issues in this survey. Since the question addressing this asked for severity of impact on a 5-point scale for 18 possible causes, the survey response is somewhat complex. **Figure 10** *(next page)* shows the top five issues. Note that the reported cause may not be the root cause of a problem. For example, other subcontractors being behind schedule may be the result of prior out-of-sequence work or work changes. This is discussed in more detail in Section 4.7.3.

Figure 9. Reported effectiveness of current look-ahead practice

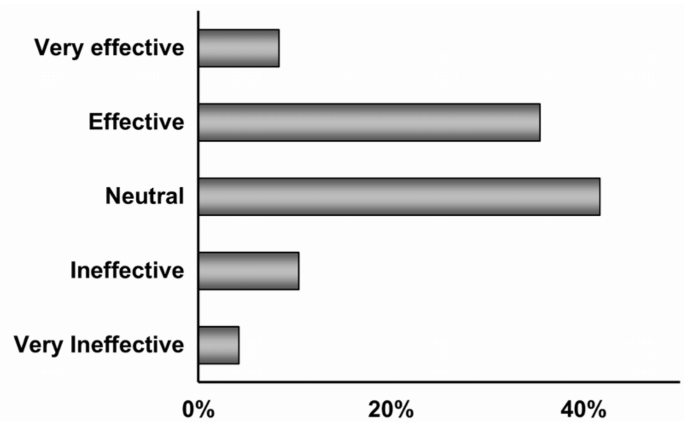
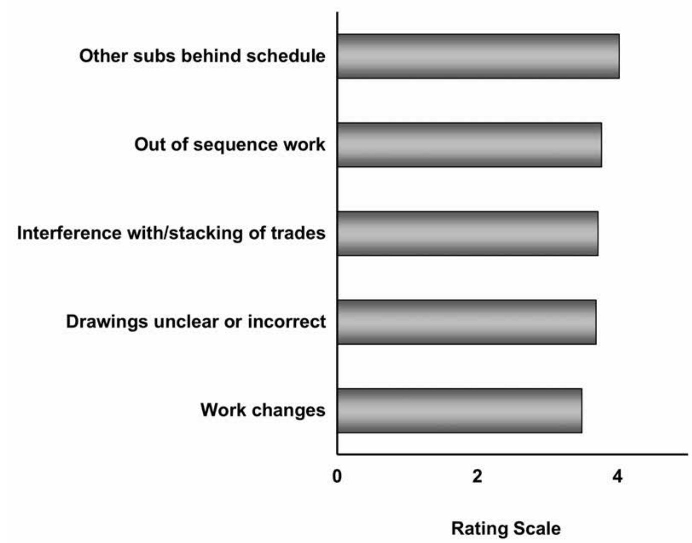


Figure 10. Issues affecting schedule deviation



An additional question asked about the respondent's agreement with 11 possible improvement methods on a 5-point scale. The level of support was 3.7 or above for all suggested methods, and four methods had agreement scores above 4, as shown in **Figure 11**. Two of these methods concerned increased involvement of electrical contractors in planning and design. The other two concerned foreman involvement in multi-week planning and foreman training.

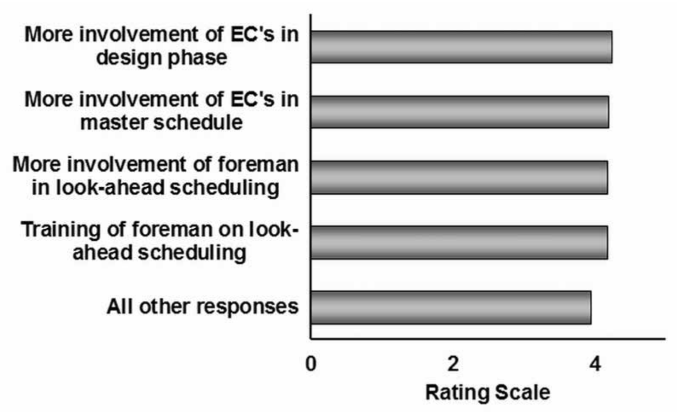
3.2 Post-Survey Interviews

After a preliminary analysis of the survey results, additional input was sought from practicing electrical contractors through interviews and an e-mail questionnaire. The questionnaire was sent to the 38 respondents to the original survey who had provided an e-mail address. Six of these responded. The responses are summarized below.

- The percent of GCs holding coordination meetings ranged from 30% to 100%, with an average of 71%.
- Nearly all coordination meetings were held weekly.
- Four of the six respondents coordinated directly with other trades through foremen; two coordinated with the GC.
- Only one indicated having a regular backup plan.
- Five of the six indicated deriving benefit from EC involvement in design, but little comment was made on how this should be done.

Three face-to-face interviews lasting about 30 minutes each were conducted with contractors in the Houston area. The interview format allowed more detailed information to be gathered on the interviewees' employers' scheduling practices. All three interviewees worked for small companies. Two companies worked primarily in commercial construction, one in light industrial construction. All used informal look-ahead scheduling methods. Coordination with other trades was not an explicit part of look-ahead scheduling for the interviewees. Overall, the interviews provided an interesting insight into the scheduling practices of smaller ECs, but were too small a sample to have significant effect on the design of the best practice.

Figure 11. Reported agreement with possible improvement methods



3.3 Gap Analysis and Discussion

The survey results confirmed several gaps between current practice and the industry best practices discussed in Chapter 2. These included:

1. Twenty-five percent of respondents did not use LAS.
2. Task plans often did not identify all constraints.
3. Seventeen percent indicated that they had no procedure to verify that all needed elements were available before beginning a task.
4. Fewer than 27% used the LAS to provide a backup plan.
5. Fewer than 37% used the LAS for tracking performance.
6. Over 40% gave less than 4 days' notice of upcoming tasks to the foreman.

Among the possible improvement methods receiving the most support were greater involvement of the foreman in and training of foremen in look-ahead scheduling.

The gap items above are addressed in the best practice and in the existing scheduling models that were the basis for the best practice. The primary benefit in identifying these gaps is to point out areas needing greater emphasis and training.

Best Practice Design

This chapter is an in-depth look at our formal look-ahead scheduling model for electrical contractors to enhance their field productivity. The model reflects the best practices identified in other construction sectors (e.g., WFP, EWP, and Last Planner), refined and adapted to meet the unique needs of electrical contractors. It will be valuable to project managers, superintendents, and foremen involved in electrical construction projects. This detailed look is complemented by the Implementation Guide (Appendix C), which provides practitioners with user-friendly field-implementation guidance and supporting tools.

4.1 Introduction

4.1.1 Design Basis

The best-practice model is primarily based on three best practices identified in various construction sectors, as listed below, as well as recommended practices by ELECTRI International and various industry and academic studies.

- **Workface Planning (WFP):** a best practice by the COAA to overcome cost-overrun issues facing large oil and gas projects
- **Enhanced Work Packaging (EWP):** the latest update of the CII's best practices, tools, and processes for work packaging
- **Last Planner:** a lean-production-based project-planning methodology that integrates a multiple-level scheduling process to improve the reliability of schedules.

The best-practice model was designed to meet the unique challenges of electrical contractors—e.g., uncertain site conditions, subcontractor status, and coordination issues with other trades. The model also reflects practitioners' opinions collected from our survey and interviews of electrical contractors.

4.1.2 Scope and Users

The best practice is a set of field-oriented procedures that begin after pre-construction—i.e., during the execution phase—and continue through project closeout. The primary individuals responsible for look-ahead scheduling are field-management personnel. As discussed in more detail below, the person with primary responsibility for the look-ahead plan, called the designated planner (DP), may be the electrical contractor's project manager, superintendent, or other staff member, depending on project complexity and the preferences of the contractor. Parties involved in the look-ahead scheduling also include the general contractor (GC) and other subcontractors in a project.

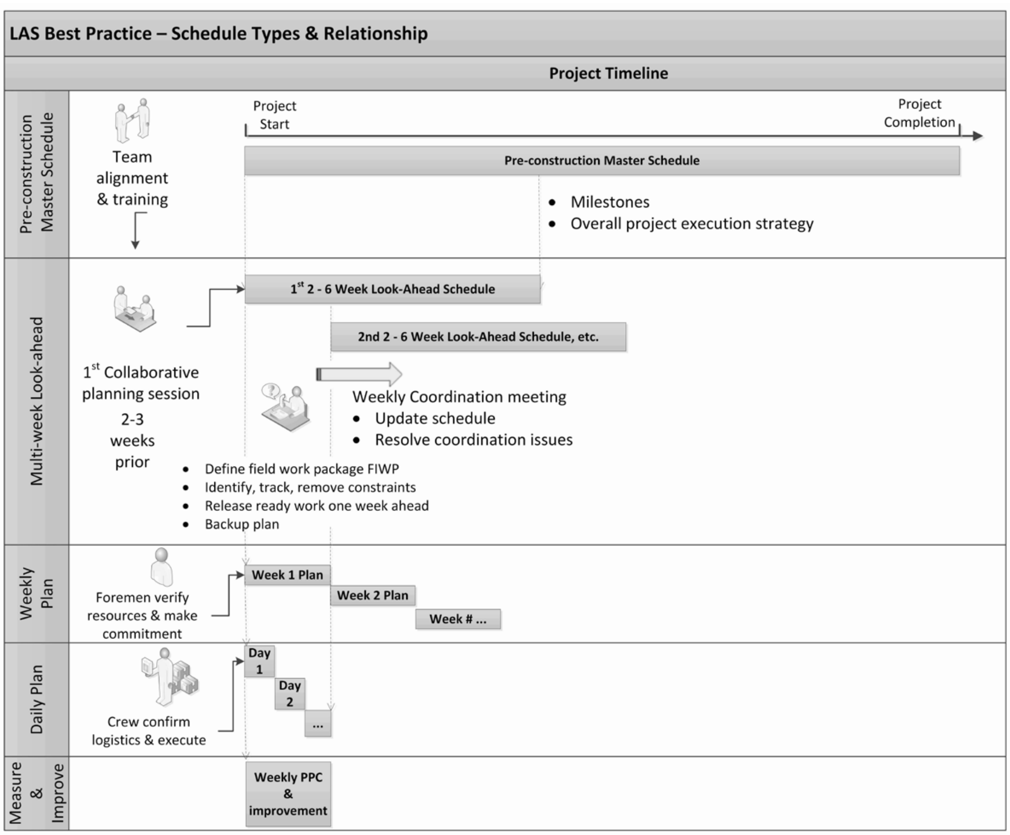
4.1.3 Key Features and Benefits

Key features and benefits of the look-ahead schedule (LAS) best-practice model include the following:

1. **Collaborative planning:** a team scheduling approach involving the GC and subcontractors for promoting a shared sense of responsibility, building relationships, creating conversations, and securing commitments
2. **Crew-level work packaging:** work package or activities defined at the detailed crew level, exposing otherwise hidden constraints and coordination requirements and forcing issues to surface earlier
3. **Foreman involvement:** best use of foreman field knowledge to improve scheduling effectiveness and buy-in
4. **Constraint management:** early identification of activity constraints and responsibility assigned for their tracking and removal
5. **Foreman commitment:** releasing an FIWP only when it is constraint-free for reliable foreman commitment
6. **Quality backup plan:** quality work backlog maintained to minimize the impacts of uncertainties and interruptions
7. **Percent Plan Complete (PPC):** PPC tracked and analyzed to monitor scheduling performance and enable continuous improvement.

When implemented effectively, this model can help the EC reduce chances of schedule interruptions, boost team morale, and strengthen the firm's image as a good project team player, which can translate into greater profitability and repeat business.

Figure 12. Overall project-planning process



4.2 Best Practice Model

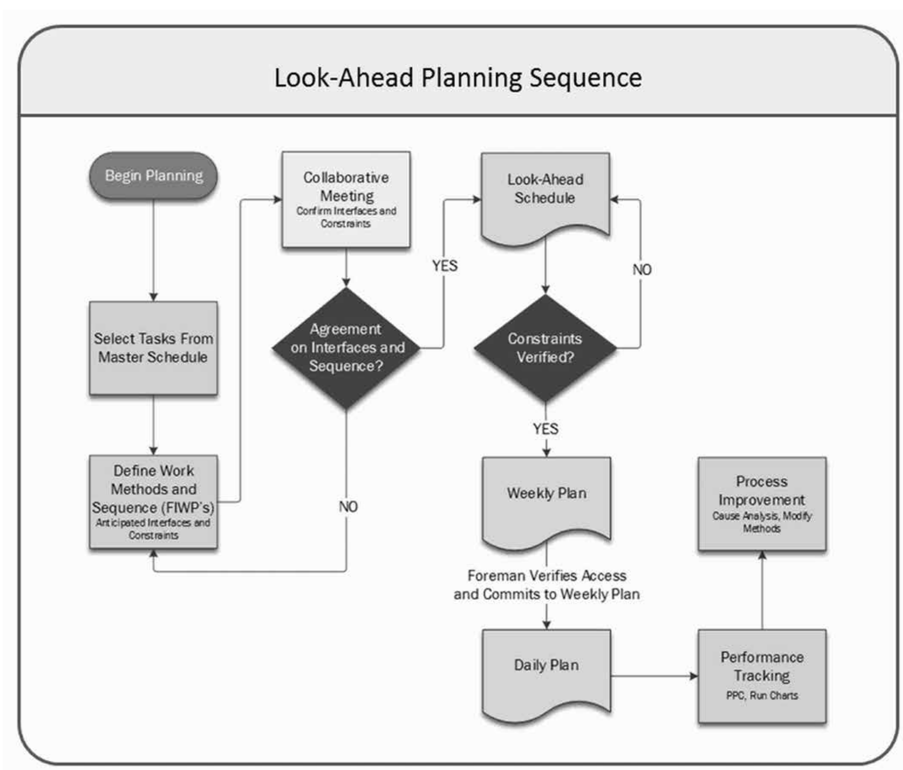
Construction planning is a process of progressive elaboration that becomes more detailed in succeeding scheduling steps. As shown in the first column of **Figure 12,** the overall project planning process consists of the following:

1. **Pre-construction Master Schedule:** describe milestones and overall project execution strategy; achieve team alignment and training
2. **Multi-week Look-ahead:** develop 2–6 week look-ahead schedule (LAS) using collaborative planning method; define field-installation work packages (FIWPs, see Section 4.4.2); track and remove FIWP constraints; release constraint-free work for the coming week; define backup plan
3. **Weekly Plan:** foremen verify resources and make commitments
4. **Daily Plan:** crew confirms logistics and site conditions for efficient, safe, and quality work performance
5. **Measure and Improve:** measure scheduling performance using Percent Plan Complete (PPC, see Section 4.7.2.), chart weekly performance and causes of delays for continuous improvement.

Each of the above plans is described below with its objective and scope, recommended practice, and implementation procedures (e.g., checklist and template).

The sequence of planning steps is shown in **Figure 13.** Two important decision steps are shown in dark gray. In each of these decision steps the work plan is modified if necessary to satisfy identified constraints. Details of this procedure are described in the following subsections.

Figure 13. Planning sequence



4.3 Pre-Construction Master Schedule

4.3.1 Objective and Scope

The pre-construction master schedule, which may also be called a master plan or milestone schedule, describes project milestones, general execution sequence, and work packaging deemed most efficient before field construction. The master schedule provides the basis for look-ahead scheduling during the construction operation stage. Depending on project complexity and the preferences of the general contractor, the pre-construction master schedule may be developed with different levels of detail, with or without input from the electrical contractor.

4.3.2 Recommended Practice

Comprehensive recommended practices for pre-construction planning can be found in the ELECTRI International publication *Electrical Pre-Construction Process Implementation Manual* (Hanna 2009). This report will only comment on one component of pre-construction planning that is relevant to look-ahead scheduling: the development of the master schedule.

1. Collaborative Planning. Developing the master schedule using the collaborative planning method.

Although it is not strictly part of the look-ahead scheduling process, the recommended practice for master scheduling is collaborative planning, which involves an interactive master schedule development session by all contractors. This meeting is also called the Initial Project Meeting or a "sticky note" session. In contrast to a master schedule prepared by the GC alone, collaborative planning promotes a team approach to achieve an agreed-upon schedule that every project team member "buys into." Numerous studies have shown that collaborative planning during this phase is beneficial to the project and complementary to look-ahead scheduling, often resulting in cost savings and faster completion times. The collaborative-planning method is also recommended for "Multi-week Look-ahead Scheduling," which will be discussed later.

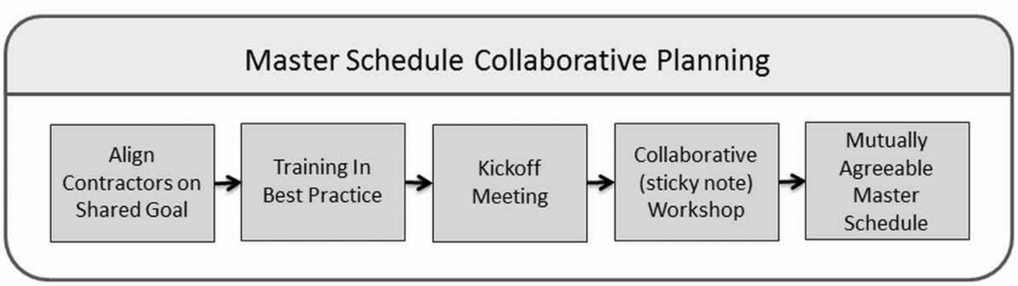
2. Team Alignment. Aligning team members on the look-ahead scheduling process.

The development of a reliable look-ahead schedule and its realization in the field is less likely to be successful if there is not close collaboration among project team members. It is critical that they be aligned and trained in the use of the look-ahead scheduling process, as described in this report.

4.3.3 Implementation Procedure

When project team members agree to use collaborative planning, the action items shown in **Figure 14** can be added to the project kick-off meeting and related activities.

Figure 14. Collaborative planning of the master schedule



1. Establish shared goals and business alignment
   - Align contractors by establishing a shared goal of completing the project on time with a minimum of delays and interruptions
   - Assure commitment on implementing the recommended LAS practice
   - Determine chain-of-command, roles and responsibilities, and communication protocols for look-ahead scheduling and work coordination.
2. Provide initial training on LAS

If team members are not experienced in the recommended best practice, training will provide them with basic skills and accelerate their knowledge and acceptance of the system. Recommended content of a training session includes:

a. Presenting an overview of the LAS best practice
b. Explaining collaborative planning principles
c. Defining work packaging and sequencing
d. Outlining the facilitation and management of the look-ahead and weekly work plan generation
e. Describing the assignment of responsibilities for plan implementation
f. Stressing the importance of working collaboratively through the look-ahead process and identifying and managing constraints
g. Training participants in the improvement cycle of:
   - Reviewing weekly work plan results
   - Measuring performance using PPC and tracking variance categories
   - Identifying root causes for issues and delays
h. Providing a working and coaching session to develop a multi-week look-ahead schedule and weekly work plan
i. Conducting a collaborative planning workshop to develop the master schedule

With team agreement, it is recommended that the master schedule be developed using a collaborative planning method. One such method is the "sticky note" session described below in Section 4.4.3.

4.4 Multi-Week Look-Ahead Schedule

4.4.1 Objective and Scope

While the master schedule provides a global view of the project execution strategy, the multi-week look-ahead schedule is a more detailed plan that lists work to be done within a relatively short time window based on the most up-to-date site conditions and performance. The purposes of the LAS are:

- To scope work at a detailed level for measurable and efficient execution by crews
- To determine the best achievable and agreed-upon work sequence among all team members
- To prepare constraint-free work packages before assignment to a crew
- To produce and maintain a quality backlog of assignments to deal with interruptions and uncertainties.

The time interval of a look-ahead schedule can range from 2 to 6 weeks. This may be specified by contract, but if it is not, the duration will depend upon the complexity of the project and the consensus between the EC and the GC. The important consideration is that it be long enough for constraints to be identified and satisfied before work is assigned. The

LAS is developed by the project team 2–3 weeks prior to the starting date of the LAS, and once developed, it is updated during the subsequent weekly contractor-coordination meetings. The above procedure will be repeated to create the second LAS for the next 2 to 6 week project period.

4.4.2 Recommended Practice

1. Collaborative Look-ahead Scheduling. Develop 2–6 week look-ahead schedule using the collaborative planning method.

Delays due to schedule conflicts among contractors are inevitable without a quality look-ahead schedule. A realistic and reliable schedule is in the eyes of the performing parties—they should be engaged in developing the schedule. As in the development of the master schedule, look-ahead scheduling using a collaborative planning process improves communication, commitment, and recognition of common goals among contractors. As indicated in **Figure 12** *(page 26),* the look-ahead scheduling development begins with a collaborative planning session, or "sticky note" session. Collaborative planning improves through peer pressure, collective intelligence, and clear communication. The major benefits of this process include:

- Promoting a shared sense of responsibility and ownership of schedules
- Encouraging communication and securing promises of action among team members
- Forcing constraints and performance issues to the surface early so they can be resolved during planning, not during construction.

A guide for conducting the collaborative planning is included in the implementation procedure section below.

2. Crew-level Work Packaging. Define field installation work packages (FIWPs) that an individual crew can complete within a week.

A master schedule that plans the work at the project level for the long term falls short in that it does not reveal complex interactions between different trades in day-to-day operation. Look-ahead scheduling fills in the gap by focusing on detailed scheduling of work in the short term. To develop a detailed schedule, work must be decomposed into smaller work packages or activities at the crew level, which exposes otherwise hidden constraints and coordination requirements and forces issues to surface earlier. This crew-level work package is called the Field Installation Work Package (FIWP), and it involves work that an individual crew can typically complete within a week. An FIWP is packaged with all necessary information about work scope, responsible crew, drawings, resources, and constraints. The main characteristics of the FIWP are:

- An FIWP is assigned to an individual foreman's crew. It is typically discipline–specific, but it may consist of a mixed crew.
- An FIWP is packaged with all necessary information that a crew needs to perform the work.
- All constraints that will affect a crew's execution of the FIWP are identified and managed, as described later in Constraint Management.
- The size of an FIWP is typically within one week's worth of work. However, it can depend on the complexity of the work: e.g., installing 1,000-kw generator would probably take 7 days, while replacing a service ground might take 1 day.

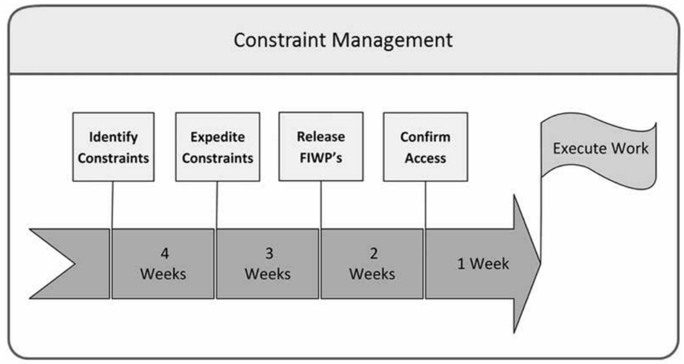
The first page of a sample FIWP is shown in **Figure 15.** A checklist for the FIWP preparation is shown in Appendix A. Also see a documented example and released FIWP in Appendix B.

Figure 15. Sample FIWP cover page

FIELD INSTALLATION WORK PACKAGE

Project Number	4151066
Project Name:	WWP Booster Pump Station Improvements
FIWP Number	FIWP4151066.019
Area/System/ SubSystem	Distribution
Prepared by:	Matt Planner
Date:	03/17/2013
Issued by:	Gary Project Manager
Date:	03/22/2013
Released by:	Bob Superintendent
Date:	03/29/2013
Assigned to:	Alberto Foreman
Date:	04/08/2013
Completed by	Alberto Foreman
Date:	04/22/2013
Scope:	Install medium voltage feeder (SF-04,SF-05,SF-06) between service area switchgear and MVA lineup in pump building. Install cable supports and fireproofing in manholes. Install medium voltage terminations. Perform Hi-pot cable test.
Deliverable:	(3) - 1087' runs of 3 phase medium voltage cable (3x750 KCMIL + 1/0 G) complete with terminations and testing.

Figure 16. Constraint-management process



3. Constraint Management. Identify FIWP constraints and assign responsibility to track and remove constraints.

Numerous constraints can delay or interrupt FIWP execution, such as missing material, equipment shortage, stacking of trades, or delayed predecessors. Executing an FIWP that is still subject to constraints is either impossible or in danger of serious loss of productivity. Look-ahead schedules that fail to capture all necessary constraints will most likely result in conflicts that come too late to resolve in the field, and thus they will cause delays.

Therefore, it is important to manage constraints in a systematic way by (1) identifying constraints for each FIWP, (2) tracking their status, and (3) assigning responsible parties to resolve them. The goal of constraint management is to prepare constraint-free FIWPs for safe and efficient execution by crews. This is the key element underlying the LAS best-practice model. The constraint-management process is shown in **Figure 16.**

An FIWP will not be released to a crew to perform unless all constraints are cleared. This involves the following:

- Identify constraints. All major constraints for each FIWP that can negatively affect its execution must be identified during the scheduling stage.
- Expedite constraints. Once constraints have been identified, they must be verified as being satisfied before the work is released to the crew. If a constraint has not been satisfied, it must be corrected by the responsible party before releasing an FIWP to a crew. This is achieved by systematically tracking and resolving constraints.
- Confirm access. The foreman and crew confirm that field conditions are ready as described in the LAS.

4. Quality Backup Plan. Maintain a quality FIWP backlog to minimize the impact of uncertainties and interruptions.

Construction operations are influenced by numerous uncertainty factors, such as unfavorable weather conditions and unexpected equipment breakdowns. When the performance of an FIWP is interrupted, a backup plan is needed to engage crews in alternative activities. The previous effort of establishing constraint-free FIWPs also allows the creation of a backlog of ready FIWPs that can be assigned as alternative work to a crew.

5. Foreman Involvement. Use foremen's field knowledge to improve scheduling effectiveness and buy-in.

Foremen are the front-line management that lead the crew to get the work done. They have the most intimate knowledge about how to perform the work and, more importantly, what the prerequisites or constraints are that affect how they do the work. They are not only qualified but also should be involved in the look-ahead scheduling practices specified above, such as collaborative planning, FIWP work packaging, constraint management, commitment, and backup planning.

4.4.3 Implementation Procedure

The above five recommended practices are integrated into the LAS procedure, a portion of which is shown in **Figure 17.** Sample checklists useful for implementation of the procedure are included here. They can be easily customized for a particular EC or project.

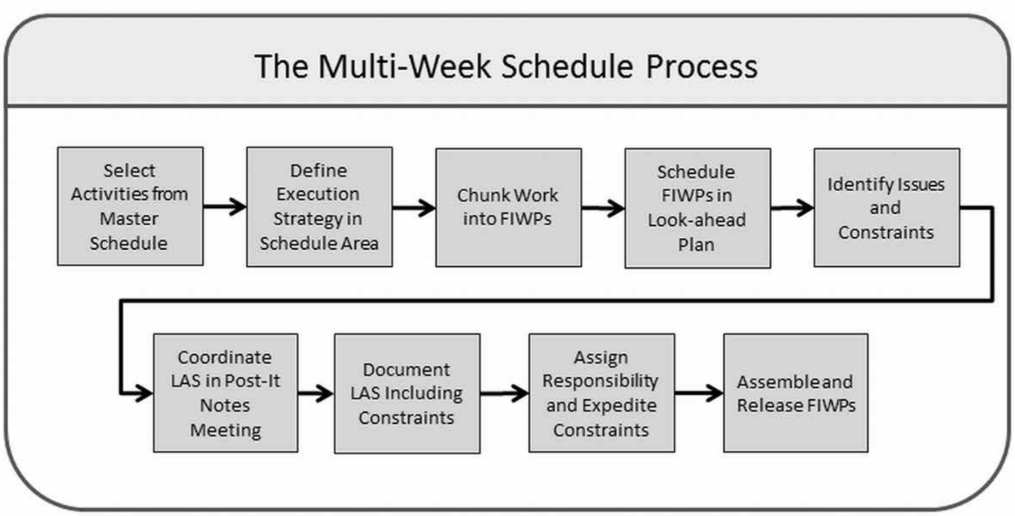
The initial look-ahead schedule may have been prepared in the initial project meeting. If not, conduct the first collaborative look-ahead scheduling workshop 2–3 weeks prior to the start date of the project.

1. Identify the LAS work scope, work method, and performing crews for the look-ahead window (e.g., 2–6 weeks)

The Designated Planner (DP) reviews the project master schedule and identifies work scope entering the look-ahead window for inclusion in the look-ahead plan. In addition, with inputs from the project manager and superintendent, the DP determines the general work method and identifies performing crews and their foremen.

Although the overall construction method will have been determined in the master schedule, the work method is more detailed for the look-ahead work period, offering an opportunity to make adjustments based on the latest design and changes, as well as expected project conditions. Design of the work method should consider the following aspects:

Figure 17. The multi-week schedule process



- The latest design of the work
- Construction method specified in the master schedule and alternative, if any
- Availability of crew and major equipment
- Expected experience and skills of crews and foremen
- Applicable craft traditions or union work rules
- Expected major constraints; e.g., site access, logistics, and safety
- Expected performance of major pre-requisite work; e.g., permitting and other contractors' work.

2. Break down work into FIWPs and identify critical constraints with consultation with responsible crew foremen

The FIWP is a crew-level work package that involves work that an individual crew can complete in a few days or within a week. We propose FIWPs with duration of a week or less to facilitate and ensure crew-level detailed scheduling. It also supports better performance tracking, which is conducted on a weekly basis.

The two major efforts in defining the FIWP are the work content and its final assembly and documentation. In this step, only FIWP work content is determined.

The DP should consult the superintendent and the performing crew foremen in defining FIWP work content. Attention should be given to anticipated critical constraints of each FIWP, with special emphasis on the interfaces with other trades. At this step, as a minimum, the following should be summarized for each FIWP:

- Work scope and quantity
- Performing crew and foreman
- Estimated duration (within a week)
- Work method and sequenced operation steps
- A list of critical constraints, especially coordination requirements with other contractors.

3. Conduct the "sticky note" session (2–3 weeks prior to the intended work start date).

Similar to the procedure used in collaborative planning during the master scheduling stage, the following "sticky note" session should be conducted. Coordination issues and conflicts among contractors cannot be prevented without collaboration at the scheduling stage. This "sticky note" session requires inputs and coordination among all project team members, including GC, EC, and trade contractors, who are typically involved in regular project coordination meetings. On a large project, materials suppliers and other contributing parties may also be involved in this session. For the EC, at a minimum, the project manager and superintendent should participate in this session.

- Each contractor is supplied with unique color cards or sticky notes.
- All contractors break down their work in a way that they feel is necessary to achieve control of their work. For the EC, this is the FIWPs identified in the previous step.
- The contractors list their activities/FIWPs on individual note cards. Each card contains, at a minimum, the name of the activity and its duration. The predecessors and successors should also be recorded, as well as any critical constraints impacting field performance.
- The contractors come forward to post their card/activity on a large white board or a wall.
- Team members then jointly identify potential conflicts and negotiate a solution to ensure efficient work performance.
- The contact person is determined for coordination issues.
- The agreed-upon look-ahead schedule is recorded and signed.
- The finalized look-ahead schedule is shared with all contractors.

It should also be noted that the finalized LAS may be updated and changed, if necessary, during subsequent weekly contractor-coordination meetings with team agreement.

2. Document the EC's look-ahead schedule including all FIWPs and their constraints.

A variety of look-ahead scheduling forms are used in the industry. **Figure 18** provides an efficient sample form that shows all required elements and combines a six-week look-ahead and a weekly plan. It allows documenting FIWPs, their timing, and constraints. In addition, it includes items for performance measurement that can be used later—e.g., progress and delay causes. Separate spreadsheets for the weekly and look-ahead sections can be created if a simpler form is preferred.

FIWPs agreed upon during the sticky note session should be included in the EC's LAS chart. The following items should be recorded for each FIWP. This information may also be duplicated in a separate work log to allow for more detailed documentation, especially of the constraints and their status.

- FIWP ID and name
- Responsible foreman
- FIWP timing and duration
- List of all constraints for each FIWP, in addition to critical constraints identified prior to the "sticky note" session—e.g., material supply and drawing availability.

A sample form of constraint log is shown in **Figure 19.**

Figure 18. Example of LAS spreadsheet

LOOK-AHEAD SCHEDULE

Project Information	TITLE AND LOCATION	CONTRACT NUMBER	PLAN FOR WEEK BEGINNING:	PLANNED BY:
	Filson gynasium	L204	2/14/14	Jimmy P

Percent Plan Complete (PPC)	
Total Tasks	3
Completed Tasks	1
Percent Complete	33%

Note: Cells with red text are automatically calculated. Shading is applied to plan and constraints cells with content.

Schedule Activity No.	WORK LOCATION AND DESCRIPTION	PERSON RESPONSIBLE	Weekly Work Plan Mon 2/14	Tue 2/15	Wed 2/16	Thu 2/17	Fri 2/18	Sat 2/20	Task Done? Yes/No	Look-Ahead Plan WEEK BEGINNING: 2/21	2/28	3/7	3/14	3/21
255010	Office and gym- Rough-In	Joe Foreman	X	X					Yes					
255020	"- Branch Wiring	Joe Foreman		X	X	X								
255030	"- Fixtures	Ed Foreman				X	X	X		X				

Schedule Activity No.	Tasks in Look-Ahead	Constraints: Work Not Ready	Other Trades	Drawings	Equipment	Overcrowding	Materials	Work Changes	Other
255010									
255020									
255030	X		X				X		

Figure 19. Constraint log

CONSTRAINT LOG

Project Information	TITLE AND LOCATION	CONTRACT NUMBER	UPDATE DATE:	UPDATED BY:
	WWTP Rehab	L204	2/14/14	Jimmy P

Schedule Activity No.	WORK LOCATION AND DESCRIPTION	CONSTRAINT DESCRIPTION	COMPANY RESPONSIBLE	PERSON RESPONSIBLE	Date Identified	Promise Date	Revised Promise Date	Date Complete	Notes
255010	Clarifiers-Install Conduit, panel & lightin	Clarifier bridge, stairs, equipment complete	Industrial TX		1/7/2014				
		Clarifier control panels delivered	Industrial TX						
		RFI-light stanchion mounting detail							
255020	"-Install Power & Control Circuits								
255030	"-Terminate Wire	RFI-Alarm outputs to autodialer		Ed Foreman					

To ensure reasonable thoroughness of constraint identification, a checklist appropriate to the involved trade and nature of the task can be used. However, due to the complexity of construction work, it is not possible to design a checklist that anticipates every item. Instead, this is handled by generic checklists that, to a greater or lesser degree, include categories of constraints. A sample checklist for preparing an FIWP package is shown in Appendix A, and additional checklists for constraint identification and verification can be found in the ELECTRI International publication *Electrical Project Management Process Implementation Manual* (Menches et al. 2010). The content portion of a constraints checklist is shown in **Figure 20.**

3. Assign responsibility and expedite constraints

If a constraint has not been satisfied, it must be corrected. The way in which this is done depends on the nature of the constraint. Removing the constraint may be within the EC's control or may require getting commitment from the GC

Figure 20. Sample constraints checklist

Constraints	Notes
☐ Preceding Work Not Ready	
☐ Interference with Other Trades	
☐ Drawings	
☐ Equipment	
☐ Overcrowding	
☐ Materials	
☐ Work Changes	
☐ Other	

or other contractors. A constraint log, as shown in Figure 19, can be used to facilitate status tracking of constraints, and unsatisfied constraints may be in any of the several categories described above. For example, the constraint may consist of unclear or incomplete drawings that may be corrected through an RFI or communication with the GC or architect/engineer. In other cases, changes in the work sequence, work method, design, or materials may solve the problem. If at all possible, changes of this type should be chosen so as to not create other problems such as out-of-sequence work, added cost, or congestion.

Figure 21 (modified from Blackmon et al. 2009) describes the process of expediting constraints in relation to different project management responsibilities within the EC organization and with other subcontractors.

In smaller firms, multiple functions may be performed by one person. However, regardless of organization size, these responsibilities must be carried out to expedite constraints. The responsible personnel will be provided a list of constraints and are expected to satisfy these constraints in a timely manner. Constraints may be tracked electronically (i.e., in a computer database), however, even those constraints whose status is nominally verifiable in a database or report may sometimes need to be checked by the DP through a site visit.

Figure 21. Functional work flow for expediting constraints

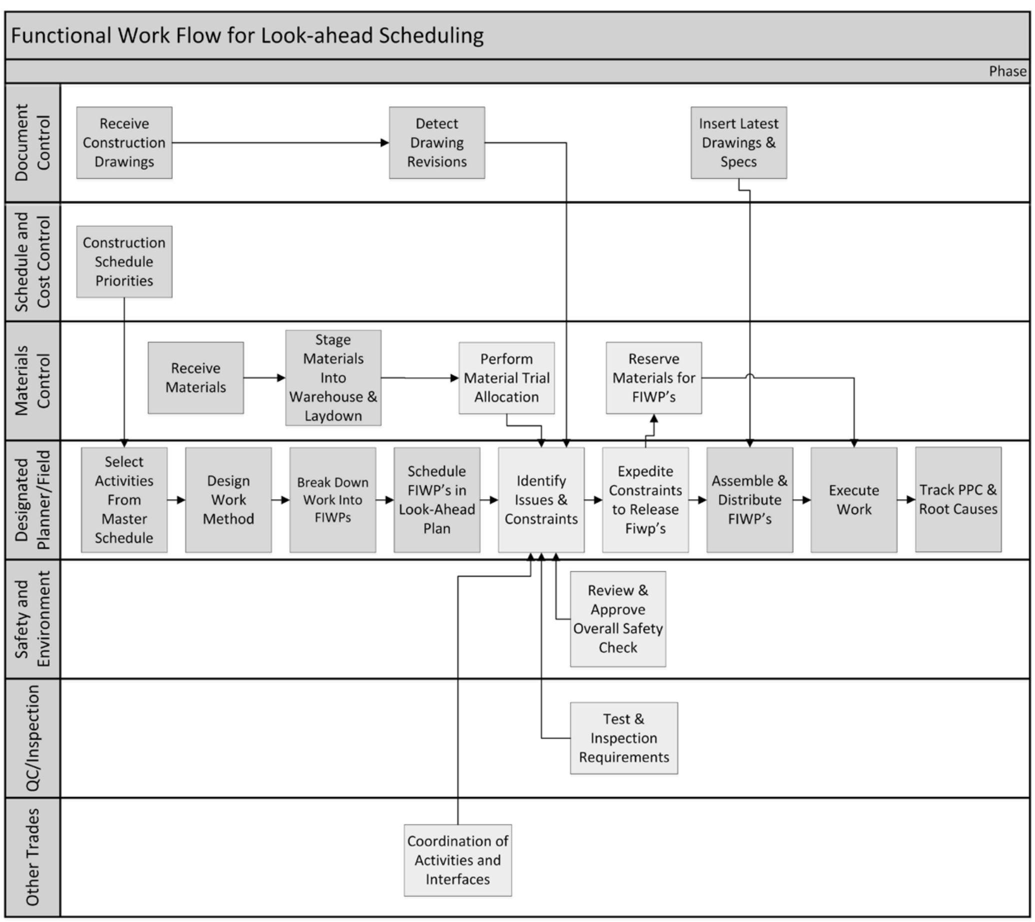


Figure 21 also identifies other trades that interface with the EC. The following should be done to expedite constraints controlled by other contractors:

- Update constraint status and expedite during weekly contractor coordination meeting.
- Verify constraint status by the DP through site visits, if necessary.

4. Assemble and release constraint-free FIWPs one week prior to field execution.

An FIWP is ready to be released to the responsible crew foreman when (1) it is constraint-free or is expected to be free within one week, and (2) it is scheduled for execution in one week. It is important that the process includes a verified final OK in order to ensure that all constraints have been identified and everything is ready before work begins.

Before releasing an FIWP to the responsible foreman, all information needed for field execution should be documented and assembled together for each FIWP. As mentioned previously, a typical fully documented FIWP will contain the items described in 4.4.2. The form and content of the FIWP document may vary with job complexity. For example, simple or routine jobs may require less information, but all necessary items should still be identified. See a documented example and released FIWP in Appendix B.

The person authorizing the release of FIWPs may vary depending on the organization. Typically, this will be the project superintendent. The superintendent or other authorized individual will release the FIWPs that are consistent with the LAS and certified by the DP to be free of constraints to the foreman in the week prior to execution.

The released FIWPs become the basis for the weekly work plan discussed next.

4.5 Weekly Work Plan

4.5.1 Objective and Scope

The weekly work plan is a detailed plan for foremen for the upcoming week's work. The objectives of the weekly work plan are:

- Providing a firm and clear weekly work plan for foremen
- Allowing foremen to verify work readiness proactively
- Achieving reliable performance commitment from foremen.

4.5.2 Recommended Practice

The weekly plan should be derived from the look-ahead schedule. It is a collaborative agreement of the involved parties on what tasks will get done in the next week. The DP and other team members decide which FIWPs have satisfied constraints and are ready for release. It should only contain constraint-free FIWPs—i.e., all constraints should have been removed. The weekly work plan will be finalized for the coming week in the weekly planning meeting.

Foreman Commitment. Releasing an FIWP only when it is constraint-free for reliable foreman commitment.

Foremen are the last management level prior to field execution. The schedule will not be reliable, and field performance will not be predictable, without the foreman's commitment and diligent work. To gain a true commitment from a foreman, only constraint-free FIWPs should be released to the crew. From the foreman's perspective, he or she should verify readiness of FIWPs. If an FIWP cannot be done due to constraints, the foreman should not promise to do it; if it can be done, the foreman should promise to do it—and get it done. This leads to a more reliable work flow and more predictable crew performance that boosts team morale.

4.5.3 Implementation Procedure

The process of weekly planning is shown diagrammatically in **Figure 22.** These activities are primarily implemented in the weekly project meeting.

1. The DP drafts the weekly plan based on ready FIWPs for the upcoming week identified in the LAS.

The weekly plan form should include a list of FIWPs, the person responsible for each FIWP, expected start and finish dates, statuses of constraints, and outstanding issues, if any.

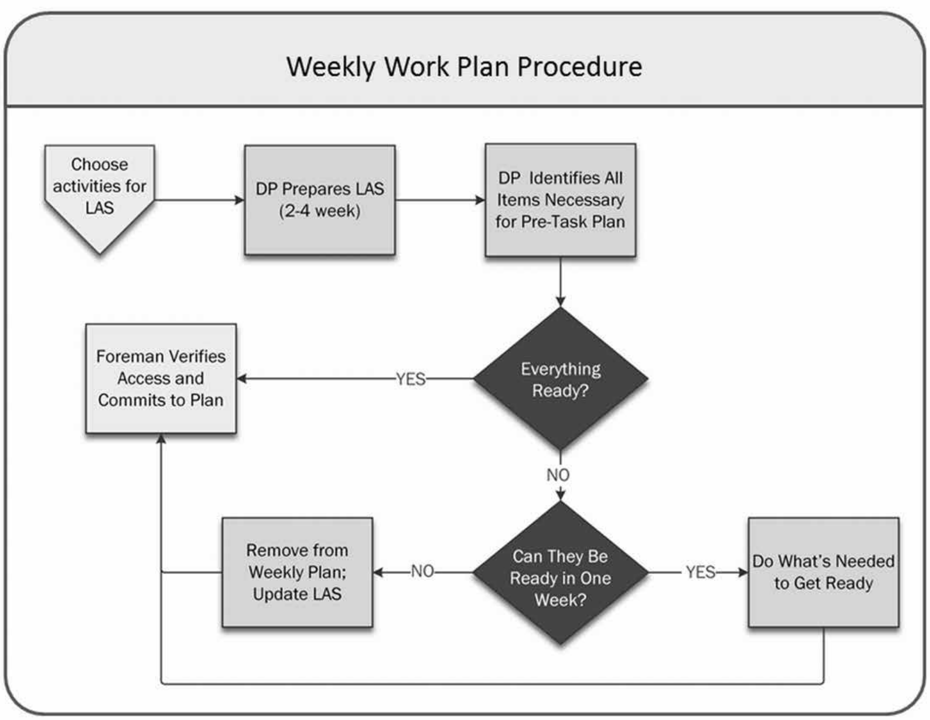
2. Responsible foremen verify FIWP readiness.

The weekly plan draft is presented to responsible foremen. Foremen will determine whether FIWPs are ready to perform in a week or not by verifying the status of all constraints. If any constraint still exists but it can be reasonably removed within one week before execution, the DP will need to act with the responsible party to remove the outstanding constraint. Otherwise, FIWPs that are not ready will be delayed, removed from the current weekly plan, and recorded for the next LAS update. The root cause of this delay should be investigated to prevent future occurrences.

3. Foremen make commitment and sign off on the weekly plan.

If all constraints have been removed, the foremen will make a commitment and sign off on the weekly plan. Ideally, the weekly verification and commitment should occur during the weekly meeting. The significant benefit is the additional motivation resulting from a public commitment to the weekly plan.

Figure 22. Weekly work plan procedure



4.6 Daily Plan

4.6.1 Objective and Scope

The daily plan specifies work planned for the day. The objectives of the daily plan are:

- Providing clear work instruction to individual workers
- Confirming and allocating resources
- Emphasizing safety practices
- Making it possible to monitor work performance.

4.6.2 Recommended Practice

The daily plan for a particular day should be derived from the weekly work plan and prepared by the DP. Foremen should be responsible for communicating the daily plan to their crew members through a daily huddle.

Daily Huddle. Communicate work instructions to crew members, confirm resource allocation, and provide reminders about safety practices.

A daily huddle is a time each day when the crew comes together to discuss the plan for the day and to make sure everyone is on the same page. Additionally, the team can review performance from the previous day and find ways to improve performance. Daily huddles encourage open communication, promote teamwork, and keep the team focused on the work at hand. In other words, it helps align the crew while making them feel like they are part of a team.

4.6.3 Implementation Procedure

1. The DP communicates the daily plan to the responsible foremen based on the plan to which they have committed. A daily plan and report form is shown in **Figure 23** *(next page)*.

2. Foreman conducts the daily huddle.

Before the workday starts, the foreman will gather his or her team to deliver key information to align the crew members for the day. A checklist for the daily huddle is shown in **Figure 24** *(page 41)*.

The foreman, with input from crew members, should identify each task to be accomplished and the method that will be used. Each crew member should have a clear understanding of his or her assignment. In addition, the team can review performance from the previous day and find ways to improve performance.

3. Foreman tracks daily performance.

Tracking daily performance and identifying sources of problems are important factors for improving job performance. Foremen should keep a daily record of work performance that includes a list of reasons for variance and additional unplanned work. The daily plan and report form in Figure 23 can be used for this purpose.

4.7 Measure and Improve

4.7.1 Objective & Scope

The objectives of field measurement and improvement include:

- Measuring current actual project performance
- Providing feedback to the EC for continuous improvement.

Figure 23. Daily plan and report form

DAILY REPORT
(ATTACH ADDITIONAL SHEETS IF NECESSARY)

Today's Date:		Circle Day of Week	Monday	Tuesday	Wed.	Thursday	Friday	Saturday	Sunday

Project Information	TITLE AND LOCATION	Filson gym		CONTRACT NO.	L204
GC	Maxon	SUPER	Joe R.	PLANNER	Kent Mills

Weather			
	☑ Did not affect work	☐ Slowed work	☐ Halted work
Cause:	☐ Cold	☐ Rain	☐ Heat	☐ Wind
AM WEATHER	PM WEATHER	MAX TEMP	MIN TEMP

CONTRACT WORK PERFORMED TODAY

Schedule Activity No.	WORK LOCATION AND DESCRIPTION	CREW	ACTUAL CREW HRS	ACTIVITY COMPLETE?
255010	Office and gym- Rough-In	Joe F.	8	Yes
255020	"- Branch Wiring	Bob F.	10	No
255030	"- Fixtures	Joe F.	6	Yes

VARIATIONS AND ADDITIONAL WORK PERFORMED TODAY

WORK LOCATION AND DESCRIPTION	AUTHORIZATION	CREW	ACTUAL CREW HRS	ACTIVITY COMPLETE?

DAILY REPORT
(Continuation Sheet)

JOB SAFETY			
	WAS A JOB SAFETY MEETING HELD THIS DATE?	YES	NO
	WERE THERE ANY LOST TIME ACCIDENTS THIS DATE?	YES	NO
	WAS HAZARDOUS MATERIAL/WASTE RELEASED INTO THE ENVIRONMENT?	YES	NO

NEW PLANS OR DRAWINGS RECEIVED
Plan Number

Staff On Site	Hours

Additional Comments

Work Was Delayed Due To:
- ☐ Preceding Work Not Ready
- ☐ Other Trades
- ☐ Drawings
- ☐ Equipment
- ☐ Overcrowding
- ☐ Materials
- ☐ Work Changes
- ☐ Other

Report prepared by:
Signature ____________________

Figure 24. Daily huddle checklist

DAILY HUDDLE CHECKLIST		
ACT.	ITEM NO.	SUB-ACTIVITIES
Communicate daily plan to crew and solicit input		
☐	1	Conduct Daily Huddle in work zone.
☐	2	Communicate on a personal level with crew members.
☐	3	Briefly review previous day's work and procedures. Discuss any lessons to be applied to today's work.
☐	4	Start job safety analysis with work steps.
☐	5	Be specific with work assignments.
☐	6	Involve crew in discussion. Solicit their input.
☐	7	Get crew's agreement to production target and procedures. Enter into Daily Report.
☐	8	Review general hazards.
☐	9	Encourage crew to look out for each other.
☐	10	Note procedure to stop work if a problem arises.

Numerous measures of productivity and project performance exist, including performance relative to budget, labor hours, earned value, completion date, task duration, fraction of tool hours, and others. However, in this report we limit our focus to measuring scheduling effectiveness—the quality and reliability of look-ahead scheduling—since the primary objective of this report is to show how reliable look-ahead schedules can be developed.

4.7.2 Recommended Practice

The quality of a look-ahead schedule is measured by how closely it matches the actual field execution. The more work that has been done according to an LAS, the better the reliability of that LAS has been. However, a quantitative measure that is easy and cost-effective to collect is still needed. The "percent plan complete" (PPC) is recommended for this LAS best-practice model.

Percent plan complete (PPC). PPC measures the degree to which work is completed as planned. It is calculated by dividing the number of FIWPs completed by the total number of FIWPs planned for the plan period, typically one week, expressed as a percentage. PPC is simple to record, objective, and adequate to measure scheduling quality. A higher PPC number indicates a look-ahead schedule with better quality and reliability. Past studies have also confirmed that there is a positive correlation between PPC and productivity—in other words, when PPC improves, productivity also improves. Unfortunately, the PPC reported by the industry has been repeatedly at levels below 60%, so there is much room for improvement.

4.7.3 Implementation Procedure

1. At the end of each week, the DP records PPC based on FIWP completion status and notes delay reasons, if any.

PPC is the ratio of the number of completed FIWPs to the total number of FIWPs planned for the week.

$$\text{Percent Plan Complete (PPC)} = \frac{\text{(Number of completed FIWPs)}}{\text{(Total number of planned FIWPs for the week)}}$$

- The status of FIWPs planned for the week is either completed or not completed. Only FIWPs that are 100% complete should be used for PPC calculation.
- FIWPs or activities that are performed but were not planned should not be counted toward PPC score because a requirement to perform unplanned work is an indication of schedule quality issues.

The reasons for FIWP delays should also be noted for later root-cause analysis.

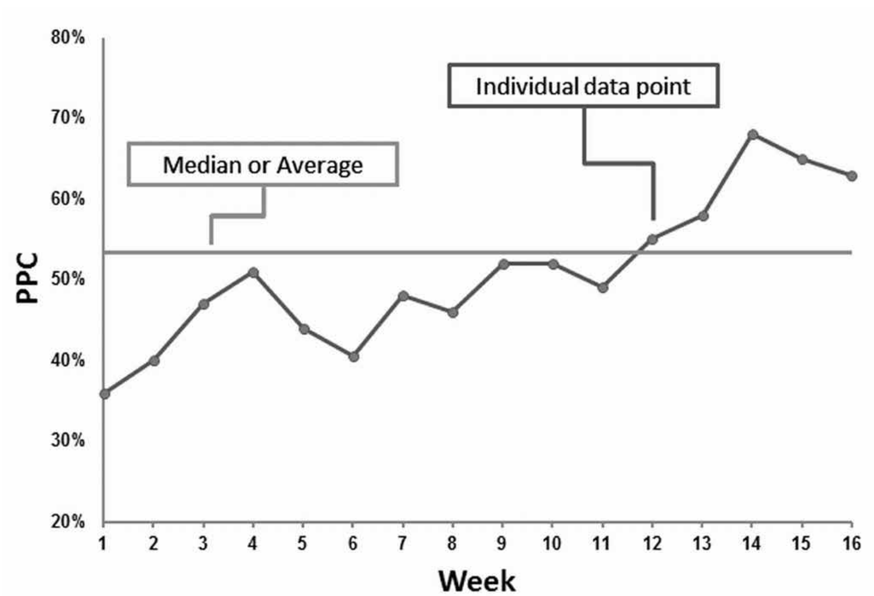
2. Plot PPC; analyze PPC and root causes of delays

PPC should be analyzed in run charts as shown in **Figure 25,** which shows the trend of PPC over the past reporting periods.

Run charts are an easily constructed, standard technique designed for the early detection of signals of improvement or degradation in a process over time. They are a time-ordered plot of measurements, in this case PPC. Trends and anomalous events can be more easily spotted on the run chart than in tables and spreadsheets. The run chart may be constructed as follows:

- Ideally, there should be a minimum of 15 data points.
- Draw a horizontal line (the x-axis), and label it with the unit of time (usually weeks).
- Draw a vertical line (the y-axis), and scale it to cover the current PPC data, plus enough room to accommodate future data points.
- Plot the data on the graph in time order and connect adjacent points with a solid line.
- Calculate the mean or median of the data (the centerline) and draw this on the graph.

Figure 25. PPC run chart



Sources of variation include people, methods, materials, measurement, and environment. Interpretation requires distinguishing meaningful variation from a normal degree of random variation in the process. Interpretation of patterns in run charts is discussed in numerous statistical quality-control publications. Patterns include shifts, trends, cyclical patterns, anomalously low or high points, runs (a group of points above or below the line), and random points above and below the line. Strict interpretation of patterns is governed by statistical guidelines, but patterns are often easily spotted. **Figure 26** shows four common patterns.

The shift and trend patterns show abrupt and gradual change in the process being measured, respectively. Judgment must be exercised to investigate variations that might be significant while not being distracted by variations that are too small to be meaningful. An abrupt shift may be the result of a change in the type of work or a new crew. A gradual upward trend may indicate improvement due to learning or the recent introduction of an improvement method.

When a run chart confirms an unsatisfactory PPC or a downward trend, root causes should be analyzed. The reasons collected during weekly PPC measurement should be tabulated, and they can be analyzed to determine the root causes for low PPC values or unreliable schedules. These causes should be categorized in meaningful groups—e.g., drawings issues and material delays—to facilitate identifying top root causes and solutions. A Pareto chart is recommended for this purpose, and **Figure 27** *(next page)* shows a sample Pareto chart. It ranks the causes in terms of their frequency.

As noted previously in the survey section, the apparent cause may not be the root cause, so some effort must be expended to identify the true source of the problem. For example, the root cause of later delays may be a delayed permit, while a superficial analysis might identify the resulting problems, such as delayed submittal approval or out-of sequence work, as the cause. It is important to track the issues back to the true cause. The root cause may not be as early in the

Figure 26. Examples of run-chart pattern

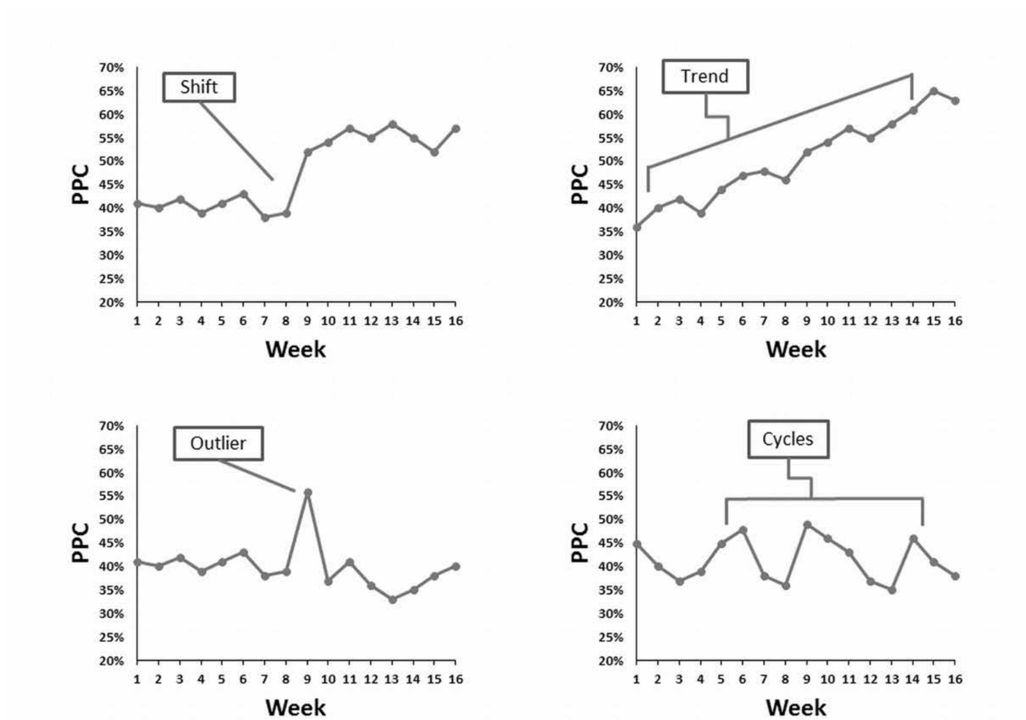
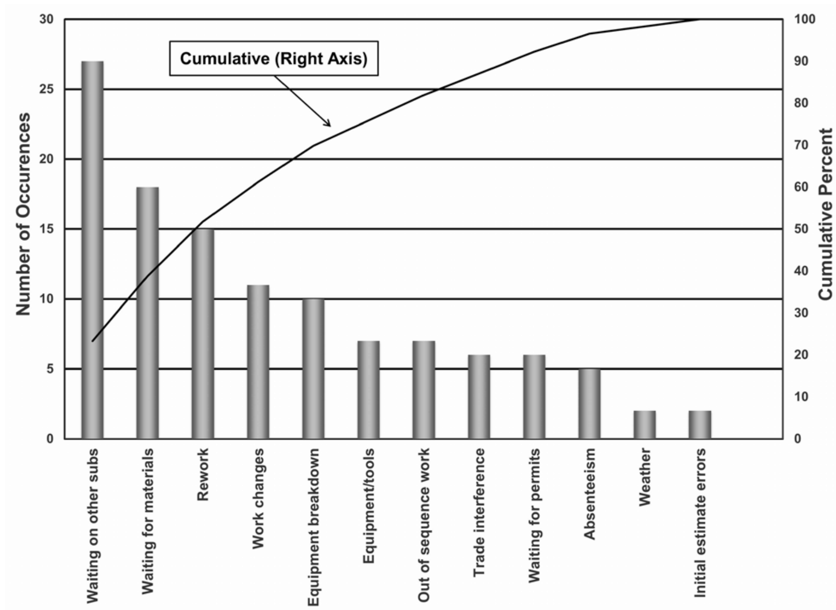


Figure 27. A sample Pareto chart



process as in this example, but corrective action cannot be effectively taken unless it is directed at the initial cause of a sequence of problems.

4.8 Major Implementation Considerations

4.8.1 Designated Planner

A primary consideration is who prepares the LAS. In the best practice, this means who is the DP. Our survey showed no strong industry preference, with the project manager or superintendent commonly given the responsibility. The DP may also be another staff member. This choice will usually depend on the size and complexity of the project.

We do not recommend a particular position to prepare the LAS, but it should be a person with a comprehensive knowledge of the trade and experience as a supervisor in order to have the necessary scheduling and construction knowledge. The Construction Owners Association of Alberta recommendation for a Workface Planner, a similar planning position, is a minimum of 5 years of trade experience and 3 years as a supervisor.

4.8.2 Computer Applications

Practically speaking, managing the LAS and keeping track of FIWPs on a project of significant size requires a computer application. This may be a spreadsheet, project management software, a custom application, or a specialized look-ahead scheduling application. The application chosen for this purpose should be used as early as possible in the look-ahead scheduling process. A screenshot of an FIWP tracking spreadsheet application included in the Implementation Guide was shown in Figure 18 *(page 34)*.

4.8.3 Implementing the LAS from a Subcontractor Perspective

The LAS best-practice model encourages communication and commitment among contractors. Ideally, this effort is led by the GC or construction manager (CM). The full benefits of the best practice model can only be achieved with team participation and collaboration. Our survey among ECs showed that the top causes of delays are related to handoff points among subcontractors (e.g., predecessor delay). Other "traditional" causes (e.g., labor performance, material shortage) are ranked relatively low. That reminds us again that collaboration is a key issue, and it is especially the case for ECs or similar trades who work "downstream" and are subject to delays by their predecessors. Before the GC and other subcontractors buy into the best practice, it is difficult to convince them to (1) do a "sticky note" planning session, (2) schedule work at a more detailed level to expose all constraints that are otherwise hidden, and (3) resolve constraints collaboratively, especially those at the handoff points among trades.

If the GC or CM has not bought into this practice, then the EC as a subcontractor can still take the lead in implementation. However, in that case, the EC faces a unique challenge due to their status as subcontractor—i.e., they cannot direct what the GC and other subcontractors do, which makes it difficult to capture meaningful constraints. The question here is not whether collaborative planning or look-ahead scheduling are good management but rather how to implement them from the EC's perspective.

In such a project environment, a viable implementation strategy is to "lead by example" or "show and prove." This implies starting small and gradually growing the LAS practice in a project. The following initial implementation strategy is recommended:

- **Hook.** Grab their attention. Initial implementation should be by the EC alone. Conduct the LAS and identify constraints, present them to the GC during a coordination meeting; and conduct a daily huddle onsite.
- **Book.** Give them the information. Explain how the best practice would work, and provide other contractors with sample procedures and templates.
- **Look.** Give them the application/lesson, and invite them to join a "sticky note" session.
- **Took.** Get them to take something from it and use it! Start from there toward a team implementation of the LAS best-practice model.

Field Case Study

5.1 Introduction

The best practice was tested in a case study in a water-treatment plant expansion project. The objective of the case study was to implement the recommended look-ahead scheduling best practice to evaluate its effectiveness and provide feedback. From the project perspective, the intended goal of the best-practice implementation was to release constraint-free work to the field and thus reduce construction delays and increase productivity.

The scope of the case study included applying the principals of collaborative planning, constraint tracking, and work packaging. Early pre-construction planning in this project had been done, and the work had begun before the case study started. The main elements of the best practice—collaborative planning and multi-week, weekly, and daily plans—were implemented. "Sticky note" sessions, daily huddles, results tracking, and root-cause analysis were not used or were used in a modified form as discussed below. Participants in the study reported improved efficiency and team motivation.

5.2 Project Description

The LAS best practice was implemented on an improvement project on a water-booster pump station in Harris County, TX. The pump station was originally constructed in 2010 and has undergone two improvement projects since then. The contract amount of the electrical portion of the project was $1.97 million. The major electrical objectives of the project were:

- Expand electrical service to include a new 1,200-A/4,160-V service parallel to the original 1,200-A/4,160-V service. The service construction included installation of a ductbank at the service area, a medium-voltage switchgear assembly, and three 1,100-foot-long runs of 750-MCM/5-kv cable in the existing ductbank to the electrical building. While installing new service feeders and equipment, the plant will be powered by two medium-voltage generators.
- Install a new 600-hp pump (#6), a flow control valve, and a drive.
- Install a new drive for the existing 1,000-hp pump #3. The existing pump's starter in the medium-voltage lineup will be removed and replaced with a contactor to feed a stand-alone drive. Power and control circuits will be rerouted to the new drive.
- Install a wireless pump-monitoring system on six pumps and a wireless receiver to provide monitoring-system input to the supervisory control and data acquisition (SCADA) system.
- Install power and control circuits for new hydrotanks, a compressor, and a flow-control valve. The existing ductbank will be rerouted to serve the new hydrotanks and flow-control valve.

- Install instrumentation at the new 600-hp pump and hydrotanks.
- Update various process instrumentation elements throughout the pump station.

Careful planning is required because much of the project is dependent upon long-lead items and coordination with other trades. The installation of the parallel service and new service feeders has to be done while the plant is powered by rental generators. The cost of the generator rental and fuel requires extremely careful coordination to limit the cost and inconvenience to plant operations.

The electrical contractor for the project employs over a hundred employees and specializes in industrial services. The company works on a variety of projects ranging from small utility district-lift stations to large wastewater treatment plants and water pump stations. This large range of project size and complexity has made it difficult to create a standard format for planning and scheduling projects, so planning has traditionally been based on the needs and requirements of the individual projects.

5.3 Best-Practice Implementation

The Designated Planner for this case study is a coordinator employed by the electrical contractor. The DP was trained in the best practice and provided with sample forms. The recommended best practice was customized to meet the project needs and preferences. The implemented best-practice procedure can be summarized as follows:

- Break activity down into Field Installation Work Packages (FIWP) collaboratively with the project manager, superintendent, and planner.
- Identify constraints and develop a tracking procedure. Constraint identification was done collaboratively with all members of the project team.
- Determine the FIWP sequences and incorporate them into a 3-week look-ahead schedule collaboratively with GC, other trades, and suppliers.
- Continually track and monitor constraint-removal status with the general contractor and other trades through regular progress meetings, on-site communication between foremen, phone calls, and e-mails.
- Release constraint-free FIWPs for field installation and document them in the weekly work plan.
- Institute daily field crew huddles to communicate the daily plan to crew members.
- Record daily progress and reasons for work delays through the use of daily reports.
- Record weekly progress and determine PPC.

To further illustrate how the best practice was implemented, the following section details various steps involved in planning and performing a particular activity, work scope #78, which involved the installation of service ductbank for parallel 4160V 1200A service. The initial planning and coordination for this work scope began at the pre-construction meeting. Due to the long lead-time status of the utility coordination and procurement of switchgear, representatives from the utility company and equipment manufacturer were present at the pre-construction meeting. This meeting enabled the electrical contractor and GC to formulate a plan for this work scope early in the project with input from the responsible parties. The look-ahead scheduling began with the definition of FIWPs, as described below.

1. Break activity down into FIWPs collaboratively with project team

Based on inputs from the EC project team, GC, utility company, and switchgear supplier, the work scope #78 was divided into 3 FIWPs: #78.01, 78.02, and 78.03, as summarized below.

- FIWP 78.01: Saw-cut and remove 1,400 sq. ft. of concrete at the service area. Concrete removal was required to facilitate installation of the underground ductbank, conduit stub-ups, and equipment pads. The planned duration was 3 days.

- FIWP 78.02: Excavate and install underground ductbank between the utility pad mount transformer and the utility terminal pole per utility company specifications. Pour the concrete encasement and backfill trench. The planned duration was 5 days.
- FIWP 78.03: Excavate and install the underground ductbank between the utility pad mount transformer, the medium voltage switchgear, and electrical manhole #1. Pour the concrete encasement and backfill trench. The planned duration was 5 days.

2. Identify constraints and formulate a plan for constraint removal

- Constraints for these FIWPs were determined internally within the EC project management team as well as through meetings with the general contractor and the project engineer.
- The constraints for this activity were utility company coordination, approved submittal data for the service switchgear, RFI response, and shop drawings.
- After the constraints were identified, the project management team determined a plan for the resolution of each constraint. Promise dates were assigned to each constraint based on feedback from the utility company and the equipment supplier.

3. Determine the FIWP sequence and incorporate them in the 3-week look-ahead schedule

- The FIWP sequence was determined collaboratively with the GC, other trades and suppliers as follows: 78.01, 78.03, and 78.02 performed sequentially.
- These FIWPs were then transferred to the 3-week LAS, as shown in **Figure 28.**

Figure 28. Sample 3-week LAS

LOOK-AHEAD SCHEDULE

Project Information	TITLE AND LOCATION	CONTRACT NUMBER	PLAN FOR WEEK BEGINNING:	PLANNED BY:
	WWP PUMP STATION IMPROVEMENTS	4251066	5/27/13	ERIC T.

Percent Plan Complete (PPC)	
Total Tasks	1
Completed Tasks	0
Percent Complete	0%

Note: Cells with red text are automatically calculated. Shading is applied to plan and constraints cells with content.

Schedule Activity No.	WORK LOCATION AND DESCRIPTION	PERSON RESPONSIBLE	Weekly Work Plan Mon 5/27	Tue 5/28	Ved 5/29	Thu 5/30	Fri 5/31	Sat 6/2	Task Done? Yes/No	Look-Ahead Plan VEEK BEGINNING: 6/3	6/10	6/17	Tasks in Look-Ahead	Constraints: Work Not Ready	Other Trades	Drawings	Equipment	Overcrowding	Materials	Work Changes	Other
78	SERVICE, SAWCUT PAVING	GC		x	x	x			YES												
78	SERVICE, DB TO EMH #1	GC								x			X			X					
78	SERVICE, DB TO TERMINAL POLE	GC									x		X								
90	ELECT BLDG, PMS CONDUIT & WIRE											X	X								x

4. Continually track and monitor constraint-removal status

The constraint tracking and removal process for this work scope is described below. To facilitate constraint management, a constraint log was used, as shown in **Figure 29.**

- The utility coordination constraint removal began with a site meeting with the electrical contractor, general contractor, engineer and the utility company. The meeting was held to determine the location of the utility terminal pole and the pad mount transformer, and to discuss the process for obtaining the necessary easement. After the initial meeting, the utility company worked to develop their design package, which contains information on the construction specs for the service ductbank and easement documents. This constraint required constant follow-up to ensure that the construction specs were reviewed by the engineer, and the owner signed the easement documents. After the utility package was reviewed, signed, and returned to the utility company, this constraint was considered resolved.
- There were some delays in a submittal response. After receiving the submittal, we reviewed it for accuracy and transmitted it to the GC to be forwarded to the engineer. An additional question required a proposed modification and RFI. The RFI became a new constraint for the service area ductbank because the response would potentially change the service area layout and number of conduits in one section of the ductbank.
- After receipt of the RFI response and design package drawings/specs, and submittal drawings, shop drawings were prepared for the service area ductbank and conduit stub-ups.

Figure 29. Sample constraint log

CONSTRAINT LOG

PROJECT NUMBER	PROJECT NAME	UPDATED BY:	UPDATE DATE
4251066	WWP PUMP STATION IMPROVEMENTS	ERIC T.	6/17/2013

SCHEDULE ACTIVITY NO.	WORK LOCATION AND DESCRIPTION	CONSTRAINT DESCRIPTION	COMPANY RESP.	PERSON RESP.	PROMISE DATE	DATE COMPLETE	NOTES
24	pump building, compresor	compressor submittal data	T&C		6/19/2013	6/18/2013	Hard copies to be mailed by Anne
24	pump building, compresor	hydrotank air compressor	T&C				
36	hydrotank, fcv	hydrotank flow control valve submittal data	T&C		6/19/2013	6/18/2013	Hard copies to be mailed by Anne
62	pump building, pump 6 commissioning	Schedule pump 6 commissioning with Eaton		ET	7/24/2013		Confirm with Joe R.
63	pump building, pump 6	pump 6 process piping	T&C		6/12/2013	6/12/2013	
63	pump building, pump 6	pump 6 FCV hydraulic actuator/local panel submittal data	T&C		6/19/2013	6/18/2013	Hard copies to be mailed by Anne
63	electrical building, pump 6	pump 6 600hp RVSS delivery		MG, ET	6/21/2013		Coordinate delivery with Joe R.
63	pump building, pump 6	pump 6 press/diff press switches		MG, ET	6/26/2013		Coordinate delivery with Duong
63	pump building, pump 6	pump 6 FCV local control panel	T&C		7/1/2013		
63	pump building, pump 6	receive and install pump 6	T&C		7/15/2013		
67	electrical building, pump 3	pump 3 1000hp VFD delivery		MG, ET	10/10/2013		
67	pump building, pump 3	Delivery of new pump 3	T&C				Need new date from TR
68	pump building, pump 3 commissioning	Schedule pump 3 commissioning with Eaton		ET			Schedule with Joe R.
76	electrical building p2 & p4	pump 2 and pump 4 replacement RVSS submittal data		ET	7/1/2013		Doty promises before 7/2/13 progress mtg.
76	electrical building p2 & p4	receive p2 & p4 RVSS		ET			promise date after approved submittal returned to Eaton
78	service area ductbank	centerpoint term & conditions package		ET	3/1/2013	4/12/2015	
78	service area ductbank	MVA drawing from Culter Hammer		ET	4/1/2013	4/24/2013	
78	service area ductbank	RFI, connection between old and new MVA	Aecom		5/6/2013	5/6/2013	no bussed connection, connect via wireway per RFI drawing
78	service area ductbank	MVA/service area shop drawing		MG	5/17/2013	5/20/2013	
81	Service area, Service MVA commissioning	Schedule service MVA commissioning with Eaton		ET			Schedule with Joe R.
83	distribution	5kv cable		ET			need to put out for quote
90	pump building, pump monitoring system	PMS wireless receiver	T&C		6/17/2013	6/17/2013	
90	pump building, pump monitoring system	PMS submittal data	T&C		6/19/2013	6/18/2013	Hard copies to be mailed by Anne
90	temp power	(2) 2mva generator rental	T&C				verify date with Tom M.
90	pump building, pump monitoring system	PMS pump sensors installed	P&P				
90	pump building, pump monitoring system	PMS terminal points wired out by BLTI	BLTI				

5. **Release constraint-free FIWPs for field installation and document them in the weekly work plan**
   - After the FIWPs were created by the DP, they were transferred to the superintendent for final review and release. The superintendent gave the FIWP to the foreman 5 days before the scheduled start of the work. During this hand off, the foreman was able to review the FIWP and commit to the scope, schedule, and sequence of the work package. See the documented sample and released FIWP in Appendix B.
   - Because the foreman had a role in the development of the FIWP, there was no issue with gaining his buy in.
   - It should also be noted that there was one backup FIWP ready for field installation. On the FIWP master list, "air compressor conduit and conductors" was listed as ready and "floating." This would have been installed if another FIWP was delayed. As the project progresses and more work is opened up, there will be additional backup FIWPs to deal with uncertainty in performing other FIWPs.
6. **Institute daily field crew huddles to communicate daily plan to crew members**
7. **Monitor daily field reports to identify causes of work delays**
   - Daily report forms were sent to the field on a daily basis during completion of this schedule activity. The forms were filled out and reports were occasionally verbally received by the DP.
8. **Record weekly progress and determine PPC**
   - FIWPs 78.01, 78.02, and 78.03 were all completed as planned during the week, which contributed to a 100% PPC.

5.4 Observations

The following observations were reported by the DP for the project as well as for other project participants:

Collaborative Planning

- Collaborative-constraint identification resulted in a clearly developed list of constraints for upcoming work and allowed early identification of all long-lead items. The DP felt that creating a master list of constraints early in the project allowed for time to develop a plan for resolving constraints.
- Input from the general contractor and other trades identified several sequencing errors in the master schedule. This input from other parties came from a combination of conversations at progress meetings, phone conversations, and emails.
- Obviously, clear communication with other trades was a positive development. Collaborative planning as a part of the process, whether via sticky note sessions or phone calls, reduced the likelihood of miscommunication and resultant delays. During the short duration of the case study, the DP felt that making an effort to involve applicable parties in the process led to an increased awareness of upcoming work items, schedules, and limitations.

Work Packaging

- Developing defined work packages allowed large portions of the work to be broken down into manageable pieces. The DP felt that more detailed work packaging (i.e., FIWPs) made every aspect of the project more manageable.
- We received positive feedback on work packaging from the crew members. The DP observed that a crew's motivation level increased with the knowledge that they had the necessary resources for success. Although the length of the case study did not enable the crew members to see a large number of work packages, they did see that there was a system and that the end result of that system made them more productive and successful.

Constraint Identification

- The constraint identification and tracking process created a feeling of confidence that major constraints had been identified and a clearly defined plan for resolution existed.
- A formal procedure of constraint tracking that tied the constraints to specific work packages allowed the project management team to get a better feel for the timeline of constraint resolution. Although it is beneficial, if you know that a constraint needs to be resolved, it is even better if you have a specific due date for the constraint. This allowed for effective time management and prioritization.

Multi-Week and Weekly Scheduling

- Incorporating FIWPs worked wonderfully in that they enabled all project team members to have a clear picture of upcoming work. Listing items down on the LAS forced the crews to take a second look at the work packages to verify that they were correct and constraint free.
- The field crew leaders were encouraged by the clear definition of tasks that resulted from the work packages and weekly plan. A foreman commented that he liked knowing what was expected for the week and knowing ahead of time what work was coming up.

Daily Plan and Daily Huddle

- The field crew members were not very receptive to the daily huddle and checklist. Part of their daily process already included an informal huddle to discuss the upcoming day's goals, safety, etc. The consensus was that there was not a need to change this process. The checklists were seen as an inconvenience and getting them filled out was like pulling teeth! The main item from the checklist was identification of work delays. The foremen already did an excellent job of conveying this information verbally to the project superintendent. Obviously, it is better to have a paper trail for project control but for now we will have to be content without it.
- The contractor did not develop a formal sheet or procedure to convey the daily plan to the field crews. The daily plan was communicated to the foreman via verbal conversation. At that point in the project, we decided that the FIWPs were sufficient to convey the daily requirements to the field.

Performance Measurement

- FIWPs during the case study period achieved 100% PPC. The DP felt that work packaging and constraint tracking/resolution played a part in completing each activity as planned. Common reasons for delays were not experienced during the installation of this work. However, it was not uncommon to experience minor delays while installing similar work under the past field scheduling practice.

Participants' Opinions

- The feedback received from crew foremen and lead-men was generally positive. They were encouraged by their part in the collaborative planning and work package development. Oftentimes, their expertise is overlooked during the planning and they appreciated having an opportunity to participate in this phase.
- The consensus from those involved on the project management side was that the process was beneficial but the amount of paperwork was probably unnecessary. Clearly, there was a need for a paper trail with respect to constraint tracking and the look-ahead schedule, but there was some kick back on the checklists and daily reports.
- The participants' opinion was that the best practice, as designed, was intended for medium-to-large projects. As a company, they would never be able to implement the best practice "as-is" on all of our projects, but could

incorporate the key features of work packaging and constraint tracking into a standard project management scheme.

Limitations

The best-practice elements that were not implemented due to the unique characteristics of the project or the reactions of field personnel to the practice included the sticky note session, formal daily reporting, and performance improvement.

- The sticky note approach to collaborative planning was not used because of the preference of the GC involved in this project. Collaborative planning was done effectively through direct conversations during coordination meetings with the GC, other trades, and the EC's personnel.
- Detailed daily reporting was not implemented consistently by field personnel.
- PPC has been recorded on the project, however, the FIWPs generally are about one week so relatively few data points have been collected so far in this case study. PPC analysis and, if appropriate, root cause analysis, will be included in the future.

5.5 Lessons Learned

The main lesson learned from the case study is that there are great scheduling benefits with a clearly defined and formal planning scheme. Although some elements of the best practice were not implemented and the case study has only had a short duration to date, the benefits were clearly seen.

Management preferences, resistance from field personnel, and the short time period prohibited us from instituting every aspect of the best practice. The primary features of the recommended best practice were employed, including the collaborative planning principle, field-oriented work packaging, and multi-week, weekly, and daily planning. In the opinion of the field personnel, the best practice improved planning effectiveness, employee motivation, teamwork, and communication.

Resistance to sticky note sessions and daily reporting was not surprising. People often resist changes or work in which they see no immediate benefit. The project team felt that collaborative conversation among all contractors on look-ahead schedules during the progress meeting was adequate for the particular project on hand. Because the sticky note method was a suggestion rather than a requirement of the best practice, this was not a significant concern. Daily reporting may have been unnecessary because the crew was very experienced in the type of work performed and the specific work site of this project. Daily tracking may be more applicable on less routine work.

A significant conclusion from the field study is that immediate complete implementation of the best practice may be impractical because this amount of change could be overwhelming. A limited introduction of the most important features could demonstrate the benefits of the method and make implementation of the remaining parts more acceptable. Complete implementation might also be unnecessary depending on the nature of the project. Simple or routine projects do not require the same degree of planning as more complex ones. A reduced form of the best practice can be effective if the primary principles of collaborative planning, field-oriented work packaging, and constraint identification and removal are followed.

Conclusions

6.1 Introduction

The importance of adequate planning is well known. A well-organized look-ahead scheduling process can significantly affect project efficiency. The best practice provided here is based on proven methods. It can form a basis for an effective look-ahead scheduling method that electrical contractors can adapt to create an effective LAS program. The approach is generic and can be adapted to the specific needs of a particular firm. It is scalable to project and company size as indicated in the field pilot study.

6.2 Best Practice Summary

This report provides a formal look-ahead scheduling best-practice model, as well as research reports documenting the theoretical background of the model and implementation resources for its practical use. The research reports discuss current look-ahead scheduling practices and issues in electrical construction, and best practices identified in other sectors and their effectiveness and applicability. This information formed the basis for a best practice adapted to the specific needs of electrical contractors based on a combination of elements from proven look-ahead scheduling methods. It consists of 4 steps:

- A collaboratively planned multi-week schedule based on work packages tailored to field operations.
- A weekly work plan including only work packages made fully ready and committed to by the foreman.
- A daily plan providing clear assignments to each worker and serving as the basis for record keeping for process improvement.
- Tracking schedule performance and root cause analysis to eliminate recurring delays and improve schedule reliability.

The model is described in detail in the body of this report. An Implementation Guide that presents the model on a practical and accessible level is included as Appendix C. The Implementation Guide consists of:

- Field implementation procedure and guidelines
- Template, checklist, and evaluation methods associated with the proposed model.

Numerous studies have shown that increased attention to planning can improve project performance. Our survey and literature review showed that portions of existing best practices are often not used in the field. Applying the principles and methods of the recommended best practice can potentially increase communication between the EC and other stakeholders, improve schedule performance, and reduce cost.

6.3 Field Case Study

Positive results were reported from the case study despite its partial application on a project that was already in progress. Management and field personnel of the EC felt that planning effectiveness, employee motivation, teamwork, and communication were improved. Resistance to some of the best-practice procedures indicated that introduction of the entire best practice may be overwhelming. Implementation of the main features can demonstrate the value of the best practice and may lead to acceptance of the complete practice.

The success of the case study showed that the best practice could improve planning effectiveness. These results are encouraging and will be further investigated in future studies.

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Appendix A
FIWP Checklist

Project Number: ____________________

Project Name: ____________________

Location: ____________________

Project Manager: ____________________

Designated Planner: ____________________

Start Date: ____________________

FIWP CHECKLIST		
	NO.	SUB-ACTIVITIES
❒	1	Work is always packaged in Field Installation Work Packages (FIWP).
❒	2	The FIWP identifies the work to be completed by the team, including technical data, drawings and specifications.
❒	3	The FIWP identifies how the general sequence of the work and the labor necessary to complete the work
❒	4	The FIWP identifies all required materials necessary to complete the work.
❒	5	The FIWP identifies all required specialty tools, scaffolding and construction equipment necessary to complete the work.
❒	6	The FIWP identifies all relevant special conditions.
❒	7	The FIWP includes/or references all quality control, safety, and environmental, and other regulatory requirements.
❒	8	The FIWP identifies all prerequisites.
❒	9	FIWP are assembled and issued at least 1 week prior to release of the work.
❒	10	The Dedicated Planner completes FIWP and signs-off as ready before FIWP is released to crew.
❒	11	A sufficient backlog of FIWP's exists to replace scheduled FIWP's that become delayed.
❒	12	Experienced construction personnel approve the schedule, scope, sequence & timing of the FIWP.
❒	13	The construction superintendent or his or her designate has final approval of the FIWP.
❒	14	Tracking levels and coordination procedures are established for the planners, general foremen, and construction superintendent to effectively coordinate and supervise the construction phase.
❒	15	FIWP progress is tracked using PPC, plotted on run charts, and analyzed to identify and correct inefficient processes.

Appendix B

Example FIWP Document

FIELD INSTALLATION WORK PACKAGE

Project Number:	4151066
Project Name:	Booster Pump Station Improvements
FIWP Number:	FIWP4151066.019
Area/System/SubSystem	Distribution

Prepared by:	Matt Planner
Date:	03/17/2013
Issued by:	Gary Project Manager
Date:	03/22/2013
Released by:	Bob Superintendent
Date:	03/29/2013
Assigned to:	Alberto Foreman
Date:	04/08/2013
Completed by:	Alberto Foreman
Date:	04/22/2013

Scope:	Install medium voltage feeder (SF-04,SF-05,SF-06) between service area switchgear and MVA lineup in pump building. Install cable supports and fireproofing in manholes. Install medium voltage terminations. Perform Hi-pot cable test.

Deliverables:	(3) - 1087' runs of 3 phase medium voltage cable (3x750 KCMIL + 1/0 G) complete with terminations and testing.
Activities:	1) Prep (3) manholes with cable supports and pull mandrel through conduits. 2) Secure tugger on pump building inside South wall structural steel behind MVA lineup. Prep wire on pulling trailer at service area. Pay special attention to wire phasing. 3) Install pulling sheaves and rope. 4) Pull SF-04 cables. Use adequate amount of pulling lube to reduce stress on cables. Leave enough cable in each manhole to make 2 loops around manhole per spec. section 16125. 5) Repeat steps for SF-05 and SF-06. 6) Secure cables to supports in manholes and install fireproofing tape to individual phase conductors. Clean manholes. 7) Clean and prep cable ends stress cone installation. Install 3M cold shrink stress cone termination kits to cable ends. 8) Perform Hi-pot testing on cables. Ensure owner/engineering rep. is present during testing. Record results on testing form and return to project supt. 9) Terminate cables.
Equipment:	1) Prep (3) manholes with cable supports and pull mandrel through conduits. 2) Secure tugger on pump building inside South wall structural steel behind MVA lineup. Prep wire on pulling trailer at service area. Pay special attention to wire phasing. 3) Install pulling sheaves and rope. 4) Pull SF-04 cables. Use adequate amount of pulling lube to reduce stress on cables. Leave enough cable in each manhole to make 2 loops around manhole per spec. section 16125 5) Repeat steps for SF-05 and SF-06.
Tools:	(6)-Wire pulling sheaves (1)-Hydraulic crimper
Materials:	(10)-5 gallon buckets, Yellow 77 wire lube (9)-1087' spools of 750 KCMIL 5KV cable (3)-1087' spools of 1/0 THHN (24)-cable support vertical rails, galvanized (72)-Horizontal cable supports, galvanized (72)-3/8" 316 SS concrete anchors, nuts and washers (144)-3M fireproofing tape rolls (18)-3M cold shrink stress cone termination, 750 KCMIL (18)-750 KCMIL compression lug w/ (2) 3/8" hole (6)-1/0 AWG compression lug w/ (1) 1/4" hole (8)-Brown, orange, yellow and green phase tape

Labor:	(5)-Electrician (7)-Electricians helper
Drawings:	E-1, Site plan E-24, Manhole detail E-28, Conduit schedule Switchgear and MVA lineup factory drawings
Work Instructions:	No work will be performed by other trades in this area. Be aware of cable phasing during setup of each pull. Take all precautions to ensure wire is not damaged during pull. Only qualified Journeymen may install stress cone terminations.
Special Conditions:	Apply fireproofing tape to individual conductors in manholes. Refer to E-24 for detail
Quality Control:	Follow manufacturer's instructions when installing stress cone terminations.

Appendix C
Implementation Guide

Practice Overview

The Implementation Guide is a set of instructions for field implementation of the best practice. It describes the basic procedure of look-ahead scheduling, which includes the following elements. The logic relationship is illustrated in the flow chart on page 27. More detailed explanation and basis for the method can be found in preceding sections of this report.

1. **Multi-week Look-ahead:** A 2-4 week look-ahead schedule (LAS) planned with crew input; define Field Installation Work Packages (short-term work plans); make FIWPs ready; release constraint-free work for the coming week; define backup plan
2. **Weekly Plan:** foremen verify resources and make commitment
3. **Daily Plan:** crew confirm logistics and site conditions for efficient, safe, and quality work performance
4. **Measure & Improve:** measure scheduling performance weekly and identify delay causes for continuous improvement

The following acronyms are used in this guide:

- DP – Designated Planner
- EC – Electrical Contractor
- FIWP – Field Installation Work Package
- GC – General contractor
- LAS – Look-Ahead Schedule
- PPC – Percent Plan Complete

The person who holds the primary responsibility for coordinating the look-ahead scheduling procedure is called the Designated Planner (DP). The DP may be the project manager, superintendent, or another staff member. This choice will depend on the size and complexity of the project. The person doing so must have an enough experience in the trade and as a supervisor in order to have the necessary scheduling and construction knowledge. A reasonable guideline is a minimum of 5 years trade experience and 3 years as a supervisor.

A look-ahead schedule typically ranges from 2 to 6 weeks. This may be specified by contract but otherwise will depend upon the nature of the job and agreement between the EC and the GC. The important consideration is for it to be long enough for all needed items to be identified and made ready before work is assigned. The first LAS on the project is developed by the project team prior to the starting date of the project. Once it is done, it is updated weekly based on crew agreement and information from the weekly contractor coordination meetings.

Step 1: Multi-week Look-Ahead

The recommended procedure is shown in the flow chart on page 32.

1. Conduct the first collaborative look-ahead scheduling workshop.

If the initial look-ahead schedule has not been prepared during the pre-construction meeting, conduct the first collaborative (or sticky note) look-ahead scheduling workshop, preferably 2–3 weeks prior to the start date of the project, following the steps below.

1. Identify the LAS work scope, work method, and performing crews for the look-ahead window (e.g. 2–6 weeks)

The DP reviews the project master schedule and identifies work scope entering the look-ahead window to include in the look-ahead plan. The DP determines the general work method and identifies performing crews and their foremen with input from the project manager and superintendent. The work method design should consider the following aspects:

a. The latest design of work
b. Construction method specified in the master schedule and alternative, if any
c. Availability of crew and major equipment
d. Expected experience and skills of crews and foremen
e. Applicable craft traditions or union work rules
f. Expected major constraints; e.g., site access, logistics, and safety
g. Expected performance of major pre-requisite work; e.g., permitting and other contractors' work

2. Break down work into FIWPs and identify critical constraints with consultation with responsible crew foremen

The FIWP is a crew-level work package that includes work that an individual crew can complete in a few days or within a week. The DP should consult the superintendent and the performing crew foremen in defining FIWP work content. Attention should be given to anticipated critical constraints, with special emphasis on the interfaces with other trades. At this step, as a minimum, the following should be summarized for each FIWP:

a. Work scope and quantity
b. Performing crew and foreman
c. Estimated duration
d. Work method and sequenced operation steps
e. A list of critical constraints, especially coordination requirements with other contractors

3. Conduct the "sticky note" session 2—3 weeks prior to the start date of the project.

(As described here, the "sticky note" session includes participation of the GC and other trade contractors. The GC or other trade contractors may not be willing to hold or participate in such a meeting. In this case, the EC should apply as many of the principles as possible internally and with the GC's planning practice.)

The sticky note session requires inputs and coordination among all project team members, including GC, EC, and trade contractors, who are typically involved in regular project coordination meetings. On a large project, material suppliers and other contributing parties may also be involved in this session. For the EC, at a minimum, the project manager and superintendent should participate in this session.

a. Each contractor is supplied with unique color cards or sticky notes.

b. All contractors break down their work in a way that they feel is necessary to achieve control of their work. For the EC, this is the FIWPs identified in the previous step.

c. The contractors list their activities/FIWPs on individual note cards. Each card contains, at a minimum, the name of the activity and its duration. The predecessors and successors should also be recorded, as well as any critical constraints impacting field performance.

d. The contractors forward to post their card/activity on a large white board or a wall.

e. Team members then jointly identify potential conflicts and negotiate a solution to ensure efficient work performance.

f. The contact person is determined for coordination issues.

g. The agreed-upon look-ahead schedule is recorded and signed.

h. The finalized look-ahead schedule is shared with all contractors.

The finalized LAS may be updated and changed, if necessary, during subsequent weekly contractor coordination meetings with team agreement.

2. Document the EC's look-ahead schedule including all FIWPs and their constraints

A sample LAS schedule that combines a six week look-ahead and a weekly plan is shown on page 49. It allows documenting FIWPs, their timing, and constraints. It also includes items for performance measurement that can be used later, e.g., progress and delay causes. Separate spreadsheets for the weekly and look-ahead sections can be created if preferred.

The following items should be recorded for each FIWP. This information may also be duplicated in a separate work log to allow for more detailed documentation, especially of the constraints and their status.

a. FIWP ID and name

b. Responsible foreman

c. FIWP timing and duration

d. List of all constraints for each FIWP in addition to critical constraints identified prior to the sticky note session, e.g. material supply and drawing availability.

An example constraint log is shown on page 50.

3. Assign responsibility and expedite constraints

The DP maintains a list of constraints, including the deadline for their removal. A constraint log as shown above can be used to facilitate status tracking of constraints. Personnel responsible for each constraint are expected to satisfy these constraints in a timely manner. If this involves other contractors, the following should be done to expedite constraints controlled by other contractors:

- Update constraint status and expedite during weekly contractor coordination meeting.
- DP verifies constraint status by site visits, if necessary.

4. Assemble and release constraint-free FIWPs one week prior to field execution

An FIWP is ready to be released to the responsible crew foreman when (1) it is constraint-free or is expected to be free within one week, and (2) it is scheduled for execution in one week. It is important that the process include a verified final OK in order to insure that all constraints have been identified and everything is ready before work begins.

Before releasing an FIWP to the responsible foreman, all information needed for field execution should have been documented and assembled together for each FIWP. The content of the FIWP may vary with job complexity. Simple or routine jobs may require less information but all necessary items should be identified. A sample FIWP is shown in Appendix B.

The person authorizing the release of FIWPs may vary depending on the organization. Typically, this will be the project superintendent. The superintendent or other authorized individual will release the FIWPs that are consistent with the LAS and certified by the DP to be free of constraints to the foreman in the week prior to execution.

The released FIWPs become the basis for the weekly work plan discussed next.

Step 2: Weekly Plan

The weekly planning procedure is primarily conducted in the weekly meeting, as shown on page 38.

1. The DP drafts the weekly plan based on ready FIWPs for the upcoming week identified in the LAS.

The weekly plan form should include a list of FIWPs, the person responsible for each FIWP, expected start and finish dates, statuses of constraints, and outstanding issues, if any.

2. Responsible foremen verify FIWP readiness.

The weekly plan draft is presented to responsible foremen. Foremen will determine whether FIWPs are ready to perform by verifying the status of all constraints. If any constraint still exists but it can be reasonably removed within one week before execution, the DP will need to act with the responsible party to remove the outstanding constraints. Otherwise, FIWPs that are not ready will be delayed, removed from the current weekly plan, and recorded for the next LAS update. The root cause of this delay should be investigated to prevent future occurrence.

3. Foremen make commitment and sign off weekly plan

If all constraints have been removed, the foremen will make a commitment and sign off on the weekly plan. The weekly verification and commitment should occur during the weekly meeting. The significant benefit is the additional motivation resulting from a public commitment to the weekly plan.

Step 3: Daily Plan

The daily plan should be derived from the weekly work plan and prepared by the DP, and foremen should be responsible for communicating the daily plan to their crew members.

1. The DP communicates the daily plan to the responsible foremen based on their plan to which they have committed. A sample daily plan and report form is shown below.

2. Foreman conducts the daily huddle.

Before the workday starts, the foreman will gather his or her team to deliver key information to align the crew members for the day. The foreman, with input from crew members, should identify each task to be accomplished and the method that will be used. Each crew member should have a clear understanding of his or her assignments. In addition, the team can review performance from the previous day and find ways to improve performance. A checklist for the Daily Huddle is shown on page 41.

3. Foreman tracks daily performance

Tracking daily performance and identifying sources of problems are important factors for improving job performance. Foremen should keep a daily record of work performance that includes a list of reasons for variance and additional unplanned work. Forms similar to the sample Daily Report and Plan form on page 40 and the Daily Huddle Checklist on page 41 can be used for this purpose.

Step 4: Measure and Improve

To measure the quality and reliability of look-ahead scheduling, Percent Plan Complete (PPC) is used to verify the degree to which work is completed as planned.

1. At the end of each week, the DP records PPC based on FIWP completion status and delay reasons, if any. PPC is calculated as follows. The more work has been done according to an LAS (i.e. a higher PPC value), the better the reliability of that LAS has been.

$$\textit{Percent Plan Complete (PPC)} = \frac{\textit{(Number of completed FIWPs)}}{\textit{(Total number of planned FIWPs for the week)}}$$

- The status of FIWPs planned for the week is either completed or not completed. Only FIWPs that are 100% complete should be used for PPC calculation.
- FIWPs or activities that are performed but were not planned should not be counted toward PPC score.

The reasons for FIWP delays should be noted for later root-cause analysis.

2. Plot and analyze PPC and root causes of delays

PPC should be analyzed in run charts similar to the sample chart shown on page 42, which shows the trend of PPC over the past reporting periods.

Run charts are a time ordered plot of the measurements, in this case PPC. The run chart can be constructed as follows:

1. Ideally, there should be a minimum of 15 data points.
2. Draw a horizontal line (the x-axis), and label it with the unit of time (usually weeks).
3. Draw a vertical line (the y-axis), and scale it to cover the current PPC data, plus sufficient room to accommodate future data points.
4. Plot the weekly PPC data on the graph in time order and join adjacent points with a solid line.
5. Calculate the mean or median of the data (the centerline) and draw this on the graph.

Sources of variation include people, methods, materials, measurement, and environment. Patterns include shifts, trends, cyclical patterns, anomalously low or high points, runs (a group of points above or below the line), and random points above and below the line.

Judgment must be exercised to investigate variations that might be significant while not being distracted by variations that are too small to be meaningful. An abrupt shift may be the result of a change in the type of work or a new crew. A gradual upward trend may indicate improvement due to learning or the recent introduction of an improvement method.

When a run chart confirms an unsatisfactory PPC or a downward trend, root causes should be analyzed. The reasons collected during weekly PPC measurement should be tabulated, and they can be analyzed to determine the root causes for low PPC values or unreliable schedules. These causes should be categorized in meaningful groups—e.g. drawings issues and material delay—to facilitate identifying top root causes and solutions. A Pareto chart is recommended for this purpose. A sample Pareto chart is shown on page 44. It ranks the causes in terms of their frequency. Corrective actions should be determined and implemented to reduce future occurrences of top causes.

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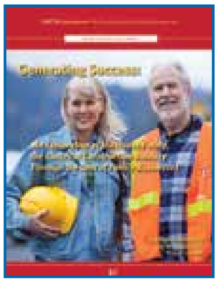

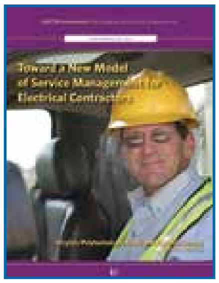

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