LAST PLANNER AND ITS ROLE AS CONCEPTUAL KANBAN

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ABSTRACT

Historically, the Last Planner™ System of Production Control has been coupled with the body of Lean Construction literature. However, the mechanism of the Last Planner and how it fits within accepted lean thinking has not always been apparent. This paper addresses this uncertainty. It examines simulated results from a lean simulation game and argues that the Last Planner serves the role of a conceptual kanban, among its functions—and therefore sits squarely within the domain of Lean theory.

KEY WORDS

Last Planner System, Kanban, Airplane game, Lean Construction

INTRODUCTION

Lean construction developed as a response to challenges within the construction industry, known for budget and schedule overruns and an adversarial, litigious culture (Kumaraswamy 1997; Owers et al. 2007; Salem et al. 2006). To address these concerns and inspired by successes observed in lean manufacturing, Lauri Koskela, Greg Howell and Glenn Ballard (Ballard 2000a; 2000b; 2008; Koskela 1992; 2000) proposed that lean theory be applied to the construction industry. They were instrumental in organizing the International Group for Lean Construction (IGLC 2009) and the Lean Construction Institute (LCI 2009), as well as statewide and international branches of these organizations.

Adoption of lean thinking requires a dedicated cultural shift within an organization. Because of this, advocates of lean construction utilize simulation games developed for the lean manufacturing industry to introduce lean to newcomers. Lean simulation games may be viewed as miniature controlled experiments that quantitatively demonstrate beneficial outcomes from lean (experimental) versus non-lean (control) plays of the game (Alarcón and Ashley 1997; Howell 1998; Rybkowski et al. 2008; Sacks et al. 2005; 2007; 2009; Tommelein et al. 1999; Verma 2003). The games are intended to provide convincing evidence that lean is more than a trendy philosophy demanding leaps of faith. Lean is a science; it works (Hopp and Spearman 1996).

One lean simulation game is popularly called the Airplane Game (Visionary Products Inc. 2007; 2008). The Airplane Game introduces newcomers to the importance of cell design, small batch size, pull scheduling and a flexible workforce—all which have been demonstrated to enhance flow (Rybkowski et al. 2008). When playing the Airplane Game, participants are positioned around a table and sequentially assemble a toy Lego® airplane, modeling a factory supply chain or assembly line. The earliest rounds of play are designed to simulate business as usual. Initially work stations are inefficiently arranged with respect to subsequent customers.

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Pieces are pushed through assembly, and are done so in large batches. Each subsequent play of the game transforms the process by introducing a single, additional, lean intervention. For example, work stations are rearranged into a logical cell of adjacencies to support flow, components transferred between participants are pulled rather than pushed, batch sizes are reduced from five to one-piece flow, and participants are permitted to assist other stations, representing the impact of work leveling and a flexible workforce. A third party mediator collects metrics after each round of play, quantifying changes such as time elapsed until first plane, number of planes completed, Work-in-Progress (WIP) and error rates. A comparison of metrics following each round of play demonstrates the importance of lean interventions. For example, when lean principles are implemented, time to first plane is reduced, number of planes completed is increased, Work-In-Progress decreases and error rates decrease.

Collecting metrics during the play of lean games, or computer simulations of these games, is one response to skeptics who might claim that improvements are merely an outcome of Hawthorne or placebo effects—phenomena about which researchers caution because they may lead to inaccurate conclusions (Leedy 2004). Of special relevance to this paper is the drop in WIP when batch sizes of both 5 and 1 are subjected to pull versus push systems, as shown by metrics collected during a computer simulation and comparison live playing of the airplane game, as shown in Table 1. Pull requires the implementation of a kanban to signal to upstream players that a downstream player is reader to receive parts.

Table 1. Results from the Airplane Game based on Computer and Live Simulation. Adapted from Rybkowski et al. (2008) and Rybkowski (2009).

	Transfer type *(system)*	**Planes completed** *(# of units)*	**Time elapsed until first plane** *(sec)*	**WIP from WS1**	**WIP from WS2** *(# of units)*	**WIP from WS3**	**WIP from WS4**	**WIP Total**
Batch Size 5								
Computer	Push	15	138	54	4	5	0	63
Live	Push	12	150	30	4	7	1	42
Computer	Pull	10	138	5	1	4	0	10
Live	Pull	10	145	5	2	3	0	10
Batch Size 1								
Computer	Push	20	46	55	0	3	0	58
Live	Push	20	43	51	1	5	0	57*
Computer	Pull	12	46	1	0	1	0	2
Live	Pull	12	39	1	1	0	0	2

*WS1 ran out of pieces at 5'20"

A number of lean interventions, such as cell design, small batch sizes, work leveling and a flexible work force, arguably make intuitive sense. However, one of the less intuitive principles of lean is the importance of pull. The concept of pull originated when Toyota's Taiichi Ohno observed the restocking of supermarket shelves during a 1950s trip to the US (Ohno 1988, pp. 25-27). According to Cheng and Podolsky (1993, p. 42), "…the pull mode of manufacturing only allows parts to be moved from the previous operation to the next when the subsequent operation is ready to process." A kanban card signals to an upstream processing station that a downstream processing station is ready to receive its parts. WIP moves between stations only when downstream stations are able to process parts. In lean parlance, this rate of production is termed takt time and is determined by the demand—or pull—of the customer. The terms kanban, just-in-time (JIT), flow, and pull are used nearly synonymously in the literature on lean (Liker 2000; Womack and Jones 2003). For simplicity, this paper will refer to the key vehicle for achieving flow, the kanban.

Principles for implementation of kanban systems are documented by scholars (Hopp and Spearman 2004; Krajewski 1987; Ohno 1988; Singh and Falkenburg 1994) and summarized by Huang and Kusiak (1996), who note that a kanban system functions to (1) level production, (2) limit complex information and hierarchical control of the factory floor, (3) prevent unregulated withdrawal of parts, (4) ensure that only parts needed at each stage are withdrawn, (5) prevent defective parts from being sent to succeeding stages, and (6) ensure that only the needed quantity of parts is produced.

APPLICATION OF KANBAN TO LEAN CONSTRUCTION

Bertelsen (2002) argues there are two camps to Lean Construction: the Transformation Flow Value (TFV) framework championed by Lauri Koskela (1992; 2000) and the Last Planner System of Production Control developed by Glenn Ballard (2000b). This paper argues that it is precisely the kanban nature of Last Planner that unites the two theories as one and the same.

Although the lean construction community acknowledges the importance of kanban and has begun to experiment with kanban, prior literature primarily addresses developing literal kanban systems on site (Jang et al. 2007; Kim et al. 2007). Koskela and Ballard speak to the role the Last Planner plays in reducing waste by preventing workers from "making do"—starting work before all items required for completion of the job are available (Koskela 2004; Koskela and Ballard 2006). However, to my knowledge, no paper has as yet directly acknowledged the kanban nature of the Last Planner. Waste-reduction is, in fact, the role of the kanban.

THE PULL OF THE KANBAN

When playing the Airplane Game, the primary author of Rybkowski et al. (2008) directed players to symbolically represent a kanban by an 8 ½" x 11" piece of paper that was used to both signal and deliver parts from an upstream station to a downstream station when the downstream station was ready to receive parts. Although a kanban generally takes the form of a card or signboard, this paper will symbolically represent it as a cart, as shown in Figure 1, that travels between the downstream station (B) and upstream station (A); an empty cart is a signal to an upstream station that it needs to be filled.

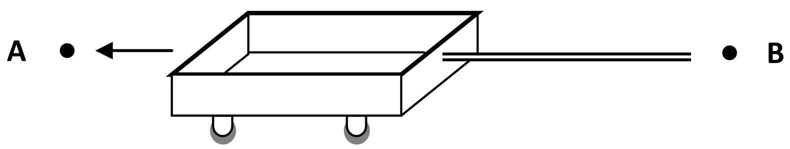

Figure 1. A metaphorical kanban cart. Reprinted from Rybkowski (2009, fig. 72).

In a manufacturing assembly line, a kanban serves at the interface between each station and ensures that the final customer or stocking requirements pull the assembly process, ideally resulting in one-piece flow (Hopp and Spearman 2004, Huang and Kusiak 1996), as depicted in Figure 2. A primary assembly line (A-B-C-D-E) is served by subsytem branches which direct assembly of parts that make their way to the primary flow stream as shown in Figure 3.

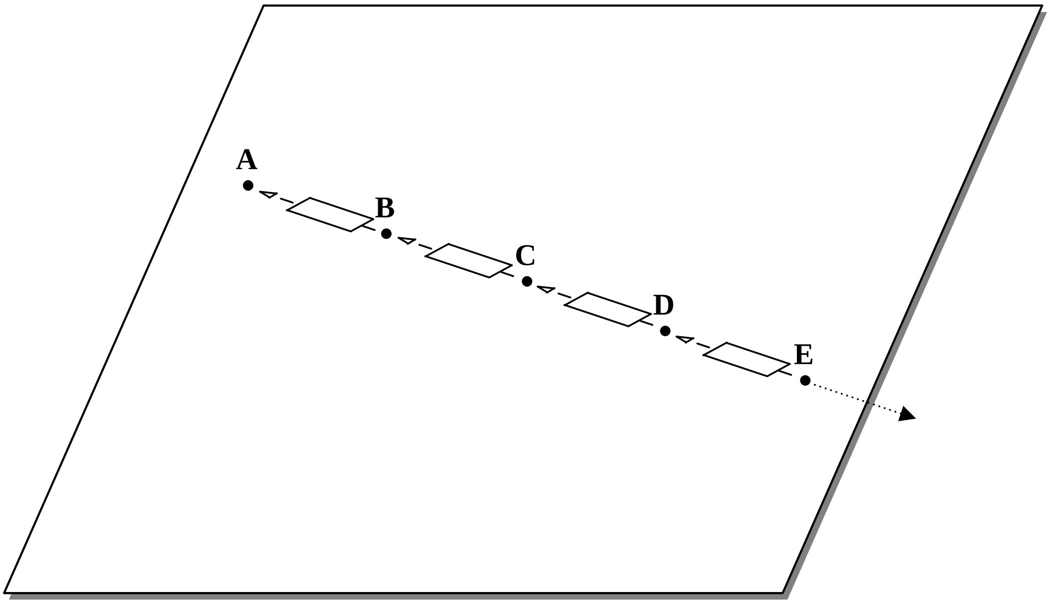

Figure 2. Kanban carts transferring resources between stations along a linear manufacturing chain. Reprinted from Rybkowski (2009, fig. 75).

Applying flow through the use of a kanban is more complicated on a construction site than on a manufacturing floor for several reasons. Unlike a fully weather-proofed and enclosed factory building, environmental elements are difficult to control on a construction site. Also, unlike a factory environment with fixed processor stations and a product to which value is added as it progresses from one station to the next, a site-built construction product is fixed; it is the processor that must be mobile.

Despite these challenges, the concept of kanban is important in construction planning and control. Without a kanban, construction stakeholders may be tempted to optimize their own processes at the expense of a project. Ronen (1992) argues there are three principle reasons specialty contractors make do, or perform work before they should. These include: (1) the efficiency syndrome (urge to utilize resources as completely as possible), (2) the pressure for immediate response (belief that starting sooner will result in earlier completion), and (3) improper division into levels of assembly (where the number of components grows to an uncontrollable level) (Koskela 2004; Ronen 1992). By way of example, Ballard describes his own experience with dry wall specialty contractors who installed their product ahead of HVAC contractors, even though this action created rework and inefficient processing for the overall product. Ballard argues that workers need to be assured by their superiors that it is better to stand inactive with their hands in their pockets than to overproduce or to perform work that is out of turn (Ballard, personal communication 2004; 2005). Recognizing the benefits of this way of working requires a fundamental shift in one's understanding of productivity.

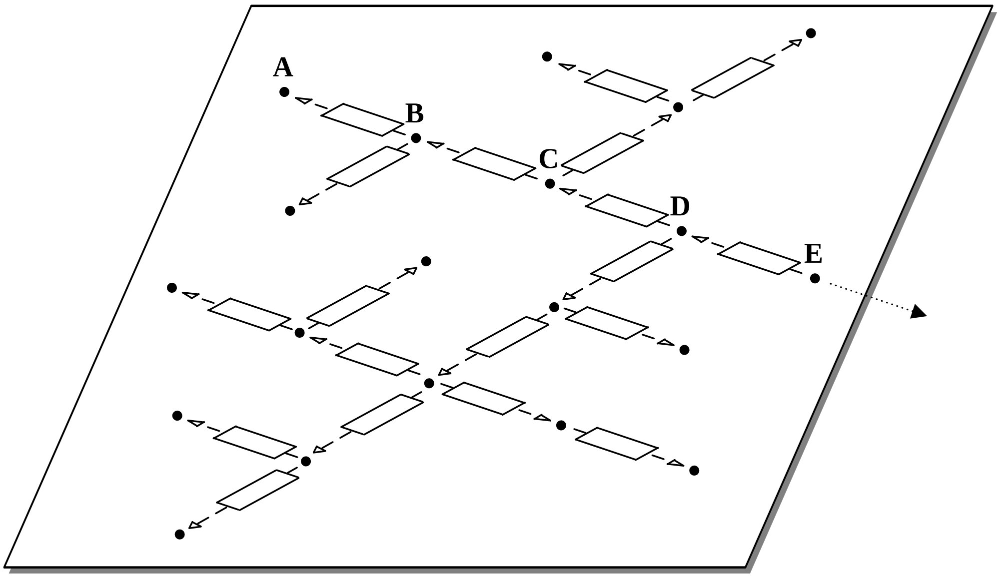

Figure 3. Kanban carts transferring resources between stations with feeder flows in preparation for assemblies to be added to the primary chain (A-B-C-D-E). Reprinted from Rybkowski (2009, fig. 76).

The Last Planner serves multiple functions, including reducing variability and enhancing learning (Ballard 2000b). However, the Last Planner arguably also offers a type of kanban the construction industry lacked before the arrival of lean construction. Instead of taking the physical form of cards, the last Last Planner may be viewed as a conceptual kanban, assuming the form of written schedules. Also, unlike a literal kanban on an industrial assembly line that is informed by individual processing stations, a Last Planner schedule is informed by a cloud of knowledge—information shared by multiple stakeholders brought early into the design and scheduling process during "Big Room" and reverse phase scheduling meetings, as depicted in Figure 4. Like a kanban that ensures an assembly is not completed either before or after the precise moment at which it is requested, an informed Weekly Work Plan (WWP) controls entry to the assembly process. Prior phases of Last Planner, including the Master Schedule, Phase Schedule and Six Week Lookahead arguably also serve as conceptual kanban systems, preparing assemblies as they are pulled through toward the WWP (Hamzeh 2009).

In Figure 5, assemblies under preparation for entry into the WWP during Lookahead Planning are graphically represented as layers of an onion where constraints are successively removed (i.e. tasks made ready). Several tasks have been grouped to acknowledge that some activities require multiple weeks to be made ready. The greyed zone represents the temporal cross section a project manager must scrutinize to ensure that assemblies will arrive by the time they are pulled onto the WWP kanban. This cross section moves to the right with the passage of time as the project develops.

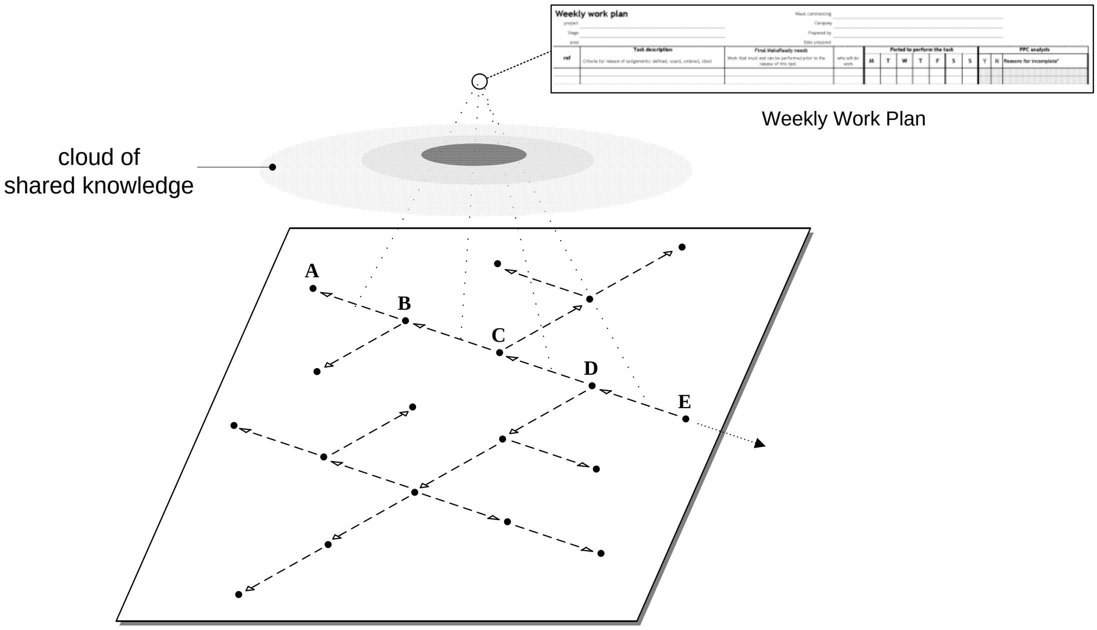

Figure 4. Cloud of shared knowledge: the Last Planner as conceptual kanban. The A-B-C-D-E stream represents the WWP. Flows feeding into the A-B-C-D-E stream represent make-ready preparation accomplished during Lookahead scheduling. Reprinted from Rybkowski (2009, fig. 80).

By way of analogy, the Last Planner may be envisioned as a train that travels between New York and San Franscisco. The train is pulled at a rate set by a predetermined arrival time in San Francisco (in Lean Construction, this delivery date was established during reverse phase scheduling). Passengers must prepare themselves to board at the precise time the train stops at their station. Just as passengers must sometimes spend time in a waiting room to ensure timely boarding, stakeholders on a lean construction project must sometimes wait to install their components at the site. In lean thinking, optimization of the whole trumps optimization of individual parts. Discussion of the lean contract—the Integrated Form of Agreement (IFOA)—is outside the scope of this paper, but is mentioned here to respond to concerns that individual stakeholders must sacrifice themselves on a lean project. On the contrary, the IFOA contract is structured to support risk-sharing and to financially reward collaborative practices (Lichtig 2006).

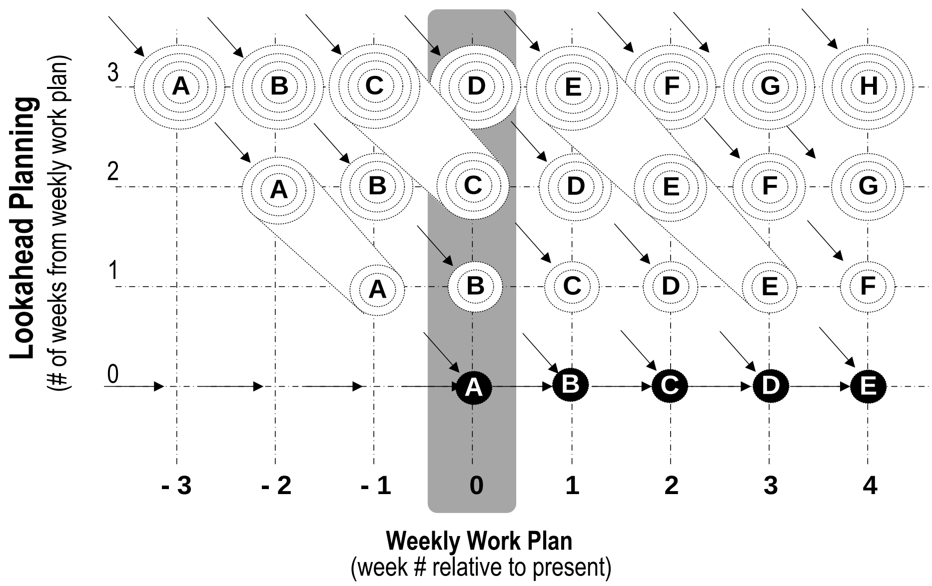

Figure 5. The Last Planner System of Production Control may be viewed as consisting of a series of conceptual kanbans. The WWP kanban is represented by the A-B-C-D-E chain along the horizontal axis. The Lookahead planning process may also be viewed as a series of conceptual kanbans that run diagonally to calendar time. Concentric circles indicate constraints that are removed over time as tasks are made ready. The Last Planner makes tasks ready through the cross-sectional view window shown in grey. Like a traditional kanban, the Last Planner ensures that tasks are completed at the precise moment at which their contribution is required.

CONCLUSION

The lean community largely tests ideas using a process known as action research—a case study research methodology that is, by its nature, a creative act (Greenwood et al. 1993; Westbrook 1995). Identifying Last Planner as a conceptual kanban matters because it addresses the concerns of skeptics who argue action research does not offer the rigor of a randomized controlled trial. Because construction sites are unique, the gold standard of scientific experimentation, the randomized controlled trial, cannot easily be applied to a construction project. The one-off nature of most construction projects undermines the ability to randomize and introduce a control—methodologies central to the implementation of a randomized controlled trial. Even if a construction project could be multiplied with an established control, as is sometimes possible with large, repetitive, residential developments, the numbers of confounding variables are typically immense. The limitations in drawing conclusions from case study and action research experimentation make links to controlled computer simulation experimentation that much more crucial.

Recognizing that the Last Planner plays a conceptually similar role as the kanban in the Airplane Game simulation—in addition to its other roles—scientifically validates the claim that Last Planner is critically responsible for reduced Work-in-Progress (a form of waste) reported in case studies where it it has been implemented (Ballard 2000; Koerckel and Ballard 2005).

The purpose of this paper is to open up the topic of Last Planner as conceptual kanban as a point for discussion and potential future research. For example, it could be worthwhile to explore mathematical equivalencies between the impact of a literal kanban system and that of the Last Planner System of Production Control.

As construction WIP is pulled through the Lookahead and WWP conceptual kanbans, assemblies are tranformed into objects of increasing value. The perception that there are "two isolated islands" in lean construction, as perceived by Bertelsen (2002), vanishes. Arguably, it is through the conceptual kanban that Koskela's TFV framework and Ballard's Last Planner become fused into one.

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