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Synchronization-based model for improving on-site data collection performance

Ming-Kuan Tsai [a,*], Jyh-Bin Yang [b], Chang-Yu Lin [a]

[a] *Department of Civil Engineering, National Chiao-Tung University, 1001 Ta Hsueh Road, Hsinchu 300, Taiwan*
[b] *Institute of Construction Management, Chung-Hua University, 707 Sec. 2 Wu Fu Road, Hsinchu 300, Taiwan*

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Abstract

Comprehending activity status is essential to successful project management. When construction workers report activity information, project managers understand activity progresses. This procedure forms information exchange and flow. However, the lack of up-to-date information still causes project problems (such as increasing unnecessary costs, making erroneous decisions and improper activity scheduling), and highlights the importance of on-site data collection. For improving this condition, this study integrates two managerial philosophies ("theory of constraints (TOC)" and lean construction) to propose a synchronization-based model. When this model was applied for a material management case study, asynchronous operations accompanied with unnecessary subprocesses were recognized as an influence on on-site information production and transmission. This study then applied synchronous operations based on worker cooperation to resolve these problems, and evaluated the efficiency obtained by the identified measurements. The proposed model offers not only a prototype of synchronous on-site data collection, but also a mechanism for activity performance improvement.

Keywords: Theory of constraints; Lean production; Lean construction; Information management; On-site data collection; Synchronization

1. Introduction

Comprehending activity and site status is essential to successful project management. Most construction companies require their staff to fill in various site reports including labor, equipment, material and progress reports. Project managers then use these reports to control activity progress and plan schedules. This procedure forms information exchange and flow. However, unauthentic on-site data collection not only causes a lack of proper information but also produces many problems, such as making erroneous decisions and increasing project costs [1]. This issue highlights the important relationship between on-site data collection and information flow.

Previously, besides recording activity details with pen and paper, most construction workers needed to complete site reports through manual operations and data transfer, such as using calculators to compute material usage and working hours [2]. Project managers thus wasted time in waiting for and searching these completed reports while checking activities and schedules. Clearly, time-consuming paperwork is a constraint on information flow from on-site data collection to off-site data analysis, eventually becoming obsolete owing to the impossibility of just-in-time information exchange [3].

Recently, integrating Information Technologies (IT) and computerized systems to increase efficiency for on-site data collection has been valued, and has become a basic component of project management [4]. Automated data identification systems (including bar coding, optical character recognition (OCR), magnetic stripe (MS), and radio frequency (RF)) are common applications to assist construction workers in completing site reports [5–8]. For example, when scanning bar codes instead of handwriting data, construction workers can directly transfer material names and quantities into computerized material reports.

Additionally, more and more construction companies have applied computer-based management information systems (MISs), rather than paper-based management, to analyze complex

* Corresponding author. Tel.: +886 3 5712121; fax: +886 3 5716257.
E-mail addresses: twmktsai@ms95.url.com.tw (M.-K. Tsai), jyhbin@chu.edu.tw (J.-B. Yang), cylin@mail.nctu.edu.tw (C.-Y. Lin).

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site information. The use of the Internet to accelerate information transmission and reduce communication barriers has led to the development of project-specific web sites [9]. When construction workers connect to MISs to store activity details using the Internet and electronic devices (e.g., laptops and personal digital assistants (PDAs)), project managers immediately obtain integrated site reports. Numerous researchers have demonstrated that IT-based on-site data collection not only offers more working efficiency for construction workers but also delivers up-to-date information for project managers [2,4,8–10].

Nonetheless, when construction workers perform IT-based on-site data collection, asynchronous operations (defined as two or more interdependent processes that are separately executed yet can be simultaneously executed) accompanied with unnecessary subprocesses (defined as executed subprocesses that require resource and offer no efficiency for activity results) remain to interrupt information flow and influence the downstream processes. For instance, during materials checking, construction workers use bar-code applications to report material details. When material statuses are changed, bar-code labels need to be updated to avoid incorrect information. Namely, incorrect bar-code labels lead to the asynchronous completion of checking materials and recording material details. Scanning incorrect bar-code labels seems to be an unnecessary subprocess.

This study integrates two managerial philosophies ("theory of constraints (TOC) [11,12]" and lean construction [13,14]) to propose a synchronization-based model for the above issue. While a material management case study is examined, this model offers continuous directions and stages to improve the recognized asynchronous operations and unnecessary subprocesses. Besides evaluating the efficiency by several identified measurements, this study shows the improvements between asynchronous and synchronous operations (including cycle time, process and flow transparency, activity productivity and information interdependence), and confirms a prototype for synchronous on-site data collection. For widely achieving synchronous operations, a synchronous system based on this prototype is developed in a companion paper [15].

2. Information flow and on-site data collection

Effective on-site data management (including on-site data collection, and data transfer, integration and storage) ensures that site information can be accurately represented [2,4]. Therefore, the objectives of information management and flow include: satisfying information requirements of project participants to avoid activity problems, schedule delays and decision errors; providing new perspectives and standard managerial tools; enhancing communication and cooperation to achieve project management functions, and so on [16–19].

When construction workers report site status, the results consist of the information produced from a series of continuous processes and subprocesses. Integrating these interdependent processes and subprocesses into a flow raises an improvement level, and creates a structured understanding to resolve existing problems [20,21]. Direct impacts of blocking or delaying one flow process can influence the next process and the whole efficiency. Similarly, as the source of information flow, on-site data collection affects off-site data analysis and project schedules. Consequently, this study focuses on on-site data collection including interdependent processes and the formed flow.

Fig. 1(a) illustrates the original procedure for collecting material details at construction sites. Construction workers executed six main processes to fulfill the requirements for material management while performing material reports. Construction workers first checked materials (process 1), and then filled in material records with pen and paper (process 2). When returning to the site offices, construction workers confirmed (process 3), corrected (process 4) and submitted (process 5) these records. Office staff stored these records (process 6) and used them to produce material reports. After reading the delivered reports (off-site data analysis), construction managers gained an understanding of the material statuses.

Since construction workers asynchronously performed the above processes, the procedure for completing on-site data collection was time-consuming. As a result, besides the increased project costs, the lack of timely material information led to poor decisions and schedules [1,2]. Unfortunately, this condition is very common in the construction industry. According to the research for tunnel construction operations, an optimized project implies that all activities are synchronized to minimize the waiting or idling time and results in 100% resource utilization [22]. Hence, efficient on-site data collection does not merely imply letting information flow to operate.

Interestingly, while construction workers apply IT applications for on-site data collection, the simultaneous performance of two or more processes increases the activity efficiency. Meanwhile, the above six processes are combined to form a new activity flow. For example, when construction workers simultaneously submit and store completed reports via the Internet, returning to site offices to deliver reports is unnecessary. Fig. 1(b) illustrates that the updated on-site data collection for IT-based applications includes three main processes: "checking materials and filling in records" (process 1), "confirming and correcting records" (process 2) and "submitting and storing records" (process 3).

However, in addition to carrying other devices for on-site data collection, construction workers cannot execute application devices while both hands are unavailable. For instance, when controlling machines to transport materials at construction sites, construction workers have difficulty in applying laser scanners to read bar codes. Accordingly, some environmental factors prevent construction workers from acquiring and exchanging information. Because of these conditions, checking materials and filling in records (process 1) are separately completed to form asynchronous operations. Meantime, these operations cause unnecessary subprocesses (e.g., waiting for the delivered data) and discontinuous information flow.

Consequently, Fig. 1(c–d) show that asynchronous operations and unnecessary subprocesses commonly occur in process 1 and affect the relation between processes 1 and 2. When asynchronous operations are synchronized and unnecessary subprocesses are eliminated, Fig. 1(e) displays that the synchronous on-site data