LOOK-AHEAD SCHEDULING FOR ELECTRICAL CONTRACTORS

A Thesis

Presented to

the Faculty of the Department of Construction Management

University of Houston

In Partial Fulfillment

of the Requirements for the Degree

Master of Science in Construction Management

By

Earl J. Ritchie, Jr.

May, 2013

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Earl J. Ritchie, Jr.

APPROVED:

Lingguang Song, PhD.

Neil N. Eldin, PhD. PE
Director, Construction Management

Hassan Moghaddam, PhD. PE

Raymond E. Cline, Jr., PhD
Associate Dean for Research and
Graduate Studies, College of Technology

DEDICATION

This thesis is dedicated to my wife, Julia W. Ritchie, whose continued love and support has been the delight of my life.

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ABSTRACT

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 delay 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. This study designed a best practice tailored to electrical contracting by combining elements of these and other project management methods into an effective field-friendly best practice. The method was designed on the basis of literature review and survey of and interviews with electrical contractors.

The best practice is based on proven methods but remains untested in actual practice. Field studies are necessary to validate the method.

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LIST OF ABBREVIATIONS

AIA	The American Institute of Architects
CCPM	Critical Chain Project Management
CII	Construction Industry Institute
CMAR	Construction Manager at Risk
COAA	Construction Owners Association of Alberta
DB	Design-build
DP	Designated Planner
FIWP	Field Installation Work Package
GC	General Contractor
EC	Electrical Contractor
IPD	Integrated Project Delivery
IPM	Initial Planning Meeting
LAS	Look-Ahead Schedule
LEAN	Lean Construction
LCI	Lean Construction Institute
NECA	National Electrical Contractors Association
PPC	Percent Plan Complete
RFI	Request for Information
WWP	Weekly Work Plan

CHAPTER 1. INTRODUCTION

1.1 Introduction

The coordination of large construction projects is a complex task. Due to the increasing interconnection between components and to the specialization of contractors, a large number of participants and their work must be organized. Scheduling is the most important means by which project planners control the entire process (Bielefield 2008). The large number of details and inability to foresee all circumstances that will occur in the course of a project require that a series of plans of increasing detail be developed, beginning with a design concept and progressing through short term schedules that coordinate the work on a weekly or daily basis. It is those short term schedules, variously called look-ahead, short interval schedules, short-range plans, roll-up schedules, window schedules, or two-week schedules (Hinze 2004), that are the subject of this thesis.

Look-ahead scheduling is not new. Processes to insure that everything is in place to begin work have historically been practiced both formally and informally and are described, typically briefly, in popular construction management textbooks. 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 short term planning. 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 best applicable to the electrical contractor. It will also be useful for other trade contractors.

1.2 Statement of the Problem

Look-ahead schedules are detailed plans that facilitate organizing activities at the crew level (Hinze 2004). Typically, they are for periods of one to three weeks and provide means of coordinating such resources as time, materials, equipment, workers, and information. As is mentioned above, work packaging and short-term scheduling are not new. The basic elements of identifying the work required, resources necessary, 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 decompose the work to a level that describes detailed planning of individual crew assignments. Historically, planning at this level 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. Per comments in numerous articles (e.g., Senior 1996, De Lima 2011), it is reasonably successful, although performance of individual foremen varies. Productivity loss is often the result of inadequate information or late notice from the general contractor, which may also remain problems in the more formal methods mentioned above. This informal scheduling is the baseline against which productivity improvements resulting from more formal techniques are measured.

Numerous studies report that craft workers spend less than 50% of their time on the job in direct work (CII 2009, Slootman 2007). The reasons for this are varied. Thomas and Oloufa (2008) identified the following 10 categories as the most significant causes of labor inefficiency:

- Congestion
- Out-of-sequence work
- Adverse weather
- Inadequate supervision
- Work performed while the facility is in operation
- Lack of information
- Lack of equipment
- Lack of tools
- Lack of materials
- Rework

Six of these – congestion, out-of-sequence-work, and lack of information, equipment, tools, or materials – can be the result of failures in planning. Despite the publication of numerous recommended construction planning methods, labor productivity has remained stagnant and has declined relative to other industries (Teicholz 2013). 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 character. Its speedy and economical performance requires experienced selection, purchase and delivery of the right kinds of electrical apparatus, appliances, equipment and materials, including their correct assembly and proper installation (NECA 2011).

Newly proposed methods of look-ahead scheduling, such as Workface Planning (WFP) (COAA 2011), Enhanced Work Packaging (EWP) (CII 2011), and Last Planner (Ballard 1994) aim to foster more efficient accomplishment of the work by addressing crew-level planning. By necessity, they have elements in common with each other and with historical planning methods, although they vary in terminology, mechanics of the procedure and, in some cases, the time horizon. With limited exceptions, these methods have not been applied specifically to electrical contracting.

1.3 Significance of the Problem

Although electrical contractors are typically involved in pre-construction planning to coordinate with other trades, the resulting 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 (Song and Liang 2011). 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. Studies conducted in other construction sectors have proved that detailed crew-level planning effort will ensure the release and execution of reliable and constraint-free work packages, and further leads to improved productivity and predictable performance (e.g. Ballard 2000a; Slootman 2007).

1.4 Objectives of the Study

The objectives of this study can be summarized as follows:

1. To identify current look-ahead scheduling practices of electrical contractors.
2. To identify the most effective look-ahead scheduling measures applicable to electrical contractors and other trade contractors.
3. To combine those measures into a recommended best practice that will increase job productivity.
4. To recommend areas for future research.

1.5 Methodology

This research was funded in part by a grant from ELECTRI International. Design and analysis of the survey and best practice design were done by a research team at the University of Houston. The research was done in five stages:

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

The literature review focused on identifying challenges unique to electrical contractors (EC's) and components of proven effective scheduling methods that could be adapted to form a successful best practice look-ahead method specifically designed for EC's. 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, EC's opinions of what their practices should be, and issues that affect their schedule performance. This information was used to identify areas where current practice is working well and areas that 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. EC's 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 understanding of current practices.

The best practice is the product of the research, incorporating the results of the steps above. Each of the five stages of the study is described more fully below.

CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

The literature on project planning and scheduling is extensive. Over 1000 sources were reviewed. These included books, peer reviewed papers, trade journal articles, product marketing literature, construction firm websites, owners' websites, trade organization websites, masters theses, PhD. dissertations, and government publications. Only a small fraction of the sources specifically addressed electric 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, not directly pertinent to the best practice design, but is necessary to place planning methods in proper context and contribute to a practical design.

The literature review 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 for electrical contractors. It has focused on key elements of 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. The descriptions that follow attempt to capture the most commonly accepted versions of the respective methods.

Also briefly discussed are several general project management methods, a few of which incorporate look-ahead scheduling in enough detail to potentially be useful in our study. 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 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 above. This classification is not comprehensive; training, absenteeism, and worker qualification are examples of other factors. Dai, et al. (2009) identified 83 factors at the craft worker level which he classified in 10 groups called latent factors. Dai, et al.'s latent factors overlap Thomas and Oloufa's classification but are not identical. Other causes occur at the owner, architect, or construction manager level 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. A discussion of factors significant to electrical contracting follows.

2.2.1 Uncertainty

Electrical contractors, along with other trade contractors, face numerous sources of uncertainty. These include the business climate, payment issues, clarity of contract documents, liability and responsibility questions, change in 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 necessity to maintain relationships to secure future work. This list is not comprehensive, however, many of these issues cannot be addressed by look-ahead planning and are best handled through contract negotiations and other parts of the business process. The focus of this study will be on those areas in which look-ahead planning can improve productivity performance. The purposes of look-ahead planning are discussed in 4.3.3.1. The best practice addresses those purposes with particular emphasis on identification and removal of constraints, trade coordination, and continuous improvement through results tracking and analysis.

2.2.2 Technical and quality requirements

The electrical scope of work is regularly the most technical and confusing work on a project. Electrical design documents are schematic in nature and require an educated, experienced subcontractor to complete the work (Smith and Hinze 2010). Technical and quality requirements of electrical construction can be summarized as follows (Horman et al. 2006).

- 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.
- The sequence of work is quite important for efficient electrical construction. There are rigid requirements dictated by the physical installation of the system.
- Electrical systems need to work seamlessly with most other systems in a facility.

- Electrical systems and electrical work demand close coordination with other systems and other work, particularly structural, mechanical, communications, and interior finishes systems. These systems must often be fit in constrained spaces.
- 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 (NECA 2012).

2.2.3 Subcontractor status

The electrical contractor is typically a sub-contractor, 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 (Horman et al. 2006). The lack of a direct contractual relationship between the electrical contractor and other subs (e.g., HVAC, plumbing, etc.) further challenges the field coordination as discussed in 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. And they are also 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 deliverables, and incur extra costs (Horman et al. 2006).

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 overmanning, overtime, shift work, and out-of-sequence work, as mentioned above. Stacking of trades, congestion problems and interference with other trades may occur (Horman et al. 2006). Look-ahead planning 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 electrical installations to comply with the National Electrical Code®, electrical products to be “listed” by nationally recognized safety testing organizations, and electricians to be qualified and licensed. The long training period and cyclic nature of the construction industry contribute to periodic or local shortage of qualified personnel (Ireland 2012).

2.3 Look-ahead Planning Methods

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.

2.3.2 Last Planner

Last Planner, 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 (Ballard 2000a).

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. PPC is analyzed with run charts, a method common to Agile Construction (Daneshgari 2010), which is discussed later in this section.

Primary tools: The six week look-ahead schedule (LAS) and weekly work plan. The look-ahead schedule is to identify constraints and to 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. Production planning meetings are held weekly. Daily progress monitoring is mentioned in some Last Planner publications.

Two key elements in Last Planner are not releasing the work until all constraints are satisfied and getting commitment from the crew to accomplish the work. The process is illustrated in Figure 1. In early versions of Last Planner, this process was called “should-can-will” analysis (Ballard 1994). In this terminology, “should” is the master schedule, “can” is what is possible given the constraints, and “will” is the commitment. Some more recent publications have modified this terminology.

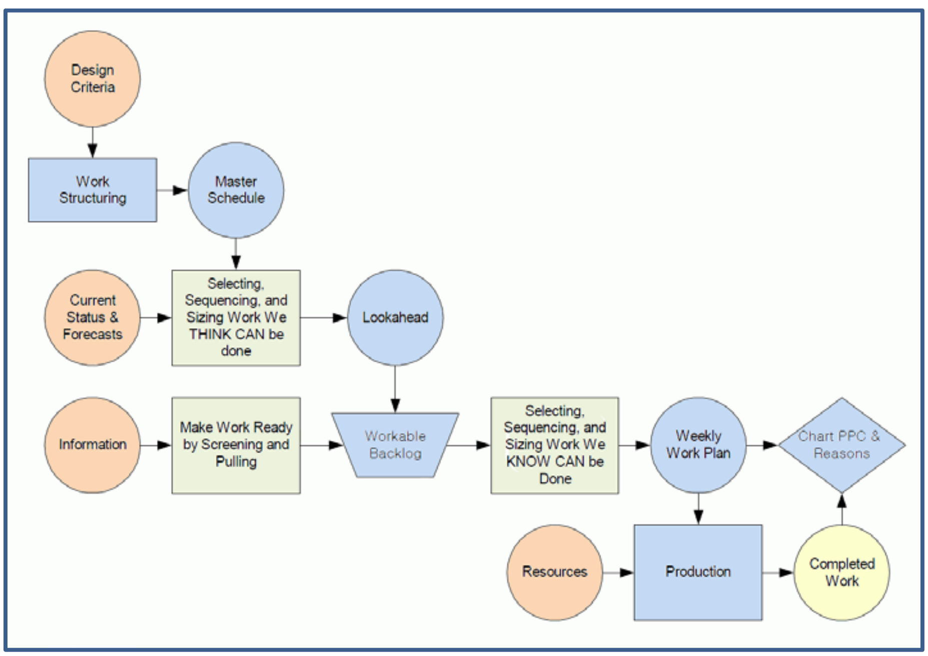


Figure 1 The Last Planner System (Choo 2003)

Unique elements: Look-ahead planning is done by field personnel. Collaboration at the design stage is recommended but 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 make it a particularly valuable scheduling concept in the recommended best practice.

Comments: When compared to techniques that are presented below, Last Planner is most relevant to electrical contracting due to Last Planner's primary focus on field level planning. For example, Workface Planning and Enhanced Work Packaging 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 is a Best Practice of the Construction Owner's Association of Alberta (COAA) intended to improve productivity in large industrial projects (COAA 2011). Per 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 culminating in the Field Installation Work Package (FIWP), 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 megaprojects but is represented to be scalable to project size (Mikaelsson et. al. 2011).

Fundamental assumptions: 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 breakdown of work in earlier phases of planning should be designed to facilitate definition of FIWP's. Note that these are the same as assumptions for the closely related Enhanced Work Packaging described later. The packages are typically one to two week's work for a single crew. Workface Planning additionally provides for the preparation of alternate FIWP's to be available in case previously scheduled FIWP's are delayed.

Primary tool: The field installation work package. This 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 FIWP. In a typical industrial construction project, the work package is ideally issued 4 weeks before work is scheduled. Once work has begun, progress is monitored daily. Workface Planning includes ancillary tools such as a set of rules, an execution plan checklist, and a Workface Planning Scorecard to facilitate implementation of the method.

Unique elements: A dedicated workface planner is required. Workface Planning is required in the contract. The sequence of look-ahead scheduling is rigidly defined.

Applicability: This tool is targeted at short-term scheduling, however, the early stage involvement and incorporation into the contract will be impractical for electrical contractors involved in 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 is very detailed and includes rigid schedule requirements. It was developed for use on mega-projects and contains some elements, such as dedicated material, scaffolding, equipment, and tool coordinators, which may not be applicable on smaller projects. Although the FIWP is applicable at the crew level, the Workface Planning method 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, however, published examples all seem to be large projects.

2.3.4 Enhanced Work Packaging

Enhanced Work Packaging is a method originated by Research Team 272 of the Construction Industry Institute (CII). The team's charter was to review existing work packaging practices and recommend a best practice implementation (CII 2011).The CII team was aware of COAA's Workface Planning and views Enhanced Work Packaging 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 (Warren 2012).

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. Once work has begun, progress is monitored daily. CII has defined ancillary tools such as example checklists and an Enhanced Work Packaging Scorecard to facilitate implementation of the method.

Unique elements: A dedicated workface planner is required. This method is more general and flexible than Workface Planning. It has greater emphasis on checklists than Workface Planning and Last Planner. CII represents that improvement can be achieved with partial implementation of the method.

Applicability: The intended purpose of this tool is the short-term scheduling which 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 in the recommended best package.

Comments: Enhanced Work Packaging is partially based on Workface Planning and bears many similarities. The Workface Planning literature focuses on process industrial projects, 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. Although some elements of these methods were incorporated in the recommended best practice, they were not emphasized because they are project level methods that do not address the level of detail needed.

2.3.5.1 Agile Construction

This method is described in Daneshgari (2010) and is offered as a National Electrical Contractors Association (NECA) course by the author. It is a project level or company level method that relies heavily on statistical process control and productivity monitoring, but includes use of short-interval schedules, including 3-week and 3-day look-aheads. Although look-ahead methods receive relatively brief coverage, use of run charts for productivity tracking and reporting form examples are useful. Analysis of run chart patterns receives more detailed description in *Agile Construction* than in Ballard's early work on Last Planner. Run chart analysis is an important element in the recommended best practice.

2.3.5.2 Lean Construction

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. Since these are principles (Howell and Ballard 1998), not methods, implementations vary. One implementation, the Lean Project Delivery System (Ballard 2000b), is a trademark of the Lean Construction Institute which has published extensively on the method and related subjects. The Lean Project Delivery System incorporates Last Planner, which is described above. Due to the variability of lean construction interpretations and the similarity in principles underlying other methods and practices, it is difficult to identify any part of the recommended best practice as influenced by lean construction except for those elements adapted from Last Planner.

2.3.5.3 Prince2

Prince2 is a project level management method developed by the U.K. government. It is popular in the U.K., Europe, and Australia. Per Siegelaub (2013), 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. It refers to a "single product" which can be managed by a Team Manager. The constraint management and work packaging concepts in Prince2 are similar to several of the methods above but Prince2 was not used as a source in the best practice design.

2.3.5.4 Integrated Project Delivery (IPD)

Integrated project delivery and IPD are terms trademarked by Integrated Project Delivery, Inc. of Orlando, FL, however, the terms are generically in the industry to describe a collaborative construction model incorporating early involvement of key players (owner, architect, and constructor) and shared decision-making. It is promoted by numerous organizations in various versions. It is sometimes described as synonymous with Lean (Kitchell 2013), however, the methods are not identical.

A well-known version of IPD is promoted by The American Institute of Architects (AIA), which has published model form contracts. The AIA literature emphasizes contractual aspects, Building Information Modeling (BIM), and an integrated project team which includes specialty contractors. ConsensusDOCS, an industry coalition, has published an IPD model contract (ConsensusDocs 2013) competitive with the AIA model form. Another trademarked collaborative method is Integrated Lean Project Delivery® (The Boldt Company 2013).

The differences between the various IPD methods are not significant to this study. IPD may facilitate the use of effective short-term scheduling but, as with any project level method, cannot be implemented by the subcontractor alone. The recommended best practice incorporates similar elements and a collaborative philosophy but IPD was not explicitly used in its design.

2.3.5.5 Quality Methods

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. Broadly, 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. An example is the use of the manufacturing technique, Kanban (Ennova 2010). Except for productivity tracking, these methods were not significant in this analysis.

2.3.5.6 Unnamed (Horman) Method

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

2.3.5.7 CPM Scheduling

The critical path method is well known, widely used, and is often required by contract. Variations include PERT and Fuzzy CPM (variable task durations). The master schedule, from which the activities (FIWPs) of the look-ahead schedule are extracted, is normally a CPM schedule.

2.3.5.8 Critical Chain Project Management (CCPM)

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 (Goldratt 1997). It also addresses scheduling multiple projects. The CCPM literature claims that resource management and bottlenecks are more explicitly handled than by other methods. The originator of CCPM, Eliyahu Goldratt, publishes his methods in “business novels” rather than formal papers, so the details can be somewhat imprecise and interpretations of the method vary. The multiple project scheduling methods offers some insight into managing alternative tasks. CCPM was not used in this study.

2.3.5.9 Theory of Constraints

The Theory of Constraints is another management method by Eliyahu Goldratt (Dettmer 1997) and is represented to be the basis of CCPM. The Theory of Constraints has been used in manufacturing processes, but it is more a problem resolution process than a project management or scheduling method. This method was useful in problem analysis but is not part of the recommended method.

2.3.5.10 PMBOK Guide

Project management as defined in the PMBOK Guide (Project Management Institute, Inc. 2008) is a formalized methodology of traditional project management published by the Project Management Institute. It has received widespread acceptance, particularly in the software engineering and electronics industries. It is recognized as an ANSI standard. Some of PMBOK principles, such as the work breakdown structure, defining activities, and sequencing activities, are fundamental to project management and are integral to previously described methods. The PMBOK Guide was not directly used in formulating the recommended best practice.

2.3.6 Additional Considerations

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

2.3.6.1 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 discussion of this was not found in the literature review.

2.3.6.2 Technology

Software, wireless devices, and other applications of technology may contribute to crew level productivity improvement. Excel spreadsheets, stand-alone software, and web-based applications advertising Last Planner or Workface Planning capability, or otherwise incorporating constraint management capability are available. Examples include ProjectFlow, OurPlan, ConstructSim, SmartPlant, and InVision. A limited investigation of these programs and other software applicable to look-ahead scheduling was done in the literature review process, however, the merit of particular software packages is not within the scope of this study.

2.3.6.3 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, however, it was not a primary focus. This study intends to find a quantitative way to measure the effectiveness and reliability of 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 look-ahead scheduling performance. Contractors will no doubt continue to use other measures to evaluate other aspects of job performance.

2.3.6.4 Impact of Human Factors

The production scheduling literature addressing manufacturing operations includes analysis of the impact of human factors on scheduling processes and results. Among these are such issues as the personality and rules of thumb of the scheduler, the scheduler's ability to gather information informally and anticipate problems, and the practice of maintaining several concurrent mental versions of the schedule (McKay and

Weir 2006). Production scheduling differs significantly from construction scheduling in that the manufacturing process is more regular than the construction process and production scheduling is often managed in part by software using mathematical optimization models. Because of these differences, observations from the production literature may not be applicable. Nonetheless, there may be valuable insights to be gained. This is a subject worthy of further investigation.

CHAPTER 3. SURVEY DESIGN AND ANALYSIS

3.1 Introduction

The survey had three primary goals:

1. Identify EC's current practices, including differences related to project or company size, type of work, and geographic area.
2. Solicit EC's opinions of best practices to identify gaps between actual practices and practices EC's thought they should use.
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.

3.2 Survey of Existing Practices

3.2.1 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 (SurveyMonkey 2012) and The Question Bank Factsheets (The Survey Question Bank 2012) were followed in question wording and design. The initial draft was prepared by the author and subsequently modified in a joint session of the team described above. The survey was again modified based on inputs from expert reviewers as described under pre-survey interviews below.

3.2.2 Pre-Survey Interviews

In order to refine the survey questions to issues of interest to EC's 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 fall 2012. Suggestions were minimal and consisted primarily of clarifications and addition of answer options.

3.2.3 Data Collection

The result of the design was a 35 question survey that primarily addressed look-ahead scheduling procedures currently in use but also includes opinions on effectiveness and potential for improvement. A copy of the survey with responses is attached as Appendix A.

The survey was conducted online on SurveyMonkey. Although participation was solicited by email, the survey was open. No validation of the respondent was required. Survey data collection began on December 3rd, 2012. Requests to publicize the survey were sent by email 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 3rd, 2013, by which time 60 responses had been received. The respondents were a geographically diverse sample and included owners or employees of both union and open shops. The majority of respondents were owners or managers of large firms.

3.2.4 Survey Results

Look-ahead planning 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. This is not noted in the discussion unless response rate was below 75% or was otherwise pertinent to the analysis.

3.2.4.1 Characteristics of Respondents

Respondents were dominantly owners or senior managers of large electrical contracting firms. Forty-four of 60 respondents (73.3%) fell into this category. Over 85% of respondents had more than 15 years of experience. Approximately 70% were from firms having over 50 employees; 93% employed more than 10. This is a reversal of the industry composition: per the 2012 Electrical Contractor Magazine survey (Kelley 2012), 74% of firms employ fewer than 10.

More than half of the firms surveyed had over 100 employees. Forty-two percent had annual revenue over $25 million. The firms work in a broad range of projects across the board in new construction, additions, retrofit, and maintenance. The work is concentrated in commercial, industrial, and institutional projects with less emphasis on residential projects as shown in Figure 2 below.

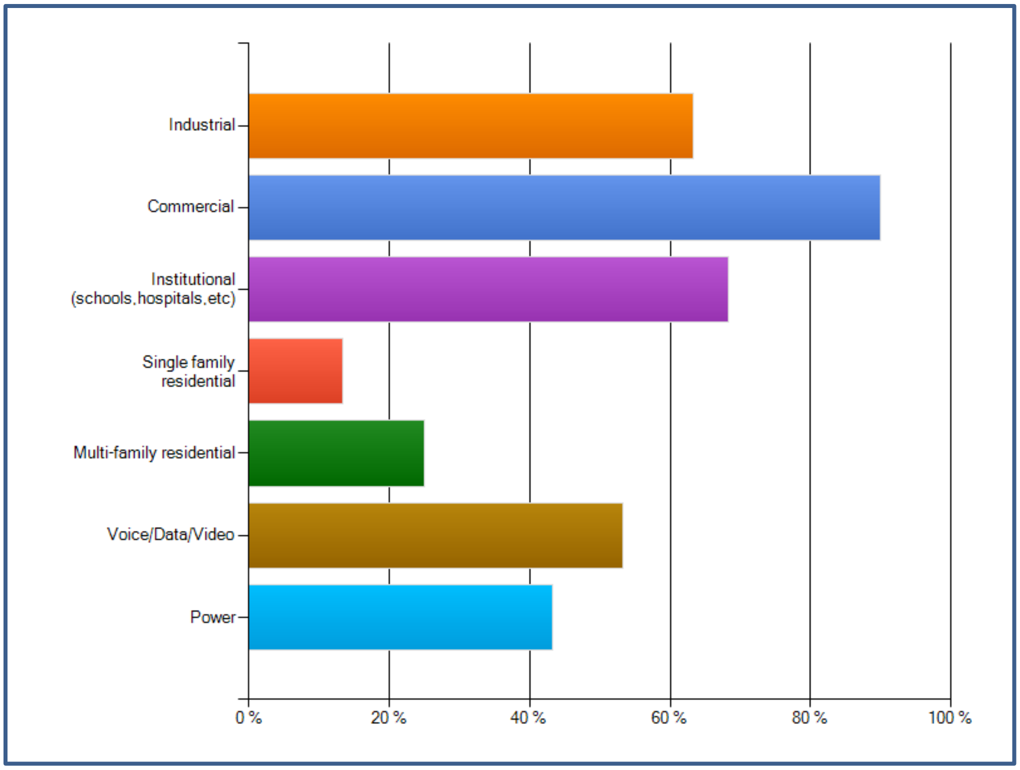


Figure 2 Project Type

Sixty-two percent of the respondents worked for union shops. The responses were reasonably geographically diverse. The South, defined per the NECA region boundary, was slightly over-represented with 55% of responses; per the 2007 U.S. Census Bureau survey, this region includes 38% of industry employees (United States Census Bureau 2013).

3.2.4.2 Current Look-Ahead Scheduling Practices

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

The majority of task durations range from one day to two weeks as shown in Figure 3 below. Task duration is likely related to project size, however, that question was not included in the survey.

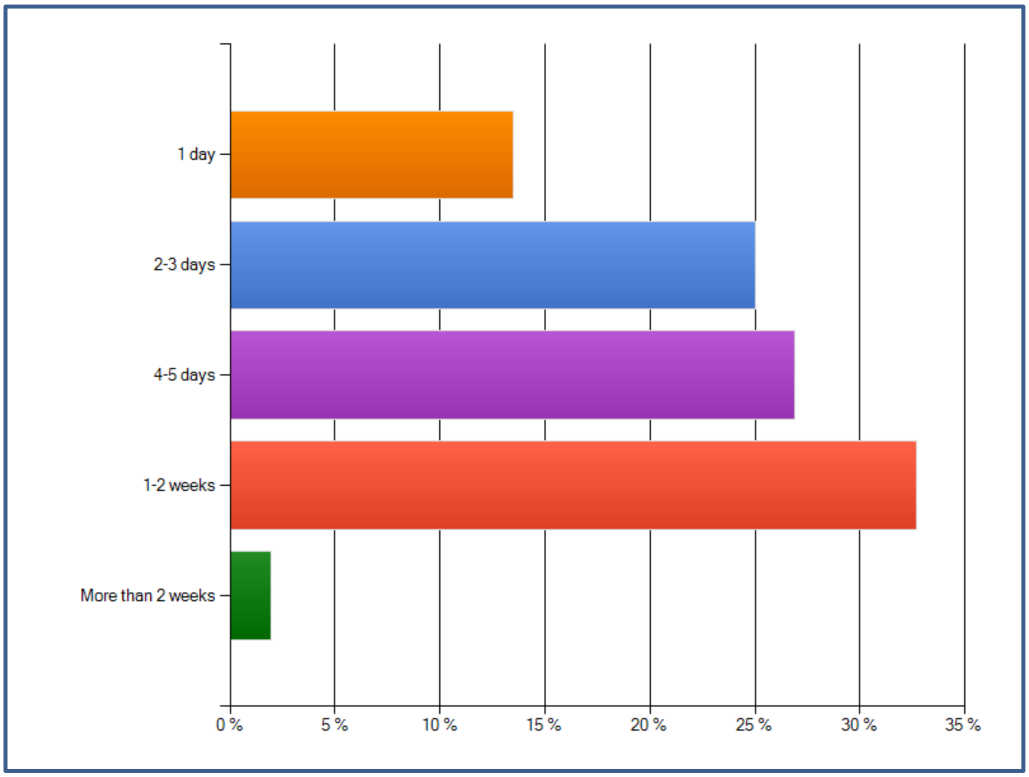


Figure 3 Average Task Duration

Seventy-three percent of look-ahead schedules are updated weekly. Twenty-five percent of these are also updated daily.

The form in which the schedule is presented varies widely. Paper daily schedules are most common, being used by over 50% of respondents. Gantt charts, calendar charts, daily schedules, and task forms are used in roughly equal proportions. Paper forms are used 65% of the time, however, schedules are sometimes presented in both paper and electronic formats. In the less frequent circumstances when CPM charts are employed, electronic forms predominate. Project planning software is used for look- ahead scheduling by 42% of respondents reporting (60% response rate). 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 rests with the project manager, superintendent, or foreman (31%, 31%, and 25%, respectively). Less than 8% of companies use a dedicated scheduler as defined in Workface Planning. The project manager and foreman are involved in defining the schedule in 80% or more of the companies. Other personnel are involved less frequently as shown in Figure 4 below. Job titles are not consistent among companies so distributions by job titles should be considered approximate.

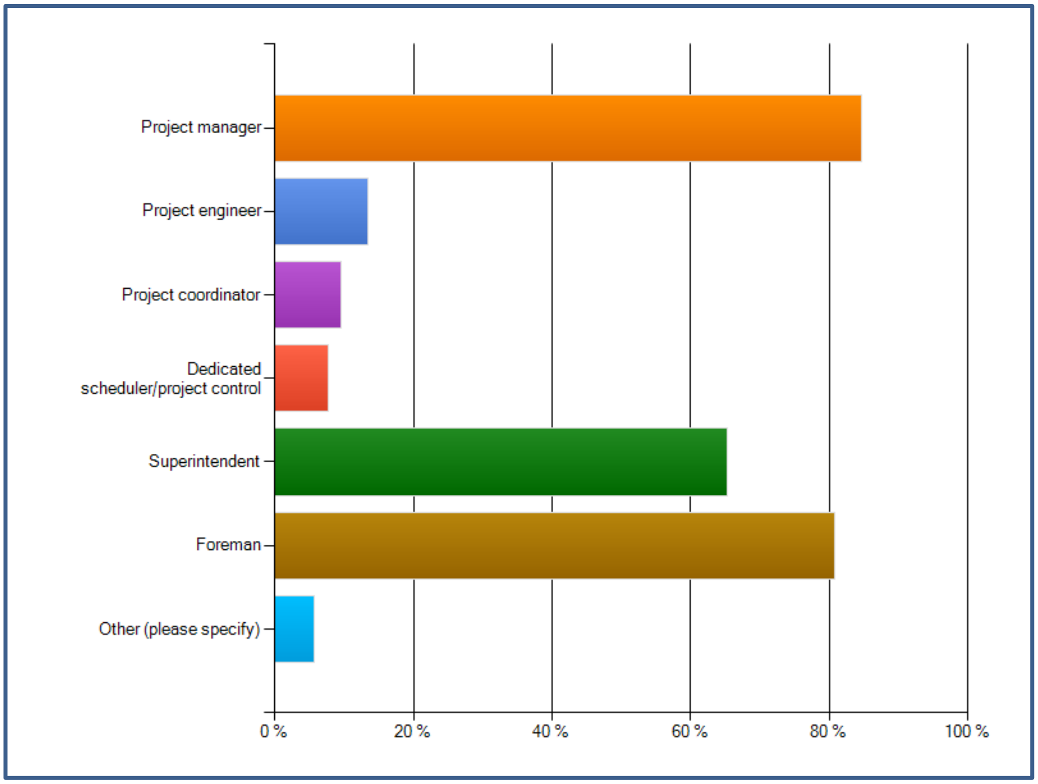


Figure 4 Individuals Involved in Look-Ahead Schedule Definition

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 5.

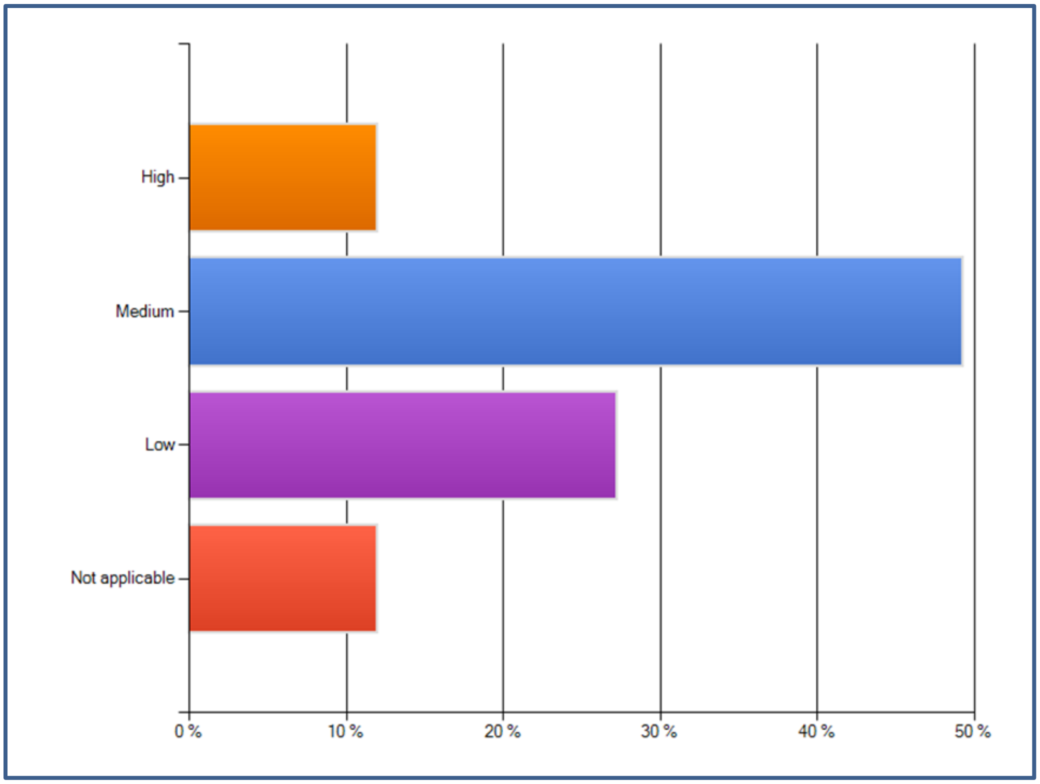


Figure 5 Ability to Influence Master Schedule

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 as Figure 6. Greater involvement of the electrical contractor in the master schedule may be appropriate.

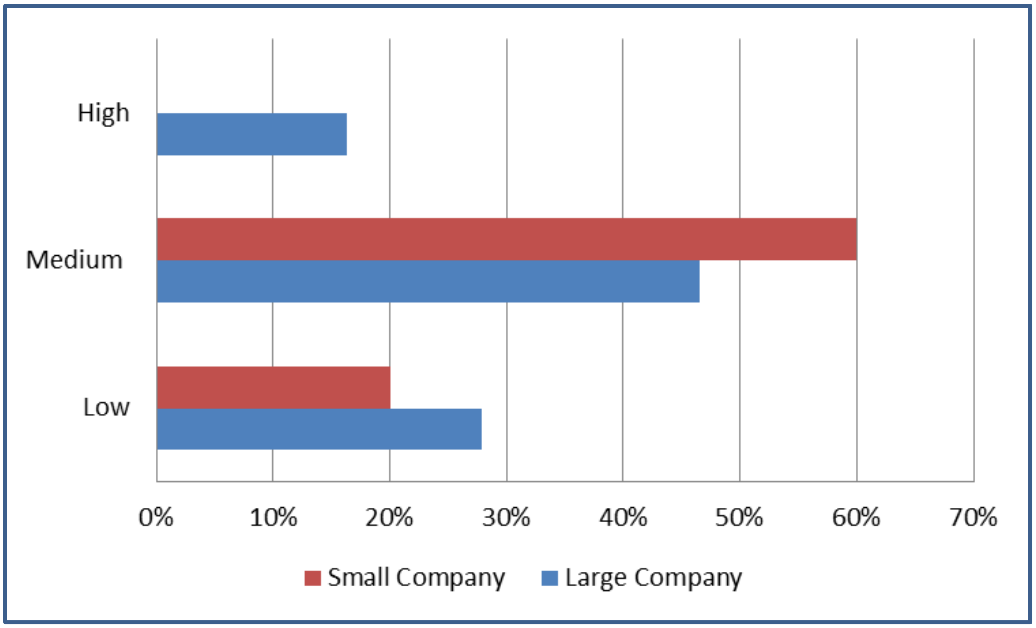


Figure 6 Ability to Influence Master Schedule by Company Size

Look-ahead schedules are overwhelmingly used primarily to ensure supply of labor, materials, and equipment, and to coordinate work as shown in Figure 7 below. Using the schedule to include a back-up plan and for measuring performance are relatively little utilized at 27% and 37% of respondents, respectively. This is another area of potential improvement, however, in a later question 73% of respondents indicated having a back-up plan at least part of the time.

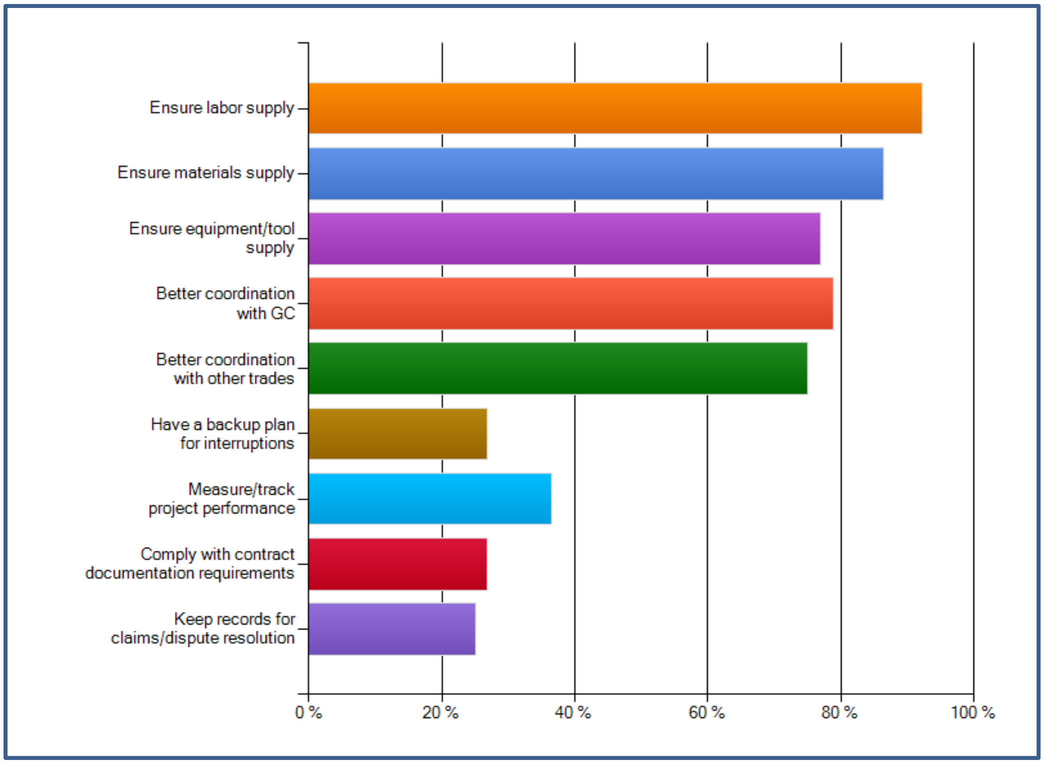


Figure 7 Main Purposes of Look-Ahead Schedule

Emphasis in task plans focuses on labor, equipment, and scope of the work; other aspects are less often defined as shown in Figure 8 below. 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 subs 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.

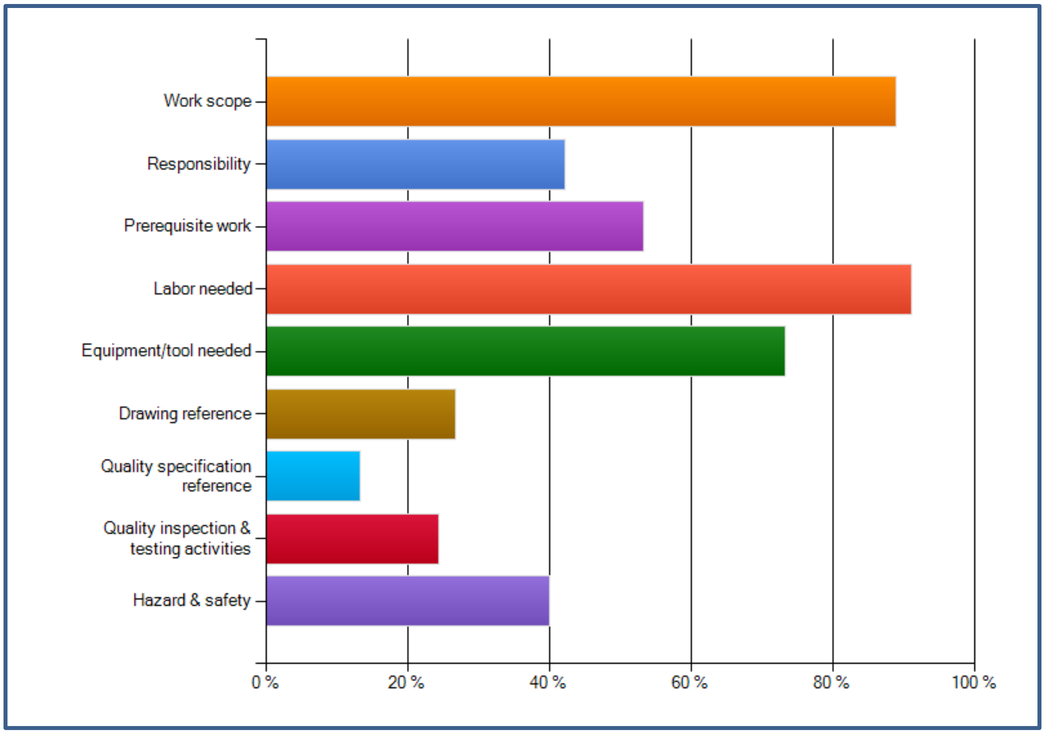


Figure 8 Elements Included in Task Plan

The amount of notice of upcoming work given to foremen varies widely as shown in Figure 9. This may be a function of the scope of the task or project, however that was not addressed in the survey questions. Smaller companies generally gave longer advance notice.

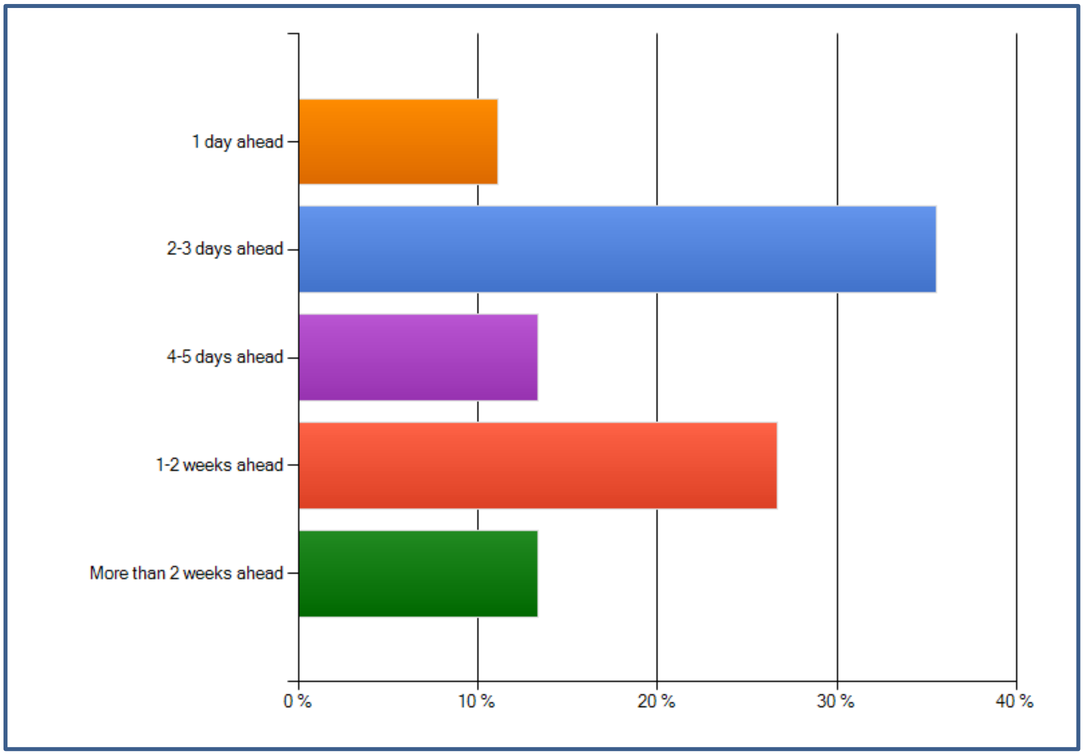


Figure 9 Task Notice to Foreman

Eighty-seven percent of respondents who answered the pertinent question (47 respondents) indicated their personal opinion of the schedule varied from the officially published schedule at least part of the time. Respondents were more than three times as likely to expect the actual time to be longer than scheduled rather than shorter (54% vs. 15%). This phenomenon has been reported in the production literature (McKay and Weir 2006) but was not found in the review of the construction management literature. It merits further research.

3.2.4.3 Trade Coordination

Sixty-one percent of respondents reported sharing their look-ahead schedule with the GC; 40% reported sharing 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 of 73, 65, and 46, respectively.

3.2.4.4 Performance Measurement and Sources of Delay

All but one respondent indicated that they used at least one measure of performance; slightly over 50% reported using 2 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 10.

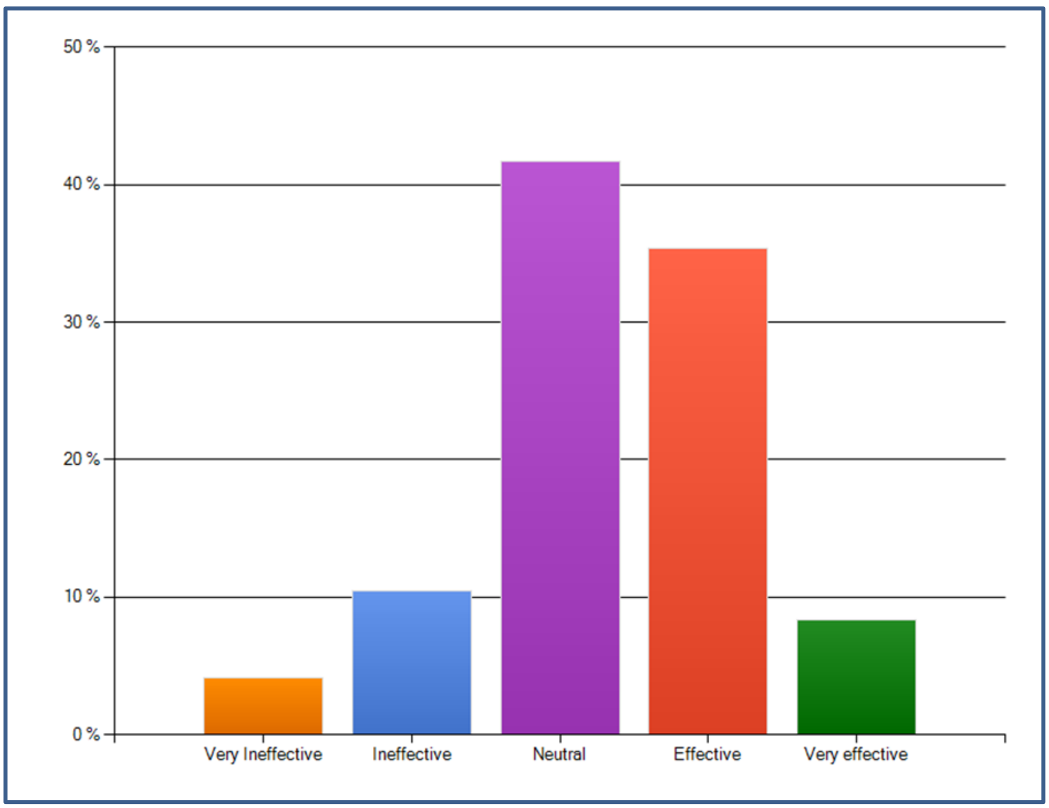


Figure 10 Reported Effectiveness of Current Look-ahead Practice

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 11 shows the top five issues. Note that the reported cause may not be the root cause of a problem. For example, other subs behind schedule may the result of prior out of sequence work or work changes. This is discussed in more detail in Section 4.3.6.3.

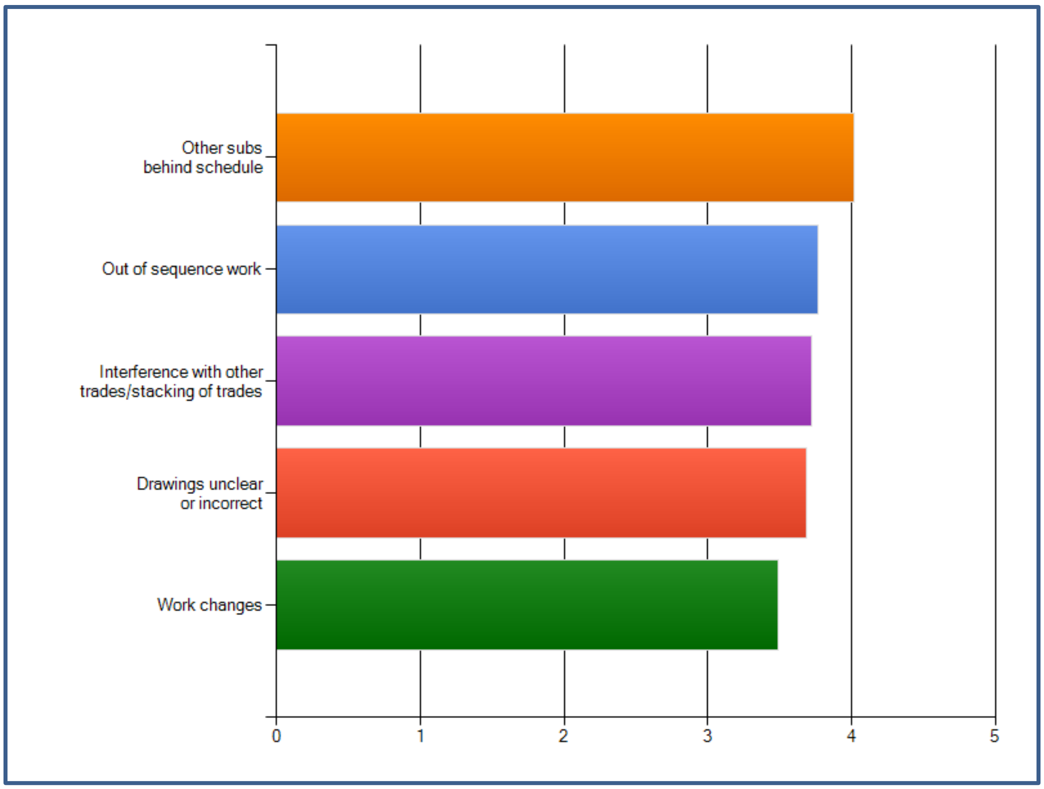


Figure 11 Issues Affecting Schedule Deviation

An additional question asked the respondent’s agreement with 11 possible improvement methods on a 5 point scale. Level of support was 3.7 or above for all suggested methods. Four methods had agreement scores above 4 as shown in Figure 12. Two of these methods were more involvement of electrical contractors in planning and design; the other two were foreman involvement in multi-week planning and foreman training.

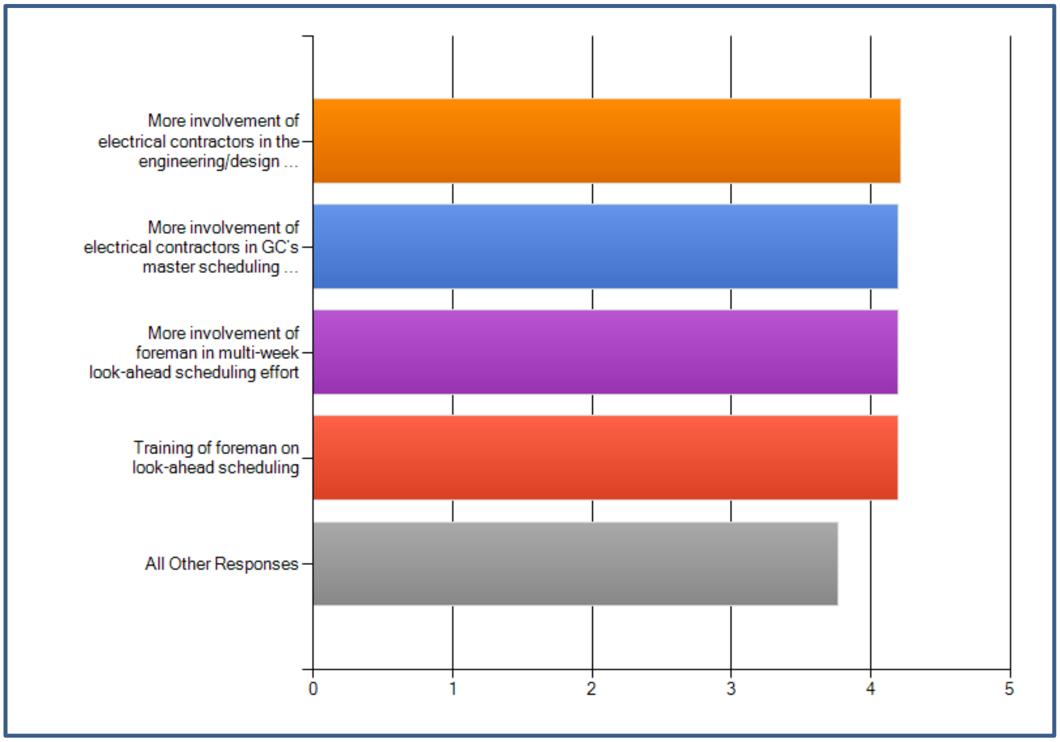


Figure 12 Reported Agreement with Possible Improvement Methods

3.3 Post-Survey Interviews

After a preliminary analysis of the survey results, additional input was sought from practicing electrical contractors by interview and an email questionnaire. The email questionnaire was sent to the 38 respondents to the original survey who had provided an email address, six of whom responded. The questions included in the email are shown as Appendix B. The responses are summarized below:

- The percent of GC's holding coordination meetings ranged from 30 to 100, with an average of 71.
- Nearly all coordination meetings were held weekly.
- Four of six coordinated directly with other trades through foremen, two with GC.

- Only one indicated a regular backup plan
- Five of six indicated benefit from EC involvement in design. Little comment was made on how to do this.

Three face-to-face interviews lasting about 30 minutes each were conducted with contractors employed 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. All used informal look-ahead scheduling methods. Coordination with other trades was not an explicit part of look-ahead scheduling. The interviews provided an interesting insight into the scheduling practices of smaller EC's but was too small a sample to have significant effect on the design of the best practice.

CHAPTER 4. BEST PRACTICE DESIGN

4.1 Introduction

In order for a project schedule to be planned, certain assumptions must be made concerning the work flow and segmentation of the work into manageable packages. The latter is the familiar work breakdown structure. How those packages are defined and sequenced will influence the efficiency of the construction process.

Planning begins at the bid preparation stage, and continues through pre-construction and execution on the jobsite to the completion and closeout of the project. Depending on the nature and complexity of the project, multiple schedule levels may be prepared, including milestone, master, look-ahead, weekly, and daily schedules. Therefore, the construction planning process is one of progressive elaboration that becomes more detailed in succeeding scheduling steps. This is shown in Figure 13.

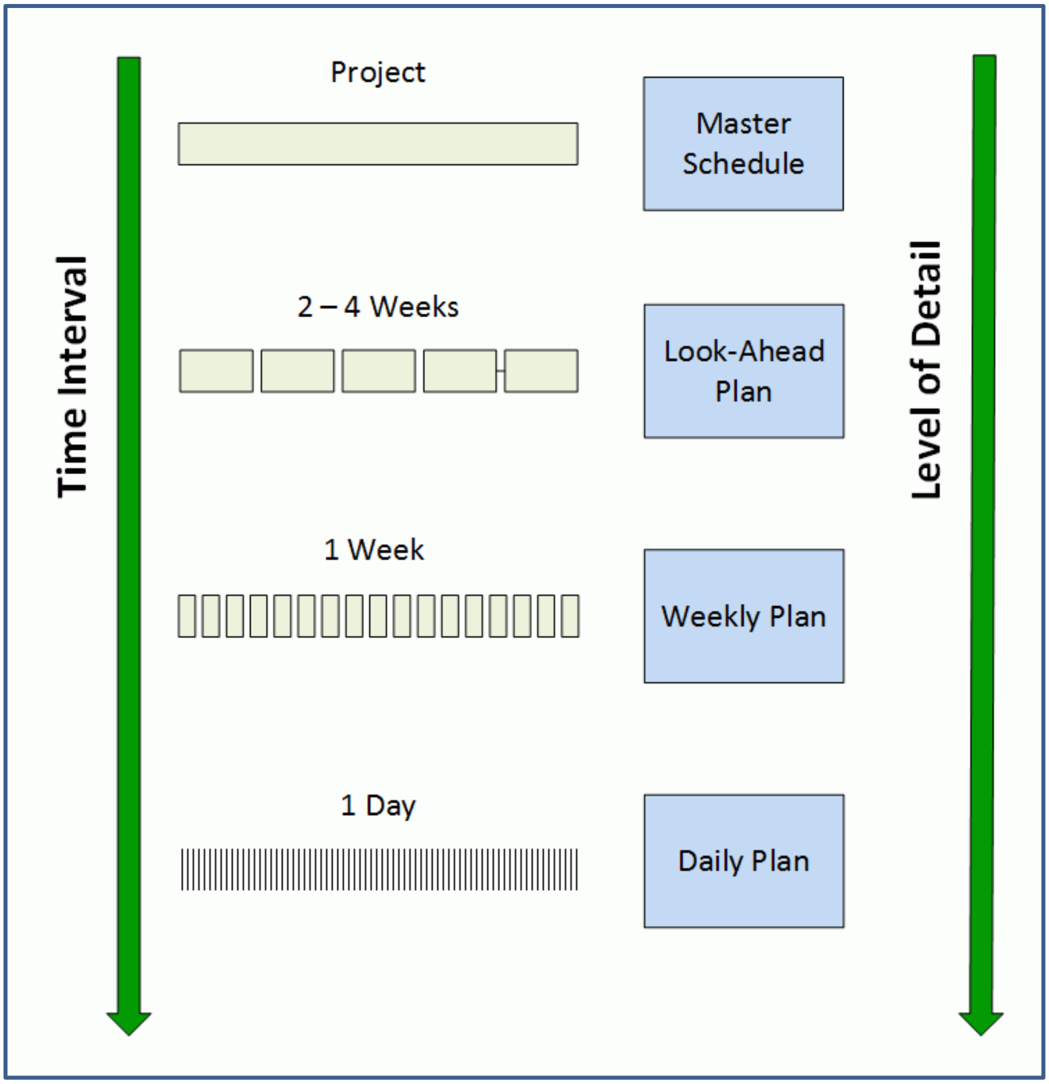


Figure 13 Planning Hierarchy (modified from Hamzeh 2009)

The importance of adequate planning at all appropriate levels is well documented in the literature. This study focuses on short-term scheduling, i.e., look-ahead, weekly, and daily planning.

4.2 Design and Pre-construction Planning

A number of previous studies specific to electrical contracting have been commissioned by ELECTRI International, the most pertinent of which have been collected in Rojas (2009). These studies, and others not specifically focused on electrical contracting, discuss involvement of subcontractors in the design and pre-construction phases.

Numerous studies (e.g., Kulkarni, et. al. 2012, Konchar and Sanvido 1998) have shown that collaborative planning during these phases is beneficial to the project and complementary to look-ahead scheduling, often resulting in cost savings and faster completion times. Significant reduction in cost and improvement in construction speed have been reported in collaborative delivery methods. The widely quoted study of 351 projects by Konchar and Sanvido (1998) referenced above found DB projects to be 6% lower cost and 33% shorter than Design-Bid-Build Contracts; Construction Management at Risk (CMAR) showed a lesser advantage.

Collaborative planning may also be achieved in design-build and other delivery methods. Collaborative front-end planning is a part of the recommended practices Workface Planning, Enhanced Work Packaging, and the Lean Project Delivery System (Ballard 2000b). These methods include procedures and design guidelines for work packages that enhance later implementation of look-ahead planning. Procedures and systems set up during pre-construction are used in the later scheduling and execution of the project. An outline of this process is shown in Figure 14.

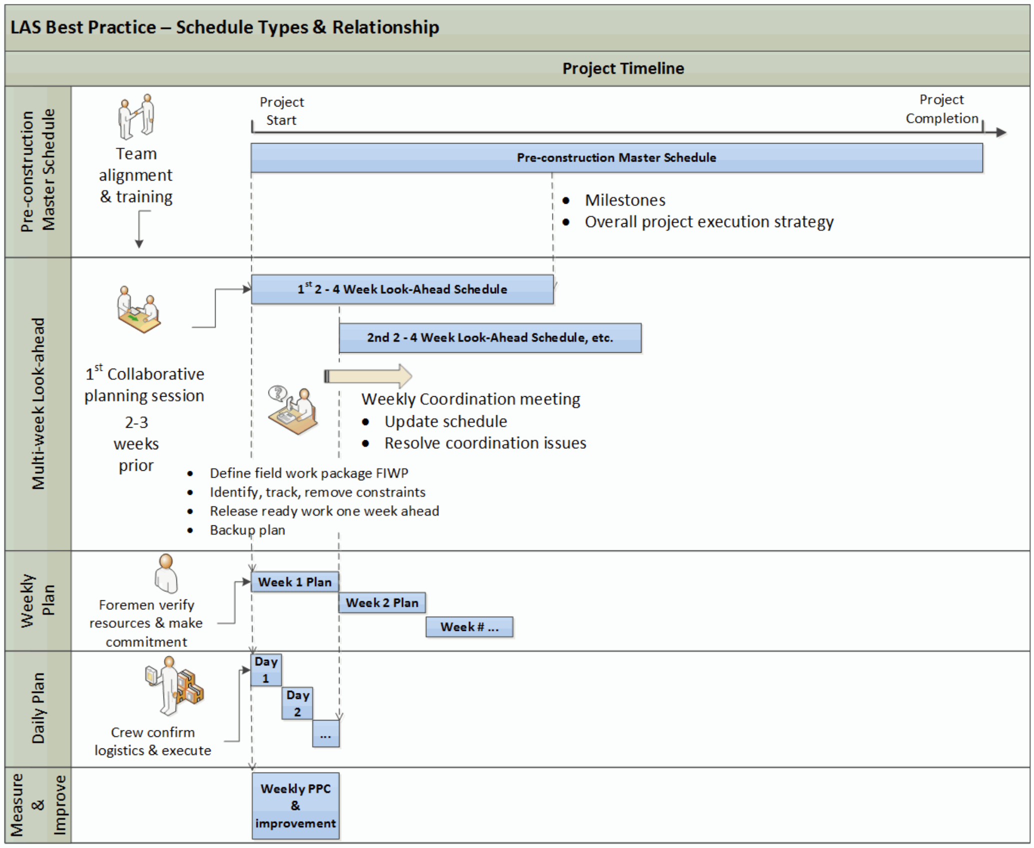


Figure 14 Scheduling Process Overview

Although the involvement of trade contractors in the design and pre-construction processes and the consideration of constructability in the design of work packages are beneficial, common practice is for the schedule and work packages to be initially designed by the architect/engineer and general contractor. Furthermore, use of a collaborative contract form does not mean that the EC will be involved in early planning. In this study, the master schedule is assumed to be defined in the design and pre-construction phase. It will contain project milestones and the general execution sequence and work packaging deemed most efficient by the architect/engineer and general contractor, with or without input from the electrical contractor.

It is possible for the electrical contractor to have input in these phases under design-build contracts, construction management contracts, or with integrated project delivery, however, this is not the case in most projects. In this model look-ahead planning by the electrical contractor begins with multi-week planning. Recommended practices for the design and pre-construction phases other than initial planning meeting (IPM) will not be further discussed here.

4.3 The Best Practice Method

4.3.1 Introduction

As shown in the first column in Figure 14 above, the overall project planning process consists of:

1. **Pre-construction Master Schedule:** Describe milestones and overall project execution strategy; achieve team alignment and training
2. **Multi-week Look-ahead:** Develop 2-4 week look-ahead schedule (LAS) using collaborative planning method; define Field Installation Work Packages (FIWPs, see Section 4.3.3.2.3); track and remove FIWP constraints; release constraint-free work for the coming week; define backup plan
3. **Weekly Plan:** Foremen verify resources and make commitment
4. **Daily Plan:** Crew confirm logistics and site conditions for efficient, safe, and quality work performance
5. **Measure & Improve:** Measure scheduling performance using Percent Plan Complete (PPC, see Sections 4.3.6.2 and 4.3.6.3), chart weekly performance and delay causes for continuous improvement

Each of the steps is described in later sections of the thesis. The recommended best practice includes steps 2–5. The steps are detailed with an objective and scope, recommended practice, and implementation procedures (e.g. checklist and template). A flow chart of the procedure is shown in Figure 15.

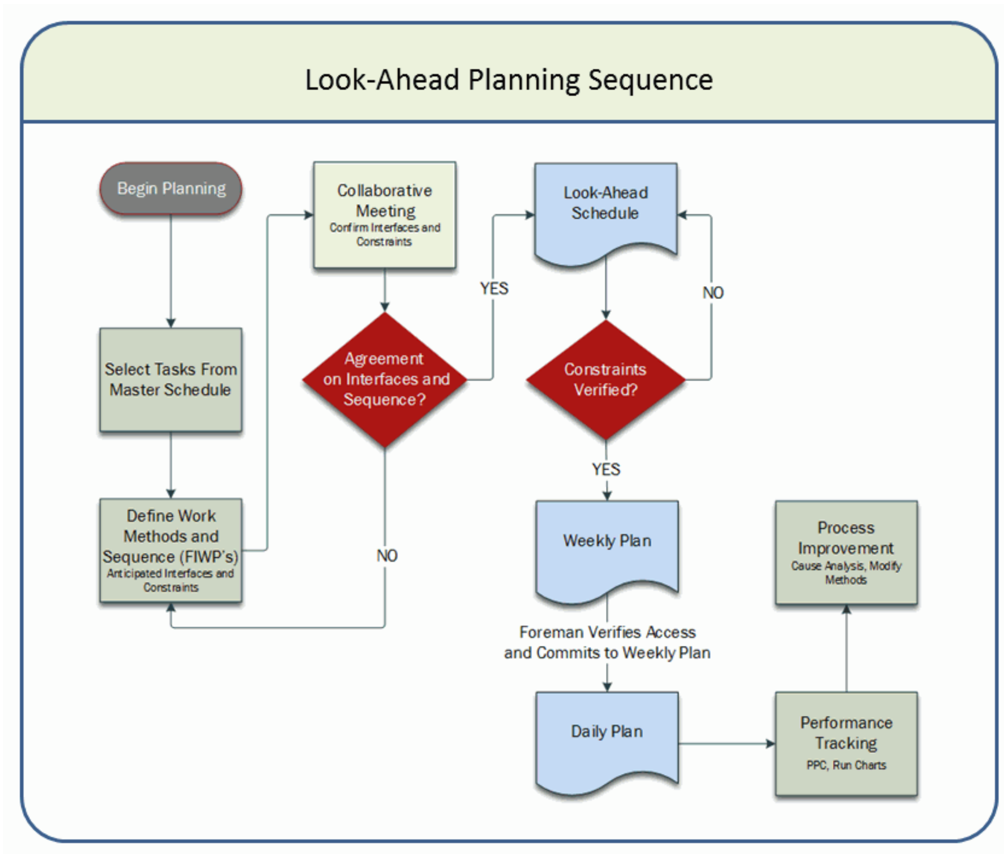


Figure 15 Best Practice Flow Chart

Key features and benefits of the LAS best practice model include:

- **Collaborative planning**: a team scheduling approach involving GC and subs for promoting shared sense of responsibility, building relationships, creating conversations, and securing commitments

- **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
- **Foreman involvement**: best use of foreman field knowledge to improve scheduling effectiveness and buy-in
- **Constraint management**: early identification of activity constraints and responsibility assigned for their tracking and removal
- **Foreman commitment**: Releasing an FIWP only when it is constraint-free for reliable foreman commitment
- **Quality backup plan**: quality work backlog maintained to minimize impact of uncertainty and interruption
- **Percent Plan Complete**: PPC tracked and analyzed to monitor scheduling performance and enable continuous improvement

When implemented effectively, the best practice can help the EC to reduce chances of schedule interruptions, boost team morale, and strength its image as a good project team player, which can translate to better profitability and repeat business.

4.3.2 Pre-construction Activities

4.3.2.1 Master Schedule

As described above, pre-construction planning and development of the master schedule, which may also be called a master plan or milestone schedule, is not part of the best practice. However, the master schedule is critical to the best practice in that it describes the overall sequence of work and is the schedule from which the look-ahead activities are taken.

4.3.2.2 Initial Training

If team members are not experienced in the best practice, training will provide them with basic skills and accelerate their knowledge and acceptance of the system. Recommended content of a one day training session (modified from The Realignment Group, Ltd. 2013) is:

1. An overview of the LAS best practice and collaborative planning principles
2. Defining FIWP's and sequencing
3. Facilitating and managing the look-ahead, and weekly work plan generation
4. Assigning responsibilities for plan implementation
5. Working collaboratively through the look-ahead process, identifying and managing constraints
6. Training participants in the improvement cycle of:
    a. Reviewing weekly work plan results
    b. Calculating PPC and tracking variance categories
    c. identifying root causes for issues and delays
7. A working and coaching session to develop a three-week look-ahead schedule and weekly work plan

4.3.2.2.1 Initial planning meeting

Because the IPM significantly influences later planning, input from all parties and sign-on to the look-ahead planning methods and procedures is critical. Although the IPM takes place before construction begins, it is an integral part of the multi-week scheduling process and discussed in Section 4.3.3 below.

4.3.3 Multi-week Look-Ahead Schedule

4.3.3.1 Objective & Scope

The multi-week or look-ahead schedule includes the definition and sequencing of work packages intended to optimize the work flow and efficiency of the electrical work. The purposes of the LAS (Ballard 1997) are:

1. Shape work flow in the best achievable sequence and rate for achieving project objectives that are within the power of the organization at each point in time.
2. Match labor and related resources to work flow.
3. Produce and maintain a backlog of assignments for each frontline supervisor and crew, screened for design, materials, and completion of prerequisite work at the CPM level.
4. Group together work that is highly interdependent, so the work method can be planned for the whole operation.
5. Identify operations to be planned jointly by multiple trades.

The steps involved in the complete look-ahead planning process are shown in Figure 16.

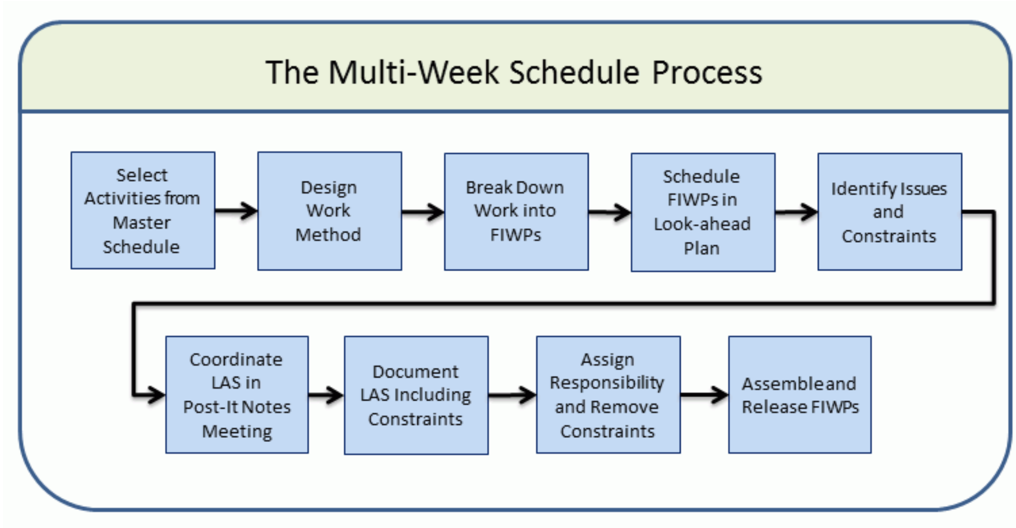


Figure 16 Look-Ahead Scheduling Process

The time interval of the LAS is described above as 2 to 4 weeks. This may be specified by contract but otherwise will depend upon the complexity of the project and the preferences of the EC or GC. The important consideration is that it be long enough for constraints to be identified and satisfied before FIWP's are assigned. Although not strictly required for look-ahead scheduling, the recommended collaborative process provides additional benefits in improved communication, commitment, and recognition of common goals.

4.3.3.2 <u>Recommended Practice</u>

4.3.3.2.1 Select Activities from Master Schedule

The process begins with a review of the updated master schedule. The designated planner (DP), with input from the project manager, superintendent, and foreman, will identify scheduled activities entering the look-ahead window for inclusion in the look-ahead plan. The selected activities should include only those ready to be assigned or whose prerequisites can be satisfied at least one week prior to expected assignment.

4.3.3.2.2 Design Execution Strategy

The design of the LAS must go beyond mere listing of the work product to be completed. It must consider components of the seven major preconditions (Figure 17) as well as work methods, alternate methods of construction, prefabrication, and other aspects of the work process.

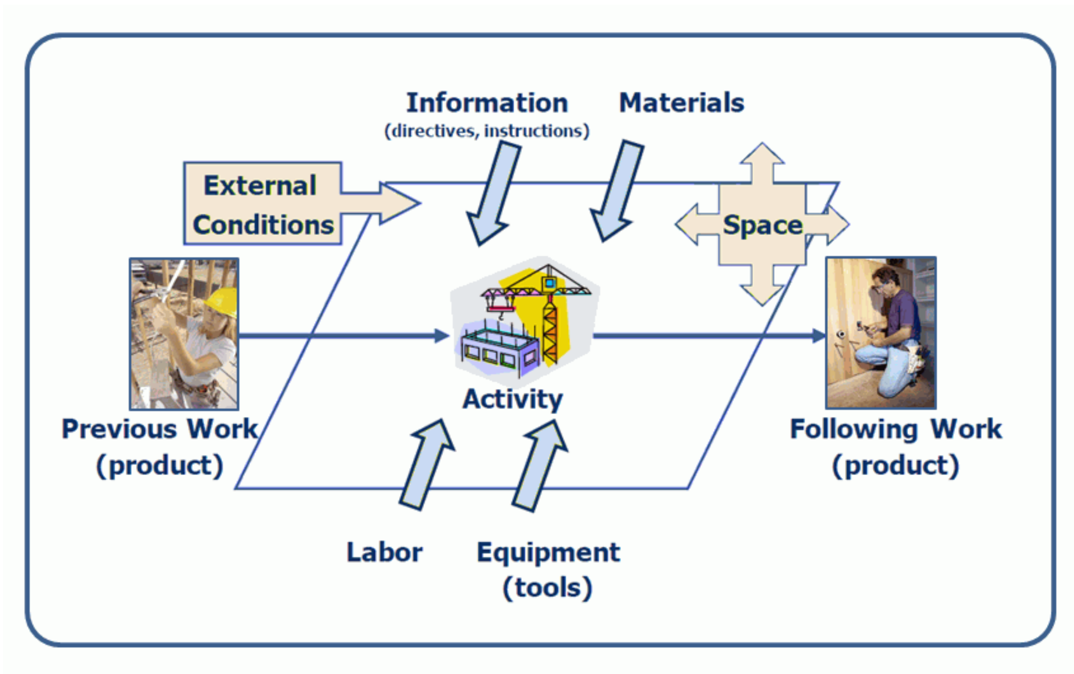


Figure 17 Preconditions for Construction Activity (modified from Hamzeh 2009)

These considerations will have been incorporated in the master schedule and, however, more detail will be included in the multi-week schedule. In addition, the status of prerequisite work may be different than is defined in the master schedule, requiring changes in the work design. Howell and Ballard (1999) describe consideration of the following aspects of the work as necessary in the design of work methods:

- The design of the work product itself
- Available technology and equipment
- Site layout and logistics

- Results of preceding work
- The size of work packages released to the crews
- Potential site environment factors (temperature, winds, etc.)
- Safety
- The expected experience and skills of craft workers and supervisors
- Craft traditions or union work rules

A primary consideration is who is to prepare the LAS. In the best practice, this means who will be the DP. Our survey showed no strong industry preference, with the project manager, superintendent, and foreman each commonly given responsibility. This choice will depend on the size and complexity of the project. A rule of thumb for assigning responsibility is to choose the lowest level which directs all activities included in the assignment. For example, if an assignment involves several crews, the responsibility would be assigned to the superintendent directing the foremen of those crews.

A particular position to prepare the LAS is not specified in the best practice, however, the person doing so must have a comprehensive knowledge in 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 trade experience and 3 years as a supervisor (Slootman 2007).

Regardless of who has primary responsibility, the look-ahead planning process requires multiple inputs and coordination among members of the EC's own personnel, the GC, and other trades. At a minimum, the project manager, superintendent, and foreman should be involved. On a large project, many others may contribute. Figure 18 shows relationships possible between functions within the electrical contracting organization alone. This degree of departmental specialization may only exist in large electrical contracting firms, however, the functions must be carried out regardless of organization size. In smaller firms multiple functions will be performed by one person.

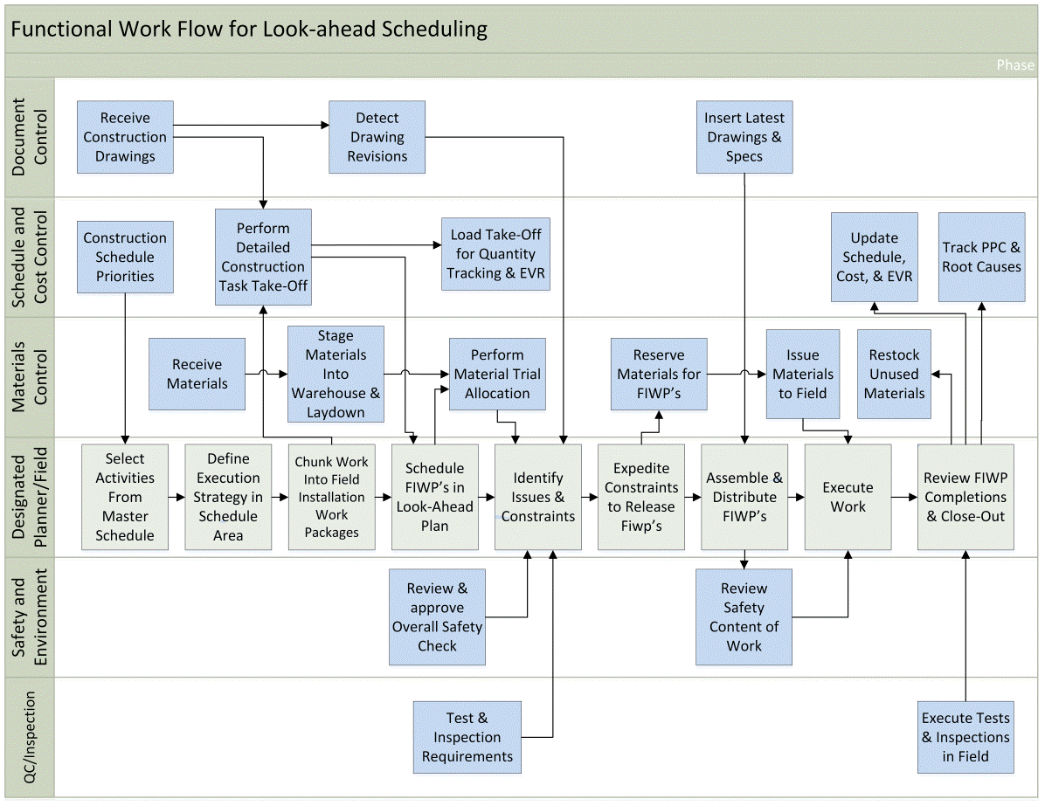


Figure 18 Functional Work Flow for LAS (modified from Blackmon 2011)

The most effective means of coordinating the look-ahead plan is through weekly face-to-face meetings of the general contractor and trade contractors. The meeting agenda should cover all items pertinent to the progress of the work, including status of the work, submittals, RFI's, and change orders. Coordination among subcontractors is one of the major responsibilities of the general contractor and most GC's will hold regular subcontractor meetings. Our survey results showed that 65% of respondents coordinated through regular contractor meetings. A small sample (6 respondents) to answering follow-up questions indicated that 70% of GC's held weekly coordination meetings.

In those cases in which the GC does not hold these meetings, the electrical contractor must find other means to coordinate with other trades. This may be by means of meetings of the designated planners of the trade contractors, or foreman-to-foreman, depending in part on project size and complexity. It should be a regular and verifiable part of the look-ahead process, not left to chance as an informal procedure. Indirect methods of communication, such as from the electrical contractor and other trades to the superintendent, are less satisfactory. Joint communication among trade contractors and GC is preferable.

The LAS schedule agreed upon in the weekly coordination meeting may not have enough detail for planning the EC's work. If not, the EC can add details as needed in joint planning among field personnel within their company.

4.3.3.2.3 Chunk work Into FIWP's

Once the construction methods and execution strategy have been completed, the FIWP's must be designed. An FIWP is a package of work that would normally be given to a single foreman team to build in a few days to two weeks. The two major considerations are the work content and its documentation. The planner preparing the FIWP discusses the work with the responsible safety, quality, superintendent, and craft personnel in a preparatory meeting, with special focus on anticipated constraints, including coordination with other subcontractors. In more detail, the characteristics of the FIWP (COAA 2010) are:

- Work for an FIWP is specific to an individual foreman's crew. It is usually discipline specific but may consist of a mixed crew.

- The size of an FIWP can depend on the complexity of the work. Therefore work may be of longer or shorter - a few days to-3 weeks in duration. (Install 1000kw generator- 9 days, replace service ground - 1 day) and may contain multiple tasks.
- FIWP packaging needs to align with all systems. (e.g., master schedule, estimating, procurement)
- An FIWP may remain ‘open’ for longer periods (on hold at <100% complete) awaiting the completion of prerequisite, integrated, and dependent activities from another FIWP. (For example - Final termination of a group of cables may be on hold until the equipment is set.)

A complete FIWP (modified from CII 2011) will contain:

- Work package summary-inclusive of description of work
- Location, system or facility code, originator, contact information
- Sequenced work steps, reference documents, estimate of labor hours and quantities, cost codes, witness or hold points, and special comments
- Coordination with other trades
- Quantity work sheet
- Safety hazard analysis, specific to tasks in work package
- MSDS
- Drawings (engineering and vendor design)
- Specifications (engineering and vendor design)
- Change documents (i.e., field change request, deficiency/
- Non-conformance report and design change notice)

- Manufacturer's installation instructions
- Model shots
- Bill of materials
- Required tools
- Installation test results forms
- As-built documentation
- Inspection checklists
- Completion verification signatures

A less comprehensive FIWP may be appropriate for simple or routine tasks. An example FIWP is shown as Appendix C.

4.3.3.2.4 Schedule FIWP's In Look-Ahead Plan

The short term schedule must coordinate with the master schedule and sequence FIWP's to allow milestones to be met in the most efficient fashion. Doing so requires understanding of the relationships of the FIWP's and anticipation of constraints. Different sequencing to accomplish the project may be possible. Consideration should be given to the strategy that achieves the best balance of safety, cost effectiveness, and schedule performance. Placement of the FIWP's in the LAS may depend upon relationships and status of prerequisite work discussed in weekly coordination meetings. Priority should be given to tasks that will release downstream work (Hamzeh 2009).

4.3.3.2.5 Identify Issues and Constraints

This is a key area in which improved look-ahead scheduling can improve job performance. Traditional scheduling is often not of sufficient duration to avoid conflicts or unsatisfied constraints. It often does not consider all necessary prerequisites. A model of the constraint management process using a four week look-ahead is shown in Figure 19.

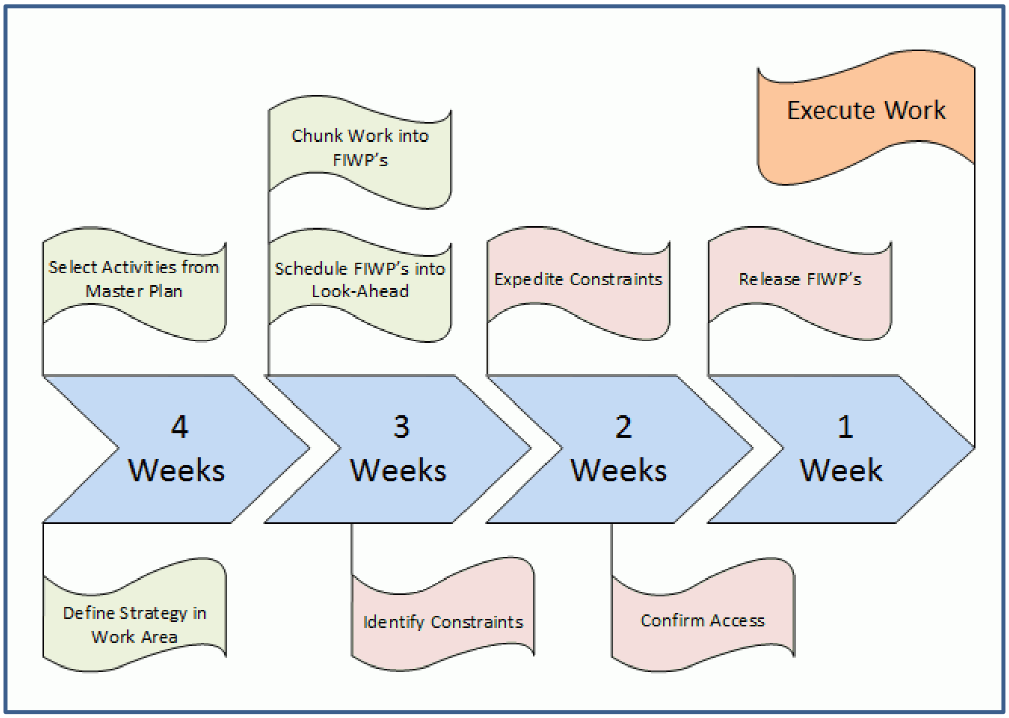


Figure 19 Constraint Management Process (modified from Ryan 2009)

The constraint identification process must identify all prerequisites for the FIWP. Typically, this is done based on a checklist appropriate to the involved trade and nature of the task. The use of checklists is strongly recommended. As mentioned in the literature review, checklists are tools used in Workface Planning and Enhanced Work Packaging, as well as several other published best practices.

Due to the complexity of construction work, it is not possible to design a template that anticipates every item. This is handled by templates that, to a greater or lesser degree, include categories of constraints. Numerous examples of such checklists have been published. Figure 20 below is a field-friendly format that can be used as either a paper form or spreadsheet.

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

Figure 20 Constraint Checklist

Regardless of the manner in which the constraint analysis is conducted, reasonable thoroughness requires input and review by multiple personnel. As a minimum, the foreman, superintendent, and project manager should all have input.

4.3.3.2.6 Coordinate LAS in collaborative planning meetings

Coordination of the LAS begins in pre-construction with the IPM and continues in weekly planning meetings. The format and procedures of both meetings are similar, although there are some differences due to the amount of planning that has taken place prior to each. These meetings are discussed below.

4.3.3.2.6.1 Initial Planning Meeting

As indicated in Figure 14 above, the process begins with a collaborative planning session. Ideally, this meeting includes the GC, subcontractors, and other stakeholders. In this meeting the involved parties jointly agree upon the methods to be used for creating the LAS, plan the initial LAS, and establish procedures that will be used for periodic updating of the LAS. This meeting is critical in that the procedures, responsibilities, and relationships defined will govern future look-ahead planning.

Because the IPM involves these organizational considerations, participation from a larger and broader group than participates in the subsequent update meetings is desirable. However, it is not within the EC's control to require participation by other parties to this meeting. If the GC elects to conduct this meeting, recommended participants are designers, consultants, inspectors, owner representatives, superintendents, project managers, and trade contractors' superintendents and project managers. If the GC does not hold an IPM, the EC must do the initial planning internally.

Among the elements defined in the IPM (modified from Hanna 2009) are:

- Procedures to define Field Installation Work Packages (FIWP's) and their sequencing
- Procedures for constraint identification, tracking and removal
- Responsibilities of the parties involved in preparing and updating the LAS
- Relationships between field personnel and other project management functions (document control, material management, etc.)
- Timing and mechanism for updating the LAS
- The initial 2-4 week LAS
- Detailed work methods for activities falling within the LAS period

A suggested meeting procedure (modified from Knapp and Hunt 2013) is:

1. Have an agenda ready for the meeting
2. Ensure that all required and updated project data is available

3. Use “Post It” notes on a wall-mounted board as described below
4. Encourage participation so that all issues are identified
5. Review previous week’s action items
6. Review previous week’s progress
7. Review planned work (FIWP’s) in look-ahead period
8. Update schedule with particular focus on any changed dependencies
9. Hold open discussion
10. Identify actions items and responsibilities
11. Document the plan with complete minutes

The dependencies and sequencing of FIWP’s are best determined in a collaborative session using “Post-It Notes” to allow flexibility in considering alternative work flows. The Post-It notes method consists of using easily moved paper notes color coded to different subcontractors to display a Gantt-like chart of project activities. Because the notes are color coded and easily moved, the relationships between subcontractors are readily seen and alternative sequencing can be displayed by simply moving the notes. An example is shown as Figure 21.

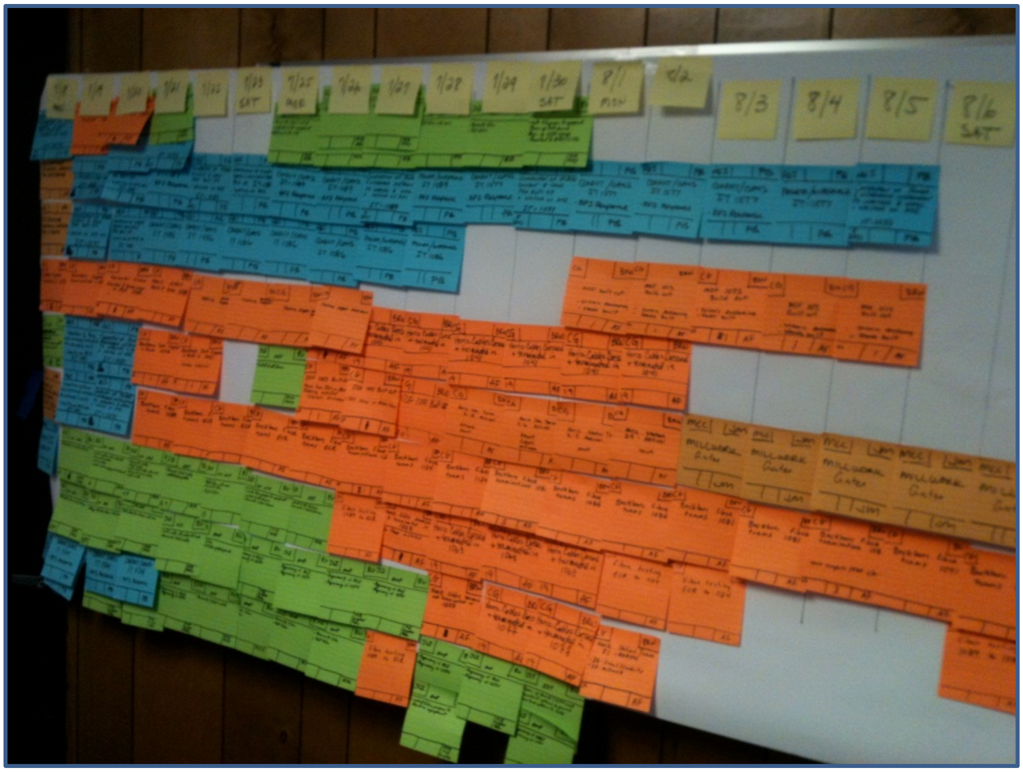


Figure 21 Post-It Note Schedule

The Post-It note procedure (modified from Knapp and Hunt 2013) is:

1. Each contractor is supplied with unique color cards or sticky notes.
2. Each contractor will break down his/her work in a way that he/she feels is necessary to achieve control of the project following the process agreed to in the prior meeting.
3. Each contractor lists their activities on individual notes. Each note contains the name of the activity and the duration of the activity at a minimum. The predecessors and successors could also be recorded, as well as any critical constraints for field performance.
4. Each contractor comes forward to post their card/activity on a large white board or a wall.

5. Team members then negotiate and optimize the sequence of activities to ensure timely project completion.
6. Record and sign off on the agreed master schedule.
7. Share finalized look-ahead schedule with all contractors.

4.3.3.2.6.2 Weekly Update Meetings

Weekly update meetings follow the same procedure as the IPM. Since these meeting require only the update of the existing schedule, only parties involved in the activities planned for next several weeks need to attend. The most effective practice is for the GC to hold weekly update meetings with all subs. If the GC does not, the EC must plan internally and coordinate with the GC. Typically, this will be through meetings between the EC and the GC's superintendent or project manager.

4.3.3.2.7 Expedite Constraints to Release FIWP's

Once constraints have been identified, they must be verified as being satisfied before the work is released to the crew. Some constraints can be tracked automatically, i.e., in a computer database (Blackmon et al. 2011), however, even those constraints whose status is nominally verifiable in a database or report may sometimes need to be checked by a site visit.

If a constraint has not been satisfied, it must be corrected. How 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 or other trades. A constraint log such as Figure 22 should be used to track status of constraint clearing.

CONSTRAINT LOG

Project Information	TITLE AND LOCATION	CONTRACT NUMBER	UPDATE DATE:	UPDATED BY:
	Filson gynasium	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	Office and gym- Rough-In			Joe Foreman	1/7/2014				
255020	"- Branch Wiring			Joe Foreman					
255030	"- Fixtures			Ed Foreman					

Figure 22 Constraint Log

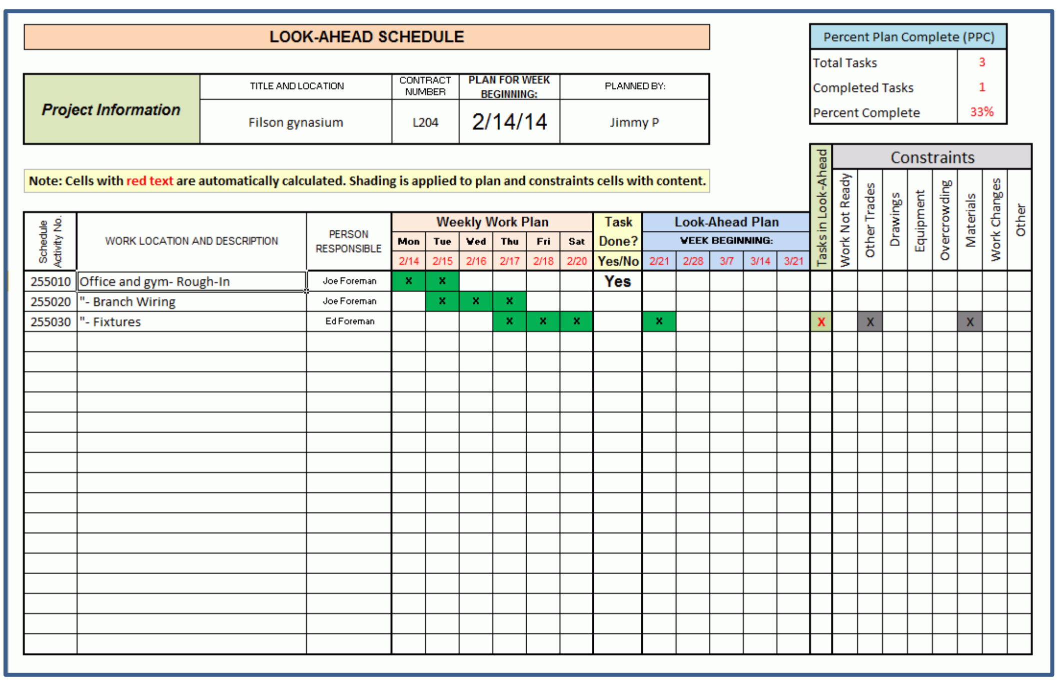
Multi-week scheduling facilitates early identification of upcoming constraints so that adequate time will be available to address them. Unsatisfied constraints may be in any of the several categories described above. For example, the constraint may be incomplete or unclear information which may be corrected 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 as to not create other problems such as out of sequence work, added cost, or congestion.

4.3.3.2.8 Assemble and Distribute FIWP's

In this team model of planning, the foreman will be aware of the status of FIWP's and tracking of constraints before the FIWP's are formally released, however, 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. The person authorized to release FIWP's may vary depending on the organization. Typically, this will be the project superintendent. The superintendent or other authorized individual will release the FIWP's that are consistent with the LAS and verified by the DP to be free of constraints to the foreman in the week prior to execution.

4.3.3.2.9 Managing the LAS

Practically speaking, managing the LAS and keeping track of FIWP's on a project of significant size requires a computer application. This may be a spreadsheet, project management software, custom application, or specialized look-ahead planning application. The application chosen for this purpose should be used as early as possible in the look-ahead scheduling process. A screenshot of a FIWP tracking spreadsheet application is shown as Figure 23.



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	Ved 2/16	Thu 2/17	Fri 2/18	Sat 2/20	Task Done? Yes/No	Look-Ahead Plan VEEK BEGINNING: 2/21	2/28	3/7	3/14	3/21	Tasks in Look-Ahead	Constraints: Work Not Ready	Other Trades	Drawings	Equipment	Overcrowding	Materials	Work Changes	Other
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					X		X				X		

Figure 23 LAS Spreadsheet

This efficient form combines a six week look-ahead and a weekly plan. It includes constraints, delay causes, and tracking, and identifies the responsible party. Separate spreadsheets for the weekly and look-ahead sections could be created if a simpler form is preferred.

4.3.4 Weekly Work Plan (WWP)

4.3.4.1 Objective & Scope

The WWP is derived from the look-ahead plan. It provides a detailed plan of FIWP's released or expected to be released in the coming week. It is updated weekly, based on discussion between the DP, GC, and other trades as described above. The objectives of weekly work plan are:

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

4.3.4.2 Recommended Practice

The weekly work plan should consist of FIWP's from the multi-week schedule that are ready to be performed, i.e. all constraints have been removed. 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 FIWP's have satisfied constraints and are ready for release. The weekly work plan will be finalized for the coming week in the weekly planning meeting and the multi-week schedule updated. As previously discussed, the weekly planning meeting may be held by the GC with all subcontractors, between EC and GC, or internally by the EC. A significant benefit to adjusting the WWP in a weekly meeting is the additional motivation resulting from a public commitment to the weekly scope of work. The process is shown diagrammatically in Figure 24. These activities are primarily implemented in the weekly project meeting.

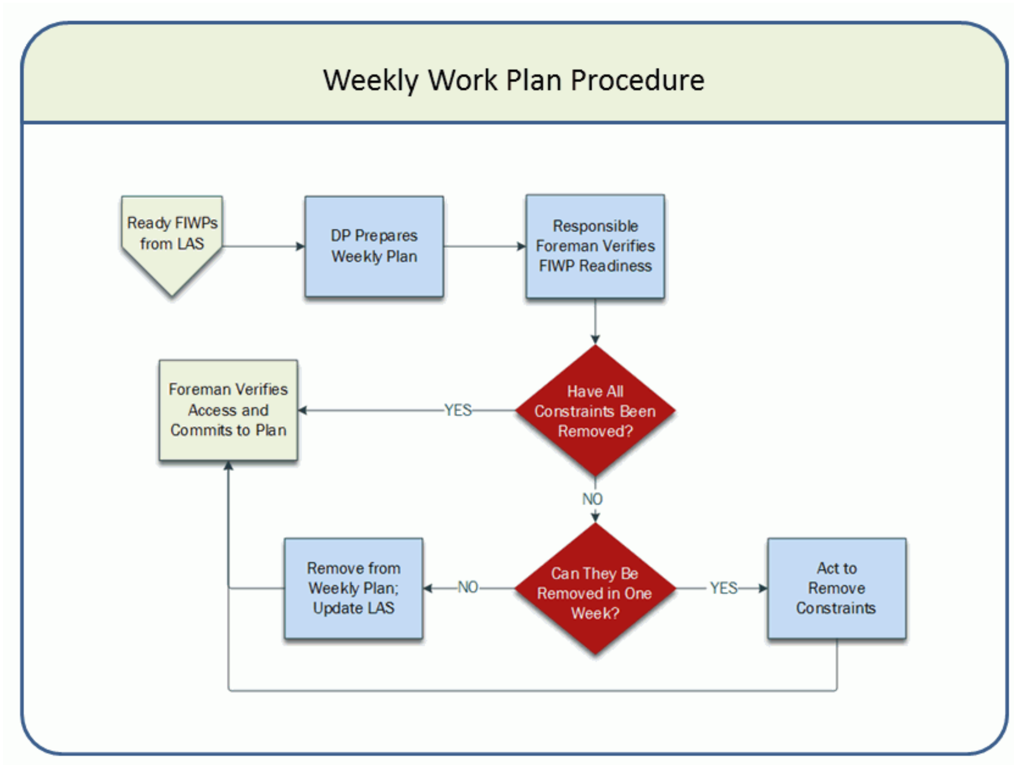


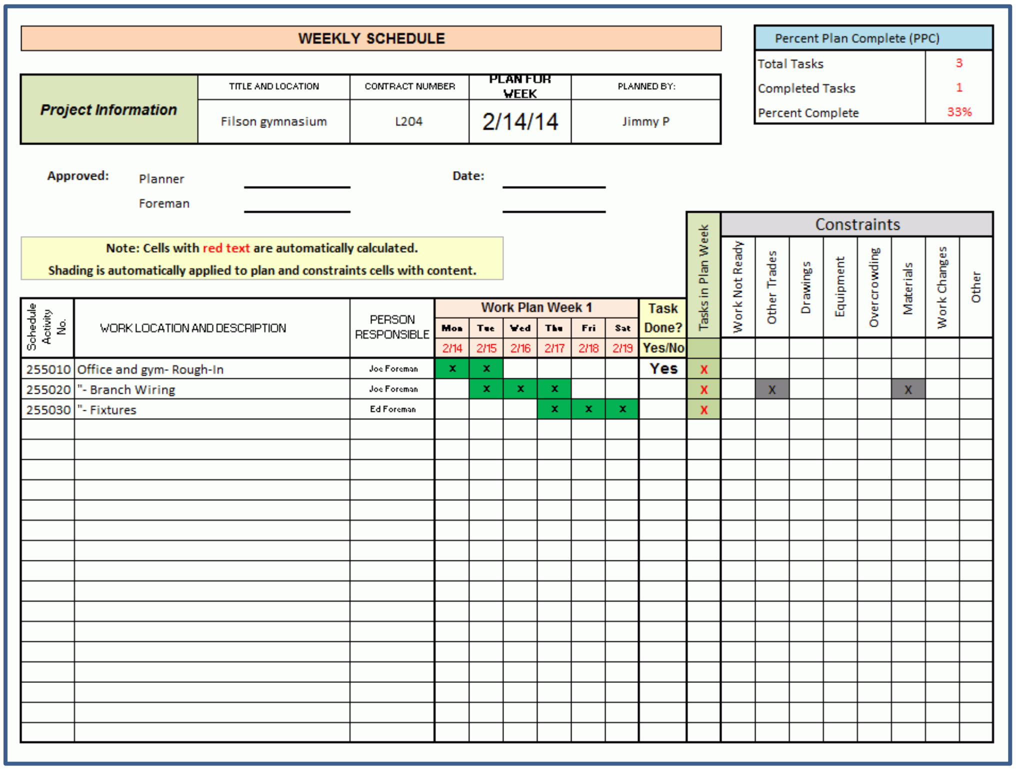
Figure 24 Weekly Work Plan Procedure

4.3.4.3 <u>Implementation Procedure</u>

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 date, status of constraints, and outstanding issues, if any.

FIWP's for the week should be identified and tracked on a form similar to Figure 23 above or Figure 25 below. The form should include the person responsible for each FIWP, completion status, issues or delay causes, and comments.



WEEKLY SCHEDULE

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

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

Approved: Planner ________ Foreman ________ Date: ________ ________

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

Schedule Activity No.	WORK LOCATION AND DESCRIPTION	PERSON RESPONSIBLE	Mon 2/14	Tue 2/15	Wed 2/16	Thu 2/17	Fri 2/18	Sat 2/19	Task Done? Yes/No	Tasks in Plan Week	Work Not Ready	Other Trades	Drawings	Equipment	Overcrowding	Materials	Work Changes	Other
			Work Plan Week 1								Constraints							
255010	Office and gym- Rough-In	Joe Foreman	x	x					Yes	x								
255020	"- Branch Wiring	Joe Foreman		x	x	x				x		X				X		
255030	"- Fixtures	Ed Foreman				x	x	x		x								

Figure 25 Weekly Schedule Form

Several tablet computer or smartphone apps, either stand-alone or integrated with scheduling software, are available for weekly or daily reporting. These may be useful in eliminating the need to transfer paper forms to computer applications and for faster reporting and analysis. These applications were not investigated.

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, including site access. If a 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 and 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 signoff weekly plan

If all constraints have been removed, then foremen will make a commitment and sign off on the weekly plan. Ideally, the weekly verification and commitment should occur during the weekly meeting.

4.3.5 Daily Plan

4.3.5.1 Objective & Scope

The daily plan specifies work planned for the day, individual work assignments, and safety practices. The objectives of the daily plan are:

- Providing clear work instruction to individual workers
- Confirming and allocating resources
- Emphasizing safety practices
- Monitoring work performance

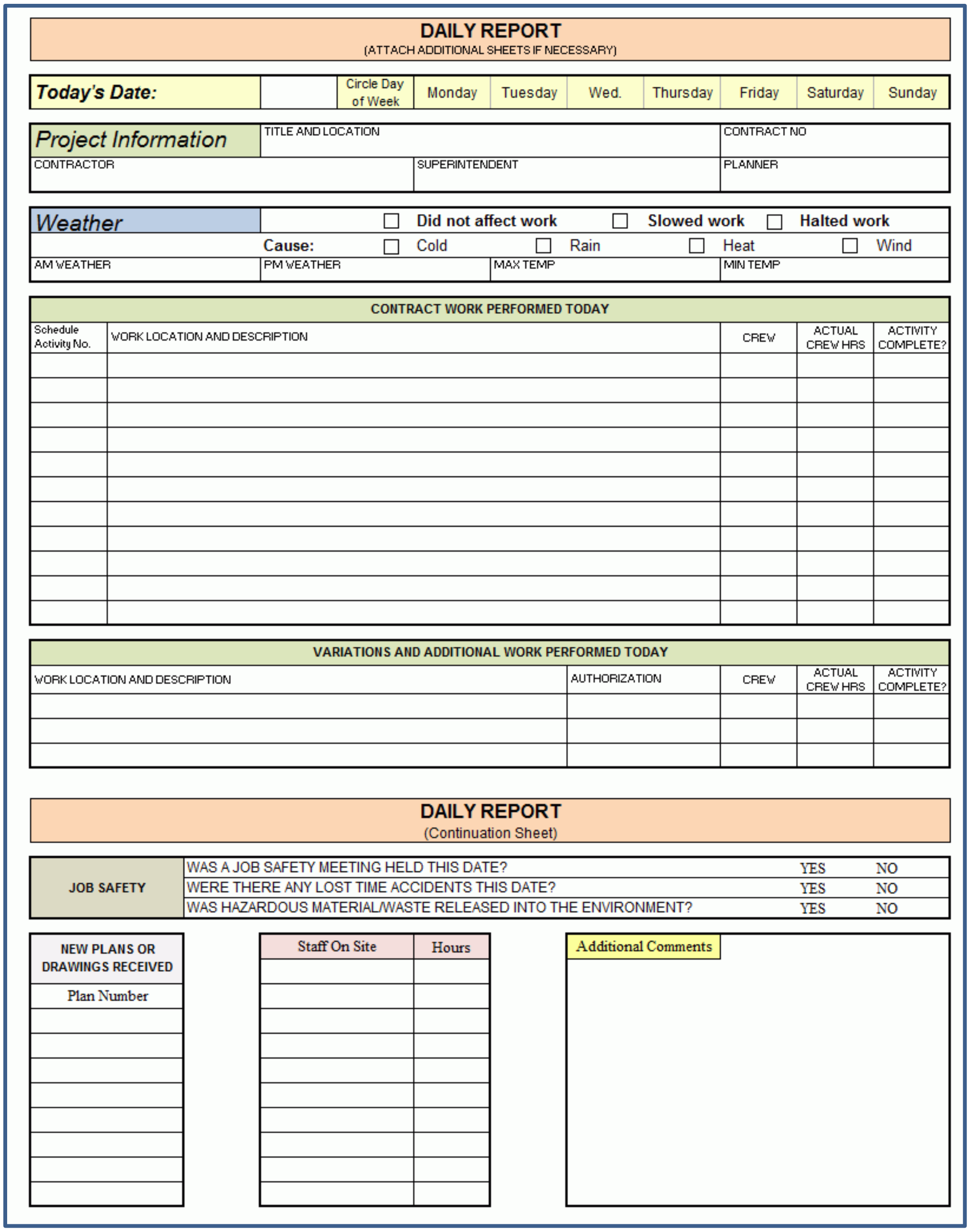
4.3.5.2 Recommended Practice

The daily plan for a particular day should be derived from the weekly work plan and prepared by the DP. The foreman should hold a daily huddle each morning to discuss any issues in the previous day’s work and work planned for the current day.

The daily huddle is a time each day when the crew comes together to discuss the plan for the day and makes 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. It helps align the crew while making them feel like they are part of the team.

4.3.5.3 Implementation Procedure

1. The DP communicates the daily plan to responsible foremen based on their committed weekly plan. The daily report form is shown in Figure 26.



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		CONTRACT NO
CONTRACTOR		SUPERINTENDENT	PLANNER

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?

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

Figure 26 Daily Report Form

2. Foreman conducts daily huddle.

Before the workday starts, the foreman will gather his/her team to deliver key information to align them for the day. A checklist for the daily huddle is shown in Figure 27.

DAILY HUDDLE CHECKLIST			
ACT.	COMPLETION DATE	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.

Figure 27 Daily Huddle Checklist (modified from Bowen Engineering 2013)

The foreman, with input from crew members, should identify each task to be accomplished and the method to do so. Each crew member should have a clear understanding of his or her assignments. The team should review performance and lessons learned from the previous day.

3. Foreman tracks daily performance

Tracking daily performance and identifying sources of problems are an important factor for improving job performance. Foremen should keep a daily record of work performance which includes a list of reasons for variance and additional unplanned work. The daily plan and report form in Figure 26 can be used for this purpose.

4.3.6 Measure & Improve

4.3.6.1 Objective & Scope

The purpose of tracking results is process improvement. The recommended tracking measure, PPC, is an indication of reliability of work completion. It is used to monitor performance and identify issues can be corrected or improved.

Numerous measures of productivity and performance exist. These may be performance relative to budget, labor hours, earned value, completion date, task duration, fraction of tool hours, and others. While each of these has its merits, it should be borne in mind that data gathering has a cost and that cost should be balanced against the benefit of the information. In addition, employees will resist record keeping for which they see no benefit.

4.3.6.2 Recommended Practice

The quality of a look-ahead schedule is measured by how closely it matches the actual field execution. The more work is completed by the scheduled completion time, the better the reliability of the LAS has been. The measure or measures chosen should be effective in describing productivity and efficient in collection. The single performance measure recommended as part of this best practice is Percent Plan Complete. It is objective, simple to record, and adequate to measure schedule performance against the plan.

> **Percent Plan Complete**: 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. A higher PPC number indicates a look-ahead schedule with better quality and reliability. Past studies also confirmed that there is a positive correlation between PPC and productivity (Ballard 1994, 1997). In other words, when PPC improves, productivity also improves. PPC reported by the industry has been repeatedly at levels below 60% (Ballard 2000). There is room for improvement.

4.3.6.3 Implementation Procedure

1. At the end of each week, the DP records PPC based on FIWP completion status and delay reasons, if any. PPC is the ratio of the number of completed FIWPs to the total number of FIWPs planned for the week.

$$PPC = \frac{Number\ of\ completed\ FIWPs}{Total\ number\ of\ planned\ FIWPs\ for\ the\ week}$$

- The status of FIWPs planned for the week is either completed or not completed. Only FIWPs that are 100% complete will be used for PPC calculation (Howell and Macomber 2013).
- FIWPs or activities that are performed but are not planned will not be counted toward PPC score. This is because a requirement to perform unplanned work is an indication of schedule quality issues.

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

2. Plot PPC; analyze PPC and root cause of delay

PPC should be analyzed in run charts as shown in Figure 28, which shows the trend of PPC over the past reporting periods.

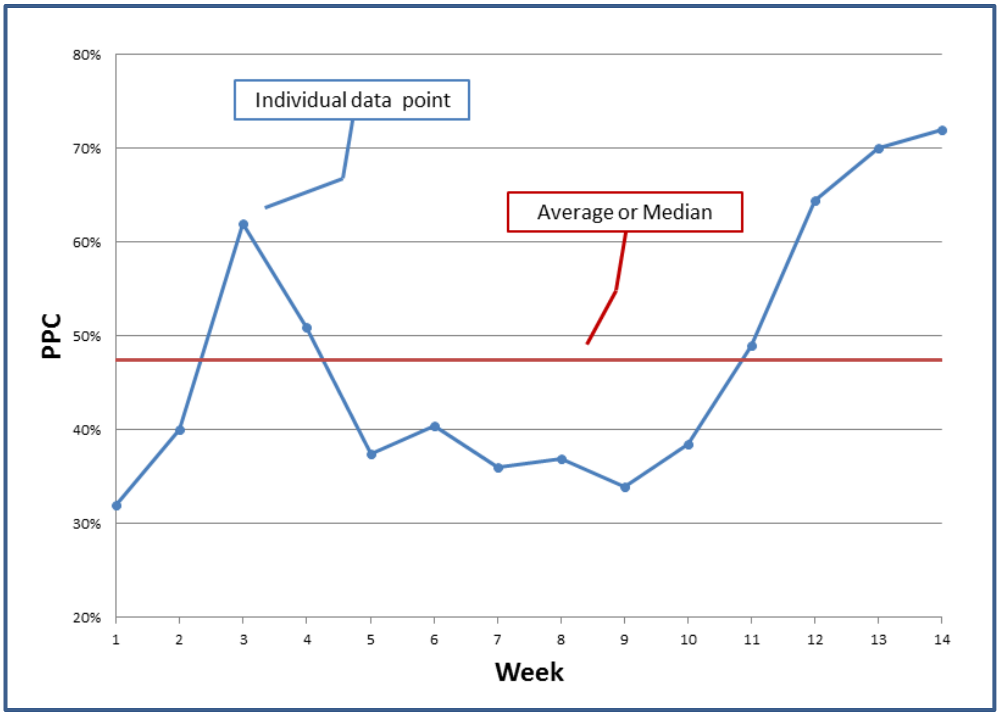


Figure 28 PPC Run Chart (Ballard 1994)

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 the 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:

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 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 (California Improvement Network 2013). 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. Interpretation aids for run charts are available in statistical software and spreadsheet add-ins, however, manual interpretation of both patterns and causes is needed to relate the observations to the work process.

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, however, patterns are often easily spotted. A concise discussion of run chart interpretation is available in Daneshgari (2010). Figure 29 shows four common patterns:

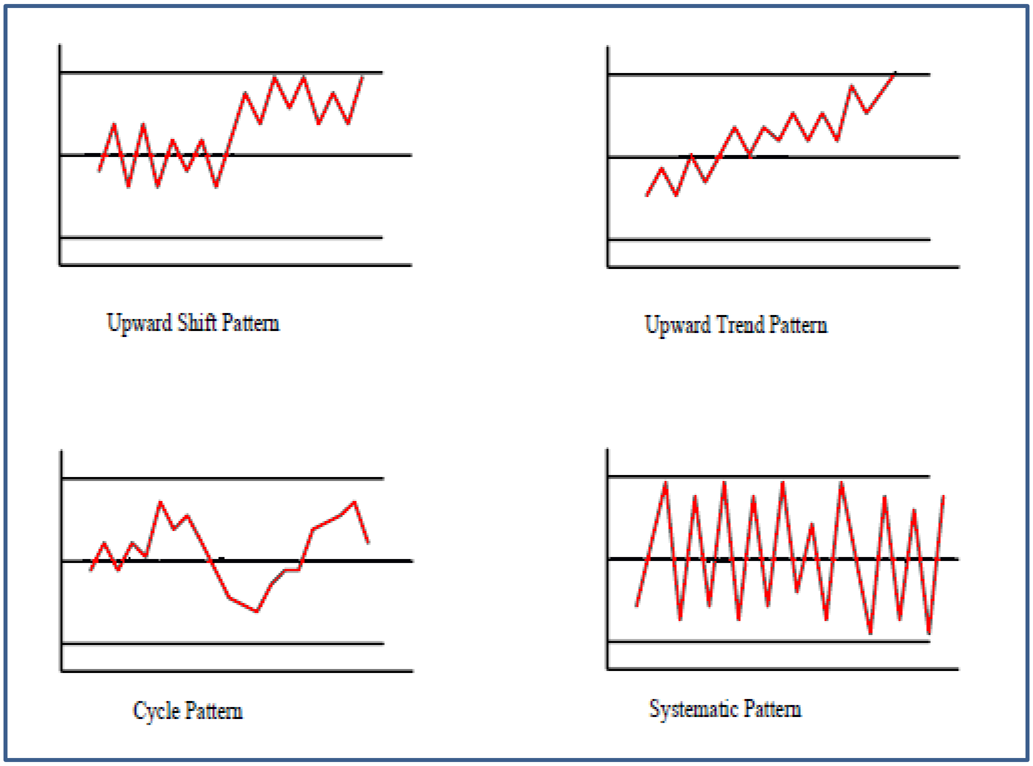


Figure 29 Example Run Chart Patterns (Guh et al. 2009)

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

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. 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. Figure 30 shows a sample Pareto chart. It ranks the causes in terms of their frequency.

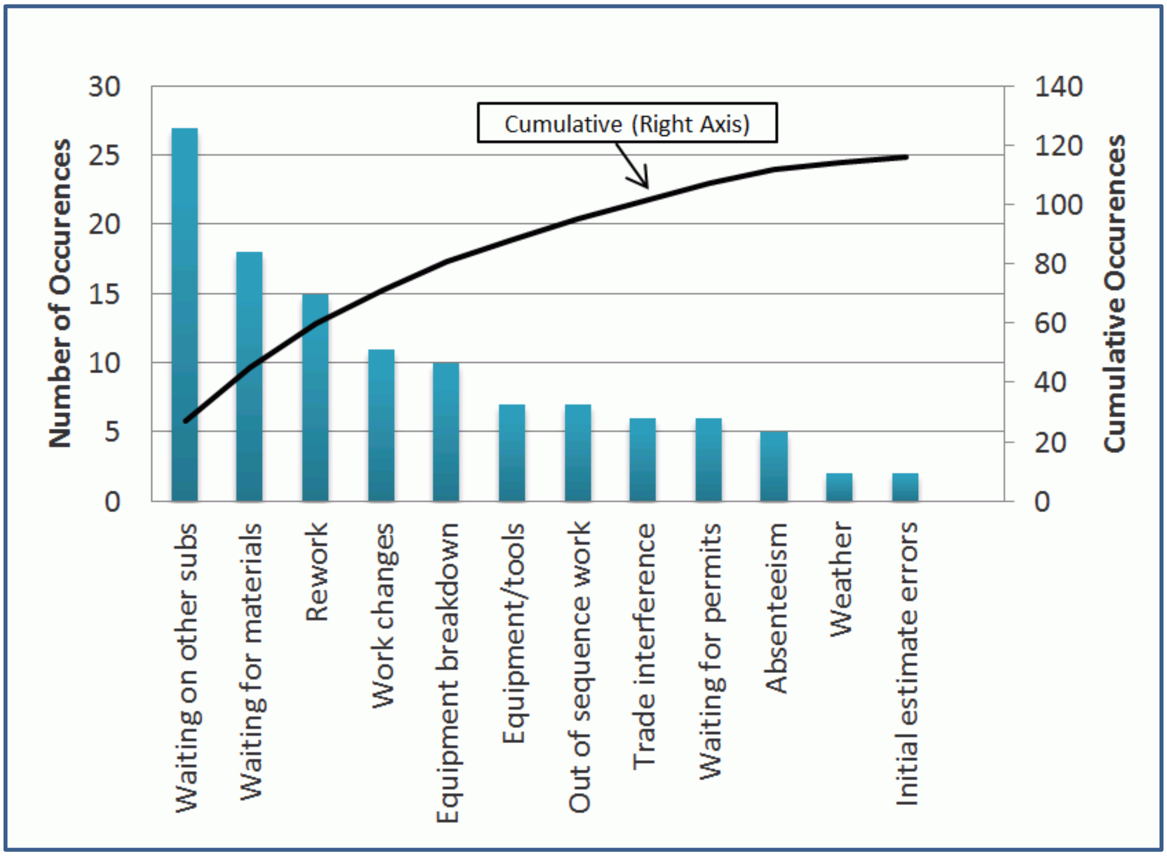


Figure 30 Pareto Chart of Delay Causes

As noted in Section 3.2.4.4, the apparent cause may not be the root cause. Some effort must be taken to identify the true source of the problem. An example of such an analysis is shown in Figure 31.

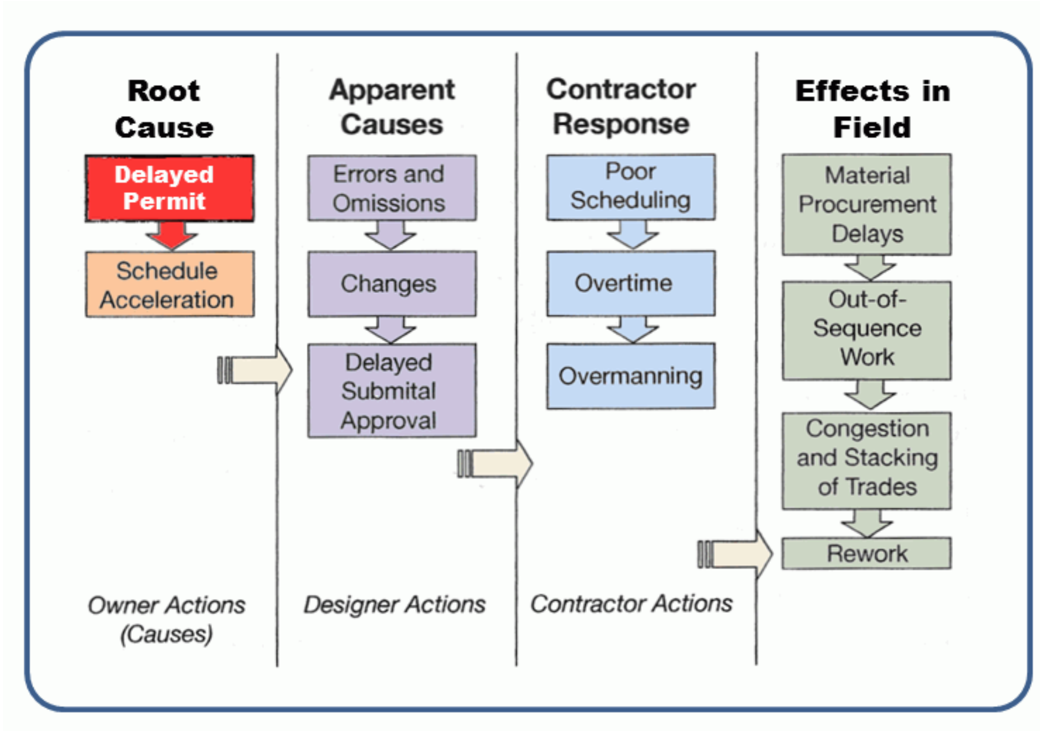


Figure 31 Root Cause Analysis (Thomas and Oloufa 2008)

In this example, the root cause of the numerous later delays was a delayed permit, shown in red. A superficial analysis might identify the resulting problems, such as delayed submittal approval or out-of sequence work, as the cause. It important to track the issues back to the true cause. The root cause may not be as early in the process as this example, however, corrective action cannot be effectively taken unless it is directed at the initial cause of a sequence of problems.

CHAPTER 5. CONCLUSIONS

5.1 Introduction

The importance of adequate planning is well known. A well-organized look-ahead scheduling process can significantly project efficiency. The procedures outlined and checklists provided here are based on proven methods. They can form a basis for an effective short term scheduling method that the electric contractor 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 but is likely to be most beneficial in medium and large scale projects.

5.2 Limitations

1. Respondents to the survey were predominantly owners or managers of medium to large firms. While their responses may be representative of the industry as a whole, some differences in the practices of small firms or the perceptions of field personnel may not have been captured.
2. While the survey participants were solicited by invitation, the survey was open to the public on SurveyMonkey. There is no way to verify that respondents were as reported.
3. The recommended practice has not been tested. This is planned as a separate part of ongoing research.
4. Although, the recommended practice is scalable, it will likely prove to be more effective on large and medium scale projects.

5.3 Recommendations for Future Research

1. The recommended scheduling process is based on proven scheduling techniques that have been demonstrated to reduce construction time and lower cost, however, it has not been tested in the field. A series of case studies in which the method would be practiced by an electrical contractor and

compared to performance on similar projects. The method should be tested in companies of different size and projects of varying type in order to identify the circumstances under which it is best applicable.

2. The production scheduling literature and the survey results indicate that human factors such as personality and working relations of the scheduler are important determinants in scheduling performance. This subject has received little attention in the construction literature. It is a potentially important factor which should be investigated.

REFERENCES

Ballard, G. (1994). "The Last Planner." Northern California Construction Institute, Monterey, California.

Ballard, G. (1997). "Lookahead planning: the missing link in production control." *Proc. 5th Annl. Conf. Intl. Group for Lean Constr.* Gold Coast, Australia, 13-26.

Ballard, G. (2000a). *Last planner system of production control*. Ph.D. Dissertation. Univ. of Birmingham, Birmingham, U. K., 2000.

Ballard, G. (2000b). "Lean Project Delivery System." <http://leanconstruction.org/media/docs/WP8-LPDS.pdf> (July 25, 2012).

Bielefeld, B. (2008). *Basics construction scheduling*, Birkhäuser, Berlin, Germany.

Blackmon, T., Saxena, R., & Song, L. (2011). "A Conceptual Framework for Total Constraint Management in Construction." *Proceedings of the 28th ISARC*, Seoul, Korea, 419-424.

Bowen Engineering. (2013). "Tips For A Great Daily Huddle Meeting." <https://www.youtube.com/watch?v=J7J3gyNoJJE> (Mar. 31. 2013).

California Improvement Network. (2013). "Using Run Charts." <http://www.calquality.org/programs/clinicalcare/meteor/documents/6.2.1RunChartResources.pdf> (Apr. 9, 2013).

Choo, H. J. (2003). *Distributed Planning and Coordination to Support Lean Construction.* Ph.D. Dissertation. Univ. of California, Berkeley, Berkeley, CA, 2003.

CII. (2009). *Craft Productivity Program - Phase 1*. Research Summary 252-1, CII, Austin, TX.

CII. (2011). *Enhanced work packaging: Design through workface execution*. Implementation Resource 272-2, CII, Austin, TX.

COAA. (2010) "Building Work Packages." <http://www.coaa.ab.ca/Portals/0/Building%20Work%20Packages.pdf> (Feb. 25, 2013).

COAA. (2011). "WorkFace Planning." <http://www.coaa.ab.ca/Productivity/WorkFacePlanning.aspx> (Dec. 31, 2011).

ConsensusDocs. (2013). "Contract Catalog." <https://www.consensusdocs.org/Catalog/collaborative> (Mar. 13, 2013).

Dai, J., Goodrum, P. M., & Maloney, W. F. (2009). "Construction craft workers' perceptions of the factors affecting their productivity." *Journal of Construction Engineering and Management*, 135(3), 217-226.

Daneshgari, P. (2010). *Agile Construction for the Electrical Contractor*, Jones and Bartlett, Sudbury, MA.

Dettmer, H. W. (1997). *Goldratt's theory of constraints: a systems approach to continuous improvement*, ASQC Quality Press, Milwaukee, WI.

Ennova. (2010). "The Application of Kanban to the Management of Construction Work Packages." <http://assets.envisionapp.com/Kanban-for-Work-Package-Management.pdf> (Sep. 21, 2012).

Goldratt, E. M. (1997). *Critical Chain*, North River Press, Great Barrington, MA.

Guh, R. S., Zorriassatine, F., Tannock, J. D. T., & O'Brien, C. (1999). "On-line control chart pattern detection and discrimination—a neural network approach." *Artificial Intelligence in Engineering*, 13(4), 413-425.

Hamzeh, F. R. (2009). Improving Construction Workflow: The Role of Production Planning and Control. Doctor of Philosophy in Engineering Dissertation, University of California, Berkeley, Berkeley, CA.

Hanna, A. S. (2009). *Electrical Pre-Construction Planning Process Implementation Manual*, ELECTRI International, Bethesda, MD.

Hinze, J. W. (2004). *Construction Planning and Scheduling*, Prentice Hall, Upper Saddle River, NJ.

Horman, M. J., Orosz, M. P., and Riley, D. R. (2006). “Sequence Planning for Electrical Construction.” *J. Const. Eng. & Manag.*, 132(4), 36-372.

Howell, G. and Ballard, G. (1998). “Implementing lean construction: understanding and action.” *Proc. 6 th Ann. Conf. Intl. Group for Lean Constr*.,Guaruja, Brazil.

Howell, G., and Ballard, G. (1999). "Design of construction operations." White Paper #4, *Lean Construction Institute Implementation Workshop*, Portland , OR.

Howell, G., & Macomber, P. H. (2013). “A Guide for New Users of the Last Planner System, Nine Steps for Success.” http://www.gregoryneilassociates.com/articles/last_planner_system_guide.pdf (Feb. 16, 2013).

Ireland, B. (2012). “The Labor Dilemma.” Electrical Construction & Management, <http://ecmweb.com/contractor/labor-dilemma> (Aug. 26, 2012).

Kelly, J. M. (2012). “2012 Profile of the Electrical Contractor.” Electrical Contractor, <http://www.ecmag.com/section/residential/2012-profile-electrical-contractor> (Aug. 25, 2012).

Kitchell Corporation. (2013). “Integrated Project Delivery (IPD).” <http://www.kitchell.com/services/integrated-project-delivery-ipd/> (Mar. 13, 2013).

Knapp, S., and Hunt, D. (2013). “Recommended Practices for the Application of LEAN Construction Methods to Building New Australian LNG Capacity.” http://www.engineersaustralia.org.au/sites/default/files/shado/Divisions/Western%20Australia%20Division/Technical%20Presentations/lean_construction_august_2012.pdf (Apr. 16, 2013).

Konchar, M., and Sanvido, V. (1998). ”Comparison of U.S. Project Delivery Systems.” J. Constr. Eng. Manage., 124(6), 435-444.

Kulkarni, A., Rybhowski, Z. K., and Smith, J. (2012). “Cost Comparison of Collaborative and IPD-like Project delivery methods versus Competitive Non-Collaborative Project Delivery methods.” *Proc. 20 th Ann. Conf. Intl. Group for Lean Constr*. <http://www.iglc20.sdsu.edu/papers/wp-content/uploads/2012/07/79%20P%20076.pdf> (Mar. 17, 2013).

McKay, K. N., and Weir, V. C. S. (2006). “The Human Factor in Planning and Scheduling.” *Handbook of Production Scheduling*, J. W. Herrmann, ed., Springer, New York, NY 23-57.

Mikaelsson, R. M., Liviniuk, T., Coughlin, J. (2011). “Managing the Lifecycle of a (sic) FIWP.” <http://www.coaa.ab.ca/LinkClick.aspx?fileticket=PXBg9DHEuYA%3D&tabid=143> (Sep. 20, 2012).

NECA. (2011). "Standing Policy Statements." <http://www.necanet.org/downloads/pdf/about/about-neca/governance/Standing_Policy_Statements.pdf> (Aug. 26, 2012).

Project Management Institute, Inc. (2008). *A Guide to the Project Management Body of Knowledge (PMBOK® Guide)*, Project Management Institute, Inc., Newtown Square, PA.

Rojas, E. M. (2009). *Construction Project Management: A Practical Guide for Building and Electrical Contractors*. J. Ross Publishing, Fort Lauderdale, FL.

Ryan, G. (2009). *Schedule for Sale: Workface Planning for Construction Projects*. AuthorHouse. Bloomington, IN.

Sears, S. K., Clough, R. H., & Sears, G. A. (2008). *Construction project management: a practical guide to field construction management*. John Wiley & Sons, Hoboken, NJ.

Siegelaub, J. M. "How PRINCE2® Can Complement the PMBOK® Guide and Your PMP®." <http://www.corpedgroup.com/resources/pm/HowPrince2CanComplement.asp> (Sep. 10, 2012).

Slootman, T. (2007). *Planning of Mega-Projects: Influence of execution planning on project performance*, Master Thesis, University of Twente, Enschede, The Netherlands.

Smith, J. G., and Hinze, J. (2010). *Construction management : subcontractor scopes of work.* CRC Press, Boca Raton, FL.

Song, L., & Liang, D. (2011). "Lean construction implementation and its implication on sustainability: a contractor's case study." *Canadian Journal of Civil Engineering*, 38(3), 350-359.

SurveyMonkey. (2012). "Smart Survey Design Guide." <http://s3.amazonaws.com/SurveyMonkeyFiles/SmartSurvey.pdf> (Aug. 27, 2012).

Teicholz, P. (2013). "Labor-Productivity Declines in the Construction Industry: Causes and Remedies (Another Look)." AECBytes, <http://www.aecbytes.com/viewpoint/2013/issue_67.html> (Mar. 16, 2013).

The Boldt Company. (2013). "Integrated Lean Project Delivery." <http://www.theboldtcompany.com/page/integrated-lean-project-delivery/> (Mar. 13, 2013).

The Realignment Group, Ltd. (2013). "Last Planner System." <http://www.projectrealign.com/lean-services/last-planner-system> (Mar. 17, 2013).

The Survey Question Bank. (2012). "The Question Bank Factsheets." <http://surveynet.ac.uk/sqb/datacollection/methodsfactsheets.asp> (Sep. 6, 2012).

Thomas, H. R., and Oloufa, A. (2008). "Negotiating Loss of Labor Inefficiency." *Construction Productivity: a Practical Guide for Building and Electrical Contractors*, E. M. Rojas, ed., J. Ross Publishing, Fort Lauderdale, FL, 201-235.

United States Census Bureau. (2013). "Industry Statistics Sampler NAICS 238210 Electrical Contractors." <https://www.census.gov/econ/industry/geo/g238210.htm> (Feb. 8, 2013).

Warren, G. (2012). “Workface Planning: Best Practices 2012.” <http://www.coaa.ab.ca/LinkClick.aspx?fileticket=pgMkNQ1Fibo%3D&tabid=391> (Sep. 22, 2012).

APPENDICES

Appendix A   Look-ahead Scheduling Survey

Electrical Contractor Scheduling Practice Survey

SurveyMonkey

1. What best describes your primary job function?

	Response Percent	Response Count
Owner	**46.7%**	**28**
Executive/Senior Manager	26.7%	16
Project Manager	18.3%	11
Project Engineer	0.0%	0
Superintendent	3.3%	2
Foreman	5.0%	3
Electrician	0.0%	0
	Other (please specify)	2
	answered question	**60**
	skipped question	**0**

2. What is your electrical construction experience?

	Response Percent	Response Count
Less than 5 years	1.7%	1
10-15 years	11.7%	7
More than 15 years	**86.7%**	**52**
	answered question	**60**
	skipped question	**0**

3. What type of company do you work for?

	Response Percent	Response Count
Electrical contractor	**95.0%**	**57**
Other trade contractor	0.0%	0
General contractor	5.0%	3
Construction management firm	0.0%	0
Other (please specify)		2
answered question		**60**
skipped question		**0**

4. Is your company a union shop or open shop?

	Response Percent	Response Count
Union shop	**61.7%**	**37**
Open shop	38.3%	23
answered question		**60**
skipped question		**0**

5. How large is your organization (total number of employees)?

	Response Percent	Response Count
Under 10	6.7%	4
10 - 19	8.3%	5
20 - 49	13.3%	8
50 - 100	20.0%	12
Over 100	**51.7%**	**31**
	answered question	**60**
	skipped question	**0**

6. What is your company's annual revenue from electrical work?

	Response Percent	Response Count
Less than $250,000	1.7%	1
$250,000 to $500,000	3.3%	2
$500,000 to $1 million	3.3%	2
$1 million to $2.5 million	8.3%	5
$2.5 million to $10 million	23.3%	14
$10 million to $25 million	18.3%	11
Over $25 million	**41.7%**	**25**
	answered question	**60**
	skipped question	**0**

7. What type of work does your company typically perform? Check all that apply.

	Response Percent	Response Count
New construction	**95.0%**	**57**
Addition or expansion	91.7%	55
Modernization/Retrofit	88.3%	53
Maintenance/Service/Repair	91.7%	55
Other (please specify)	8.3%	5
	answered question	**60**
	skipped question	**0**

8. What best describes the project types your company works in? Check all that apply.

	Response Percent	Response Count
Industrial	63.3%	38
Commercial	**90.0%**	**54**
Institutional (schools,hospitals,etc)	68.3%	41
Single family residential	13.3%	8
Multi-family residential	25.0%	15
Voice/Data/Video	53.3%	32
Power	43.3%	26
Other (please specify)	10.0%	6
	answered question	**60**
	skipped question	**0**

9. Where is the majority of your company's work performed? Check all that apply. (See map below for region boundaries.)

	Response Percent	Response Count
West	10.0%	6
Midwest	23.3%	14
Northeast	15.0%	9
South	**55.0%**	**33**
Canada	3.3%	2
	answered question	**60**
	skipped question	**0**

10. What are the typical types of schedule/plan used in your company? Choose all that apply.

	Response Percent	Response Count
Master project schedule	**78.0%**	**46**
Monthly schedule	30.5%	18
Multi-week schedule (e.g. 2, 3 ... weeks)	47.5%	28
Weekly schedule	49.2%	29
Daily schedule (for all activities during a day)	50.8%	30
Pre-task plan (plan for an individual task)	40.7%	24
None	3.4%	2
Other (please specify)	1.7%	1
	answered question	**59**
	skipped question	**1**

11. Is your company usually involved in the general contractor's (GC) master scheduling effort?

	Response Percent	Response Count
Yes	32.2%	19
No	16.9%	10
Sometimes, depends on projects	**50.8%**	**30**
	answered question	**59**
	skipped question	**1**

12. When your company is involved in GC's master scheduling, what is your ability to influence the master schedule?

	Response Percent	Response Count
High	11.9%	7
Medium	**49.2%**	**29**
Low	27.1%	16
Not applicable	11.9%	7
	answered question	**59**
	skipped question	**1**

13. The remaining survey questions refers to "Look-ahead" schedules (i.e. short-interval schedule or similar), which is defined here as "a more detailed plan showing upcoming work to be done for a relatively short time window." What is the typical scheduling horizon in your look-ahead schedule?

	Response Percent	Response Count
1 week	18.6%	11
2 weeks	**35.6%**	**21**
3 weeks	30.5%	18
4 weeks	8.5%	5
5-6 weeks	1.7%	1
7-9 weeks	0.0%	0
More than 9 weeks	0.0%	0
No look-ahead schedule used	5.1%	3
	Other (please specify)	3
	answered question	**59**
	skipped question	**1**

14. Who has the primary responsibility for managing the look-ahead schedule (i.e. develop, maintain, and update)?

	Response Percent	Response Count
Project manager	**30.8%**	**16**
Project engineer	0.0%	0
Project coordinator	0.0%	0
Dedicated scheduler/project control	7.7%	4
Superintendent	**30.8%**	**16**
Foreman	25.0%	13
Other (please specify)	5.8%	3
	answered question	**52**
	skipped question	**8**

15. What are the individuals typically involved/consulted in defining task scope, duration, and sequence when creating a look-ahead schedule? Choose all that apply.

	Response Percent	Response Count
Project manager	**84.6%**	**44**
Project engineer	13.5%	7
Project coordinator	9.6%	5
Dedicated scheduler/project control	7.7%	4
Superintendent	65.4%	34
Foreman	80.8%	42
Other (please specify)	5.8%	3
	answered question	**52**
	skipped question	**8**

16. What are the main purposes of using look-ahead schedules? Choose all that apply.

	Response Percent	Response Count
Ensure labor supply	**92.3%**	**48**
Ensure materials supply	86.5%	45
Ensure equipment/tool supply	76.9%	40
Better coordination with GC	78.8%	41
Better coordination with other trades	75.0%	39
Have a backup plan for interruptions	26.9%	14
Measure/track project performance	36.5%	19
Comply with contract documentation requirements	26.9%	14
Keep records for claims/dispute resolution	25.0%	13
Other (please specify)	1.9%	1
	answered question	**52**
	skipped question	**8**

17. What are the formats used in your look-ahead schedule? Choose all that apply.

	Paper form	Spreadsheet	Other electronic form	Rating Count
Bar/Gantt chart	**43.5% (10)**	**43.5% (10)**	39.1% (9)	23
Calendar chart	**69.0% (20)**	27.6% (8)	27.6% (8)	29
CPM chart	35.3% (6)	**41.2% (7)**	**41.2% (7)**	17
Daily schedule form	**87.1% (27)**	25.8% (8)	12.9% (4)	31
Pre-task plan form	**77.3% (17)**	36.4% (8)	9.1% (2)	22
			Other (please specify)	3
			answered question	**52**
			skipped question	**8**

18. Do you use project planning software? If so, is it used for look-ahead scheduling?

	Used	Used for Look-ahead Scheduling	Rating Count
Microsoft Project	**100.0% (17)**	35.3% (6)	17
Primavera P3/P6	**100.0% (14)**	42.9% (6)	14
Primavera Contractor	**100.0% (4)**	75.0% (3)	4
Suretrack	**85.7% (6)**	42.9% (3)	7
ConEst	**100.0% (4)**	50.0% (2)	4
Accubid	**100.0% (10)**	30.0% (3)	10
		Other (please specify)	3
		answered question	**31**
		skipped question	**29**

19. How frequently are look-ahead schedules usually updated?

	Response Percent	Response Count
Daily	9.6%	5
Every 2-4 days	3.8%	2
Every week	**73.1%**	**38**
Every 2 week	1.9%	1
Every 3-4 week	1.9%	1
Not updated regularly	9.6%	5
	answered question	**52**
	skipped question	**8**

20. What is the average duration of tasks in your look-ahead schedule?

	Response Percent	Response Count
1 day	13.5%	7
2-3 days	25.0%	13
4-5 days	26.9%	14
1-2 weeks	**32.7%**	**17**
More than 2 weeks	1.9%	1
	answered question	**52**
	skipped question	**8**

21. What are the typical elements specified when planning a task? Choose all that apply.

	Response Percent	Response Count
Work scope	90.4%	47
Responsibility	42.3%	22
Prerequisite work	51.9%	27
Labor needed	**92.3%**	**48**
Equipment/tool needed	75.0%	39
Drawing reference	26.9%	14
Quality specification reference	13.5%	7
Quality inspection & testing activities	21.2%	11
Hazard & safety	44.2%	23
None	0.0%	0
Other (please specify)		1
answered question		**52**
skipped question		**8**

22. Is there a process to check that all required elements are available before giving a foreman/crew a go-ahead for a task?

	Response Percent	Response Count
Yes, checked by Project Manager/Engineer or Coordinator/Scheduler	17.3%	9
Yes, checked by Superintendent	15.4%	8
Yes, checked by foreman	23.1%	12
No	17.3%	9
Varies with jobs	**25.0%**	**13**
Varies with general contractor.	1.9%	1
	Other (please specify)	3
	answered question	**52**
	skipped question	**8**

23. Usually, how far ahead (before the planned start date), a foreman is informed about his/her upcoming task?

	Response Percent	Response Count
1 day ahead	9.6%	5
2-3 days ahead	**32.7%**	**17**
4-5 days ahead	13.5%	7
1-2 weeks ahead	28.8%	15
More than 2 weeks ahead	15.4%	8
	answered question	**52**
	skipped question	**8**

24. Is there a pre-defined contingency plan (i.e. alternative tasks from a backlog) if a planned task deviates from the original plan?

	Response Percent	Response Count
Yes, always	9.6%	5
Yes, sometimes	**63.5%**	**33**
No, will identify alternative plan after a deviation happens	26.9%	14
	answered question	**52**
	skipped question	**8**

25. Do you often have a personal opinion of the schedule that is different from the official schedule?

	Response Percent	Response Count
Yes	**44.7%**	**21**
No	12.8%	6
Varies	42.6%	20
	answered question	**47**
	skipped question	**13**

26. If your opinion of the schedule is different, is it generally

	Response Percent	Response Count
Shorter	15.4%	6
Longer	**53.8%**	**21**
Same duration, but different work sequence	30.8%	12
	Other (please specify)	5
	answered question	**39**
	skipped question	**21**

27. Your look-ahead schedule is typically shared with (choose all that apply):

	Response Percent	Response Count
GC	**61.5%**	**32**
Other relevant trade contractors	40.4%	21
Internal use only	55.8%	29
	Other (please specify)	3
	answered question	**52**
	skipped question	**8**

28. If you share a plan with other contractors, is it verbal or written?

	Response Percent	Response Count
Only verbal	23.1%	12
Only written	13.5%	7
Both	**36.5%**	**19**
Depends on contractor	26.9%	14
	answered question	**52**
	skipped question	**8**

29. How does your company verify whether prerequisite work controlled by other contractors are satisfied before beginning a task? Choose all that apply.

	Response Percent	Response Count
Read from master schedule	25.0%	13
Regular contractor meeting	65.4%	34
Personal site visit & inspection	**73.1%**	**38**
Direct inquiry to those contractors	46.2%	24
	Other (please specify)	1
	answered question	**52**
	skipped question	**8**

30. How is schedule performance of a task typically measured? Choose all that apply.

	Response Percent	Response Count
Planned vs. actual task duration	**64.6%**	**31**
Planned vs. actual task productivity	31.3%	15
Planned vs. actual task START date	41.7%	20
Planned vs. actual task FINISH data	52.1%	25
Other (please specify)		2
answered question		**48**
skipped question		**12**

31. How would you rate the effectiveness of your current look-ahead scheduling practice?

	Very Ineffective	Ineffective	Neutral	Effective	Very effective	Rating Average	Rating Count
Scheduling effectiveness	4.2% (2)	10.4% (5)	**41.7% (20)**	35.4% (17)	8.3% (4)	3.33	48
answered question							**48**
skipped question							**12**

32. Please indicate the impact level of the following issues on schedule deviation:

	Very Low	Low	Medium	High	Very High	Rating Average	Rating Count
Understaffed	10.6% (5)	21.3% (10)	27.7% (13)	**29.8% (14)**	10.6% (5)	3.09	47
Waiting for materials	4.3% (2)	25.5% (12)	21.3% (10)	**34.0% (16)**	14.9% (7)	3.30	47
Waiting for equipment/tools	12.8% (6)	**29.8% (14)**	19.1% (9)	25.5% (12)	12.8% (6)	2.96	47
Waiting for permits	23.4% (11)	**25.5% (12)**	23.4% (11)	14.9% (7)	12.8% (6)	2.68	47
Equipment breakdown	**26.1% (12)**	23.9% (11)	**26.1% (12)**	10.9% (5)	13.0% (6)	2.61	46
Other subs behind schedule	2.1% (1)	2.1% (1)	25.0% (12)	33.3% (16)	**37.5% (18)**	4.02	48
Out of sequence work	0.0% (0)	8.5% (4)	31.9% (15)	**34.0% (16)**	25.5% (12)	3.77	47
Overcrowding	2.1% (1)	20.8% (10)	**27.1% (13)**	**27.1% (13)**	22.9% (11)	3.48	48
Interference with other trades/stacking of trades	4.3% (2)	10.6% (5)	23.4% (11)	**31.9% (15)**	29.8% (14)	3.72	47
Unclear instructions/waiting for instructions	4.3% (2)	17.0% (8)	**34.0% (16)**	21.3% (10)	23.4% (11)	3.43	47
Drawings unclear or incorrect	6.3% (3)	6.3% (3)	25.0% (12)	**37.5% (18)**	25.0% (12)	3.69	48
Shortage of skilled labor	17.0% (8)	19.1% (9)	**31.9% (15)**	17.0% (8)	14.9% (7)	2.94	47
Poor crew performance	4.3% (2)	25.5% (12)	**36.2% (17)**	19.1% (9)	14.9% (7)	3.15	47
Absenteeism	12.8% (6)	**29.8% (14)**	21.3% (10)	21.3% (10)	14.9% (7)	2.96	47
Initial estimate errors	10.9% (5)	**54.3% (25)**	21.7% (10)	8.7% (4)	4.3% (2)	2.41	46

Work changes	2.1% (1)	12.8% (6)	31.9% (15)	**40.4% (19)**	12.8% (6)	3.49	47
Rework	12.8% (6)	**31.9% (15)**	12.8% (6)	14.9% (7)	27.7% (13)	3.13	47
Weather	12.8% (6)	19.1% (9)	**48.9% (23)**	14.9% (7)	4.3% (2)	2.79	47
						Other (please specify)	0
						answered question	**48**
						skipped question	**12**

33. Please indicate your level of agreement with whether the following efforts would further improve your look-ahead scheduling effectiveness:

	Strong disagree	Disagree	Neutral	Agree	Strongly agree	N/A	Rating Average	Rating Count
More involvement of electrical contractors in GC's master scheduling effort	4.3% (2)	0.0% (0)	10.6% (5)	**42.6% (20)**	**42.6% (20)**	0.0% (0)	4.19	47
More involvement of electrical contractors in the engineering/design phase	4.3% (2)	0.0% (0)	12.8% (6)	34.0% (16)	**48.9% (23)**	0.0% (0)	4.23	47
Further detailed breakdown of schedule at the field operation level	4.3% (2)	8.7% (4)	15.2% (7)	**47.8% (22)**	23.9% (11)	0.0% (0)	3.78	46
More involvement of foreman in multi-week look-ahead scheduling effort	0.0% (0)	4.3% (2)	14.9% (7)	**40.4% (19)**	**40.4% (19)**	0.0% (0)	4.17	47
Training of foreman on look-ahead scheduling	0.0% (0)	8.5% (4)	8.5% (4)	40.4% (19)	**42.6% (20)**	0.0% (0)	4.17	47
Establishing a procedure to satisfy prerequisite work before releasing tasks to crew	2.1% (1)	8.5% (4)	23.4% (11)	**42.6% (20)**	23.4% (11)	0.0% (0)	3.77	47
Improving sharing of look-ahead schedules with GC and other trades	2.1% (1)	6.4% (3)	29.8% (14)	**42.6% (20)**	19.1% (9)	0.0% (0)	3.70	47
Extending the schedule horizon (e.g. from 1 week to multi-weeks)	0.0% (0)	10.6% (5)	23.4% (11)	**48.9% (23)**	17.0% (8)	0.0% (0)	3.72	47
Having a plan B when original plan is interrupted	0.0% (0)	0.0% (0)	36.2% (17)	**44.7% (21)**	19.1% (9)	0.0% (0)	3.83	47
Visualizing scheduling information for better understanding and sharing	2.1% (1)	0.0% (0)	25.5% (12)	**46.8% (22)**	25.5% (12)	0.0% (0)	3.94	47
Collecting actual field data to identify performance issues	2.1% (1)	0.0% (0)	31.9% (15)	**38.3% (18)**	27.7% (13)	0.0% (0)	3.89	47
							Other (please specify)	0
							answered question	**47**
							skipped question	**13**

34. If look-ahead scheduling is not used, what are the reasons? Choose all that apply.

	Response Percent	Response Count
Satisfied with current practice	0.0%	0
Tried and didn't see improvement	**50.0%**	**1**
Don't think it will work	0.0%	0
Implementation costs too high	0.0%	0
Too busy to do	**50.0%**	**1**
Not familiar with the method	**50.0%**	**1**
	Other (please specify)	1
	answered question	**2**
	skipped question	**58**

35. Please provide any other comments you think would be helpful.

	Response Count
	8
answered question	**8**
skipped question	**52**

36. Thank you for taking the survey! If you wish to receive the final survey results, please provide your email address below. (We will not release or use it for any other purposes):

		Response Count
		38
	answered question	**38**
	skipped question	**22**

Appendix B Follow-up Email Questions

- On what percent of your jobs does the GC hold regular coordination meetings with all subs? How often?
- How do you typically communicate with other subs to avoid coordination issues (e.g. delay and stacking of trades)?
- Drawings were identified in the survey as one of the major reasons for schedule delay, but are not typically considered as an important item during look-ahead scheduling. What is your practice in ensuring drawings are ready for crews?
- If you have a backup plan to deal with interrupted tasks (e.g. due to weather delay or missing material), what is the nature/type of work specified in your backup plan? How effective is the backup plan in minimizing the impact of task interruption?
- Many survey respondents indicate “More involvement of electrical contractors in the engineering/design phase” as a way for improving construction performance. If you agree, what would be the inputs that an electrical contractor can bring to the design table? How could the information be presented?

FIELD INSTALLATION WORK PACKAGE

Project Number	4151066
Project Name:	Spears Rd. 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.

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:	Wire pulling trailer 2" rope 5" mandrel
Tools:	(1)-Wire Tugger (6)-Wire pulling sheaves (1)-Hydraulic crimper

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:	Wire pulling trailer 2" rope 5" mandrel
Tools:	(1)-Wire Tugger (6)-Wire pulling sheaves (1)-Hydraulic crimper
Special Conditions:	Apply fireproofing tape to individual conductors in manholes. Refer to E-24 for detail.
Quality Control:	Follow manufacturers instructions when installing stress cone terminations.