Khan, S. and Tzortzopoulos, P., 2015. Improving Design Workflow with the Last Planner System: Two Action Research Studies. In: *Proc. 23rd Ann. Conf. of the Int'l. Group for Lean Construction*. Perth, Australia, July 29-31, pp. 568-577, available at www.iglc.net

IMPROVING DESIGN WORKFLOW WITH THE LAST PLANNER SYSTEM:TWO ACTION RESEARCH STUDIES

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ABSTRACT

Variability in workflow during the design stage of building projects has been widely acknowledged as a problem related to poor planning and control of design tasks and has been identified as a major cause of delay in building projects. The Last Planner system (LPS) of production planning and control helps to create predictable and reliable workflow by enabling the management of the range of relationships, interfaces and deliverables involved in a project. This paper presents results of implementing LPS in design to minimize variability in workflow within BIM-based building design projects. Action research was used to implement and evaluate the effectiveness of LPS weekly work planning (WWP) to improve workflow during the design development phase of two building design projects. The research was carried out with the collaboration between design practitioners at two building design firms in Florida and the researchers as facilitators. Overall PPC (Percent Plan Complete) measurements suggest that design workflow improved in both projects after WWP was implemented. However, efforts to use BIM in a lean way in the two projects (discussed in detail in an IGLC22 conference paper by the authors of this paper) were believed to be partly responsible for the improvement in design workflow.

KEYWORDS

Design workflow variability, LPS, BIM.

INTRODUCTION

Traditional design planning practice lacks a mechanism to manage workflow (Koskela, Ballard and Tanhuanpää, 1997). The planning of design tasks has traditionally been done from the top down with a project management team, consisting of a project manager and the lead designers (the architect and the engineers), meeting regularly to identify upcoming tasks on a master schedule and, without making sure that the tasks can actually be done, pushing them down to drafting (CAD or BIM) technicians to execute. The primary goal of traditional push planning is to finish design tasks by due dates as determined on the master schedule,

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design management being based on a drawing due date schedule and a summary drawing circulation list (Koskela, Ballard and Tanhuanpää, 1997). The order or timing of individual design tasks are not scheduled but left to be self-managed by each design discipline (Koskela, Ballard and Tanhuanpää, 1997). Traditional push planning is therefore not very reliable.

LPS has been applied very successfully in the past as a planning and control tool during the construction stage of building projects (Ballard and Howell, 1994; Koskenvesa and Koskela, 2012). However, the few reported applications of LPS during the design stage of building projects (e.g., by Hamzeh, Ballard and Tommelein, 2009; Bhatla and Leite, 2012; Wesz, Formoso and Tzortzopoulos, 2013) have been somewhat general in nature and limited in scope.

LPS has four planning levels: Master Planning, Phase Planning, Look-ahead Planning and Weekly Work Planning. At the WWP level, the right sequence of work and the right amount of work that can be done are selected (Ballard and Howell, 1994). LPS can help to increase task planning reliability and reduce workflow variability at the WWP level by filtering planned tasks to ensure that preceding tasks have been completed and by securing firm commitment of resources by the Last Planners (AlSehaimi, Tzortzopoulos and Koskela, 2013).

As a pull planning tool, WWP has been used very effectively in the past during the construction stage of building projects by the various building trades to plan and control their tasks collaboratively in order to increase task planning reliability and reduce construction workflow variability, but its application to design has not been so widely investigated. This paper demonstrates that WWP can also be used effectively during design by the various design disciplines to plan and control their tasks collaboratively in order to increase task planning reliability and reduce design workflow variability.

RESEARCH METHOD

Action research (AR) allows an existing solution, like WWP, to be evaluated in an organizational context, with the knowledge acquired from the implementation used to make recommendations for future application of the solution (Iivari and Venable, 2009). Researchers who adopt AR are likely to be practitioners who wish to improve understanding of their practice or more likely to be academics who have been invited into an organization by decision-makers aware of a problem requiring action research but lacking the requisite methodological knowledge to conduct it (O'Brien, 2001).

Using AR, the researchers worked closely with design practitioners to implement, monitor, and evaluate the effectiveness of, WWP during the design development phase of a building design project at two architecture/engineering (AE) firms in Florida. Design development is the phase of the building design process in which the preliminary design model, created by the architect during the schematic design phase, is shared with other members of the multidisciplinary design team to be used as a starting point for their specialized design input. It is also the phase that requires a tremendous amount of coordination of the efforts of the various design disciplines to finalize both form and function. The design development phase was scheduled to last sixteen weeks in both projects.

One of the firms is located in Melbourne and was designing a $23.9 million, 14,865m², seven-story hotel to be built in Melbourne Beach, using the design-bid-build method of procurement. The action research study ran from May 2013 to August, 2013. The hotel design team consisted of a project manager, an architect, two intern architects (IAs), a structural engineer, a mechanical engineer, an electrical engineer, a plumbing engineer, four engineers-in-training (EITs), a BIM manager, and six BIM technicians.

The other firm is located in Fort Pierce and was designing a $13.6 million, 8,919m², six-story apartment building to be built in Sebastian, using the design-bid-build method of procurement. The action research study ran from July 2013 to October 2013. The apartment design team consisted of a project manager, the architect, an IA, a structural engineer, a mechanical/electrical/plumbing (MEP) engineer, three EIT, a BIM manager, and five BIM technicians.

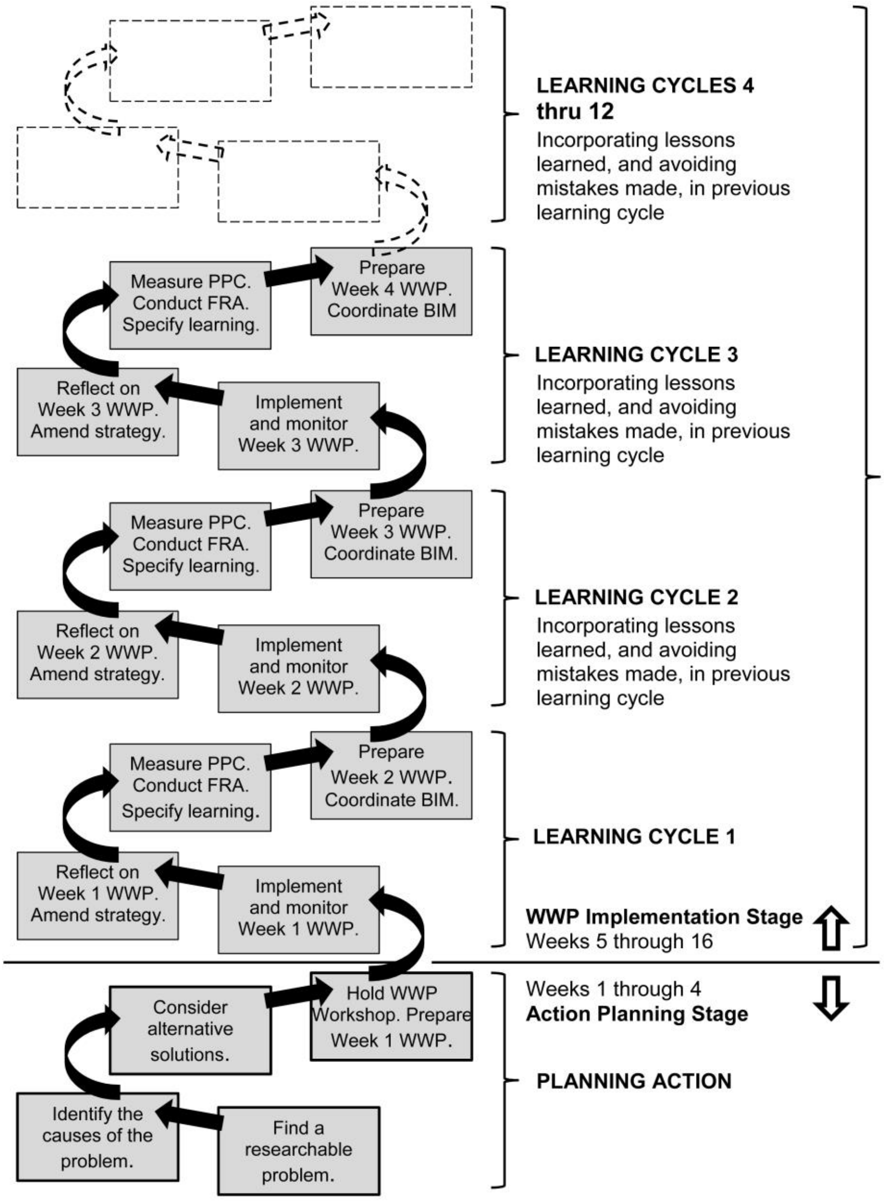

Figure 1: The action research spiral

The WWP planning/implementation/monitoring/evaluation process took the form of a spiral, as depicted as in Figure 1. The rising spiral of steps signified the learning acquired in each cycle and integrated into the next learning cycle, which resulted in a higher level of professional development that motivated the practitioners to set higher goals and reach an even higher level of professional growth. The effectiveness of WWP as a design planning and control tool was evaluated quantitatively using PPC and qualitatively using a questionnaire to obtain the views of the practitioners on the usefulness/effectiveness of WWP.

During the initial four weeks, an exploratory study was conducted at each firm to assess the current design planning practice, BIM usage and design workflow during the design development phase, suggest an alternative approach to improve them, if necessary, and train the practitioners to adopt the new approach. The exploratory study involved interviewing the project manager, attending four weekly task planning (WTP) meetings and observing the practitioners at work. PPC measures were also collected. Other methods used to collect data included literature review, document analyses, participatory observation, informal discussions, interviews and questionnaires.

RESULTS

THE OLD PUSH-PLANNING APPROACH

The exploratory studies revealed that both firms were practising the traditional top-down style of design planning shown in Figure 2. The project management team, consisting of a project manager, the project architect, the project engineers and the BIM manager, met each week to agree on the design tasks that *should* be performed in the coming week and, without making sure that they *can* be done, pushing them down with instructions and/or sketches to the IAs, EITs and BIM technicians to execute. The WTP meetings were characterized by informal conflict resolutions and commitments to accomplish tasks.

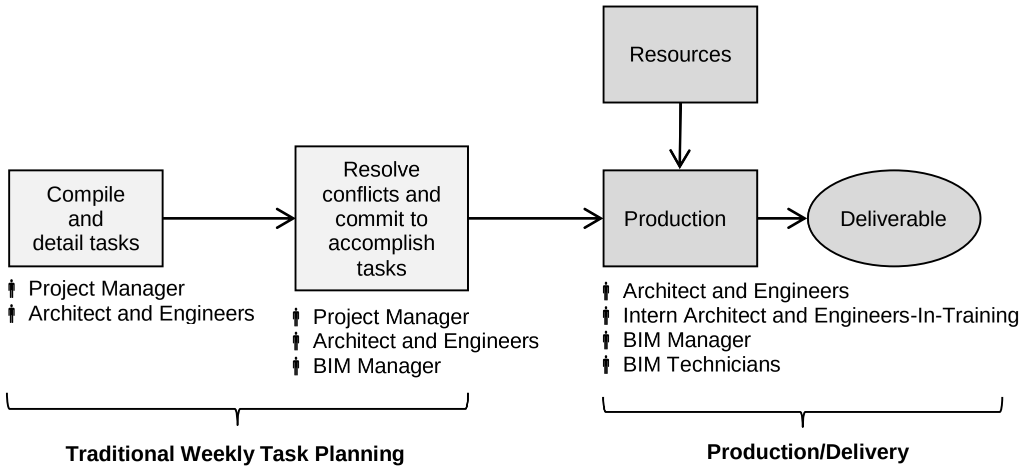

Figure 2: The old push-planning approach before adoption of the new approach

The IAs, EITs and BIM technicians were left out of the planning process. The tasks they were assigned to perform were taken from a master schedule prepared at the beginning of the design project, shortly before the schematic design phase began. Their primary goal was to finish design tasks by due dates dictated by the master schedule. The focus of WTP was therefore on project completion rather than on production control: the execution of individual design tasks was managed internally by each design discipline and coordinated externally with the other design disciplines in an ad hoc manner. This was a key cause of variability in design workflow.

Furthermore, the existing workflow at the two AE firms had been established over a number of years to produce a set of coordinated architectural, structural, mechanical, electrical, and plumbing drawings for building projects. The design process began with the architect, structural engineer and project manager conceptualizing the architectural form and structural system and then conveying the design to project engineers who followed through with designs and drawings.

In both projects, BIM technicians created 3D models of the different building systems from sketches and instructions provided by the architect and engineers, who did not have the skill to create the models themselves. Designers also had the BIM technicians extracting 2D drawings from the 3D models for review, quality assurance, quality control and communication with the client. This moving back and forth between 2D drawings and 3D models recalled the days when architects and engineers depended on draftsmen to generate drawings for them to communicate their designs. The firms had not moved beyond the old 2D drawing paradigm to the new 3D modeling paradigm associated with the most efficient use of BIM.

By itself, push planning is not an effective approach to task scheduling. However, it is necessary in building design, and failure to supplement it with pull planning essentially deprives building designers of a technique for producing desired results (Ballard, 1999). Based on the findings of the exploratory studies, the use of WWP collaborative planning was recommended to provide the push scheduling with the pull necessary to increase task planning reliability and reduce design workflow variability. The project managers agreed to try WWP during the final twelve weeks of the design development phase. Efforts would also be made to use BIM in a lean way in the two projects. A WWP training workshop was held for the practitioners, after which WWP was implemented for twelve weeks.

HOW THE NEW PUSH-PLUS-PULL PLANNING APPROACH WORKED

In this approach, instead of a small exclusive project management team meeting to push tasks down to the IAs, EITs and BIM technicians be performed during the coming week, the entire design team met in the firm's conference room each Friday afternoon to participate in the design planning process and make commitment to finish the tasks on the master schedule that were to be performed in the coming week by agreed dates. Post-it sheets—a different color for each design discipline—were used to display the tasks and their prerequisite(s) and constraint(s) on a whiteboard.

The duties of Last Planners, the persons responsible for production unit control, i.e., the persons responsible for completion of individual tasks at the operational level (Ballard, 1999), fell naturally upon the lead designers (the architect and engineers) who, in consultation with members of all design disciplines, decided the tasks to be performed in the coming week, using a strict can-be-done filter in their selection. The Last Planners were therefore responsible for ensuring that the right sequence of work and the right amount of work that could be done are selected for the coming week.

The IAs and EITs were responsible for decomposing tasks a week in advance and proactively seeing that they were ready to be performed when scheduled, monitoring the progress of tasks daily, and performing Failure Reason Analyses (FRA), that is, investigating and logging on a FRA form the root cause of non-completion of any task. The lessons learned from the FRAs, otherwise referred to as root-cause analyses, were used to prevent similar problems from recurring. PPCs and FRAs were reviewed during the WWP meetings.

This approach (see Figure 3) avoided assignment of tasks that should be performed, but which were hampered by incomplete prerequisites or unresolved constraints. No task was scheduled unless an agreement was reached on who was responsible for timely prerequisite handover and who will perform the task and by when. If it was determined that more manpower or other resources would be needed to complete a task by a certain time, then more manpower or other resources would be allocated to that task.

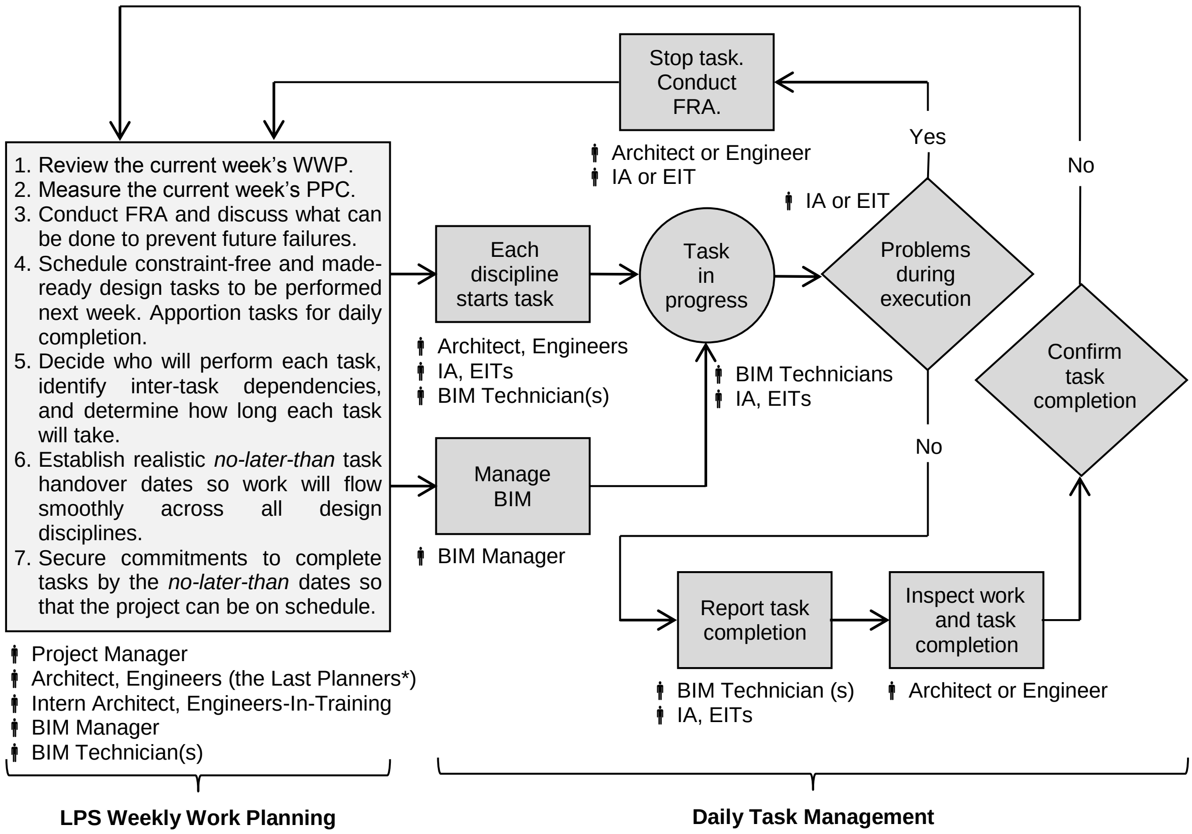

Figure 3: New push-plus-pull planning approach

PERCENTAGE PLAN COMPLETED

PPC measures served as a tangible incentive for the project teams to improve the predictability and reliability of the WWP and provided empirical evidence of the effectiveness of WWP as a design planning and control tool. As shown in Figures 4 and 5, in both projects, WWP PPCs were higher than WTP PPCs. There was 12% rise in average overall PPCs in the hotel project and a 14% rise in average overall PPCs in the apartment project, suggesting that there was an increase in task planning reliability and thus reduction in workflow variability during the WWP implementations. The hotel design development phase finished three days ahead of schedule, and the apartment design development phase finished two days ahead of schedule, which meant a 2.50% and a 3.75% increase in production cost efficiency, respectively, in this phase of the projects. According to the practitioners, this phase often finished at least one week after schedule.

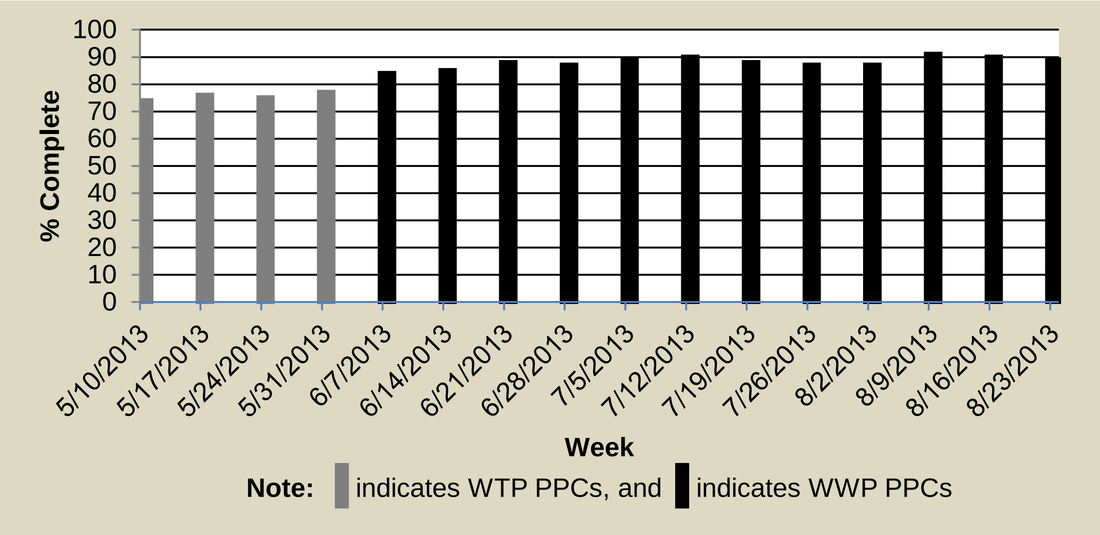

Figure 4: Percentage Plan Completed (PPC), hotel project

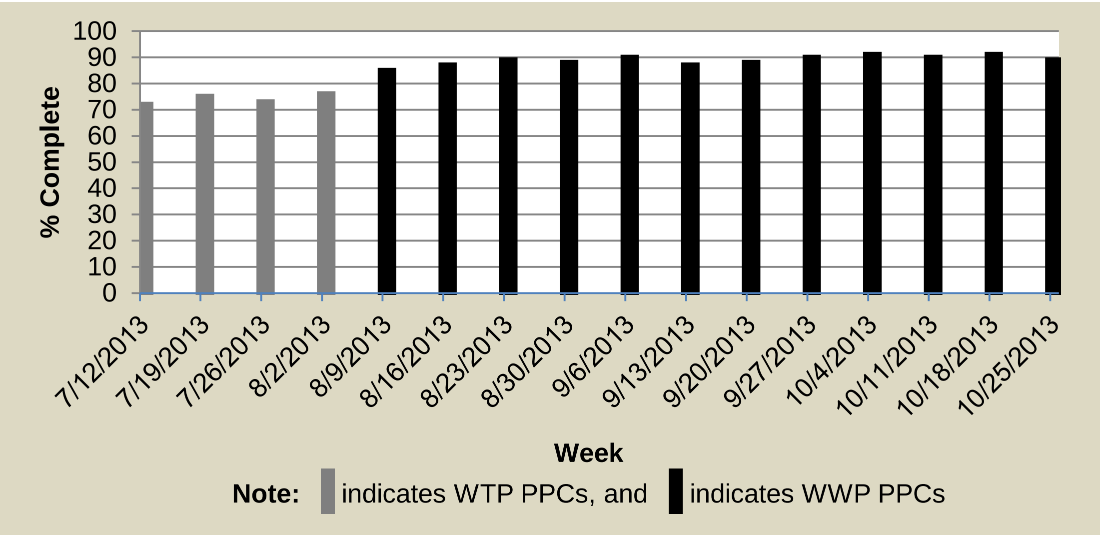

Figure 5: Percentage Plan Complete (PPC), apartment project

FAILURE REASON ANALYSES

A key feature of the continuous improvement process was the study of the reasons why tasks promised in the WWP to be completed by a certain time were not completed by that time. FRAs were conducted to help improve each weekly cycle of WWP implementation. This involved analyzing the causes of failure to complete daily assignments, thus facilitating learning from mistakes and helping to prevent those mistakes from happening again. The four main reasons for non-completion of assignments are shown in Table 1. Regarding the reasons for non-completion, the IAs and EITs explained that it would take some time and effort for all the practitioners to fully understand what they must do to maximize the value of pull planning.

Table 1: Number and percentage of occurrences of non-completion of assignments

Reason	Project			
	Hotel		Apartment	
	Occurrences	Percentage	Occurrences	Percentage
Waiting for prerequisite work	22	36%	20	38%
Insufficient input information	19	31%	13	25%
Underestimation of time	17	28%	16	31%
Rework	3	5%	3	6%

PRACTITIONERS' VIEWS OF USEFULNESS/EFFECTIVENESS OF WWP

Table 2 shows the responses of the practitioners in the two projects to some of the statements in a questionnaire regarding the effectiveness and usefulness of WWP as a design planning and control tool.

Table 2: Practitioners' Perceptions of the Effectiveness and Usefulness of WWP

Response / Statement	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree	Total
LPS WWP was more effective as a design planning/control tool than traditional WTP.	29 (89%)	4 (11%)	0 (0%)	0 (0%)	0 (0%)	33 (100%)
Collaborative planning resulted in improved information exchange.	25 (76%)	8 (24%)	0 (0%)	0 (0%)	0 (0%)	33 (100%)
Make-ready planning resulted in improved information exchange.	21 (64%)	12 (11%)	0 (0%)	0 (0%)	0 (0%)	33 (100%)
Collaborative planning resulted in improved design workflow.	28 (85%)	5 (15%)	0 (0%)	0 (0%)	0 (0%)	33 (100%)
Make-ready planning resulted in improved design workflow.	23 (70%)	10 (30%)	0 (0%)	0 (0%)	0 (0%)	33 (100%)
PPC was useful as a reliable measure of design workflow.	24 (73%)	9 (27%)	0 (0%)	0 (0%)	0 (0%)	33 (100%)
FRAs resulted in improved project performance.	19 (58%)	14 (42%)	0 (0%)	0 (0%)	0 (0%)	33 (100%)

A follow-up interview with the two project managers in December 2013 revealed that the project teams continued to meet weekly during the construction documents phase as well; however, since this phase involved mostly the generation of construction drawings and specifications and very little designing, detailed design planning was not as critical to design workflow during this phase as it was during the design development phase. Similarly, in February 2015, in another follow-up interview, the project managers affirmed that they were convinced enough of the benefits of implementing WWP during the design development phase to continue applying it during this phase of future projects; however, they did not see much value in implementing it during the schematic design phase as this phase is predominantly the domain of the architect, is highly iterative and uncertain, does not require as much coordination between the design disciplines as the design development phase and, therefore, does not need as much detailed planning and control.

CONCLUSION

The results were consistent with those of previous similar research (e.g. Koskela, Ballard and Tanhuanpää, 1997; Ballard, 1999; Hamzeh, Ballard and Tommelein, 2009; Tiwari and Sarathy, 2012). WWP provided the practitioners in the two design projects with a systematic process of design planning and control that was focused on increasing task planning reliability and reducing design workflow variability. Teething problems aside, the practitioners soon recognized and appreciated the effect that WWP had in encouraging well-informed decisions and negotiations between them. WWP promoted richer collaboration and firmer commitment between the design disciplines. Drawing on their own experience and knowledge and on those of the other practitioners, the practitioners interacted and exchanged information as they moved through their tasks, allowing for greater integration of overall team effort. WWP ensured that every practitioner had a voice in the planning process, with the right to speak up and say whether or not a task could be completed by a certain time and with the responsibility to make commitments to finish tasks by a realistic time. This had a positive effect on the morale of the design teams.

Based on the knowledge gained in this research, the following steps are recommended for the successful implementation of WWP in building design projects:

- Secure the trust, interest and cooperation of the project manager in the new process (In this research, the fact that the researchers were themselves experienced architects went a long way toward securing the goodwill of the project manager).
- Conduct an exploratory study to assess the current design planning practice and workflow and determine whether WWP alone would be the most practical level of LPS to implement and would produce the most improvements without disrupting the master schedule.
- Hold a training workshop to familiarize the practitioners with WWP and its benefits and to prepare them to apply it.
- Assign roles and responsibilities that match the skills and background of the practitioners (In this research, the lead designers were natural candidates for the Last Planners role, and the IAs and IETs for the troubleshooting role).
- Include those practitioners who are responsible for performing the tasks in the task planning process (In this research, the active participation of the IAs, IETs and BIM technicians in the task planning process helped immensely to make task planning more realistic, more predictable and more reliable).
- Decompose tasks a week before their expected execution date and proactively make them ready to be performed by their *no-later-than* dates.

- Select for execution the right sequence of tasks and the right amount of tasks that can be done, thus avoiding assignment of tasks that ought to be carried out, but which are hampered by unresolved constraints.
- Obtain commitments from practitioners responsible for performing the tasks that they would complete the tasks by agreed-upon *no-later-than* dates.
- Monitor the progress of tasks daily to make sure that they are not waiting on prerequisite work and that they are not hampered by unforeseen constraints. In this way, tasks will proceed as scheduled and will be completed by their *no-later-than* dates (In this research, this duty was assigned to the IAs and IETs—excellent training for future Last Planners).
- Identify causes for non-completion of any task that was selected for execution and avoid repetition of those causes in future implementations.

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