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Reducing plan variations in delivering sustainable building projects

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A R T I C L E I N F O

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A B S T R A C T

In line with promoting the mission of sustainable development, the sustainable building practice has been increasingly adopted in recent years. However, the process of delivering a high performance sustainable building has led to a more complex construction practice through the increment of specialized processes. Such complexities have affected construction sequencing and timing, leading to workflow variability and excess in the estimated construction time and cost. In this study reducing plan variations is considered a key improvement in the delivery process of sustainable building projects. This research used the Last Planner System (LPS) to develop a more reliable production planning process to reduce plan variations. A case study was conducted focusing on the measurement of production performance of activities and the reasons for non-completion before and after LPS implementation. The critical areas relating to poor production performance of activities were identified. Results demonstrated differences in production performance and causes of plan variations between activities in relation to and with no relation to sustainable deliverables. While the difference in the production performance is not considerable, the difference in the causes of variability is significant. The implementation of LPS resulted in a significant reduction of plan variations. As variability decreased, production performance of activities increased. The findings from this study contribute to alternative methods for an effective production planning process for sustainable building projects.

1. Introduction

Sustainable buildings have emerged as high performance properties that are expected to have less impact on the environment. However, it has been well appreciated that complexities in delivering sustainable building projects affect the effectiveness of the delivery process (Cheng and Venkataraman, 2012; Horman et al., 2004, 2006; Salkin et al., 2012). The complexities are mainly related to the newly imposed requirements needed for achieving high sustainability standards, for instance unavailability of eco-friendly materials, complex architectural design, practices against outdated construction laws, conflicting standards and poor skilled workforce. Such complexities have challenged current building planning and delivery processes, and these deficiencies have compromised the reliability of master plans and production plans causing high incidence of plan variations (Lapinski et al., 2005; Riley et al., 2004). Plan variations are influenced by the amount of uncertainty (Wambeke et al., 2012). For example there may be uncertainty as to whether materials and/or equipment are delivered at the right time, or the recurrence of rework due to inexperienced workers, or even the frequency of design errors encountered (Horman et al., 2004; Thomas and Sanvido, 2000). Plan variations not only compromise the delivery of sustainable building projects but when delays occur they are also considered to be a form of waste (Koskela, 2000; Liker, 2004).

In the building industry a key process for the successful delivery of building projects is the production planning process. The production planning process typically includes the coordination of trade contractors, planning of material supply chain, continuous availability of work and contingencies for possible uncertainties involved in completing a task (Eccles, 1981; Gann, 1996). This research highlights the importance of eliminating plan variations in the production planning process as a key improvement in the delivery process of sustainable building projects. Plan variations have significant relation to the ability to effectively and efficiently accomplish the sustainability objectives related to day-to-day construction activities. Previous studies have already demonstrated that traditional planning is often associated with unreliable production plans with great variability, which prolongs cycle times and decreases the outputs of the project by increasing the amount of waste in the construction process (Ballard, 2000; Koskela, 2000). It has been argued that complex building projects, as in the case of sustainable buildings, is where deficiencies of traditional building planning practices are exacerbated (Alarcon et al., 2005; Höök and

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Stehn, 2008; Thomas et al., 2002). Therefore, the focus of this research is to find out a solution for reducing plan variations while overcoming the effects associated to the complexities in attaining sustainability goals in sustainable building projects.

This research examines the effectiveness of using the Last Planner System (LPS) in reducing plan variations. LPS based on Lean Construction principles is proposed for leading to a more reliable production planning process. A case study involving a sustainable building project was performed to demonstrate how plans variations can be reduced or eliminated while using the LPS. In order to achieve the aim of this research, two research objectives were pursued:

1. To identify and eliminate the main sources of plan variations compromising the attainment of sustainability goals in sustainable building projects
2. To evaluate the extent to which the implementation of LPS reduces plan variations

2. The principle of the Last Planner System

Koskela (2000) defined Lean Construction as "a way to design production systems to minimize waste of materials, time, and effort in order to generate the maximum possible amount of value in construction". LPS is based on Lean Construction principles. LPS has been designed for managing construction planning, by emphasizing process efficiency and focusing on achieving objectives (Ballard and Howell, 2003; Faniran et al., 1997). LPS proactively eliminates constraints from activities to conform to plan rather than responding to after-the-fact detection of variance to plan. A detailed description of the LPS can be found in Ballard (2000). One of the principal characteristics of the LPS is its 'pull planning system' basis, which refers to the process of creating a lookahead and a weekly work plan for increasing workflow reliability (Ballard and Howell, 1994). Ballard (2000) proposed a metric as part of LPS called percentage plan complete (PPC) for examining workflow reliability. PPC is calculated as a ratio of the number of assignments completed to that planned in a given period of time. PPC value is expressed as a percentage with a range between 0% and 100%. A PPC of 100% means all the work assigned is completed as planned and it is the best-case scenario. According to Ballard and Howell (2003), PPC values are highly variable and usually range from 30% to 70% without LPS implementation. A good performance is above 80% and a poor one is below 60%.

3. Research strategy/methodology

Case studies are an appropriate research strategy when there is little known about the topics of interest. A comprehensive case study allows the researcher to pursue a progressive strategy, from exploration of a proposition to more focused examination of trials (Stake, 2000). Given the nature of the research objectives constructed in this study, a case study was employed to investigate the effectiveness of using LPS method in reducing plan variations in sustainable building projects.

A main building contractor who is a leading construction company in Southeast Asia for over 50 years was identified and invited to participate in the case study. The company was selected for its experience in the building sector. By the time this study was conducted, the company was executing 18 building projects and 5 of them were pursuing sustainable building certifications. The company was chosen also because they were interested in reducing plan variations in their projects through a more effective planning system.

The project involved in the case study is 'Project SB-T2' which is a residential development in Hong Kong consisting of two towers with 69 floors each and a total of 275 flats. A platinum certification was achieved in this project under the Hong Kong Building Environmental Assessment Method 'HK-BEAM 4/04 for New Buildings'. Platinum is the highest sustainability level certification under this scheme.

Data was collected from this project for a period of 17 weeks divided in three stages. In the first stage i.e. from week 1 to week 5, data was collected for measuring plan variations and its main causes before LPS was implemented. In the second stage i.e. from week 6 to week 10, data was collected for measuring plan variations after LPS implementation. The third stage i.e. from week 11 to week 17, was used as a control stage. Data was collected for verifying whether improvements achieved after LPS implementation were successfully maintained. Data was collected from defined sources such as a master schedule, weekly plans, activity descriptions and activity duration times. The information shows the expected daily completion/progress of activities. The real progress of activities and the reasons for non-completion (Reasons-NC) were recorded from observing the two towers of Project SB-T2 by the foremen and revised by the site coordinator and assistant building engineers. Data was collected on daily basis and used to calculate the daily PPC. The research team used the 12 Reasons-NC identified by Alarcon et al. (2005) and Ballard (2000) as the baseline for their reasons of plan variations. The Reasons-NC are presented in Table 1.

Fig. 1 is the representation in a flow diagram of the production planning process used for Project SB-T2 before LPS was implemented. The first two steps were related to the definition and acquisition of necessary inputs for generating the production plans. Having all inputs ready, the next process was to generate a preliminary production plan following the traditional approach of Push Planning System (i.e. selecting, sequencing and sizing the work by assuming that can be done). The preliminary production plan was later passed forward for revision and approval to the Planning Manager. The Senior Site Agent and the Senior Project Manager made a second stage of revision and approval before the production plan was presented to the 'General Coordination Meeting'. The 'General Coordination Meetings' were held every two weeks with concerned project team members, sub-contractors and suppliers. The production plan was discussed for approval in each meeting. If the production plan was approved, it was ready for distribution to interested parties such as subcontractors, suppliers and foremen. Otherwise necessary modifications were made by the Assistant Building Engineers and revised and approved by the Senior Site Agent.

Table 1
Reasons for non-completion.

Reason-NC (ID)	Reasons for non-completion
1	Waiting for materials from warehouse
2	Waiting for materials from supplier
3	Waiting for workers/tools/equipment
4	Lack of access
5	Equipment breakdowns
6	Changes/redoing work (design errors)
7	Changes/redoing work (site errors)
8	Moves to other work area (priority change)
9	Waiting for information
10	Lack of continuity (prerequisite work not completed)
11	Overcrowded working areas
12	Inclement weather
13	Other