AN UPDATE ON LAST PLANNER[1]

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ABSTRACT

The Last Planner system of production control has now been in use for a number of years. Its inventors provide an update consisting of a description of innovations and changes, thoughts on theoretical foundations, proposals regarding work structuring, phase scheduling and reliable promising, and recommendations for further development. Special emphasis is placed on the relationship between scheduling and production control, and also on the technique of phase scheduling to specify the handoffs that are the control foci for Last Planner.

KEY WORDS

Last Planner, linguistic action, phase scheduling, production control, project control, work structuring

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1 The terms "Last Planner" and "Last Planner System" are trademarked by the Lean Construction Institute. As a courtesy to readers, the trademark symbols are omitted in this publication.

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INTRODUCTION

The Last Planner system of production control has been implemented in some form in a number of countries since 1992[3], with the pace of implementation increasing markedly after the publication in 1998 of "Shielding Production" (Ballard and Howell, 1998). To our knowledge, it has been implemented in the United States, United Kingdom, Denmark, Finland, Indonesia, Australia, Venezuela, Brazil, Chile, Ecuador, and Peru. In some cases, implementation has yielded remarkable results; for example, a 90% increase in operating profit for a Peruvian general contractor performing most of its work direct hire (GyM 2002). The Last Planner system was understood to provide a component missing from the traditional project management tool kit. That understanding seems to have been validated. However, it was also assumed that provision of the missing component would prevent the poor project performance that had become a persistent feature of the traditional approach. In other words, we understood the problem in terms of a missing piece and failed to understand that production control was missing because there was no place for it in traditional project management thinking. Consequently, we have not found hard rock in current practice to which to hinge Last Planner and have been compelled to create additional components and to attack the very foundations of project management.[4]

One important such component is the phase schedule, which links work structuring and production control, providing goals to which to steer. Of the numerous papers on Last Planner presented at the IGLC 10 conference, none mentioned phase scheduling, despite the fact that the Lean Construction Institute white paper on phase scheduling was published on the LCI website April 27, 2000 (Ballard 2000*)*. Phase scheduling is the link between work structuring and production control. Without it, there is no assurance that the right work is being made ready and executed at the right time to achieve project objectives.

We have long stressed the importance of variability and suggested as far back as IGLC 4 in Birmingham that Last Planner and the entirety of lean thinking applies most directly to projects that are highly dynamic; i.e., uncertain, complex and quick (cf. minutes of IGLC business meeting, U. of Birmingham, 1996). More recently, researchers in the lean construction community have begun to explore the theory of complex, adaptive systems and to develop systematic links between complexity theory and the lean community's theory of project based production systems.

A theory of management has been developed which locates the Last Planner control function within the management task of operating a project based production system (Koskela, 2000; Ballard & Howell, 2003). This new theory clarifies the meaning of the term "control" and the relationship between planning-as-goal-setting (scheduling and budgeting) and control (causing planned handoffs to occur and thereby enabling achievement of schedule goals).

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[3] The first published mention of Last Planner was in a paper presented at the founding conference of the IGLC (Ballard, 1993). The first publication devoted explicitly to Last Planner was in 1994 (Ballard, 1994).

[4] We, the authors, are much indebted to others for the development of theory and deeper understanding of Last Planner. In this paper, we will often use the term "we" to indicate a tribe of likeminded thinkers extending well beyond ourselves. When in doubt, attribute errors and failures to Ballard and Howell and you will be close enough to right.

At IGLC 9 in Singapore, a link was established between Last Planner and linguistic-action theory. We have just begun to fully understand the implications, but clearly see that coordinated action is achieved through a complex network of requests and promises that is intimately personal and arguably the only viable method of coordination in dynamic conditions. In this paper we only mention the connection between Last Planner and linguistic action.

Despite their fundamental importance, this paper will not address the relationship between Last Planner and the theory of complex, adaptive systems, the theory of linguistic-action or theories of management because these are subjects of other published papers. We rather concentrate on several underdeveloped issues; namely, the link between scheduling and production control and phase scheduling as a technique for forging that link. In addition, there are several developments and innovations that have emerged from the experience of implementing Last Planner. Given the large number of implementations, it would be miraculous if there were nothing to learn from that experience, and indeed there is a great deal to learn. These cannot be developed in detail, but are offered in the spirit of mutual learning for future theorizing and practical application. The paper is organized to address the following issues in the order listed, followed by a conclusion recommending future research:

- Work structuring: linking scheduling and production control
- Phase scheduling: providing goals for Last Planner
- A list of improvements and recommendations that have emerged from theory and practice.

WORK STRUCTURING: LINKING SCHEDULING AND PRODUCTION CONTROL

In the Lean Project Delivery System, the term "work structuring" is used to indicate the various activities involved in specifying how work is to be done, from structuring the project and supply chains organizationally all the way to detailed methods for fabrication and assembly, and including configuration of supply systems (flows of materials and information) with project execution (work flow and resource flow) (Ballard, 1999*)*. We chose not to use the term "process design" because we wanted to critique the prevailing practice of work breakdown structures. We have proposed that schedules are products of work structuring that specify goals and the handoffs between specialists required to achieve those goals. Production control has the job of achieving those handoffs or initiating replanning should that prove infeasible.

The relationship between traditional work structuring and 'lean' work structuring needs clarification. The structuring of a project organizationally is typically done through contracts between separate organizations, and through the assignment of responsibilities to divisions within the various organizations, which can be understood as quasi-contracts. The allocation of work scopes to various parts of the project organization is shown in work breakdown structures, which answer the questions:

- What is the scope of work…for the entire project, …for subprojects A and B, …for subsubprojects A-1 and A-2, …

- Who has responsibility for what work scopes?

In this realm of 'contract management', schedules perform the function of specifying the start, duration and completion dates for the various work scopes the 'contractors' are responsible for delivering, just as budgets specify the amount of money that should be spent for resources expended in that delivery. But to convert this SHOULD to DID, it is necessary to first set achievable goals and then to control (steer) the production process towards achievement of those goals. In the vast majority of circumstances, there is some interdependence between the various work scopes and the organizations responsible for their delivery. Typically there are multiple handoffs between the 'contractors', plus the interdependency from working in the same space and sharing resources such as lifting equipment (Howell, et al., 1993). Consequently planning must be done across work scopes, and not only for work scopes in isolation. When contracts are structured without regard to production, such interdependency is abstracted away. Consequently, unachievable schedule goals are often established and the coordination of interdependent activities is left to the workers struggling in the mud.

Setting achievable goals is done through production-based scheduling and budgeting[5], which consider the processes through which delivery of work scopes (contracts) is to be accomplished. Consequently, project schedules must be expressed in process terms, not simply in terms of work scope. Phase scheduling has been proposed as a tool for generating such schedules. The Last Planner system has been proposed as a tool for steering production towards those schedule goals.

'LEAN' WORK BREAKDOWN STRUCTURES

Everyone recognizes that processes can be divided and aggregated virtually at will, all the way down to therbligs[6], the elemental motions used in motion study. But no one has provided criteria for work breakdown structures that go much beyond 'suit the circumstances'.

The traditional questions behind work breakdown structures are legitimate and must be answered. However, the traditional assumption is that progressive subdivision of work scope eventually turns into specification of processes. What is to be done somehow mysteriously transmutes into how it is to be done. We agree that work breakdown structures have the job of linking product and process, but do not believe that can be done through subdividing work scopes. What is required is a hinge between product and process. We think that hinge is 'handoffs-between-specialists'. But before discussing the phase scheduling process through which such handoffs are specified, some preparation is required regarding work breakdown structures.

What is the current understanding of the connection between product and process as regards work breakdown structures? The Project Management Institute does not link 'what'

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[5] In this paper we do not consider how cost is incorporated in the production control process. Although the practice is well established, it has not been fully documented. That will be the subject of future papers. The basic approach is to focus primarily on cost-to-complete. Comparison of actual versus planned expenditures may reveal problems to be solved, but the fundamental question for production control is "Is there a viable plan for completion, including sufficient resources; i.e., can we get there from here?" Replanning is a key function of production control, revealing the dynamic link between scheduling and controlling.

[6] Motion study was invented by Frank Gilbreth. "Therblig" is constructed from the letters in "Gilbreth".

with ‘how’ beyond decomposing project scope into activities to deliver sub components. The scope is decomposed “…into smaller, more manageable components until the deliverables are defined in sufficient detail to support development of project activities (planning, executing and controlling)” (PMI 2000). Halpin and Woodhead go beyond PMI in “The Design of Construction Operations” to define these levels:

- project: 'work scope'
- activity: 'cost & time control level; physical segment of project' (a subdivision of work scope)
- operation: 'synthesis of work processes'
- process: 'recognizable portion of construction operation'
- work task: ‘assignment’

They locate the transition from scope to process, from ‘what’ to ‘how’, between "activity" and "operation" when the choice of construction technology is made (Halpin & Woodhead, 1976)[7]. However, the transition is not explained. No linking pin or hinge is provided.

We accept Halpin and Woodhead’s hierarchy with the critical exception of the “activity” level, which is misnamed, as it is simply a further subdivision of work scope, of which there can be an indefinite number. We substitute “phase” in its place, indicating the time chunks in which the product is to be built, typically based on product functional systems; e.g., the substructure of a building. The scope-to-process transition in our proposal occurs in the movement from specifying a phase, its duration, and target completion date in a master schedule to designing a production system for producing that 'product' within those constraints, which is done in phase scheduling. Example:

- Project: Commercial office building
- Phase: Site Preparation, Substructure, Superstructure, Skin, Building Systems, Fit Out
- Operation (within the Substructure phase): Layout, Excavate, Shore, Place Drilled Caissons, Cap Piles, Place Underground Utilities, Build Foundations, Build Walls
- Process (within the Place Drilled Caissons activity): Fabricate Cage, Drill Hole, Place Cage, Pour Concrete
- Step[8] (within the operation Fabricate Cage): Acquire Materials, Place straight bar in jig, Weld coiled bar helically around cylinder, Fit and tack lifting bands, Weld out lifting bands

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[7] This is perhaps an excusable omission given their focus on design of construction operations. However, in their view, work is organized by craft and decomposed into work tasks. No particular attention is paid to the assignment of work, Rather assignments are understood as the natural consequence of work break down structure. The choice of technology and traditions of craft and contract establish the operations necessary to complete the scope.

[8] We are not aware of any generally accepted terminology for the hierarchy indicated here by operation-process-process steps. Shingo’s famous advice to first design process (material and information flow)

- Assignment (for today): Perform welding steps in the operation Fabricate Cage. Fabricate cages 101, 102, and 103 in that order.

Focusing on phase scheduling, it is perhaps apparent that operations tend to align with the specialties performed by different companies or different types of work groups. For example, one company might do Layout, Excavate and Shore. Another might Place Drilled Caissons (piling), a mechanical contracting firm is likely to place underground piping, an electrical contractor underground wire and cable, possibly a separate controls/instrumentation contractor for control systems, and finally a carpenter-based contractor might build foundations, slabs, and walls.

The integration and coordination of these various specialists' operations is the purpose of the phase schedule. The level of detail in the phase schedule is determined by the requirement that the phase schedule specify the handoffs between the specialists involved in doing the work in that phase. In this context, "specialist" is equivalent to "work group type". Thus, the handoff between excavation and shoring should be specified even when the work is performed by a single contractor because excavation and shoring are distinct capabilities and tend to be the responsibility of distinct work groups, even though they may be performed interactively one with the other and the work groups may belong to the same organization.

To summarize, we propose the concept of "phase", based on product functional systems, to occupy that level of the work breakdown structure that comes after the subdivisions of the product to be built. The work to be done by specialists involved in a phase is then structured not by further subdivision of product but by specification of process. That is done through the technique we have labeled "phase scheduling".

PHASE SCHEDULING[9]

We recommend that master schedules for projects or subprojects be at milestone level, specifying the timing of the various phases through which the project will move. Following a Last Responsible Moment strategy (Ballard & Zabelle, 2000) , the phase scheduling technique is used to develop a more detailed work plan that specifies the handoffs between the specialists involved in that phase. These handoffs then become goals to be achieved through production control. Schedules provide the goals towards which Last Planner steers, replanning as necessary toward progressively more fundamental goals. In other words, we try to achieve each handoff between specialists specified in the most highly detailed project schedule, the phase schedule. Failing that, we fall back to the phase schedule milestone itself, attempting to develop a plan-to-complete that allows achieving that goal. Failing that, we fall back to the master schedule and try to find a plan-to-complete that allows recovery to the master schedule milestones.

LCI recommends using pull techniques and team planning to develop schedules for each phase of work, from design through turnover. The phase schedules thus produced are based

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before designing operations (conversion processes) is a different use of the terms than that of Halpin and Woodhead (Shingo 1988).

[9] Much of this section is a reproduction of the Lean Construction Institute's White Paper #7: Phase Scheduling (Ballard, 1997).

on targets and milestones from the master project schedule and provide a basis for lookahead planning.

A pull technique is based on working from a target completion date backwards[10], which causes tasks to be defined and sequenced so that their completion releases work; i.e., achieves a handoff. A rule of "pulling" is to only do work that releases work - requested by someone else. Following that rule reduces the waste of overproduction, one of Ohno's seven types of waste.[11] Working backwards from a target completion date eliminates work that has customarily been done but doesn't add value[12].

Team planning involves representatives of all organizations that do work within the phase[13]. Typically, team members write on sheets of paper brief descriptions of work they must perform in order to release work to others or work that must be completed by others to release work to them. They tape or stick those sheets on a wall in their expected sequence of performance. Usually, planning breaks out in the room as people begin developing new methods and negotiating sequence and batch size when they see the results of their activities on others.

The first step of formalizing the planning and the phase schedule is to develop a logic network by moving and adjusting the sheets. The next step is to determine durations and see if there is any time left between the calculated start date and the possible start date. It is critical that durations not be padded to allow for variability in performing the work[14]. We first want to produce an 'ideal' schedule based on average duration estimates (technically, the median rather than mean since the distribution of duration values is skewed to the long side), a practice recommended by Goldratt in *Critical Chain* (p. 45, Goldratt, 1997).

The team is then invited to reexamine the schedule for logic and intensity (application of resources and methods) in order to generate a bigger gap. Then they decide how to spend that time: 1) assign to the most uncertain and potentially variable task durations, 2) delay start in order to invest more time in prior work or to allow the latest information to emerge, or 3) accelerate the phase completion date. If the gap cannot be made sufficiently positive to absorb variability, the phase completion date must slip out, and attention turns to making up

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10 Some companies describe this process as "Reverse Phase Scheduling"

11 Workable backlog tasks may not release work, but are only to be used as necessary to maintain resource utilization and continuity, and is not to be used if doing that work now makes later work more difficult or hazardous (Ballard and Howell, 1998).

12 We are here in the realm of production system design and setting goals for the system. Here we can contribute to waste elimination by not designing it into the system. The actual elimination of waste is a function of system operation and control, which must face old habits of thought and action, inadequate supply systems, and many more obstacles.

13 We did not invent team planning and do not know who did. The authors first encountered team planning on a Jacobs Engineering project in 1994.

14 It is standard practice to try to build as much padding as possible into the duration of tasks for which you are responsible. This results from lacking a mechanism for coordination. The Last Planner system will eventually create confidence both that interests will be protected and that work flow will be managed. Consequently, designer and builder specialists can provide unpadded durations for their assigned tasks, confident that uncertainties will be buffered and that unfair burdens will be rectified.

that time in later phases. **The key point is to deliberately and publicly generate, quantify, and allocate schedule contingency[15].**

PURPOSE OF PHASE SCHEDULING

The purpose of phase scheduling is to produce a plan for completing a phase of work that maximizes value generation and one that everyone involved understands and supports; to produce a plan from which scheduled activities are drawn into the lookahead process to be exploded into operational detail and made ready for assignment in weekly work plans.

PARTICIPANTS

Participants in the phase scheduling process are representatives of those with work to do in the phase. For example, a team working to schedule a construction phase would typically involve the general contractor and subcontractors, and perhaps stakeholders such as designers, client, and regulatory agencies. Participants should bring relevant schedules and drawings including the master schedule and perhaps even the contract.

PROCESS:

1. Define the work to be included in the phase; e.g., foundations, building skin, etc.
2. Determine the completion date for the phase, plus any major interim releases from prior phases or to subsequent phases.
3. Using team planning and sticky backed cards on a wall, develop the network of activities required to complete the phase, working backwards from the completion date, and incorporating any interim milestones.
4. Apply durations to each activity, with no contingency or padding in the duration estimates.
5. Reexamine logic to try to shorten the duration.
6. Determine the earliest practical start date for the phase.
7. If there is time left over after comparing the time between start and completion with the duration of the activities on the wall, decide what activities to buffer or pad with additional time.
    a. Which activity durations are most fragile?
    b. Rank order the fragile activities by degree of uncertainty.
    c. Allocate available time to the fragile activities in rank order.

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[15] We part company from Goldratt when we allocate schedule contingency to individual activities. We aim to create a stable plan. Goldratt advocates taking every opportunity to accelerate task completion, which places a tremendous burden on participants. If reducing duration is a goal, we would make that objective explicit in the planning meeting and test the basis for setting each duration carefully and define how the organization would take advantage of early completions, for example by early signaling by performers that activity duration is now likely to be reduced.

8. Note: this is contingency you intend to spend, unlike budget contingency.
9. Is the team comfortable that the available buffers are sufficient to assure completion within the milestone(s)? If not, either replan or shift milestones as needed and possible.
10. If there is excess time available beyond that needed for buffering, decide whether to accelerate the schedule or use the excess to increase the probability of on-time completion.
11. Reserve unallocated time in a general contingency buffer for the phase.

In summary, phase scheduling is proposed as a technique for developing a plan for completing work within a phase of a master schedule. It can also be used as one means for developing master schedules themselves. The plans are produced using a team approach, backward pass and public allocation of schedule contingency to absorb or buffer remaining variability. The handoffs between the various specialists involved in the phase become the focal points for control through the Last Planner system. Failure to specify these handoffs leaves Last Planner without clear objectives. Consequently, phase scheduling is an integral part of the lean project management system.[16]

NEWS FROM THE FRONT LINES[17]

Implementation experience and better thinking have contributed to the following list of recommended changes in Last Planner practice:

- Make customer acceptance explicitly the measure of release; i.e., task completion. That implies the necessity of specifying on the weekly work plan to whom the work will be released. The customer of a handoff is obviously best situated to judge whether or not it was acceptable as to time and content. This is current practice at MTH in Denmark and was also implemented by Aera Energy in its "work flow card" initiative. (For more information, contact the authors.)
- Identify tasks and assignments that are either handoffs to someone else or that have implications for coordinating the use of shared resources. This is consistent with the focus of control on handoffs between specialists. Execution of a task may involve going through any number of process steps, but as long as there is no handoff to someone else, control is exercised by some other means than Last Planner. That by itself might suggest assignments extending over more than one day, but many tasks will involve sharing resources such as space, equipment, deliveries and such, so should be specified in the Last Planner system even

[16] We do not mean to suggest that phase scheduling is the only technique needed or useful for performing the scheduling function. Integration of phase scheduling with linear scheduling, simulation and other tools is a task for future papers.

[17] After IGLC 10 in August, 2002, Professor Carlos Formoso graciously invited Glenn Ballard to spend some time at the University of Rio Grande do Sul. During that visit, Ballard made a presentation to the students and faculty of the construction management and engineering program, which included thoughts on improving Last Planner, many of which are reproduced here.

though their completion does not accomplish a handoff/release of work to someone else.

- Extend commitment planning to individual workers. The objective is to have the workers control work flow, as they do in a Toyota assembly plant.
- The learning component of Last Planner does not appear to be used; at least not in a way that leaves a trace. Our standing recommendation has been to identify reasons for each failure to deliver on a commitment, using the 5 Why's technique to identify actionable causes in an effort to avoid repetitive failure for the same reason or cause. Some more formal mechanism seems to be required for that learning process to happen. A recommendation is to rotate responsibility for making a brief report in weekly planning sessions on action taken to prevent plan failures, and to praise learning rather than blame failure. In tandem with that, emphasis should be placed on the direction and rate of change in PPC rather than on its absolute level. In other words, supposing one team first measures its PPC at 60% and another at 30%. That doesn't mean very much. What matters is how rapidly each term learns to do better planning, the measure of which is the change in PPC.
- Incorporate linguistic action and reliable promising[18]. At IGLC 9 in Singapore, a link was established between Last Planner and linguistic-action theory. We may not yet fully understand the implications, but clearly see that coordinated action is achieved through a complex network of requests and promises that is intimately personal and arguably the only viable method of coordination in dynamic conditions.
- Measure PPC against planned day (versus week) for release. This becomes the default value for the commitment time bucket. In specific circumstances release might be appropriately measured against a planned week, hour, etc., just as the lookahead window might be 3 weeks or 12 weeks. NB: This is not the same as making daily commitments, but rather is a matter of 'planning to the day'.

QUESTIONS

- Should work groups (squads, gangs, crews) meet daily to align assignments, identify make ready actions needed within the day, and identify problems requiring replanning? Previous Last Planner meetings have been weekly. The participants have been the "last planners"; i.e., the front line supervisors who speak for the direct workers that are members of their work group. A possible extension is to have each Last Planner hold daily meetings with their own work groups. The commitments made within a work group in these daily meetings may or may not be recorded in the Last Planner system. Some are currently trying to extend the complete Last Planner system to the work group level.

[18] See Macomber and Howell (2003).

- How far in advance should commitments be made? The standing practice is to make commitments at the end of one week for execution during the next week. Thus the lead time may vary from one working day to five. Some are experimenting with making commitments daily. That is being done within a context of 'work streams'; i.e., the sequence of predescessor-successor activities required to 'make ready' execution of the commitment. This context eliminates the potential problem that the lead time for commitments is too short to coordinate action. But that leads to the next question…
- Should multiple levels of commitment be recognized? What appears to be emerging is a process in which the level of commitment changes as a task moves into different time buckets. This occurs on the basis of previously agreed rules of behaviour, without direct contact between the people involved. For example, there is a type of commitment made when a subcontractor agrees to a phase schedule produced jointly with others. That commitment, like all commitments, is necessarily conditional upon the performance of those on whom he/she is dependent. We have proposed in Lean Construction Institute seminars that the appropriate rule should be to allow a committed task to remain in the phase schedule unless or until it is impossible to execute as scheduled. The rule for tasks that enter the project lookahead window is to notify 'customers' as soon as the provider loses confidence that the task can be executed as planned. The rule for weekly work plans is to include only tasks from which all constraints have been removed and regarding which the promiser is convinced she can deliver as promised. Accordingly, there are different levels of commitment and correspondingly different rules for the behavior of providers and customers. The Last Planner system is extremely dependent upon these rules being shared and followed by the specialists trying to coordinate action among themselves.
- How to better assure that Last Planner is used within a distributed control system? We are concerned specifically about the tendency for higher level managers to micromanage weekly work planning rather than maintain a system assurance role. Routinely, direct examination of weekly work plans should be made only by the immediate supervisor. Management levels above that should do what's necessary to assure themselves that Last Planner is being used properly by their subordinates, which likely will include occasional examination of plans, but generally will rely on examination of PPC and learning initiatives triggered by plan failures. There is tension here between the transparency required for mutual adjustment and the risk such transparency poses of mismanagement. One solution is to limit access to information; e.g., through password access to specific data in Last Planner. Another is to educate/select managers that understand and value distributed control. The latter is obviously preferable, but may not be achievable entirely and certainly not immediately.
- Does application of the Last Planner system reduce the variability in duration of construction activities? Variability reduction is a key objective of the Last Planner system and consequently should be measured. Furthermore, if the average

duration and variability around that average can be measured, then schedule contingencies (buffers) can be more accurately sized.

CONCLUSION

The Last Planner system of production control has been broadly and successfully implemented in the last several years. It is time now to return to both theoretical and practical work on production control, taking advantage of the experience that has accumulated. This paper can be no more than a call for that theoretical and practical action, some aspects of which have been presented in this paper.

Major theoretical and practical initiatives related to Last Planner have already been launched. Those include its relationship to linguistic-action theory, the theory of management, and the theory of complex, adaptive systems.

Among the critical new issues are work structuring and the relationship between scheduling and production control. We have proposed a basis for structuring work for flow. We have also proposed phase scheduling as a means for creating a work plan specifying handoffs between specialists using team pull.

We have also made a number of observations and recommendations concerning the application of the Last Planner system, in addition to some questions regarding theory and practice.

Theorists and practitioners are encouraged to pursue these and other research and practical opportunities revealed by the previous application of Last Planner throughout the world.

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