

THE LAST PLANNER SYSTEM FOR
RELIABLE PROJECT DELIVERY

By

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ABSTRACT

THE LAST PLANNER SYSTEM FOR RELIABLE PROJECT DELIVERY

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The Last Planner System is a production planning system designed to produce predictable work flow and rapid learning in programming, design, construction and commissioning of projects.

The Last Planner System (LPS) is developed by Glenn Ballard and Greg Howell as a production planning and control system to assist in smoothing variations in construction work flow, developing planning foresight, and reducing uncertainty in construction operations. The LPS challenges the old practices of developing schedules and pushing them from top management down to frontline people to execute. It advocates collaborative planning, performing collaborative constraint analysis, and learning from planning failures. The LPS is not only a system for production planning and control but also an enabler for social exchange on construction projects. It institutionalizes coordination and communication by incorporating them

into everyday activities and into a managerial structure for project planning and control, team building, and continuous improvement.

The primary results of implementing LPS, including benefits, barriers, and the critical success factors for a commercial construction project are presented in this thesis. The results demonstrate numerous benefits in terms of improving construction planning and site management. However, there were some potential barriers reported which hinder the achievement of full potential of LPS. Finally, a comparison between pre- and post-implementation outcomes for the case study is briefly presented.

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LIST OF ABBREVIATIONS

3WLAP	Three Week Look-ahead Planning
6WLAP	Six Week Look-ahead Planning
AEC	Architecture, Engineering, and Construction
BS	Baseline Schedule
CO	Change Order
CPM	Critical Path Method
CSFs	Critical Success Factors
EVM	Earned Value Method
GC	General Contractor
IPD	Integrated Project Delivery
JIT	Just-in-Time
LAP	Look-ahead Planning
LCI	Lean Construction Institute
LP	Last Planners
LPS	Last Planner System
PCT	Percent Complete
PPC	Percent Plan Complete
PPS	Phase Pull Schedule
RFI	Request For Information
SCM	Supply Chain Management
TQM	Total Quality Management
UTA	University of Texas at Arlington
WWP	Weekly Work Plan

CHAPTER 1

INTRODUCTION

This chapter presents a brief introduction of the Last Planner System as a key technique of Lean Construction philosophy to ensure reliable project delivery. It also discusses objectives and methodology conducted to accomplish the expected outcome of the research.

1.1 Background

Surveys indicate that up to 30% of construction costs are due to inefficiencies, mistakes, delays, and poor communications (Forbes et al. 2004). The construction industry faces many similar obstacles in both the developed and developing nations. In both nations the concept of construction performance does not emphasize on productivity and quality initiatives. The work of many researchers has revealed an industry tendency to measure performance in terms of the following: completion on time, completion within budget, and meeting construction codes. Very little attention has been directed to owner satisfaction as a performance measure.

Traditionally, the typical research in the field of construction management tends to be description and explanation driven, which are insufficient to solve persistent managerial problems (Alsehami and Koskela, 2008a). In this context, Alsehami and Koskela (2008b) proposed that rather than solely explanatory studies, novel management techniques could be developed and practically implemented in non-traditional research approaches such as constructive and action research. This may help to address some of the persistent managerial difficulties, enhance performance, and contribute to knowledge in construction management.

Lean construction maximizes value and reduces waste. It accomplishes these objectives through the use of Supply Chain Management (SCM) and Just-In-Time (JIT) techniques as well

as the open sharing of information between all the parties involved in the production process. Lean concept, developed by Taichii Ohno in the 1950s, is based on lean manufacturing. The lean philosophy includes minimizing waste in all forms and continuous improvement of processes and systems.

Ballard and Howell designed the Last Planner System as one of the methods for applying lean techniques to construction. It provides productive unit and workflow controls and facilitates quick response to correct for deviations from expected outcomes by using root cause analysis. Control is defined as “causing events to conform to plan,” as opposed to the construction tradition of monitoring progress against schedule and budget projections.

Last Planner System (LPS) focuses on reducing workflow uncertainty. It was developed to assist the project planner in reducing the uncertainty inherent in the planning process. LPS makes use of a systematic planning procedure to produce reliable work plans aimed at shielding the downstream work processes from upstream uncertainty by using commitment planning and by matching work load to available resources. Kartam describes the Last Planner as, “the person responsible for producing the last level of plans in the planning hierarchy” (Kartam et al. 1995a, 1995b).

Architecture, Engineering, and Construction (AEC) processes are inherently variable and uncertain. The Last Planner System (LPS) has been successfully implemented in construction projects to increase the reliability of planning, increase production performance, and improve workflow in design and construction operations (Ballard & Howell, 2004). The Last Planner System offers a systematic process for construction planning, given that the organizations involved have embraced a “lean” philosophy.

The following chapter, Literature Study, discusses Lean Construction Philosophy and Last Planner System in detail.

1.2 Need Statement

The motivation to write a thesis on this topic arrived from several and varied resources. The author's interest in lean philosophy originally comes from an extensive study of previous researches related to implementation of lean process in construction industry.

Another source of motivation was the industry itself, where all firms were focusing and attempting to fulfill the increasing demand of Integrated Project Delivery (IPD) as a key to success. Also, the concept of sustainability is very closely linked to lean construction in several aspects. While it is desirable to use lean methods to construct buildings and facilities with little waste and as cost effectively as possible, it is also highly important to design them such that they will operate in a manner that promotes the sustainability of natural resources.

1.3 Objectives

The main objective of this thesis is to analyze results of implementing the Last Planner System in the construction industry through a case study.

This research also aims to,

1. Measure and evaluate improvements or changes to project planning and controlling system resulting from implementation of last planner system.
2. Document and evaluate responses from project key players and participants.

1.4 Scope

Last planner implementation strategy is based on basic assumptions derived from past researches in the same area. The scope of this thesis limited to implementation and evaluation of last planner system of lean construction among several available techniques and tools. Due to time constraints, the current research was restricted to only one live case study of commercial construction industry. Results derived from the analysis will be generalized for applicability to other construction projects.

1.5 Methodology

This study was carried out in five major stages. Figure 1.1 shows the flow of these stages. The methodology of this thesis is summarized below:

1. Literature study – an intensive study of previous work in the area of lean construction which assisted the author in developing implementation strategy.
2. Research Design – this stage focused on developing an initial framework for implementing last planner system on selected case study.
3. Data Collection – methods for data collection which included direct observation, interviews and questionnaires, and documentary analysis.
4. Data Analysis and Evaluation – a simple yet meaningful analysis of measured data and evaluation of LPS implementation fulfilled objectives of this thesis.
5. Final Report – an overview of the outcomes of study have been documented in this thesis report.

1.6 Expected Outcomes

This thesis aims to produce the following outcomes:

1. The benefits of last planner system will be demonstrated by the improved performance of project planning process at each and every phase.
2. The industry will be provided with a study that reports obstacles and issues associated with implementation of last planner system on a construction project.
3. Also, recommendations and suggestions will be proposed to overcome such difficulties for the effective implementation of LPS.

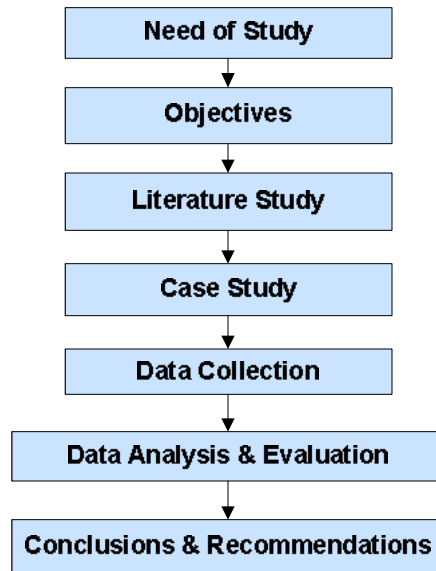


Figure 1.1: Research Framework

1.7 Structure of Thesis

Chapter 1 presents introduction, need statement, methodology and expected outcome of this research. Chapter 2 provides a literature review on the Last Planner System and tools to implement LPS. Chapter 3 describes a LPS implementation strategy in detail by giving a step by step narrative. Chapter 4 outlines results of the research. Chapter 5 draws conclusions and offers recommendations for further study. References and appendices are provided at the end of this research.

1.8 Chapter Summary

This chapter included the issues with the current construction industry and the concept of Lean Construction as a solution for these issues. This chapter also included the need, objectives, methodology, and expected outcomes of this research.

CHAPTER 2

LITERATURE STUDY

2.1 Introduction

This chapter consists of a review of findings from a comprehensive literature search that was conducted as part of this research. As discussed in Chapter 1, a literature search was used as one of the means to understand more about existing research works on this topic and to get better knowledge of Last Planner System. The subjects searched include (i) Key Principles of Lean Construction, (ii) Lean Philosophy of Project Planning, (iii) Last Planner System, (iv) Should-Can-Will-Did analysis, (v) Last Planner System Essentials

2.2 Key Principles of Lean Construction

Womack and Jones (1996) identified following five key principles for the basis of design of any lean construction system.

- Value: There is a need to clarify the customer's needs in order to clarify activities or products that signify value.
- Value Stream: By mapping the whole value stream, establishing cooperation between the participants, and identifying and eliminating waste, the construction process can be improved.
- Flow: Business flow includes project information (specifications, contracts, plans, etc.). Job site flow involves the activities and the way they have to be done.
- Supply flow: refers to the materials used in a project.
- Pull: The efforts of all participants stabilize pulls during the construction process.
- Perfection: Work instructions, procedures and quality controls are established.

2.3 Lean Philosophy of Project Planning

According to Ballard (1994), one of the most effective ways to increase productivity is to plan more efficiently, improving production by reducing delays, getting the work done in the best constructability sequence, matching manpower to available work, coordinating multiple interdependent activities, etc. In Lean Construction, planning and control are considered to be complementary and dynamic processes maintained during the course of the project. Planning defines the criteria and creates the strategies required to reach the project objectives. At the same time, control makes sure that each event will occur following the planned sequence. Re-planning must be done when the previously established sequences are no longer applicable or convenient. Feedback facilitates learning when the events do not occur as planned (Ballard 2000; Howell 1999). Howell (1999) argued that control is redefined from “monitoring results” to “making things happen.” A planning system’s performance is measured and improved to assure reliable workflow and predictable project outcomes. In Lean Construction as in much in manufacturing, planning and control are two sides of a coin that revolves throughout a project:

- Planning: defining criteria for success and producing strategies for achieving objectives.
- Control: causing events to conform to plan and promoting learning and re-planning.

Ballard (1994) states that better planning results from overcoming several obstacles common in the construction industry, including:

1. Management focus is on control, which prevents bad changes; and neglects breakthrough, which causes good changes.
2. Planning is not conceived as a system, but is rather understood in terms of the skills and talents of the individuals who are in charge of planning.
3. Planning is considered to consist of scheduling, at the same time not taking crew level planning into equal consideration.
4. Planning system performance is not measured.

5. Planning failures are not analyzed to identify and act on root causes.

One of the best known lean techniques is the Last Planner System which has been demonstrated to be a very useful tool for the management of the construction process, and continuous monitoring of the planning efficiency. The Last Planner integrated components are; master plan, phase planning, look-ahead planning, weekly planning, Percent Planned Complete (PPC) and reasons for incomplete, when systematically implemented can bring many advantages and add major benefits to construction management practice in general and planning practice in particular.

2.4 Last Planner System (LPS)

The Last Planner System was developed by Ballard (2000) and Howell (1999) as a production planning and control system to assist in smoothing variations in construction work flow, developing planning foresight, and reducing uncertainty in construction operations. The system originally addressed variations in workflow at the weekly work plan level but soon expanded to cover the full planning and schedule development process from master scheduling to phase scheduling through Look-ahead Planning (LAP) and Weekly Work Planning (WWP).

As a lean tool, LPS advocates:

1. Planning in greater detail as time gets closer to executing the work,
2. Developing the work plan with those who are going to perform the work,
3. Identifying and removing work constraints ahead of time as a team to make work ready and increase reliability of work plans,
4. Making reliable promises and driving work execution based on coordination and active negotiation with trade partners and project participants, and
5. Learning from planning failures by finding the root causes and taking preventive actions (Ballard, 2000; Ballard et al., 2007).

Figure 2.1 shows the LPS comprising four levels of planning processes with different chronological spans: master scheduling, phase scheduling, look-ahead planning, and commitment planning.

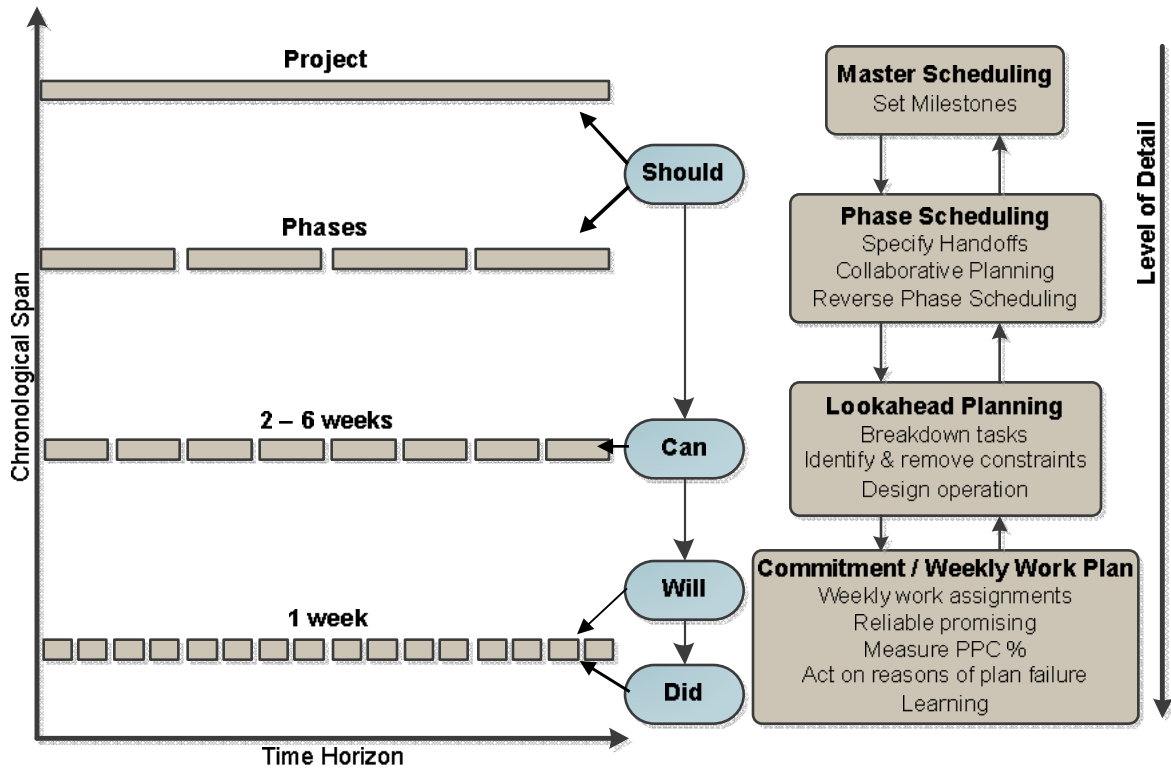


Figure 2.1: Planning Stages / Levels in the Last Planner System
Source: Modified from Ballard, 2000

1. The master schedule is the output of front-end planning describing work to be carried out over the entire duration of a project. It identifies major milestone dates and incorporates critical path method (CPM) logic to determine overall project duration (Tommelein & Ballard, 1997).
2. Phase scheduling generates a detailed schedule covering each project phase such as foundations, structural frame, and finishing. In a collaborative planning setup, the phase or pull schedule employs reverse phase scheduling and identifies handoffs between the various specialty organizations to find the best way to meet milestones stated in the master schedule (Ballard & Howell, 2004).

3. Look-ahead planning signifies the first step of production planning with a time frame usually spanning between two to six weeks. At this stage, activities are broken down into the level of processes/operations, constraints are identified, responsibilities are assigned, and assignments are Made Ready (Ballard, 1997; Hamzeh et al., 2008).
4. Commitment planning represents the most detailed plan in the system showing interdependence between the works of various specialist organizations. It directly drives the production process. At the end of each plan period, assignments are reviewed to measure the reliability of planning and the production system. Analyzing reasons for plan failures and acting on these reasons is used as the basis of learning and continuous improvement (Ballard, 2000).

2.5 Should-Can-Will-Did Analysis

Decisions regarding what work to do in what sequence over what durations using what resources and methods are made at every level of the organization, and occur throughout the life of the project. Ultimately, some planner produces assignments that direct physical production. This “last planner” is last in the chain because the output of his/her planning process is not a directive for a lower level planning process, but results in production as shown in Figure 2.3 (Ballard and Howell, 1998).

Stabilizing the work environment begins by learning to make and keep commitments. Last planners can be expected to make commitments (WILL) to doing what SHOULD be done, only to the extent that it CAN be done. Expressing this as a rule, we might say: Select assignments from workable backlog; i.e. from activities you know can be done.

Last planner only releases workable jobs to the field, as opposed to the traditional practice (Figure 2.2) of pushing assignments onto construction crews and design squads in order to meet scheduled dates. In addition to looking ahead and prescreening upcoming tasks

for constraints, assignments are also expected to meet specific quality requirements for definition, sequence, and size. In addition, since mistakes will still be made, the control system is structured to promote learning from plan failures, in an effort to avoid making the same mistakes twice.

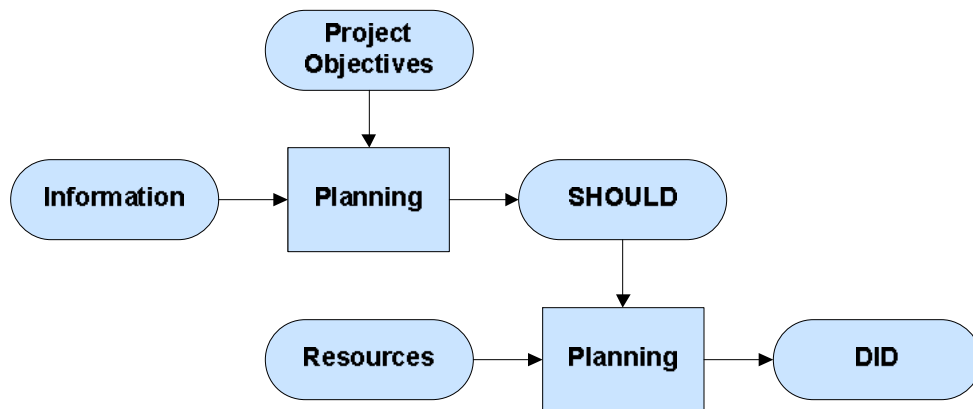


Figure 2.2: Traditional Planning Process
(Adapted from Ballard and Howell 1998)

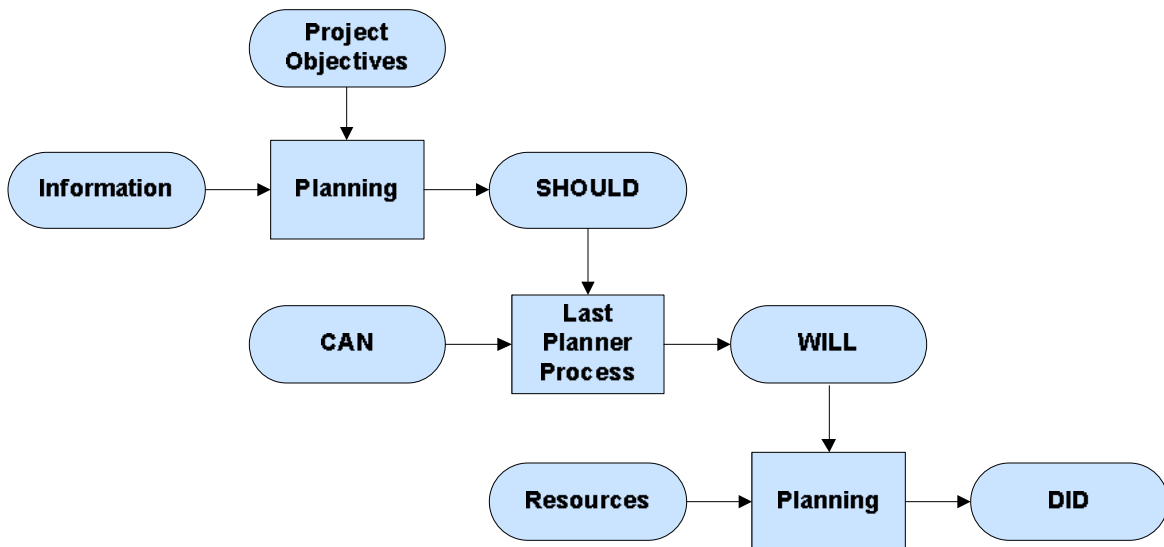


Figure 2.3: Last Planner Planning Process
(Adapted from Ballard and Howell 1998)

Making quality assignments shields production units from work flow uncertainty, enabling those units to improve their own productivity and also to improve the productivity of the downstream production units that receive and build on their work and hence are dependent on

reliable release of prerequisite work or shared resources in order to do their own planning (Ballard and Howell 1998).

2.6 Last Planner System Essentials

The essentials of the Last Planner System can be summarized as follows:

2.6.1 *Milestone Schedule*

- The milestone schedule should divide the project into logical phases. The duration should be established in manner so that those responsible for the project are confident that the work can be completed as planned. This may require the development of a more detailed CPM, conversations with those responsible for work on the critical path or other investigations.

2.6.2 *Pull Schedule (Baseline Schedule)*

- All the team members responsible for the work to deliver a milestone will participate in developing the Phase Pull Schedule (PPS).
- PPS should be developed in a face to face conversation that establishes context, define the milestone deliverable, develops an execution strategy, identifies tasks and organizes them in a pull plan working from the end of the phase back.
- All tasks on the PPS must produce a deliverable defined in terms accepted by their customer.
- PPS is complete when the team members agree on the hand-off criteria between activities, sequence and likely timing of the work. The team members are confident that activities have access to adequate resources and time to complete the work and have identified long lead items.

2.6.3 Look-ahead Plan

- Activities in the PPS established tasks in the 6 Week Look-ahead Plan (6WLAP) each week.
- The link between task in the LAP and PPS activities should be recorded and maintained.
- Sub-tasks can be created and linked to tasks in the LAP. Typically, the hand-off of work between trades is established in PPS level tasks. Sub-tasks are usually managed within each craft.
- Tasks and sub-tasks produce deliverables.

2.6.4 Identifying Constraints

- Constraints are those directives, resources and prerequisite work not shown on the PPS that are required to start and complete tasks.
- The link between constraints and tasks will be maintained.
- Tasks (and sub-tasks) on entering LAP are screened for constraints by the responsible individual and at least again when assigned to Last Planners (LP).
- Responsible individual will remove those constraints normally within their authority and make requests to other for those beyond their authority.
- Requests that require a promise from someone outside organization will be made through established channels and recorded on the project constraint log.
- The constraint log will reflect the state of request in workflow loop terms – declined, accepted, in negotiation, promised, in progress, and complete.
- The LAP (and perhaps the PPS) will be changed in response to constraints that cannot be removed by the time required.

2.6.5 Preparing Weekly Work Plan

- All the tasks in the Weekly Work Plan (WWP) should be in the 6WLAP and linked to PPS.

- WWP should contain only tasks that are ready to be performed. This means that all constraints have been removed. The LP is confident that any remaining Make Ready needs will be available when needed and the site and workforce are ready.
- Only tasks in a condition to start and finish on time should be included in WWP. In rare cases, work that is not in a ready condition may be included even though the LP is not confident it can be Made Ready or completed. In this case, the next LP must be notified that the work may not be delivered.
- Assignments on the WWP should be sized for daily completion. Larger assignments may be made if this not practical, that is work will span several days and interim completion is difficult to establish.
- Inspection task should be included in WWP when inspections are required before the next crew begins.

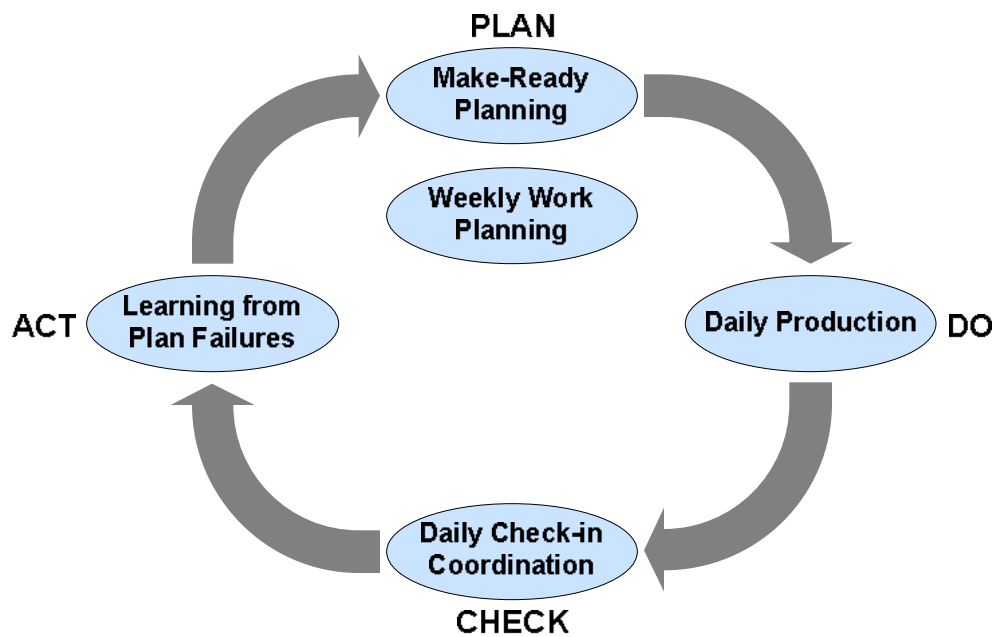


Figure 2.4: Weekly Planning and Execution Cycle

Table 2.1: Constraint Log

CONSTRAINT LOG												UPDATE DATE:	11-Aug-11
PROJECT:			UT Arlington College Park										
PHASE:			Stage 1 & 2										
RESPONSIBLE INDIVIDUAL:													
CONST ID	CONST REF. #	Activity ID	ACTIVITY EFFECTED BY CONSTRAINT	CONSTRAINT DESCRIPTION	RFI #	CUSTOMER	STEWARD	PERFORMER	DATE IDENTIFIED BY CUSTOMER	DATE REQUIRED BY CUSTOMER	DATE PROMISED BY PERFORMER	DATE ACCEPTED BY CUSTOMER	
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Table 2.2: Weekly Work Plan

WEEKLY WORK PLAN																		Week Beginning: July 04				
Area:		Site		CATEGORIES OF PLAN VARIANCE																		
Subcontractor:		Combined		1 Coordination		4 Weather		7 Materials		10 Approvals		13 Site Conditions										
				2 Eng/Design		5 Prerequisite Work		8 Contracts/CO's		11 Equipment		14 Inspections										
Last Planner:				3 Owner Decision		6 Labor		9 Submittals		12 RFI's		15 Other										
Activity ID	Area	Level	Responsible Party	Activity Description					Responsible Individual	Start Date		7/4/11						Done?		LEARNING	Category	
				Safe	Defined	Sound	Right Sized	Proper Sequence		Mon	Tue	Wed	Thu	Fri	Sat	Sun	Yes	No	REASONS FOR VARIANCE			
										7/4	7/5	7/6	7/7	7/8	7/9	7/10						
				Workable Backlog (What work can I do w/o affecting other trades if above																		

2.7 Chapter Summary

This chapter presented the findings from a comprehensive literature search. The subjects searched include (i) Key Principles of Lean Construction, (ii) Lean Philosophy of Project Planning, (iii) Last Planner System, (iv) Should-Can-Will-Did analysis, (v) Last Planner System Essentials. This chapter defined the levels in LPS. Additionally, this chapter compared the traditional planning process with Last Planner planning process.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter discusses the methodology adopted to obtain the results of this research. The overview of this methodology was presented in Chapter 1.

3.2 Research Development and Aims

The research is based on a general contractor's regional management seeking to improve its planning performance and reliability of project delivery. The issue of Lean Construction was introduced in the course development and training sessions. Further discussions followed over a period of approximately two years during which senior managers in the company were persuaded to support a trial of Last Planner System (LPS). The overall aim was to test the system in an ongoing project and engage the company's employees and subcontractors with the process. The process was based upon the following:

- Subcontractors would be involved in the weekly planning process.
- Look-ahead schedules would be employed to ensure work is made ready to facilitate the achievement of weekly plans.
- Weekly targets would be chosen from the look-ahead schedule, and agreed with the subcontractors.
- Percent Plan Complete (PPC) of weekly targets would be analyzed and discussed with the subcontractors, as a means to drive improvements.

The key issues to be considered in the implementation of the Last Planner research methodology would be that:

- The research should be aimed at more complex projects that are essentially non-repetitive in nature as this is where company seeks improvements.
- The emphasis should be on practical application of Last Planner Methodology i.e. the site staff should be able to modify the system to suit the project situation.
- An attempt should be made to identify the barriers to implementation of LPS.

3.3 Research Method

A case study on an *action research mode* was conducted to examine the impact of LPS on improving construction planning practice on commercial construction project. An action research project emerges from and has to contribute to the practical concern of people and the solution of existing practical problems (Järvinen, 2007). Dick (2002) argued that action research is a flexible spiral process which allows action (change, improvement and research understanding, knowledge) to be achieved at the same time. Data was collected by:

- a) Conducting interviews aimed to evaluate current management practices,
- b) Attending weekly meetings as a facilitator of LPS application over a period of seventeen weeks,
- c) Conducting interviews with participants during the implementation process,
- d) Participant and non-participant observation, and finally
- e) A survey questionnaire was conducted to assess the stakeholders' perceptions on implementation of LPS.

Justifying the adoption of action research, the main aim of the study was to contribute to practice, bring improvement to the managerial practice which could not be achieved by means of other research approaches. In addition, action research provides a richness of insight which

could not be gained in other ways (Gummesson, 2000). Moreover, the author believes that organizations should benefit from knowledge and research advancements rather than just being subjects in the research.

3.4 Last Planner System Implementation Process

3.4.1 *The Project*

The LPS was implemented in a commercial construction project, UT Arlington College Park located on the University of Texas at Arlington campus, having an estimated contract value of \$65 million. The scope of the project involved construction of 3 multi-storey parking garages with a car parking capacity of 1800, with 500 student apartments and residence halls, retail spaces, and a welcome center. The project was divided in two phases. Phase 1 included two parking garages and related site work. All residence halls, the apartment structure and the remaining parking garage were scheduled to be completed during Phase 2. Both phases allocated 12 and 13 months construction time frame respectively with 24 months of overall project duration. Table 3.1 summarizes the project.

Table 3.1: Summary of Case Study Project

<i>Project</i>	<i>Contract Value</i>	<i>Duration</i>	<i>% time elapsed when LPS starts</i>	<i>Subcontractors involved in LPS</i>
UTA College Park, Arlington, Texas				
Phase 1	\$65 million GMP	12 months	80%	None
Phase 2		13 months	0%	Structural Architectural Mechanical Electrical Plumbing

An initial meeting was held with the project team in March 2011, and several other follow-up meetings followed over the subsequent three months to develop and agree upon the Last Planner methodology. It was clear that both the PM and the planner took active initiatives in the idea of using Last Planner as one of a number of tools to deliver on a very tight construction schedule. The meetings involved the PM, planner, superintendents, project

engineers, field engineers, and foremen with a General Contractor (GC), so that a wide range of staff had an understanding and interest in the development and implementation of the Last Planner methodology.

The research team's initial proposals were based on research papers on Last Planner and guidelines of the Lean Construction Institute (LCI). The project team, however, proposed to modify the system advocated by the researchers for application specifically to this project. They kept the principles of Last Planner but developed their own forms, their own ideas of the correct timing and membership of meetings and used two "Lead Planners" to be the main drivers of *look-ahead* and to run the meetings. They also developed the LCI's information into a specific presentation of Last Planner, for delivery to the subcontractors. This was produced on Microsoft PowerPoint, and featured a series of highly visual images aimed at capturing the interest of the subcontractors. The Last Planner meeting and discussions were closely monitored by the author.

3.4.2 The LPS Implementation Strategy

The research plan was to undertake the implementation process in four stages. This incremental implementation is believed to gradually stabilize the elements of LPS, minimize resistance to change, and have the additional advantage of providing an opportunity to evaluate each stage and take the lessons learned to the next one. Figure 3.1 shows the implementation strategy of LPS in the studied cases.

1. First Stage

In the first stage, a workshop on Lean Construction and training for the use of LPS were provided to the team to highlight the benefits and to discuss the perceived advantages of Lean Construction and LPS, after which there was a two-week observation period to monitor the current planning practice, to interview the participants and to make notes. In addition, this stage

aimed to train the team how to calculate the PPC, identifying reasons for failure during these two weeks, but this is not included in the data as LPS was not implemented during this stage. Further, during this stage, PPC was calculated, and reasons for incomplete assignments were traced and recorded.

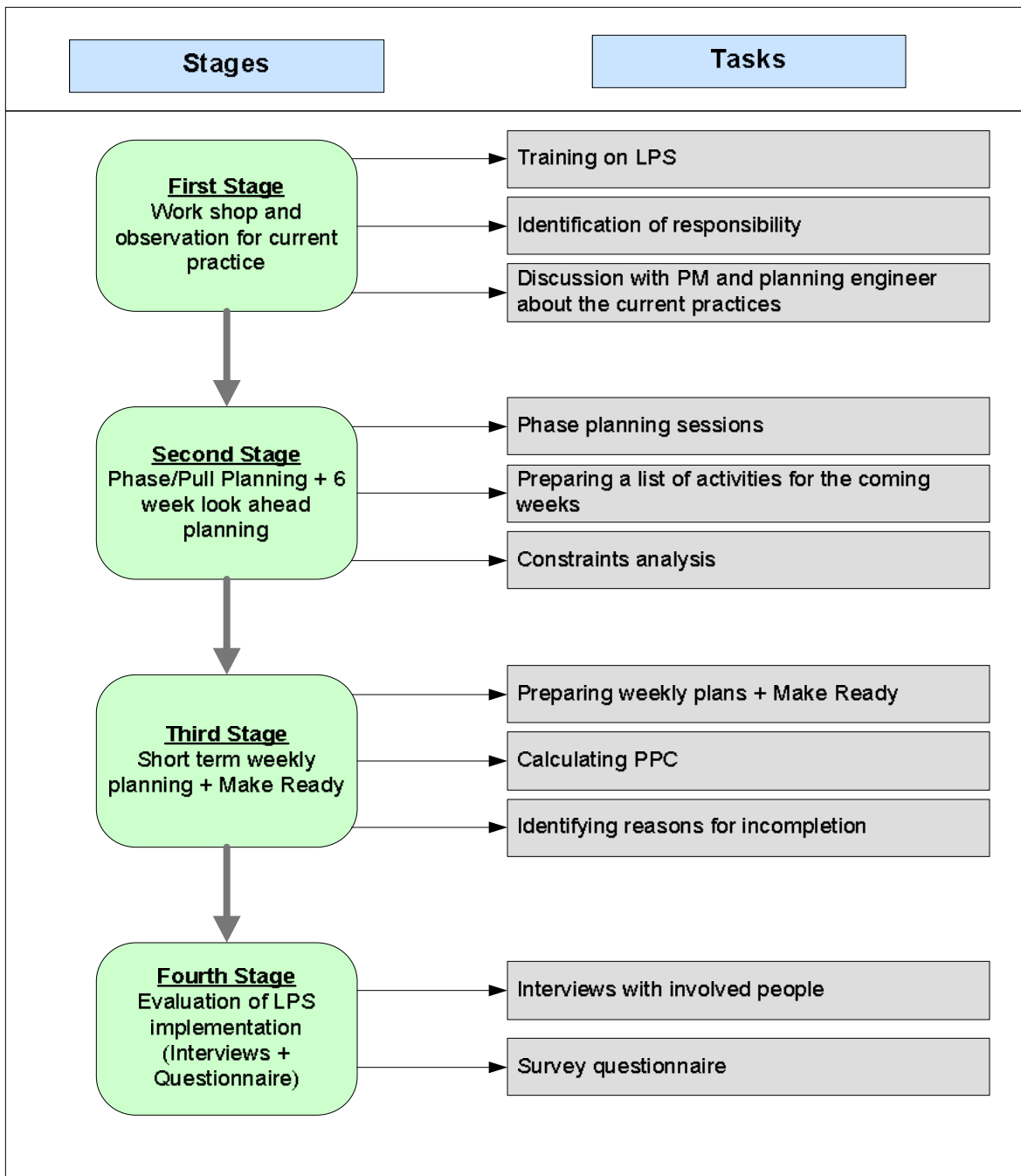


Figure 3.1: LPS Implementation Strategy in the Studied Project

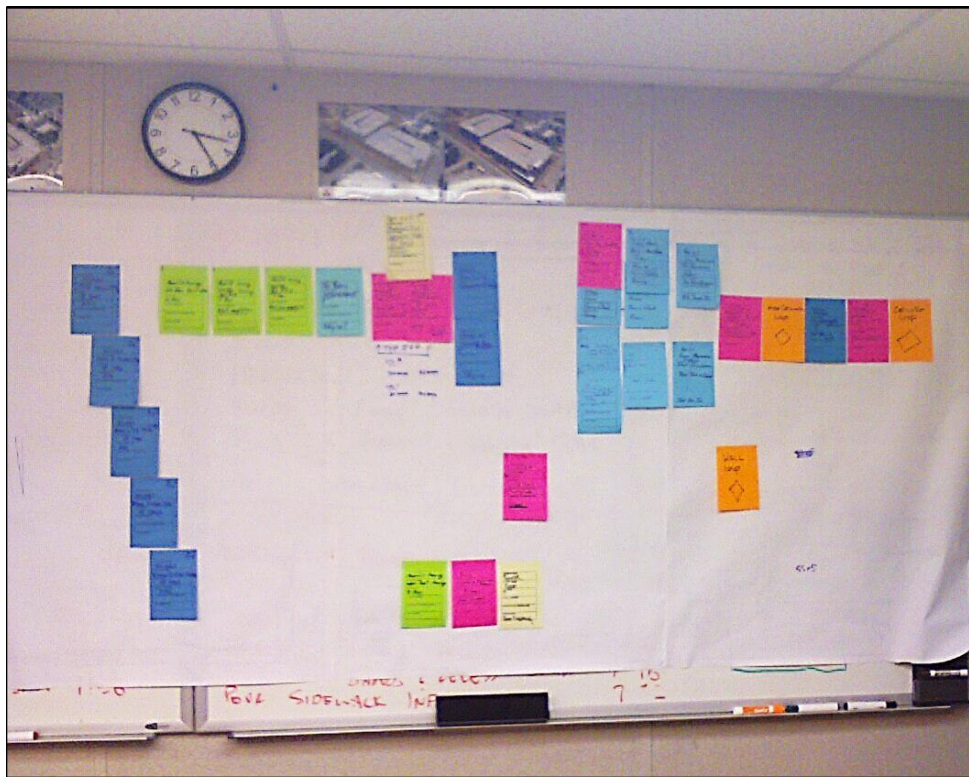
2. Second Stage

In this stage, one of the main components of LPS was applied; the phase pull planning introduced. Two weekly meetings were held with the involvement of all project parties (contractor's project management and field supervisory staff, client representatives, consultant engineers, and subcontractors).

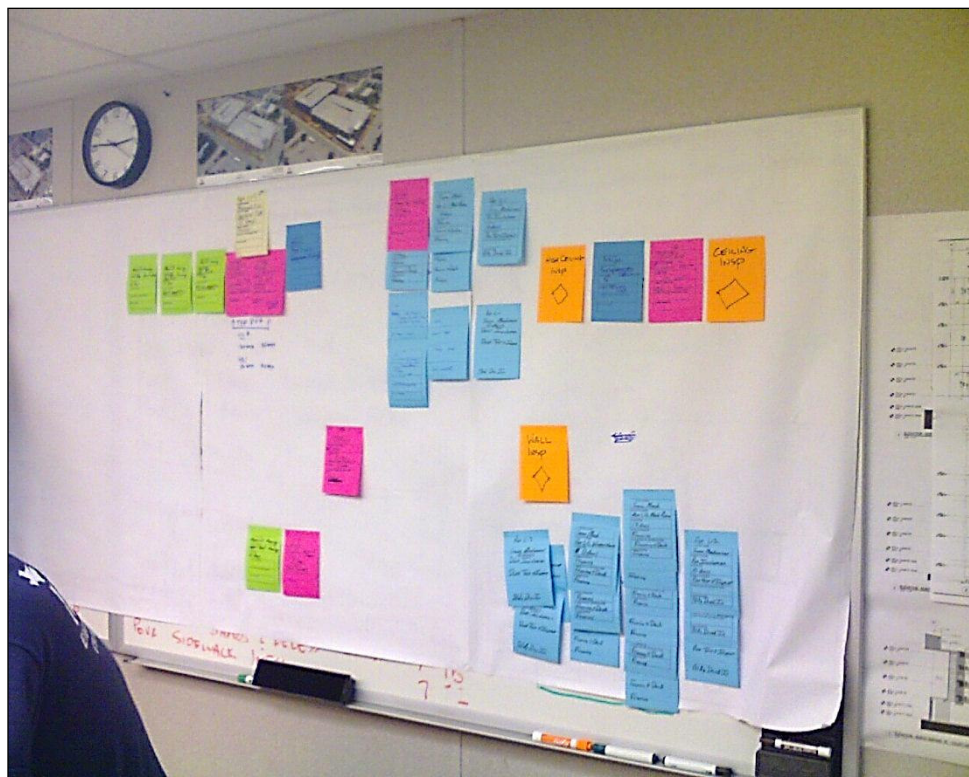
During this stage, in addition to the weekly planning and Make Ready that already introduced, other main component of LPS; Look-ahead Planning was undertaken. In the case study project, look-ahead planning incorporated the six-week look-ahead window. Look-ahead planning was extracted from the Master Plan of a Phase 2 and then coordinated in the Last Planner sheets. In the project, phase planning sessions were carried out for the Phase 2 aiming to provide certain goals and then worked out backward from the target completion date to achieve the proposed milestones. Each session was dedicated to certain type of activities (structural, architectural, mechanical, electrical and plumbing).

Figures 3.2 (a), (b) and Figure 3.3 are the photographs taken during Phase Pull Schedule (PPS) sessions held at the contractors' office. All major subcontractors; i.e., mechanical, electrical, plumbing, structural, architectural, and fire proofing, participated in this sessions scheduled two months prior to actual commencement of Phase 2. Key personnel from owner, designer and general contractor attended these meetings and contributed with a review of the process. All subcontractors were responsible for pulling out duration and precise sequencing of construction activities by using distinguished color coded system.

Lead planner established major milestones for different trades and then participants worked backward to achieve target completion date of these goals. The process was carried out by pasting activities on the wall, later transformed in to detailed Gantt chart by company scheduler using Primavera P6 for each building on project.



(a)



(b)

Figure 3.2: (a) Initial Sequencing of Independent Activities, (b) Coordination of Construction Sequence on Billboard



Figure 3.3: Outcome of Pull Production Planning Meeting

3. Third Stage

This stage was the longest of all the stages. Implementing LPS on site was facilitated by the first author and it was agreed that PPC and reasons for incomplete assignments would be traced and recorded on a weekly basis for a period of seventeen weeks. It was an attempt to help the team in driving improvement to see how the LPS improved the planning practice. In this stage, the focus was on short-term planning and Make Ready only and little attention was directed to Look-ahead planning.

Weekly meetings were held with involvement of all project parties (contractor's team, client representatives, and subcontractors). In this stage, data (PPC and reasons for incomplete tasks) were collected during the end of summer and beginning of fall season in the country. At this time of the year, the highest temperature is usually recorded, and in 2011 it reached 110 degrees Fahrenheit in the day-time. During the month of October, formwork subcontractor proclaimed bankruptcy. Taken together, these factors significantly affected labor productivity, and hence, assignments completion.

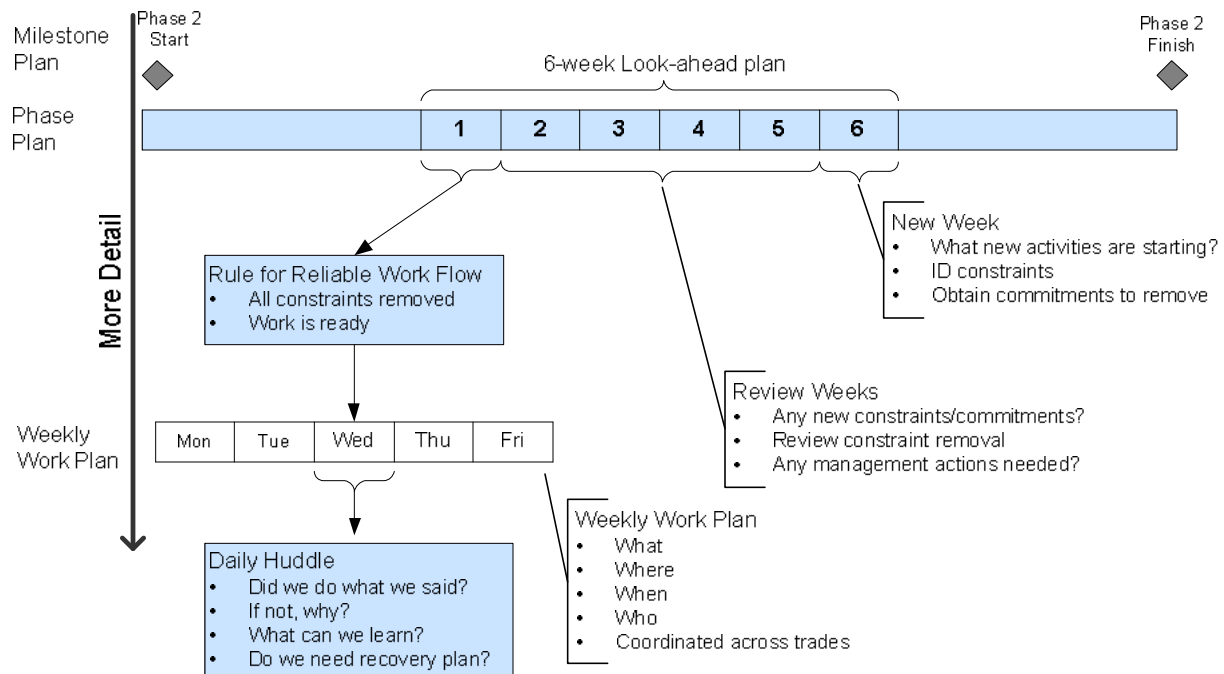


Figure 3.4: Preparing WWP from 6 Week Look-ahead Plan

4. Fourth Stage

This stage focused on a survey questionnaire administered to evaluate the process of LPS implementation aimed to allow all participants to self-report the achieved benefits, CSFs, and barriers to LPS implementation in the projects. The respondents were given sufficient time to read the questionnaire, think about it and ask any questions they wished. Most participants answered in group interviews (with an informal, friendly discussion theme) in the presence of the author, the author explained the questions, provided any clarification necessary, and asked the participants to choose the answers they believed to be the most appropriate.

The questionnaire contained nine questions. Questions related to the achieved benefits, CSFs and barriers for LPS implementation were formulated using a five-point Likert scale that requested opinion about different attributes gathered from the outcome of previous studies in LPS, from the literature in LPS and Lean Construction, and from observations and notes taken

during the involvement of the researcher in the implementation. Please refer to Appendix - A for the survey questionnaire.

3.5 Chapter Summary

LPS was implemented on a commercial construction project with an action research strategy comprised of four major stages (i) LPS training, (ii) Phase pull schedule sessions, (iii) Development of 6WLAP and WWP, and (iv) LPS implementation evaluation process supported by interviews cum questionnaire. The results of the study are discussed in details in Chapter 4, while providing evidence of benefits in terms of the discipline of planning process and good support for the system from the company participants.

CHAPTER 4
RESEARCH ANALYSIS AND RESULTS

4.1 Introduction

The previous chapter provided the implementation strategy to this research. This chapter presents the concept and results of Percent Planned Complete (PPC). Additionally, results derived from a short survey cum interviews are presented at the end of this chapter.

4.2 Weekly Percent Plan Complete (PPC)

In Phase 2 of the UTA College Park project, the Percent Plan Complete (PPC) rose from 60% in the first week, peaked at 88% in the fourth week, to a level of 83% after 17 weeks. The average PPC for Phase 2 was 73% compared to 62% in Phase 1.

Percent plan complete (PPC) is a measure of workflow reliability (Ballard 2000) and is calculated by dividing the number of near-term tasks completed by the total number of tasks made for the plan period (Ballard 2000). The equation for PPC is as follows:

$$PPC (\%) = \frac{\text{number of completed tasks}}{\text{number of assigned tasks}} \times 100 \dots\dots\dots \text{(Equation 1)}$$

Data required for PPC calculation are “the number of assigned tasks” and “the number of completed tasks”. They are easily acquired from project engineers or foremen without any additional time and effort. No additional monitoring such as of resource consumption is required for this measurement.

The author played the role of facilitator for implementing LPS over the period of approximately seventeen weeks at UTA College Park project. The author also gathered data for Phase 1 to facilitate peer review of PPC ratios for both phases.

The weekly data collected from the field was analyzed and three different PPCs were computed. Each of the PPC ratios tell a different story in regards to the reliability of the contractor's weekly plans as compared to the 6 Week Look-ahead Plan (6WLAP) and the baseline schedule or Phase Pull Schedule (PPS). Figure 4.1 shows plot of the three PPC values on the implementation strategy employed for UTA College Park project. The diagram below is the modified representation of last planner planning process described in Chapter 2 (refer Figure 2.3). Here relations of PPC 1, PPC 2, and PPC 3 (with WWP, 6WLAP, and baseline schedule respectively) within LPS have been graphically shown in Figure 4.1.

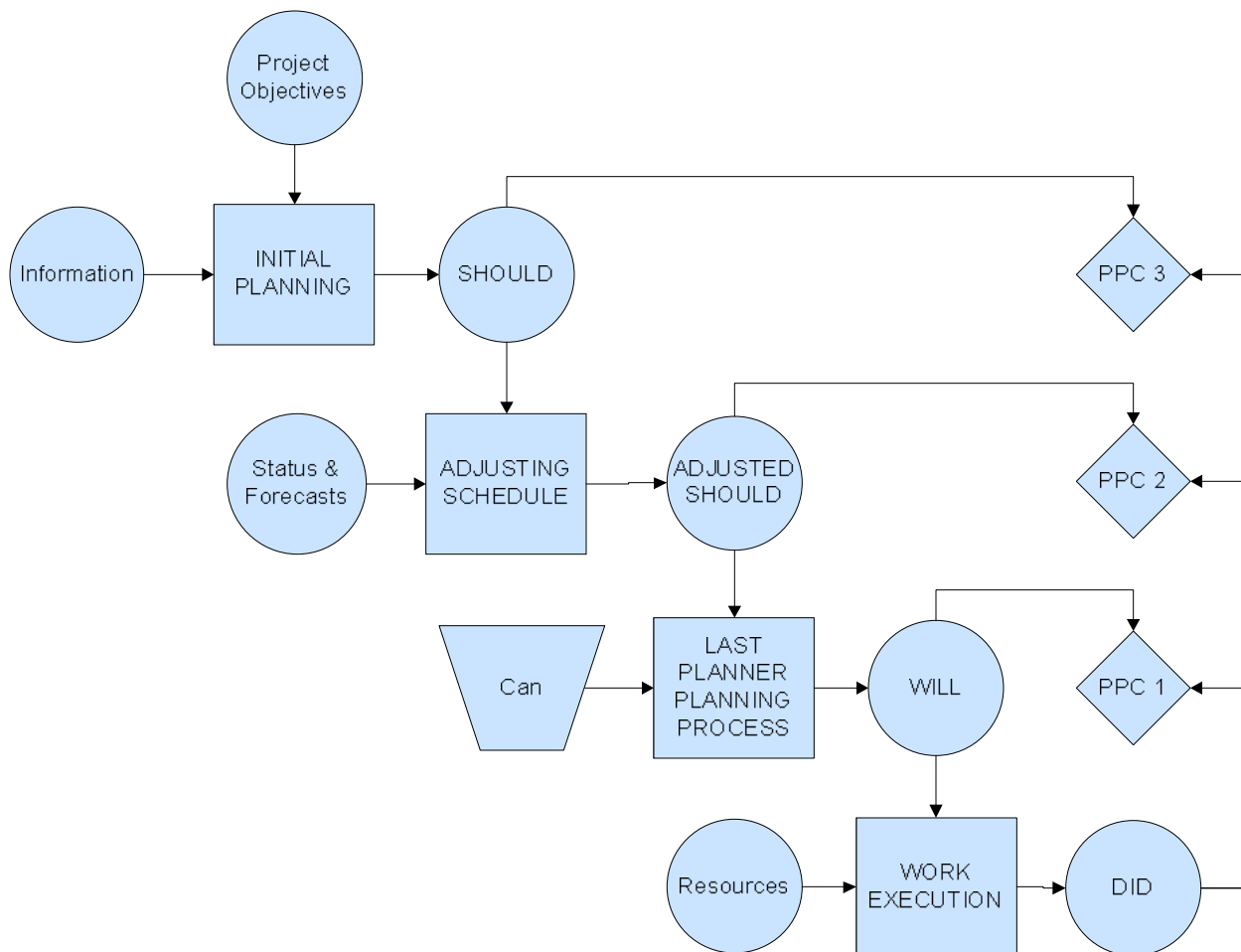


Figure 4.1: Relation of PPC Ratios within LPS

The following steps detail the process used to collect and analyze the data, which was obtained during the weekly meetings with the subcontractors:

1. Examine the baseline schedule and extract the activities that ought to be performed during the following week. This step generated the SHOULD list of work assignments.
2. Examine the monthly schedule and extract the activities that ought to be performed during the following week taking into account resource and space availability. This step generated the ADJUSTED SHOULD list of work assignments.
3. Have the project superintendent develop a list of work assignments for the following week taking into consideration the amount of resources actually available, space availability, and status of shop drawings. This step generated the WILL list.
4. Monitor the actual execution of work items included in the WILL list.
5. Discuss with the project superintendent and project engineer the work done during the week just ending and generate the WILL list for the following week (step 3). The

following items were covered in the weekly meetings:

- a) Obtain the percent complete (PCT) for each of the WILL activities on which the contractor worked during the week just ending,
- b) WILL activities with a PCT greater than 50% are given a value of 1 in the PPC calculations while WILL activities with less than 50% PCT are given a value of 0. This arbitrary weighting represents a key departure from LPS original definition (a value of 1 for 100% PCT and 0 otherwise),
- c) Calculate and plot the PPC ratios for the week just ending according to the definitions of Table 4.1, and
- d) Uncompleted WILL activities, i.e., those assigned a value of 0, are investigated and the reasons for non-completions are documented.

Table 4.1: Percent Plan Complete (PPC) Definitions

Ratio	Definition (The \cap symbol performs an intersection of two lists)	Meaning	Computed for
PPC 1	$\frac{(DID \cap WILL)}{WILL}$	How the as-built compares to the weekly work plan (WWP)	Phase 2
PPC 2	$\frac{(DID \cap ADJUSTED\ SHOULD)}{ADJUSTED\ SHOULD}$	How the as-built compares to the 6 week look-ahead plan (6WLAP) & three week look-ahead plan (3WLAP)	Phase 1 & 2
PPC 3	$\frac{(DID \cap SHOULD)}{SHOULD}$	How the as-built compares to the baseline schedule	Phase 1 & 2

(Source: Garza and Leong, 2000)

4.3 UTA College Park Phase 1

4.3.1 PPC Ratios

The PPC 2 ratio shown in Figure 4.2, a result of number of tasks completed as compared to tasks listed on 3 week look-ahead plan, represents planning performance during Phase 1. The PPC 2 ratio for Phase 1 averages 62% indicating that for the UTA College Park project only two out of three anticipated weekly assignments were actually worked on, i.e., activities in the WILL list which achieved a percent complete (PCT) of more than 50%. This short term look-ahead ratio suggests that the existing week-to-week planning needs improvement to avoid time overrun.

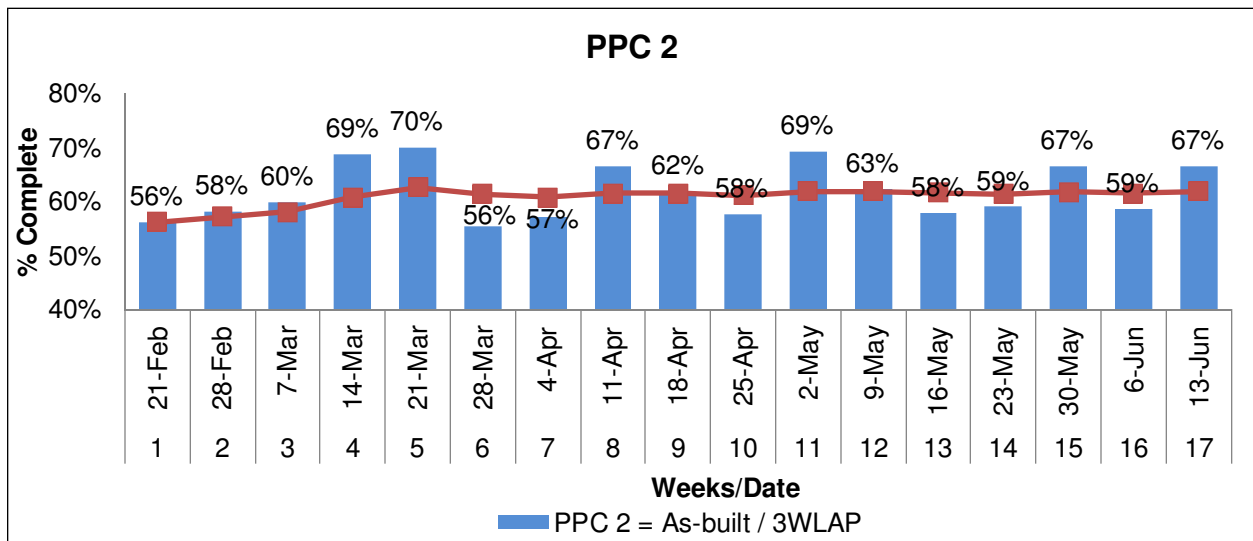


Figure 4.2: Phase 1 PPC Ratio for As-built & 3WLAP

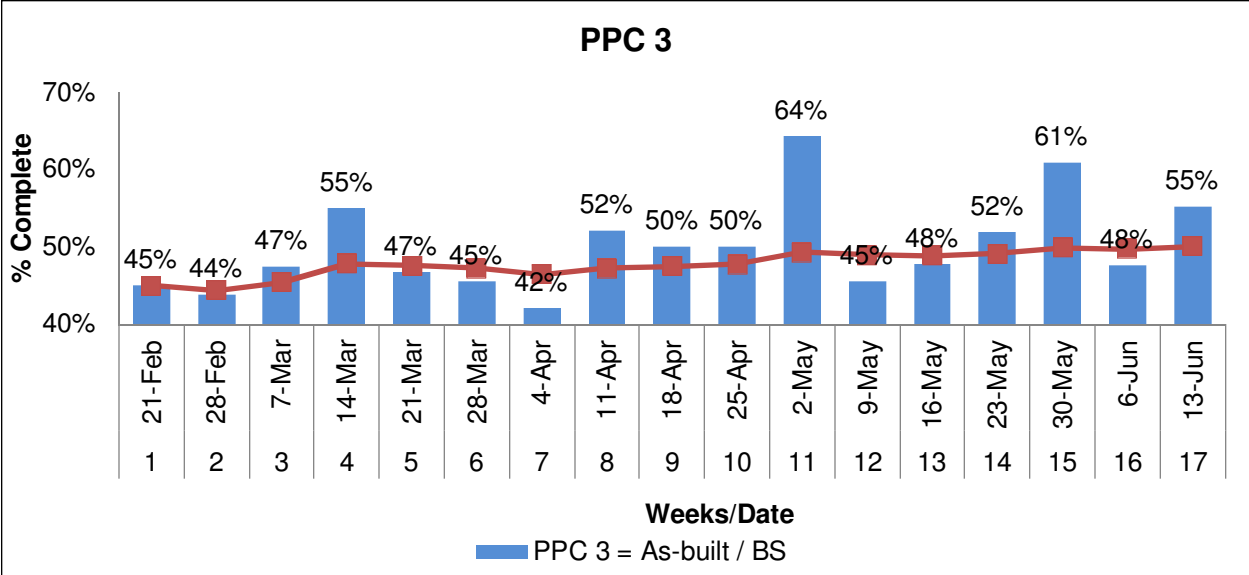
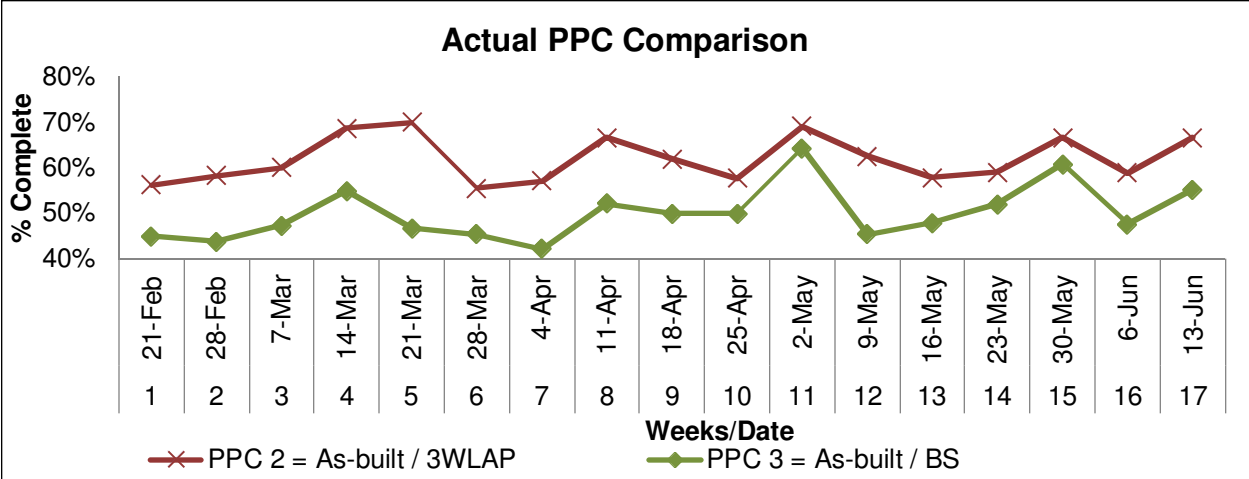


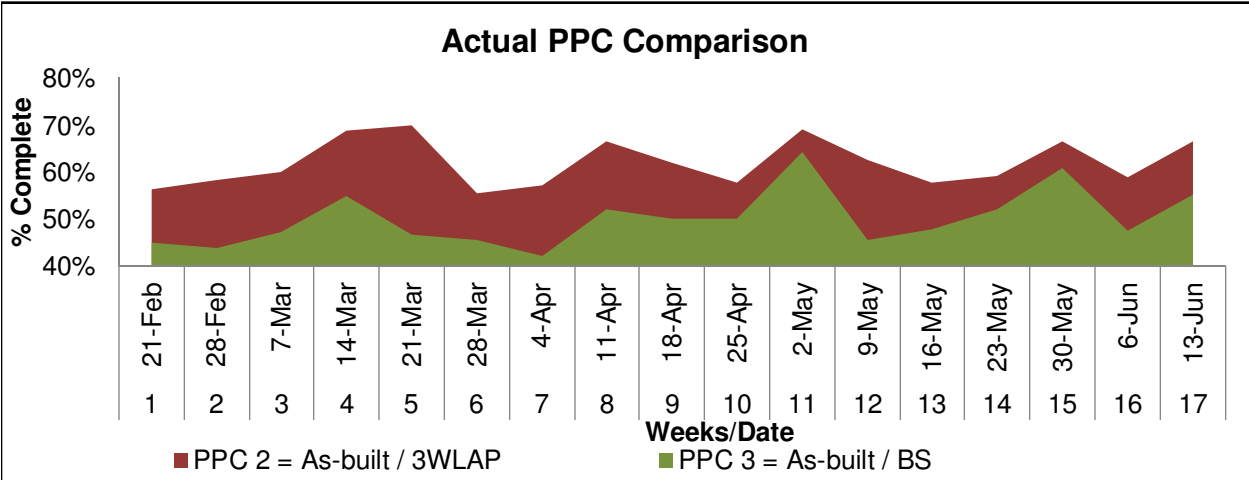
Figure 4.3: Phase 1 PPC Ratio for As-built & Baseline Schedule

The PPC 3 ratio shown in Figure 4.3, a result of number of tasks completed as compared to tasks listed on Baseline Schedule (BS), represents planning performance of master schedule during Phase 1. The PPC 3 ratio for Phase 1 averages 50% indicating that for the UTA College Park project only one out of two anticipated weekly assignments were actually worked on, i.e., activities in the WILL list which achieved a percent complete (PCT) of more than 50%. This short term look-ahead ratio suggests that the existing master schedule needs a lot of improvement to achieve satisfactory results.

Figures 4.4 (a) & (b) show a plot of actual PPC 2 versus PPC 3. There is an average of 12% difference between what is anticipated from week-to-week and what was anticipated at the start of the project. In other words, the work assignments that are planned on 3WLAP do not resemble the baseline schedule. Figures 4.5 (a) & (b) shows a plot of week-by-week moving average PPC 2 versus PPC 3.



(a)

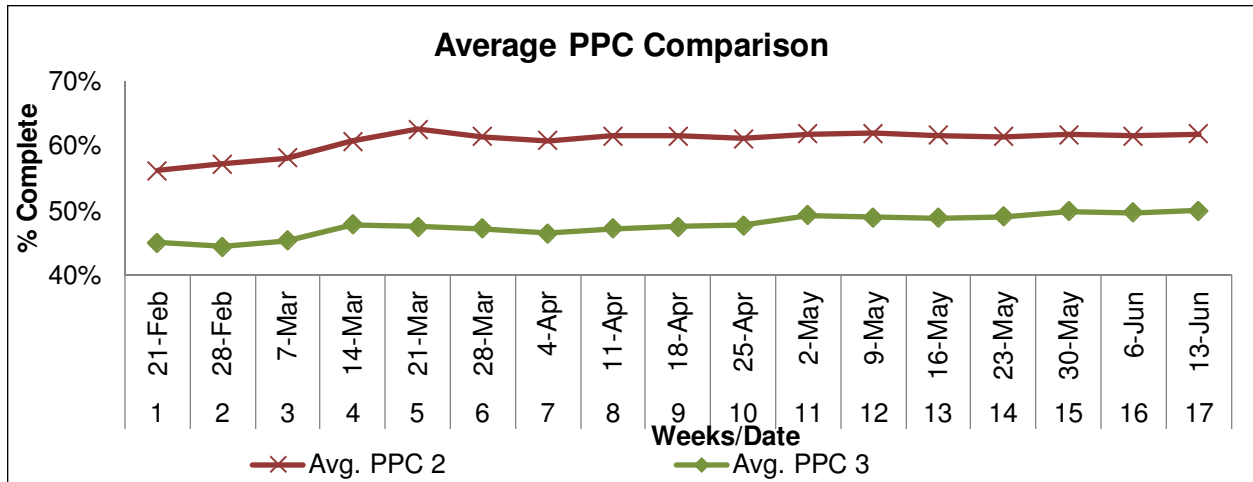


(b)

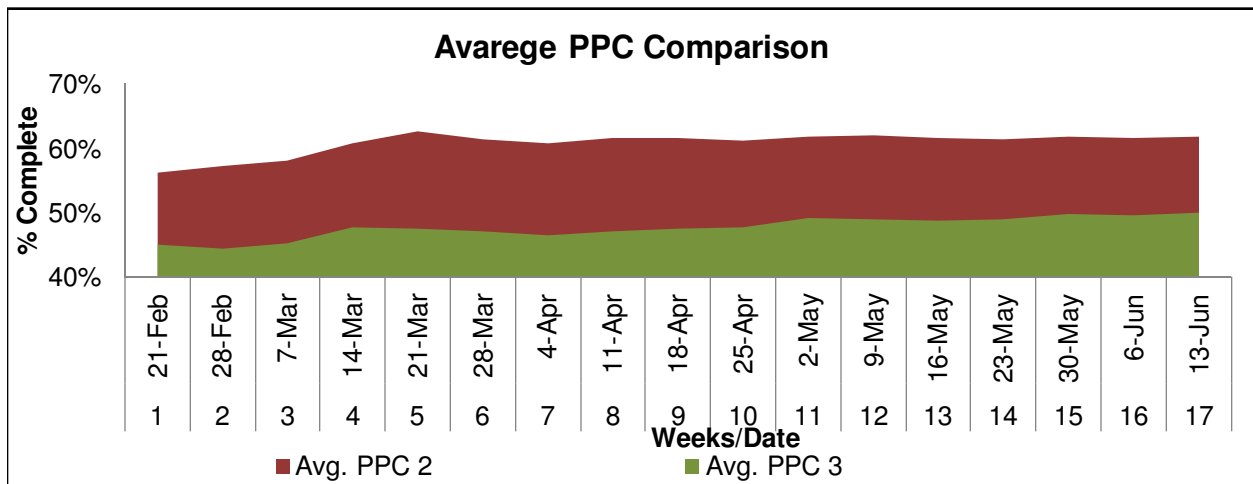
Figure 4.4: Phase 1 Actual PPC Comparison (a) Weekly PPC Ratios Comparison for Phase 1, (b) Deviation Look-ahead Plan and Baseline Schedule

4.3.2 Reasons for Incomplete Assignment

Figure 4.6 presents the various reasons for incomplete assignments reported on case study. Prerequisite work and coordination issues were some of the main reasons for incomplete assignments in the project. This perhaps, due to the nature of the stage that the project had reached as most activities – including architectural ones – were entirely dependent on structural assignments being completed.



(a)



(b)

Figure 4.5: Phase 1 Week-by-Week Moving Average (a) Weekly PPC Ratios Comparison, (b) Deviation Look-ahead Plan and Baseline Schedule

The second major reason was the incomplete information and late submittal requests for finishing activities. The general contractor was delayed on the subcontract buyout process resulted in late submission of submittals.

The third major reason during the end of Phase 1 was a lack in the number of quality control inspectors appointed by owner. There were two construction inspectors hired by owner in the starting of project. Later the owner fell back on one inspector due to lack of funding. Hence many tasks were incomplete without inspections.

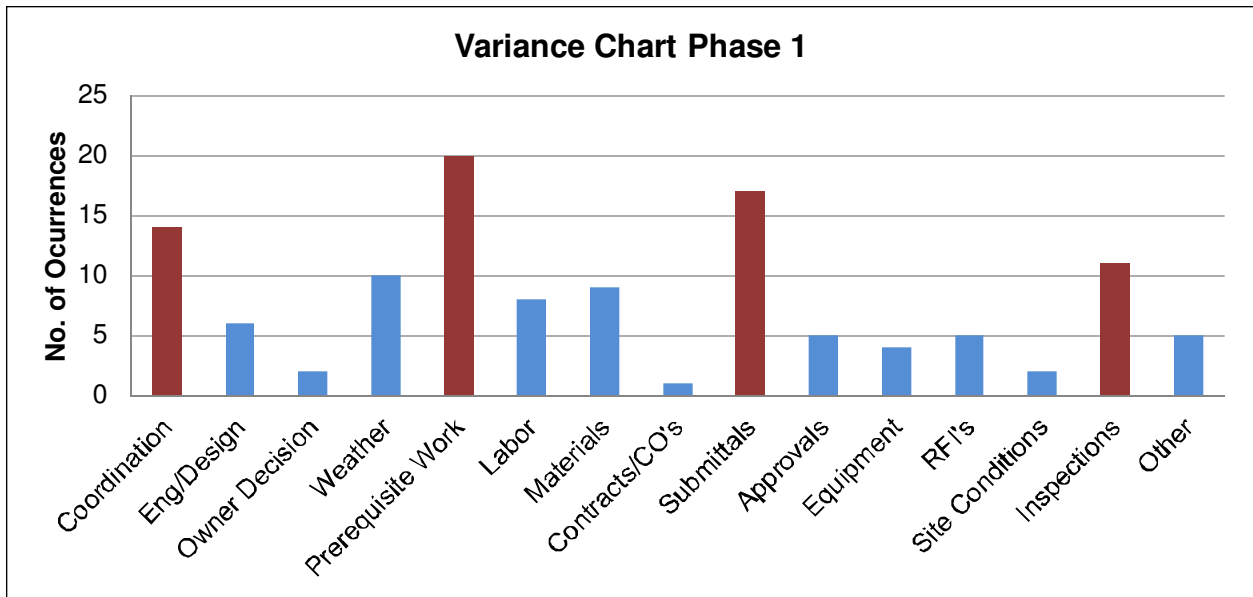


Figure 4.6: Phase 1 Reasons for Incomplete Assignments During Observation Period

4.4 UTA College Park Phase 2

Following are the different PPC ratios calculated for Phase 2:

4.4.1 *PPC Ratios*

The PPC 1 ratio shown in Figure 4.7, a result of number of tasks completed as compared to tasks listed on Weekly Work Plan (WWP), represents improved planning reliability during Phase 2. The PPC 1 ratio for Phase 2 averages 73%, indicates that three out of four anticipated weekly assignments were actually worked on, i.e., activities in the WILL list which achieved a percent complete (PCT) of more than 50%. This short term look-ahead ratio shows improved planning performance after implementation of Last Planner System (LPS).

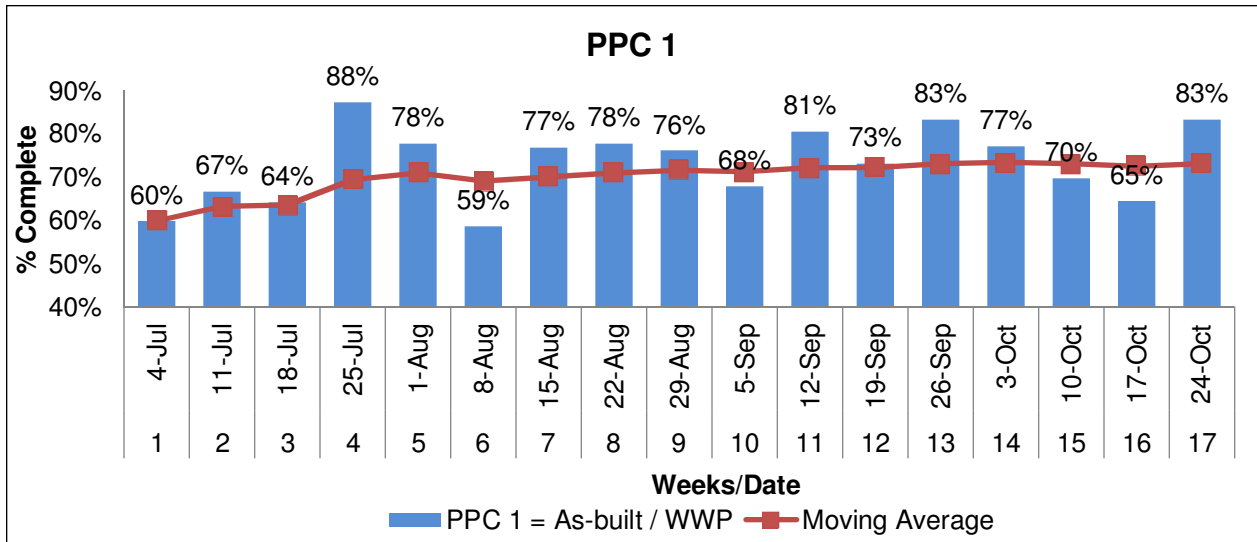


Figure 4.7: Phase 2 PPC Ratio for As-built & WWP

The PPC 2 ratio shown in Figure 4.8, a result of number of tasks completed as compare to tasks listed on 6 Week Look-ahead Plan (6WLAP), represents improved performance of look-ahead planning during phase 2. The PPC 2 ratio for phase 2 averages 71% indicating that for the UTA College Park project three out of four anticipated weekly assignments were actually worked on, i.e., activities in the WILL list which achieved a percent complete (PCT) of more than 50%.

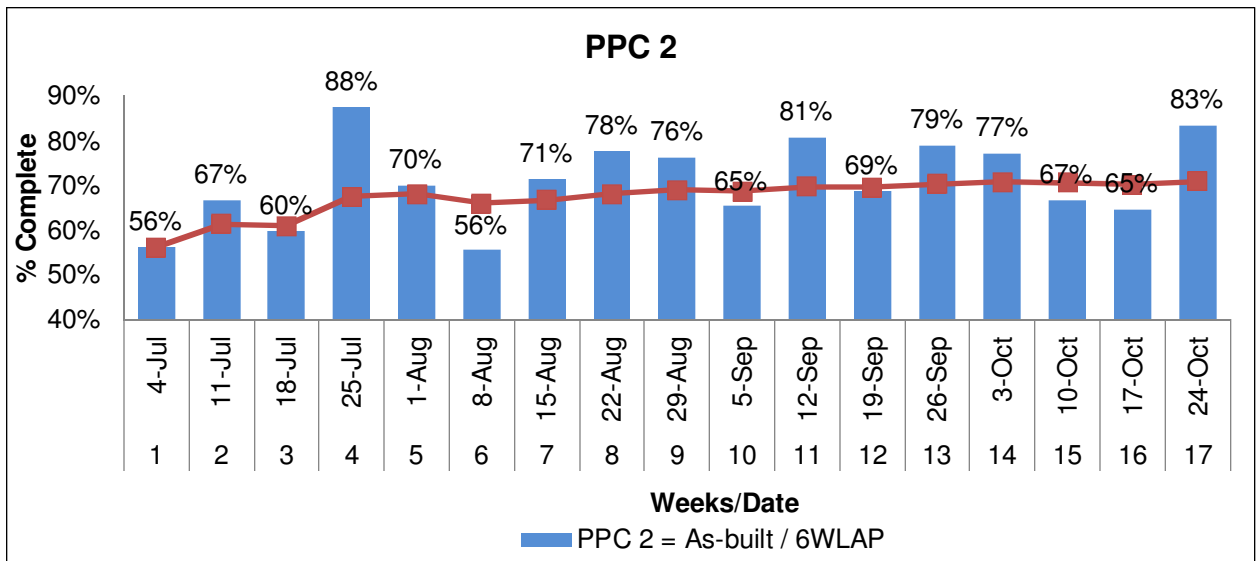


Figure 4.8: Phase 2 PPC Ratio for As-built & 6WLAP

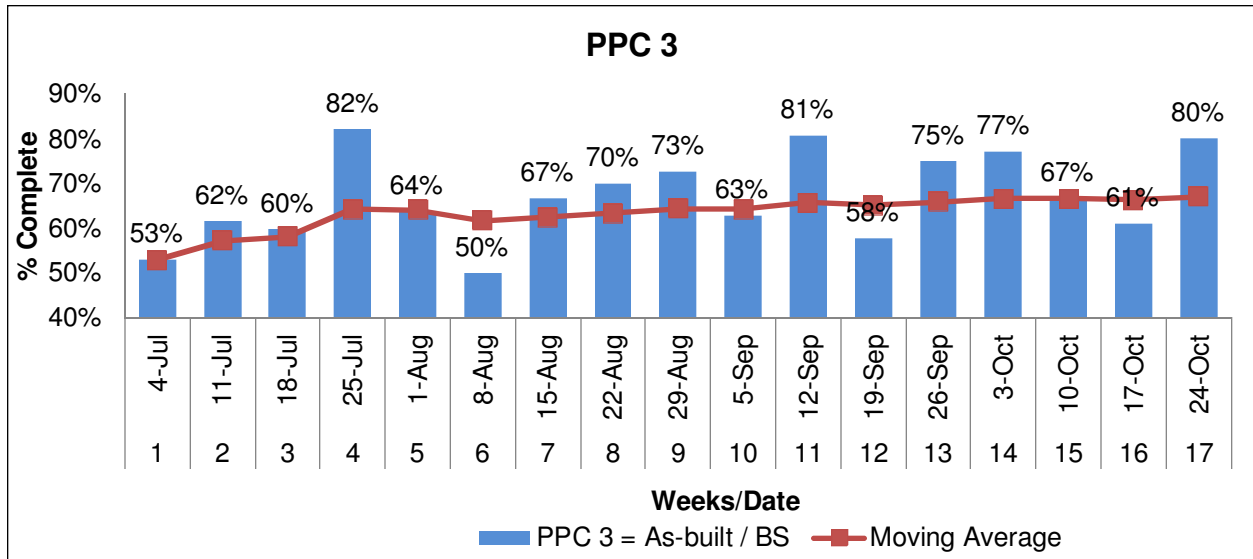
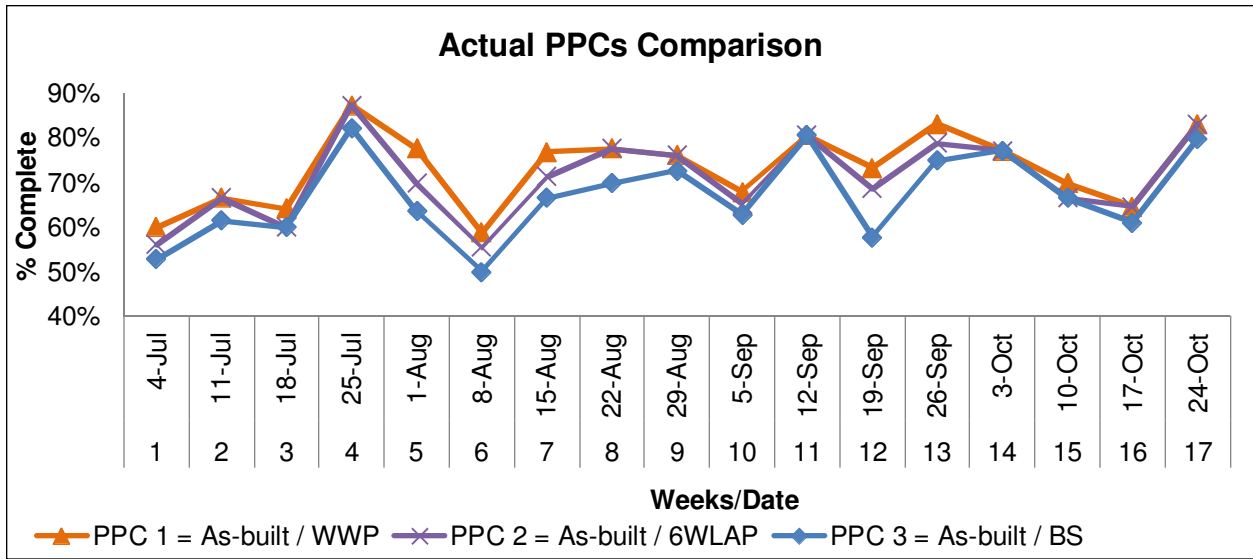


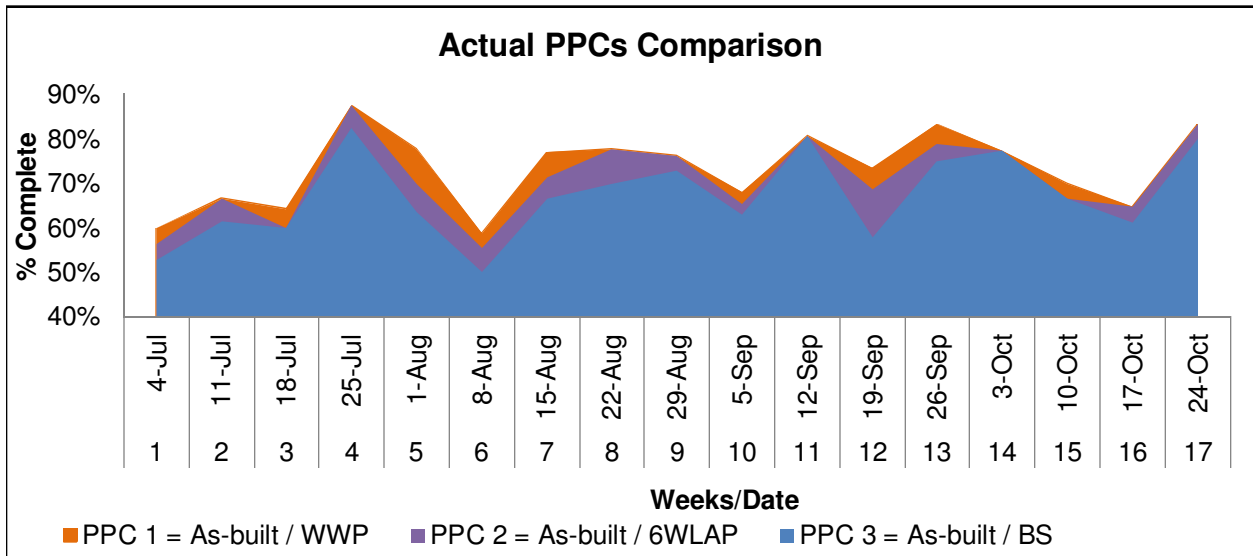
Figure 4.9: Phase 2 PPC Ratio for As-built & Baseline Schedule/PPS

The PPC 3 ratio shown in Figure 4.9 is a result of number of tasks completed as compare to tasks listed on Baseline Schedule (BS) or Phase Pull Schedule (PPS) with an average of 67% - shows considerable improvement compared to 50% during Phase 1.

Figures 4.10 (a) & (b) shows a plot of actual PPC 1 versus PPC 2 & PPC 3. There is an average of 2% to 6% difference between what is anticipated from week-to-week and what was anticipated with 6WLAP and at the start of the project respectively. In other words, areas in orange and purple shows noncompliance between as built versus 6WLAP and BS/PPS. Figure 4.11 (a) & (b) shows a plot of week-by-week moving average PPC 1 versus PPC 2 & PPC 3. Area distinguished by orange color represents weekly plan failures, area with purple color represents monthly plan failures, and area in white below 100% line indicates execution failures.

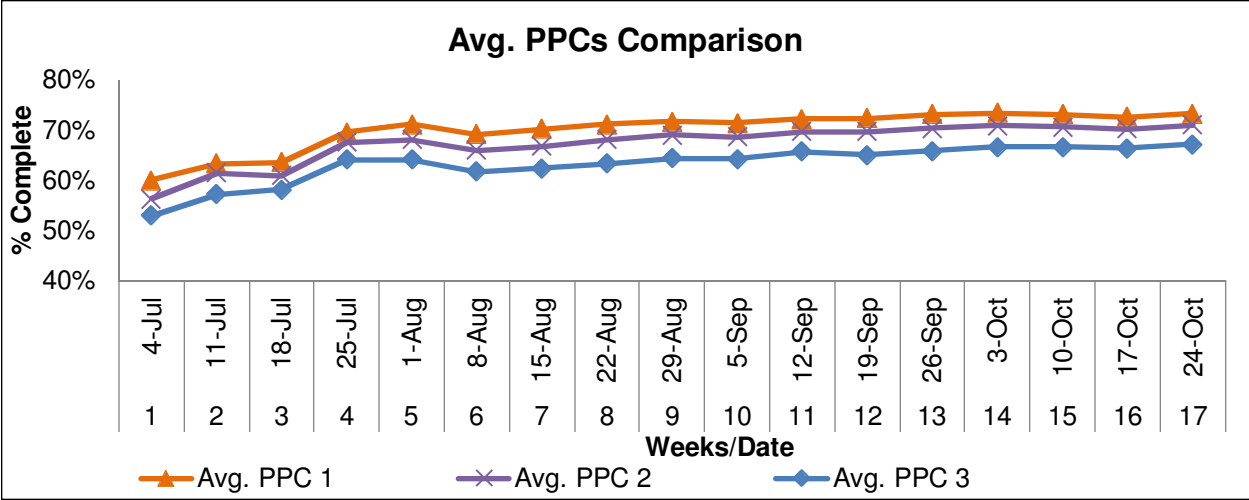


(a)

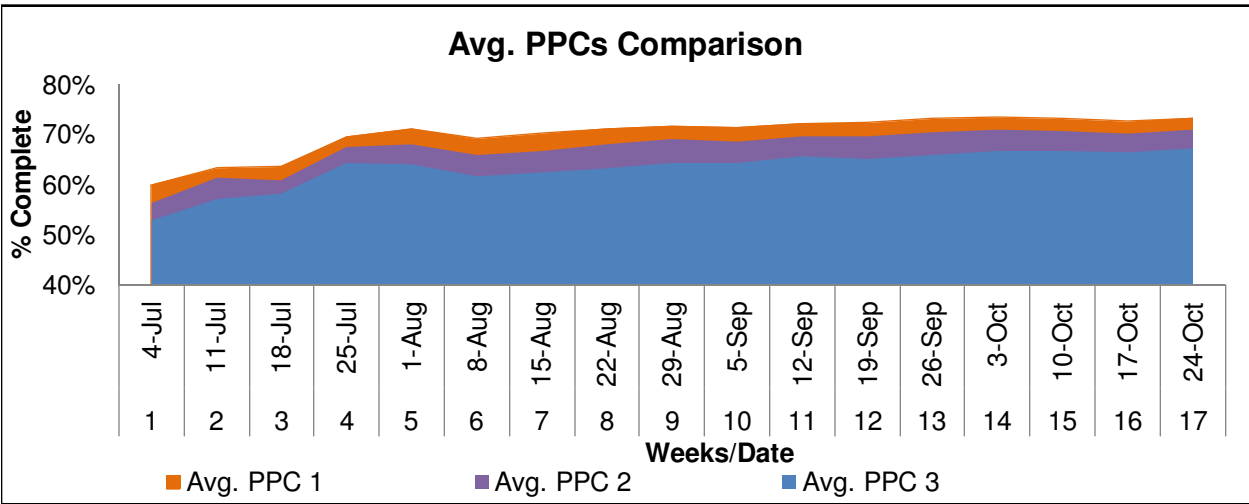


(b)

Figure 4.10: Phase 2 Actual PPC Comparison (a) Weekly PPC Ratios Comparison, (b) Variance between Look-ahead Plan and Baseline Schedule



(a)



(b)

Figure 4.11: Phase 2 Week-by-Week Moving Average (a) Weekly PPC Ratios Comparison, (b) Variance between Look-ahead Plan and Baseline Schedule

4.4.2 Reasons for Incomplete Assignments

Figure 4.12 presents the various reasons for incomplete assignments reported on case study. For the Phase 2, labor supply was the main reason for incomplete assignments. It was evident that the formwork subcontractor was always struggling to keep pace with the weekly plans and look-ahead plans because the available workforce was insufficient to meet the project needs. As most of the work was subcontracted with lump-sum values, labors on site appear to have exceeded their capabilities, to put aside maximum possible profit margin due to current economic depression and stiff competition within industry.

Still prerequisite work and coordination issues were some of the other major reasons for incomplete assignments in the project during Phase 2. This perhaps, due to the complexity of project and very restricted working space available.

The third reason was weather. This is due to during initial stage of LPS implementation majority of project was at foundation level. Delays were mainly due heavy rain causing interruption to activities for substructure.

Rest of the reasons were below occurrence level of 4, as presented in Figure 4.12, and last planner team was committed to control these reasons in future.

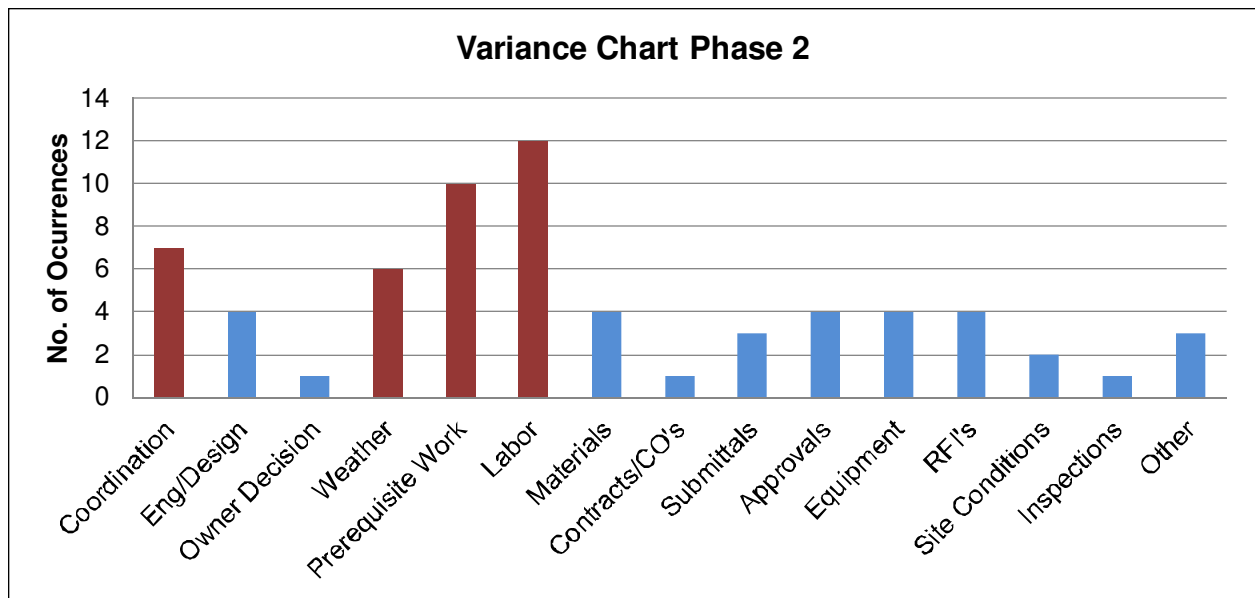
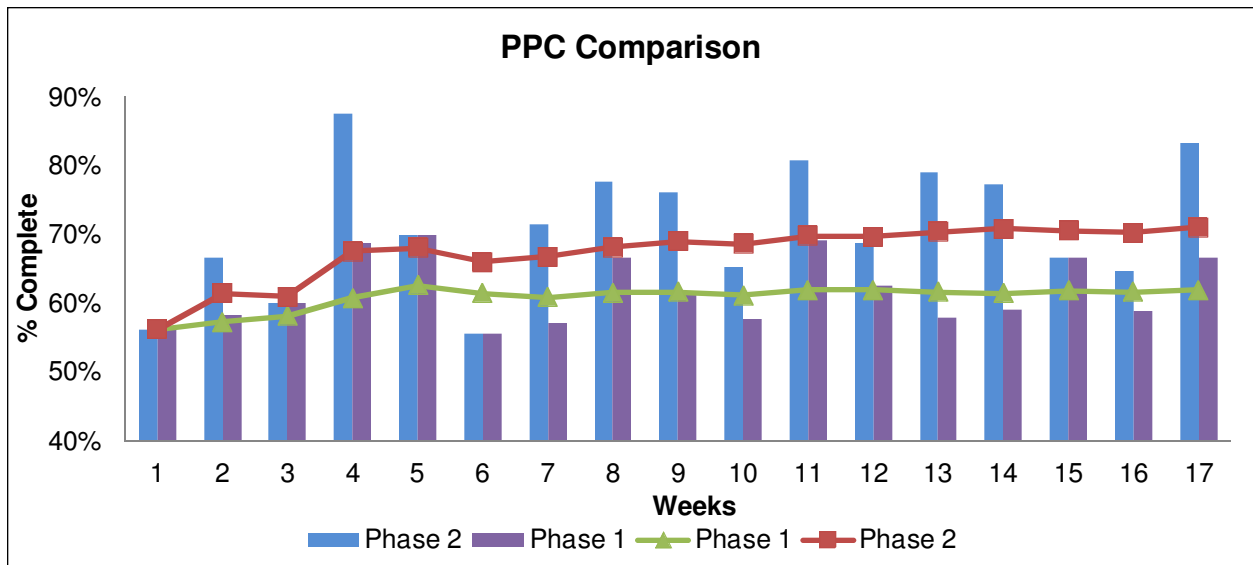


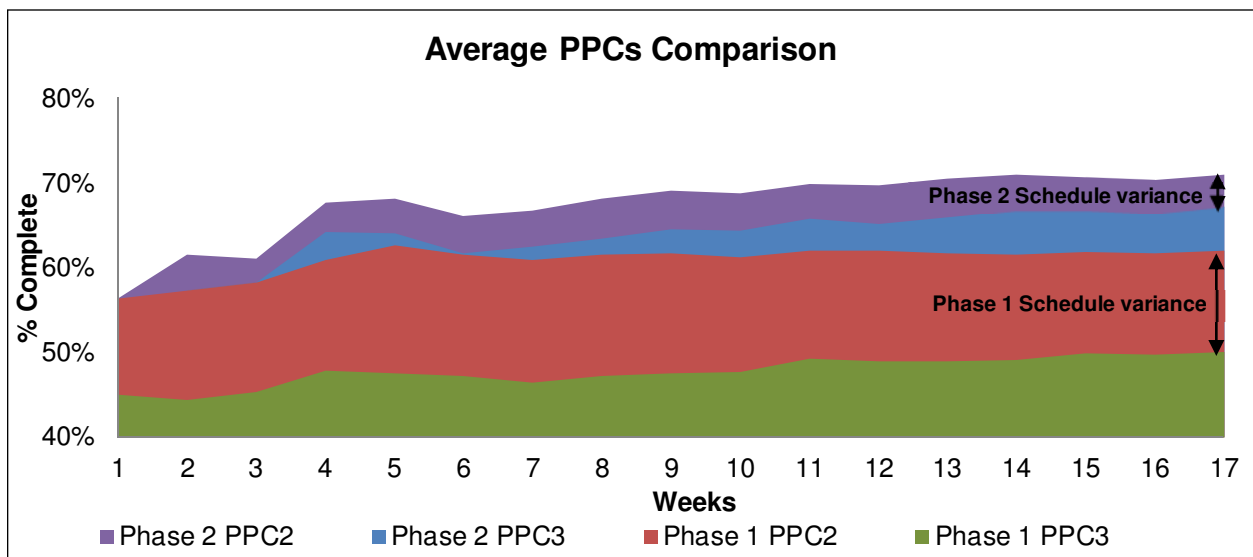
Figure 4.12: Phase 2 Reasons for Incomplete Assignments during Observation Period

4.5 Comparison of Pre and Post Implementation of LPS

Figure 4.13 (a) shows the comparison between PPC ratios calculated for Phase 1 and Phase 2. The average PPC for Phase 1 was 62% which was improved up to 73% after implementing LPS in Phase 2. The gap, between activities planned on look-ahead planning compared to activities planned during preparation of baseline schedule, is considerably reduced in Phase 2 as shown in Figure 4.13 (b).



(a)



(b)

Figure 4.13: Comparison of Phase 1 and 2 (a) Weekly PPC Ratios Comparison, (b) Comparison of Variance between Look-ahead Planning and Baseline Schedule

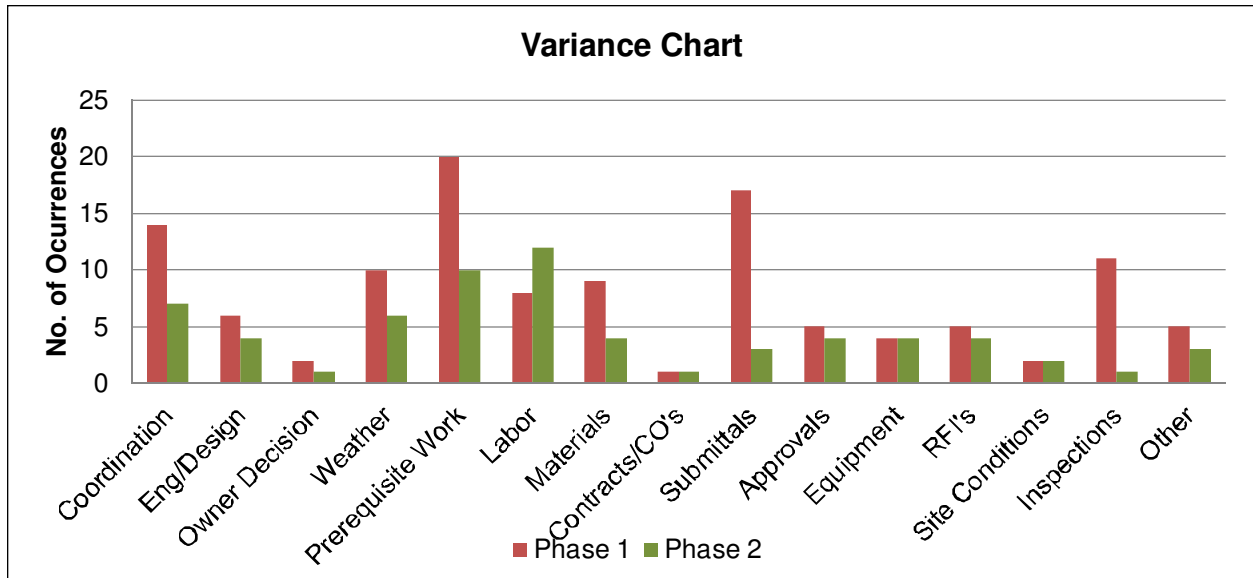


Figure 4.14: Comparison of Phase 1 & 2 Reasons of Non-completion

Figure 4.14 shows categories of reasons of non-completed assignments. As discussed earlier some of the main root causes in Phase 1 were prerequisite work, submittals, coordination between project participants, and inspections. As a part of LPS, the project team committed to remove possible constraints listed on constraint log. Above chart summarizes decreased level of root causes. The category related to labor reported an increase in occurrences because the formwork subcontractor filed for bankruptcy, which resulted in non-complete activities for concrete structure.

4.6 Outcome of Survey Questionnaire and Interviews

This section includes graphical representation of survey results derived at the end of research period. Most of the questionnaires were filled out during interview sessions conducted by the author. In the studied project, the sample is 26 respondents; from all parties involved. The primary aim of the survey was to evaluate and surface out achieved benefits, Critical Success Factors (CSFs), and barriers of LPS implementation on the project.

The distribution of survey participants is represented in Figure 4.15. It was ensured that the survey participants belonged to various sections of the commercial construction industry

thus enabling the researcher to not only gain the perspectives from the view of owners, contractors, subcontractors, project managers but also engineers and designers.

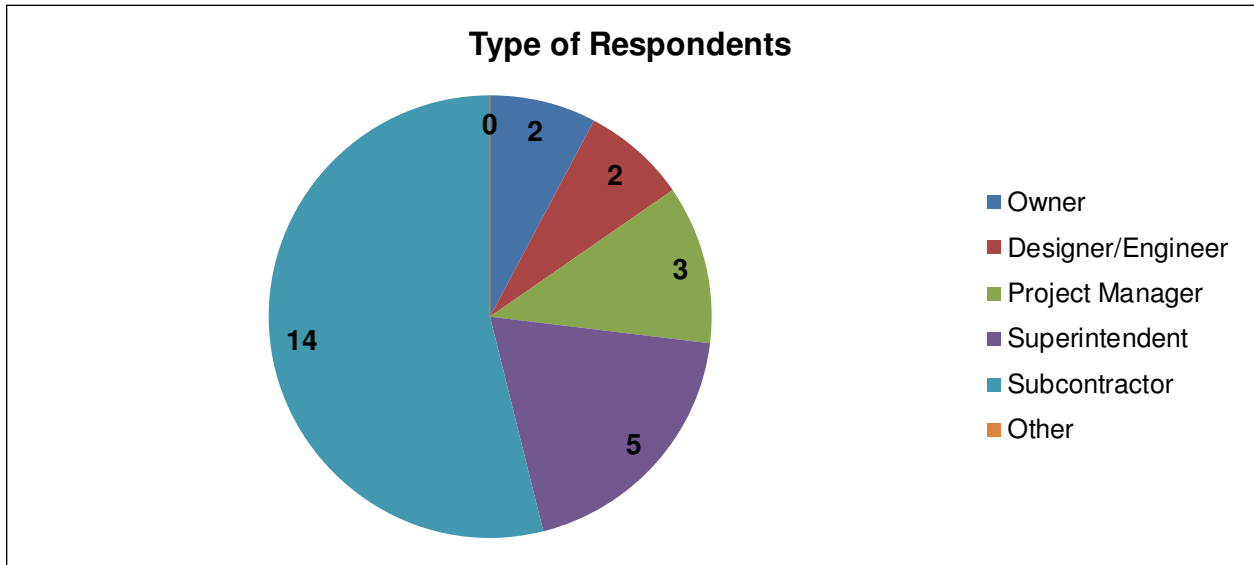


Figure 4.15: Distribution of Respondents by Position

The survey results (Figure 4.16) showed that most of the participants had very limited or no experience with LPS system. However, the planner and one senior superintendent did have 2 to 3 year of experience with LPS, which facilitated effective implementation of LPS while involving majority of subcontractors.

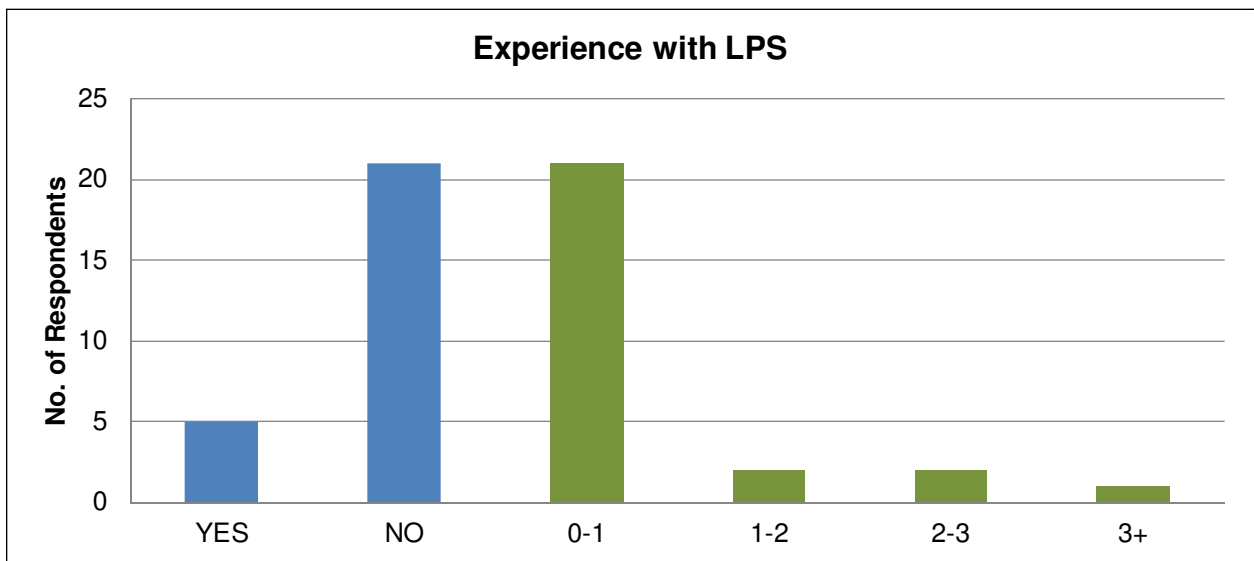


Figure 4.16: Respondents Experience with LPS

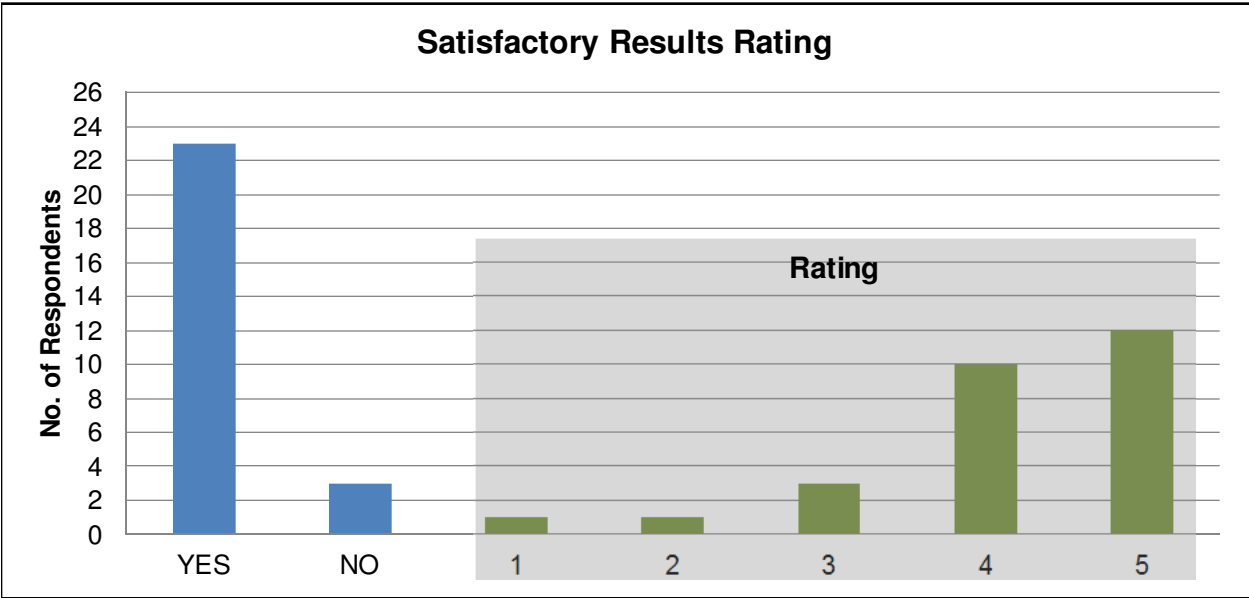


Figure 4.17: LPS Success Rate Scenario on Project

Interruption of the project prevents from drawing a firm conclusion; however, participants considered the Last Planner System successful and superior to traditional methods of project control. Figure 4.17 suggests tremendous opportunity for further improvement with an average rating score of 4.15 on a scale of 1 to 5.

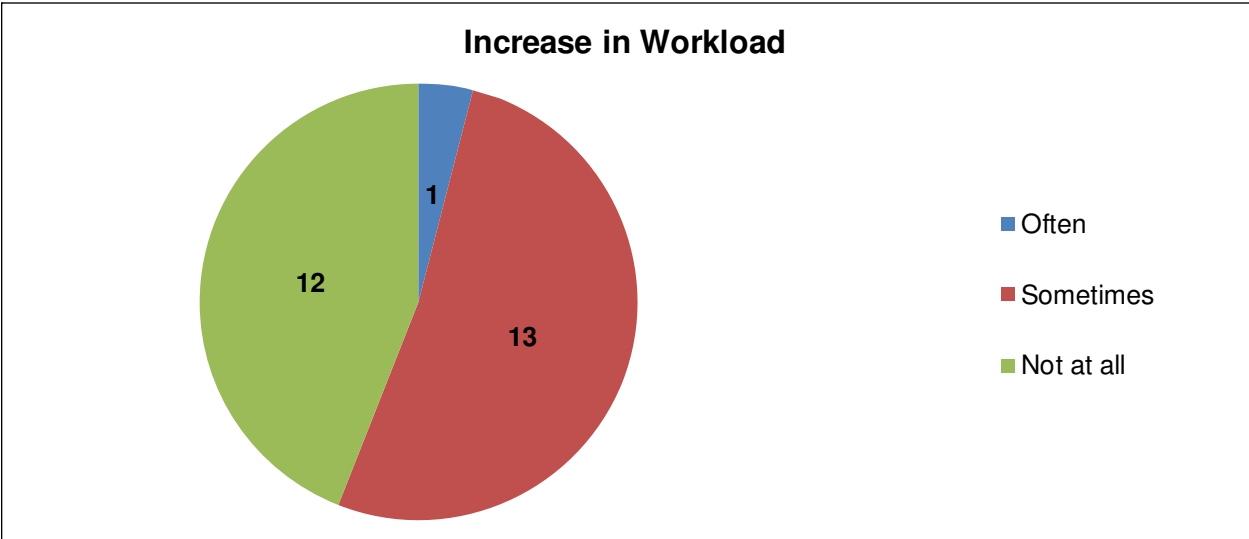


Figure 4.18: Workload Status due to LPS Implementation

LPS implementation in this project did not increase the work load for 11 participants and 13 believed that the weekly planning meetings were extremely valuable, because they were forced to plan their work in detail, refer Figure 4.18. However, most of the PPC calculations and analysis were done by the author between two Weekly Work Planning meetings.

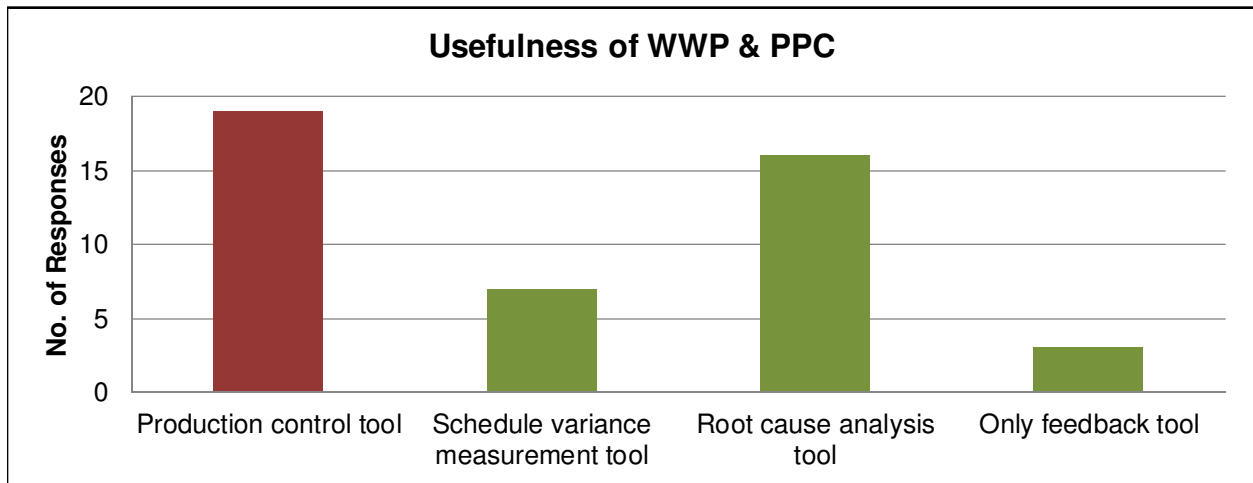


Figure 4.19: Usefulness of WWP & PPC

The survey results, as shown in Figure 4.19, revealed effectiveness of WWP and PPC as various tools to manage planning process. It was observed by the author that majority of participants selected two or three most applicable options on their questionnaire forms amongst available options; i.e. production control tool, schedule variance measurement tool, root cause analysis tool, and feedback tool for project controllers. More than 42% of responses were in favor of PPC’s usage as a production control tool and 36% were advocated PPC was also useful in obtaining root causes of incomplete assignments.

Table 4.2 The Perceived Benefits, CSFs and Barriers for LPS in Project

Benefits	CSFs	Barriers
<ol style="list-style-type: none"> 1. Enabling site supervisors to plan their workload. 2. Improving planning and controlling practice 3. Enabling accurate prediction of resources 4. Reducing uncertainty 	<ol style="list-style-type: none"> 1. Top management support. 2. Contractual commitment. 3. Involvement of all stakeholders. 4. Communication and coordination between parties to achieve team work. 5. Close relationship with subcontractors/suppliers. 	<ol style="list-style-type: none"> 1. Involvement of subcontractors 2. Owner’s involvement 3. Designer/Engineer’s involvement 4. Resistance to change 5. Awareness of LPS

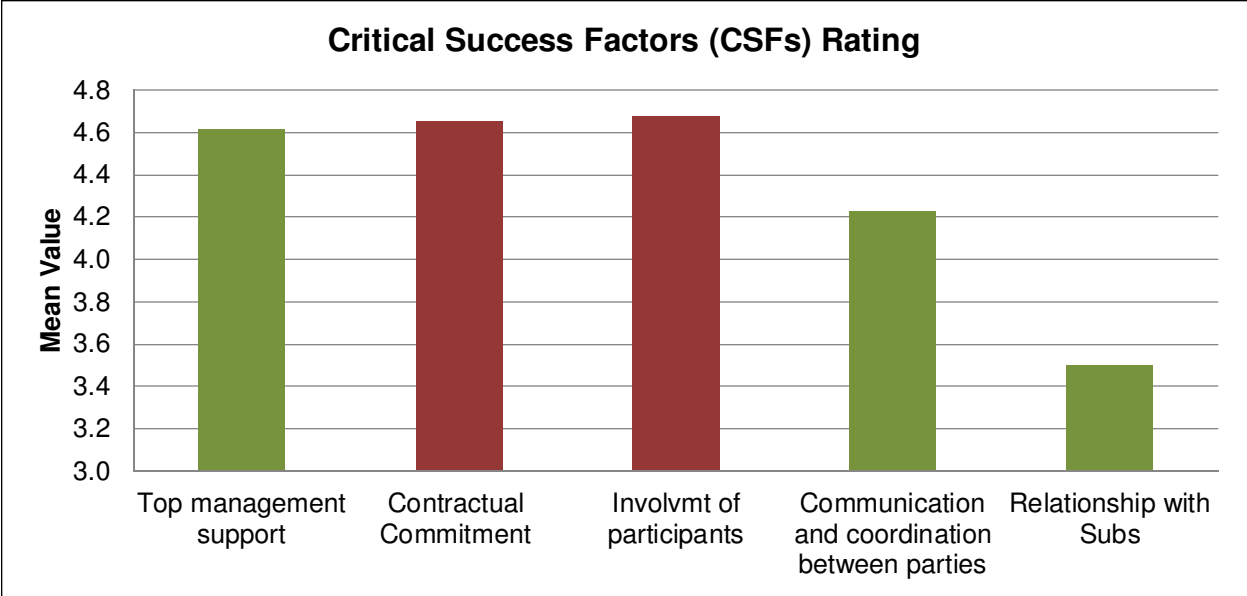


Figure 4.20: Criticality Rating of CSFs

Benefits, CSFs and barriers revealed from interviews and survey questionnaire are briefly presented in Table 4.2. The benefits and CSFs are similar to a large extent with differences only in the degree of agreement between respondents. The most identified important CSFs based on their criticality rating (shown in Figure 4.20) are involvement of all stakeholders, getting contractual commitment from all project participants, and top management support. Also, most of the identified barriers are lack of full involvement from subcontractors and people's resistance to change their mind set towards existing planning control process. Another crucial factor was limited knowledge of Lean Construction and Last Planner System within project participants (Figure 4.21).

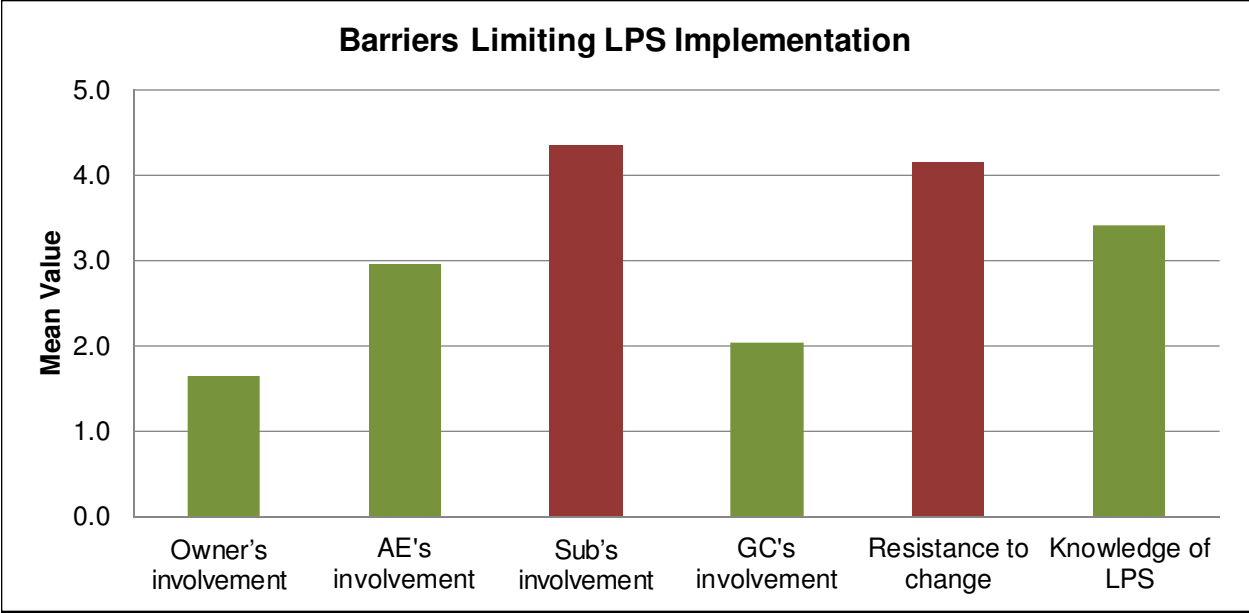


Figure 4.21: Barriers Limiting Implementation of LPS

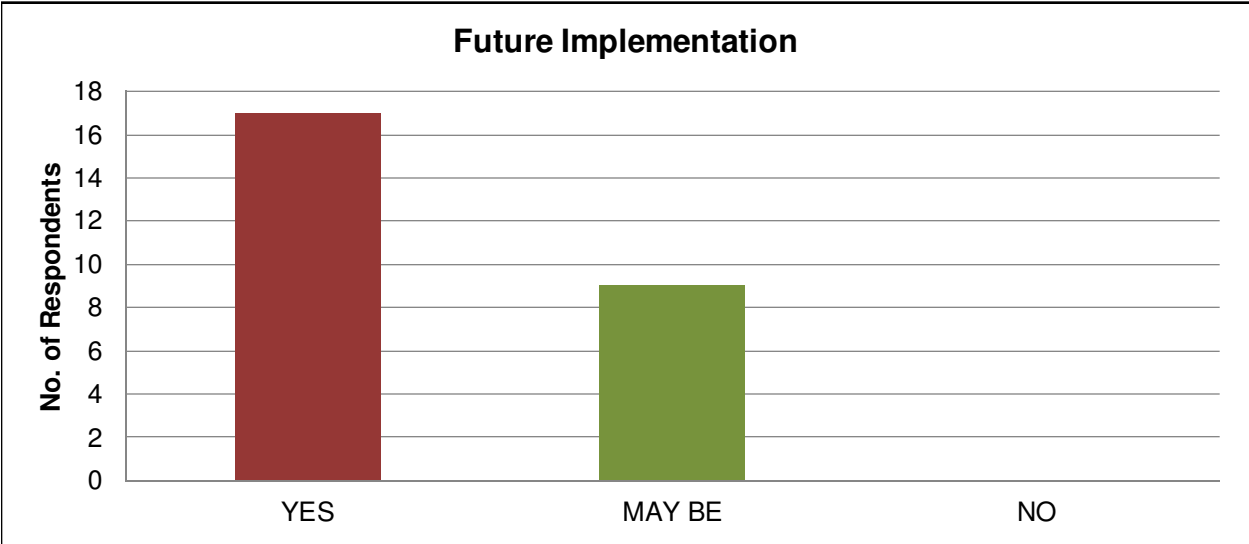


Figure 4.22: Opportunity in Future Application

Out of all the survey participants 65% strongly believed that LSP should be implemented on upcoming projects and rest of them partially agreed (Figure 4.22). Applicability and effectiveness of the LPS over entire project duration remains definitively determined, however the generative nature of construction project at operational level suggests that a cost control system such as Earned Value Method (EVM) can be integrated with LPS. In response to

author's question for possibility of integration between LPS and EVM, the results were recorded as shown in Figure 4.23.

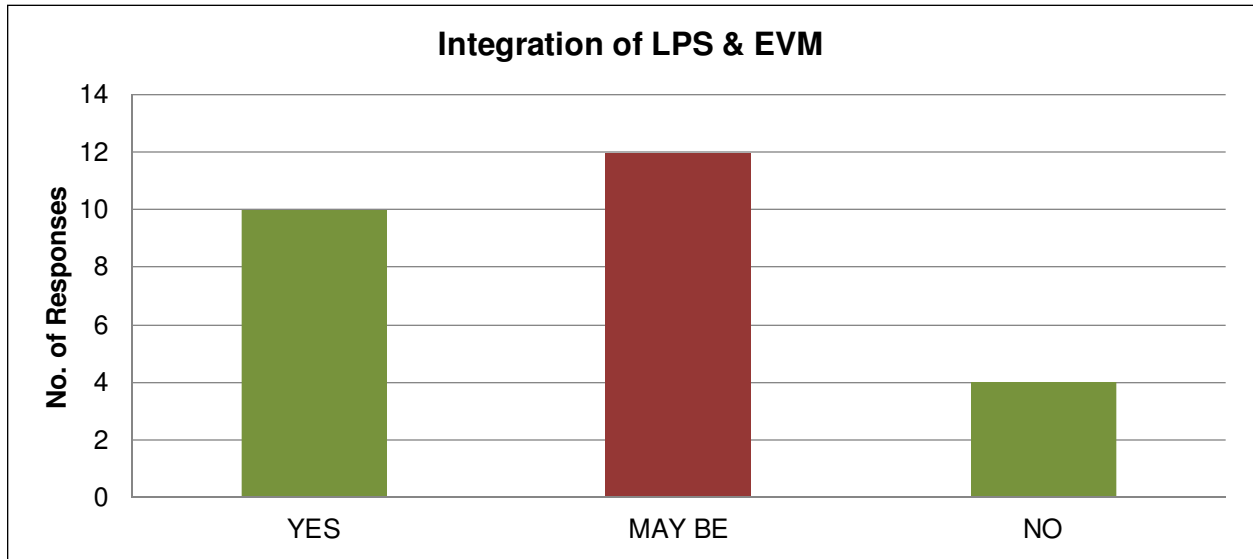


Figure 4.23: Possibility of Integration between LPS & EVM

4.7 Chapter Summary

Reliability and validity of findings is especially difficult in survey research because of the potential difference between what people say and what they do. In spite of that, the author was able to identify where some of the problems and barriers were encountered and it was clear that many of these were cultural and organizational. It is less of a problem for action research because of its public nature and availability of measurement data such as PPC. PPC ratios calculated for Phase 2 (73%) indicates significant improvement in reliability of planning process. Notwithstanding this point, the researcher and the project team were of the opinion that the project had benefited substantially from using the LPS and that without its use the project might have suffered a larger time overrun.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

5.1 Introduction

This chapter presents the conclusions drawn from the results and findings obtained in this thesis. It also includes the recommendations that can be incorporated into further study for the same subject area.

5.2 Conclusions

The objective of this study was to implement and evaluate the Last Planner System on a given project. This study has provided new insights with respect to the issues surrounding the implementation of a new concept on an ongoing project and the issues related to implementing the Last Planner Technique. The following conclusions can be derived from this thesis:

1. The T-test value showed significant difference between PPC ratios for pre- and post-LPS implementation found in this research, indicated improvement in the project planning process at an operational level.
2. The LPS technique proved that it could enhance planning aspects of construction management practice and bring numerous advantages. Comparison between PPC ratios computed for Phase 1 and Phase 2 indicated the successful implementation of the LPS in the project. Moreover the successful implementation of the LPS was supported by the fact that the project management team was able to recover approximately two weeks of time assigned to construction activities for structure, which was delayed by late completion of Phase 1.
3. Half of the survey participants admitted that the LPS increase workload sometimes. However, the LPS was a new concept for majority of the respondents.

4. The root causes of non-completion were documented for Phase 1. The results derived from Weekly Work Plan showed that the project team was able to limit root causes of non-completion for Phase 2.
5. Although, there were some obstacles preventing the achievement of full potentials of LPS, the implementation process in the project was successful, as confirmed by the results and outcomes of the survey questionnaire.
6. Survey results identified level of involvement from subcontracting firms as one of the main barriers hindering the LPS implementation. Majority of general contractor's and owner's representatives proposed getting contractual commitment from the subcontractors.

5.3 Limitations

This research evaluates the successful implementation of LPS by comparing the PPC ratios calculated for Phase 1 and Phase 2 of the case study project. However, this comparison has the following limitations:

1. The nature and scope of the work in Phase 2 was partially different than it was in Phase 1. For example, Phase 1 included two parking garages only while Phase 2 included one parking garage with three residence halls, and one apartment structure. The differences in the nature of Phases 1 and 2 can impact the rate of completion of planned activities and may have biased PPC values in each Phase.
2. Different subcontractors were employed for mechanical and plumbing parts of the case study project in Phases 1 and 2. Therefore, there is a possibility of improved planning process due to experience of the new subcontractors. However, involvement of new subcontractors might also result in higher number of initial non-completed activities compared to planned activities, due to learning curve productivity.

The above limitations are some of the variables which may have altered the strict comparison of PPC ratios as calculated in Phases 1 and 2. Therefore, these limitations may restrict generic use of the results obtained. However, the survey outcome provides and confirms benefits of LPS.

5.4 Recommendations for Future Research

The recommendations for future research on the Last Planner System can be summarized as following:

1. The research results are based on the data that was collected within a period of only seventeen weeks due to time constraints. A further long-term research study, covering the entire project duration, is recommended to validate the effects of hidden benefits such as cost improvements, and skill improvements of jobsite personnel.
2. The future research can perform statistical analysis, such as a T-test, to measure the significance of improvements among PPC values.
3. Development of a training program, which will train the future last planners (schedulers, superintendents and foremen) and communicate the goals to all parties in the construction project. Traditionally, the project participants resist the change process unless they believe it is both useful and possible, demonstrated through a proper training program.
4. Customize the existing valuable steps of LPS according to the future projects/organizations and eliminate wasteful steps.
5. Future studies on LPS can incorporate project control system such as earned value method along with weekly work plans to improve decision making process at operational level.
6. A similar study can be tested for different construction projects, i.e., infrastructure, communications, heavy engineering, transportation, civil, healthcare, government, etc.

APPENDIX - A
SURVEY QUESTIONNAIRE



Hello,

This voluntary questionnaire is part of a study being conducted on Last Planner System of 'Lean Construction'. The purpose of this study is to analyze results of implementing last planner system in the construction industry. The questions are designed to help us understand outcomes of the system and impacts on each individual involved in the process. Identifying what you think about Last Planner System for reliable project delivery will be instrumental in order to reach that goal.

Your very valuable input will help us to derive conclusions, determine success rate of implementation, and recommendations to improve implementation process future projects because only you can supply the required information. This study is being conducted by Alok Patel (contact information provided below) under direction from Dr. Mohammad Najafi, P.E. Professor at the University of Texas at Arlington (contact information provided below). A copy of the Survey Results can be sent to you by e-mail at your request.

The questionnaire asks you for information on your experience with Last Planner System. The survey contains 9 questions, and we estimate it will take an average of 5 minutes to complete the survey. Your completion of this survey is voluntary. You are free to not answer any question or to stop participating at any time. There are no risks or individual benefits (except receiving a copy of the research findings as noted above) associated with taking this survey. The responses collected will be kept confidential by the researcher to the maximum extent allowable by law. By completing this survey, you indicate your voluntary consent to participate in this study and have your own answers included in the project data set.

Thank you in advance for your help, we do appreciate your time.

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Your Contact Information

Name:	
Company:	
Address:	
City/Town:	
State:	
ZIP Code:	
Email ID:	
Phone:	

Semi Structured Questionnaire Form						
No.	Question	Please answer/select all that apply (X)				
1.	Please indicate your position within industry.	Owner		Subcontractor		
		Designer/Engineer		Project Manager		
		Superintendent		Other		
		Specify if other				
2.	Do you have previous experience with LPS? If yes, please indicate in years.	YES	NO	Experience		
				0-1	1-2	2-3
3.	The results achieved, are they satisfactory or not? If yes, please rate on scale of 1 to 5 considering 1 is least and 5 is most satisfactory. (Circle one)	YES	NO	Rating		
				1	2	3
4.	Was it laborious to work according to the method?	Often		Sometimes		Not at all
5.	How WWP & PPC is useful to you? Select all applicable options.	Production control tool		Root cause analysis tool		
		Schedule variance measurement tool		Only feedback tool		
6.	Please rate critical success factors (CSFs) listed below on scale of 1 to 5.					
	• Top management support	1	2	3	4	5
	• Contractual Commitment	1	2	3	4	5
	• Involvement of all participants	1	2	3	4	5
	• Communication and coordination between parties	1	2	3	4	5
• Relationship with Subs	1	2	3	4	5	
7.	What were the main difficulties faced by the company during the implementation?					
	• Owner's involvement	1	2	3	4	5
	• Designer/Engineer's involvement	1	2	3	4	5
	• Subcontractor's involvement	1	2	3	4	5
	• Contractor's involvement	1	2	3	4	5
	• Manage resistance to change	1	2	3	4	5
	• Educate participants with LPS	1	2	3	4	5
8.	Should the method be used in the future projects?	YES		MAY BE		NO
9.	Do you think integration of Last Planner System (LPS) and Earned Value Method (EVM) will be more useful at the operational level?	YES		MAY BE		NO

APPENDIX - B
GLOSSARY OF TERMS

6 Week Make Work Ready Plan (6W MWR plan)	A schedule, usually based on the pull/phase schedule that clearly identifies all the activities to be performed in the next 6 weeks. The 6W MWR plan is updated each week – always identifying new activities coming 6 weeks out so that the project management team can make appropriate arrangements to perform that work. When an activity cannot be advanced, the reason “why” is identified and listed as constraint. In some cases the 6W MWR plan is based on an existing CPM schedule though this minimizes the effect of coordination achieved in the pull/phase schedule. The 6W MWR plan has been prepared as an Excel spreadsheet in the past but is now regularly prepared using one of the scheduling software packages.
Activity	An identifiable chunk of work with recognized requirements to begin and recognized end point – or conditions of satisfaction. (see also “task”)
Assignment	A task that has been requested by a client or offered by performer – conditions of Satisfaction negotiated and agreed by each – and placed on WWP for performance. The assignment must meet the below characteristics prior to inclusion on the WWP.
Capacity	The amount of work a production unit, whether individual or group, can accomplish in a given amount of time. Example: Jim the engineer can perform 10 piping stress analyses per day on average, but the analyses to be done this week are particularly difficult. He will only be able to do 7. Jim’s average capacity is 10, but his capacity for the specific work to be done this week is 7.
Category of Variance	There are a number of factors that can keep an assignment from being completed – by assigning a category of variance to each uncompleted task a team is able to work on eliminating those causes in the future. Several categories are listed below – each project or company can develop their own categories as they work with LPS
Constraint Log	A list of constraints with a promise date to resolve and responsibility for resolving it. Typically developed during a review of the 6WLAP plan when it is discovered that activities cannot be advanced as required.
Constraints	An item or requirement that keeps an activity from being advanced or completed as scheduled. It is not a predecessor activity already shown on the schedule but something that is not shown on the schedule such as a new client requirement, a contract that must be issued prior to work beginning, approval from an architect to change a design, etc.
Contract/CO’s	A contract or change order has not been signed or approved to allow work to be completed
Control	To cause events to conform to plan, or to initiate re-planning and learning. Example: Exploding master schedule activities into greater detail, screening the resultant tasks against constraints, and acting to remove those constraints are all control actions intended to cause events to conform to plan, or to identify as early as practical the need for re-planning. Learning is initiated through analysis of reasons for failing to cause events to conform to plan.
Critical Path Method (CPM) Schedule	A schedule prepared from a number of activities that are shown with their durations and predecessors/successor activities. Typically the CPM schedule is prepared with use of software such as MS Project, Suretrack or Primavera P6 – the name comes from the ability of the software to calculate a “Critical Path” – those activities that must be completed as

	schedule or the calculated end date will slip.
Customer	The user of one's output. Example: John needs the results of our acoustical tests in order to select the best location for his mechanical equipment. John is our customer because he will use what we produce.
Hand-off	The act of releasing an item or activity to the person or group who is going to perform the next step or operation on that item or activity. For example, a structural steel design is "hand-off" to the steel detailer to complete shop drawings.
Integrated Project Delivery (IPD)	Integrated Project Delivery (IPD) leverages early contributions of knowledge and expertise through the utilization of new technologies, allowing all team members to better realize their highest potentials while expanding the value they provide throughout the project lifecycle.
Last Planner	The person or group that makes assignments to direct workers. 'Squad boss' and 'discipline lead' are common names for last planners in design processes.
Lookahead Planning	The middle level in the planning system hierarchy, below front end planning and above commitment-level planning, dedicated to controlling the flow of work through the production system.
Make Ready	Take actions needed to remove constraints from assignments to make them sound.
Master Schedule	A schedule that identifies major events in a project (start-up, turn-over to client, order long delivery components, mobilize in field, complete design, government reviews, etc.) and their timing. It is the basis for contractual agreements between the owner and other team members.
Milestone	An item on the Master Schedule that define the end or beginning of a phase or a contractually required event.
Phase	A period of the project where a specific group of activities is scheduled to be accomplished such as building design, completion of foundations, erection of exterior walls, building dry-in, etc. A phase can be either a time period or a group of activities leading to the accomplishment of a defined goal/milestone.
Plan Percent Complete (PPC)	A basic measure of how well the planning system is working – calculated as the "number of assignments completed on the day stated" divided by the "total numbers of assignments made for the week". In many cases the PPC will be less than 50% when a project starts to monitor the PPC and will rise to 80 or 90% as the team becomes conscious of the need to actually perform work as planned.
Plan Reliability	The extent to which a plan is an accurate forecast of future events, measured by PPC. For example, if your weekly work plans have a 60% PPC, they accurately predict completion/release of 60% of the weekly assignments.
Planning	Defining criteria for success and producing strategies for achieving objectives.
Prerequisite Work	Work done by others on materials or information that serves as an input or substrate for your work. Example: You need to know the surface area of glass, provided by the architect, in order to size cooling equipment.
Productivity	The ratio of the amount of work produced to the resources used in its production. Example: x drawings per labor hour.
Pull/Phase	A schedule prepared for a specified phase of a project using a pull

Schedule	technique to determine hands-offs. Typically it is prepared by the team actually responsible for doing the work – engineers, architects, owners, designers for a “design phase”, designers, specialty contractors, GC for a “construction phase”. The team members start at the conclusion of the phase and work backwards, at each step identifying the requirements to declare a chunk of work complete and their needs to start that chunk. Many times it is performed by pasting description of the chunks of work on a wall, establishing duration and efficient work flow pattern and then converting the final solution to a Gantt chart type of schedule.
Resources	Labor or instruments of labor. Resources have production capacities as well as costs. Consequently, materials and information are not resources, but rather what resources act on or process.
Schedule/sequence	The assignment was incorrectly scheduled to be performed at this time or it was not realized that another task needed to be completed prior to this one.
Should-Can-Will-Did	To be effective, production management systems must tell us what we <i>should</i> do and what we <i>can</i> do, so that we can decide what we <i>will</i> do, then compare with what we <i>did</i> to improve our planning.
Task	An identifiable chunk of work – preparation of design documents, erection of steel, testing of an HVAC system, turn-over of a building floor – similar to an “activity”.
Underloading	Making assignments to a production unit or resource within a production unit that absorbs less than 100% of its capacity. Underloading is necessary to accommodate variation in processing time or production rate, in order to assure plan reliability. Underloading is also done to release time for workers to take part in training or learning, or for equipment to be maintained.
Utilization	The percentage of a resource’s capacity that is actually used. Example: Because of time lost waiting for materials, our labor utilization last week was only 40%.
Variance	When an assignment is not completed as stated, it is considered a variance from the weekly work plan
Weather	Weather problems (rain, snow, ice, extreme heat) occur that were not anticipated or planned for.
Weekly Work Plan (WWP)	The “basic” document of LPS – a list of assignments with a day certain for completion that has been agreed to by the performer. The WWP is used to determine the success of the planning effort and to determine what factors limit performance. All the activities shown on the 6W MWR plan for the current week are included on the WWP – in most cases they are expanded to include more detailed assignments that allow coordination between the different performers to occur at a Weekly Work Plan Meeting.
Work Flow	A fact of life in construction – one task must be completed prior to another being started (or, in rare cases, completed) and being able to provide timely hands-off from one task to another allows the “work flow”
Workable backlog	An activity or assignment that is ready to be worked on but is not scheduled to be performed as this time. If the team agrees that performance of this activity will not hinder other work then it can be placed on the list of Workable Backlog as part of the WWP. Completion or non-completion of these activities are not recorded or counted in calculations

	of PPC. A reasonable amount of Workable Backlog allows performers who are stopped from doing their assignments on the WWP or finish them early to continue work without causing harm to others – thus maintaining a reliable work flow.
YES/NO	At the end of a week – each assignment is determined to have been completed as stated/scheduled – a “YES” – or not to have been completed as scheduled – a “NO.” There is no credit for partial completion or for starting an assignment because assignment is not ready for the next person or team to work on it and the work flow is interrupted.

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BIOGRAPHICAL INFORMATION

At the time of presentation of this paper, Alok Patel has a Bachelors Degree in Civil Engineering from the CEPT University, India. He has continued to maintain a strong academic standing while pursuing a Masters in the area of Construction Management and Engineering at the University of Texas at Arlington. Mr. Patel was employed by the University of Texas at Arlington as a Graduate Research Assistant for the semester of Fall 2010. He has been under employment of Austin Commercial, L.P. as a Graduate Intern for the semesters of Spring 2011 and Fall 2011. Mr. Patel has served as Vice President on the UT Arlington student chapter of the North American Society of Trenchless Technology and has been an active member of Tau Beta Pi honor society.