THE LAST PLANNER SYSTEM OF PRODUCTION CONTROL

by

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ABSTRACT

Project controls have traditionally been focused on after-the-fact detection of variances. This thesis proposes a control system, the Last Planner system, that causes the realization of plans, and thus supplements project management's concern for management of contracts with the management of production.

The Last Planner system has previously been successively applied by firms with direct responsibility for production management; e.g., speciality contractors. This thesis extends system application to those coordinating specialists, both in design and construction, through a series of case studies, one of which also explores the limits on unilateral implementation by specialists.

In addition to the extended application, two questions drive this research. The first question is 1) *What can be done by way of tools provided and improved implementation of the Last Planner system of production control to increase plan reliability above the 70% PPC level?* Previous research revealed substantial improvement in productivity for those who improved plan reliability to the 70% level, consequently there is reason to hope for further improvement, possibly in all performance dimensions, especially with application across an entire project rather than limited to individual speciality firms. That question is explored in three case studies, the last of which achieves the 90% target.

The second research question is *2) How/Can Last Planner be successfully applied to increase plan reliability during design processes*[1]*?* That question is explored in an extensive case study, which significantly contributes to understanding the design process from the perspective of active control, but unfortunately does not fully answer the question, primarily because the project was aborted prior to start of construction. However, it is argued that the Last Planner system is especially appropriate for design production control because of the value-generating nature of design, which renders ineffective traditional techniques such as detailed front end planning and control through after-the-fact detection of variances.

[1] In this thesis, the term “design” is used to designate both design and engineering activities, not shaping space to aesthetic criteria.

Issues for future research are proposed, including root cause analysis of plan failures and quantification of the benefits of increased plan reliability for both design and construction processes.

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CHAPTER ONE: INTRODUCTION

1.0 Conceptual Framework

Production processes can be conceived in at least three different ways: 1) as a process of converting inputs to outputs, 2) as a flow of materials and information through time and space, and 3) as a process for generating value for customers. All three conceptions are appropriate and necessary. However, the conversion model has been dominant in the AEC (architectural/engineering/construction) industry until very recently (Koskela and Huovila, 1997).

Table 1.1

	Conversion View	Flow View	Value Generation
Nature of Construction	a series of activities which convert inputs to outputs.	the flows of information & resources, which release work: composed of conversion, inspection, moving and waiting.	a value creating process which defines and meets customer requirements.
Main Principles	Hierarchical decomposition of activities; control and optimization by activity.	Decomposition at joints. Elimination of waste (unnecessary activities), time reduction.	Elimination of value loss - the gap between achieved and possible value.
Methods & Practices	Work breakdown structure, critical path method. Planning concerned with timing start and responsibility for activities through contracting or assigning.	Team approach, rapid reduction of uncertainty, shielding, balancing, decoupling. Planning concerned with timing, quality and release of work.	Development and testing of ends against means to determine requirements. Planning concerned with work structure, process and participation.
Practical Contribution	Taking care to do necessary things.	Taking care that the unnecessary is done as little as possible.	Taking care that customer requirements are met in the best possible manner.

Conversion/Flow/Value[2]

The design and construction of AEC facilities (buildings, process plants, airport terminals, highways, etc.) poses difficult management problems to which the models and techniques based on the conversion view have proven inadequate. Tradeoffs between competing design criteria must be made throughout the design process, often with incomplete information and under intense budget and schedule pressure. Increasingly, projects are subject to uncertainty because of the pace of technological change and the rapid shifting of market opportunities and competitor actions.

Production management concepts and techniques based on the conversion model have not proven capable of solving these difficult problems. The heart of the conversion model is the assumption that the work to be done can be divided into parts and managed as if those parts were independent one from another. Management techniques such as work breakdown structures and earned value analysis belong to this conversion model. Work breakdown structures are driven by scoping and budget concerns and have the objectives of insuring that all the work scope is included in one of the parts, insuring that no work scopes overlap, and allocating costs to each part such that the rollup yields the total for the project. This division into parts is necessary in order to allocate responsibility to internal or external work centers, which can subsequently be controlled against scope, budget, and schedule commitments.

This is fundamentally a contracting mentality, which facilitates the management of contracts rather than the management of production or work flow. Production management is the 'local' responsibility of those to whom the various parts are assigned or contracted. If everyone meets their contractual obligations, the project performs successfully. Unfortunately, this approach is the opposite of robust. When something goes wrong, as it very often does, the entire structure is prone to collapse.

If a management philosophy and tools are needed that fully integrate the conversion, flow, and value models, we might consider the product development processes employed by firms designing and manufacturing consumer products (automobiles, printers, toasters, etc.). Such processes have developed potentially useful concepts especially in the area of value; identification of customer needs and translation into engineering specifications (Ulrich and Eppinger 1993). Product development processes also are struggling with other issues relevant to the design of AEC facilities, including design decomposition, organizational means for integration, etc. (Hayes, et al, 1988; Eppinger, et al, 1990; Gebala and Eppinger, 1991).

As a contribution to the integration of all three models, this thesis applies the flow model to managing the design and construction of AEC facilities. Conceptualizing the design and construction process as a flow of information and materials lends itself to reducing waste by minimizing time information or materials spend waiting to be used, time spent inspecting information or materials for conformance to requirements, time spent reworking information or materials to achieve conformance, and time spent moving information or materials from one specialist to the next. Further, conceptualizing the design and construction process as a flow of information and materials allows coordination of interdependent flows and the integration of design with supply and site construction.

1.2 Assumptions

Fundamental assumptions underlying this research include the following:

- Current construction industry production management thinking and practice is dominated by the conversion model, consequently value generation and flow management concepts and techniques are underdeveloped.
- To be consistent with all three models, conversion, flow, and value, production management should be conceived as having the purpose of creating customer value while minimizing waste in time and cost. “Customer value” is understood to include not only the fitness for use of the facility considered with regard to functionality, but also with regard to all other criteria to which the customer attaches value, e.g., project delivery within a time and for a cost that meets the customer’s market and financial needs.
- "Production" is understood to include both designing and making. The historical development of production theory in manufacturing has erroneously suggested that production is entirely concerned with 'making'.[3]
- Production management is conceived to consist of criteria determination and work structuring in the ‘planning’ phase, and to consist of work flow control and production unit control in the ‘execution’ or ‘control’ phase.

This thesis treats only control functions, not planning functions. It does not treat the very first and fundamental production management activity; i.e., the determination of customer needs and their translation into design criteria. Criteria determination belongs to the value generation view. This thesis treats only the flow view. Similarly, work structuring activities such as identification, sequencing, and scheduling tasks are also not

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[3] There may be differences between the U.S. and U.K. in the use of these terms. Hence the effort to be precise. For the most part, the theory of producing artifacts has emerged from efforts to better manage factories. More recently, in some instances, the term "manufacturing" has acquired greater scope than merely factory production.

treated here. The scope of this thesis is the control functions of production unit control and work flow control.

1.3 Contribution to Knowledge

This dissertation proposes to make the following contributions to knowledge:

- Adapted from manufacturing[4], a system for production control, the Last Planner system, is presented that exemplifies the concept of control as causing events to conform to plan, as distinct from the traditional conception of project control in terms of after-the-fact variance detection.
- Appropriate application of the production control system is shown to improve work flow reliability, which promises substantial benefits in project cost and duration reduction.
- Improvements to the Last Planner system of production control are developed and tested in a series of case studies, resulting in new concepts and techniques.

Project controls in the AEC industry have focused on detecting variances from project objectives for cost and schedule, and have not directly dealt with the management of production. The Last Planner system of production control has proven an effective tool for improving the productivity of the production units that implement its procedures and techniques (Ballard and Howell, 1997). This dissertation shifts the focus from the productivity of the immediate production unit to the reliability of work flow between production units, and also extends application of the system to design.

1.4 The Author's Role in the Research

[4] I.e., from the models and theories developed in industrial engineering

The Last Planner system has been in development by the author since 1992. Several papers have previously been published by this author on the subject, the first of them in 1993 (Ballard, 1993) at the founding conference of the International Group for Lean Construction. Last Planner research began with a focus on improving the quality of assignments in weekly work plans (Koch Refinery Mid-Plants Project, 1993-4[5]), added a lookahead process to shape and control work flow (PARC, 1995[6]; DMOS-6, 1996[7]), and eventually was extended from construction to design (Nokia[8] and Hewlett-Packard[9], 1996). During that development, the objective shifted from improving productivity to improving the reliability of work flow. This resulted from a change in conceptual framework. The initial framework came from the quality management and productivity improvement initiatives that dominated construction industry performance improvement efforts in the 1980s. The shift to work flow reliability reflected the author's increasing awareness of the revolution in manufacturing inspired by the Toyota Production System and eventually labeled "lean production", and also contact with the thinking of Lauri Koskela regarding production theory and its application to the construction industry.

A key metric of the Last Planner system is the percentage of assignments completed (PPC), which is clearly a defect rate and a product of the quality management mentality. Given the objective of improving productivity, measurements were made of the relationship between the defect rate of a crew, its PPC, and the productivity of that crew. Not surprisingly, such measurements revealed a positive correlation[10]. However, the

[5] Ballard and Howell, 1997
[6] Ballard, Howell, and Casten (1996)
[7] Ballard and Howell, 1997
[8] Koskela, Ballard, and Tanhuanpaa (1997)
[9] Miles (1998)
[10] For examples, see the references footnoted previously.

activity focus characteristic of the productivity improvement 'mind' concealed the importance of that crew's PPC for the productivity of the crews that followed it and built upon its work product. Even the introduction of a lookahead process was motivated initially by the observation that simply shielding a crew from poor assignments was insufficient to optimize crew productivity. To do so required matching load and capacity, both of which required managing load or work flow. The more powerful and fundamental opportunity to coordinate action among multiple crews was hidden by the dominance of what Koskela has called the "conversion model" and its exclusive focus on the activity as the unit of control rather than work flow.

Prior to the founding of the Lean Construction Institute (LCI) in August of 1997[11], the Last Planner system had evolved to roughly its current form, with a clear conceptual basis in production theory a la Koskela and an explicit and self-conscious objective of managing work flow. What remained to be done was to learn how to improve work flow reliability above the 35%-65% range commonly discovered up to that time. One purpose of this dissertation is to describe what was done to improve work flow reliability, measured by PPC, and the results achieved. That improving work flow reliability is beneficial hardly requires argument. However, identifying and quantifying the specific benefits will be a matter for future research. The second purpose of this research is to explore applicability of the Last Planner system to design.

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[11] The Lean Construction Institute was founded in August of 1997 as a partnership between Gregory A. Howell and Glenn Ballard, dedicated to research, training and consulting in construction industry production management. Subsequently, Iris Tommelein and Todd Zabelle have become partners in the enterprise, along with Mark Reynolds, Managing Director of Lean Construction International, based in London. All the case studies reported in this thesis were undertaken as research projects for LCI, of which this author is Research Director. All case studies were carried out under the

1.4 Structure of the Dissertation

Traditional project control theory and practice is described and critiqued in Chapter Two. The Last Planner System of Production Control is presented in Chapter Three as satisfying the requirements revealed by the critique. Chapter Four describes the research methodology used in the dissertation and is followed by Chapters 5, 6, 7, 8, and 9, each devoted to a case study. Conclusions from the case studies are reported in Chapter 10, followed by a glossary of terms, a list of references, a bibliography, and an appendix consisting of documents from the design case, Next Stage.

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direction of this author, who also was the primary participant in project events and the primary collector of case study data.

CHAPTER TWO: CRITIQUE OF PRODUCTION CONTROL

2.1 What is Production Control?

The purpose of this chapter is to provide a critique of production control theory and practice. But first it is necessary to clarify what is meant by “production control”.

2.1.1 The Meaning of “Production”

Production has been an explicit topic of study primarily in industrial engineering, which has dealt almost entirely with one type of production; namely, manufacturing (in the sense of 'making'), with only occasional forays into construction, plant maintenance, building maintenance, agriculture, forestry, mining, fishing, etc. Design and engineering have infrequently been conceived as production processes; the focus almost entirely being placed on making things rather than designing them.

Although the meaning of the term at its most universal is synonymous with “making”, “manufacturing” is most commonly[12] used to denote the making of many copies from a single design, and consequently is primarily focused on products for a mass market, most of those products being moveable from the place manufactured to the place of use. There are exceptions to the products being moveable, although still copies from a single design; e.g., ships and airplanes. Within the world of construction, manufacturing in this sense is approached mostly closely by 'manufactured housing'.

[12] Exceptions occur with thinkers and writings regarding product development, which by its nature must integrate designing and making, at least in the sense of making prototypes.

Various types of making have been proposed, among them ‘assembly’, the joining of parts into a whole, as distinct from ‘fabricating’, the shaping of materials. For example, construction is often categorized as a type of ‘fixed position manufacturing’ (Schmenner, 1993), along with shipbuilding and airplane assembly. In all these instances of assembly, the assembled product eventually becomes too large to be moved through assembly stations, so the stations (work crews) must be moved through them, adding additional components and subassemblies until the artifact (building, bridge, tunnel, plant, house, highway, etc) is completed.

Many publications exist on the topic of production management in manufacturing, the larger part of which adopt the perspective of the industrial or production engineer (Bertrand et al, 1990; Hopp and Spearman, 1996; Murrill, 1991; Vollman et al, 1992). A subset of this category concern themselves with the psychological/sociological aspects of manufacturing management (Scherer, 1998). The development of alternatives to mass production over the last 40 years has been revolutionary. Early and influential production management theorists include Jack Burbidge (1983; 1988) and W. Edwards Deming (1986), to mention but a few from the West. Taiichi Ohno (1988) and Shigeo Shingo (1988) were the primary architects of the Toyota Production System, the archetype for lean production, so named in part to counterpose it to "mass" production. Burbidge's groundbreaking thought began to emerge in the 1960s. Deming was instrumental in the implementation of quality management and statistical quality control concepts and techniques in Japan after the 2nd World War. The work of Ohno and Shingo was concentrated in the period of the late 50's into the 70's. *The Machine That Changed the World* (Womack et al., 1990) reported the findings of an international study of the automotive industry and was followed by *Lean Thinking* (Womack and Jones, 1996) which presented the principles and basic concepts behind the new forms of manufacturing and proposed to extend them to the entire enterprise. Womack and Jones have popularized and made more easily accessible the concepts and techniques of lean production.

Defining production as the designing and making of artifacts allows us to understand how construction is a type of production and also that design is an essential component in production generally and in construction specifically. Lauri Koskela (Koskela 1992, 1999; Koskela and Huovila 1997; Koskela et al. 1996, 1997) is the foremost production theorist in construction. His study of the applicability of newly emergent manufacturing concepts and techniques to the construction industry has driven him back to the development of a theory of production as such (Koskela, 1999).

2.1.2 THE MEANING OF "CONTROL"

The term "control" has a wide range of meanings. According to the Concise Oxford Dictionary, its meanings include to dominate, command; to check, verify; to regulate. It has long been associated with accounting. The Old French *contreroller*: to keep a roll of accounts.

Accounting is the essence of project control theory, more fully described in section 2.2.2 below (Diekmann and Thrush, 1986; Project Management Body of Knowledge (PMBOK), 1996; Riggs, 1986). The essential activity is monitoring actual costs or schedule performance against target in order to identify negative variances. Corrective action is obviously necessary in order to correct such negative variances, but the literature hardly addresses corrective action.

Industrial process control introduces feedback and feedforward mechanisms for regulating a process (Murrill, 1993). Feedback is initiated by a comparison of actual with target outputs. Feedforward is initiated by a comparison of actual with target inputs.

The artificial intelligence community contributes the blackboard system of control, in which coordination of a number of interdependent specialists is managed by rules for taking turns 'writing on a blackboard'; i.e., for contributing to their collaborative work (Hayes-Roth, 1985). AI adherents have been in the forefront of empirical study of design, and despite their technological orientation, have found social and organizational issues to be of great importance. Finger et al (1995) conclude: “The social process plays a major role in the articulation and realization of the product design, particularly in large projects.” (p.89). Bucciarelli (1984) reports that designers spend 85-90% of their time talking, writing, negotiating, meeting, searching, etc. as opposed to drawing and calculating.

Production control theorists working in manufacturing distinguish two primary ways of regulating work flow in manufacturing systems: push and pull. Push systems release materials or information into a system based on preassigned due dates (from a master production schedule, for example) for the products of which they are parts. Pull systems release materials or information into a system based on the state of the system (the amount of work in process, the quality of available assignments, etc) in addition to due dates (Hopp and Spearman, 1996). In factory systems, pull may be derivative ultimately from customer orders. In construction, pull is ultimately derivative from target completion dates, but specifically applies to the internal customer of each process. Applicability of these concepts to production control has been explored by this author (Ballard, 1999).

Some theorists (Kelly, 1994) propose that complex, dynamic systems are regulated not by anything resembling a central mind, but through the independent action of distributed decision makers. The following excerpt from Eric Scherer's introduction to *Shop Floor Control-A Systems Perspective* indicates the emergence of a new conceptual framework,

> *"To master the challenges of the future, there must be a change in our thinking paradigm. Manufacturing is not deterministic! …the problem of systems design for shop floor control is no longer the problem of 'optimization'. The reductionistic paradigm … needs to be replaced by a holistic paradigm of agile activity, dynamic behavior, and evolutionary development."*

2.2 Project Management

2.2.1 The Project Management Body of Knowledge

The construction industry is organized in projects and current production theory and practice are heavily influenced by the concepts and techniques of project management. According to PMI's *A Guide to the Project Management Body of Knowledge*, "a project is a temporary endeavor undertaken to produce a unique product or service." The making (i.e., manufacturing) of multiple copies of a product does not occur through projects so understood. This focus on product uniqueness and the project form of organization has dominated thinking about production of the built environment so far as to discourage learning from non-project industries such as product manufacturing (Koskela, 1992).

Again according to PMI (1996), project management includes the management of integration, scope, time, cost, quality, human resources, communications, risk, and procurement. Any or all of these could conceivably concern the actual production process itself, but perhaps most of all time and cost.

Time management is said to consist of activity definition, activity sequencing, activity duration estimating, schedule development, and schedule control. The focus is entirely on delivering project objectives; in Koskela's terms, on the transformation or conversion processes (activities) and not on flow or value generation processes. Activities are to be defined so as to facilitate a division of labor and subsequent tracking (accounting) of conformance to requirements. There is no mention of structuring work for flow or of defining activities so that they facilitate the actual performance of the work. Activity sequencing assumes that handoffs from one set of specialists to the next occur only once; that there is no repetition or cycling to be managed ("conditional diagramming methods" are mentioned-see page 63-but not developed). Schedule control is concerned with managing changes to the schedule rather than with execution of scheduled work; with the exception of expediting as a type of time management corrective action (see page 72). Cost management is treated very much in the same way as time management. The question for project management thus remains: 'Who manages production and how?'

PMI differentiates between project processes and product-oriented processes (page 27), the former being characteristic of all types of projects and the latter specific to the various types of production with which projects may be involved. What is missing in this distinction is the concept of the project itself as a temporary production system linked to other temporary and permanent production systems for materials, equipment, labor, etc. Projects as such have no necessary connection with production. For example, a project may be to solve a problem of getting voters to register. In this broad sense of the term, 'project' becomes virtually synonymous with a single instantiation of the problem solving process, and project management consists of the tools and techniques for managing problem solving processes in groups. On projects that do have production objectives, production itself takes place alongside project management, but is not directly the business of project management. Consequently, project control consists of monitoring progress toward project objectives and taking corrective action when the ship appears to be off course.

This concept of project control is very different from production control, which is dedicated to causing events to conform to plan and to replanning when events cannot be conformed. Production control conceives production as a flow of materials and information among cooperating specialists, dedicated to the generation of value for customer and stakeholders.

2.2.2 CRITIQUE OF THE TRADITIONAL PROJECT CONTROL MODEL

Project control has been hitherto conceived and carried out consistently with the conversion or transformation view of projects (Koskela and Huovila, 1997). The received wisdom regarding AEC project control systems is founded on a widely shared conception of their purpose. “This (project control) system must provide the information needed for the project team and project participants to identify and correct problem areas and, ultimately, to keep project costs and schedule ‘under control’.” (Diekmann and Thrush, 1986). The objective is to detect negative variances from target, so corrective action can be taken. This is quite different from the active concept of control dominant in manufacturing production control systems, especially those employing a pull strategy, in which the purpose of control is to cause events to conform to plan. In the following, we further examine traditional project controls and their difference from the concept of control in the Last Planner system, which is to be introduced in Chapter 3.

In traditional project control, the objects of control are time and resources. Resources (labor hours, material, equipment, indirects) are planned and controlled through cost control systems, the objective of which is productivity, i.e., efficient use of resources. A budget is prepared for each resource, the use of resources is monitored against their budgets, and periodic forecasts are made of resource requirements based on the current state of the project.

Controlling time involves planning, scheduling, and monitoring. Planning decides what is to be accomplished and in what sequence. Scheduling determines task duration and timing. Monitoring checks progress of tasks against the schedule and forecasts when work will be completed. The objective of time control is production or progress, not productivity.

Decisions made regarding budget and schedule, productivity and production must recognize their interdependence. Productivity and production are formally related in earned value systems, which propose a solution to the problem that progress and expenditure of resources need not coincide. Rates of resource consumption are established for the various kinds of work to be performed on a project; e.g., 9.32 engineering labour-hours per piping isometric drawing or 12.4 labour-hours per purchase order. Completing an individual piping isometric drawing earns 9.32 labour-hours regardless of the actual number of hours consumed in its production. Progress toward project completion is tracked by accumulating the earned hours and comparing that to the total hours to be earned for the entire project. For example, suppose the project schedule calls for production of 10 piping isometric drawings at time t, but only 9 drawings have been produced. Only 83.88 (9 x 9.32) hours have been earned of the 93.2 scheduled, so that portion of the project is 10% behind schedule (83.88/93.2=.90). That is a measure of production against schedule.

Productivity can be quite a different story. Suppose it has taken only 80 hours to produce the 9 piping isometric drawings. Since 83.88 hours were earned, the performance factor is .95 and the piping group is operating at 95% of its budget for isometric drawings. In this case, the project is behind schedule, but under budget. Production is poor and productivity is good.

Earned value analysis is a means for controlling projects through productivity and progress. By itself, it would have the design manager believe that a project is performing well if it is earning labor hours at the budget unit rate and also earning sufficient hours to maintain a scheduled earnings plan expressed as percentages of earned hours to total hours to be earned. The obvious weakness in this control mechanism is that projects may exhibit budget productivity and be on the earnings plan, but not be doing the right work in the right way at the right time. Although things appear to be on track, the train is destined to eventually run off the rails because work is being produced that does not conform to product quality requirements or to process quality requirements (e.g., out of sequence). Consequently, quality control is invoked as a separate control mechanism, although rarely if ever controlling against the objective of expressing customer needs in engineering specifications, but rather controlling against the objectives of avoiding calculational and dimensional errors. As for the issue of the timing of work, it has proven necessary to establish schedule milestones to enforce adherence to a work sequence. These rear guard actions are frequently ineffective against the dominant progress and productivity controls, which consequently cause managers to throw the lever in the wrong direction because they misevaluate actual project performance (Howell and Ballard, 1996).

Work Breakdown Structure (WBS) is a key element in traditional project controls. “A WBS provides a framework for integrated schedule and cost planning and allows for monitoring and control by management by establishing the manner in which estimates are assigned and costs are accumulated and summarized.” (p. 21, Diekmann and Thrush, 1986). The objective is to divide the work to be done in the project into parts so they can be monitored and controlled. No mention is made of the production process as such. [NB: Inclusion of the flow view adds new criteria to the decomposition process. Roughly speaking, we want to break the whole into parts so we can more easily put the parts back together again. Structure work for flow and assembly, not only for budgeting and monitoring.]

Further decomposition in the traditional process eventually defines work packages as the smallest unit. Work packages often correspond to contract packages or to pay items within a single contract. The dominance of the conversion view is perhaps best revealed in the following quotes: “A work package is a cost center.” (p. 73, Neil, James M. *Construction Cost Estimating for Project Control*, 1982). “The WBS provides the framework for defining the project from the top all the way down to its smallest components and for accumulating the costs associated with each piece. In so doing, the WBS provides a data base from which problem areas can be identified, forecasts made, and corrective action can be taken.” (p. 21, Diekmann and Thrush, 1986). It appears to be assumed that costs arise within that part of the project in which they are detected. Further, control is essentially control of behaviour, given the default assumption that tasks/work packages/contracts can be carried out. The flow view, with its interdependence of parts (both as regards the 'product' and the process of making that product), is neglected in this perspective. Equally neglected is consideration of capability.

We are clearly dealing here with a type of push system and the controls appropriate to a push system.

Despite the focus on cost and schedule ‘accounting’, theorists recognize the primacy of the control act itself. “Without corrective actions a project control system becomes merely a cost/schedule reporting system.” (p. 29, Diekmann and Thrush, 1986). However, the traditional view is that control consists of correcting deviations from plan. Deviations are expected, but that expectation is not rooted in the idea that variation is natural, but rather that sin is inevitable. Diekmann and Thrush devote less than two pages of a 108 page paper to corrective action and provide no more advice than to inform managers and supervisors at every level in the project about deviations so they can “…correct those trouble spots.” (p. 28). They appear to assume that causes of deviation will be apparent and the appropriate corrective action obvious. “These problems can be easily traced to their source allowing early detection of unfavorable trends.” (p. 33, Diekmann and Thrush, 1986). If the standard corrective actions are indeed ‘Try harder!’ and ‘Add more men!’, that would be consistent with the traditional view.

Advocates of system dynamics have proposed to supplement traditional network analyses and models, adding to the “…growing evidence that network analysis on its own is not sufficient to model and manage the behaviour of projects.” (Williams et al., 1995, p. 154). They propose to provide additional information to project managers so they avoid misevaluating the state of the project and consequently making decisions that cause things to get worse rather than better (See p. 125 of Rodrigues, 1994). Ballard and Howell (1996) suggest that it is impossible to make good decisions about causes or corrections of deviations, relying only on productivity and progress data, without understanding work flow. One can hardly avoid concluding that the traditional control system is indeed based almost exclusively on the conversion or activity view of the production system.

2.3 Previous Applications of Production Control Concepts to the AEC Industry

A survey of the literature reveals several primary contributors to the theory and practice of production (as opposed to project) control in the construction industry. Ballard and Howell’s contributions are described in Chapter Three. Melles and Wamelink (1993) developed a very similar line of thinking independently, culminating in their joint PhD thesis at Delft University, The Netherlands. Lauri Koskela, Senior Researcher at Finland’s building research institute, VTT, is the leading theorist in production management in construction. The University of Reading has been active in the field of production management for a number of years. John Bennett’s *Construction Management* from 1985 is an excellent example of their work. Addis’ 1990 book, *Structural engineering: the nature and theory of design*, is also a highly relevant work for this research. Alexander Laufer’s work on project planning takes a production control orientation by virtue of its focus on uncertainty and variability and their management. Given the relative obscurity of Melles and Wamelink’s, only their work is presented in detail. The work of Koskela is described only to the extent needed to remind the reader of his vital contributions. That should in no way be taken as an indication of relative importance of the various contributions.

2.3.1 MELLES AND WAMELINK

Introducing their discussion of the theory of production control, Melles and Wamelink (1993) explain, “Contrary to what is customary in the construction industry we shall not assume, beforehand, the theories in the field of project management. …Production control in construction companies has traditionally been aimed at the control of projects." For Melles and Wamelink, production control consists of "…the activities relating to the adjustment of all aspects of the production process, so that the preconditions in which the production process is to be executed, are met." Drawing on manufacturing production control, they emphasize: 1) Thinking in terms of hierarchical levels of decision; i.e., control at company level, factory level, and production unit level, and 2) Thinking in terms of decision functions within the hierarchical levels; i.e., aggregate production control, material coordination, workload control, workorder release, workload acceptance, detailed workorder scheduling, capacity allocation, and shop floor control. The manufacturing model on which they rely is that of Bertrand et al., 1990.

Melles and Wamelink propose a 'translation' of the manufacturing model into decision functions appropriate to various types of construction, identifying at the 'factory' level project coordination (achieved in part by network schedules), mobilisation planning (by means of "six weeks scheme"), and allocation planning (by means of "task scheme").

In addition to the primary contribution of directing attention to manufacturing theory and practice, Melles and Wamelink's work identifies functionalities AEC industry production control systems should possess. Their specific objective was to assist in the design of information systems. Consequently, they did not explicitly apply their model to evaluation of current management systems and practice. However, the overwhelmingly negative results of so doing are implicit in their critique of project management software. For example, speaking of project coordination, they comment, "…it can immediately be deduced that the project management software available on the market is indeed about a certain aspect (within the framework, the decision function project coordination). The other decision functions (resource planning, mobilization planning, etc.) are, generally speaking, not recognizable." (p. 35). This critique is made more explicitly in Wamelink et al., 1993.

2.3.2 KOSKELA

Lauri Koskela (1999) proposes the following design criteria or principles for a production control system. In fact, he claims they are true for the Last Planner system, which is to be presented in Chapter Three:

> "The first principle is that the assignments should be sound regarding their prerequisites. This principle has also been called the Complete Kit by Ronen (Ronen 1992). The Complete Kit suggests that work should not start until all the items required for completion of a job are available. Thus, this principle strives to minimize work in suboptimal conditions.
>
> "The second principle is that the realization of assignments is measured and monitored. The related metrics, Percent Plan Complete (PPC), is the number of planned activities completed, divided by the total number of planned activities, and expressed as a percentage. This focus on plan realization diminishes the risk of variability propagation to downstream flows and tasks.
>
> "Thirdly, causes for non-realization are investigated and those causes are removed. Thus, in fact, continuous, in-process improvement is realized.
>
> "The fourth principle suggests maintaining a buffer of tasks which are sound for each crew. Thus, if the assigned task turns out to be impossible to carry out, the crew can switch to another task. This principle is instrumental in avoiding lost

production (due to starving) or reduced productivity (due to suboptimal conditions).

"The fifth priciple suggests that in lookahead planning (with time horizon of 3-4 weeks), the prerequisites of upcoming assignments are actively made ready. This, in fact, is a pull system that is instrumental in ensuring that all the prerequisites are available for the assignments. On the other hand, it ensures that too great material buffers do not emerge on site."

2.4 Criteria for a Design Production Control System

The preceding review and critique of the literature suggests the following guidelines and criteria for an effective design production control system:

- *Variability must be mitigated and remaining variability managed.* Variability is virtually disregarded in current control systems. But the construction industry certainly has its share of variability: variability in quality, variability in processing times, variability in deliveries, etc. Neglect of variability causes greater variability, and there is always an associated penalty. According to Hopp and Spearman (1996), variability results in some or all of the following:
    - buffering of flows, which increases lead times and work-in-process
    - lower resource utilization
    - lost throughput
- *Assignments are sound regarding their prerequisites.*
- *The realization of assignments is measured and monitored.*
- *Causes for failing to complete planned work are investigated and those causes are removed.*
- *A buffer of sound assignments is maintained for each crew or production unit.*
- *The prerequisites of upcoming assignments are actively made ready.*
- *The traditional schedule-push system is supplemented with pull techniques.* Not only do pull systems usually perform better than push systems (Hopp and Spearman, 1996), but pull systems are

especially needed in conditions of variability.

- *Production control facilitates work flow and value generation.* Production thinking and practice in all areas has focused primarily on the task goals of production and neglected flow and value (Huovila and Koskela, 1997). The object of traditional project control has been behavior. What needs to be controlled is work flow.
- *The project is conceived as a temporary production system.* The model for corrective action in traditional project control is course correction, drawn by analogy from the path of a vehicle bound for a specific destination with a target arrival time and a specified spending budget or otherwise limited resources. If the project is to be conceived rather as a temporary production system, the course correction model is radically oversimplified and inappropriate. The flow of materials and information is what is to be controlled. They flow through very complex networks of temporary and permanent production systems. Corrective action must be taken within an understanding of these networks and of the impact of changes in sequence, processing methodologies, buffer location and sizing, local control strategies (e.g., pull or push), etc.
- *Decision making is distributed in production control systems.* Traditional project control assumes the necessity and possibility of central control. The underlying image is that of a single mind and many hands. Arguably, dynamic production systems cannot be controlled centrally, but rather are adaptive creatures driven by decision making at their periphery.
- *Production control resists the tendency [of designers and engineers] toward local suboptimization* (Green, 1992). Green's comment was specifically directed to the tendency of designers and engineers toward local suboptimization, but that is a general tendency of any system in which there is a division of labor.

In Chapter Three, the Last Planner system of production control is described and evaluated against these criteria.

CHAPTER THREE: DESCRIPTION AND HISTORY OF THE LAST PLANNER SYSTEM OF PRODUCTION CONTROL

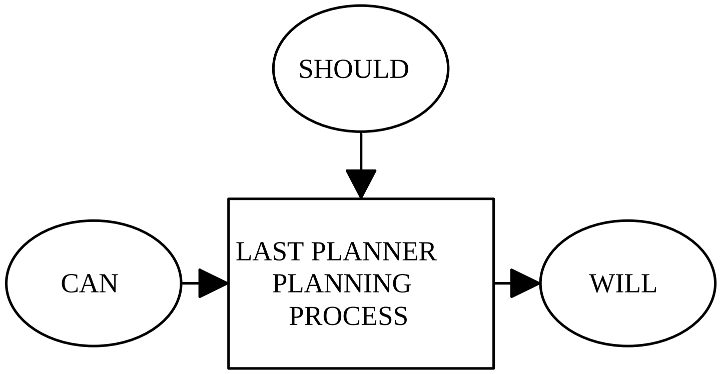
3.1 Hierarchical Structure

Aside from the simplest and smallest jobs, design and construction require planning and control done by different people, at different places within the organization, and at different times during the life of a project. Planning high in the organization tends to focus on global objectives and constraints, governing the entire project. These objectives drive lower level planning processes that specify means for achieving those ends. Ultimately, someone (individual or group) decides what physical, specific work will be done tomorrow. That type of plans has been called "assignments". They are unique because they drive direct work rather than the production of other plans. The person or group that produces assignments is called the "Last Planner" (Ballard and Howell 1994).

3.2 Should-Can-Will-Did

The term "assignments" stresses the communication of requirements from Last Planner to design squad or construction crew. But these products of planning at the production unit level are also commitments to the rest of the organization. They say what WILL be done, and (hopefully) are the result of a planning process that best matches WILL with SHOULD within the constraints of CAN.

Figure 3.1



The formation of assignments in the Last Planner planning process.

Unfortunately, last planner performance is sometimes evaluated as if there could be no possible difference between SHOULD and CAN. "What will we do next week?" "Whatever is on the schedule," or "Whatever is generating the most heat." Supervisors consider it their job to keep pressure on subordinates to produce despite obstacles. Granted that it is necessary to overcome obstacles, that does not excuse creating them or leaving them in place. Erratic delivery of resources such as input information and unpredictable completion of prerequisite work invalidates the presumed equation of WILL with SHOULD, and quickly results in the abandonment of planning that directs actual production.

Failure to proactively control at the production unit level increases uncertainty and deprives workers of planning as a tool for shaping the future. What is needed is to shift the focus of control from the workers to the flow of work that links them together. The Last Planner production control system is a philosophy, rules and procedures, and a set of tools that facilitiate the implementation of those procedures. Regarding the procedures, the system has two components: production unit control and work flow control. The job of the first is to make progressively better assignments to direct workers through continuous learning and corrective action. The function of work flow control is perhaps evident in its name—to proactively cause work to flow across production units in the best achieveable sequence and rate.

3.3 Production Unit Control

The key performance dimension of a planning system at the production unit level is its output quality; i.e. the quality of plans produced by the Last Planner. The following are some of the critical quality characteristics of an assignment:

- The assignment is well defined.
- The right sequence of work is selected.
- The right amount of work is selected.
- The work selected is practical or sound; i.e., can be done.

"Well defined" means described sufficiently that it can be made ready and completion can be unambiguously determined. The "right sequence" is that sequence consistent with the internal logic of the work itself, project commitments and goals, and execution strategies. The "right amount" is that amount the planners judge their production units capable of completing after review of budget unit rates and after examining the specific work to be done. "Practical" means that all prerequisite work is in place and all resources are available.

The quality of a front line supervisor's assignments may be reviewed by a superior prior to issue, but such in-process inspection does not routinely produce measurement data, even when corrections are necessary. Planning system performance is more easily measured indirectly, through the results of plan execution.

Percent Plan Complete (PPC) is the number of planned activities completed divided by the total number of planned activities, expressed as a percentage. PPC becomes the standard against which control is exercised at the production unit level, being derivative from an extremely complex set of directives: project schedules, execution strategies, budget unit rates, etc. Given quality plans, higher PPC corresponds to doing more of the right work with given resources, i.e. to higher productivity and progress.

Percent Plan Complete measures the extent to which the front line supervisor's commitment (WILL) was realized. Analysis of nonconformances can then lead back to root causes, so improvement can be made in future performance. Measuring performance at the Last Planner level does not mean you only make changes at that level. Root causes of poor plan quality or failure to execute planned work may be found at any organizational level, process or function. PPC analysis can become a powerful focal point for breakthrough initiatives.

The first thing needed is identification of reasons why planned work was not done, preferably by front line supervisors or the engineers or craftsmen directly responsible for plan execution. Reasons could include:

- Faulty directives or information provided to the Last Planner; e.g. the information system incorrectly indicated that information was available or that prerequisite work was complete.
- Failure to apply quality criteria to assignments; e.g. too much work was planned.
- Failure in coordination of shared resources; e.g. lack of a computer or plotter.
- Change in priority; e.g. workers reassigned temporarily to a "hot" task.
- Design error or vendor error discovered in the attempt to carry out a planned activity.

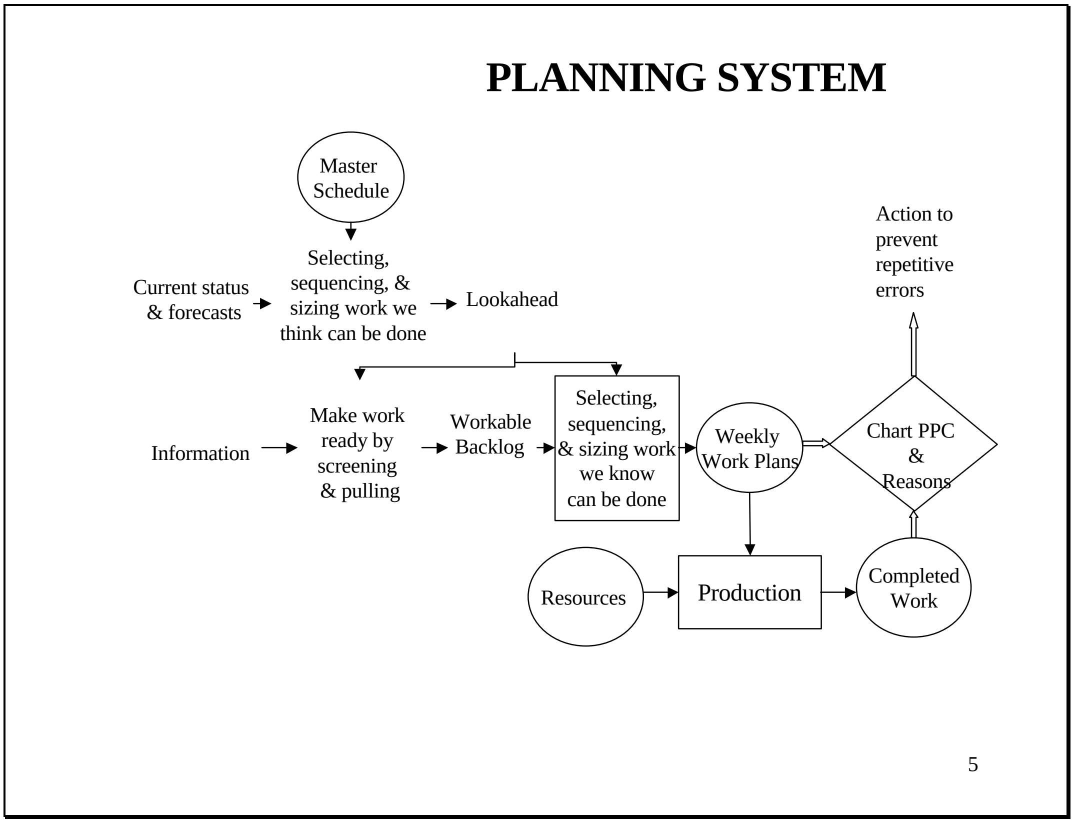
This provides the initial data needed for analysis and improvement of PPC, and consequently for improving project performance.

3.4 Work Flow Control

Here we turn to the topic of work flow control; i.e., causing work to move between production units in a desired sequence and rate. Production Unit Control coordinates the execution of work *within* production units such as construction crews and design squads. Work Flow Control coordinates the flow of design, supply, and installation *through* production units.

In the hierarchy of plans and schedules, the lookahead process has the job of work flow control. Lookahead schedules are common in current industry practice, but typically perform only the function of highlighting what SHOULD be done in the near term. In contrast, the lookahead process within the Last Planner system serves multiple functions, as listed in Table 3.1. These functions are accomplished through various specific processes, including activity definition, constraints analysis, pulling work from upstream production units, and matching load and capacity, each of which will be discussed in the following pages.

Figure 3.2



Last Planner System with Lookahead Process highlighted

The vehicle for the lookahead process is a schedule of potential assignments for the next 3 to 12 weeks. The number of weeks over which a lookahead process extends is decided based on project characteristics, the reliability of the planning system, and the lead times for acquiring information, materials, labor, and equipment. Tables 3.2 and 3.3 are examples of construction and engineering lookahead schedules, respectively. The lookahead schedule is not a simple drop out from the master schedule. Indeed, it is often beneficial to have the team that is to do the work in the next phase of a project collectively produce a phase schedule that serves to coordinate actions that extend beyond the lookahead window (the period of time we choose to look ahead).

Table 3.1

Functions of the Lookahead Process
• **Shape work flow sequence and rate** • **Match work flow and capacity** • **Decompose master schedule activities into work packages and operations** • **Develop detailed methods for executing work** • **Maintain a backlog of ready work** • **Update and revise higher level schedules as needed.**

Functions of the Lookahead Process

Prior to entry into the lookahead window, master schedule or phase schedule activities are exploded into a level of detail appropriate for assignment on weekly work plans, which typically yields multiple assignments for each activity. Then each assignment is subjected to constraints analysis to determine what must be done in order to make it ready to be executed. The general rule is to allow into the lookahead window, or allow to advance from one week to the next within the lookahead window, only activities that can be made ready for completion on schedule. If the planner is not confident that the constraints can be removed, the potential assignments are retarded to a later date.

Figure 3.3 is a schematic of the lookahead process, showing work flowing through time from right to left. Potential assignments enter the lookahead window 6 weeks ahead of scheduled execution, then move forward a week each week until they are allowed to enter into workable backlog, indicating that all constraints have been removed and that they are in the proper sequence for execution. If the planner were to discover a constraint (perhaps a design change or acquisition of a soils report) that could not be removed in time, the assignment would not be allowed to move forward. The objective is to maintain a backlog of sound work, ready to be performed, with assurance that everything in workable backlog is indeed workable.[13] Weekly work plans are then formed from workable backlog, thus improving the productivity of those who receive the assignments and increasing the reliability of work flow to the next production unit.

Table 3.2

PROJECT: Pilot **5 WK LOOKAHEAD**

ACTIVITY	1/13/97						1/20/97						1/27/97						2/3/97						**NEEDS**
	M	**T**	**W**	**T**	**F**	**S**	**M**	**T**	**W**	**T**	**F**	**S**	**M**	**T**	**W**	**T**	**F**	**S**	**M**	**T**	**W**	**T**	**F**	**S**	
Scott's crew																									
"CUP" AHUs-10 CHW, 2 HW	X	X	X	X	X		X	X	X	X	X		X	X	X	X	X								CHW delivers 1-8-97 thru 1-13. HW delivers 1-20.
Punch, label, & tag AHUs															x	x	x								Materials on site
Ron's crew																									
DI Steam to Humidifier			x	x	x																				Materials on site
DI Steam Blowdown	x	x																							Check material
DI Steam Cond. to coolers (13)							x	x	x	x	x		x	x	x	x	x		x	x	x				Material on site
Charles' crew																									
200 deg HW 1-"H"	x	x	x																						Matl delivery 1-8-97
200 deg HW 1-"B" & 1-"D"							x	x	x	x	x		x	x	x	x	x								Release matl for 1-15-97
1st flr 200 deg HW guides & anchors	x	x	x	x	x								x	x	x	x	x								Material on site. Need West Wing flr covered.
Richard's crew																									
2-"A" HW & CHW	x	x	x	x	x																				Control valves for added VAV coils
CHW in C-E-G tunnels	x	x	x	x	x		x	x	x	x	x		x	x	x	x	x								Need tunnels painted & release materials
Misc FCUs & cond. drains in "I", "J", & "K" 1st flr							x	x	x	x	x		x	x	x	x	x								Take off & order materials
Punch, label & tag							x	x	x	x	x		x	x	x	x	x								Material on site

Construction Lookahead Schedule[14]

[13] Deliberately building inventories, inventories of ready work in this case, may seem contradictory to the goals of just-in-time. To clarify, inventories of all sort are to be minimized, but as long as there is variability in the flow of materials and information, buffers will be needed to absorb that variability. Reducing variability allows reduction of buffer inventories.

[14] The "5 Week Lookahead Schedule" excludes the week covered by the Weekly Work Plan, so shows only 4 weeks.

3.4.1 CONSTRAINTS ANALYSIS

Once assignments are identified, they are subjected to constraints analysis. Different types of assignments have different constraints. The construction example in Table 3.4 lists contract, design, submittals, materials, prerequisite work, space, equipment, and labor; plus an open-ended category for all other constraints. Other constraints might include permits, inspections, approvals, and so on. Design constraints can virtually be read from the Activity Definition Model: clarity of directives (level of accuracy required, intended use of the output, applicable section of code), prerequisite work (data, evaluations, models), labor and technical resources. We previously met these constraints in the discussion of Production Unit Control; then as reasons for failing to complete assignments on weekly work plans.

Table 3.3

Engineering Lookahead Schedule

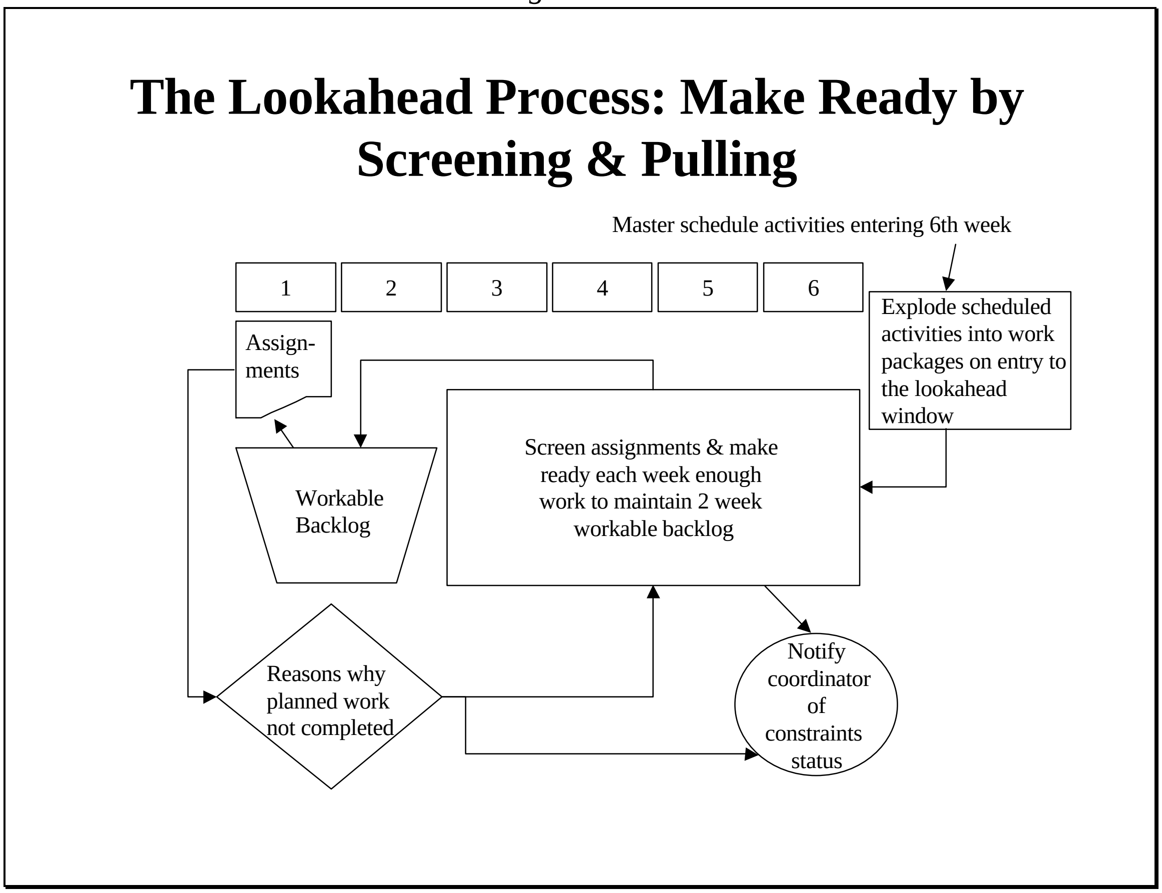
Project:
Discipline: Process
Planner: s
Checked By; x
Prep. Dt: 3/14/02

Activity	Week Ending: 3/28/02					Week Ending: 4/4/02					Week Ending: 4/11/02					Week Ending: 4/18/02					OUTSTANDING NEEDS
	M	T	W	T	F	M	T	W	T	F	M	T	W	T	F	M	T	W	T	F	
Provide const support (Q & A)			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	Need questions from subs.
Review submittal(s)						x	x														Need submittals from sub.
Aid with tool install dsgn effort.		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	Frozen layout, pkg 1 dwgs.
Design drains from tools to tunnel tie-ins.			x	x	x																Frozen layout, input from tool install on installation preferences
Help layout people complete a layout that will work well with tool install routing and drains into the tunnel.	x	x																			Correct tool list.
Complete Pkg 2 specifications							x	x	x	x	x										Final eqpt and mtl usage from mech & tool install.
Create work plans					x					x					x					x	
Send package to QA/QC reviewer for drain design review																	x	x			Final design dwgs for drains; plot time
Start/complete QA/QC review																			x	x	Set of Package 2 review docs, dwgs

Engineering Lookahead Schedule

Constraints analysis requires suppliers of goods and services to actively manage their production and delivery, and provides the coordinator with early warning of problems, hopefully with sufficient lead time to plan around them. In the absence of constraints analysis, the tendency is to assume a throw-it-over-the-wall mentality; to become reactive to what happens to show up in your in-box or laydown yard.

Figure 3.3



Make Ready by Screening and Pulling

3.4.2 PULLING

Pulling is a method of introducing materials or information into a production process. The alternative method is to push inputs into a process based on target delivery or completion dates. Construction schedules have traditionally been push mechanisms, seeking to cause intersections in the future of interdependent actions.

Table 3.4

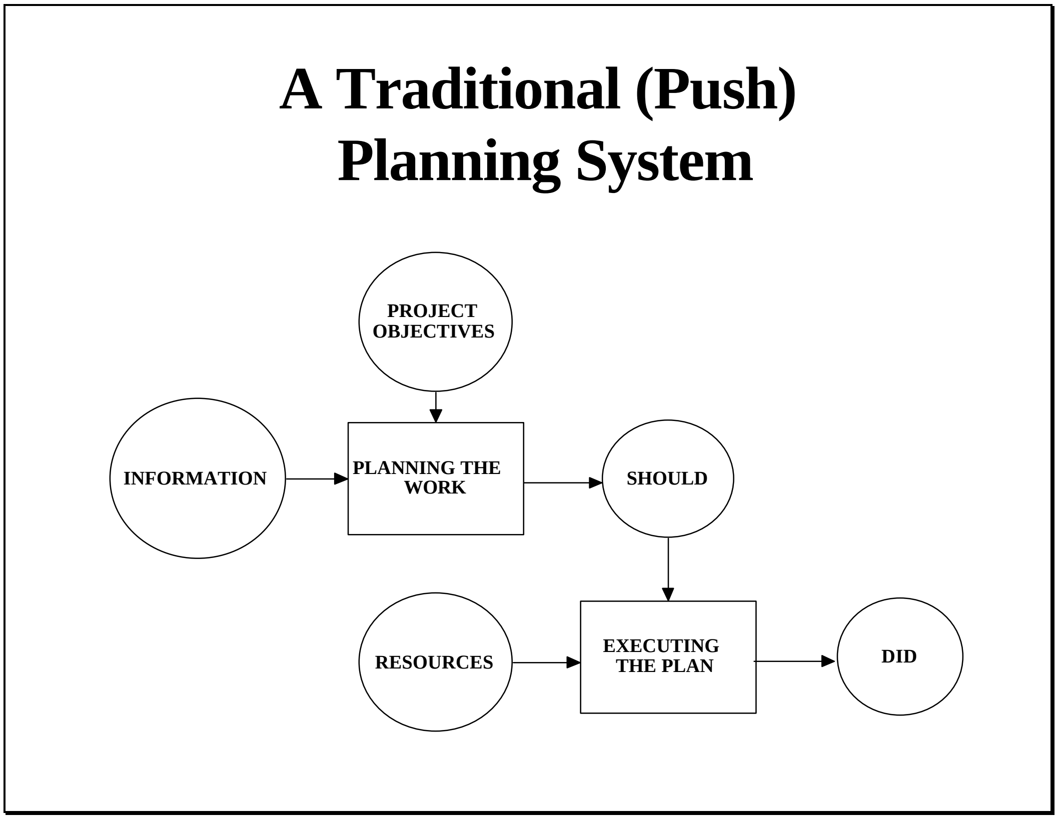
Screening Assignments: Statusing Constraints

ID	Activity	Start	Contract	Design	Submittals	Materials	Pre-Requisite	Space	Equipment	Labor	Other
260	Small Interior Wall Forms Lines 4-M.8, 3-M, 3-K, 4-K.8, 3-H	2/9/98	OK	RFI 68	OK	OK	rebar	OK	OK	OK	None
310	Large Interior Wall Line L Form	2/9/98									
700	Interior Small Walls 3F and 3D Forms	2/9/98									
1142	Small Interior Wall Forms Lines 5-M.8, and 5-K.8	2/9/98									
170	East Wall Between Lines 2 and 6 Line Double Up	2/13/98									
720	Interior Small Walls 3F and 3D Double-up	2/13/98									
1146	Small Interior Walls Lines 5-M.8, and 5-K.8 Double-up	2/13/98									
322	Large Interior Wall Line L Doubleup	2/16/98									
290	Small Interior Walls Lines 4-M.8, 3-M, 3-K, 4-K.8, 3-H Double-up	2/17/98									
735	Interior Small Walls 3F and 3D Strip	2/18/98									

Constraints Analysis

By contrast, pulling allows materials or information into a production process only if the process is capable of doing that work. In our Last Planner system, conformance of assignments to quality criteria constitute such a check on capability. Further, making assignments ready in the lookahead process is explicitly an application of pull techniques. Consequently, Last Planner is a type of pull system.

Figure 3.4



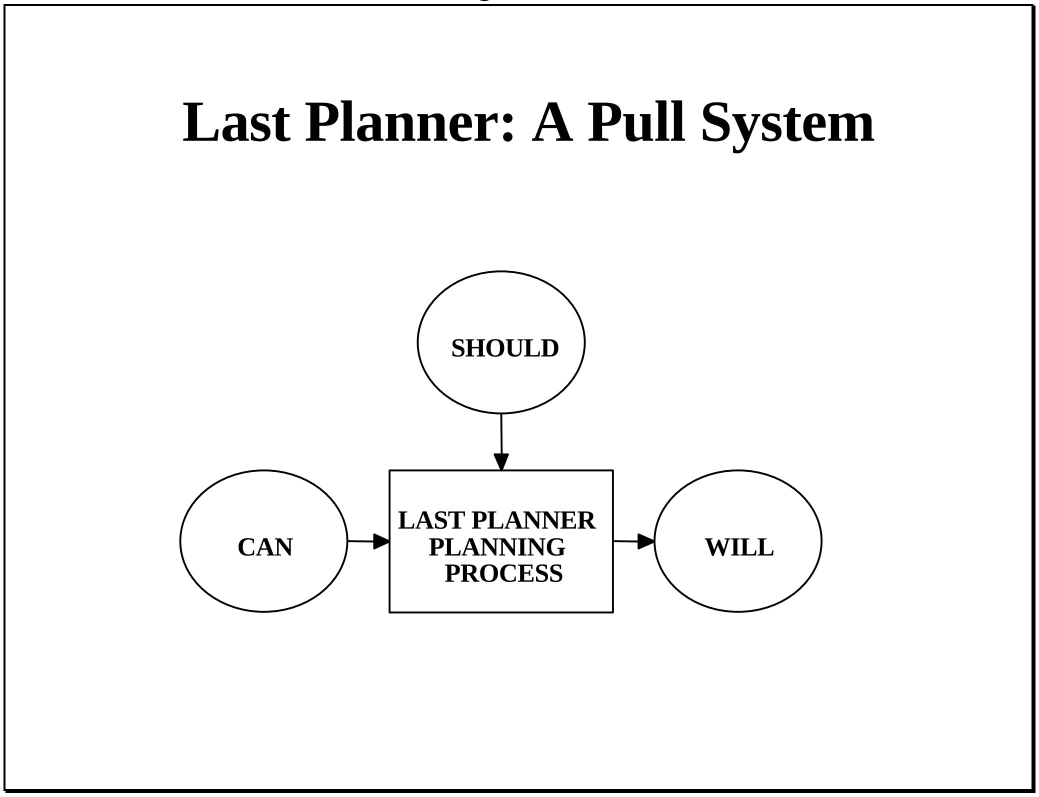
A Traditional (Push) Planning System

Certain things have long been pulled as opposed to pushed; e.g., concrete. With its short shelf life, concrete cannot be ordered too far in advance of need. Fortunately, the lead time[15] for concrete is short, so it is usually possible to wait until you know when it will be needed before ordering it.

Generally, a window of reliability greater than supplier lead time is needed in order for pulling to be most effective. Otherwise, the pulled items may not match up with the work to which they are to be applied. In the industry now, supplier lead times are for the most part much greater than our accurate foresight regarding work completion, hence perhaps a reason for the infrequent use of pulling mechanisms.

[15] Lead time is the time in advance of delivery one must place an order. It is often referred to as "supplier lead time".

Figure 3.5



Last Planner: A Pull System

3.4.3 MATCHING LOAD AND CAPACITY

Matching load to capacity within a production system is critical for productivity of the production units through which work flows in the system, and is also critical for system cycle time, the time required for something to go from one end to the other.

Along with its other functions, the lookahead process is supposed to maintain a backlog of workable assignments for each production unit (PU). To do so requires estimating the load various chunks of work will place on PUs and the capacities of PUs to process those chunks of work. Current estimating unit rates, such as the labor hours required to erect a ton of steel, are at best averages based on historical data, which are themselves laden with the tremendous amounts of waste imbedded in conventional practice. When load and capacity are estimated, are we assuming 30% resource utilization or 60%? What assumptions are being made about variation around averages? Can we expect actual unit rates to fall short of the average half the time? Clearly we need much more accurate data than is typically available.

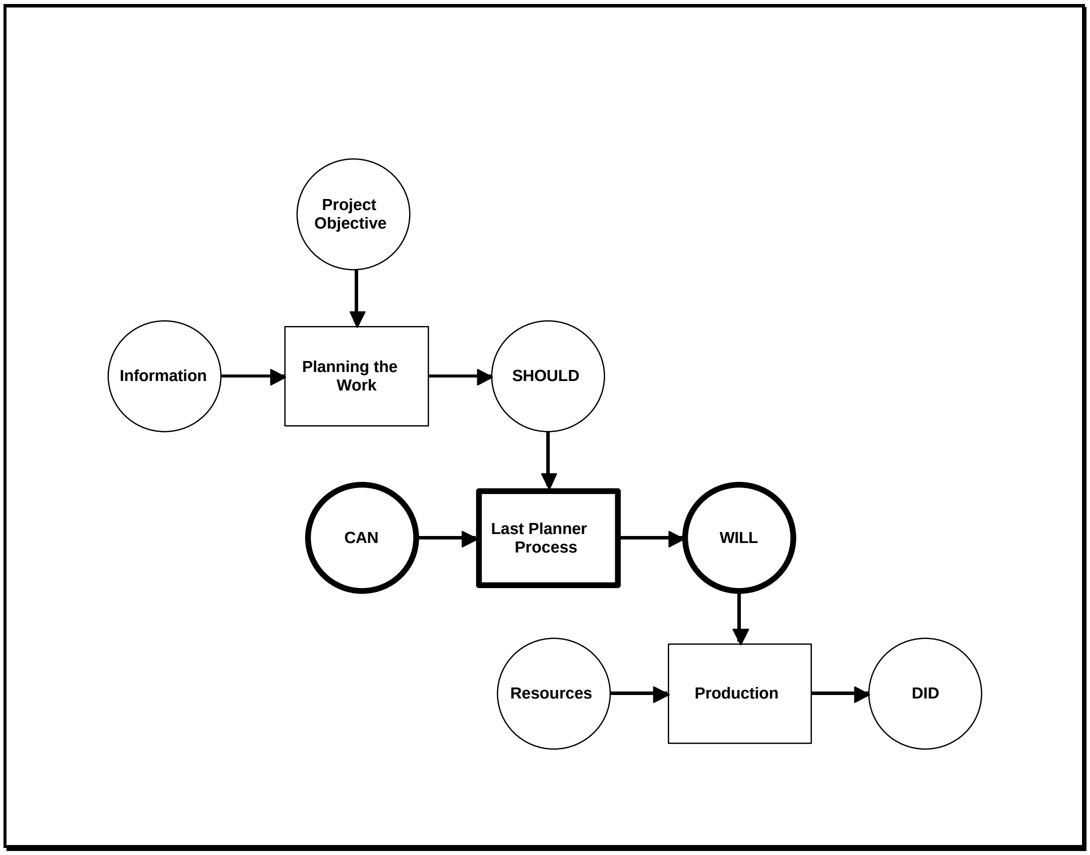
Whatever the accuracy of load and capacity estimates, the planner must still make some adjustments. Either load can be changed to match capacity, capacity can be changed to match load, or, more commonly, a combination of the two. Given the advantages of maintaining a stable work force and avoiding frequent changes, the preference is often for adjusting load. However, that will not be the case when there are pressures to meet scheduled milestones or end dates.

Load can be changed to match capacity by retarding or accelerating work flow. Capacity can be changed to match load by reducing or increasing resources. Pulling helps balance load to capacity because the PU can request what it needs and in the needed amounts.

3.4.4 THE LAST PLANNER SYSTEM AS A WHOLE

Last Planner adds a production control component to the traditional project management system. As shown in Figure 3.6, Last Planner can be understood as a mechanism for transforming what SHOULD be done into what CAN be done, thus forming an inventory of ready work, from which Weekly Work Plans can be formed. Including assignments on Weekly Work Plans is a commitment by the Last Planners (foremen, squad bosses) to what they actually WILL do.

Figure 3.6



The Last Planner System

3.5 A Brief History of the Last Planner System of Production Control

The functions of production management systems are planning and control. Planning establishes goals and a desired sequence of events for achieving goals. Control causes events to approximate the desired sequence, initiates replanning when the established sequence is either no longer feasible or no longer desirable, and initiates learning when events fail to conform to plan (Ballard, 1998). When environments are dynamic and the production system is uncertain and variable, reliable planning cannot be performed in detail much before the events being planned. Consequently, deciding what and how much work is to be done next by a design squad or a construction crew is rarely a matter of simply following a master schedule established at the beginning of the project. How are such decisions made and can they be made better? These questions were the drivers of initial research in the area of production unit level planning and control under the title of the "Last Planner System", a summary report of which is included in Ballard and Howell (1997).

A key early finding was that only about half of the assignments made to construction crews at the beginning of a week were completed when planned. Experiments were performed to test the hypothesis that failures were in large part a result of lack of adequate work selection rules (these might also be called work release rules). Quality criteria were proposed for assignments regarding definition, sequence, soundness, and size. In addition, the percentage of assignments completed was tracked (PPC: percent plan complete) and reasons for noncompletion were identified, which amounted to a requirement that learning be incorporated in the control process.

Definition: Are assignments specific enough that the right type and amount of materials can be collected, work can be coordinated with other trades, and it is possible to tell at the end of the week if the assignment was completed?

Soundness: Are all assignments sound, that is: Are all materials on hand? Is design complete? Is prerequisite work complete? Note: During the plan week, the foreman will have additional tasks to perform in order to make assignments ready to be executed, e.g., coordination with trades working in the same area, movement of materials to the point of installation, etc. However, the intent is to do whatever can be done to get the work ready before the week in which it is to be done.

Sequence: Are assignments selected from those that are sound in the constructability order needed by the production unit itself and in the order needed by customer processes? Are additional, lower priority assignments identified as workable backlog, i.e., additional quality tasks available in case assignments fail or productivity exceeds expectations?

Size: Are assignments sized to the productive capability of each crew or subcrew, while still being achievable within the plan period? Does the assignment produce work for the next production unit in the size and format required?

Learning: Are assignments that are not completed within the week tracked and reasons identified?

As a result of applying these criteria, plan reliability (the percentage of assignments completed) increased, and with it, crew productivity also increased (Ballard and Howell, 1997)[16].

The use of explicit work selection rules and quality criteria for assignments was termed "shielding production from upstream uncertainty and variation." (Ballard and Howell 1994) Such shielding assures to a large degree that productive capacity is not wasted waiting for or looking for materials and such. However, because of its short term nature, shielding cannot avoid underloading resources when work flow is out of sequence or insufficient in quantity. Further, reasons for failing to complete planned assignments were dominated in most cases by materials-related problems. Consequently, a second element of the Last Planner System was created upstream of weekly work planning to control work flow and to make assignments ready by proactively acquiring the materials and design information needed, and by expediting and monitoring the completion of prerequisite work (Ballard, 1997).

The tool for work flow control was lookahead schedules. The construction industry commonly uses lookahead schedules to focus supervisors' attention on what work is supposed to be done in the near future. Experiments in work flow control were performed using lookahead schedules in a very different way than had been traditional. A

[16] On the whole, improvements tended to be from PPC levels around 50% to the 65-70% level, with a corresponding increase of 30% in productivity. Productivity improvement has ranged from 10% to 40%+. It is hypothesized that these differences result from different initial resource utilization levels. For example, if initial utilization is 50%, corresponding to a PPC of 50%, then increasing PPC to 70% is matched with an increase in utilization to 65%, which amounts to a 30% improvement in productivity.

set of rules was proposed for allowing scheduled activities to remain or enter into each of the three primary hierarchical levels of the scheduling system:

- Rule 1: Allow scheduled activities to remain in the master schedule unless positive knowledge exists that the activity should not or cannot be executed when scheduled.
- Rule 2: Allow scheduled activities to remain in the lookahead window only if the planner is confident that the activity can be made ready for execution when scheduled.
- Rule 3: Allow scheduled activities to be released for selection into weekly work plans only if all constraints have been removed; i.e., only if the activity has in fact been made ready.

In addition, a set of objectives was proposed for the lookahead process:

- Shape work flow sequence and rate
- Match work flow and capacity
- Decompose master schedule activities into work packages and operations
- Develop detailed methods for executing work
- Maintain a backlog of ready work

Lookahead windows are structured such that week 1 is next week, the week for which a weekly work plan is being produced. Week 2 is two weeks in the future. Week 3 is three weeks in the future, and so on. Early data indicated that plans as close to scheduled execution as Week 2 only contained about half the assignments that later appeared on the weekly work plans for that week. Week 3's percentage was only 40% (Ballard, 1997). Failures to anticipate assignments appear to result in large part from lack of detailed operations design and consequently could be remedied by incorporating detailed operations design into the lookahead process (see *First Run Studies* in the Glossary of Terms)..

While some operations design can be performed once the type of operation and its general conditions are known, detailed design (certainly of construction operations) cannot be done until certain additional information is available; i.e., information regarding material staging areas, adjacent trades, competing claims on shared resources, which individuals will be assigned to the work, etc. Consequently, detailed operations design should be performed within the lookahead window, close in time to the scheduled start of the operation. It is provisionally assumed that this timing requirement applies also to design activities, but this will be subject to research findings.

3.6 Previous Applications of the Last Planner System to Design

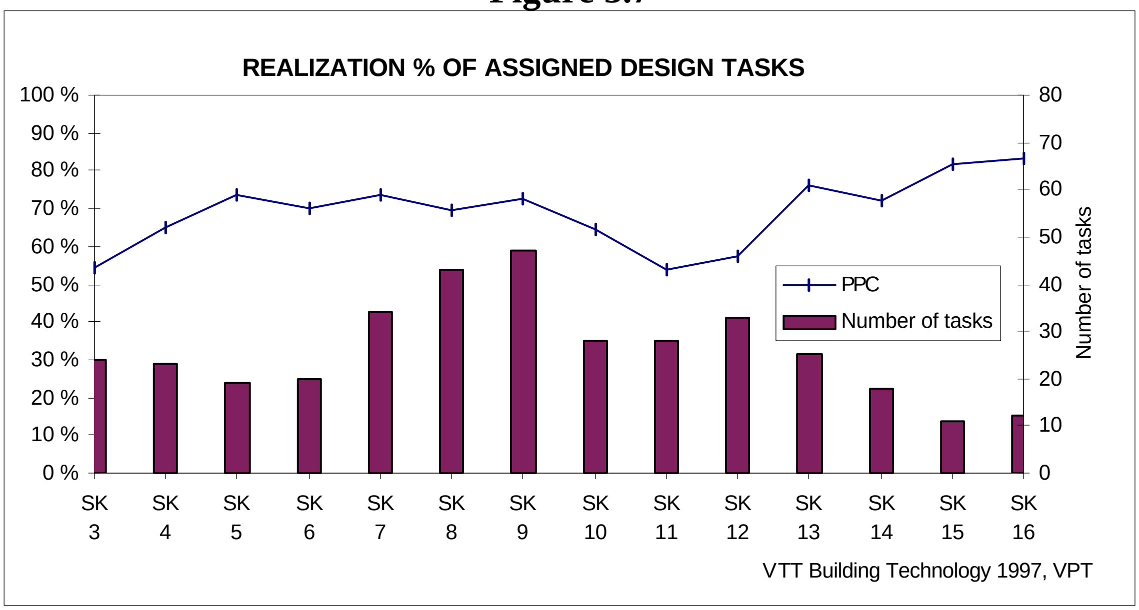
Previous to the research reported in this dissertation, the Last Planner System had not been applied in full to design production control. However, elements of the Last Planner System have previously been applied to the management of production during the design phase of projects. Koskela et al (1997) report that the traditional method of design management on their test project was incapable of producing quality assignments, and described the traditional method as follows:

> *"A drawing due date schedule, and a summary drawing circulation list form the basis of design management. There are design meetings every two weeks or so, where a contractor representative (site manager) acts as the chairman. The contractor may also organize meetings to address specific problems between design disciplines.*
>
> *Thus, the primary control set is to reach the drawing due dates. Instead the order or timing of individual design tasks is not scheduled, but are left for self-management by the design team. In practice, the design tasks to be executed or input information needed are discussed in the weekly design meetings. However, this procedure is not perfect. There is no effective follow-up of decided action, and only a part of output due is often available. It seems that often parties come unprepared to the meeting. Design decisions are often made in improvized style, and decisions taken are not always remembered in next meetings."* (p. 9)

Among the improvement actions taken was progressive detailing of the schedule (in one month chunks), documentation of input information needs reported in design meetings, explicit commitment of design supervisors to tasks in the next few weeks, monitoring of assignments completed, and identification of reasons for noncompletion. As a result, PPC soon rose to the 70% level. (The negative dip in design meetings [SK] 10-12 resulted from a major design change.) The design time for the building was 30% under the standard time for the type of building and participants rated the method favorably, as shown in Figure 3.7.

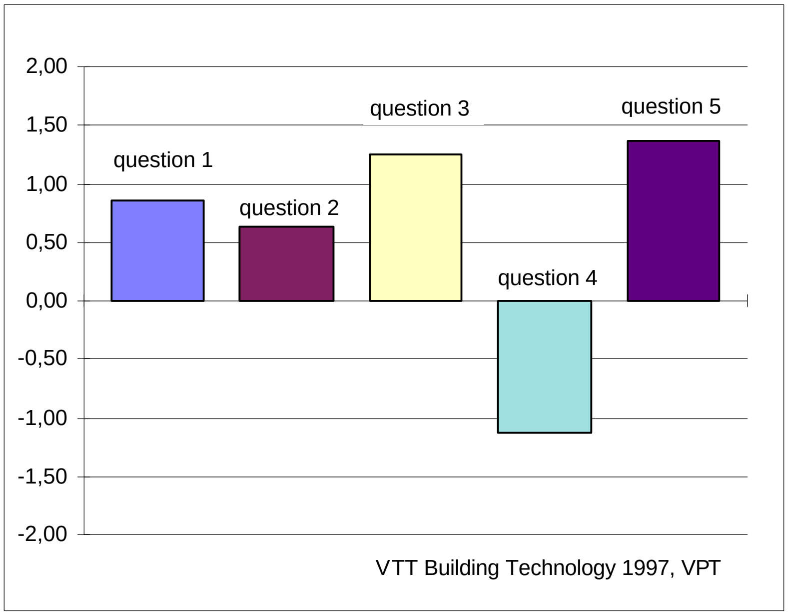
Miles (1998) reports a more complete and extensive implementation of the Last Planner System, which included the lookahead process. Overall PPC averaged around 75%, design was completed approximately 10% earlier than anticipated, and design costs were reduced by 7%. The research also replicated in design earlier findings in construction (Howell, 1996) regarding the prevalence of plan quality failures. They found that failures to complete assignments were divided in a ratio of 2 to 1 between internal impacts they potentially could control and external impacts over which they had little or no control.

Figure 3.7



PPC (Koskela et al, 1997)

Figure 3.8



The average replies, on a scale of -2 to 2, to the questions :
1. Was the availability of input data improved?
2. Was the decision making in design process improved?
3. Did the method yield benefits?
4. Was it laborious to work according to the method?
5. Should the method be used in the next project?

Participant Survey (Koskela et al, 1997)

3.7 Evaluation of Last Planner against Criteria for Production Control Systems

The criteria proposed in the previous chapter were:

- *Variability is mitigated and remaining variability managed.*
- *Assignments are sound regarding their prerequisites.*
- *The realization of assignments is measured and monitored.*
- *Causes for failing to complete planned work are investigated and those causes are removed.*
- *A buffer of sound assignments is maintained for each crew or production unit.*
- *The prerequisites of upcoming assignments are actively made ready.*
- *The traditional schedule-push system is supplemented with pull techniques.*
- *Design production control facilitates work flow and value generation.*
- *The project is conceived as a temporary production system.*
- *Decision making is distributed in design production control systems.*
- *Design production contro resists the tendency toward local suboptimization.*

That the Last Planner system of production control conforms to these criteria and principles should be apparent. It is explicitly dedicated to the reduction and management of variability. One of the quality criteria for assignments is soundness. PPC measurement is central. Reasons for plan failure are tracked and analyzed. The lookahead process has the explicit purpose of maintaining a buffer of sound tasks and also actively makes scheduled tasks sound and facilitates work flow and value generation. Pulling is evident both in the assignment quality criteria and in the make ready function within the lookahead process. The framework for Last Planner is the conception of projects as temporary production systems. Distributed decision making is evident in the requirement that only quality assignments be accepted and also in the work flow control decisions to be made within the lookahead process. And, finally, Last Planner resists the tendency toward local suboptimization in its application of the criterion 'sequencing', applied both in lookahead planning and to weekly work plan assignments.

3.8 Research Questions

This new production planning and management method has been in development since 1992 (Ballard & Howell 1997). It has been successfully used in a series of projects ranging from oil refineries to commercial building construction. Hitherto it has been used primarily in site construction, rather than in design and engineering and its implementation has generally resulted in an improvement of work flow reliability, as measured by percent plan complete, to 65-70% PPC. The questions driving this research are: 1) *What can be done by way of tools provided and improved implementation of the Last Planner system of production control to increase plan reliability above the 70% PPC level? 2) How/Can Last Planner be successfully applied to increase plan reliability during design processes ?*

It is intuitively obvious that making work flow more reliable (predictable) can reduce the cost or duration of the total project. When the numerous specialists can rely on delivery of calculations, drawings, materials, and prerequisite work from other specialists, both within and outside the project team, they are better able to plan their own work, and better planning yields better performance. All else being equal, with greater flow reliability should come more efficient production, less wasted effort and rework, and better matching of resources to tasks. Even partial and limited improvements in work flow reliability have demonstrated schedule and cost improvements (Koskela et al., 1997 and Miles, 1998).

It is also apparent that construction benefits from greater reliability in the flow to the construction site of information and materials. The impact of more reliable flow of design information on project cost and duration is much greater in the construction phase of projects than in design. When constructors can take action in advance of receiving design information that coordinates the flow of labor and equipment, material deliveries, and completion of prerequisite work, the project runs more smoothly and efficiently. We have numerous instances from construction processes showing the benefits of increasing material and information flow reliability even within the job site itself (Ballard, et al, 1996; Ballard and Howell, 1997).

Consequently, it is appropriate to focus the research question on improving work flow reliability, with confidence that improving reliability is beneficial to project performance. Subsequent research may seek to refine and quantify these causal relationships, but the current research needed is to establish more effective methods for production control in general and to extend production control techniques to design.

CHAPTER FOUR: RESEARCH METHODOLOGY

4.1 Introduction

This thesis is about engineering management, not about epistemology. However, some epistemological assumptions lie behind any attempt to add to knowledge, in whatever field. Making those assumptions explicit allows the reader to better understand and assess claims and inferences. The purpose of this introduction is to clarify epistemological assumptions. Three issues will be addressed: 1) To what field of knowledge is this thesis proposing to contribute? 2) Difficulties associated with competing paradigms in the field. 3) The research strategy and methods used in this thesis.

4.1.1 ENGINEERING MANAGEMENT AS A FIELD OF STUDY

The topic of this thesis is engineering management, which is assumed to belong to the general field of technology rather than science. Roozenburg and Eeckels propose that technology and science pursue different goals through different processes or methodologies (Roozenburg and Eeckels, 1995, pp. 32-35). Science pursues knowledge acquisition, while "technology-the design, making, and using of artifacts-is a systematized form of action." Both can be pursued methodically. For both, certain rules have been developed, the observance of which is supposed to "…contribute to efficient performance of the activity involved." Both processes involve reasoning. Which conditions should these two different reasoning processes meet, so they can claim reliability, meaning that the conclusions to which they lead are correct or true? The criterion for reliability of scientific reasoning is the truth of the resulting statements. The criterion for reliability of technological reasoning is the effectiveness of the action process, based on that reasoning. Of course we may pose a 'scientific question' about a technological claim: 'Is it indeed true that the proposed action will be effective?' That is precisely the type of question posed in this thesis. 'Is it true that implementing a specific set of policies and techniques collectively called "the Last Planner system of production control" improves the reliability of work flow?'

Given this 'scientific' question about a technological matter, what methodological rules are appropriate? What kind of data is needed to answer the question and what kind of inferences can we expect to make from such data? Many engineering management theses pose claims about some aspect of engineering management action, use surveys to collect data regarding same, then apply statistical analyses to test the adequacy of their claim. This methodology works from a sample of a population to claims about the population itself by statistical generalization. 'If 79% of a 151 member sample report that they include safety records in their prequalification of contractors, what generalization can I make regarding all members of the population that prequalifies contractors?' Rules of statistical generalization exist for answering such questions.

However, statistical generalization from sample to population is an appropriate methodology in the field of engineering management only if one is interested in testing claims about current behavior. If the objective is to introduce new policies and behaviors with the intent of improving engineering management practice, a different type of methodology is needed. The world of engineering management practice may well be void of practitioners following the proposed new policies and techniques, so there is no sample to take. The question is not 'How many people employ the Last Planner system and with what effect?' What's needed is a type of experiment rather than a survey[17]. The relevant question has the form 'Will the desired consequences result from taking the proposed action?'

What type of 'experiment' is needed to pursue the research questions: 1) What can be done by way of tools provided and improved implementation of the Last Planner system of production control to increase plan reliability as measured by Percent Plan Complete? 2) How/Can Last Planner be successfully applied to increase plan reliability during design processes**?** As is said in the States, "experiment" is a loaded term. Scholars differentiate between so-called 'true' experiments and quasi-experiments (Campbell and Stanley, 1966). Some propose that case studies be conceived as a type of experiment, having similar methodological rules (Yin, 1994). No position is taken here regarding these matters except that some type of experiment is the appropriate methodology for the type of research question posed as distinct from a survey of current practice. 'Experiment' is conceived in practical terms to mean acting in the world with an intended effect. As with all experiments, the researcher must be open to learning more or different things than expected. As with all experiments, generalization from findings is problematic.

Experiments don't prove conclusions in the sense of logical deduction even in the field of natural science. Experimental reasoning is a type of reductive reasoning from particular to general quite unlike either formal logical reasoning or statistical generalization. Everything depends on the specifics of given situations. What are the

[17] Surveys may be used in conjunction with an experiment or a case study devoted to implementation of a policy. For example, one could survey participants for opinions regarding the effectiveness of the policy. The point here is that survey cannot be the principal or primary research strategy for conducting policy evaluation.

relevant variables and to what extent can they be controlled? Some experiments in natural science can approximately isolate one (set of) variable(s) from others and so argue more persuasively that 'things don't burn in the absence of oxygen.' However, even that extreme type of argument depends essentially on the cohesion and consistency of theories. As long as the phlogiston theory held sway, oxygen was invisible to the mind's eye (Kuhn, 1962). Generalization from experiments is fundamentally a matter of telling a good story; i.e., having a good theory.

4.1.2 COMPETING ENGINEERING MANAGEMENT PARADIGMS

According to Thomas Kuhn, in his *The Structure of Scientific Revolutions* (1962), theories emerge from paradigms, which are fundamental propositions and assumptions about the subject matter that tend to remain implicit except in periods when paradigms change. It could be argued that engineering management is currently in just such a period of paradigm shift. In such periods, communication becomes even more perilous than normal because the community of researchers and practitioners no longer share a common language and presuppositions. The research question posed in this thesis belongs to an emerging engineering management paradigm, in conflict with the prevailing paradigm. Consequently, care must be taken lest the change in language and presuppositions hinder the reader. That can best be done by making changes in language and presuppositions explicit. Recognizing that paradigm shifts are periods of intellectual conflict, it is not expected that all readers will accept the proposed changes.

In the midst of a paradigm shift, it is difficult and perhaps impossible to clearly delineate the boundaries of the opposed camps. The conflict is itself producing that delineation, at the conclusion of which the vanguished disappears into the sands of time and the victor rides forward toward its own inevitable yet incomprehensible future defeat. Nonetheless, an effort is required to clarify ‘where all this is coming from.’

The conflict in engineering management was presented in Chapter Two as an opposition between those who adopt the view of production (the design and making of physical artifacts) as transforming or converting inputs into outputs and those who add the flow and value views. At first glance, this hardly appears to belong in the same league as the shift from a geocentric to a heliocentric cosmology—perhaps the most famous example of a paradigm shift. Nonetheless, the shift from the conversion to the flow and value views is enormously important. A prime example is variability, which is itself virtually invisible from the conversion-only view. Manufacturing has taken the lead in the development of production theory, yet according to manufacturing theorists, “…variability is not well understood in manufacturing….” (Hopp and Spearman, 1996, p. 311) One can only assume that variability is even less well understood in the AEC industry, where it would seem to be even more an issue. From a pure conversion view, variability is managed primarily through the provision of schedule and cost contingencies at the global level of projects, but is neglected in the structuring of work flows and operations. Once contracts are let, variability ‘officially’ appears only in the form of failure to meet contractual obligations.

Closely related to the conversion/flow distinction is that between project and production management. Project management concepts and techniques are oriented to the determination of project objectives and the means for achieving them (planning), then to monitoring progress toward those objectives (control). This is a highly abstract perspective, appropriate to any endeavour that is goal-driven and time-limited; i.e., to projects. Unfortunately, project management concepts and techniques are employed in attempts to manage production processes that take on project form without regard to the specific nature of the projects and production to be managed. This is the more unfortunate as many projects involve production; i.e., designing and making things. Management of production projects requires the use of production management concepts and techniques, which in turn are derivative from the conversion/flow/value views.

Is variability in processing times, arrival rates, errors, and breakdowns visible to those comfortable with the project management/conversion paradigm? Such matters might be considered to belong to 'mere' production; to be in the province of the engineering or construction crafts rather than a matter for management. For such readers, the research questions posed in this thesis may well appear either trivial or irrelevant.

4.2 Research Design

4.2.1 RESEARCH QUESTION

Prior to selecting a research strategy, it is necessary to determine the research topic, question, and purpose. The topic of this research is engineering management; more specifically, improving control of design and construction processes on architectural/engineering/construction projects. The questions driving this research are: 1) 1) *What can be done by way of tools provided and improved implementation of the Last Planner system of production control to increase plan reliability above the 70% PPC level? 2) How/Can Last Planner be successfully applied to increase plan* *reliability during design processes*[18]*?* The purpose of the research is to evaluate and improve the effectiveness of this managerial policy and practice.

Evaluation is a type of applied or action research (McNeill, 1989), concerned with technology in the broad sense; i.e., goal-oriented action. Evaluations typically pursue improvement of the subject policy or practice in addition to rating effectiveness against objectives. Simple rating is often made more difficult because of changes made mid-stream in the policy or practice being evaluated. Opportunity for improvement seldom waits on the desire for an unambiguous definition of what is to be evaluated. Indeed, evaluation and improvement often blur together, especially when the researcher is involved in the creation and implementation of the policies and practices being implemented and evaluated, as is the case with this researcher and research. Some might worry about an involved researcher's objectivity. On the other hand, it may simply be that technological research demands another concept and procedure than that of traditional, fact finding research.

Evaluation does not fit neatly within the classification of traditional purposes of enquiry; i.e., exploratory, descriptive, explanatory. The conceptual model for technological research appears to have been drawn from the natural sciences, for which the (immediate) goal is rather to understand than to change the world. Policy evaluation involves exploration, description, and explanation, but subordinates those purposes to the overriding purpose of improving practice. Nonetheless, improving practice requires understanding what works and does not work, and to as great an extent as possible, understanding why what works and what does not. Consequently, the purpose of this

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[18] In this thesis, the term "design" is used to designate both design and engineering activities; not shaping space to aesthetic criteria.

research includes determining the extent to which the Last Planner system is effective and why it is or is not effective.

4.2.2 RESEARCH STRATEGIES

The three traditional research strategies are experiment, survey, and case study (Robson, 1993, p.40). It has previously been argued in this chapter that a survey strategy is inappropriate for the question posed by this research. The research strategies that could possibly lend themselves to investigation of this research question include true experiments, quasi-experiments, and case studies.

True experiments require establishing a control group that differs in no relevant way from the experimental group. A true experiment was not appropriate because of the difficulty of establishing a control group and lack of control over extraneous variables. At first glance, it would seem to be possible to use a pre-test, post-test, single group design, measuring flow reliability of the same group before and after implementation of the Last Planner system. This approach has several difficulties: 1) Work flow reliability is not an explicit, measured objective of traditional production control systems, so pre-test quantitative data is not available, and 2) our ability to generalize from the experimental results is limited by the possibility that those who choose to try the Last Planner method are somehow different from those who do not so choose. The second difficulty could be managed by conditioning and qualifying the inferences drawn from the experiment. The first difficulty, the lack of quantitative data on flow reliability for the pre-test, could be handled by substituting subjective data, in the form of interview results. However, this is clearly an inferior solution, and so pushes the researcher to find a more effective research strategy.

Quasi-experiments are "…experiments without random assignment to treatment and comparison groups." (Campbell and Stanley, 1966, cited in Robson, 1993, p. 98) They admittedly sacrifice some of the rigor of true experiments, but are nonetheless appropriate for a large range of inquiry, where true experiments are impossible or inappropriate. The key issue regarding quasi-experiments is what inferences can be drawn. It is proposed that inferences be justified in terms of study design, the context in which the study occurs, and the pattern of results obtained (Cook and Campbell, 1979). While this strategy responds to the difficulty of generalizability posed above, it still leaves us without pre-test quantitative data on flow reliability in design, and consequently, is not by itself an adequate strategy for pursuing this research.

Case study is "…a strategy for doing research through empirical investigation of a contemporary phenomenon within its real life context using multiple sources of evidence" (Robson, p. 52). Case studies are an appropriate research strategy when there is little known about the topic of interest, in this case, for example, how production is managed in design; and a change in theory or practice (production control) is proposed (Robson, p.169). Multiple case studies allow the researcher to pursue a progressive strategy, from exploration of a question to more focused examination of trials. Given the policy nature of the research question being posed, a multiple case study strategy seems appropriate.

4.3 Research Methods

4.3.1 DATA COLLECTION

Executing a research strategy requires methods for data collection and analysis. What research methods are available, especially for case studies, the research strategy to be pursued in this thesis? Of those available, which fit best with conditions such as accessibility to people and documents, involvement of the researcher in managerial decision making, time available, etc?

Methods for data collection include direct observation, interviews and questionnaires, and documentary analysis. A variant of direct observation is participant observation; i.e., observational reporting by a researcher who is part of the group being observed.

All these methods of data collection are used in this research. In all cases, the researcher served as a consultant to the project team, and consequently was in the role of participant observer rather than a neutral observer. Specific observational data was collected from participation in project coordination meetings and other events devoted to planning and controlling design and construction processes. Interviews or questionnaires were used in all cases to collect team member assessments, both during the course of each project and at the conclusion of each. Interviews were also used to collect other participants' observations of meetings and events relevant to project control at which the researcher was not present. Records collected included meeting minutes and memos, various forms of schedules, and action item logs. In all cases, measurements were made and recorded of short-term assignments, their due dates, actual completion dates, and reasons for failure to complete assignments on their due dates.

4.3.2 Data Analysis and Evaluation

McNeill (1989) suggests three key concepts: reliability, validity, and representativeness. Reliability concerns the extent to which research can be repeated by others with the same results. "Validity refers to the problem of whether the data collected is a true picture of what is being studied." Representativeness concerns whether the objects of study are typical of others, and consequently, the extent to which we can generalize.

Reliability in action research is inevitably questionable because of the active role played by the researcher in generating the phenomena being studied. Validity of findings is especially difficult in survey research because of the potential difference between what people say and what they do. It is less a problem for action research because of its public nature and the availability of measurement data such as PPC (Percent Plan Complete). Generalizability from the cases is a question that cannot be completely answered, no more than it can for a limited number of laboratory experiments. However, unlike laboratory experiments, policy implementations are made in the messy reality of organizations and social relations. Few if any variables can be completely controlled. In the case of this research, attempts are made to control key variables of implementation and execution of the system. However, it is recognized that control is partial and incomplete. Nonetheless, having demonstrated even on a single project that plan reliability can be improved is sufficient to establish system effectiveness. Future work may be devoted to better understanding the conditions necessary for such success.

Another difficulty is that plan reliability is measured by PPC ('percent plan complete'; i.e., percentage of assignments completed), but PPC does not directly measure plan quality. First of all, success or failure in assignment completion may be a consequence either of the quality of the assignment or of its execution. Since the Last Planner system primarily attempts to improve plan quality, execution failures and therefore PPC may not vary with its effectiveness. In addition, apart from unsound assignments, it is often difficult to differentiate between an execution and a quality failure. Was the assignment poorly defined or was the problem with the lack of effort or skill on the part of the designers or builders?

Yet a further difficulty is the ambiguity of assignment 'completion' when assignments have not been well defined. An assignment to "Produce as many piping drawings as you can by the end of the week" might be marked as completed. The researcher can partially guard against this problem by reviewing assignments for adequate definition. However, it is virtually impossible for the researcher to prevent someone marking assignments completed in order to 'make the worse appear better'. The best defense might be to convince those doing the marking that PPC is not a measure of individual but of system performance. Unfortunately, that is not quite true. Individuals can be better or worse at defining, sizing, sequencing, and assessing the soundness of assignments. PPC records of individual front line supervisors can be revealing of those capabilities.

For these various reasons, evaluating the impact of the Last Planner system on plan reliability is no straightforward matter. Similar difficulties beset improving the system, which occurs through understanding and preventing plan quality failures. It is often difficult to accurately determine reasons for failure. Unsoundness of assignments is the easiest to determine because something is lacking that is needed to do the assignment properly; e.g., a soils report, a stress calculation, a decision between alternative designs, etc. Failures from sizing or sequencing are more difficult to identify. The later case studies incorporate efforts to improve plan failure analysis based on experiences in the previous cases.

4.3.3 CASE STUDIES

The research was done through a series of case studies. The first case, the CCSR project, was an exploratory extension of the Last Planner system to the coordination of multiple trades on a construction project. The primary improvement from that case was the addition of the constraints analysis process. The second case, the Next Stage project, is an exploratory case study on the extension of the Last Planner system to design production control. Case Three shows the efforts of a speciality contractor, Pacific Contracting, to improve its work flow reliability. It may well reveal the limits on a speciality contractor implementing the Last Planner system unilaterally. Case Four, the Old Chemistry Building Renovation project, shows the potential for improvement in work flow reliability from a more thorough and deliberate education and training of the project team. Case Five is the Zeneca Project, one of several implementations of the Last Planner system undertaken by Barnes Construction with significant education and coaching provided to the participants, and application of the latest thinking and techniques in the Last Planner system.

CHAPTER FIVE: CASE ONE-CCSR PROJECT

5.1 Project Description and Last Planner Implementation

The CCSR Project was a laboratory building for Stanford University for which the general contractor was Linbeck Construction. CCSR stood for Center for Clinical Services Research. Prior to CCSR, the Last Planner system of production control had been implemented primarily by contractors doing direct production work. There was some question about how to apply Last Planner to subcontracted projects and how effective that application might be. CCSR was selected as a pilot project to explore feasibility and develop techniques. The specific research question was: *How/Can plan reliability be improved during site construction on largely subcontracted projects?*

The research plan was to introduce the techniques listed below during weekly subcontractor coordination meetings, then measure PPC and track reasons for noncompletion of weekly assignments.[19] In addition to the Last Planner procedures and techniques previously developed, the intent was to do the following:

1. Detailed scheduling by phase[20].
2. Intensive subcontractor involvement in phase scheduling.
3. Collection of status input from subs before the scheduling meeting.
4. Trying to select only tasks each week that are free of constraints.

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[19] The author introduced the system to the project and visited periodically during the course of the subsequent three month pilot. Under the author's direction, Abraham Katz, a Stanford graduate student, assisted the project superintendent with scheduling and documentation as part of an independent study performed for Professor Martin Fischer. The author is a consulting professor at Stanford and also at the University of California at Berkeley.

5. Measuring PPC, identifying and acting on reasons.

A weekly planning cycle (Table 5.1) was established that specified who was to do what during each week as regards planning and control. For example, subcontractors were to status their tasks scheduled for the next 3 weeks by noon Monday, so the general contractor (GC) could revise the short interval schedule, which in their case covered a 6 week lookahead period.

Status reporting consisted of completing a constraints analysis form, shown in Table 5.2, which shows selected scheduled tasks for three of the subcontractors on the project. Common constraints on the readiness of scheduled tasks for assignment and execution were included on the form; i.e., contract, design, submittals, materials, prerequisite work, space, equipment, and labor. An open-ended, "other" category was also provided to capture less common constraints. The intention was to focus attention and action on making scheduled tasks ready by removing their constraints.

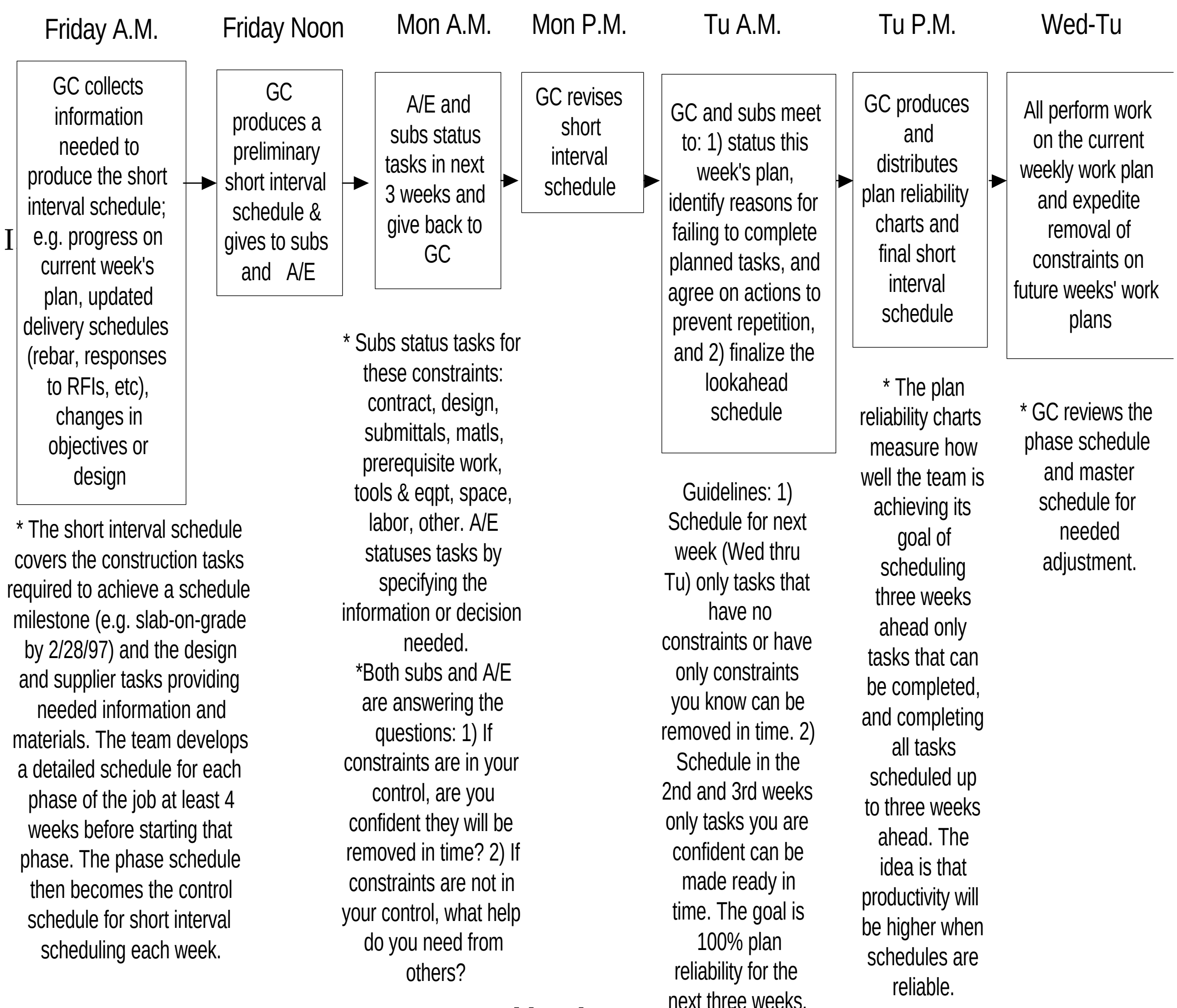
5.2 PPC and Reasons

Several kinds of data were collected: PPC and reasons, auxiliary documents such as phase and master schedules, and the observations of the researcher. PPC and reasons data was collected each week from 12/24/97 through 3/3/98, during the wettest season in the San Francisco area in recorded history. Although the project had taken weatherizing precautions to minimize weather-related delays, such as type of fill material and drainage systems, nonetheless rain was

[20] A phase was conceived in terms of a relatively independent facility system. For example, the first phase-during which this research was conducted-was from

by far the most frequently cited reason for failing to completed assignments on weekly work plans

Table 5.1



CCSR-Weekly Planning Cycle

Table 5.2

CCSR Weekly Planning Cycle

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excavation to slab-on-grade.

Table 5.2

Wills

II. ID	**Activity**	**Start**	**Contract**	**Design**	**Submittals**	**Material**	**Pre-Requisite**	**Space**	**Equipment**	**Labor**	**Other**
950	Tunnel Lobby - Walls Rebar	3/4/98									
1040	Footings 6 & 7 Dowels	3/4/98									
1220	Footings 6 & 7 Between A and H Dowels, and Footings E & G Dowels Between 4.5 and 8	3/4/98									
630	Line 4 Wall and Line C Wall Rebar	3/6/98									
344	Large Interior Wall Line J and H.8 Rebar	3/9/98									
1154	Small Interior Wall Rebar Lines 6-K, and 6-M, 6-P	3/9/98									

Cupertino Electric

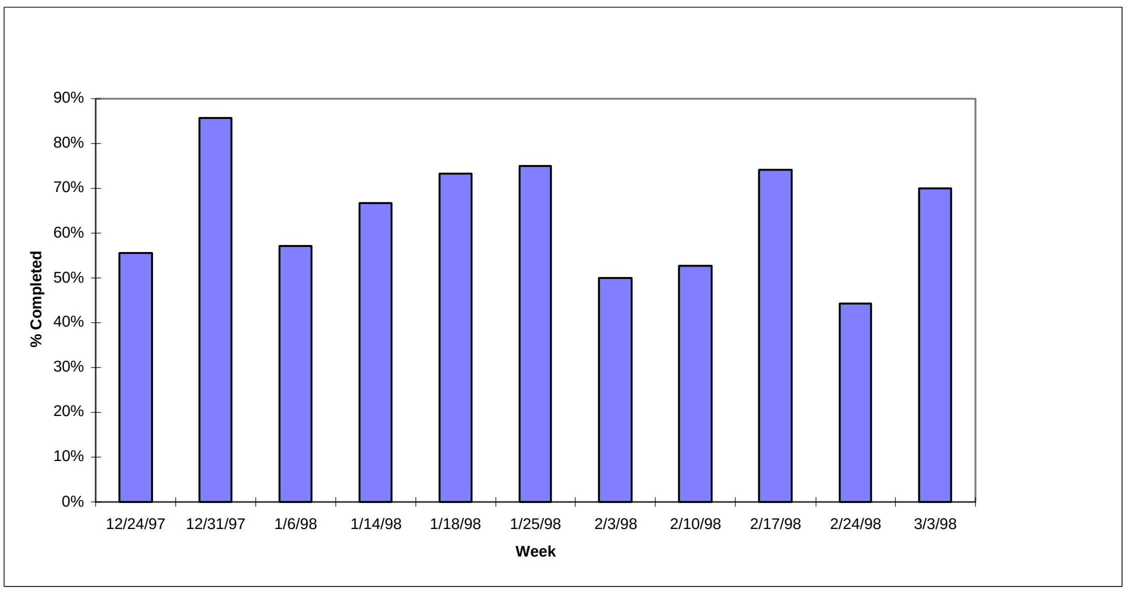
ID	**Activity**	**Start**	**Contract**	**Design**	**Submittals**	**Material**	**Pre-Requisite**	**Space**	**Equipment**	**Labor**	**Other**
402	Inspection	3/4/98									
	Underground Electrical N-W S-W Quadrant	3/5/98									

CCSR-Constraints Analysis Form

PPC was measured as shown in Figure 5.1, ranging from an initial measurement of 56% during the week of 12/24/97 to 70% in the week of 3/3/98. Rain was cited as the reason for 18 plan failures (see Figure 5.2) and was a contributing reason to even more. Other frequently cited reasons were lack of prerequisite work (14), availability or quality of design information (8), and submittals (6).

Removing rain as a reason, weekly PPC would have been as shown in Figure 5.3, with a mean PPC for the research period of 71% (149 of 211 assignments completed), which compared favorably to work flow reliability achieved through previous application of the Last Planner system to projects which were not subcontracted.[21]

Figure 5.1



CCSR-Weekly PPC

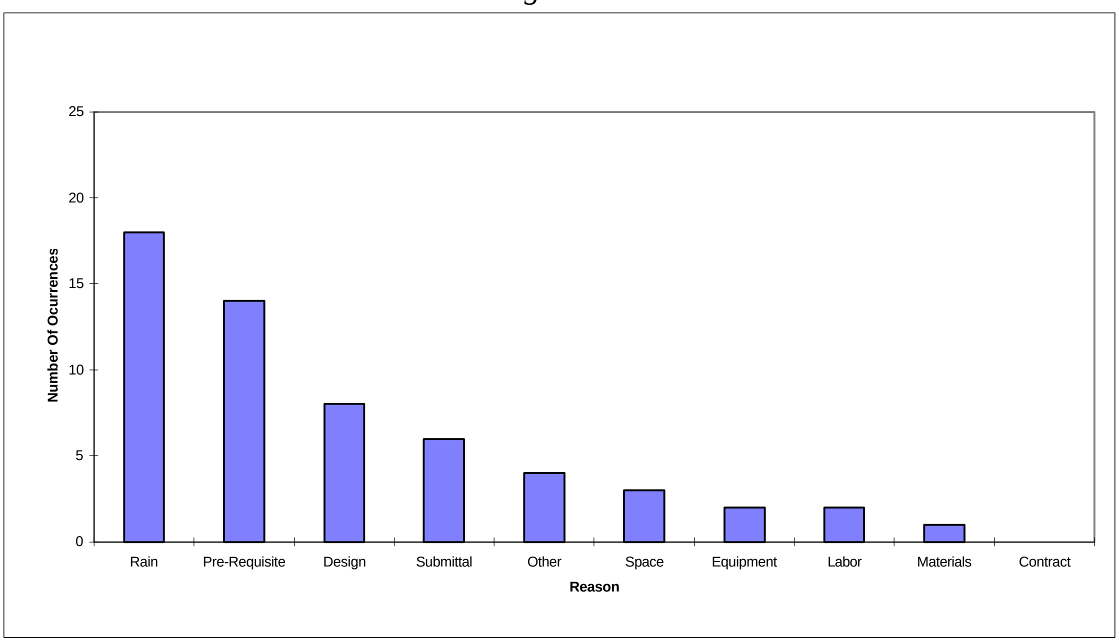
[21] Ballard et al., 1996; Ballard and Howell, 1997

Table 5.3

Week	**12/24/97**	**12/31/97**	**1/6/98**	**1/14/98**	**1/18/98**	**1/25/98**	**2/3/98**	**2/10/98**	**2/17/98**	**2/24/98**	**3/3/98**	
PPC	56%	86%	57%	67%	73%	75%	50%	53%	74%	44%	70%	
Tasks Completed	5	6	8	10	11	18	7	10	23	19	14	
Tasks Planned	9	7	14	15	15	24	14	19	31	43	20	
Rain			1		1	3	6	2	2	1	2	18
Pre-Requisite			2	2	1			7	2			14
Design			1			1			4	2		8
Submittal				2	2	2						6
Other		1					1			1	1	4
Space										1	2	3
Equipment			2									2
Labor										1	1	2
Materials				1								1
Contract												0

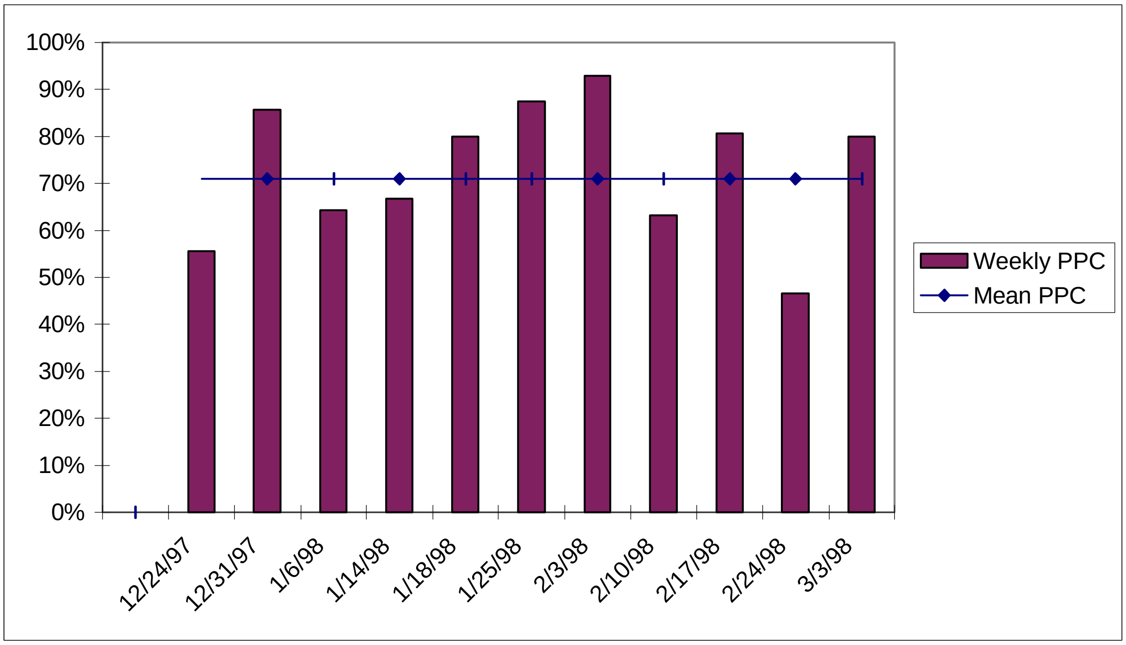
CCSR-PPC and Reasons Data

Figure 5.2



CCSR-Reasons for Noncompletion

Figure 5.3



CCSR-PPC without rain

As shown in Table 5.4, reasons for plan failure were categorized as either an Execution Failure or a Plan Failure[22]. Of the 57 total failures[23], 28 were determined to have resulted from some defect in planning, while 29 were attributed to some defect in execution. The 18 failures caused by rain were categorized as execution failures. Disregarding rain, Plan Failures would have amounted to 28 of 38, or 74%, further evidence that to a substantial degree, our fate is in our own hands as regards planning and work flow. In even extreme weather conditions, fully half of noncompletions resulted from poor planning.

[22] This distinction was introduced into the Last Planner system in Ballard (1994).

[23] Note the absence of detailed information for failures in the week of 12/24/97. Their inclusion would add 4 noncompletions to the total.

Table 5.4

Week 12/31

Activity	**Reason**	Type Of Failure
item 6 - Sump Pit Lid Form	Other: Low Priority	Plan

Week 1/6

Activity	**Reason**	Type Of Failure
item 3 - Underground Plumbing	Rain	Execution
Item 13 - East Wall Forms	Design: RFI	Execution
Item 32 - Elevator Wall Forms	Pre-Requisite: Not Identified	Plan
Item 43 - 2&3 Line Excavation	Equipment: Backhoe	Execution
Item 44 - A,C & 4 Line Excavation	Equipment: Backhoe	Execution
Item 45 - 2&3 Line Rebar	No Excavation	Plan

Week 1/14

Activity	**Reason**	Type Of Failure
item 26 - Elevator 1&2 SOG Pour	Floor Drain Submittals	Plan
Item 44 - Elevator Pour Up to Tunnel Level	Shop Drawings	Plan
Item 43 - Form South East Quadrant	Waiting Rebar Fabrication	Plan
Item 29 - Rebar J Line	Waiting On Excavation	Plan
Item 7 - Access Panel	Submittal	Plan

Week 1/18

Activity	**Reason**	Type Of Failure
210 - Design Change Rebar Submittals	Not Back	Plan
270 - Interior Wall Rebar Submittals	Not Back	Plan
A,C, & 4 Line Excavation	Productivity/Rain	Execution
A,C, & 4 Line Rebar	No Excavation	Plan

Week 1/25

Activity	**Reason**	Type Of Failure

Excavate Line F and 7 (MidWest)	Rain	Execution
Interior Wall Forms	Rain	Execution
N,Q,L Lines Rebar Installation	Rain	Execution
Reveals Location	Waiting On Architect	Plan
RFI Line 7 (Cupertino)	Answer Incomplete	Plan
Tunnel Piping Submittal	Approval	Plan

Week 2/3

Activity	**Reason**	Type Of Failure
Excavate F Line	Rain	Execution
Backfill Sump pit	Rain	Execution
Template Footings A and 4 Line	Rain	Execution
Electrical Conduit Elevator 5	Rain	Execution
Small and Large Walls Single Form	Rain	Execution
Wall Double up @ Tunnel Lobby	Waiting For Inspection	Plan
Backfill N-E/S-E Quad.	Rain	Execution

Week 2/10

Activity	**Reason**	Type Of Failure
Plumbing between lines J & M	Rain	Execution
Plumbing Line 6.5	Rain	Execution
Small Interior Walls Form	Eleveator Jack Drilling / Rain	Execution
Small Interior Walls Double Up	Eleveator Jack Drilling / Rain	Execution
Large Interior Walls Form	Eleveator Jack Drilling / Rain	Execution
Large Interior Walls Double Up	Eleveator Jack Drilling / Rain	Execution
Small Wall Rebar	Eleveator Jack Drilling / Rain	Execution
Line L wall Rebar	Eleveator Jack Drilling / Rain	Execution
E & G Line Rebar from 2 to 5	Eleveator Jack Drilling / Rain	Execution

Week 2/17

Activity	Reason	Type Of Failure
Elevator Wal Backfill	Rain	Execution
Line J Excavation	Backfill Plumbing/Rain/Mud	Execution
Line 6.5 Excavation	After 6 & 7 Line Concrete	Plan
Small Interior Wall Forms	Design Change	Plan
Small Walls Double Up	Design Change	Plan
Small Walls Rebar	Design Change	Plan
Perimeter Wall Line 2 Rebar	Design Change	Plan
Footings 6 & 7 Rebar	Rain	Execution

Week 2/24

Activity	Reason	Type Of Failure
Planter Excavation	Space	Plan
Interior Small Walls	Rebar Change/Permit	Plan
Tunnel lobby SOG	Sequence Change	Plan
Line L Wall	Rebar Change/Permit	Plan
Line J Footing	Rain	Execution
Wall Line 2 From A-D	Man Power	Plan

Week 3/3

Activity	Reason	Type Of Failure
Footings E&G Excavation	Space For Crane	Plan
Line J Concrete	Rain	Execution
Footings 6&7 Concrete	Rain	Execution
Court Yard Planter	Crane Reach	Plan
Small Interior Walls	Man Power	Plan
Pipe Ties In @ Tunne	Waiting On Stanford Info	Plan

CCSR-Reasons for Noncompletion (detailed and categorized)

5.3 Observations

Subcontractors were not selected based on their understanding or willingness to participate in the Last Planner production control system. They were selected based on traditional criteria such as financial soundness and bid price. Subcontractor personnel first learned about the system and the expectations regarding their roles and responsibilities within it after coming to the site. Not surprisingly, some were more capable and enthusiastic about participating than others. Even so, the project superintendent continued to use the Last Planner system and reported that eventually all foremen were participating and that they began to hold each other accountable for keeping their weekly work plan commitments. Nonetheless, it would have been preferable both to incorporate participation in the production control system in the selection criteria and subcontracts, and also to have devoted more time and effort to education and training.

Shortly after introducing the system, it became apparent that more active involvement of others besides the site foremen was needed. Subcontractor project managers were invited to attend the weekly meetings and were better able to understand what was going on, and specifically better able to provide status information regarding constraints such as submittals, design issues, fabrication, and deliveries. There was also efforts made to involve the architect and design engineers on the project. Unfortunately, those efforts failed, in part because of the stage of design completion and the fact that the production architect/engineer was on a lump sum contract and concerned lest they run out of money before they ran out of work.

Analysis of constraints was a key element introduced into the Last Planner system on CCSR. Efforts to collect constraints information from subcontractors prior to the coordination meeting were mostly unsuccessful, perhaps in large part because there is no tradition in our industry for such activities. Consequently, much of meeting time was dedicated to data collection rather than planning and problem solving.

5.4 Learnings

Learnings for future projects included:

- Incorporate production control requirements into subcontracts.
- Select subcontractors for their ability and willingness to participate in the production control system.
- Involve owner, architect, and engineers in the production control process; preferably from the beginning of design.
- Send to subcontractor project managers by email or fax each week constraint reports with the next 5-6 weeks scheduled activities listed and ask them to status their activities and report back. Make sure this happens so meeting time can be used for planning and problem solving as opposed to data collection.
- Use team planning techniques to produce schedules for each phase of work, with participation by foremen, superintendents, and designers.
- Incorporate reasons identification, analysis, and corrective action into weekly coordinating meetings. Otherwise, there is a danger that incompletions become accepted as unavoidable.

CHAPTER SIX: CASE 2-NEXT STAGE PROJECT

6.1 Description of the Project and Last Planner Implementation

Next Stage Development was created to design, build, and operate a series of 7,000 seat enclosed amphitheaters in various U.S. cities, accommodating Broadway shows and musical entertainment with amplified sound. Its first project was the Texas Showplace, located in Dallas, Texas. Architect, design consultants, engineering firms, fabricators, and construction contractors were selected based on qualifications and willingness to participate in the project. The intent was to create an All-Star team by selecting the very best.

The general contractor and equity participant in Next Stage Development is Linbeck Construction, a founding member of the Lean Construction Institute, which was cofounded by the author and Greg Howell in August, 1997. Next Stage's management chose to implement elements of "lean thinking" in the design and construction of its facilities, specifically including the Last Planner method of production control. A Kickoff Meeting was held for the production team May 19-21, 1998 in Houston, Texas and co-facilitated by the author. Key outcomes of the meeting were 1) forming the fifty plus individuals and multiple companies into a team, and 2) collectively producing a "value stream" (Womack and Jones' [1996] term for the flow diagram of a production process that produces value for the stakeholders in the process). This author's report on the Kickoff Meeting is included in Appendix A.

In the Kickoff Meeting, the participants were divided into a number of different teams, corresponding roughly to the facility systems: Site/Civil, Structural, Enclosure/ Architectural, Mechanical/Electrical/Plumbing/Fire Protection, Theatrical/Interiors, and

Project Support. These teams remained intact as the administrative units for production of the design.

After the Kickoff Meeting, the design process continued, initially with a target completion date of 11/15/99. However, after roughly the middle of August, 1998, delays in arranging equity financing and performance commitments caused the construction start and end date to slip ever further out, until the project was finally suspended..

The design process was managed primarily through biweekly teleconference (Appendix B). Tasks needing completion within the next two week period were logged as Action Items (Appendix C) , with responsibility and due date assigned. Tasks needing completion beyond the next two week period were logged as Issues (Appendix D). Design decisions were recorded in a Design Decisions Log (Appendix E). When action items were not completed as scheduled, reasons were assigned from a standard list (Table 6.1) and a new due date was provided.

Table 6.1

1. Lack of decision
2. Lack of prerequisites
3. Lack of resources
4. Priority change
5. Insufficient time
6. Late start
7. Conflicting demands
8. Acts of God or the Devil
9. Project changes
10. Other

Next Stage-Reasons for Noncompletion

6.2 Data

6.2.1 PPC AND REASONS

The percentage of action items completed was tracked and published biweekly.

Table 6.2

PPC - NextStage™ Texas ShowPlace Planning Percent Complete for Preconstruction Meetings

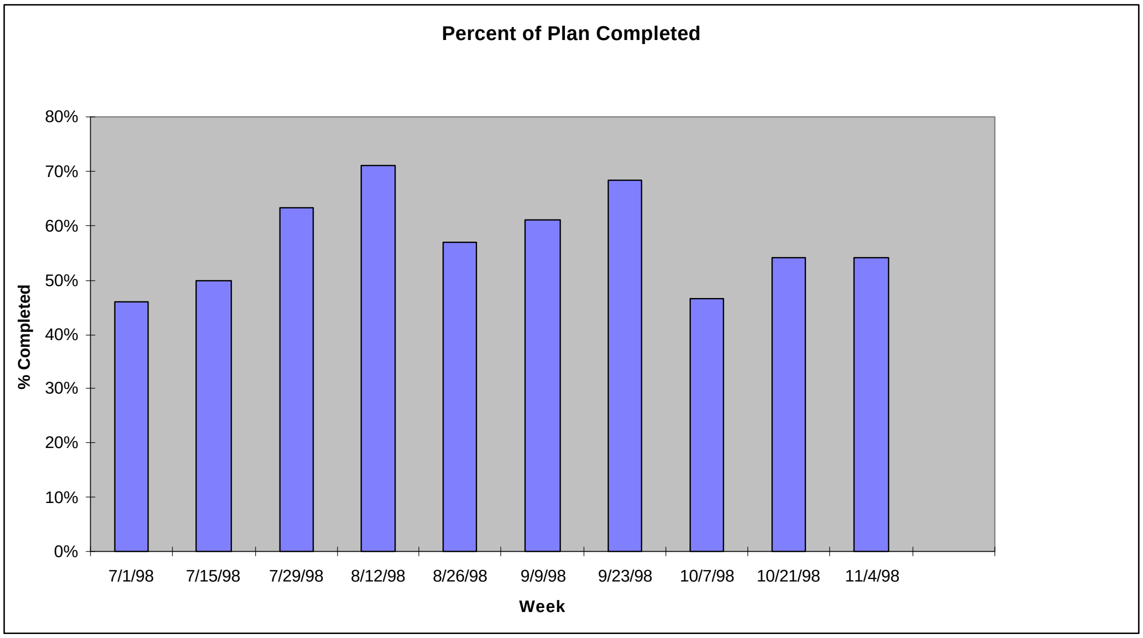
Week	7/1/98	7/15/98	7/29/98	8/12/98	8/26/98	9/9/98	9/23/98	10/7/98	10/21/98	11/4/98
4 week moving ave.				57%	60%	63%	64%	58%	57%	55%
PPC	46%	50%	63%	71%	57%	61%	68%	47%	54%	54%
Tasks Completed	28	33	48	37	29	36	26	20	26	20
Tasks Planned	61	66	76	52	51	59	38	43	48	37

Next Stage-PPC Data

The number of tasks or action items completed was divided by the number planned each two week period and a percentage calculated. For example, In the two week period beginning 11/4/98, 37 action items were assigned, of which 20 were completed, which amounts to 54%. In addition, a four week moving average was calculated in order to smooth the data and hopefully reveal trends. Through 11/4/98, the four week moving average was 55%, calculated by averaging the previous four weeks data.

The columns in Figure 6.1 represent the aggregate average completion percentage for all teams for each two week planning periods. PPC rose from an initial measurement of 46% to above 70% in the 4th two week planning period. Subsequently, perhaps connected with the end date slipping out, PPC rose and fell in a generally downward trend, winding up around 55%.

Figure 6.1



Next Stage PPC Data

There was considerable variation between teams. Through 9/9/98, PPC of the various teams was as follows:

Site/Civil	78%
Structural	35%
Enclosure/Architectural	62%
Mechanical/Electrical/Plumbing/Fire Protection	55%
Theatrical/Interiors	52%
Project Support	85%

Table 6.3 exhibits the reasons categories used on the project and the frequency of reason by category each week of the data collection period. It is apparent that three categories dominate; i.e., lack of prerequisite work, insufficient time, and conflicting demands, in that order. Unfortunately, such categories reveal little about root causes, so do not facilitate corrective action.

Table 6.3

Reasons/ Date	7/1/98	7/15/98	7/29/98	8/12/98	8/26/98	9/9/98	9/23/98	10/7/98	10/21/98	11/4/98	12/2/98	All Weeks
Decision	1	1	3	1	1		1	3	3	3		17
Prerequisites	7	16	8	2	7	10	3	5	6	4		68
Resources		1	2	0								3
Priority Change	3	4	6	1		1						15
Insufficient Time	5	6	1	6	6	10	8	10	6	4		62
Late start		4	1	1				1		1		8
Conflicting Demands	7	7	3	1	7	2		4	6	5		42
Acts of God			3	0								3
Project Changes				0					1			1
Other				2	1							3

Next Stage-Reasons

6.2.2 OBSERVATIONS

(See Appendices A and B for a report on the Kickoff meeting and the author's notes on project teleconferences.)

6.2.3 FEEDBACK FROM PARTICIPANTS

In October, 1998, the Site/Civil team agreed to select five plan failures and analyze them to root causes by asking "Why?" up to five times in succession. Review of Site/Civil's analyses revealed that failure to understand criteria for successful completion of assignments was the most common cause. Generally, failures were caused by not understanding something critically important; City requirements for traffic analysis, applicable codes for drainage, actual soil conditions, who had responsibility for what. Presenting reasons were often quite distant from root causes and frequently the failing party did not control the root cause. This sample also raised significant questions about adherence to quality requirements for assignments. For example, why did Site/Civil accept #1 (were they sure they had the capacity to take on this additional task?) or #2 (why did they think Mechanical would give them the information they needed in time for Civil to do its work?)?

> Failure #1: Failed to transmit site plan package to the general contractor as promised. Reason provided: conflicting demands—"I was overwhelmed during this period." 5 why's revealed that the required time was underestimated for collecting the information needed because the City's requirements for traffic analysis were different and greater than had been assumed.
>
> Failure #2: Failed to revise and submit site drainage for revised commissary roof drainage. Reason provided: prerequisite work. The mechanical contractor originally provided drainage data on pipe sizes, inverts, etc., then discovered that City codes required additional collection points. Civil is waiting on Mechanical to provide data on these additional collection points.
>
> Failure #3: Failed to complete Road "D" plan to support easement and operating items. Reason provided: prerequisite work. The root cause was the same as for #1; i.e., failure to understand City requirements for traffic analysis.
>
> Failure #4: Failed to make an engineering determination from 3 alternative pavement designs provided. Reason provided: prerequisite work and insufficient time. "This item was not anticipated. Why was it not anticipated? The City refused to accept our pavement design. Why did they refuse to accept our

pavement design? Soil conditions were different from past projects. The lack of prerequisite design work referred to the soil borings in the borrow site. We also are investigating other sources for dirt. Why was time insufficient? We neglected to plan for the time required to mobilize soils testing." The root cause was assuming soil conditions would be the same. A process flow diagram might have revealed the significance of that assumption.

Failure #5: Failed to determine/coordinate location of easements after final design by Texas Utilities. Reason provided: prerequisite work. "Prerequisite design work involved the determination of routing and service options. There was confusion over who was responsible. There were delays on the part of TU Electric due to the absence of key people." Failure to specify who was to do what prevented requesting a specific commitment from TU Electric. If TU Electric refused to make that commitment, Civil could have refused to accept its action item until receipt of their input. If TU Electric had committed, Civil might have been informed when key people were absent.

Low PPC was attributed by some members of the management team to the lack of a construction start date, and the consequent use by suppliers of resources on more urgent projects. The high percentage of plan failures due to conflicting demands appears to be supportive of this claim. However, this reasons analysis exercise and observation of teleconferences suggests that contributing causes were failure to apply quality criteria to assignments and failure to learn from plan failures through analysis and action on reasons.

6.3 The Nature of the Design Process and Implications for Process Control

'Making' has the job of conforming to requirements. Design produces those requirements. If there were complete predictability of design's output, design would generate no value. Consequently, variability plays a different role in design as opposed to construction (Reinertsen, 1997). This raises the question of the type of control appropriate to generative processes like design.

Let us first consider more closely the nature of the design process. Consider the task of producing a piping isometric drawing versus the task of doing a piping layout for a given area. In order to do the layout, the designer must know where other objects are located in the space. She must know locations, dimensions, material compositions, and operating characteristics of end-points. Some of these constraints and conditions of her problem will not change. Some may well change in response to her difficulty achieving a satisfactory solution. Consequently, the final piping layout will emerge from a process of negotiation and adjustment, which cannot be determined in advance.

An example from the Next Stage case illustrates the point. The design team was faced with selecting the theater seats, which might appear at first glance to be a fairly simple problem of applying criteria derivative from the general level of 'quality' desired in the facility balanced against the purchase price of the seats. In fact, the criteria are far from straightforward or simple. Seats can either be mounted on the floor or riser-mounted, the choice between them being interdependent with the structural pads for the seats, which in turn constrains choices regarding the return air plenum, which can either go through the floor or risers. That choice in turn impacts cleaning time and cost: how quickly can they set up for the next show? As it happens, chairs come with different types of upholstery, which can change the amount and type of smoke to be removed.

Components such as chairs may not be offered in all varieties; e.g., although we might prefer a riser-mounted chair, such chairs only come with a certain type of upholstery that would overload current plans for smoke removal. Everything's connected to everything. We are designing one whole, so parts have the logic of part to whole, potentially conflicting properties, etc. Product design decisions can impact the entire range of 'ilties': buildability, operability, maintainability, etc., etc. In this case, delay in selecting chairs delayed final determination of structural geometry, which in turn delayed completion of the 3D model of the structure.

Overly 'rationalistic' models of problem solving processes are inappropriate for the design process, which rather oscillates between criteria and alternatives, as in a good conversation from which everyone learns (See Conklin and Weil's "Wicked Problems" for another presentation of this idea.). In their *Soft Systems Methodology*, Checkland and Scholes offer the same critique of 'hard' systems thinking as applied to action research; i.e., such thinking failed because it assumed that objectives were defined and the task was simply to determine how to achieve those objectives. Rather than conceiving the project process to consist of determining design criteria then applying those criteria in the production of the design, design should be conceived as a value generating process dedicated to the progressive determination of both ends and means.

Specialization is essential for successful design. No one can understand in detail all the different types of criteria, constraints, and alternatives that might be considered. However, specialists tend toward suboptimization because they become advocates for what they understand to be important, often without sufficient understanding of what else is important[24]. Specialists are often advocates for the priority of specific criteria!

Given this value generating nature of design, controls based on the model of after-the-fact detection of negative variances inevitably focus entirely on controlling time and cost, leaving design quality as the dependent variable (p.199, Reinertsen, 1997). What is needed is a production control system that explodes tasks near in time to their performance, one that counteracts the tendency to suboptimization by explicitly focusing common attention on design criteria, one that facilitates value generation and information flow among specialists; i.e., the Last Planner system.

6.4 Evaluation of Last Planner Implementation

Four Next Stage project managers evaluated implementation and effectiveness of the Last Planner system in response to a short survey produced by the author. The four rated Last Planner effectiveness relative to traditional forms of project control 5, 5, 6, and 7 on a scale of 1 to 7, which is equivalent to saying that Last Planner was 44% more effective than traditional practice. However, examination of actual practice on the project suggests tremendous opportunity for further improvement.

Plus: -attempted to select only assignments needed to release other work

-measured and communicated PPC and reasons

[24] See Lloyd, et al., 1997 for the tendency to see one's task in terms of one's 'product' rather than in terms of participating in an iterative, interactive, evolving process.

Minus: -minimal preparation of participants

-no work flow control and make ready process

-poor definition of assignments

-no action on reasons

Each action item was determined completed or incomplete, and reasons were selected from the list of categories. However, no analysis of reasons was done, either during or between teleconferences. There was also no apparent attempt to act on the reasons that were identified. Work selection was tested against the 'pull' requirement by asking why it was needed to be done now, but rarely were assignments rejected for unsoundness or size. Frequently, it appeared that assignments were accepted with the implicit commitment to do one's best rather than an explicit commitment to complete based on knowledge of the execution process, understanding of relevant criteria, identification of needed informational inputs, and allocation of necessary resources. Assignments were not systematically exploded into an operations level of detail and, consequently, the interdependence of assignments was often not understood.

In summary, Next Stage did not fully change its production control system from the traditional, and either did not implement or did not implement completely the elements of the Last Planner system; i.e., work flow control, production unit control, and a learning process. Nonetheless, the Next Stage experience was valuable for its contributions to learning and further development of the Last Planner System. Much has been learned and developed since the Next Stage case. Opportunities and needs for the future are well summarized by Ed Beck, Linbeck project manager, in the following response to the author's survey question: *What improvements in LPS (Last Planner System) objectives, procedures, or implementation do you suggest for future projects?*

- Client buy-in at the user level
- Complete orientation of all participants
- A simpler value stream
- A more systematic format
- A better list of reasons to categorize planning failures
- Utilization of the 5 why's
- Utilization of the 6 week lookahead
- A more expeditious way to meet and create a weekly plan
- Periodic revisiting of the value stream
- Publishing graphs and reasons and answers to questions to all
- A tune-up meeting at strategic times along the course of the project
- Periodic assessment comparing what is happening versus what normally happens.

6.5 Learnings

The Next Stage case study reinforced the need to improve plan reliability in design processes and also suggested improvements to the production control system required to achieve better plan reliability.

-make sure project management understands the production control system and its objectives

-provide additional training to participants

-include ‘puller’ on action item log

-explode scheduled activities using the Activity Definition Model; i.e., specify the process to be used to complete an assignment, the directives or criteria to which it must conform, the prerequisite work needed from others, and the resources necessary to do the work.

-establish a lookahead window with screening criteria for advancement

-track the status of assignments as they move through the lookahead window

-adopt a sizing criterion for assignments that consistently demands less output from production units than their estimated capacity to accommodate variability in capacity. (This seems especially important for design. Other studies suggest that routinely 20% of capacity is used to do needed but previously undefined work each week.)

-improve the categorization of reasons and reasons analysis to facilitate implementation of the learning process, which consists of: analyze reasons to actionable causes, assign or take corrective action, and record results.

CHAPTER SEVEN: CASE THREE-PACIFIC CONTRACTING

7.1 Project Description and Last Planner Implementation

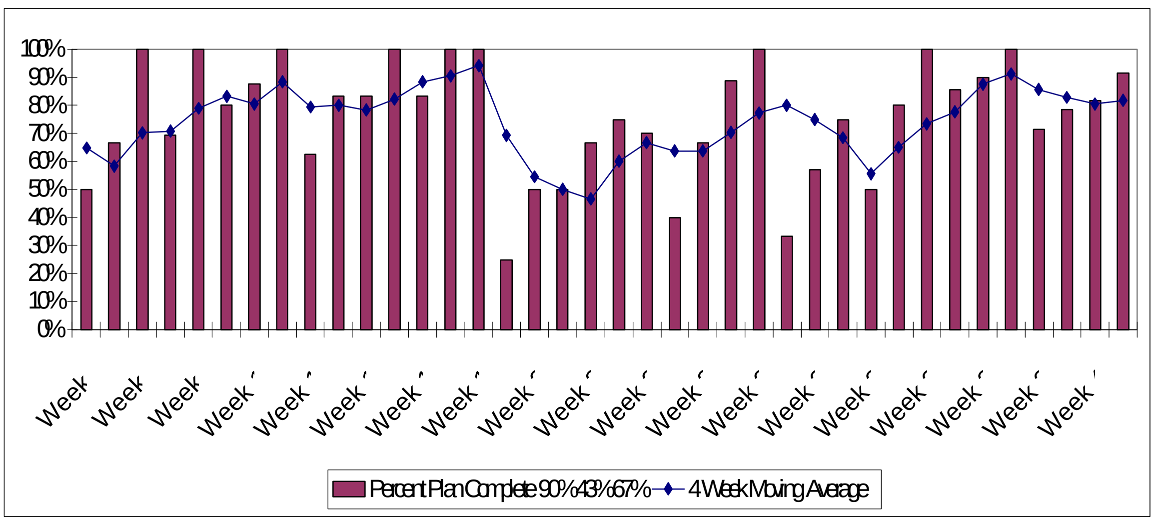
Pacific Contracting is a speciality contractor primarily involved in design and installation of building envelopes; i.e., cladding and roofing systems. The author began working with the company in 1995 as a consultant. Subsequently, Pacific Contracting became a charter member of the Lean Construction Institute and its President, Todd Zabelle, became an LCI partner.

Implementation of the Last Planner system by a speciality contractor is important for several reasons. First of all, specialists work for many general contractors, not all of whom may endorse the Last Planner principles and objectives. Secondly, the specialist has a different role in the production system than does a general contractor or construction manager. The latter's role is primarily to coordinate production, but the production itself is done by specialists, even if they are directly employed by the general contractor. Drawing on a manufacturing analogy, the speciality contractor is like a job shop, while the coordinator is like an assembler. Many of the functions of the Last Planner system, such as matching load to capacity, fall more particularly on the specialist, whether design or construction, than on the coordinator of design or construction processes.

7.2 PPC and Reasons

Pacific Contracting, using the latest tools and techniques developed by the author, participated in the effort to discover how to improve PPC to and above the 90% level, an LCI research project. The data collection period extended for 41 weeks, ending in mid-October, 1999[25]. As can be seen from Figure 7.1, there appears to have been a period of improvement through Week 19, then a decline followed by another upward trend through Week 28, followed by a brief period of decline, with finally another upward trend through the period of data collection.

Figure 7.1



Pacific Contracting-PPC

[25] The LCI research on improving PPC continued beyond the data collection period reported in this dissertation.

A possible explanation for the decline is that a very small number of assignments were actually made ready in time to be placed on weekly work plans, so that a single noncompletion registered as a relatively large percentage of failures. As shown in Table 7.1, from Week 17 through Week 23, no more than 4 tasks were assigned on weekly work plans. From Week 19 through 23, at least one weekly assignment was not completed, limiting PPC to a maximum of 75%. This likely impact of lookahead planning on PPC adds impetus to the need for future development of metrics specifically for the lookahead process and its improvement.

Table 7.1

Week	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Percent Plan Complete	90%	43%	67%	50%	67%	100%	69%	100%
4 Week Moving Average	0%	0%	0%	65%	58%	70%	71%	79%
Activities Scheduled	10	7	9	8	12	8	13	5
Activities Complete	9	3	6	4	8	8	9	5
Total Incompletions	1	4	3	4	4	0	4	0
Activities Scheduled	10	7	9	8	12	8	13	5
Client	0	0	0	0	0	0	0	0
Engineering	0	0	0	0	1	0	0	0
Materials	0	0	0	1	0	0	1	0
Equipment	0	0	0	0	0	0	0	0
Craft	0	0	0	0	0	0	0	0
Pre-Requisite	0	1	1	0	0	0	0	0
Subcontractor	0	2	1	0	0	0	2	0
Plan	1	1	1	3	3	0	1	0
Weather	0	0	0	0	0	0	0	0

Week	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Percent Plan Complete	80%	88%	100%	63%	83%	83%	100%	83%
4 Week Moving Average	83%	81%	88%	79%	80%	78%	82%	88%
Activities Scheduled	10	8	3	8	6	6	8	6
Activities Complete	8	7	3	5	5	5	8	5
Total Incompletions	2	1	0	3	1	1	0	1
Activities Scheduled	0	0	0	0	0	0	8	6
Client	0	0	0	0	0	0	0	0
Engineering	0	0	0	1	0	0	0	0
Materials	0	0	0	0	0	0	0	0
Equipment	0	0	0	0	1	0	0	0
Craft	0	0	0	0	0	1	0	0
Pre-Requisite	0	0	0	0	0	0	0	0
Subcontractor	1	0	0	1	0	0	0	0
Plan	1	1	0	1	0	0	0	0
Weather	1	1	0	1	0	0	0	1

Week	**17**	**18**	**19**	***20***	**21**	**22**	**23**	**24**
Percent Plan Complete	100%	100%	25%	50%	50%	67%	75%	70%
4 Week Moving Average	90%	94%	69%	55%	50%	47%	60%	67%
Activities Scheduled	1	2	4	4	4	3	4	10
Activities Complete	1	2	1	2	2	2	3	7
Total Incompletions	0	0	3	2	2	1	1	3
Activities Scheduled	1	2	4	4	4	3	4	10
Client	0	0	0	0	0	0	1	1
Engineering	0	0	1	0	0	0	0	0
Materials	0	0	0	0	0	0	0	0
Equipment	0	0	0	0	0	0	0	0
Craft	0	0	0	0	2	0	0	0
Pre-Requisite	0	0	2	0	0	0	0	0
Subcontractor	0	0	0	1	0	0	0	2
Plan	0	0	0	1	0	1	0	0
Weather	0	0	0	0	0	0	0	0

Week	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**
Percent Plan Complete	40%	67%	89%	100%	33%	57%	75%	50%
4 Week Moving Average	64%	64%	70%	77%	80%	75%	68%	56%
Activities Scheduled	5	3	9	5	3	7	4	4
Activities Complete	2	2	8	5	1	4	3	2
Total Incompletions	3	1	1	0	2	3	1	2
Activities Scheduled	5	3	9	5	3	7	4	4
Client	1	0	0	0	0	1	1	0
Engineering	2	0	0	0	0	0	0	1
Materials	0	0	0	0	1	1	0	0
Equipment	0	0	0	0	0	0	0	0
Craft	0	0	0	0	0	0	0	0
Pre-Requisite	0	0	0	0	0	0	0	1
Subcontractor	0	0	0	0	1	0	0	0
Plan	0	1	1	0	0	1	0	0
Weather	0	0	0	0	0	0	0	0

Week	33	34	35	36	37	38	39	40	41
Percent Plan Compl	80%	100%	86%	90%	100%	71%	79%	82%	92%
4 Week Moving Ave	65%	73%	78%	88%	91%	86%	83%	81%	82%
Activities Schedule	5	2	7	10	4	7	14	11	12
Activities Complete	4	2	6	9	4	5	11	9	11
Total Incompletions	1	0	1	1	0	2	3	2	1
Activities Schedule	5	2	7	10	4	7	14	11	12
Client	0	0	0	1	0	0	0	0	0
Engineering	0	0	0	0	0	0	0	0	0
Materials	0	0	0	0	0	0	0	0	0
Equipment	0	0	0	0	0	0	0	0	0
Craft	0	0	1	0	0	2	2	0	0
Pre-Requisite	0	0	0	0	0	0	0	0	1
Subcontractor	0	0	0	0	0	0	0	0	0
Plan	1	0	0	0	0	0	1	2	0
Weather	0	0	0	0	0	0	0	0	0

Pacific Contracting-PPC Data and Reasons

Pacific Contracting categorized reasons for noncompletion of weekly assignments in terms of Client, Engineering, Materials, Equipment, Craft, Prerequisite Work, Subcontractor, Plan, or Weather. Bret Zabelle, Operations Manager for Pacific Contracting, provided the following comments regarding their reasons categories:

> "As I started to write our definition of engineering as a reason, I had a moment of clarity. Engineering cannot be a reason. You either have the engineering for a task complete or you don't. If you don't have the engineering complete, the task should not be scheduled on a work plan. The only instances I can think of for engineering is miscalculation of quantities, structural collapse or failure.

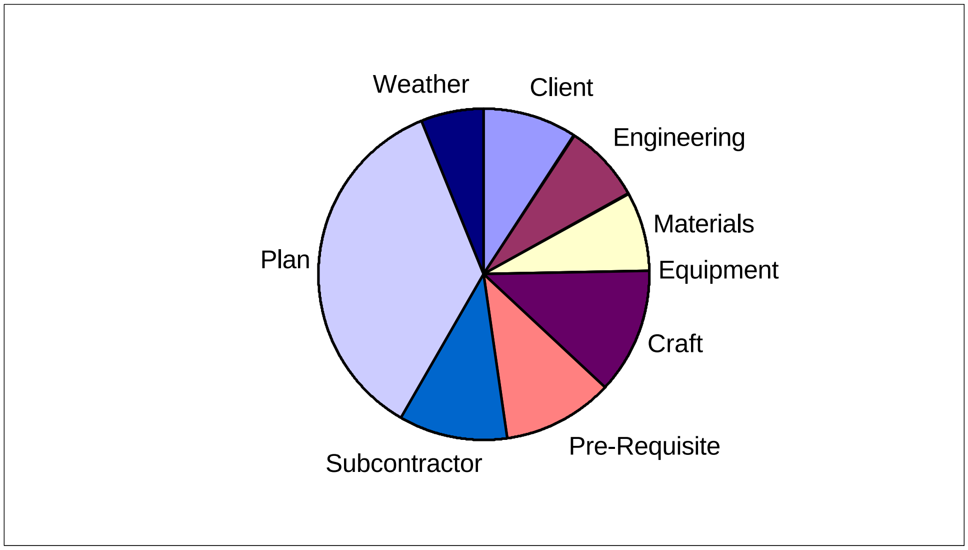
> "Craft:When all the resources are available to perform a task on the WWP (weekly work plan) and the craft workers do something different. Also refers to craft absenteeism.

> "Subcontractor: This is similar to engineering as a reason. If we have a subcontractor who did not complete prerequisite work in front of us, we should not put our activity on the WWP until it is available. Also refers to fabricators. They promise components will be fabricated by a certain date and fail.
>
> "Plan: Planning failures occur when we do stupid things like schedule activities if the engineering is not complete, materials, tools and workers are not available, our own subcontractors or other contractors have not completed prerequisite activities. Sometimes we schedule tasks that are more complex than we thought."

Considering reasons for failures to complete weekly assignments, as shown in Table 7.1 and also graphically in Figure 7.2, much the most common reason was "Plan", Pacific Contracting's own disregard of assignment quality criteria or inability to understand how the planned work was to be done, and to anticipate all the steps and resources necessary. The next most frequent reason was errors of some sort in execution of assignments by Pacific Contracting's craft supervisors and workers.

Altogether, the vast majority of weekly work plan failures were well within the control of Pacific Contracting. However, it should be remembered that matters might be just the opposite as regards the lookahead process which makes ready assignments for selection in weekly work plans. Again, we are reminded of the importance of measuring and analyzing lookahead process performance.

Figure 7.2



Pacific Contracting-Reasons

7.3 Observations

During the period of data collection, Pacific Contracting did not work with a single general contractor that embraced the Last Planner system. Specialists appear to have tremendous difficulty achieving high levels of PPC when not working on 'last planner' projects. The consequent lack of resource utilization is a waste the recovery of which could contribute to faster or more projects. On the other side of the matter, speciality contractor efforts to avoid that waste seem inevitably to decrease both plan reliability and progress of projects as seen from the perspective of project coordinators.

Once work is available to speciality contractors, they appear-based on this one instance-to be able to achieve a relatively high level of plan reliability, limited mostly by their own ability to plan and execute.

7.4 Learnings

For speciality contractors to increase plan reliability to the 90% level and above requires that the coordinators of the projects on which they work embrace the Last Planner system's objectives and especially the lookahead process, which is dedicated to making tasks ready for assignment and to balancing load and capacity. For their part, speciality contractors must adhere to the discipline of Last Planner rules and perhaps also use the technique of first run studies[26] more consistently and well.

[26] First run studies are extensive planning of upcoming operations by a cross functional team including representatives of those who are to do the first operation, followed by methodical study, redesign of the operation, and retrial until a standard is established to meet or beat for execution of that operation. First run studies follow the Shewhart Plan-Do-Check-Act cycle, made popular by W. Edwards Deming.

CHAPTER EIGHT: CASE FOUR-OLD CHEMISTRY BUILDING RENOVATION PROJECT

8.1 Project Description and Last Planner Implementation

Linbeck Construction, a founding member of the Lean Construction Institute, was the general contractor for Rice University's Old Chemistry Building Renovation Project in Houston, Texas. Linbeck brought John Pasch, Rice's facilities manager, to the Neenan Company's annual winter conference in 1998. At that conference, James Womack spoke on the need and opportunity to extend lean production (manufacturing) concepts and techniques to the construction industry and Greg Howell[27] shared the Lean Construction Institute's vision of that application. John was sufficiently impressed that he allowed Linbeck to negotiate with its primary subcontractors rather than competitively bid them as had been the University's practice. At this point, a substantial building program stood in the offing and Linbeck was one of three contractors competing for the lion's share.

Kathy Jones, Linbeck's project manager, had the author conduct several educational and training sessions with project personnel, including the architect. Unfortunately, the architect refused to participate in the Last Planner system. However, the subcontractors became totally committed and enthusiastic about the planning process during the course of the job, as did Rice University's personnel. The project was completed to a very aggressive schedule to the satisfaction of users and within the budget. Rice University was so well pleased with the performance that Linbeck won its Fondren Library Project, and is well situated to do roughly half a billion dollars worth of work in the Rice Program over the next several years.

8.2 PPC and Reasons

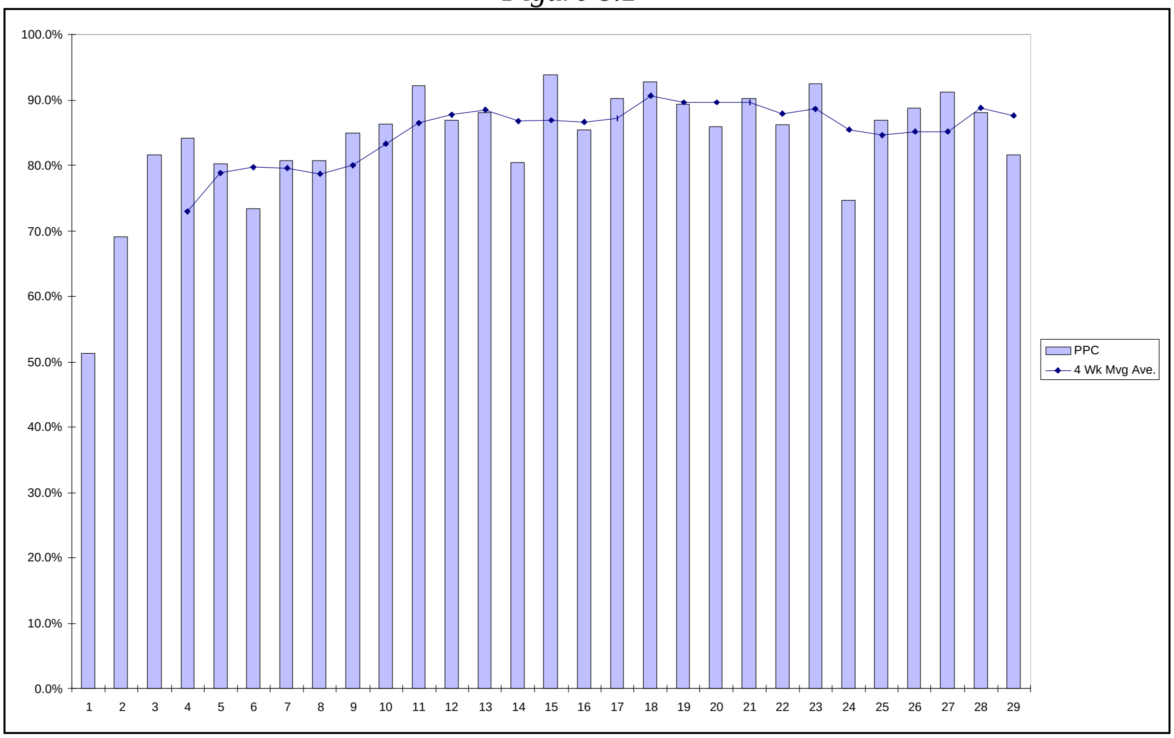
The author facilitated team scheduling exercises that produced an overall project schedule, then a more detailed schedule for the initial phase of work and the design development needed to support it. That phase schedule became the driver for weekly work planning, the results of which are shown in Figure 8.1.

Over a period of approximately eleven weeks, PPC rose to a level of 85% or so, then stabilized at that level for the duration of the project. This was an unprecedented accomplishment at the time, and resulted from the dedication of the owner, general contractor, and subcontractor personnel to the Last Planner System and its goal of plan reliability. Kathy Jones reinforced the Last Planner principles by fining those who used the expression 'I hope' or 'hopefully' in connection with a commitment to do work. (The fine was a six pack of beer to be collected at the project-ending celebration.) The project manager for one subcontractor volunteered at an LCI research workshop that "It's fun to go to work now!"

---

[27] Co-founder with the author of the Lean Construction Institute in August, 1997.

Figure 8.1



Old Chemistry Building-PPC

Table 8.1

Date	1/25/99	2/1/99	2/8/99	2/15/99	2/22/99	2/29/99	3/8/99	3/15/99	3/22/99	3/29/99	4/5/99	4/12/99	4/19/99	4/26/99
Tasks Completed	20	38	40	48	49	44	46	46	56	57	71	66	66	66
Tasks Assigned	39	55	49	57	61	60	57	57	66	66	77	76	75	82

Date	5/3/99	5/10/99	5/17/99	5/24/99	6/1/99	6/7/99	6/14/99	6/21/99	6/28/99	7/6/99	7/12/99	7/19/99	7/26/99
Tasks Completed	60	53	65	64	50	55	65	69	62	62	66	63	73
Tasks Assigned	64	62	72	69	56	64	72	80	67	83	76	71	80

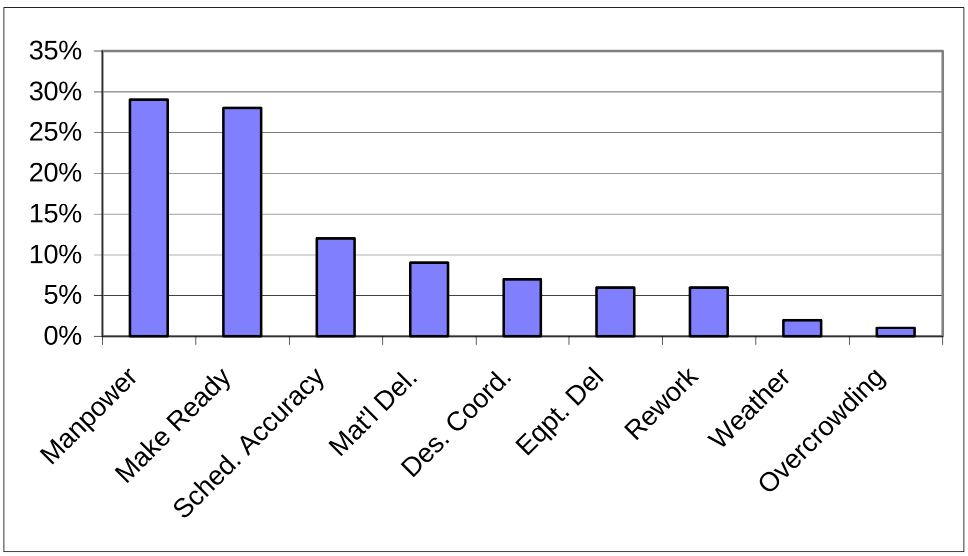
Date	8/2/99	8/9/99
Tasks Completed	59	53
Tasks Assigned	67	65

Old Chemistry Building-PPC Data

Of the relatively few failures to complete weekly assignments, most were caused by lack of manpower or failure to complete prerequisite work ("make ready"). As this occurred during a building boom in the Houston area, the low frequency of manpower problems is a testament to the subcontractors' dedication to the project.

The remaining reasons categories were Schedule Accuracy (the assignment shouldn't have been made), Material Deliveries, Design Coordination, Equipment (part of the building, not construction equipment), Rework, Weather, and Overcrowding.

Figure 8.2



Old Chemistry Building-Reasons for Noncompletions

8.3 Observations

Lack of participation by the architect was a serious deficiency on the project, perhaps concealed by the high PPC and low incidence of design coordination as a reason for failing to complete weekly work plan assignments. Design problems did impact the job, but that impact would only be evident in schedule changes and in the lookahead process.

Unfortunately, the lookahead process was not fully and formally developed on this project, in part because it was still being defined and its techniques created at the time Old Chemistry was initiated.

Linbeck intends to extend the Last Planner System to the design phase of the Fondren Library Project, and has Rice University's agreement to keep the same subcontractors in place for that project. This commercial alliance among Linbeck and its 'preferred' suppliers is a critical component in the recipe for success.

8.4 Learnings

On the positive side, the Old Chemistry Building Renovation Project demonstrated that PPC could be maintained consistently at a level of 85% through development and nurturing of teamwork and the subsequent team enforcement of norms and rules. The commercial success of the general contractor and its subcontractors indicates the power and impact of increasing plan reliability. Specific techniques that were trialed successfully on this project included team scheduling, specifically team production of detailed phase schedules, resulting from intense negotiation among the speciality contractors themselves, within a schedule framework established by the general contractor.

As for things that might be done better on future projects, implementation of Last Planner in design and involvement of design professionals is certainly number one. Lesser issues, but still important, include the need for a more transparent lookahead process and the need for more explicit learning from analysis and action on reasons for failures.

CHAPTER NINE: CASE FIVE-ZENECA PROJECT

9.1 PROJECT DESCRIPTION AND LAST PLANNER IMPLEMENTATION

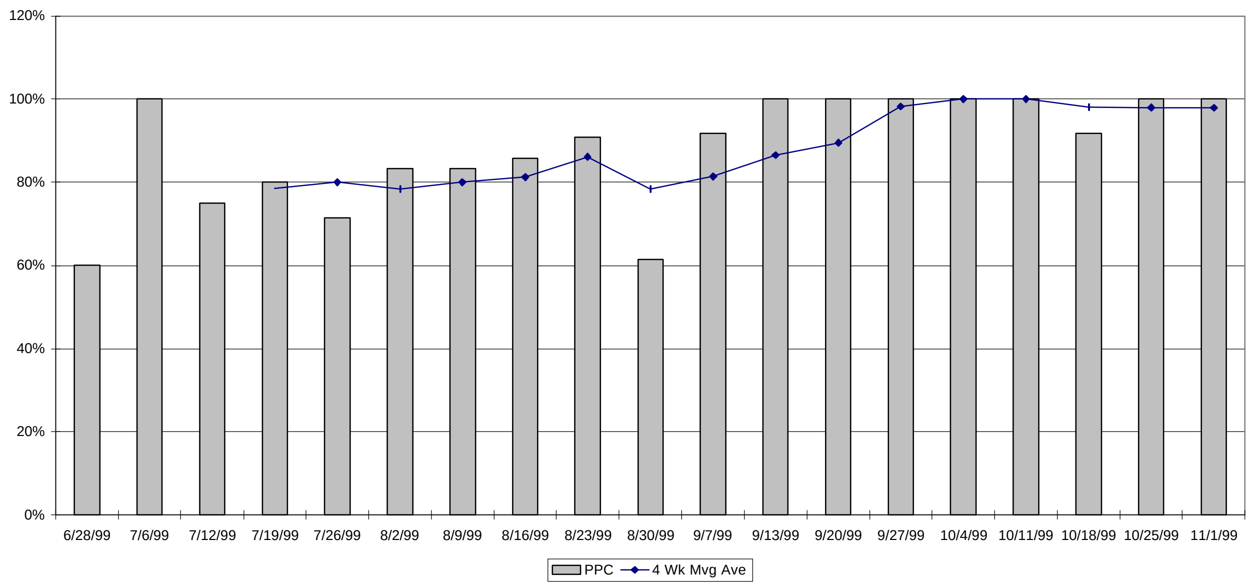
Barnes Construction is a member of the Lean Construction Institute and is embarked on transforming itself into a lean organization. Part of that transformation is to be achieved by implementation and perfection of the Last Planner system of production control. Implementation of the Last Planner system began with classroom training, followed by site visits and coaching, all provided by the author.

Zeneca is a biotechnology company located in Richmond, California near San Francisco. The Zeneca Project reported here is one of a series of seismic retrofits of laboratory and office buildings being performed by Barnes. Of all the cases included in this dissertation, the Barnes case incorporates most of all previous learnings and the latest developments in technique and implementation. One of the critical improvements to be seen is in the methodical analysis and removal of constraints from scheduled tasks.

9.2 PPC AND REASONS

As shown in Figure 9.1, the period of data collection extended from the week of 6/26/99 through the week of 10/11/99. It appears that PPC gradually improved throughout that period until culminating in four consecutive weeks in which PPC measured 100%.

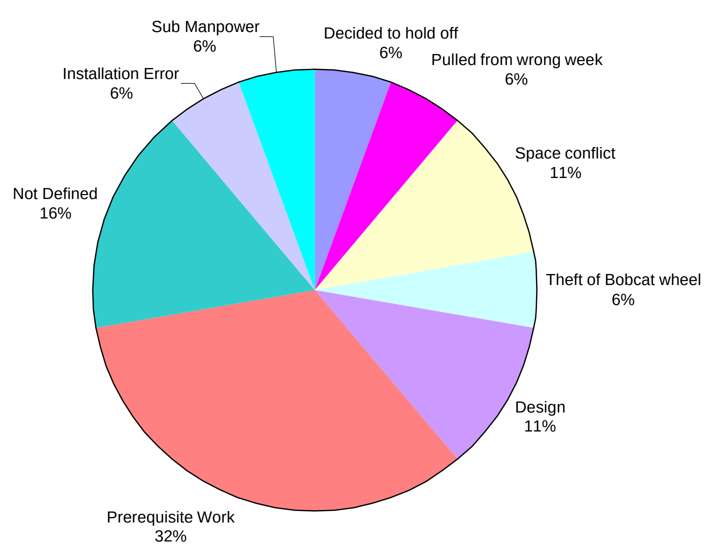
Figure 9.1



Zeneca-PPC

With such a high percentage of weekly assignments completed, there were relatively few

Figure 9.2



Zeneca-Reasons

noncompletions, and so few occasions for identifying reasons for noncompletions. Such as were identified are shown in Figure 9.2.

9.3 Constraint Analysis and Make Ready

The technique of constraints analysis, pioneered on the CCSR Project, became a key tool in Zeneca's success. As originally envisioned, status information regarding constraints was collected each week on all tasks scheduled to start within the next 6 weeks. Notes and action items were added to the constraint analysis form to serve as a reminder to various parties regarding the actions they needed to take to make tasks ready in time to be performed. The primary rule applied to this lookahead process was to only allow tasks to retain their scheduled starts if the planners were confident they could be made ready in time. Otherwise, they were to appeal for help to higher levels of their organizations, then, if make ready actions indeed could not be taken in time, defer the task until it could be made ready.

Following is a statement, by this writer, of the directives governing the Last Planner system installation and execution at Barnes:

Barnes Production Control Requirements

1. Hold weekly subcontractor coordination meetings on each project. Insist subcontractors give input into weekly work plans and lookahead schedules.
2. Select weekly work plan assignments from those that meet quality criteria of definition, soundness, sequence, and size. Issue weekly work plans and expect every superintendent and foreman to have them in their pocket. Use the weekly work plan form and be sure to complete all sections, including make ready needs and workable backlog. When assigned tasks extend beyond one week, specify what work is to be completed within the week.
3. Each week, calculate the percent plan complete (PPC) for the previous week and identify reasons for each assignment that was not completed. Try to get to root

or actionable causes. Don't beat people up for plan failure, but insist that they learn from their experience.

4. Maintain a 5 week lookahead schedule at a level of detail needed to identify make ready needs. Add 1 week each week.
5. Do constraints analysis on each activity on the 5 week lookahead schedule, using the constraints analysis form. Remember to mark an activity as unconstrained only if you have positive knowledge that the constraint does not exist or has been removed ('guilty until proven innocent').
6. Each week, email or fax the constraints analysis form to each subcontractor that has activities scheduled on the lookahead and ask them to provide status information.
7. Assign make ready actions as appropriate; e.g., the technical engineer will resolve RFIs, the project sponsor will expedite outstanding payments, the project controls manager will deal with contract and change order issues, etc. Obviously, subcontractors will also have make ready tasks such as generating submittals, expediting fabrication and deliveries, acquiring necessary equipment and tools, reserving labor, etc.
8. Maintain a statused and current master project schedule.
9. Involve subcontractors in producing master and phase schedules. Phase schedules are detailed plans for completing a specific phase of project work; e.g., site preparation, foundations, superstructure, skin, etc. Use the team scheduling technique in which participants describe activities on sheets that they stick on a wall, then negotiate details, sequencing, etc.

Project Checklist

1. Does the project hold weekly subcontractor coordinating meetings?
2. Are weekly work plan forms completed each week, including make ready needs and workable backlog?
3. Are weekly assignments adequately defined; e.g., is the work to be completed during the week specified?
4. Are weekly work plans used in the field; e.g., does every foreman and superintendent carry it with them?
5. Are weekly work plans reviewed in the coordinating meetings, PPC calculated, and reasons identified?
6. Is a 5 week lookahead schedule maintained, with one week added each week?
7. Are subcontractors requested each week to provide status information regarding constraints on the activities listed on the project lookahead schedule?
8. Which subcontractors provide information each week for constraints analysis? Which subcontractors don't?
9. Are make ready actions assigned each week?
10. What people carry out their make ready assignments? Who doesn't?
11. Is the rule followed that activities keep their scheduled dates only if the planner is confident they can be made ready in time?
12. Of those activities scheduled to start within the next 3 weeks, what percentage are not made ready?

13. Is the rule followed to only allow activities onto weekly work plans that have had all constraints removed that could be removed before the start of the plan week?
14. What is the project's PPC? Is it rising, falling, or staying the same?
15. What are the dominant reasons for failing to complete assignments on weekly work plans?
16. Is a master project schedule and phase schedule maintained current and updated once a week?
17. Are subcontractors involved in producing master and phase schedules using team scheduling?

Table 9.1

ctivit ID	Activity Description	Planned Start Date	spons Party	Contract / hange Orde	Design AE Complete	Design Submittal	Design RFI's	Materials	Labor	quipme	Prereq Work	Weather
	Install dowel templ	12-Aug	NLB	X	X	X	X	X	X	X	Above	X
	Pour mat slab @E-	17-Aug	NLB	X	X	X	X	Concrete	X	X	Above	X
	Move tower shoring	23-Aug	Safw	X	X	X	X	X	X	Crane	Above	X
	Hard demo (Beams	30-Aug	Cal-\	X	X	X	X	X	X	X	Above	X
	One side walls	13-Sep	Peck	X	X	X	X	X	X	X	Collectors	X
	Install wall rebar	16-Sep	McG	X	X	X	X	X	X	X	Above	X
	Epoxy dowels	22-Sep	NLB	X	X	X	X	X	X	X	Above	X
	Pull Test	23-Sep	ICI	X	X	X	X	X	X	X	Above	X
	Close forms	24-Sep	Peck	X	X	X	X	X	X	X	Above	X
	Install tower shorin	23-Aug	Safw	X	X	X	X	X	X	Crane	Cure	X
	Excavate footing	13-Sep	Cal-\	X	X	X	Possible footi		X	X	Collectors	X
	Chip footings if nec	16-Sep	Cal-\	X	X	X	ecess	X	X	X	X	X
	Drill and epoxy dov	16-Sep	NLB	X	X	X	X	X	X	X	X	X
	Install rebar @mat	17-Sep	McG	X	X	X	X	X	X	X	Above	X
	Rebar template	24-Sep	NLB	X	X	X	X	X	X	X	Above	X

Zeneca-Constraint Analysis Form

9.4 OBSERVATIONS

The extremely high level of plan reliability achieved on Zeneca may have resulted in part from its being relatively simple, not technically but rather operationally. A relatively few subcontractors were involved[28], and few were required to work in close proximity, either temporally or spatially. On the other hand, the production control processes and techniques employed appear also to have made a contribution. Apart from the Old Chemistry Building Renovation Project, in no other case were subcontractors more intimately involved in the lookahead process or in weekly work planning. Further, the contractor's execution of the lookahead process, particularly constraints analysis and assignment of action items to remove constraints, was much more rigorous than on previous projects.

9.5 LEARNINGS

It is possible to achieve PPC levels above 90% over an extended period of time through consistent implementation of Last Planner system techniques. Especially important in

[28] Once the rebar installation was well underway, rarely were more than 5 subcontractors scheduled to work on the project in any week. *Safway-shoring, McGrath-rebar installation, ICI-rebar inspection, Peck & Hiller-formwork, Cal-Wrecking-demolition, National-concrete coring.* By contrast, on an interiors project underway at the same time, an average of 10 subcontractors were given assignments each week.

this regard are constraint analysis and subcontractor participation in planning and control.

CHAPTER TEN: CONCLUSIONS

10.1 Summary of Case Study Results

Data collection for the five case studies was concluded in the following order and dates, all within the period in which this dissertation was in progress:

❑ Case One-CCSR Project	Jan-Mar '98
❑ Case Two-Next Stage	July-Nov '98
❑ Case Three-Pacific Contracting	Jan-Oct '99
❑ Case Four-Old Chemistry Building Renovation	Feb-Aug '99
❑ Case Five-Zeneca	June-Oct '99

CCSR addressed the question how to apply the Last Planner system to subcontracted projects as distinct from the direct hire production to which for the most part it had previously been applied. The application was successful and piloted constraints analysis as a tool for evaluating the readiness of potential assignments and for identifying the actions needed to make them ready.

Next Stage was an exploratory case study on the application of Last Planner to design. Interruption of the project prevents drawing firm conclusions, however participants considered the Last Planner system successful and superior to traditional methods of project control. Numerous learnings were drawn from the case, perhaps the most important being the need to explode design tasks into operational detail near in time to their execution, in order to accommodate the self-generating characteristic of the design process. The Activity Definition Model was created for that purpose and has subsequently been applied extensively for the purpose of task explosion.

The Pacific Contracting case explored the limitations faced by a speciality contractor trying to unilaterally apply the Last Planner system. Diligent adherence to system rules allowed the contractor to achieve an average 76% PPC level. However, several periods of precipitously lower performance appear to have been correlated with failure of their customer projects to make work ready when scheduled, reducing the amount of work available to Pacific Contracting and consequently making them vulnerable to low PPC should they experience any plan failures at all. Another interesting finding was that plan failures within their control tended to be primarily from lack of detailed, advance operations design. Pacific Contracting has rededicated themselves to the routine use of First Run Studies in response to this finding.

The Old Chemistry Building Renovation case revealed a sustained PPC of 85%. With the opportunity to benefit from previous cases, the project team also added a very successful education and team building component to achieve this breakthrough result.

The fifth and last case study, Barnes Construction's Zeneca Project, sustained a PPC near 100%, apparently settling the question whether or not that level of plan reliability can be achieved. It is not suggested that every project will be able to achieve the same results even should they imitate Zeneca's rigorous application of Last Planner rules and techniques. The relatively few subcontractors involved during the measurement period may have simplified the coordination problem beyond the norm. However, the extensive involvement of subcontractors in planning and constraints analysis is a model to be imitated by all.

10.2 Research Question: *What can be done by way of tools provided and improved implementation of the Last Planner system of production control to increase plan reliability above the 70% PPC level?*

Review of the case studies suggests that plan reliability improves with adherence to the Last Planner system rules, with extensive education and involvement of participants, and with use of techniques such as task explosion, constraints analysis, make ready actions, shielding production from uncertainty through selection of quality assignments, and identification and action on reasons for failing to complete assigned tasks. The PPC levels recorded were significantly better than previous measurements. Previously, measured PPC above 70% was very rare (Ballard and Howell, 1997). In the latter three case studies, all achieved PPC levels of 76% or higher, with Zeneca consistently above 90%.

10.3 Research Question: *How/Can Last Planner be successfully applied to increase plan reliability during design processes?*

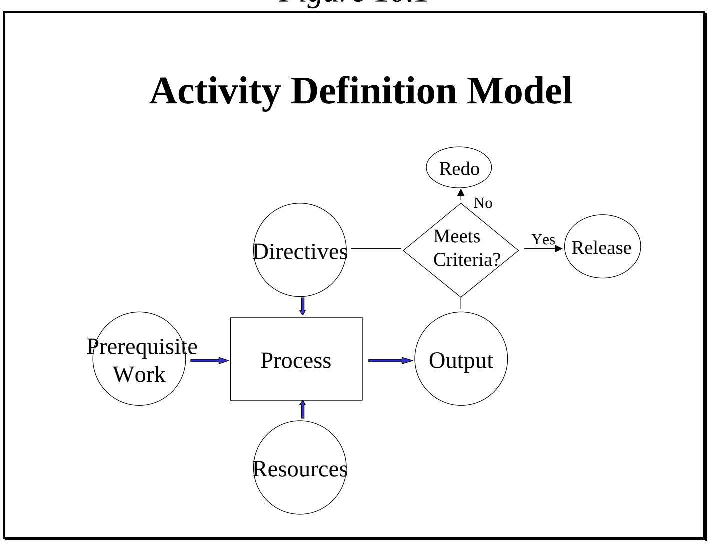
Evidence for settling this question is not so decisive. The exploratory case suggested but did not confirm that Last Planner can effectively be applied to design production control. However, the Last Planner system as now developed appears to be precisely matched to the nature of the design process. Unlike making, which covers a wide range of tasks, including making multiple copies of a single design, design itself is essentially generative. As such, a process control system is required that does not assume a simple matching of criteria and design alternatives, but rather facilitates a progressive, dialectical development of both.

Perhaps the most valuable contribution of the case was its clarification of the nature of the design process and consequently of the obstacles to management control. The primary response to those obstacles has been the development and implementation of the Activity Definition Model as a technique for exploding design tasks as they enter the lookahead process. Ideas and suggestions for further research on this question are described below.

10.4 Directions for Future Research

The case studies suggest the need for further modifications to the Last Planner System, some specifically intended to make it better fit design applications and others for general improvement. The prevalence of confusion over directives as a reason for plan failure in the Next Stage case study indicates a need for more explicit specification of the directives governing design tasks. A tool for making that specification is the Activity Definition Model[29] shown in Figure 10.1.

Figure 10.1



Activity Definition Model

ACTIVITY DEFINITION

OUTPUT represents the result or deliverable produced by performing the scheduled activity. In the case of complex deliverables, a process flow diagram is created and each of its deliverables is decomposed using the same activity definition model.

What are the DIRECTIVES governing my output, process, and inputs? To what criteria must my output conform in order to serve the needs of our customer production units? What PREREQUISITES do I need from others? What RESOURCES do I need to allocate to this assignment?

Before releasing the output to the PUs that need it, it is to be evaluated against the criteria and , if nonconforming, either the criteria are revised based on new insights into customer or stakeholder needs, or the output is revised to better meet the criteria[30].

JOINT SUPPLIER/CUSTOMER ASSIGNMENTS

A critical element for success is explicit agreement between ‘customer’ and ‘supplier’ regarding those criteria. The PU producing the output should understand how it is to be used by the customer PUs before production. Subsequently, inspection can be either by the producer or jointly by producer and customer.

Self-inspection and joint supplier/customer inspection are key concepts in the method of in-process inspection, which reduces defects through empowerment of the workers themselves, as opposed to exclusive reliance on external inspectors. This quality assurance prior to releasing work between PUs has been extended by some lean contractors to the progressing of work. Only products and installations that have passed quality control inspection can be counted as completed work, and then only if they are in the work packages (batches) needed by the customer PUs.

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[29] Although developed independently by this author in the mid-1980s, the Activity Definition Model is similar to IDEF, although arguably the concept of "directives" is different from the IDEF concept of "constraints".

[30] Conformance of outputs to design criteria is not a matter of matching. It is rather the exception than the rule that any design alternative maximally satisfies all the multiple criteria. The question is rather at what level of value must tradeoffs be made among

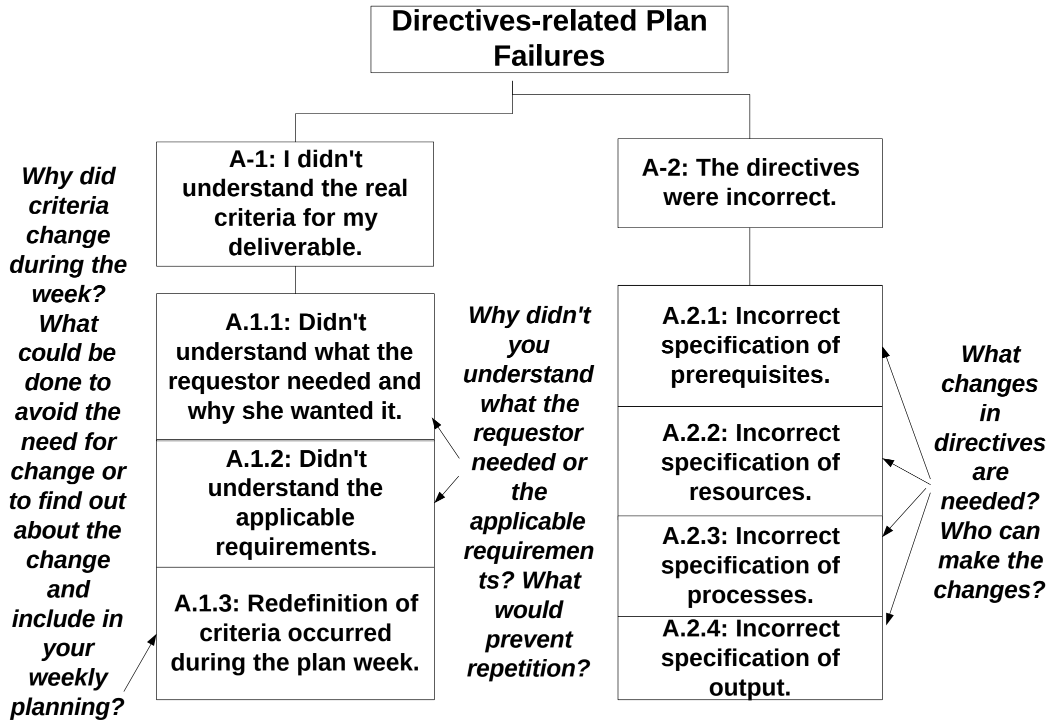
Recognizing the critical need for the supplier process and the customer process to agree on directives, and the objective of selecting and executing only those assignments that release work to others, it is proposed to make the supplier and customer jointly responsible for successful completion of assignments. The supplier should make sure he/she understands what the customer needs. The customer equally should make sure the supplier understands what he/she needs. Aside from assignments generated by push scheduling, in the absence of an explicit pull signal from the customer, the supplier can assume that the task does not need to be performed at this time.

REASONS CATEGORIZATION AND ANALYSIS

The reasons categories used on the Next Stage Project did not promote identification of root causes. Consequently, it is proposed to use the elements of the Activity Definition Model as the primary categories and also to provide a guide for reasons analysis that will facilitate identification of actionable causes.

those competing criteria. Exploration of such issues is part of the future research agenda beyond the scope of this thesis.

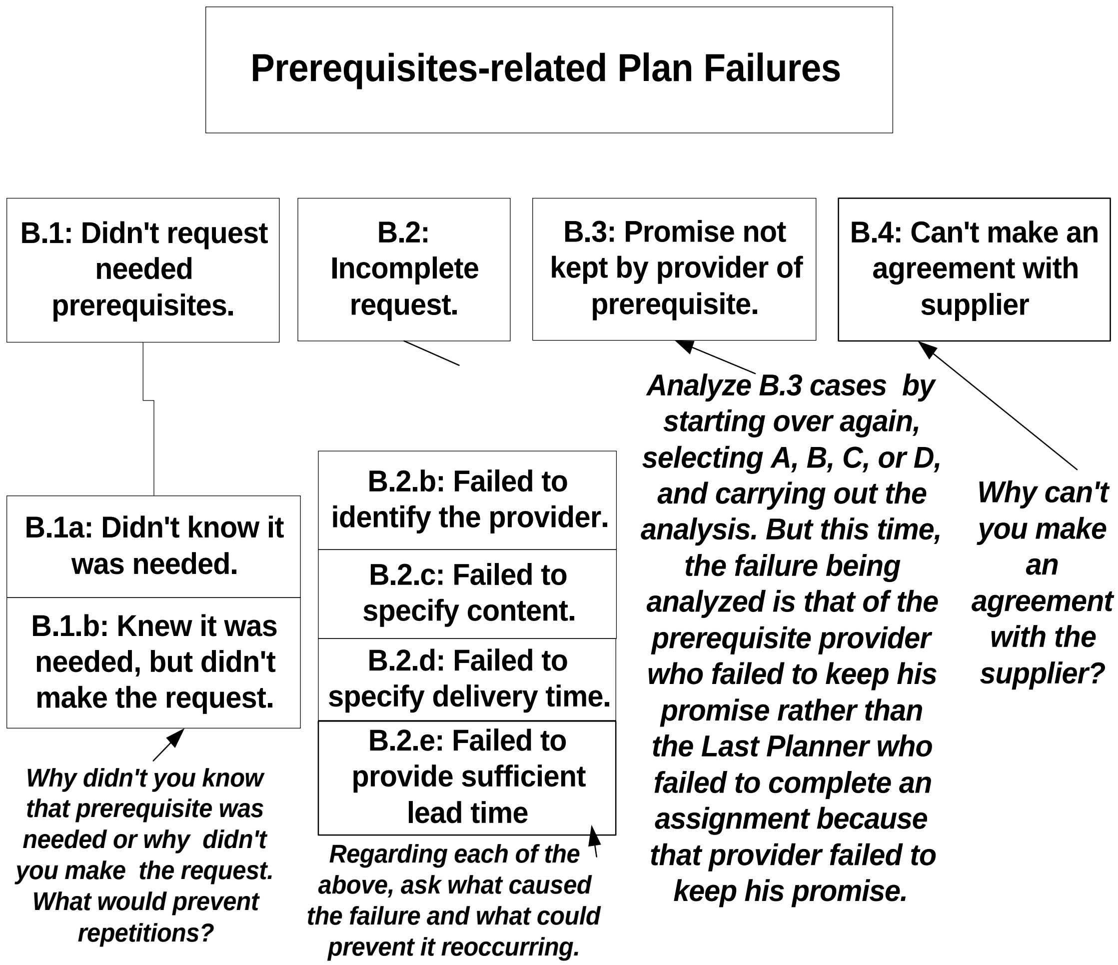
Figure 10.2



Reasons Analysis Hierarchy-Directives

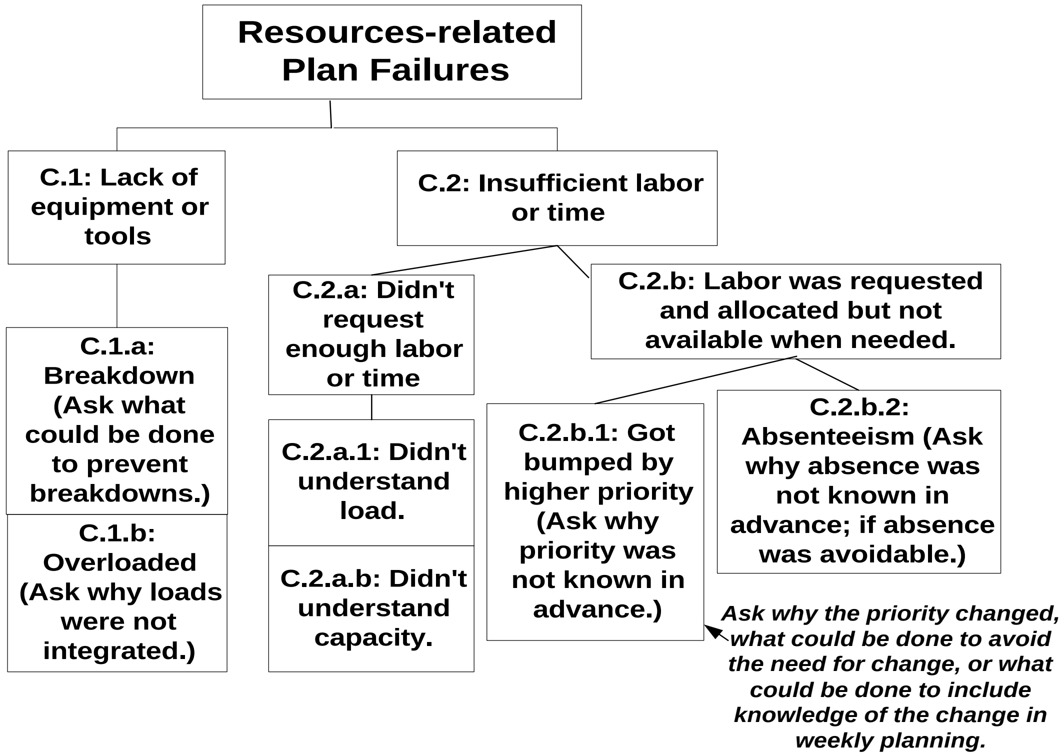
The primary categories are directives, prerequisites, resources, and process. Once placed within one of these categories, a plan failure can be analyzed in accordance with the guidelines expressed in Figures 10.2-10.5.

Figure 10.3



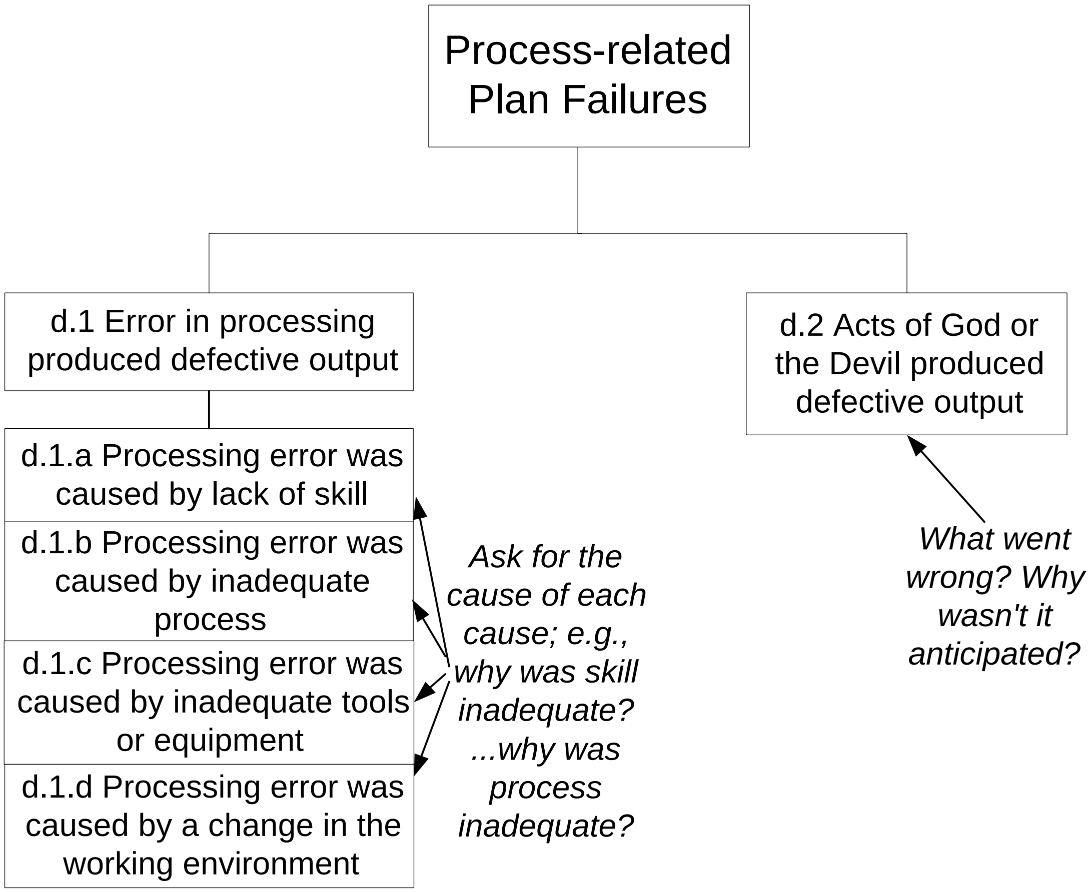
Reasons Analysis Hierarchy-Prerequisites

Figure 10.4



Reasons Analysis Hierarchy-Resource

Figure 10.5



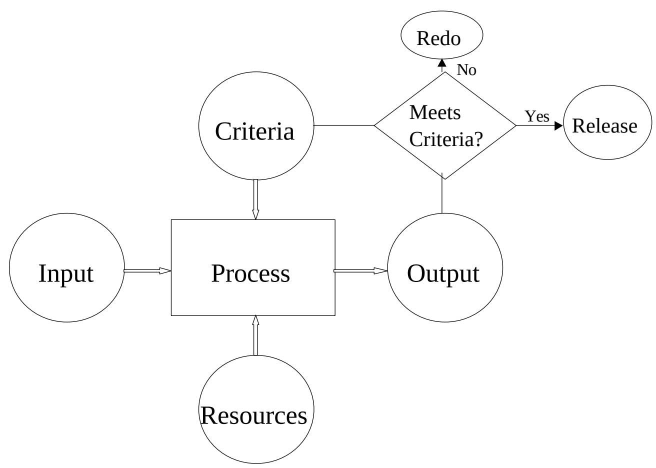
Reasons Analysis Hierarchy-Process

10.5 Conclusion

The Last Planner system of production control, improved through the case studies included in this thesis, has been shown to be effective in achieving and maintaining plan reliability above the 90% level in site installation. Applicability and effectiveness of the Last Planner system to design remains to be definitively determined, however the generative nature of the design process suggests that a control system such as Last Planner is needed, as opposed to approaches that rely on push scheduling and early selection from alternatives. Further development of the Last Planner system is suggested regarding activity definition, joint supplier/customer assignments, and reasons analysis. In addition, research is needed to quantify and understand the benefits of greater plan reliability for safety, quality, time, and cost.

GLOSSARY OF TERMS[31]

activity definition model An input-process-output representation of design tasks, supplemented by specification of criteria (entering the process rectangle from above) and of resources (entering the process rectangle from below) and an inspection process resulting either in redo or release to the customer process. The model is used as a guide to exploding design tasks into a level of detail at which their readiness for execution can be assessed and advanced.



assignment a directive or order given to a worker or workers directly producing or contributing to the production of design or construction. Example: Scott, you and Julie are to make the changes in wall locations detailed in memo #123 by the end of the week. Anne, you find out what the building authorities will require for a structural permit.

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.

commitment planning Planning that results in commitments to deliver on which others in the production system can rely because they follow the rule that only sound

[31] This glossary was produced specifically for this thesis. An expanded version, with some modifications in definitions, is available at <www.leanconstruction.org>. It was produced by this author and Iris Tommelein, LCI principal and Associate Professor at the University of California at Berkeley.

assignments are to be accepted or made. Example: On my work plan for next week, I have included providing Cheryl the soils data she needs to evaluate alternative substructure systems for the building. All known constraints have been removed from my task, I understand what's required and how the information will be used, and I have reserved needed labor and equipment.

constraints something that stands in the way of a task being executable or sound. Typical constraints on design tasks are inputs from others, clarity of criteria for what is to be produced or provided, approvals or releases, and labor or equipment resources. Screening tasks for readiness is assessing the status of their constraints. Removing constraints is making a task ready to be assigned.

control to cause events to conform to plan, or to initiate replanning 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 replanning. Learning is initiated through analysis of reasons for failing to cause events to conform to plan.

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.

design Design is a type of goal-directed, reductive reasoning. There are always many possible designs. Product design reasons from function to form. Process design reasons from ends to means.

design criteria the characteristics required for acceptance of product or process design. Example: The structural engineer needs both geometric and load inputs from the architect, mechanical engineer, and electrical engineer. Loads need only be accurate within 20%. Example: The cladding design must be consistent with the architectural standards of the local historical society. In addition, it must be within the 2 million pound budget and installable within a 6 week window concluding no later than 6th April, 2000.

exploding expressing a task in greater detail, typically by producing a flow diagram of the process of which the output is the task being exploded, then determining the sub-tasks needed to make the task ready for assignment and execution when scheduled. Sub-tasks are categorized in terms of the activity definition model, resulting in actions to clarify or specify criteria, requests for inputs from suppliers, and reservation of needed resources.

first run studies extensive planning of upcoming operations by a cross functional team including representatives of those who are to do the first operation, followed by methodical study, redesign of the operation, and retrial until a standard is established to meet or beat for execution of that operation. First run studies follow the Shewhart Plan-Do-Check-Act cycle, made popular by W. Edwards Deming.

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.

load the amount of output expected from a production unit or individual worker within a given time. Within a weekly work plan, what is to be accomplished by a design squad or individual designer, engineer, draftsperson, etc. A quality assignment 'loads' a resource within its capacity.

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.

lookahead schedule the output of lookahead planning, resulting from exploding master schedule activities by means of the activity definition model, screening the resultant tasks before allowing entry into the lookahead window or advancement within the window, and execution of actions needed to make tasks ready for assignment when scheduled. Lookahead schedules may be presented in list form or bar charts.

lookahead window how far ahead of scheduled start activities in the master schedule are subjected to explosion, screening, or make ready. Typically design processes have lookahead windows extending from 3 to 12 weeks into the future.

make ready take actions needed to remove constraints from assignments to make them sound.

planning defining criteria for success and producing strategies for achieving objectives.

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.

PPC percent plan complete; i.e., the number of planned completions divided into the number of actual completions.

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.

production unit(PU) a group of direct production workers that do or share responsibility for similar work, drawing on the same skills and techniques. Example: a team of electrical designers and engineers responsible for a specific area or functions of a building.

productivity the ratio of the amount of work produced to the resources used in its production. Example: x drawings per labour hour.

PU See *production unit.*

pulling initiating the delivery of materials or information based on the readiness of the process into which they will enter for conversion into outputs. Example: Request delivery of prerequisite information at or before the time you will be ready to process that information. Note: what's different here is that the readiness of the process is known rather than wished. Either the process is ready prior to requesting delivery or plan reliability is sufficiently high that work plans can be used to predict readiness.

*reasons…*for failing to complete weekly assignments; e.g., lack of prerequisites, insufficient time, unclear requirements. Reasons can also be sought for failing to advance scheduled tasks from master schedule to lookahead schedule or from one week to the next within the lookahead schedule.

resources labour or instruments of labour. Resources have production capacities as well as costs. Consequently, materials and information are not resources, but rather what resources act on or process.

screening determining the status of tasks in the lookahead window relative to their constraints, and choosing to advance or retard tasks based on their constraint status and the probability of removing constraints.

*shielding..*production units from uncertainty and variation by making only quality assignments.

should-can-will-did to be effective, production management systems must tell us what we *should* do and what we *can* do, so that we can decide what we *will* do, then compare with what we *did* to improve our planning.

sizing…...assignments to the capacity of the production unit to do the work. Example: Ruben and James should be able to collect that data and analyze it by Thursday. But, I forgot, it's Ruben and Tim. Tim's not as experienced. I'd better give them an extra day.

sound assignments that have had all constraints possible removed. Example: We never make assignments that are not sound. We always check if we have or can get necessary information from others, if the requirements are clear, etc.

supplier the provider of needed inputs; prerequisite work, materials, information, resources, directives, etc.

supplier lead time the time from sending a request for delivery to the delivery.

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 labour utilization last week was only 40%.

weekly work plan a list of assignments to be completed within the specified week; typically produced as near as possible to the beginning of the week.

window of reliability how far in advance future work completions can be accurately forecast. Example: If you can accurately forecast only 1 day in advance when work will be completed, then your window of reliability is 1 day.

workable backlog assignments that have met all quality criteria, except that some must yet satisfy the sequence criterion by prior execution of prerequisite work already scheduled. Other backlog assignments may be performed within a range of time without interfering with other tasks. Example: Completing those spare parts lists doesn't have to be completed for 3 months, but it won't harm anything if they are produced earlier, so use them as fallback or fill-in work when needed.

work flow the movement of information and materials through a network of production units, each of which processes them before releasing to those downstream.

work flow control causing information or materials to move through a network of production units in a desired sequence and rate.

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APPENDIX A: NEXT STAGE PRODUCTION TEAM KICKOFF MEETING

MTG NOTES: MAPPING SESSION, 4/98

-how do they establish need dates and estimate durations?
-how decide who should be involved in what discussions?
-Case: seat selection

(floor-mounted or riser-mounted) is interdependent with (structural pads for seats), which in turn constrains the (return air plenum), which can go either (through the floor or risers), which has an impact on (cleaning time and cost: how quickly can they setup for the next show?). As it happens, chairs come with different types of upholstery, which can change the amount and type of smoke to be removed. Points: -components such as chairs may not be offered in all varieties; e.g., although we might prefer a riser-mounted chair, such chairs only come with a certain type of upholstery that would overload current plans for smoke removal. –everything's connected to everything/designing one whole, so parts have the logic of part to whole, potentially conflicting properties, etc.
-Important to include directives in conversion maps?
-Discovered in an earlier mapping session with the structural team that could start structural engineering six weeks later and have steel delivered six weeks earlier than initially estimated. Result of having members of the steel supply chain together in the discussion: structural engineer, fabricator, and erector. Consolidated construction drawings, fabrication drawings, and shop (field erection) drawings into a single set.
-The production team and I are starting after 'schematic design'. What happened then?
-Design production consists of making calculations, producing drawings, sourcing, etc. These provide info. for further decision making, which is the big issue.
-Might use some product development techniques, e.g. functionalities, et al.

NOTES ON NEXT STAGE KICKOFF MTG 5/19-21/98

- Design completed prior to meeting: Size and function of theater (enclosed "amphitheater", 7000 seats-by Auerbach Associates, theater consultants), look and size and most materials of exterior (by ELS Architects, who were selected with theater consultant's help) and type of structure (steel frame)- they could make a model. This approximates conceptual design and perhaps some elements traditionally included in design development.
- Ed Beck assembled some members of the building teams prior to the meeting and mapped their value streams, using block flow diagramming, but switched to MS Project when he merged the maps. Lots of negative reaction to the CPM-too small and detailed, hard to read and follow.

- Teams were mgmt/support, theatrical/interiors, MEP/FP, building enclosure/architectural, and civil/structural. About half the team members had participated in the initial process mapping with Ed.
- One purpose of the meeting was to test the feasibility of completing the project by an 11/15 move-in date and, if feasible, to create a schedule for doing so. The other primary purpose was to create a team willing and able to work together.
- The first half day was devoted to introductions (very effective exercise that got people loosened up and surfaced expectations), clarification of the business objectives of NextStages, and the design history. The second half day was devoted to a brief intro. to the concepts and history of lean thinking and to the airplane game. The second day started with teams reviewing their process maps for completeness, then transitioned after some confusion into subgroups working on problems and a central group creating a milestone-level CPM for the construction phase, working backwards from the 11/15 move-in. The first half of the third day (plus some) was spent first reviewing and refining the inputs requested of each team by others, then by extending the milestone schedule through design to the present. Burning issues were recorded. Teams created more detailed internal schedules that fit within the milestone schedule. Many obstacles were identified and removed in side caucuses-“kill the snake now”.
- Participants seemed to like it. Architects and engineers said they liked getting input from fabricators and installers. Everyone liked getting decisions made on the spot rather than going through multiple loops of submission, review, rejection, rework, submission, etc.

PROBLEMS SOLVED/DECISIONS MADE

- Integrated base frame for ‘suspended’ scaffolding into ceiling grid of House.
- GO on wind test.
- Agreed to decide on audio proposal asap.
- Included cladding attachments in 3D model so can fabricate in shop.
- Agreed to start keeping a design decision log (tho’ inexplicit assignment of responsibility and inexplicit process)
- Decoupled front window and sunscreen.
- Eliminated one roof elevation.
- Substituted PVC membrane for BUR.
- ***????? Need to collect these for the record***

EXPERIMENTAL ELEMENTS

- Selection by qualifications not price
- Shared business and design information
- Open book accounting

- ♦ Group planning
- ♦ Pull planning (backward pass)
- ♦ Cross functional team including owner, architect, engineers, fabricators, and erectors/installers
- ♦ Initial attempt to integrate product and process design (needs to be highlighted and done self-consciously, with prior specification of design criteria for each)
- ♦ Production control extended to design as well as construction (future)
- ♦ Consolidation of drawings: design development, contract documents (construction doc's), and shop drawings. (Joint production of same by engineer, fabricator, and installer?)

WHAT MIGHT HAVE BEEN DONE BETTER

- Mapping with the teams in advance was probably valuable, but would have been more so if all team members were present.
- Timing: Many said this should have been done earlier, but that may have been with reference to the end date rather than to the stage of design development. Should it be done earlier in design development?
- The collaborative process is historically based on the Construction Management/Guaranteed Maximum Price (CM/GMP) approach. Subcontractors and fabricators have not previously been included in the collaboration, which was restricted to the owner, contractor, and architect, with the contractor serving as the owner's watchdog over cost during the design process. Management of the design has not been part of the process. Residue of that approach are still present in NextStages, which seems to have thought of the architect and theater consultant as having the closest relationship to the owner, then engineers, then fabricators and installers. The general contractor still will contract with the subcontractors, who will (typically) deal directly with suppliers and fabricators. Better to have installers be in the first tier around the table, then have them bring in fabricators and engineers? Should the architect be integrated with the enclosure team, since their concern is with shaping space?
- Better to have the teams use the same format for mapping so they could be more visible and more easily integrated into a whole? Better to use workmapping graphic terminology than block flow diagramming?
- Explicit attempt to integrate product and process design, with prior specification of design criteria for each.
- Explicit commitment to joint production of drawings by engineer, fabricator, and installer and sub-group planning of that process.

▪ *WHAT'S DIFFERENT AT ICE HOUSE?*

- Installers in first tier
- Workmapping

- Installers (and fabricators?) involved in schematic/conceptual design
- Explicit identification of criteria for design of product and process
- Different commercial arrangements?

NOTES TO FILE

- Design decision log: there was no record of the design brief or basis for making design and planning decisions. (What's the relationship between production planning and design? They are essentially the same kind of processes, both are design processes, but one is of the product and the other of process for designing or building the product. Ed initially resisted mixing design decision making in with scheduling, but they forced themselves together, which seems quite natural and inevitable given that they are both design processes.)
- Need to create new names for the phases of the design/construction process in order to break the grip of the conventional schematic/design development/contract documents/shop drawings model?
- I strongly suspect that many design decisions are now made with a mind to protecting what the decision maker knows is important, but without understanding what else is important.
- Everyone seemed released by the prospect of working for the good of the job as a whole, but also many said that it was just a matter of having costs reimbursable. So simple if true, but I believe that form needs to be filled with production management content a la lean thinking.
- How measure the impact of consolidating DDs, CDs, and SDs into a single set of drawings?
- How measure the impact of integrated, team design of product and process?
- How measure the impact of production control over the entire design-procure-install process?
- Need a better process for identifying and developing client values.
- Ditto for translating those values into design criteria.
- Need a way to publicize decisions that change the product or process design criteria-transparency.

WHAT TO RESEARCH AND WHAT/HOW TO MEASURE?

The cross functional team approach to integrated design of product and process. Also how values are identified, how they are translated into design criteria, and how those criteria are actually applied in the design process. *Keep documents (maps, schedules, meeting minutes), collect participant evaluations, seek hard measurements of improvement in product design, cost, or delivery time.*

Application of shielding to control of design production. Describe process, collect data (PPC, reasons, actions), collect participant evaluations, seek hard measurements of improvement; eg. productivity, durations, costs.

APPENDIX B: NEXT STAGE PROJECT TELECONFERENCES

Coordination on the Next Stage project was done largely by means of biweekly teleconferences, in which each design team 'met' in succession throughout one long day, with the management team present throughout. The notes below are those of this author made prior to or during the teleconferences of 7/29/98, 8/26/98, 9/9/98, 9/23/98, 10/7/98, and 12/16/98.

PREP FOR 7/29/98 TELECONFERENCE, 7/28/98

-The big issue was lack of pipe inverts (elevations?) at building drainage collection points.
-Should PPC measure at milestone, submilestone, action item level, or all three?
-Are “dates required” actually that or date it's thought the task will be done?
-Consider deferring decisions to accommodate uncertainty.
-How much is driven by permitting and approvals?
-Making assignments at systems team level-action items. Too detailed?
-Opaque what planning is done from which assignments are accepted; e.g., how do specialists know loads and capacities?
-Ditto what planning is done after plan period assignments are accepted; e.g., do teams or specialists create a detailed schedule for the plan period, or incorporate these assignments in their schedule along with others?
-Goal: eliminate plan quality failures. Then absorb execution failures into planning.
-Need to prioritize action items? NB: difficult to size.
-How to identify when one action item depends on another in the same plan period?
-Need to clarify purpose of the teleconference? Is it a planning meeting to identify tasks, or a meeting to status the plan and learn how to plan better?
-Need to make the planning system explicit: levels and corresponding processes.
-What experiments at Next Stage?

  -Pull scheduling; pull as work selection criterion
  -Group scheduling
  -Organization in system teams
  -How to control design?
  -How to plan design?
  -How to achieve concurrency?
  -How to develop a supply chain?
  -How to best use 3D(+) modeling?

-How might Last Planner benefit design?

-If the designer knows what work is upcoming, he/she (or others) can prepare for it: better understand the task, make ready: pull prerequisites, resolve conflicting directives, collect information. Also, design mgmt can better match capacity to load, reducing idle resource time and overproduction. Avoid having too many or too few specific skill sets to do the available work.
-If more assigned tasks are sound (ready), less designer time is spent switching between assignments. Also, assignments can be more often completed when scheduled, better advancing the design project.

TELECONFERENCE, 7/29/98

-See AA07.01.8.03 “Resolve building storm/sanitary site collection points and pipe inverts.” [my comment: need elev. of storm drains and above from ME] This was assigned as a group task to the mechanical engineer, civil engineer, project manager, and the plumber due 7/10 and subsequently rescheduled to 7/28. See also AA07.15.98.09 “Complete site drainage design criteria” [my comment: need pipe inverts at bldg collection points]
-Poor definition of assignment in AA07.15.98.16 “Meet with Lone Star Park to discuss terms and conditions for purchasing their borrow material.” Marked completed, but output unclear.
-NB: importance of really understanding the action: -what’s it mean? –what’s prerequisite? –how long to perform once sound?
-AB07.01.8.08 wasn’t pulled, so due date was deferred to 8.12.98.
-Perhaps an example of lack of definition: AC07.15.98.02 “Resolve insulation requirements for shell of the building.” Failed for lack of info from ME on heat loads. Didn’t ask them specifically although they were included under “Action by”.
-Completion of 3D model impacted by multiple minor changes. Driver is intention to use model to produce fabrication drawings. Loading info. is needed later, but need roughout loads up front. Geometry is needed first—was delayed by changes in seating platforms.
-“value stream had no cushion.” Need to redo value stream to capture that learning?
-Interesting example of the complexity of actions lurking beneath a seemingly simple assignment: AD07.15.98.07 “Coordinate location of proscenium deluge system with other systems.” Questions that arose in discussion: ‘Does the curtain have a membrane that will require wetting both sides? How to control the deluge system? Possibly applicable code requires heat sensors on stage-not yet provided. Code not explicit about sensor locations, etc.’
-IB07.15.98.03 “Schedule for steel fabrication may be too tight.” Concerned about tolerances in design and construction, especially regarding the seating platforms.
-Apparent problem: ‘Committing’ to an action that has predescessors, perhaps in a chain, some of which do not have identified prerequisites. A constraint: difficult to know very far in advance what that logic is because it is developed as each step is taken?

-NB: Important to note when a design criterion is being produced? Also…to track decisions re design criteria?
-Make 'issues' deliberately include next 1-2 plan periods and use to develop definition of the actions needed?
-Are most/many failures from lack of definition? If so, need a make ready period in which….
-Clearly the actual planning/replanning rhythmn is faster than biweekly.
-Biweekly: *Adjust milestone (and submilestone?) schedule *Each team statuses & categorizes the previous plan period. *Each team develops a work plan for the next plan period. *Teams "meet" to merge work plans. *Hold this meeting, then finalize team workplan and coordinate by phone-"Can you…?"

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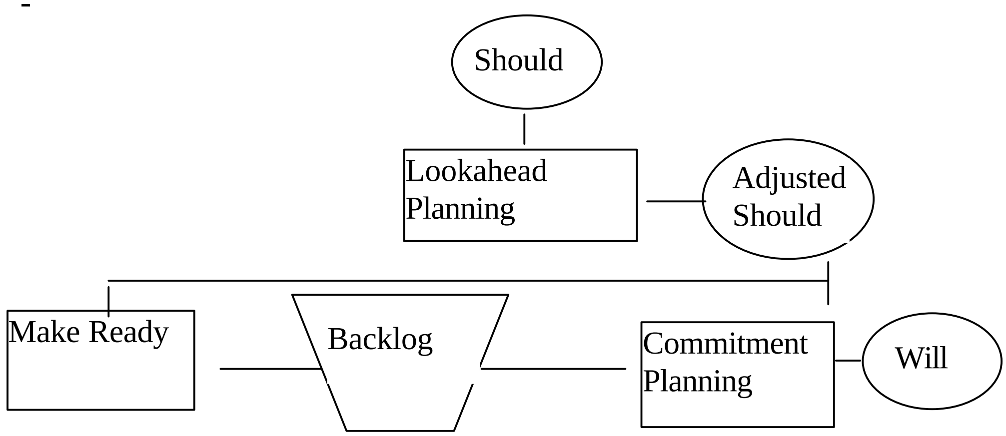


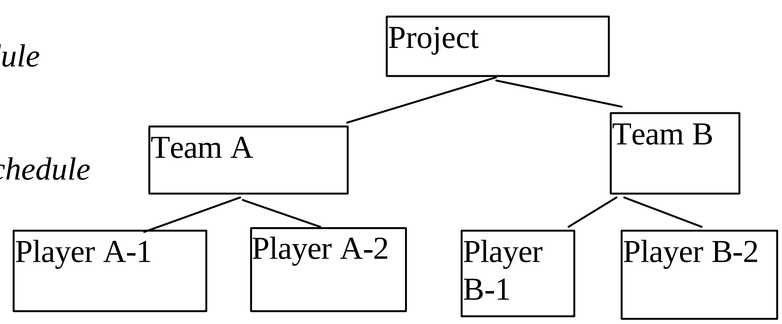
*Does this structure work for design? Are strong commitments possible?
*Design tasks are often closely coupled in time, so lots of 'deliveries' are needed within the plan period.

-What statusing and categorizing can be done by individual players? Is a teleconference the best way to do this?
-Why didn't Jerry ask Gary for the piping inverts?
-

Milestone Schedule

Sub-Milestone Schedule

Work Plan



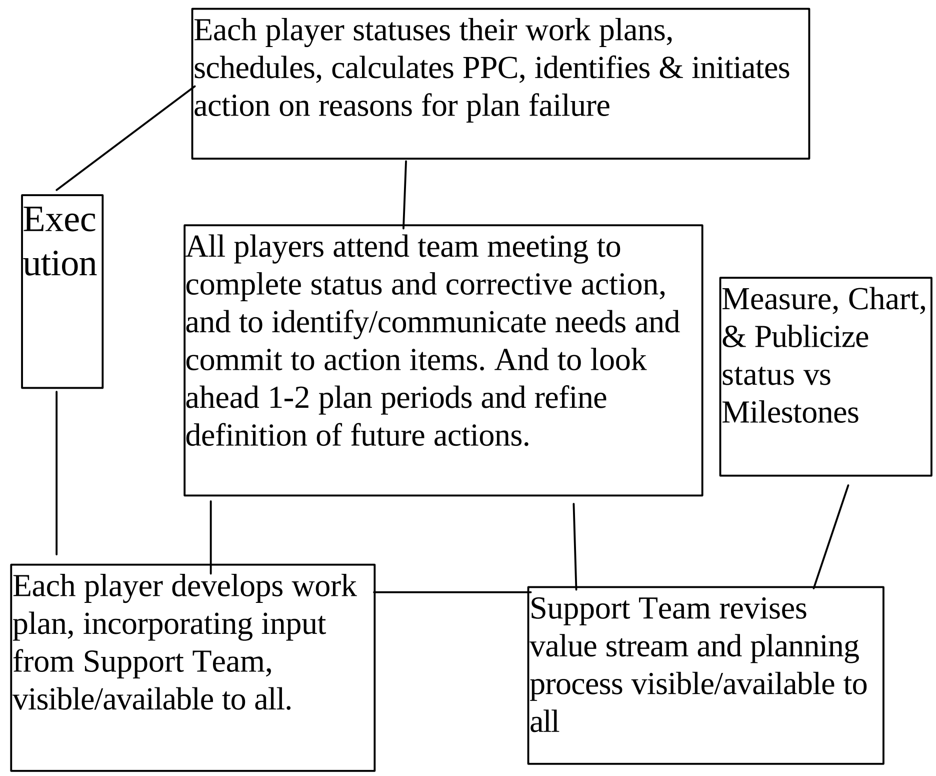
*Each player is responsible for pulling what they need from others?

-Perhaps the key virtue in design is rapid replanning rather than plan reliability.

-A key is understanding each other's needs and the value stream.
-<u>Levels of Schedule</u>

- Milestone Schedule/Value Stream
- Submilestone (work release between teams)-PPC measured
- Work Plans (actions by players within teams)-PPC measured for use by player; reported to project as indicator of reliability.
- Action Item List
- Decision List
- Issues List
- Player schedules

-



-Whoever needs something from someone else is responsible for precisely defining the need and should pull it from them.
-How to confirm pull? Must someone else give you an order or should each player work independently toward the milestones unless he receives an order? Share work plans so others know what you're doing.
-It's really hard to know the design criteria for specific design products.
-Many action items result from needs for input info.-loads (structural, heat, energy, etc.), dimensions, etc. Fits with problem solving model?
-Might help if they had a limited glossary of action types: 1) determine design/decision criteria, 2) understand the design task and process, 3) collect input info., 4) generate alternatives 5) evaluate alternatives, 6) select from alternatives/decide, 7) approve…
[activity definition model].

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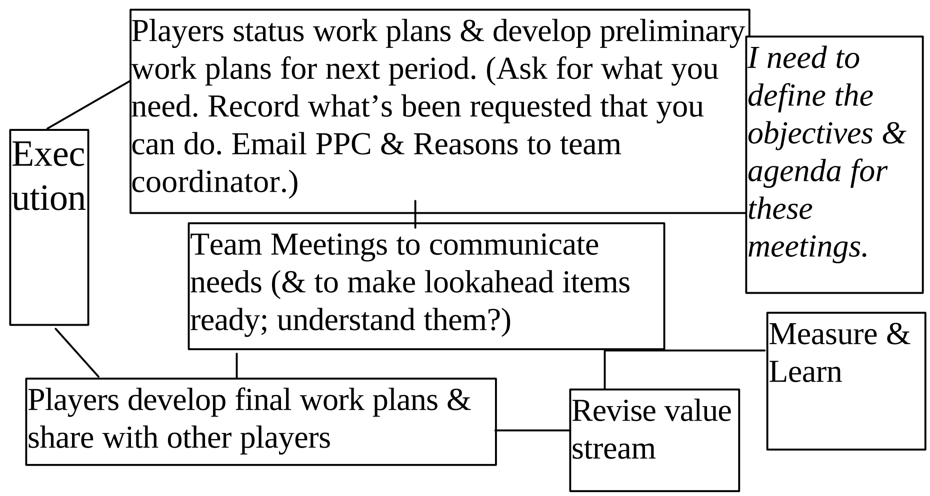

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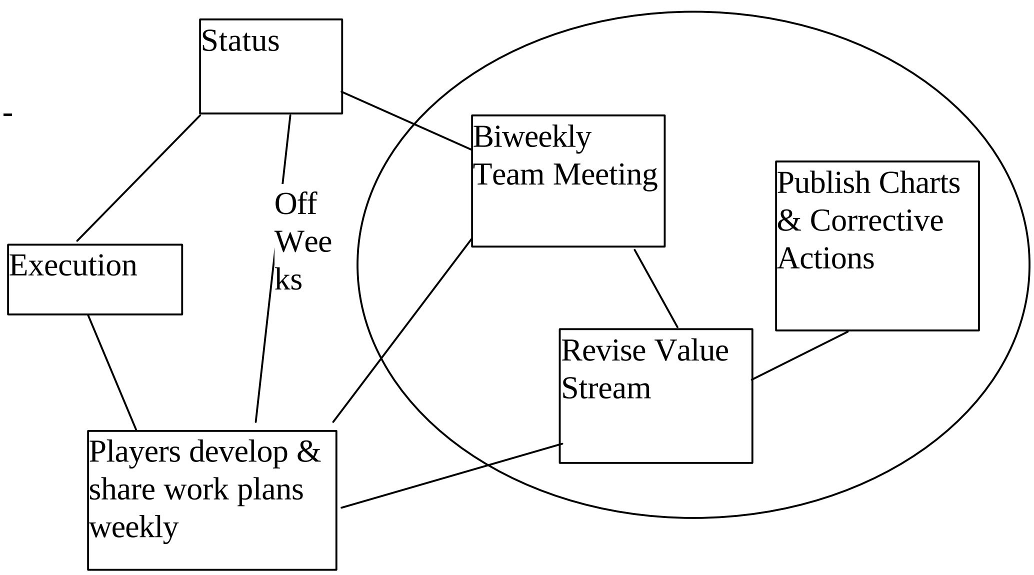


-Still need to decide who does what design (detailing?)-engineering consultants or speciality contractors?
-These don't all look like commitments to me.
-Definition of action items is a problem. Don't fully understand what's being pulled (what's needed), design/decision criteria, prerequisites.
-'Make ready'-applied to design-starts with understanding the design task, process & dependencies, & criteria. Should be done prior to work entering the plan period.
-Are all players developing work plans that include both action items and work needed to support value stream unless modified by pulls? Urge them to track

their own PPC and act on Reasons. Urge them to come to meetings with action items statused & categorized and perhaps with something to share about corrective action.
-Need to update value stream each 2 weeks.
-Make system transparent.

TELECONFERENCE 8/26/98

-AA08.12.98.01 “Revise and submit site drainage…” is a follow-on from the earlier added collection points issue. Civil engineer still waiting on roof drains info from mechanical engineer. AA08.26.98.10 “Second set of overflow drains connect to main system….” Discovered apparent code requirement for a separate downspout for overflow drain until it turns underground; previously misunderstood. Project mgmt believes the city will accept an alternative design if well argued. Some concern expressed that the requirement may have good reason; i.e., redundant protection of roof from overloading and collapse. Learning: important (always?) to understand the basis for the directive. NB: Decision point when ‘negotiating’ directives: ‘fight or flee’.
-Seems like good discipline in action item identification etc.
-When step back and look at the master schedule?
-Example of criteria clarification and importance: AA08.26.98.08 “Contact TAS/Barrier Free Texas to initiate early review and resolve the filing and approval process.” CE discovered that they wanted minimum travel from handicap parking to front entrance, hence a new action item to conform design to this criterion. Previously assumed less stringent requirement.
-Not identifying or analyzing reasons. How to best do so?
-AB08.26.98.04 Computer memory had to be added to run the model. (Str. Eng. hasn’t done 3D model before, or smaller?) Str Eng is producing drawings as they build the model. Need to complete model in order to determine member sizes.
-Need order mill steel 1 month before breaking ground—decision confirmed.
-Would be neat if could easily and quickly see the consequences of choosing week n or week n+1 for completion of an action. If could, then could choose sometimes to expedite, add resources, etc. in order to do earlier, if desirable.
-Example of interdependencies: AC07.15.98.02 “Resolving insulation requirements for shell of the building.” Sound/power ratings of cooling towers will drive amount of insulation or double sheet rock.
-Good example of detailed info needed by one specialist (cladding contractor) from another (architect): AC08.26.8.02 “Clearly identify on the concept drawings the location of each color, and determine quantity of the vertical, horizontal and smooth panels so the cost for custom colors for each type can be assessed.”
-Ongoing saga of the fire protection curtain: AD08.26.98.03 “Follow up on proscenium deluge system meeting….” NB: poor definition—“follow up”. Really a life safety issue that belongs in Theatrical. Opaque curtain is allowed by code but is not customary.

-Waiting on food service consultant added late to team-Creative Industries. Didn't expedite getting equipment layout from them. Supposed pull was from ME, but he didn't realize that.

TELECONFERENCE 9/9/98

-How well do participants think this management process is working? Useful to track PPC and reasons? Any actions taken on reasons? How much time is spent and wasted (respent) re clarity of directives?

-Design output(s)	Criteria	Authority	Advisors	Basis
parking lot layout	provide handicap w/ min travel to bldg entrance	city?	Texas Access	
roof overflow prot. drains systems	separate downspout from overflow drain until it turns underground	city	-	ind.

Pull request	Reason needed	Requestor	Requestee

-Critical to find the 'hard' points of the design space. If cost limit is exceeded, may have to sacrifice functionality, capacity, or 'quality'.
-Must be discouraging that construction keeps slipping. How to use the added time? When/how to stop?
-NB: Different issues and tools may be useful for different disciplines. E.g., civil seems to depend heavily on permitting requirements. Try to list design outputs and applicable requirements, and criteria (must have/nice to have) for each discipline and system team.
-There was a mention that ELS would make their next milestone, indicating some attention is being paid to the milestone schedule.
-A different kind of problem—agree on criteria, but disagree on what satisfies them. Or, designed to one set of criteria, but a specialist designs to a new set (e.g., acoustical insulation). Specialists are advocates for specific criteria!
-How often do we not fully understand the design decision to be made? E.g., select and locate mechanical equipment to suit requirements for loads at least cost, then factor in acoustical criteria and discover a cost of $200K in insulation, wall type, etc.
-Interim assessment of Last Planner?
-Reasons analysis and action-how to?
-Record criteria?…in decisions log?/or activity definition 'explosion'
-redraw design value stream, incorporating learnings
-record pull in action items log so they can expedite and clarify?

-Team tackle increase in acoustical-related costs: architect (visual, space layout), acoustical consultant (calculates mitigation techniques), mechanical engineer (point sources). Acoustical consultant calculates need for 50 foot masonry wall to provide desired acoustical insulation from mechanical equipment noise. Alternative is to select quieter equipment, relocate equipment, or shield equipment locally.
-Issue: Bass Performing Arts Center had a target NB=18, but actual turned out to be=13. How to ensure not overspending?
-NB: teams are driven by specific milestones; e.g., "complete 3D model" now appears to be the guiding star for the structural team. What's driving each team in each phase? Equipment selection must be a big issue for mechanical and electrical. Also equipment locations, which includes ducting, etc.
-Need a schedule for completing the design. Calculate from a supposed 11/15 construction start date?
-Seems like if we better understand the interdependence of decisions, we could better manage the design process.
-NB: highly specialized consultants are expert in: 1) the real requirements; wiggle room-what can be negotiated; alternatives (wind tunnel tests to determine 'actual' wind loads), 2) ways of meeting the real requirements plus desired criteria, 3) sometimes expertise or technological means for calculating or assessing alternatives; e.g., a testing lab. or special software.
-AA08.12.98.01 Continuing saga of site drainage—CE didn't receive info. needed. Apparently no pull. Wasn't needed in plan period. Still don't know if there is an unavoidable code requirement for multiple leaders, but city is confident they can allow us 'what we want'.
-Example of one period action item requiring prerequisites from another scheduled for same period: AA09.09.98.08 and …09. 8 was to get test data on possible borrow material. 9 was to make a rec from 3 alt pavement designs. Why did we think we could do this in the period? May have assumed local material could be used. Obviously expected to get test results sooner than today, when CE actually received them.
-Handicap parking saga: Must reconfigure; put more handicap spots in front of bldg.
-CE didn't complete many action items during the plan period. What hours were spent and what was accomplished?
-Considering change in seating. No change to building structure expected. How big a deal? Decided to defer 3D model transfer until a decision on seating is made.
-Metal color samples saga: AC08.26.98.01. Manufacturer waiting on receipt of third of three color samples from paint company.
-Confusion re criteria: AD09.09.98.07. EE thought theatrical didn't want transformer in dimmer room, but actually didn't want it in amplifier room. Even so, unclear what transformer location is best.
-Deluge curtain saga: Determined applicable code—NFPA (Nat'l. Fire Protection Ass'n.) 13.
-Rough categorization of decisions in Decision Log: design itself, problem definition, process, needs definition.

-No review of PPC or reasons within the meeting.

TELECONFERENCE 9/23/98

-What can be done to improve sequencing, make ready (soundness), and sizing?

-Revisit the design value stream to make sure we understand the best sequence.

-Explode master schedule activities as they enter the lookahead window. Use activity definition model to make sure we understand the scope of activities.

-Identify who/what is pulling each assignment in the lookahead.

-Have pullers pull.

-Issue minutes by Friday after Wednesday meetings.

-Have assignees apply assignment quality criteria; empower them to say 'no'.

-Learn how long tasks actually take and adjust future estimates. Also, be con- servative.

-Understand the consequences of failing to complete assignments, so can take better risks.

-Be more precise in the statement of assignments. Avoid "review", "follow up", etc.

-Analyze reasons to actionable causes. Use 5 Whys.

-I'm uncomfortable with the idea that these meetings produce assignments. Often need additional definition before can apply quality criteria. Why not allow changes negotiated between 'suppliers' and 'customers', with notice to all? In other words, make planning continuous rather than periodic?

-Clear need to issue 'minutes' immediately after each meeting. Players not using action item log.

-Decided to 'target' completion of wall/acoustic design (AB09.09.98.0?) although not sure will complete. Should understand implications of failure.

-Dangerous to complete design without knowing the users of the facility?

-It's not bad to do more than what's on the action item log. It is bad to not do what's on the log. E.g., the architect chose to spend available time to complete glass and stair design package, and let slip detailing external wall mockup. Could have tagged latter as a workable backlog item.

-Communication 'preferences': some people are not comfortable with multiple channels: phone, email, fax, etc.

-Not being colocated is a problem. Personal connections, ease of communication, getting the right people together, lack of unplanned meetings (water cooler, corridor).

-Is there a list of equipment with vendor, price, weight, energy requirements, heat generated, etc?

-Is/Should there be a statement of design criteria for each system, subsystem, component? Is the Decisions Log sufficient? Per architects, some theatrical consultants produce room documents/books.

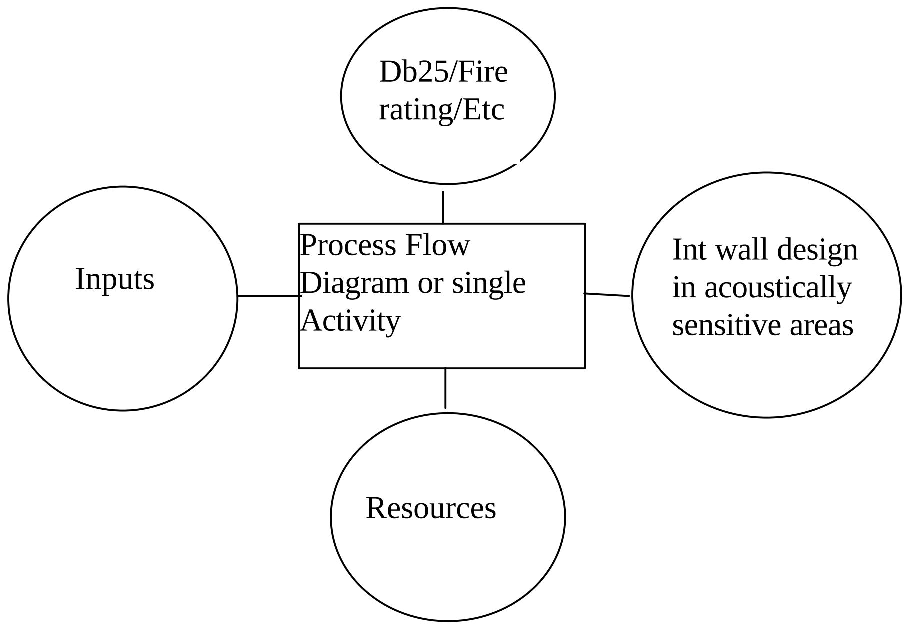
-My actions:

-Analyze reasons with architect.

-Understand how individual planning systems hinge to centralized planning system. When/how do players match load to capacity? Do they check that match before accepting assignments? Each player has work to do that does not appear on the master schedule and may not be pulled externally.

-Identify action items that involve clarifying or generating design criteria.

-Develop examples of activity definition models



-Could do for seat layout, cladding, roofing, etc.

-First screen in evaluating/generating alternative designs is—does it meet design criteria? 2nd concern: is one preferable in re nonbinding criteria such as constructability, ease of acquiring materials, cost, time, etc?

-Need a category "Not pulled"?

-Pull what you need: 'customer' processes not consistently expediting what they need from 'suppliers'.

-Collectively define the task up front; who leads?

-Item No. Item Desc. Action by Pulled by Revised Date Date Completed Need This Plan Period?

-I would like to see how each player identifies and tracks their work and how they use the planning system. Are players able to make good commitments; balance load and capacity?---One weakness appears to be lack of common understanding of action items at close of meetings.

-Type as we go and email instant for review of wording.

-Design work can reveal more definition of a design activity. E.g., handicap parking: developed a layout before fully understanding the design criteria.

Investigation revealed that change to conform to actual criteria may require more fill material.
-Discussion: Civil has had high PPC. Because of external deadlines? Is there an issue of commitment? On the contrary view, I suggest we find out:

-Are those accepting action items applying quality criteria?

-Are players able to accurately match load and capacity?

-Are players able to accurately predict 'deliveries'? Do they expedite deliveries?

-Are players able to sequence activities to best meet project objectives?

-Analysis of reasons: 89/125 (71%)=40 (prerequisites)+24(insufficient time)+25(conflicting demands). Regarding prerequisites, we're apparently not very good at predicting or causing delivery of needed inputs. Regarding insufficient time, we apparently are not very good at estimating the time needed to accomplish specific tasks. Regarding conflicting demands, may need clarification. Does this mean unexpected demands or failure to accurately quantify multiple demands? If the former, there's a problem with identifying priorities even 2 weeks ahead of time. If the latter, same problem as with insufficient time. (NB: some "prerequisite"-based failures are ripple effects; failure of prerequisites within same plan period.)

1.Sequence: identify priorities 2 weeks ahead-demands on time and relative priority of demands. Do we understand the design process? Can we identify what needs to be done in what order? Do we understand what's involved in doing each of these activities?
2.Soundness: predict deliveries; expedite deliveries
3.Size: quantify time needed to accomplish tasks

TELECONFERENCE 10/7/98

-Blueline/Online coming up. Will post minutes thereon this time.
-Added administrative assistant to speed production of minutes.
-Target start date now 12/1/98, but February is most likely.

Civil

-CE confused re pull for first item. Thought it wasn't pulled, but is given target date. In any case, still lacks storm drain info.
-Easement requested. Added to final plat. Includes electrical yard. CE will copy Fisk Elec and Texas Utilities. Curt asks if it goes through landscaping-obviously the architect has not been involved-requested copy. Still need Texas Utilities acceptance of our elec yard layout. –Have agreement to tie overflow drains into ceiling verticals. Making proposal to city.
-For action item 05 we need the mechanical engineer. Civil has to conform his plans for additional drains. (This issue just refuses to die!)
-Grand Prairie school district has 30,000 CY of fill material about 4 miles from our site. Sandy clay. Pi of 21 & 25. Suitable for cement stabilization. Asking for proposals. Est. cost of handling $5/CY. Est. cost of material $1? Our budget is $5 total for select material. This is not select material. Would be $1 over budget.

May be able to mix with cheaper material from other sources. Not ready to select pavement design.[NB: Estimates become controls; e.g., $5/CY for select material.]
-(11) General Electric Service scope of work—need Fisk Electric.
-55 foot light pole is agreed.
-(4) Revised handicapped parking plan and posted 9/25.
[Is an issue showing interdependence of action items?]
-Issues:

-Life Safety pkg.: ELS has issued a draft and is collecting comments. Asked to receive by 9th. Life Safety consultant back next week. Target issue date is the 16th.
-Timmel to ask TU what they propose to give us.
-Lone Star borrow material not yet pulled.
-Lone Star easement—Halff has sent note requesting.
-No new issues from review of site value stream.
-Statusing site value stream

-Erosion control plan filed? Yes.
-Final plat complete? Yes. Sent to Kaminsky's attorney for review.
-Grading permit. Not applied, but should be automatic when needed.
-Down to closing on land and filing for permits.
-Land trade with District-need to happen 10/14.

-4 Week Moving Average PPC=61%. How to improve?

Proposed to analyze in depth a sample of failures from each team, selecting only from top 3 reasons. Could a team representative perform 5 Whys on 3 failures of each of the 3 types and report to Ballard?

-Seating configuration: curve schema GO pending cost estimate by Bruce Perry. Bruce: No difference in cost for stud framing (Merrick Brothers) between segmented and curved. Estimate: $10k for layout. NB: Bruce careful to state his assumptions re the design./Need return air openings—to be worked out. Better to form in concrete or steel?/ELS will detail each type of riser mount heights—3 types./Acoustical issues? ELS thinks not, but will check with consultant./Decision: Change platform design. Agree will cost <$200K. 5 weeks to price in detail. Need to work out framing requirements. Merrick says 8 feet. HW says 20 feet. Same type framing? [Watch this one. How well did we identify the ripple effect of this design change?]

Structural:

-Riser issue: height of riser, material, attachment method; Merrick, Haynes-Whaley, Irwin, ELS.
-3D model on hold for revisions to seating platform. Need to complete before final estimate.
-NB: Robert is clearly pulling duration estimates from his nether region. Often requests for info. have the flavor of demands for commitment—or just plain wishful thinking.]

-Prefab stairs. Can use for fire stairs but lobby stairs must be detailed by structural engineer.
-Structural and foundation permit date will be pushed back by 2 weeks to 11/24. [Need to do more process mapping! Harder to do at a distance.]
-Update from Haynes-Whaley, Str. Eng: Good meeting with ELS last week. Finalizing fly tower. Need input from Jaffe re concrete pads for mechanical eqpt. on low roof. Offline discussions to be held on interior wall design. Steve of CC wants Peterson to install tall house wall-discuss with HW. Peterson to install all purlins.
-[NB: The traditional method seems to be for each discipline to push forward independently, then adjust as as inputs are acquired from others. To what extent do they proceed on assumptions or pull/wait for what they need?]

Skin:

-NB: Joel asks each team/person if they need anything they don't have.
-Metal samples and price are in hand. Price not an issue.
-Wall mockup pkg. from ELS: each c. 10'x20' high; to show 3 conditions; e.g., vertical panels and soffits. Locate offsite on adjacent property-Kaminsky's. Also applies to construction trailers? Can defer grading until last minute? Cost: ELS to provide simplified drawings. [Why not do a computer model?]
-Need some concrete under rooftop units on low roofs, but no masonry wall. Not sure re no. of layers of gyp. board in stud wall. Only possible exception is unit serving dressing room. [Why has this been so hard/taken so long to resolve?]
-ELS to give CC the change point from X to Y at back of house.
-Material for low canopy roof will be visible from lobby. Need different material?

MEPF:

-How many items of kitchen eqpt. do we now have? No. of supply and exhaust fans have increased from 6 to 24. Why? Amy couldn't say. To handle offline.
-Impact of smoking area on exhaust.
-8400 feet of 2 inch slots in seat framing.
-Biggest issue to resolve is concessions.
-Acoustic shielding of mechanical units: when deal with duct noise? When will duct layout be done? 10/12: main duct runs laid out and sized.
[Collecting status info., clarifying current state of design: "Are there any mechanical units on the other side of the building?"]
-NB: NC25 not maximum in lobbies and cheap seats.
-Fire pump: What available water pressure? Need a pump? Yes-125hp. Should be served off emergency generator? Fisk to examine.
-Locations/sources of cable, telephone, etc? Need to meet with phone co.
-How many phone outlets will be required? No. of incoming lines? Need to show on floor plan-phone, data, closed circuit TV. Bill Cambra.
-[Civil engineer seems to handle all ins and outs from property.]
-Requirements for cable TV? Comes into telephone data room. Satellite dish on site? On roof backstage?

-Before addition of loading dock, first floor plans showed gas meter location which now doesn't work. Where is gas meter now? Where to bring gas to?
-U.G. plumbing at perimeter: lower priority-work to 5 week schedule. [The issue seems to be what's needed in order to design the underground plumbing.]
-Duct designer needs seat redesign backgrounds. Need to evaluate but add 2 weeks for design change (10/26).
-Lighting heat loads complete. Emergency power loads need to be updated-now 230 hp, but kitchen eqpt not settled. Also normal loads.
-Mtg on structural issues at ELS last week got chunks of work done. [colocation issue!]
-[watch for interdependencies/gnarly issues: kitchen, seating, acoustics]

Pricing:

-Cost of project has clearly risen, but need definitive estimate. Becoming <u>the</u> hot item.
-Estimating is based on drawing takeoffs. Want reproducibles.
-Electronic transfer hasn't worked. Don't transmit error free.

TELECONFERENCE 12/16/98

-Current categorization of reasons does not reveal actionable causes.
-Has pricing diverted attention from scheduling?
-Why is the estimate so important? Amount of $ needed; financing. Fix GMPs for each player.
-Don't always understand the decision chain; e.g., color selections would seem to be needed late, but may be needed earlier to match exterior and interior colors.
-ELS considering board vs stone wall to lower cost. But not much such matl. Would violate City's architectural review? Considering using inside to replace something else. May be more labor than stone. NB: Functionalities are revealed by technology and component selections. E.g. need 10 by 10 area for scissor lift to be used to relamp lights in high lobby ceiling. Could have chosen lights that could be lowered for relamping.
-The longer the plan period, the more difficult it is to defer commitments until receipt of prerequisites, rather than betting on the come. The shorter the plan period, the less lead time is available for planning future periods.
-Missing water and electricity in parking lot.
-Overflow drain issue: now 2 separate systems <u>are</u> required (issue that won't die!).
-NB: local differences—CHPA didn't know gas meter size beforehand.
-scheduled new item: begin fire protection drawings by 1/15. 6-8 week design period. Need for permit. Focus on distribution system rather than sprinklers.

APPENDIX C: NEXT STAGE ACTION ITEMS LOG

The following log was the primary coordinating device used on the Next Stage project. Each teleconference was given a sequence number, beginning with AA07.01.98, indicating the design team (AA indicated Site/Civil, BB indicated Structural, etc.) date of the teleconference. Action items that were identified within each teleconference were given a sequence number such as AA07.01.98.01. Assignment of action items was made to the various companies participating on the project by use of their initials, e.g., ELS stood for the architectural firm. The date required was specified. If an action item failed to be completed by the required date, a reason number was (usually) indicated in the column labeled RNC, and a new required date listed in the column Date Required. Once completed, a date completed was provided and the rows devoted to the action item were darkened.

1. Lack of decision
2. Lack of prerequisites
3. Lack of resources
4. Priority change
5. Insufficient time
6. Late start
7. Conflicting demands
8. Acts of God or the Devil
9. Project changes
10. Other

Action items are grouped by design team, sequenced in the order Site/Civil (AA), Structural (AB), Enclosure/Architectural (AC), Mechanical/Electrical/Plumbing/Fire Protection (AD), Theatrical/Interiors (AE), and Project Support (AF).

Linbeck Next Stage Development

The Texas Showplace

Action Items Log

As of December 2, 1998 Project Progress Meeting — Revised: 12.14.98

Date Originated-Item No.	*Item Description*	*Action By*	*RNC*	*Date Required*	*Date Completed*
A. Site/Civil					
	Texas Accessibility Standards:				
AA07.01.98.01	• Provide TAS requirements to ELS	HA		07.07.98	07.07.98
AA07.01.98.02	• Identify preliminary and final TAS review process.	ELS		07.14.98	07.14.98
AA07.01.98.03	Resolve building storm/sanitary *site collection points* and pipe inverts; still lacking inverts. *Coordinate profiles with water line surrounding building to be deeded to City*.	CHPA/HA/ *LCC/TSPH*	2	07.10.98 07.31.98	08.02.98
AA07.01.98.04	Develop site and parking lighting *compatible with Lone Star Race Park* for site plan submission for Planning and Zoning approval *(Control Road "B")*.	TEE/*FE/ HA*	6	07.14.98 08.12.98	08.12.98
AA07.01.98.05	Provide color rendering for submission for Planning and Zoning review/approval; resolve landscape issues (IA07.01.98.05).	ELS	7	07.14.98 07.27.98	07.27.98
AA07.01.98.06	Transmit Site Plan package (2 sets) to LCC.	HA	7	07.14.98 07.17.98	07.17.98
AA07.01.98.07	Review/Revise value stream diagram.	HA		07.14.98	07.14.98
AA07.01.98.08	Provide/confirm building electrical load for site utility plan.	TEE/HA/ FE	7	07.14.98 07.17.98	07.28.98
AA07.01.98.09	Provide invert elevation for storm water pipe at loading area.	HA		07.14.98	07.14.98
AA07.15.98.01	Provide recommendation for Accessibility Specialist to ELS	HA		07.17.98	07.15.98
AA07.15.98.02	Contact power company for project information.	TEE		07.20.98	07.20.98
AA07.15.98.03	Have traffic impact analysis completed.	HA		07.20.98	07.20.98
AA07.15.98.04	Send copy of traffic plans and traffic impact analysis to Lone Star Park.	HA		07.20.98	07.20.98
AA07.15.98.05	Complete conceptual point grading plan around building.	ELS	6	07.20.98 08.12.98	08.11.98

AA07.15.98.06	Resolve grading at diagonal wall with landscape architect.	ELS	6	07.20.98 08.12.98	08.11.98
AA07.15.98.07	Obtain Accessibility Specialist list from Texas Dept. of Licensing.	ELS		07.22.98	07.22.98
AA07.15.98.08	Select an Accessibility Specialist	HA/ELS		07.28.98	07.28.98
AA07.15.98.09	Complete site drainage design criteria	HA	2	07.24.98 08.12.98	08.12.98
AA07.15.98.10	Complete off-site civil design of City required items of work (IA07.01.98.04). *Submitted comments, not required for City Council, but for Plat Approval (Approved at Planning and Zoning meeting).*	HA		07.24.98 09.09.98	09.09.98
AA07.15.98.11	Complete Road "D" plan to support easement and operating items negotiations with Lone Star Park *(Received conceptual design approval 07.24.98)*.	HA	2	07.24.98 08.12.98	08.12.98
AA07.15.98.12	Resolve and provide presentation materials to City Planning for internal staff review.	HA		07.24.98	07.24.98
AA07.15.98.13	Planning Department internal staff briefing (IA07.01.98.02).	NS/HA		07.27.98	07.27.98
AA07.15.98.14	Confirm city mailings/posting on-site notice announcing zoning revision hearing (IA07.01.98.03).	NS/HA		07.27.98	07.27.98
AA07.15.98.15	Determine amount of project requirement for borrow material.	HA		07.28.98	07.27.98
AA07.15.98.16	Meet with Lone Star Park to discuss terms and conditions for purchasing their borrow material.	NS/LCC		07.28.98	07.27.98
AA07.29.98.01	Resolve date of City Council hearing; coordinate date with Economic Development assistance package hearing/approval.	NS		07.31.98	08.12.98
AA07.29.98.02	Dialog with Lone Star Race Park manager regarding lighting fixtures.	TEE		08.03.98	08.12.98
AA07.29.98.03	File original drawings/graphics for Planning & Zoning meeting (IA0701.98.07).	HA		08.03.98	08.12.98
AA07.29.98.04	Meet with Grand Prairie building officials to determine multiple permit packages and document requirements (IF07.15,98.05).	ELS/HA/NS		08.06.98	08.06.98
AA07.29.98.05	Planning and Zoning hearing/approval (IA07.15.98.01).	NS/HA		08.10.98 08.24.98	08.24.98
AA07.29.98.06	Decision regarding rescheduling 08.18.98 City Council hearing	NS/ELSHA		08.12.98	08.12.98
AA07.29.98.07	Complete water line/easement design around building.	HA		08.12.98	08.12.98
AA07.29.98.08	Resolve construction start date (IA08.26.98.01).	NS		Issues Log	08.26.98
AA07.29.98.09	Resolve electric power supply options, permanent and temporary. *M. Dickman met R. Cox of Texas Utilities (IA08.26.98.02)*	TEE/HA/LCC		Issues Log	08.26.98

AA07.29.98.10	Advance terms and conditions for purchasing borrow material from Lone Star Park (IA07.01.98.09/IA07.15.98.06). *Evaluate material. Pull is the GMP. Est. 50,000 yds select material.*	NS/HA		08.12.98 09.09.98	09.09.98
AA07.29.98.11	Prepare revised Site/Civil estimate.	HA		08.12.98	08.26.98
AA08.12.98.01	Revise and submit site drainage (*added collection points*) for revised commissary roof drainage *(in Pricing Documents)* and *sanitary (not changed) Received commissary plan. Storm drain info to HA by 09.16.98 for completion by 09.23.98 (10.07.98).*	CHPA/HA	272	08.19.98 09.23.98 10.07.98	10.21.98
AA08.12.98.02	Update site estimate.	HA		08.26.98	08.26.98
AA08.12.98.03	Revise and submit site plan to reflect commissary, *and its impact on site - truck entry, loading area, trash containers, etc.*	HA/ELS/CHPA/NS		08.19.98	08.26.98
AA08.12.98.04	Design lighting operation/wiring for Road D (IA08..26.98.03). *Sketch within one month by TEE. Needs current site plan.*	NS/HA/TEE		Issues Log	08.26.98
AA08.12.98.05	Traffic operational plan to be sent to HA.	NS		08.14.98	08.26.98
AA08.12.98.06	Resolve traffic/road design issues with Lone Star Park (IA07.01.98.01).	NS/HA			08.12.98
AA08.12.98.07	Complete right-of-way abandonment (IA07.01.98.10).	NS/HA		08.18.98 09.01.98	08.12.98
AA08.12.98.08	Complete district land trade (IA07.01.98.11).	NS/HA		09.01.98	08.12.98
AA08.12.98.09	Review of documents/Final Plat for improvement dedication to City. (IA07.15.98.04)	NS/HA			08.12.98
AA08.12.98.10	Rethink overflow drain vs. scuppers for roof drainage. (Related item AD08.12.98.01)	ELS/CHPA		08.26.98	08.26.98
AA08.12.98.11	Resolve traffic analysis outstanding items, i.e. access route to new commissary prior to planning and zoning hearing. Prepare related explanatory drawing. *Director of planning confirmed that there was no need to revise & resubmit.*	HA		08.14.98	08.26.98
AA08.12.98.12	Present revised site plan at Planning & Zoning hearing.	NS/HA		08.19.98	08.26.98
AA08.26.98.01	Provide LCC with a full set of documents HA used to prepare estimate.	HA		08.26.98	
AA08.26.98.02	Decision on sign *size and* location metes and bounds to support easement documents.	NS/HA/ELS	1	08.26.98 09.23.98	09.23.98
AA08.26.98.03	Decision on date for City Council meeting/approval, 09.02.98 (IA07.01.98.08).	NS		08.28.98	
AA08.26.98.04	Contact R.Cox,Texas Utilities about coordinating base CAD file.	HA		08.31.98	
AA08.26.98.05	Contact R.Cox, Texas Utilties about service provisions and Texas Utilities participation.	NS		08.31.98	
AA08.26.98.06	Resolve pavement thickness design prior to the City Council hearing.	HA		09.01.98	

AA08.26.98.07	Prepare an exploration plan for borrow material evaluation and comparison.	HA		09.09.98	
AA08.26.98.08	Contact TAS/Barrier Free Texas to initiate early review and resolve the filing and approval process *(BFT completerd early review with comments. Filing can be in 2 or more packages)*.	ELS		09.09.98	
AA08.26.98.09	Cost-Benefit analysis both light poles and various schemes.	HA/TEE		09.09.98	
AA08.26.98.10	Second set of overflow roof drains connect to main system. To be confirmed by Grand Prairie.	ELS/CHPA		09.09.98	
AA08.26.98.11	Texas Utilities acceptance of current configuration of electrical yard (AA09.09.98.11).	FE	2	09.09.98 10.07.98	Combined Below
AA09.09.98.01	TAS Accessibility Specialist review to be complete prior to TAS filing (IA07.15.98.02).	ELS		09.09.98	09.09.98
AA09.09.98.02	Organize TAS submittal documents for internal and external review (IA07.15.98.03).	HA/ELS		09.09.98	09.09.98
AA09.09.98.03	Define Lighting for site, including fixture type and configuration/spacing to match Lone Star Park where feasible (IA08.12.98.01).	HA/ELS/NS/ TEE		09.09.98	09.09.98
AA09.09.98.04	Confirm LCC estimate such that utilizing 55 foot poles (13) for the parking lot lighting, each with 3-1000 watt fixtures, at 300 feet o.c. will result in a net cost savings of $15,000 over 40 foot poles (38) with 1-1000 watt fixture.	FE/LCC		09.23.98	09.23.98
AA09.09.98.05	Determine the most effective design/cost solution to provide overflow roof drainage. (AD10.07.98.01)	CHPA/ELS/ LCC	2	09.23.98 10.07.98	To MEPF
AA09.09.98.06	Discuss the overflow roof drain situation with City of Grand Prairie and attempt to negotiate dual system.	NS		09.23.98	09.23.98
AA09.09.98.07	Revise off-site civil design to delete right turn lane from Beltline Road and add a right turn lane on Lonestar Pkwy where it turns onto Beltline Road, per the City's request.	HA		09.23.98	09.23.98
AA09.09.98.08	Results of testing program to obtain geotech information on borrow material. Drilling to commence 09.10.98.	HA		09.23.98	09.23.98
AA09.09.98.09	Based upon borrow material characteristics, make engineeering determination from 3 alternative pavement designs provided. *High PI of borrow material requires inport of select fill; choose pavement design based on select fill specification.*	HA	2 5 2	09.23.98 10.07.98 10.21.98 11.04.98	11.04.98
AA09.09.98.10	Obtain comparables on fill material for negotiation with LSP.	HA	5	09.23.98 10.23.98	10.21.98

AA09.09.98.11	*Upon Texas Utilities final design, and acceptance of current configuration of electrical yard (AA08.26.98.11)*;resolve the general electric service/scope of work with TU (loop service w/manual transfer switch). *Revised yard layout sent to TU. TU approved.*	FE/TEE	2 2 7 2	09.23.98 10.07.98 10.21.98 11.04.98 12.02.98	12.02.98
AA09.09.98.12	*Upon final design by Texas Utitlities*, determine/coordinate location of easements.	HA	2	09.23.98 10.07.98	10.07.98
AA09.09.98.13	Determine location of handicap parking relative to main entrance doors; determine if side doors will be handicap accessible doors for either egress or ingress.	ELS/HA		09.23.98	09.23.98
AA09.09.98.14	Complete study and adjustment of civil list of cost increases.	HA/NS/LCC		09.23.98	09.23.98
AA09.23.98.01	Approval of assistance package by Grand Prairie City Council.	NS/HA		09.23.98	09.23.98
AA09.23.98.02	Followup overflow drain issues with Sharon Cherry, Building Official, City of Grand Prairie. (AD10.07.98.01)	CHPA		10.07.98	To MEPF
AA09.23.98.03	Confirm depths of 55 foot light pole bases and added cost to finalize decision to use over 38 foot poles.	TEE		10.07.98	10.07.98
AA09.23.98.04	Relocate handicap parking and revise related site grading.	HA		10.07.98	09.25.98
AA10.07.98.01	Prepare documents/Life Safety Issues for initial TAS review submission (IA07.29.98.02).	ELS		10.07.98	10.07.98
AA10.07.98.02	For city requested right hand turn lane from Beltline Road to Lone Star Parkway, send sketch/metes & bounds to City Comptroller/Sports Facilities Development Corp., A. Cammerata, to make aware of need.	HA		10.07.98	10.07.98
AA10.07.98.03	Review and comment on draft Life Safety document prior to initial TAS review submission.	NS		10.09.98	10.21.98
AA10.07.98.04	Send sketch to Texas Utilities for new location of on-site pad mouinted equipment *(switchgear location, pad sizes)*.	TEE/FE		10.14.98	To MEPF 10.21.98
AA10.07.98.05	Complete revised floor plan background upon which to revise underground/underslab utilities/structure.	ELS		10.16.98	10.21.98
AA10.21.98.01	Follow up borrow material availability and cost from Grand Prairie ISD. Should be less than $1/CY (IA10.07.98.01).	NS/HA		10.21.98	10.21.98
AA10.21.98.02	Complete paving estimate.	HA		10.23.98	11.04.98
AA10.21.98.03	Resolve requirements of joint use of single utility trench. *Info sent to TEE.*	FE	5	11.04.98 12.02.98	12.02.98
AA10.21.98.04	Request for Letter from Texas Utilities memorializing service and their agreed upon responsibilities.	NS	7 7	11.04.98 12.16.98	12.02.98

AA10.21.98.05	Sketch of transformer enclosure louvers to Texas Utilities. *No longer necessary due to approval of AA09.09.98.11.*	ELS	7	11.04.98 12.02.98	12.02.98
AA10.21.98.06	Decide location of Gas Meter. *Location decided by CHPA plan; not yet approved by TU*	HA/TEE/ ELS	5	11.04.98 12.04.98	12.02.98
AA10.21.98.07	*Closing occurred 11.02.98*; Final Plat *utility signatures to be obtained* and recorded. *Half completed.*	HA	2 5	11.04.98 12.16.98	12.02.98
AA11.04.98.01	Complete City land trade; complete land transfer with City Comptroller/Sports Facilities Development Corp (IA10.21.98.02).	NS/HA		11.04.98	11.04.98
AA11.04.98.01	Negotiate with Kaminsky,LSRP (and, later, GPISD), to purchase common fill borrow material, 30,000 cuyd at $0.75/cuyd in place (IA09.09.98.01); look for sand in Kaminsky material.	NS/HA	7	12.02.98	12.16.98
AA12.02.98.01	Texas Utilities approval of gas meter location.	HA		12.16.98	
AA12.02.98.02	Revise site sanitary and storm connection points to accomodate changes in the mechanical/plumbing plan ($10,000 est.added cost); alternatively, run lines internal to the building.	HA/CHPA		12.16.98	
AA12.02.98.03	Resolve proposed program changes to add special events power and water to parking lot.	NS/ELS/CH PA/HA		12.16.98	
AA12.02.98.04	Decide early construction program.	NS/ELS/HA		12.16.98	
AA12.02.98.05	Decide contracting format for sitework (Gen Cond, Supplmntl, Conditions of Contract) (IA11.04.98.01).	NS/HA/LCC		12.16.98	
AA12.02.98.06	Send copy of Engineering Joint Council documents.	HA		12.16.98	
AA12.02.98.07	Revise grade change at side of commisary.	HA		12.16.98	
AA12.02.98.08	Landscape not yet released by NS; use HA budget for pricing.	HA		12.16.98	
<u>B. Structural</u>					
AB09.09.98.01	Complete 3-D model with member sizes and down load to SPI (IB08.26.98.01). Compete with column sizes; correct download errors..	HW	5	09.23.98 10.02.98	09.23.98
AB07.01.98.01	• Provide/fax structural tables for beam sizes/spacing to ELS.	HW		07.02.98	07.02.98
AB07.01.98.02	Resolve balcony *structural design* and sight lines; *requires seating envelope/platform to be resolved.*	ELS/HW	1	07.28.98 08.12.98	08.12.98
AB07.01.98.03	Revised *low* roof slopes required by HW for structural design.	ELS		07.28.98	07.28.98
AB07.01.98.04	Provide elevator shaft dimensions and	ELS		07.07.98	07.13.98

	structural loads to HW.				
AB07.01.98.05	Provide preliminary chase locations and sizes to HW.	ELS/CHPA	7	07.07.98 08.12.98	08.12.98
AB07.01.98.06	Resolve roof loading from hung structural platform, scaffolding live load, and acoustical panels.	ELS/HW/JHSA	7	07.07.98 *07.28.98*	07.28.98
AB07.01.98.07	Resolve seating platform design, elevations, and structural load; *geometry, sight lines refinement based upon revised seat.*	ELS/HW	2	07.07.98 08.05.98	08.12.98
AB07.01.98.08	Provide/confirm *location* and structural loads *(confirm)* of electrical equipment to HW *(greater than 500 lbs).*	TEE	7	07.14.98 08.12.98	08.12.98
AB07.01.98.09	Provide location and structural loads for theatrical rigging system to HW. *Also, point loads for proscenium reduction system. Geometry of loading is critical. Set for 3-D model.*	TS/*AA*		07.14.98 08.26.98	08.26.98
AB07.01.98.10	Provide/confirm location and structural loads of speakers/audio equipment to HW.	JHSA		07.14.98	07.29.98
AB07.01.98.11	Provide/confirm location, electrical load, and structural loads of lighting *projectors at* balcony to HW/TEE.	AA		07.14.98	07.29.98
AB07.01.98.12	Provide/confirm location and structural loads of audience/house and proscenium reduction systems to HW.	AA		07.14.98	07.29.98
AB07.01.98.13	Confirm receipt of CHPA drawings indicating duct and pipe locations and loads, including proscenium deluge system.	HW		07.14.98	07.29.98
AB07.01.98.14	Provide final results of wind tunnel test.	ELS/HW	5	07.14.98 08.12.98	08.12.98
AB07.15.98.01	Resolve alternative balcony beam sizes and spacing options; integrate with the 3D model.	HW/ELS	5	07.24.98	07.29.98
AB07.15.98.02	Resolve design wind forces/pressures on the building.	HW	5	07.24.98 08.12.98	08.12.98
AB07.15.98.03	Prepare 90 day structural steel commitment and expenditure schedule, include options for millrun steel and warehouse steel.	HSC	3	07.28.98 08.26.98	08.26.98
AB07.29.98.01	Resolve concessionaire reprogramming effect on back of house low roof. *ELS package rec'd last week, based on Scheme 'A'.*	NS/ELS/VS		08.05.98 08.26.98	08.26.98
AB07.29.98.02	Determine effect of delaying 3D model to 09.16.98 on project schedule, *i.e. fabrication/detailing.*	HW/HSC/LCC		08.12.98 08.26.98	08.26.98
AB07.29.98.03	Decision required to maintain construction start date and approve structural steel order for mill run steel and fab shop commitment without 3D Model(IB07.15.98.02).	NS		08.12.98	08.12.98
AB07.29.98.04	Complete new background drawings for back of house.	ELS		08.12.98 08.26.98	08.26.98
AB07.29.98.05	Provide all input to HW for structural detail of	ELS		08.12.98	08.12.98

	platform levels.				
AB08.12.98.01	Review schedule of four weeks for steel fabrication. (IB07.15.98.03) (AD08.12.98.05)	ELS		ASAP	08.12.98
AB08.12.98.02	Offline conference regarding utilizing 'Total Station' to do computerized field layout.	NS/LCC/ELS/ HW		08.26.98	08.26.98
AB08.26.98.01	Provide HW structural loads for box boom alternate locations.	JHSA/AA /ELS	2	09.01.98 09.23.98	09.23.98
AB08.26.98.02	Verify that box boom alternate locations hit 4000# support points.	JHSA/AA /ELS/ HW	2	09.01.98 09.23.98	09.23.98
AB08.26.98.03	Confirm assumptions for proscenium loads. *Provide sliding panel information. Major loads resolved and will be faxed.*	AA/ELS/ HW	2	09.04.98 09.23.98	09.23.98
AB08.26.98.04	Provide preliminary review of 3-D model to HSC/SPI/PB for review of connections and heavy steel members(IB07.01.98.01).	HW		09.04.98	09.09.98
AB08.26.98.05	Review value stream based on mill order steel *to determine order lead time*.	HSC/LCC		09.04.98	09.09.98
AB08.26.98.06	Coordination meeting *upon completion of 3D model* to finalize effect of stage and grid on structure. *(IB08.26.98.02)*	JHSA/AA/ELS/ HW/LCC		Issues Log	09.09.98
AB08.26.98.07	Define/*rev*iew the structural detailing in a coordination meeting to develop the sequence/schedule to serve the shop drawing/fabrication schedule.	HW/HSC/SPI/ PB/LCC		09.09.98	09.09.98
AB09.09.98.01	Complete 3-D model with member sizes and down load to SPI (IB08.26.98.01). Compete with column sizes; correct download errors.	HW	5	09.23.98 10.02.98	09.23.98
AB09.09.98.02	Meeting @ HW on Monday 9/14/98 @ 1:30 p.m. to determine detailing input sequence needed by HW & SPI to accommodate fabrication schedule shown in 21 month value stream.	HW/HSC/SPI/ LCC/PB		09.14.98	09.23.98
AB09.09.98.03	Finalize wall design/acoustics for F.O.H. mechanical rooms. *CHPA to confirm AHUs/configuration to mitigate wall acoustics; also, alternative wall designs.*	JHSA/ELS/ CHPA	2	09.23.98 10.07.98	10.07.98
AB09.09.98.04	Review HW 3D model data transmission for system compatibility.	HS/SPI		09.23.98	09.23.98
AB09.23.98.01	Schedule work session upon completion of 3D model with structural and theatrical consultants to address issues and detailing of stage house and auditorium roof. *Coordination meetings set for 09.29.98 and 09.30.98. (Formerly AB08.26.98.06) (IB08.26.98.02).*	NS/ELS/HW/ HSC/PB/JHSA/ CHPA/TEE/ AA/TSC/SPL/ PA		09.30.98	09.23.98
AB09.23.98.02	Review design/structural implications of alternate interior wall systems requiring acoustical consideration.	JHSA/HW/ELS		10.07.98	10.07.98

AB10.07.98.01	Develop/detail steel platform design for curved seating format, including curved and slotted riser, and installation of riser mounted seating (involve Irwin Seating). Draw section for each typical riser height.	ELS/HW/M BS /AA/LCC		10.09.98	10.21.98
AB10.07.98.02	Revise structure to reflect development of the fly tower and rigging wall. Provide rigging wall section.	HW/ELS/ AA	2	10.09.98 11.04.98	11.04.98
AB10.07.98.03	Coordination meeting with CC regarding purlin framing, wall sections, and wind girts (locations relative to interior finishes); fabrication and installation responsibility. Provide plan and wall section.	HW/ELS		10.15.98	10.21.98
AB10.07.98.04	Revise framing to accommodate concrete under roof top units at BOH, *top of offices*.	HW/ELS	5	10.21.98 11.02.98	11.04.98
AB10.21.98.01	Identify allowable deflection for purlins supporting interior finishes.	HW		11.04.98	11.04.98
AB10.21.98.02	Resolve purlin design with regard to interior finishes.	HW/ELS/CC		11.04.98	11.04.98
AB10.21.98.03	Review riser design with regard to platform construction.	MBS		11.04.98	11.04.98
AB10.21.98.04	Establish overall general design for seating risers. *Resolve concept design reviewed with MBSI.*	HW	1 2	11.04.98	12.02.98 12.16.98
AB10.21.98.05	Complete seating platform design to be able to complete 3D Model download by *12.11.98* (and ABM by *12.18.98*) (IB07.15.98.01). *Havens currently doing hand take-off for costing.*	ELS	2 5	11.06.98	12.02.98
AB10.21.98.06	Resolve retaining wall location which has been influenced by the seating platform curve.	ELS/HW/ PB/ LCC	7 7	11.04.98	12.02.98 12.16.98
AB10.21.98.07	Review four seating mounting details with Irwin Seating.	ELS		11.04.98	11.04.98
AB10.21.98.08	Resolve the structural support and acoustical requirements at "meet and greet" areas at west side of building; *HVAC Units moved*.	ELS/HW/JH SA		11.04.98	11.04.98
AB10.21.98.09	Revisit/update steel detailing value stream sequences to decide how far to proceed.	HW/HS/SPI/ LCC		11.04.98	11.04.98
AB11.04.98.01	Revise 3-D Model to reflect curved seating format (IB10.07.98.01).	HW		11.04.98	11.04.98
AB12.02.98.01	Review prefab stair utilization (IC08.12.98.02, IB08.12.98.01). Specifications allow the use of prefab stairs at specific locations.	ELS		12.02.98	12.02.98
AB12.02.98.02	Resolve pricing set coordination issues, i.e. column locations, to be able to complete 3D Model.	ELS/HW		12.16.98	
AB12.02.98.03	HW/PB meeting on 12.03.98 to review erection sequence on which ABM's are based.	HW/PB		12.16.98	

AB12.02.98.04	Resolve proposed changes relative to 3D Model, i.e. stage house.	NS/ELS/HW		12.16.98	

C. Enclosure/Architectural

AC07.15.98.02	Resolve insulation requirements for shell of the building. *Refine energy calculations for specific R value for walls and roof (IC07.01.98.01). Sound/Power ratings of cooling towers will drive amount of insulation or dbl sheet rock.*	ELS/JHSA/ CHPA		07.28.98 08.18.98	08.26.98
AC07.29.98.01	Prepare life safety narrative outline.	ELS		08.12.98	08.06.98
AC08.12.98.01	Evaluate status of input for structural detailing. *Value stream.*	HW		08.26.98	08.26.98
AC08.12.98.02	Determine 'R' value for roof considering both thermal insulation and noise. (IC07.15.98.01) (DC08.12.98.01)	ELS/JHSA/ CHPA		08.12.98	08.12.98
AC07.15.98.01	Complete louver selection (IC07.01.98.04).	ELS/CC		07.22.98	07.29.98
AC07.15.98.03	Resolve material selection at the building base.	ELS/LCC		Issues Log	07.29.98
AC08.12.98.03	Complete roof and wall input concept drawings. (IC07.01.98.02) *Wal designs should be complete before roof design begins, and roof drawings will take about ten days after that. Scuppers are not an issue.*	ELS/CHPA		08.25.98	08.26.98
AC08.26.98.01	Provide metal samples of color and finish for selection *(deleting 'and exterior mock ups'); two of three received.*	CC/ELS	5	09.09.98 10.07.98	10.07.98
AC08.26.98.02	Clearly identify on the concept drawings the location of each color, and determine quantity of each of the vertical, horizontal and smooth panels so the cost for custom colors for each type can be assessed.	ELS/CC		09.09.98	09.09.98
AC09.09.98.01	ELS issuance of *exterior* glass and stair design package to CC (IC07.01.98.03).	ELS		09.17.98	09.23.98
AC09.09.98.02	ELS to detail the desired exterior wall mock-up and proposed location at the site (IC08.26.98.01).	ELS	4	09.23.98 09.30.98	10.07.98
AC09.09.98.03	Determine metal panel custom colors based on ELS submitted color chips and quantities for each of the colors.	CC/ELS	2	10.07.98	10.07.98
AC09.09.98.04	Determine metal panel custom colors premium cost based on economic order quantities.	ELS/CC	2	10.07.98	10.07.98
AC09.09.98.05	Determine if roof valley lines to drain locations can be accomplished with concrete rather than being built up by PC.	ELS/HW		09.23.98	09.23.98
AC09.23.98.01	Confirm concrete wall and roof deck at back of house low area.	ELS		10.07.98	10.07.98
AC10.07.98.01	Revise exterior wall mock-up detail; propose	ELS		10.21.98	10.21.98

	site location.				
AC10.07.98.02	Provide drawing of alternate value engineered BOH metal panels; reduced parapet height.	ELS		10.21.98	10.21.98
AC10.07.98.03	Resolve number of layers of gypsum board as alternative to CMU to achieve accoustical objective - Vomitory, etc. *To be included in Pricing Documents.*	ELSJHSA	2	10.21.98 11.06.98	11.04.98
AC10.21.98.01	Provide enclosure mock-up pricing.	LCC/CC	5	11.13.98	12.02.98
AC10.21.98.02	Coordinate interior finish support (interior studs and drywall) with high wall metal panel suport girts.	HW/CC/ELS		11.04.98	11.04.98
AC10.21.98.03	Identify roofing material for each roofing section, esp. low canopy roof visible from lobby balcony - *aggregate/paver roofscape*; provide pricing *and samples*.	ELS/LCC /PC	7 6	11.04.98	12.02.98 12.16.98
AC11.04.98.01	Resolve mock-up schedule: 2 months to fabricate panels; *2 months* to erect mock-up, make changes, and make decision (3 months to fabricate building panels; 120 to 150 day building critical path).	ELS/LCC /CC/	1 NS	12.02.98	12.16.98
AC11.04.98.02	Resolve door acoustical ratings. *Will not have ratings.*	ELS/JHSA		12.02.98	12.02.98
AC12.02.98.01	Determine if a mock-up(s) of exterior wall will be required; to be price based. *Ordering, fabricating, erecting, and making decisions based upon the mock-up are critical path tasks (IC09.09.98.01).*	NS		12.07.98	

D. Mechanical/Electrical/Plumbing/Fire Protection

AD07.01.98.01	Post Drawings on FTP site.	CHPA	3	07.06.98 08.12.98	08.12.98
AD07.01.98.02	Provide/confirm audio system power requirements to TEE.	JHSA		07.07.98	07.07.98
AD07.01.98.03	Provide/confirm audio system cooling requirements to CHPA.	JHSA		07.07.98	07.07.98
AD07.01.98.04	Provide/confirm emergency power items to TEE/CHPA.	ELS		07.08.98	07.14.98
AD07.01.98.05	Provide/confirm normal and emergency loads to TEE.	CHPA	7	07.08.98 07.30.98	07.30.98
AD07.01.98.06	Provide/confirm architectural/theatrical lighting and video power loads to TEE/CHPA.	AA		07.08.98	07.08.98
AD07.01.98.07	Resolve location of main electrical room (162) and electronics storage and shop (158) to facilitate piping from cooling tower. LCC to provide pricing input. Not applicable due to commissary design change.	ELS/TEE/ CHPA/*LC C*	5	07.08.98 08.12.98	08.12.98
AD07.01.98.08	Provide pipe/duct weights to HW	CHPA		07.14.98	07.14.98

AD07.01.98.09	Provide concession/food service electrical loads to TEE/*CHPA. Revise food service loads due to program change. Note: Concession charts were received and show equipment loads and revised floor plan raise the cost from the current estimate.*	NS/ELS		07.08.98 08.26.98	08.26.98
AD07.01.98.10	Provide CATV and Data information to TEE.	NS/JHSA/AA		Issues Log	07.29.98
AD07.01.98.11	Provide elevator electrical loads/data to TEE.	ELS/LCC		07.08.98	07.08.98
AD07.01.98.12	Provide life safety *[and exit sign loads]* (Rolf Jensen Assoc.) to TEE.	ELS		07.08.98	07.29.98
AD07.01.98.13	Provide/confirm location of raceway loads to HW/TEE/CHPA.	AA/JHSA	5	07.14.98 08.12.98	08.12.98
AD07.01.98.14	Provide transformer sizes to TEE.	AA/JHSA		07.14.98	07.14.98
AD07.01.98.15	Provide/confirm general lighting loads to CHPA.	TEE		07.14.98	07.14.98
AD07.01.98.16	Provide emergency power motor sizes to TEE.	CHPA		07.14.98	07.14.98
AD07.01.98.17	Provide fire pump information to TEE.	WSFP		07.14.98	07.14.98
AD07.01.98.18	Provide concession/food service layout information (Volume Services). Big picture matrix: 3000 SF	NS/ELS	2	07.14.98 07.31.98	08.12.98
AD07.01.98.19	Air zones approval; *block out areas served by AHU's for review* (zones of operation; zones for control, ID07.01.98.02).	NS/CHPA/MMC/ELS	7	07.14.98 07.30.98	08.12.98
AD07.15.98.01	Confirm subcontractor participation in evaluating on-line project management approach.	FE		07.22.98	07.22.98
AD07.15.98.02	Resolve sheet metal duct work design; provide to JHSA for approval.	CHPA/LL	7	07.20.98 07.31.98	08.12.98
AD07.15.98.03	Provide feedback/approval of sheet metal ductwork design to ELS (ID07.01.98.01).	JHSA	2	07.22.98 08.03.98	08.12.98
AD07.15.98.04	Provide lobby lighting loads to ELS.	TEE/AA		07.22.98	07.22.98
AD07.15.98.05	Meet with cablevision to explore infrastructure requirements for in-house television system.	NS		Thtrcl/Int	07.29.98
AD07.15.98.06	Lighting operations approval; block out areas served by lighting - zones of operation/control (IE07.01.98.02).	TEE/AA		07.28.98	07.28.98
AD07.15.98.07	Coordinate location of proscenium deluge system with other systems.	WSFP/HW/CHPA/AA	6	07.28.98 08.05.98	08.12.98
AD07.29.98.01	Follow up proscenium deluge system meeting - operation, pipe size, curtain physical make-up. (ID08.12.98.04)	WSFP/HW/CHPA/AA/LCC/ELS	2	Issues Log	08.12.98
AD07.29.98.02	Follow up acoustics meeting after JHSA reviews sheetmetal design. (ID08.12.98.02)	JHSA/ELS/CHPA/LC	2	Issues Log	08.12.98

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AD07.29.98.03	Resolve safety requirements for proscenium deluge system with Rolf Jensen. (ID08.12.98.03)	WSFP/CHPA/AA/LCC	2	Issues Log	08.12.98
AD07.29.98.04	Resolve supply duct routing from house to mechanical chase/AHU. Reworded as: House duct route and outlet locations move to follow new architectural layout. (ID08.12.98.04)	CHPA/JHSA/ELS/LCC	2	Issues Log	08.12.98
AD07.29.98.05	Resolve additional MEPF requirements for adding commissary kitchen.	CHPA/TEE WSFP/FE/LCC		08.05.98 08.26.98	08.26.98
AD07.29.98.06	Resolve additional requirements for addition/revision to suite level toilet rooms. *Add to floor plan.*	CHPA/TEE ELS/LCC		08.05.98 08.26.98	08.26.98
AD07.29.98.07	Coordinate ceiling acoustical panels and house air outlets. Now combines with AD07.29.98.04 above, becoming ID08.12.98.04.	CHPA/JHSA / ELS/LCC		Issues Log	08.12.98
AD07.29.98.08	Add acoustics value stream into project value stream. (ID08.12.98.05)	JHSA/LCC		Issues Log	08.12.98
AD07.29.98.09	Meet onsite with Texas Utilities to permanent and temporary electric service.	TEE/ELS/HA/FE/LCC/NS		08.12.98 08.19.98	08.26.98
AD08.12.98.01	Resolve roof drainage design to complete enclosure package. (Related item AA08.12.98.10)	CHPA/ELS		08.25/98	08.26.98
AD08.12.98.02	Determine ASHRAE design temperatures. Consider adjusting D/FW design standards due to temperature change condition.	NS		08.19.98	08.26.98
AD08.12.98.03	Verify exact locations on marked plan to be designated 'smoking areas'.	NS		08.19.98 09.09.98	09.09.98
AD08.12.98.04	Determine effect of *suite* smoking areas on mechanical system.	CHPA	2	09.09.98 09.16.98	09.23.98
AD08.12.98.05	Reconfigure ductwork at *auditorium* hard ceiling for JHSA/ELS review.	CHPA/MMC/LL/LCC	5	08.26.98 09.10.98	09.23.98
AD08.12.98.06	Team to test assumptions for delivery duct layouts in complying with acoustic requirements. *Note: Revised duct plans will be available by 4 Sept. 98. Drawings to JHSA 09.10.98.*	CHPA/MCC/LL/LCC	2	08.26.98 09.17.98	09.23.98
AD08.12.98.07	Prepare summary list of electrical load requirements for presentation to Texas Utilities.	TEE		08.19.98	08.26.98
AD08.26.98.01	Determine roof drain pipe routing and resolve potential pipe and roof drain locations conflicts.	CHPA	5	09.09.98	10.07.98
AD08.26.98.02	Confirm roof drainage overflow design with Grand Prairie.	CHPA		09.09.98	09.09.98

AD08.26.98.03	Follow up proscenium deluge system meeting - operation, pipe size, curtain physical make-up (AD07.29.98.01 & AD07.29.98.07) (ID08.12.98.01).	WSFP/HW/ CHPA/AA/LCC/ELS	2	09.09.98 Move to Theatrical	09.09.98
AD08.26.98.04	Obtain sound/power ratings and provide to JHSA. *Waiting on Cook Fan ratings.*	CHPA/MMC	2	09.09.98 09.16.98	09.23.98
AD08.26.98.05	Provide *concept* equipment layout for food service areas. *Detailed design upon vendor selection.*	NS/CI	7	09.09.98 09.23.98	09.23.98
AD08.26.98.06	Determine increased power requirements for food service areas.	NS/CI/TEE		09.09.98	09.09.98
AD09.09.98.01	House duct route and outlet locations move to follow new architectural layout (AD07.29.98.04, ID08.12.98.04).	CHPA/JHSA / ELS/LCC		09.09.98	09.09.98
AD09.09.98.02	Determine routing/enclosure of exterior duct at front of house (ID08.26.98.02).	CHPA		09.09.98	09.09.98
AD09.09.98.03	Review implications of two-hour house/lobby separation vs 21,000 cfm lobby smoke exhaust *(selected)*, life safety and cost.	ELS/CHPA/ LCC		09.09.98 09.23.98	09.23.98
AD09.09.98.04	Provide per Texas barrier-free access, a unisex single toilet for each grouping of mens and womans toilets.	ELS		09.09.98 09.23.98	09.23.98
AD09.09.98.05	Provide building infrastructure requirements for CATV, theatrical, and Data information to TEE. Identify the spaces within the building; 09.29/30.98 Meeting (ID07.01.98.10).	NS/JHSA/AA		09.23.98	09.23.98
AD09.09.98.06	Follow up acoustics meeting after JHSA reviews sheetmetal design (AD07.29.98.02, ID08.12.98.04, ID08.12.98.02).	JHSA/ELS/ CHPA/LCC		09.23.98	09.23.98
AD09.09.98.07	Coordinate duct sizing and delivery design options.	CHPA/LL		09.23.98	09.23.98
AD09.09.98.08	Review acoustical requirements for mech. equipment wall systems, *central plant* (formerly AC09.09.98.06) From E/A 09.23.98	ELS/JHSA	5	09.23.98	10.07.98
AD09.09.98.09	Front Mech.Room: CMU walls may be needed acoustically; currently metal studs/drywall;may require heavier walls (8" block w/2 layers gypsum) or change in building envelope enlarging mech.room (formerly AC09.09.98.07);JHSA sketch to HW.From E/A 09.23.98	ELS/JHSA	2	09.23.98	10.07.98
AD09.23.98.01	Provide data for small ahu/fan coil unit in basement mechanical equipment room.	CHPA		09.30.98	10.07.98
AD09.23.98.02	Provide TEE/FE scope of design as a basis for preconstruction letter agrement and projected cash flow.	TEE		10.07.98	10.07.98
AD09.23.98.03	Confirm/revise layout of electrical room and electrical yard.	TEE		10.07.98	10.07.98

AD09.23.98.04	Provide for *4* to *6* food service exhaust duct fans and returns in lobby area (original program included 2 to 3). Provide location of kitchen supply fans(AD10.07.98.04). Holding for concession consultant equipment concept.	CHPA/CI/ ELS MMC/LL	1 1 2	10.07.98 12.01.98	10.21.98
AD10.07.98.01	Determine effect of concession smoking areas on mechanical systems. (ID09.23.01)	CHPA		10.07.98	From S/C 10.07.98
AD10.07.98.02	Determine the most effective design/cost solution to provide overflow roof drainage. Followup overflow drain issues with Sharon Cherry, Building Official, City of Grand Prairie (AA09.09.98.05 & AA09.23.98.02). Provide sketch/documentation to GP.	CHPA	2 5 7	09.23.98 10.07.98 10.14.98 11.04.98	From S/C 10.07.98 11.04.98
AD10.07.98.03	Provide revised AHU layout at FOH mechanical rooms.	CHPA		10.21.98	10.21.98
AD10.07.98.04	Meet with cablevision to explore infrastructure requirements/*formats* for in-house *live broadcast and closed circuit* television system (AD07.15.98.05). *Identify options/design responsibility/proposal/scope of work.*	NS	#	08.07.98 09.23.98	09.23.98
AD10.07.98.05	Revise Food Service/Commissary program including upper level food service capabilities (IE07.01.98.01). (Scheme B received from ELS during the meeting.)	NS/VS/ELS		08.05.98 08.26.98	08.26.98
AD10.07.98.06	Revise Suite Level toilet room program/design. NextStage to review layouts.	NS/CHPA/E LS		08.05.98 08.26.98	08.26.98
AD10.07.98.08	Develop commissary utility metering level.	NS/CII		08.14.98	08.26.98
AD10.07.98.09	Confirm that structural engineers have theatrical dimming rack and Audio amplifier rack loads.	JHS/SP	7	08.14.98 09.23.98	09.10.98
AD10.07.98.10	Clarify the conceptual design/layout in the concessions area relative to headroom condition.	ELS/CI	7	09.09.98 09.23.98	09.23.98
AD10.07.98.11	Define type and size of stage rear doors for framing input.	ELSl/AA		09.09.98	09.09.98
AD10.07.98.12	Finalize plan layout as a result of adding commissary.	ELS/NS		08.14.98	08.26.98
AD10.07.98.13	Provide location of kitchen supply fans.	CHPA	1	10.21.98 11.04.98	Combined Above
AD10.07.98.14	Revise roof drain design to reflect roof changes.	CHPA		10.21.98	10.21.98
AD10.07.98.15	Review commissary program and confirm food service exhaust duct fans and returns. *New concept.*	NS		10.21.98	10.21.98
AD10.07.98.16	Resolve need for fire pump; determine water pressure required at roof and proscenium.	CHPA/RJA/ WSFP/ELS		10.21.98	10.21.98
AD10.07.98.17	Confirm connection of fire pump with respect to main and emergency generator.	TEE/FE		10.21.98	10.21.98
AD10.07.98.18	Provide layout and size of BOH (rear) duct runs for acoustical analysis.	CHPA/LL	2	10.21.98 11.04.98	11.04.98

AD10.07.98.19	Provide layout showing telephone, data, and CCTV locations to be serviced with empty conduit. *Provide CATV and data information to TEE (AD07.01.98.10/IE07.29.98.01).*	NS	5	10.21.98 10.28.98 11.04.98	11.04.98
AD10.07.98.20	Meet with telephone company to review the project. *Coordinate with NS. NS to negotiate costs.*	NS/ELS/ TEE/ *FE*	5 7	10.21.98 11.04.98 12.02.98	12.02.98
AD10.07.98.21	Review/confirm normal and emergency power loads. *Schedule requires updating.*	TEE	2 2	10.21.98 11.04.98 12.02.98	12.02.98
AD10.21.98.01	Send sketch to Texas Utilities for new location of on-site pad mounted equipment *(switchgear location, pad sizes)* (AA10.07.98.04). *Develop alternate options for TU consideration.*	TEE/FE	5 5	10.14.98 10.23.98 11.04.98	11.04.98
AD10.21.98.02	Provide latest mechanical unit layouts; verify weight and layout of new units.	CHPA		11.04.98	11.04.98
AD10.21.98.03	Review/mark-up underseat air slot bands.	CHPA		11.04.98	11.04.98
AD10.21.98.04	Completion of Electrical Pricing Documents, including complete underground/underslab electrical construction documents (ID10.07.98.03). *One line and recepticle/power drawings only submitted.*	TEE	5 5	11.09.98 12.16.98	11.16.98
AD10.21.98.05	Reconsider deluge system decision/design based upon Rolf Jensen Associates review. Deluge "A" included in pricing documents. *Alternate:"B" closely spaced sprinkler heads reacting individually;also, proscenium reduction system functions as a fire curtain.*	ELS/CHP A/ WSFP	2 1	11.04.98 12.16.98	12.02.98
AD11.04.98.01	Control of AHU noise as it travels down the duct path (ID10.07.98.01). *Base units changed.*	CHPA/JHSA		12.02.98	12.02.98
AD11.04.98.02	Outline options for acoustical consideration (ID10.07.98.02).	CHPA/JHSA		12.02.98	12.02.98
AD11.04.98.03	Followup overflow drain issues with Sharon Cherry, Building Official, City of Grand Prairie. *Awaiting return response.*	CHPA	2	12.02.98	12.16.98
AD11.04.98.04	Provide gas meter information - size, clearance.	TSPH/CH PA	5	12.02.98	12.16.98
AD11.04.98.05	Based upon consessionaire design provide gas requirements for cook areas.	CHPA	2	12.02.98	12.16.98
AD11.04.98.06	Resolve generator requirements.	CHPA/TEE		12.02.98	12.02.98
AD11.04.98.07	Confirm assumptions regarding lighting controls (ID12.02.98.01).	CHPA/TEE		12.02.98	Issues Log 12.02.98
AD12.02.98.01	Decision regarding code/security acceptance of open yard flexibility w/o having separations between electrical switch gear, cooling tower, etc.	FE		12.16.98	
AD12.02.98.02	Provide Electrical Specifications.	TEE		12.16.98	

E. Theatrical/Interiors

AE07.01.98.01	Send/fax theatrical event proforma to AA/JHSA.	NS		07.02.98	07.02.98
AE07.01.98.02	JHSA and SPL to meet to review audio concepts.	JHSA/SPL	7	07.07.98 08.12.98	08.12.98
AE07.01.98.03	AA and PAL to review theatrical lighting concepts.	AA/PAL		07.07.98	08.12.98
AE07.01.98.04	Confirmation of theatrical systems based on event proforma.	AA/PAL/JHSA /SPL		07.07.98	08.12.98
AE07.01.98.05	Confirm/*resolve* size of mid-house control position to ELS.	AA/JHSA/NS		07.07.98 08.12.98	08.26.98
AE07.01.98.06	Develop alternative audience/house reduction designs based upon new design parameters.	ELS/AA		07.10.98	08.12.98
AE07.15.98.01	Resolve house reduction system options (AF07.01.98.05). *Provide loads for both options to HW.*	NS	2	07.22.98 08.05.98	08.12.98
AE07.15.98.02	Resolve front lighting and vertical side box boom positions (*probably 2*). *Provide loads to HW*.	AA/PA	5	07.28.98 07.31.98	08.12.98
AE07.15.98.03	Resolve seat selection options; obtain chair samples and confirm dimensional envelope. (IE08.12.98.04)	NS/AA/ELS	5	Issues Log	08.12.98
AE09.09.98.01	Follow up proscenium deluge system meeting - operation, pipe size, curtain physical make-up: *Resolve curtain opaque surface.* (AD07.29.98.01 & AD07.29.98.07)(ID08.12.98.01) (IE09.23.98.01).	WSFP/HW/ CHPA/AA/ LCC/ELS	2	09.09.98 09.23.98	Issues Log 09.23.98
AE09.09.98.02	*Obtain chair samples and confirm within current seating envelope (AE07.15.98.03,IE08.12.98.04). NS to meet with ELS to make a decision on seating (IE08.12.98.01).* Review metal perforated vs. plastic bottom seats, and provide observations/ concerns to NS.	AA/JHSA /ELS/ LCC	5 5 6 1	09.23.98 10.07.98 10.21.98 11.04.98 12.02.98	12.02.98
AE09.09.98.03	Resolve life safety requirements for proscenium deluge system (wet fire curtain) with Rolf Jensen (AD07.29.98.03) (IE09.23.98.01).	ELS/CHP		09.23.98	Issues Log 09.23.98
AE09.09.98.04	Resolve alternate designs for mid-house control position. Row of removable seats in front.	AA/JHSA/NS/ ELS		09.23.98	09.23.98
AE09.09.98.05	Resolve structurally and operationally whether Box Booms will track or be fixed point loads. *Will be rigged.*	NS/AA/ELS		09.23.98	09.23.98
AE09.09.98.06	Determine effect of image magnification on walls and ceiling. *Provide 2-20 foot diameter screens; projector to be 30 feet out.*	AA/ELS		09.23.98	09.23.98

AE09.09.98.07	Prepare conceptual design for commissary and loading dock area, including trash compactor location.	CI/ELS		09.23.98	09.23.98
AE09.09.98.08	The commissary/loading dock changes need to be reflected on the ELS drawings, and provided to Creative Ind.	ELS	2	09.23.98	10.07.98
AE09.09.98.09	Submit Life Safety Program to Grand Prairie (IE08.12.98.05).	ELS		10.16.98	10.21.98
AE09.23.98.01	Provide layout sketch for *other equipment* - *electrical, ie. disconnects* - in the amplifier/*dimmer* rooms. Review size of amplifyer/dimmer room (AE10.21.98.01).	TEE	2 7	10.07.98 10.21.98 11.04.98	12.02.98
AE10.07.98.01	Resolve forestage rigging grid issue. *Confirm both structurals and 3-D model are based on 10' o.c., 4000# pt.lds; maximum gross tonnage, 3300#.* (IE08.12.98.03)	AA/JHSA		10.07.98	10.07.98
AE10.07.98.02	Determine the extent of theatrical lighting system that is necessary, *i.e. dimmer racks, etc.* to be provided as a part of the base building capital investment. NS developed description of essential equipment. (IE09.09.98.01)	ELS/AA AA/ELS/NS		10.07.98	10.07.98
AE10.07.98.03	Review proscenium deluge system:operation, *3in* pipe size, *volume*, curtain makeup: *Resolve life safety requirements,(wet fire curtain/curtain* opaque *surface) with Rolf Jensen.*(AD07.29.98.01 & AD07.29.98.07) (ID08.12.98.01)(AD07.29.98.07) (09.09.98.01/.03).	WSFP/HW/ CHPA/AA/ LCC/ELS		10.07.98	10.07.98
AE10.07.98.04	Forward acoustical testing reports from Irwin Seating to JHSA.	AA	7 7	10.14.98 10.21.98 11.04.98	11.04.98
AE10.07.98.05	Relocate Electrical room to opposite side of AV Room; identify size of AV Room; and, distribute for verification.	ELS		10.14.98	10.21.98
AE10.07.98.06	Provide revised auditorium backgrounds.	ELS		10.18.98	10.21.98
AE10.07.98.07	Provide systems plans for each level including wiring devices and conduit layout. (IE09.23.98.02)	AA/JHSA		10.21.98	10.21.98
AE10.07.98.08	Video//TV broadcast decision. (IE07.15.98.01)	NS/JHSA/A A		10.21.98	10.21.98
AE10.07.98.09	Resolve use of series of gratings instead of "no fall protection."	ELS/AA	2	10.21.98 11.04.98	11.04.98
AE10.07.98.10	Review combination of 3-seat sizes by section to arrive at a final seating plan; adjust aisles and vomitories *(Now Fixed)*. Irwin Seating to meet w/NS. *Irwin to do seat layout/count.*	ELS/AA	9	10.21.98 11.04.98 12.02.98	12.02.98
AE10.07.98.11	Obtain sample of Irwin metal pan perforated seat with curved lip. No differential envelope (IE12.02.98.01).	LCC	5 5	10.21.98 11.04.98 12.02.98	Issues Log 12/02.98

AE10.21.98.01	Review size of amplifyer/dimmer room.	ELS/AA/JHSA		11.04.98	See Above
AE10.21.98.02	Send new pit layout/dimensions to JHSA and AA for review (IE08.26.98.02).	ELS		10.28.98	11.04.98
AE10.21.98.03	Review/revise audience reduction system (IE10.07.98.02).	NS/ELS/AA		11.11.98	11.04.98
AE10.21.98.04	Review design program with NS independent producer/ reviewer, Peter Wexler. Ongoing.	ELS/AA/JHSA		12.02.98	12.02.98
AE10.21.98.05	Review proposed 3 reconfigurations and sizes for control booth/ FOH mixing position necessitated by radial seating change. Resolve constraints	AA/JHSA	2	11.04.98 12.02.98	12.02.98
AE11.04.98.01	Revisit discussion regarding height of grid above proscenium. Proscenium: Rock 50 FT, Broadway 32 FT Min. (IE10.07.98.03).	NS		11.04.98	11.04.98
AE12.02.98.01	Send copy of Production Arts Lighting GMP proposal to NS/ELS.	LCC		12.04.98	
AE12.02.98.02	Raise Stage House trim height from 80 Ft to 81Ft-3In by lightening stage house steel and adjustin roof pitch. Requires addding back rigging pit: 6Ft by 60Ft of basement space, per earlier drawing issue.	ELS/HW		12.16.98	
AE12.02.98.03	Send picture and dimensions of typical sound board to ELS, for selection of appropriate sized sissor lift.	JHSA		12.16.98	
AE12.02.98.04	Develop actual speaker locations/'look' of the proscenium; development meeting next week to generate describing graphics.	JHSA/SPL		12.16.98	
AE12.02.98.05	Colors and materials for lobby and house beign pulled by logo/ color development; colors and materials presentation after January 1st.	NS/ELS		01.11.98	

F. Project Support

AF07.01.98.01	Approval of audio and theatrical lighting concepts.	NS		07.07.98	07.07.98
AF07.01.98.02	Issue project insurance memorandum for discussion.	LCC		07.07.98	07.07.98
AF07.01.98.03	Issue subcontractor preconstruction agreements for discussion, (IF08.26.98.01). *(Crown Corr agreement issued).*	LCC		Issues Log	08.26.98
AF07.01.98.04	Resolve design agreement legal issues and complete ELS design agreement. *Effort continuing. Documents may not be filed for permits until legal issues are resolved and designers can be identified in the drawing title block (IF10.21.98.01).*	NS/ELS	5 5	07.10.98 10.21.98	Issues Log 10.21.98
AF07.01.98.05	Approval of audience/house reduction design solution.	NS		Thtrcl/Int	07.29.98

AF07.01.98.06	Identify potential national vendor partners. Effort continuing (IF08.26.98.02).	LCC/ELS		Issues Log	08.26.98
AF07.01.98.07	Identify project components not currently represented by team. Effort continuing.	LCC/ELS		Issues Log	08.26.98
AF07.01.98.08	Update and issue current project budget, as revised.	LCC		07.14.98	07.29.98
AF07.01.98.09	Project Logs: • Develop a consistent format for project logs for review.	LCC		07.07.98	07.09.98
AF07.01.98.10	• Refine meeting action items, issue/maintain Action Items Log.	LCC		07.07.98	07.09.98
AF07.01.98.11	• Develop, issue and maintain Issues Log, and Decision Log.	LCC		07.10.98	07.09.98
AF07.01.98.12	Develop, issue and maintain Project Document Log.	ELS		07.14.98	07.29.98
AF07.01.98.13	• Approval of project logs and format.	NS		07.14.98	07.15.98
AF07.15.98.01	Amend log format to show Issue, Action Item, Decision trail; each item to have a discrete identity.	LCC/NS		07.29.98	07.29.98
AF07.15.98.02	Probability of construction start date - Status Report (IF08.26.98.03).	NS		Issues Log	08.26.98
AF07.15.98.03	Submit agreement for engineering *and other consultant* services (AF07.15.98.04).	NS/HA		Issues Log	08.26.98
AF07.15.98.04	Submit agreement for architectural services and other consultant design agreements.	ELS/HA		07.28.98	07.29.98
AF07.15.98.05	Resolve agreement with food service concessionaire.	NS		07.28.98	07.28.98
AF07.15.98.06	Revise estimate schedule for GMP.	NS/LCC		07.28.98	07.28.98
AF07.29.98.01	Prepare target cash flow estimate for both consultant design and subcontractor design efforts.	NS/ELS/LCC		08.12.98 08.26.98	09.09.98
AF07.29.98.02	Expand current summary project budget to detailed estimate (IF08.26.98.04)	LCC		Issues Log	08.26.98
AF07.29.98.03	Electronic communication of project information. Install project documents on communication web site server (IF07.15.98.06).	NC/ELS/ LCC	7	08.12.98 10.07.98	10.07.98
AF07.29.98.04	Include Food Service consultant, Creative Industries, in project progress meetings.	NS/LCC		08.12.98 08.26.98	08.12.98
AF07.29.98.05	Review and report on the status of document preparation.	ELS		08.12.98	08.12.98
AF08.12.98.01	Prepare notes from 8/6/98 meeting with Grand Prairie building officials.	ELS		09.09.98	09.09.98
AF08.12.98.02	Prepare list of proposed permit packages and timeline. *(Timeline preparation moved to Issues Log item IF09.09.98.01.)*	ELS/LCC		09.09.98	09.09.98
AF08.26.98.01	Issue Crown Corr Agreement.	NS/LCC		09.09.98	09.09.98
AF08.26.98.02	Issue Pacific Agreement.	NS/LCC		09.09.98	09.09.98
AF08.26.98.03	Issue Havens Agreement.	NS/LCC		09.09.98	09.09.98
AF08.26.98.04	Define format/dates for ELS consultants	ELS/LCC		Deleted	09.09.98

	design scope of work. *No one recognized this as an action item or was a duplicate.*				
AF08.26.98.00	Resolve design agreement legal issues with ELS.	NS		09.09.98 09.23.98	To AF 07 .01.98.04
AF08.26.98.05	Prepare cash flow to January 1999 by month for ELS and their consultants based on current value stream (AF10.21.98.01).	ELS	5 5	09.09.98 10.21.98	Combined Below
AF08.26.98.06	Prepare cash flow to January 1999 by month for LCC and consultants based on current value stream (AF10.21.98.01).	LCC	5 5	09.09.98 10.21.98	Combined Below
AF08.26.98.07	Prepare cash flow to January 1999 by month for NS and consultants based on current value stream.	NS		09.09.98	09.09.98
AF08.26.98.08	Issue SPL Agreement letter (IF10.21.98.02).	NS/AA/LCC	5 5	09.09.98 10.21.98	Issues Log 10.21.98
AF09.09.98.01	Bob Timmel to review list of cost increases with Bruce, Pam and Mike on Friday 09.11.98	NS/LCC		09.11.98	09.14.98
AF09.09.98.02	Bob Timmel to review list of cost increases with Leo3.	NS		09.14.98	09.14.98
AF09.23.98.01	Prepare permit package timeline (AF08.12.98.02/ IF09.09.98.01).	ELS/LCC		10.07.98	10.07.98
AF09.23.98.02	Continuing improvement in the planning process: improving ability to make quality assignments and ability to meet commitments (IF10.07.98.01).	All		10.07.98	Issues Log 10.07.98
AF10.07.98.01	Review with each team the most effective way to proceed with the development of construction documents *and target cash flows (IF07.15.98.03)*.	NS/LCC		10.21.98	10.21.98
AF10.21.98.01	Prepare project workplan/target cash flows(w/manhours): design cash flows assume 12.21.98 construction start (AF08.26.98.05, AF08.26.98.06, IF10.07.98.02).	ELS/LCC	5	11.04.98 12.02.98	12.02.98
AF10.21.98.01	Prepare project workplan/target cash flows(w/manhours): construction cash flows assume 02.15.98 construction start and18.5 month construction schedule.	LCC	7	12.02.98	12.16.98
AF11.04.98.01	Early construction/other work to achieve visual site impact.	NS/ELS/ LCC	1	12.02.98	12.16.98
AF11.04.98.02	Develop early value stream for remaining critical early preconstruction items of work.	LCC/NS/ ELS/ HA	7	12.02.98	12.16.98
AF12.02.98.01	Blueline Online: recommendation to not implement until the site is stable.	ELS		12.16.98	
JDK	**End of Action Items**				

APPENDIX D: NEXT STAGE ISSUES LOG

During Next Stage teleconferences, issues requiring action beyond the coming two week period were placed in an issues log, from which they then moved onto the action items log when the timing was appropriate. Issues were numbered in the same way as were action items, except for the IA, IB, etc. prefix.

Linbeck Next Stage Development

The Texas ShowPlace

Issues Log

	As Of December 02, 1998 Project Progress Meeting	Revised:	12.14.98
Date Originated-Item No.	*Item Description*	*Action By*	*Target Date*
A. Site/Civil			
IA08.26.98.04	Relocation of on-site pad mounted equipment by Texas Utilities.	HA/TEE	
IA09.09.98.02	Legal Action filed against NS, by local radio station, re: within 2400 ft, operating since 1950's, 'sole station', fear of our metal building.	NS	
IA10.21.98.01	Select electrical yard surface material; if paved, then concrete.	HA	
IA11.04.98.01	Determine the most effective way to contract for the site work (AA12.02.98.05).	HA/LCC	Action Log 12.02.98
B. Structural			
IB08.12.98.01	Review utilization of prefab stairs (IC08.12.98.02, AB12.02.98.04).	ELS/LCC	Action Log 12.02.98

IB09.09.98.03	Review structural connections and heavy steel members. (AB08.26.98.04 & IB07.01.98.01)	HSC/SPI/PB	
IB09.23.98.01	Holding an *02.15.99* start of construction requires steel mill order by *01.15.99*; detailing to start by *02.15.99*; fabrication to start *03.29.99, and erection to start on 05.10.99*	NS/LCC/HSC/ SPI	
IB09.23.98.02	After 3D Model, Foundation and Structural Permit submisssion target *01.04.99* for a *02.05.99* receipt of permit.	HW/ELS	
IB12.02.98.01	Mock-up color selection critical; NS moving on other color decisions based on previously selected building material colors.	NS/ELS	
IB12.02.98.02	Select aggregate/paver material for visible low roof; aggregate is more cost effective if wind load is not an issue.	NS/ELS	
IB12.02.98.03	Provide for access to lobby by larger equipment, 10Ft X 10FT, for automobile, large boom type lift to access relamping.	NS/ELS	

C. Enclosure/Architectural

IC07.29.98.01	Resolve material selection at the building base (AC08.12.98.04).	ELS/LCC	
IC09.09.98.01	Determine if a mock-up(s) of exterior wall will be required; *to be price based (AC12.02.98.01).*	NS/ELS	Action Log 12.02.98

D. Mechanical/Electrical/Plumbing/Fire Protection

ID07.15.98.01	File application and pay fees for temporary power and telephone four weeks before needed.	NS/LCC	
ID08.12.98.05	Add acoustics value stream into project value stream.	JHSA/LCC	
ID08.26.98.01	Finalize concession design upon selection of concessionaire vendor.	NS/CI/ELS/ CHPA/TEE	
ID10.21.98.01	Block diagram equipment layout by Levy Restaurants	NS/LR	*12.08.98*
ID12.02.98.01	Confirm assumptions regarding lighting controls. *Automated M/P systems can control other timed systems, i.e. parking lighting, etc. Ongoing work issue (AD11.04.98.07).*	CHPA/TEE	

E. Theatrical/Interiors

IE08.26.98.01	Seating count down from 6900 to 6400. May go up to 6550 plus 256 for suites. *Refer to memo of 08.27.98.*	NS/ELS	
IE10.07.98.01	Evaluate continuing scaffolding or working up from structural platforms. Method of construction issue	LCC	

	to be decided by LCC.		
IE12.02.98.01	Obtain sample of Irwin metal pan perforated seat with curved lip. No differential envelope (AE10.07.98.11).	LCC	
IE12.02.98.02	Irwin Seating critical path, 12 months from design to delivery.	NS	
IE12.02.98.03	D.Flannery to layout TV camera positions in the house.	NS	
IE12.02.98.04	Price Division 16 infrastructure for video and communication.	LCC	
IE12.02.98.05	Provide video communication equipment price.	JHSA	

F. Project Support

IF07.01.98.01	Develop post-preconstruction contract documents for review.	LCC	
IF07.15.98.02	Integrate preconstruction agreement with GMP contract.	LCC	
IF07.15.98.04	Develop *site utilization/mobilization plan*.	LCC	
IF07.29.98.01	Define long term role of food service consultant.	NS	
IF07.29.98.02	Review/revise Value Stream in relation to schedule revisions, project changes, etc.	LCC	
IF08.12.98.01	Resolution of project insurance program.	All	
IF08.26.98.01	Issue subcontractor preconstuction agreements for discussion, (AF07.01.98.03). Crown Corr agreement issued.	All	
IF08.26.98.02	Identify potential national vendor partners. Effort continuing (AF07.01.98.06).	LCC/ELS	
IF08.26.98.03	Probability of construction start date - Status Report (AF07.15.98.02).	NS	
IF08.26.98.04	Expand current summary project budget to detailed estimate when 3-D model has been completed.(AF07.29.98.02/IF09.09.98.02).	LCC	
IF09.09.98.03	Define a point in the design process where it makes sense to stop additional work until a definitive construction start date is known; and, independent of a construction start date.	NS/ELS/CHPA/TEE/LCC	
IF09.09.98.04	Define how, and at what point, cost escalation becomes a consideration.	NS/LCC	
IF10.07.98.01	Continuing improvement in the planning process; improving ability to make quality assignments and ability to meet commitments (AF09.23.98.02).	All	
IF10.21.98.01	Resolve design agreement legal issues and complete ELS design agreement. *Effort continuing. Documents may not be filed for permits until legal issues are resolved and designers can be identified in the drawing title block (AF07.01.98.04).*	NS/ELS	11.28.98
IF10.21.98.02	Issue SPL Agreement letter (AF08.26.98.08).	NS/AA/LCC	*12.16.98*

IF10.21.98.03	Identify items critical to value stream and follow through; be clear about what should be on the value stream.	ALL
IF12.02.98.01	Concession architect:Lawrence Berkely Associates. Plans and room finishes to be sent to NS. Counters and facade to be allowances; LCC to construct shell.	NS

JDK **End of Issues**

APPENDIX E: NEXT STAGE DECISION LOG

Next Stage maintained a log of design decisions, numbered similarly to action items and issues, but with a DA prefix for Site/Civil, DB for Structural, etc.

Decision Log

As Of December 02, 1998 Project Progress Meeting Revised: 12.14.98

Date Originated-Item No.	*Item Description*	*Decision By*	*Decision Date*
A. Site/Civil			
DA07.15.98.01	Retain the services of a TAS Accessibility Specialist.	NS:RT	07.15.98
DA07.15.98.02	There will be multiple collection points for storm and sanitary drainage around the building (IA07.01.98.03).	CHPA:GP HA:JR	07.15.98
DA07.29.98.01	Specify same site and parking lighting fixtures as Lone Star Park, unless not feasible or too costly.	NS:RT	07.29.98
DA07.29.98.02	Barrier Free Texas selected as Accessibility Specialist.	NS:RT/ELS:KS	07.29.98
DA07.29.98.03	Uncertain timetable does not allow taking borrow material from existing sewer contractor.	NS:RT	07.29.98
DA08.12.98.01	Use existing lighting for Road D, rewired for new/joint operation with Lone Star Park.	NS:RT	08.12.98
DA08.12.98.02	Grading permit approval does not require architectural document submission.	ELS:DF	08.12.98
DA08.26.98.01	Roadway and building relationships are not affected by the commissary.	HA:JR	08.26.98
DA08.26.98.02	Commissary **Scheme A** selected *(reversal from Scheme B).*	NS:BC	08.26.98
DA08.26.98.03	Roof drain overflow to be piped into primary drainage system.	CHPA:GP	08.26.98
DA09.09.98.01	Commence geotechnical exploration/drilling of LSP borrow material.	NS:RT	09.09.98
DA10.07.98.01	Utilize 55 foot light poles in parking area.	TEE:CS	10.07.98
DA11.04.98.01	If GPISD material is available at the start of construction, then will make an offer for subgrade material for automobile parking.	NS:RT	11.04.98

B. Structural

DB07.15.98.01	Cantilever balcony structure is not practical nor feasible; *cross aisles raised to make cantilever work.*	JA:HW KS:ELS	07.15.98 08.26.98
DB07.29.98.01	Tapered beams will be utilized to support the balcony.	HW:JA/ ELS:KS	07.29.98
DB08.12.98.01	There will be no electrical point loads in the structure greater than 500 lbs (AB07.01.98.08).	TEE:CS	08.12.98
DB08.12.98.02	Design criteria for building exterior will be based upon wind tunnel test results (AB07.01.98.14).	HW:RT	08.12.98
DB08.12.98.03	Resolved audience reduction and box beam loads and location.	ELS:KS / AA:AS	08.12.98
DB08.12.98.04	Proceed with structural design based upon existing perimeter envelope and seating platform.	NS:RT	08.12.98
DB08.12.98.05	Extend four week steel fabrication schedule from 4 weeks to 6 weeks (IB07.15.98.03 / AB08.12.98.01).	HSC:JK	08.12.98
DB08.12.98.06	Resolved low roof impact on structural design by selecting concession scheme 'B'. *Reversed to Scheme A.*	NS:BC NS:BC	08.12.98 08.26.98
DB08.12.98.07	Project will not start construction 09.15.98; and, will not utilize warehouse steel.	NS:RT	08.12.98
DB08.12.98.08	Acceptable construction tolerance on seating is 1/2" per riser, platform to platform.	ELS:KS	08.12.98
DB09.09.98.01	Initial steel mill order must be made 1 month prior to start of construction.	HSC:JK	09.09.98
DB09.23.98.01	Complete 3D model check; hold-up connection study, detailing, and, trans-mission of 3-D model until resolution of potential seating layout change.	NS:RT	09.23.98
DB10.07.98.01	Eliminate CMU walls at FOH mechanical rooms due to revised AHU layout.	JHSA:RL	10.07.98
DB12.02.98.01	Revise column locations at rear of stage house to center the door.	BC:NS	12.02.98

C. Enclosure/Architectural

DC07.01.98.01	Construction/shop drawings not necessary to provide GMP for exterior wall enclosure.	CC:SC	07.01.98
DC07.15.98.01	There is not a food service requirement for louvers (IC07.01.98.05).	CHPA:GP	07.15.98
DC07.15.98.02	The site has a "quiet area" designation relating to outside area noise.	JHSA:RL	07.15.98
DC07.15.98.03.	GMP for roof can be provided without having the roof design completed.	PC:TZ	07.15.98

DC08.12.98.01	Walls to be rated R20 & Roof R30 Insulation (IC07.15.98.01 / AC08.12.98.02).	CHPA:GP LCC:BP	08.12.98
DC08.26.98.01	R30 Roof and R20 Wall will be the thermal transmission ratings used.		08.26.98
DC08.26.98.02	Roof design by Pacific to follow Crown Corr drawings.	PC:TZ	08.26.98
DC10.07.98.01	Can specify custom metal panel colors based upon nominal price increase.	NS:RT	10.07.98

D. Mechanical/Electrical/Plumbing/Fire Protection

DD07.15.98.01	TEE:CS to participate in evaluating online project management approach.	TEE:CS	07.15.98
DD07.29.98.01	FE:WMcD to participate in evaluating online project management approach.	FE:WMcD	07.29.98
DD08.12.98.01	The raceway loads will not affect structural point loading (AD07.01.98.13).	TEE:CS HW:RT	08.12.98
DD08.12.98.02	Location of main electrical room and electronics storage will maintain existing relationship.	TEE:CS LCC:MI	08.12.98
DD08.12.98.03	The back of the house will be a no smoking area.	NS:BC	08.12.98
DD08.12.98.04	Utilize 75 KVA as added electrical load from commissary.	TEE:CS	08.12.98
DD08.26.98.01	Proceed with concession/commissary MEP design based on current 08.26.98 consultant concept/interim design criteria.		08.26.98
DD08.26.98.02	HVAC design is to be per ASHRAE standards, as shown in current Project System Description.	CHPA:GP	08.26.98
DD08.26.98.03	Provide individual climate control in suites.	NS:BC	08.26.98
DD09.09.98.01	Smoking area includes suites and select concession areas (Rooms 123,124)	NS:BC	09.09.98
DD09.23.98.01	Proceed with 21,000 cfm lobby smoke exhaust as opposed to a house/lobby rated separation.	NS:BC,ELS :KS CHPA:GP	09.23.98

E. Theatrical/Interiors

DE07.01.98.01	NC 25 accepted as design criteria.	JHSA:CJ	07.01.98
DE07.29.98.01	Provide suite level public toilet rooms; eliminate toilet rooms in suites, but provide infrastructure MEP.	NS:RT	07.29.98
DE07.29.98.02	Provide expanded commissary kitchen and support areas.	NS:RT	07.29.98
DE08.26.98.01	Sound and lighting control house *mix position* cannot be moved into rear aisle due to handicapped seating quota. This room requires the size shown on sketch current as of 08.26.98.	JHSA:DR ELS:KS	08.26.98
DE08.26.98.02	Hold on final concession design for contracted concessionaire.	NS:RT	08.26.98

DE09.23.98.01	Box Booms will be rigged.	NS:BC	09.23.98
DE10.07.98.01	Change seating configuration to curved format.	NS:RT	10.07.98
DE10.07.98.02	Provide proscenium deluge system with opaque curtain.	NS:RT ELS:KS	10.07.98
DE10.07.98.03	There will not be a front balcony projection position.	NS:BC	10.07.98
DE10.07.98.04	Eliminate the rigging pit due to revised counterweight design.	AA:AS	10.07.98
DE10.21.98.01	Utilize Video/TV/Broadcast scope prepared by AA/JHSA to define building infrastructure to be provided.	NS:BC	10.21.98
DE12.02.98.01	Approximately 95% of speakers will be rigged or stacked on stage; all lighting and sound support will be within 60 Feet of stage.	NS:BC AA:AS	12.02.98

F. Project Support

DF07.01.98.01	It is not necessary to follow Factory Mutual design criteria.	NS:RT	07.01.98
DF07.01.98.02	Project progress meetings will utilize "Last Planner" style.	NS:RT	07.01.98
DF07.15.98.01	Design process to maintain 21 month value stream production schedule.	NS:RT	07.15.98
DF07.15.98.02	Multiple submissions will be made to the City to satisfy the needs of obtaining multiple permit approvals.	NS:RT	07.15.98
DF09.23.98.01	Keep the design process progressing toward an 11.30.98 construction start; the only reason to hold up progress of the drawings is if it is not efficient for the design to proceed.	NS:LL	09.23.98

End of Decisions