Development of Web-based Teams Management System in Construction

Yu-Cheng Lin

Abstract—Construction project control attempts to obtain real-time information and effectively enhance dynamic control and management via information sharing and analysis among project participants to eliminate construction conflicts and project delays. However, survey results for Taiwan indicate that construction commercial project management software is not widely accepted for subcontractors and suppliers. To solve the project communications problems among participants, this study presents a novel system called the Construction Dynamic Teams Communication Management (Con-DTCM) system for small-to-medium sized subcontractors and suppliers in Taiwanese Construction industry, and demonstrates that the Con-DTCM system responds to the most recent project information efficiently and enhances management of project teams (general contractor, suppliers and subcontractors) through web-based environment. Web-based technology effectively enhances information sharing during construction project management, and generates cost savings via the Internet. The main unique characteristic of the proposed Con-DTCM system is extremely user friendly and easily design compared with current commercial project management applications. The Con-DTCM system is applied to a case study of construction of a building project in Taiwan to confirm the proposed methodology and demonstrate the effectiveness of information sharing during the construction phase. The advantages of the Con-DTCM system are in improving project control and management efficiency for general contractors, and in providing dynamic project tracking and management, which enables subcontractors and suppliers to acquire the most recent project-related information. Furthermore, this study presents and implements a generic system architecture.

Keywords—Construction project management; Information System; Portal; Web; Small-to-medium enterprises.

I. INTRODUCTION

Construction projects are typically extremely complex as project development typically comprises several phases, thus requiring a diverse array of specialized services and involvement of numerous participants. Therefore, real-time project monitoring and controlling of construction project participants may be necessary and helpful for completing projects within budgets and on schedule. With the advent of the Internet technology, web-based information management solutions have facilitated information distribution and sharing among project participants. Contractors and subcontractors generally require access to construction project information to control and manage construction projects. However, most

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small- and medium-sized subcontractors and suppliers in Taiwan frequently use email and fax to communicate with the general contractor, other subcontractors or suppliers. Consequently, communication among project teams is ineffective, reducing efficiency and resulting in a lack of information and confusion.

Information technology (IT) is essential to controlling and managing construction projects, particularly by enhancing communication and coordination among project participants. Utilization of web technology enhances information sharing in construction projects and will become increasingly important in the future. Moreover, integrating promising information technologies such as web technology (e.g., portal solutions) can improve information flow and convenience in construction project management. Web-based systems are convenient and cost-effective tools for gathering, filtering, managing, and sharing construction information (Doherty, 1998). However, according to questionnaire results, commercial construction project management software is currently not accepted widely by small-to-medium sized subcontractors and suppliers in Taiwan because most commercial construction project management programs are considered expensive and have excessive functionality. To solve these problems, this study presents a novel system called the Construction Dynamic Teams Communication Management (Con-DTCM) system for project teams (general contractor, small-to-medium sized subcontractors and suppliers) in the Taiwanese construction industry, and demonstrates that the proposed system is efficient in information sharing and enhances project information management by the project teams involved in construction projects.

II. PROBLEM STATEMENTS

Project monitoring and controlling can be enhanced by real-time information sharing. However, information communication is very important in construction project management. Information acquisition problems in construction projects result from the fact that most project data and information are gathered from project participants. The effectiveness of information and data acquisition influences information flow between the general contractor and project participants. Usually, inefficiencies and communication problems occur when project participants have different versions of the same software program or different programs

(Sidney, 2007). Furthermore, most subcontractors and suppliers in Taiwan use email and faxes to communicate with the general contractor, subcontractors or other suppliers. Consequently, information sharing and communication among contractors and subcontractors is ineffective, thereby reducing efficiency and resulting in a lack of information and information confusion.

To solve these problems, a questionnaire was created in 2008 to identify problems and how construction project management software usage in the Taiwanese construction industry impacts small-to-medium sized subcontractors and suppliers. According to questionnaire results for 20 construction subcontractor project managers, 20 supplier project managers and senior engineers from 32 participating small-to-medium sized subcontractors and suppliers in Taiwan, the primary problems in commercial project management software are as follows: (1) most subcontractors and suppliers may not purchase commercial project management software, such as P3 and Microsoft Project, to manage their projects due to cost; (2) most subcontractors and suppliers agree that commercial project management software provides too many functionalities, and consequently, do not want to purchase the software; (3) rework problems typically exist regarding data entry by project participants during project information communication and exchange; (4) the interfaces of most commercial project management programs are difficult to learn, despite being designed for senior engineers who are not necessarily familiar with computer usage; and, (5) most commercial project management software setup for web-based use are difficult and complicated for general users; and, (6) most free or online project management programs are unsuitable for small-to-medium sized subcontractors and suppliers. Although commercial project management software and web-based project management software are popular, few suitable systems and platforms have been developed especially for small-to-medium sized subcontractors and suppliers to assist them in monitoring and controlling important project information when participating in projects. Therefore, providing the basic functionalities in project management systems and increasing user friendliness for small-to-medium sized subcontractors and suppliers is a major challenge in this work.

Over the last ten years, numerous academic studies of web technologies have been applied to project management in the construction industry. (1) Chan and Leung (2004) presented a conceptual model of metadata-based information system for data exchange among web-based documents for construction project management. (2) Lam and Ng (2006) developed a web-based quality management system as an effective tool for gathering, filtering, managing, assessing, and sharing data at project and corporate levels. (3) Li et al. (2003) developed a web-based GIS e-commerce system for construction material procurement. (4) Molenaar and Songer (2001) developed a web-based decision support system for design/build selection among United States public sector agencies. (5) Ng et al. (2003) created a web-based centralized multiclient cooperative

contractor registration system to enhance contractor prequalification and registration practices. (6) Kong et al. (2004) developed a system integrated web technology for information sharing between construction material e-commerce systems. (7) Cheung et al. (2004) generated a web-based construction project performance monitoring system to assist project managers in project control. (8) Nitithamyoug and Skibniewski (2004) identified the determinants of success or failure for web-based construction project management systems.

III. RESEARCH OBJECTIVES

To solve the project communications problems among project teams, this study presents the novel Con-DTCM system for construction project teams (small-to-medium sized subcontractors and suppliers). This study demonstrates that the Con-DTCM system responds to information efficiently and improves project management for project teams in a construction project environment. The proposed Con-DTCM system improves project control efficiency and cost-effectiveness, enhances practical communication among project teams, and increases flexibility of project delivery and response times.

The Con-DTCM system is applied to a case study of constructing a building project in Taiwan to verify the effectiveness of the proposed methodology in sharing information related to project control during construction. The primary goals of the Con-DTCM system are to improve project control and management efficiency for general contractors, and enhance dynamic project tracking and management, thereby enabling project teams to acquire the most recent information.

The main objectives of this study are as follows (1) develop a simple and friendly web-based teams management system that allows small-to-medium sized subcontractors and suppliers to manage their projects; (2) apply such a system to increase data collection and information sharing efficiency; (3) enable subcontractors and suppliers to update data from anywhere and immediately upload data to the Con-DTCM system and allow small-to-medium sized suppliers and subcontractors to receive real-time project-related information such that they can make effective decisions regarding future project management and control; and, (4) support project managers in dynamically monitoring and controlling construction processes. Given appropriate modifications, the Con-DTCM system can be utilized by general contractors and small-to-medium sized subcontractors and suppliers.

IV. SYSTEM IMPLEMENTATION

The Con-DTCM system is a personalized gateway, enabling participants to access information provided by other project participants. The Con-DTCM system is a solution that uses a single, unified database linked to all functional systems with different levels of access to information that depend user roles

within organizations and across organizations. Similar to project scheduling management, system requirements and functions are the basis of the Con-DTCM system. All data are stored and classified using multi-project- and multi-activity-based units in the Con-DTCM system. Furthermore, the Con-DTCM services are available to all project teams via a user-friendly portal, which also serves as a real-time and on-line communication channel for project participants. All authorized participants can utilize web project management controls based on data shared via the Con-DTCM system. When data are updated on the server, the server automatically sends e-mails to the general contractor's project manager, and to participants involved in the activity. The following section describes the development of the Con-DTCM system.

System Architecture

The Con-DTCM system is based on the Microsoft Windows 2003 operating system with an Internet Information Server (IIS) as the web server. The system prototype was developed using Java Server Pages (JSP), which are easily incorporated into HTML and JavaScript technologies, to transform an Internet browser into a user-friendly interface. In the Con-DTCM system, all project-related information acquired by project participants is centralized in a system database. Depending on access privileges, project participants can access all or some of this information via the portal.

The Con-DTCM system server has three distinct layers—presentation, application and database layers—each with its own responsibilities. The presentation layer defines administration and end-user interfaces suited to an end user's work. Users can access information via web browsers, such as Microsoft Internet Explorer and Firefox. Moreover, administrators can control and manage information via the web browser and a separate server interface. The application layer utilizes various applications for information collection and management. These applications enable system security, information sharing, project control and monitoring and system administration. The database layer includes SQL Server 2003.

The Con-DTCM system includes general contractor module and subcontractor and supplier module.

The general contractor module serves as an access control mechanism preventing unauthorized users from entering and/or retrieving sensitive project information. The Con-DTCM system requires that all relevant project teams or participants register. A general contractor can view all participating project-related information in all functionalities. Registering as an approved system users requires companies to input a unique User ID and password. Due to the variance between project information or reports required by different project participants, companies are allotted access rights and authorities different from those of project participants. For instance, a general contractor is granted access to newest project-related information submitted by subcontractors and suppliers. Thus, project managers can monitor the performance of project teams and the project itself.

The subcontractor and supplier module allows all subcontractors and suppliers to obtain needed information based on their system authorities. The Con-DTCM system provides subcontractors and suppliers with information regarding related activity information. Subcontractors and suppliers can check the most recent information related a specific activity or activities. A significant amount of information provided by other participants can be viewed in the read-only module.

System Feature Module

This section demonstrates the feature modules of the Con-DTCM system.

Registration Management Module

The registration management module serves as an access control mechanism to prevent unauthorized users from entering and/or retrieving sensitive project management data. The Con-DTCM system requires that all relevant project teams register. Registering as an approved system user requires companies to input a unique User ID and password for authentication purposes. As the project-related information or reports required by different project participants vary, general contractors are allotted different access rights and authorities.

Schedule Management Module

The schedule management module provides project participants with a platform for entering their handling activies in the authorized project catalogue. Participants can enter data related to the planned schedule, update actual schedule-related data, and compare work completed with original schedule, situations that have occurred and manpower, machines and material. Once subcontractors and suppliers have finished entering their schedule-related data, a general contractor can login to the system and track the most recent schedule information.

Cost Management Module

The cost management module provides project participants with a platform for entering their handling activies in the authorized project catalogue. Participants can enter data related to the planned cost, update actual cost-related data, and compare work completed with original cost, situations that have occurred and manpower, machines and material. Once subcontractors and suppliers have finished entering their cost-related data, a general contractor can login to the system and track the most recent cost certificate and payment information.

Progress Monitoring Module

This progress monitoring module allows project participants to track key events. Additionally, project participants can share the current progress or delivery condition of these events. The progress monitoring module has an easy access option allowing participants to trace and record all information related to the event status. Additionally, project participants can share changed information and compare differences between planned events and related predecessor activites and successor activites. The module is a novel approach and characteristic of information sharing in progress that is unavailable in current

commercial schedule management software.

Alert Management Module

This alert management module is helps general contractors, subcontractors and suppliers observe the impact of the most recently delayed or changed events. Importantly, since the dates related to notification of delays and changes are recorded systematically; thus, project participants can easily establish liability related to delays. Furthermore, this module provides a convenient access and a push-based function that helps engineers respond to certain situations in advance of delayed or changed events.

Multimedia Management Module

The multimedia management module stores digital project-related multimedia files, such as project digital photos and digital films, in a single location. Users can directly upload digital files, edit descriptions and view digital films and without needing to install multimedia software. This module enables on-site engineers to upload and view photos and video. These multimedia records can then be used to share important records and for e-learning.

Online Communication Module

This communication management module is an activity-based communication platform similar to a MSN Messenger and e-mail, and enables a ''threaded'' discussion to take place online. Team members can post questions, responses, and comment thereby generating a permanent record related to a particular issue. For sensitive topics, discussion in the sensitive topics can be protected using a secure password.

Document Management Module

The document management module enables users to download electronic documents directly via the Con-DTCM system. This module uses a single location to store general project-related files, including contracts, drawings, specifications and information. This module has a "search" function such that required information can be found and retrieved easily, thereby saving time in dynamic construction environments. Most uploaded files are automatically converted into pdf documents by the Con-DTCM system. This process allows participants to manage, track, and organize these files in a central location. This feature also allows participants to determine who accessed files or downloaded documents, and when the file was edited and uploaded to the system.

Online Report Module

The online report module is an easy-access environment in which users identify their needs and analyze information based on user requirements in the Con-DTCM system. The online report module has basic analytical functions (e.g, simple bar charts and the earned valued approach). Authorized records are maintained by a contractors, subcontractors, and suppliers and can be extracted and summarized in reports.

A 13-month field test was performed. The participants involved included 1 general contractor, 5 subcontractors and 12 suppliers. The Con-DTCM system was installed on the general contractor's main server during the test. A user guide and three Con-DTCM system workshops were held to briefly demonstrate how to use the Con-DTCM system. The Con-DTCM system enhanced construction project monitoring and controlling in three different categories, namely, improved work efficiency, reduced operating costs, and enhancing real-time information sharing.

Improvement of working efficiency

Use of web technology to collect and share information significantly enhanced the efficiency of project management processes. For example, the Con-DTCM system eliminated the need for engineers to manually input data again after receiving final reports. Moreover, using the web-based Con-DTCM system for real-time information tracking enhanced monitoring efficiency is increased by 23–28%. Experimental results demonstrate that the Con-DTCM system significantly enhances progress in construction project control and management. Overall, use of the Con-DTCM system rapidly and efficiently manages subcontractors and suppliers operations, and pre-manages operational sequences.

Reduction of operational costs

The total cost of equipment in this study was US $26,800, which included system programming and one PC server. Operational costs were reduced after the Con-DTCM system was implemented in the following two ways: (1) cost of manually inputting information twice was decreased; and, (2) the Con-DTCM system is setup and maintained by the general contractor. All project participants (subcontractors and suppliers) only registered and used the system free of charge.

Enhancing Real-time Information Sharing

The degree of satisfaction for general contractors for real-time sharing of important information increased by 53% after using Con-DTCM system. Furthermore, the degree of satisfaction of subcontractors and suppliers for real-time sharing of important information increased by 67%. All users could access the most recent project information and acquire a brief report directly from the web. Experimental results show that the Con-DTCM system significantly enhances rapid response during the control and monitoring processes. The proposed system rapidly and efficiently responds the most recent information for subcontractors and suppliers. Furthermore, the general contractor acquired data and information provided online communication service for subcontractors and suppliers. Overall, using the Con-DTCM system reduces ineffective communication and coordination among participants.

V. CONCLUSIONS

A Taiwanese survey indicated that most commercial project management software is too complex and difficult for small-to-medium sized subcontractors and suppliers to use. Therefore, an easy and user-friendly interface is essential for small-to-medium sized subcontractors and suppliers that must enter the project data and information into a system. This study presented the Con-DTCM system for construction projects to overcome this problem. The proposed system effectively

improves the efficiency and effectiveness of information sharing among participants, thus enhancing the ability of managers to control and monitor project progress. The Con-DTCM system improves efficiency in acquiring project-related information from subcontractors and suppliers, and provides monitoring services for controlling construction progress. On the supply side, small-to-medium sized subcontractors and suppliers utilized the Con-DTCM system to overcome time and space constraints, enabling seamless integration of work processes due to the accuracy of data capturing. The Con-DTCM system offers a Hub center that provides small-to-medium sized subcontractors and suppliers with real-time updated project-related information. The proposed Con-DTCM system has two notable characteristics. First, the system is extremely user-friendly and simple to operate compared with current alternatives. Second, no payments to small-to-medium sized subcontractors and suppliers are needed. This study demonstrates that the Con-DTCM system significantly enhances construction project control and management of suppliers and subcontractors. Furthermore, applying the Con-DTCM system provides effective web-based project management for building factories in Taiwan's construction industry. The integration of production and dynamic real-time information from all project teams helps the general contractor manager monitor and control the entire construction process. Furthermore, the directly predecessor activities will be updated with the most recent information regarding selected activities for rescheduling material component production and assessment in real time. Real-time feedback on the status of each project and activity is provided to facilitate re-sequencing of detailed information and the process steps required. The advantages of the Con-DTCM system are improving project control and management efficiency for all project teams, and providing a user-friendly design for web-based project management that helps small-to-medium sized subcontractors and suppliers access the most recent project-related information. Furthermore, one of the primary benefits of applying the Con-DTCM system in the construction industry includes low implementation costs, minimal IT expertise requirements, and easy application upgrade. Overall, field test results demonstrate that the Con-DTCM system is an effective and simple platform for construction project management, especially for subcontractors and suppliers.

The Con-DTCM system principally helps participants share their information easily and effectively. Questionnaire results indicate that the primary advantages of the Con-DTCM system are as follows: (1) real-time information in the Con-DTCM system is represented clearly and dynamically and, thus, data analysis and information sharing among participants; and, (2) project teams can find needed real-time information easily and effectively.

VI. RECOMMENDATIONS

Based on case study findings, the proposed system is a highly effective platform for monitoring progress in project management. The following suggestions are presented as the next steps in the implementation process for further research. Other functionalities, such as interface management function, in proposed system are suggested for further development. Furthermore, some users are needed for knowledge management in the proposed system.

1. Cost currently limits the widespread use of commercial project management software in the construction industry. Providing free or low-cost software is a solution for general contractors who would generally have to purchase or rent software.

2. Most users typically worry about the confidentiality of information saved outside of a company. Some companies have proposed establishing their own servers as a means of saving all information provided by their company.

3. The information to be shared among project participants must be identified in advance since the information shared differs among projects, participants must discuss information sharing before modifying and developing the system.

4. In the case study, the general contractor covered the cost of maintaining the system for construction projects because most small-to-medium sized subcontractors and suppliers were unable or unwilling to pay.

5. In the future, general contractors may rent a Con-DTCM system cheaply and setup the system equipment. Project participants then simply register and use the system free of charge. General contractors are typically extremely willing to rent the Con-DTCM system and allow project participants to use the system free of charge. Furthermore, subcontractors and suppliers can cooperate when using the Con-DTCM system as they do not need to pay rental fees when managing their projects using the Con-DTCM system.

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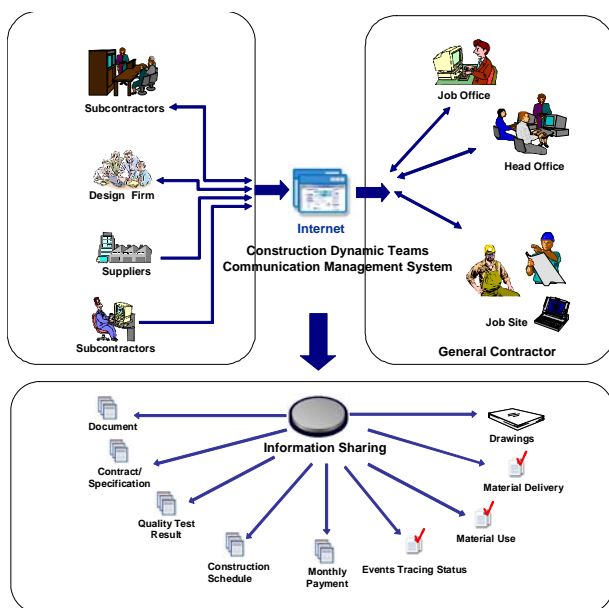
Fig. 1 The Application of Con-DTCM System Applied in the Project Teams