Virtual Design and Construction (VDC)-Aided System for Logistics Monitoring: Supply Chains in Liquefied Natural Gas (LNG) Plant Construction

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***Abstract:** Many conventional management methods have emphasized the minimization of required resources along the supply chain. Accordingly, this paper presents a proposed method called the Virtual Design and Construction (VDC)-aided system. It is based on object-oriented resource control, in order to accomplish a feed-forward control monitoring supply chain logistics. The system is supported by two main parts: (1) IT-based Technologies; and (2) VDC Models. They enable the system to convey proactive information from the detection technology to its linked visualization. The paper includes a field study as the system's pre-test: the Scaffolding Works in a LNG Mega Project. The study demonstrates a system of real-time productivity monitoring by use of the RFID-based Mobile Information Hub. The on-line 'productivity dashboard' provides an opportunity to display the continuing processes for each work-package. This research project offers the observed opportunities created by the developed system. Future work will entail research experiments aimed towards system validation.*

***Keywords:** Virtual Design and Construction (VDC); Logistics Monitoring; Supply Chain; LNG Plant Construction; Radio Frequency Identification RFID; Productivity; Shutdown Maintenance*

I. INTRODUCTION AND BACKGROUND

The central tenant of many business methodologies is the drive for the minimization of process waste throughout the supply chain. The methodologies include Lean thinking [1], Total Quality Management (TQM) [2], Supply Chain Management (SCM) [3], and Dynamic Quality Control (DQC) [4]. These collaboratively highlight the reduction of process waste that is also known as Muda production wastes [5] [6]. The goal of this philosophy is to find the process to minimize any unnecessary efforts while reaching acceptable qualities. The waste in these philosophies differs from its traditional definition. It is defined, for example, by Hiroyuki Hirano as "everything that is not absolutely essential" [7]. Therefore, management needs to focus on the minimization of required resources such as equipment, materials, space and labourers, which are absolutely essential to create values [4] [8].

When it comes to mega projects, resource control can be an extremely challenging task for managers, as this can cause an excessive process loss throughout the entire supply chain. Many previous research efforts, therefore, utilize the Input-Process-Output (IPO) model to study process efficiency, as a systematic approach to investigate procedures [9] [5] [10] [11]. In this recognition, the process control can be defined as the design of a multiple input to measure a multiple output in order to estimate fault and/or problems during the whole process [12]. Thus, required inputs need to be controlled in a prescribed way based on the defined structure of the IPO model.

This paper presents a proposed model for the feed-forward process control. The model is based on the traditional IPO model pursuing an object-based resource control. On the basis of many conventional management methods, this model shows an integrated method, combining Virtual Design and Construction (VDC) with IT-based Technologies. Specifically, the Radio Frequency Identification (RFID) device was utilized to reinforce the current VDC model, and the logistics of each identified resource were analysed to accomplish the process improvement. The case study in this paper present a mega project - the scaffolding works for the Liquefied Natural Gas (LNG) Plant Facility in Darwin, Northern Territory, Australia. The next section introduces the concept of the feed-forward control.

II. ACCOMPLISHMENT OF FEED-FORWARD CONTROL IN PROCESS MODEL

Process modelling is one of the key parts of consequence analysis regarding hazardous events, including loss of process resources [12]. Figure 1 presents a conceptual process model for the construction process, which includes both basic (Input-Process-Output: IPO) and control components. The model, as a part of the actual

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construction, needs well-defined physical boundaries [12]. A system in the model is influenced by its input and generates its output as the outcome of process function. The modelling aims to predict the behaviour of the real system in order to quantify the knowledge of the process [15].

Figure 1 illustrates two basic process control concepts applicable to construction: 1) corrective feed-back control and 2) preventive feed-forward control [16]. A third approach, also depicted in the figure, is referred to as Six Sigma which is an extension of Deming's DMAIC model: D) Define, M) Measure, A) Analyse, I) Improve, and C) Control. Many previous research publications in not only process modelling, but also quality discipline, affirmed the importance of process improvement. For example, Tersine [17] wrote that "The primary drivers of any improvement process for diminution of waste are the reduction of valueless time, valueless activity and valueless variance. … A process that is much faster, more efficient and more precise translates into increased profitability via greater productivity".

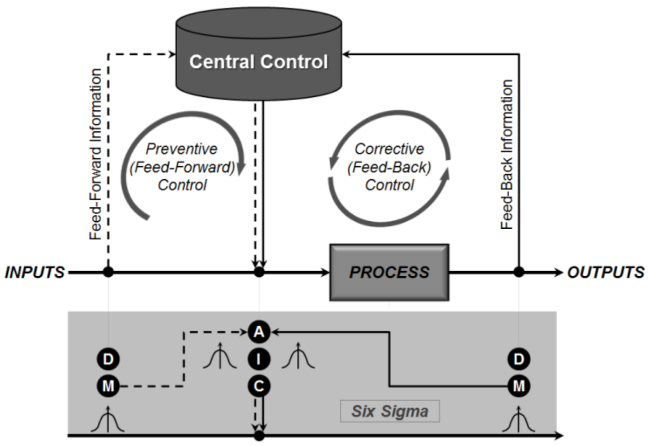

Fig. 1 CONCEPTUAL PROCESS MODEL COMBINED WITH SIX SIGMA

The key for the accomplishment of process control is the transfer from feed-back to feed-forward control. The concept of feed-forward is directly linked to the dynamic system, since the control action precedes the process. The dynamic system acquires the feed-forward information that represents the characteristics of inputs on the IPO framework. This information is able to be defined by the causal relationship between input and output. As a preventive approach, the dynamic control is expected to concentrate on process input, and its effect is then able to be predicted via causality analysis. Therefore, an intelligent control is able to supervise the process information system and proactive control action, which are the core elements in preventive process control.

The model in this paper extends the conventional process model with the adoption of an RFID method as a tool to manage object-based information along the process flow. The following sections present the test and the implementation of the model in the real world of construction supply chains after a discussion of the system development.

III. DEVELOPING A VDC-AIDED SYSTEM FOR FEEDFORWARD PROCESS CONTROL

This section presents a system model that describes the VDC-aided process control combined by two methods: (1) Virtual Design and Construction VDC; and (2) IT-Based Technologies. The key of the feed-forward control is how to generate and manage the essential information of the process. This information needs to be provided in a proactive mode to prevent any loss occurring along the supply chains. In other words, this feed-forward preventive concept is expected to prepare the process improvement proactively.

Figure 2 presents a model to specify the concept of the VDC-Aided Process Control. Initially, the resource object is identified by IT-based technologies on the site, and the VDC provides an object-based visualized model to support communications. The framework of this system therefore includes IT-based technologies such as RFID devices and Augmented Reality (AR). These technologies aim to activate a communication channel along the supply chain. In addition, the virtual construction supports the visualization of the required tasks, thus facilitating information sharing among the supply chain participants. The VDC model supported by a database library interworked with IT-based technologies.

The scaffolding work tasks, for example, require large amounts of information in managing material resources along their supply chain: such as manufacturing, shipping, planning, procurement, and electing/dismantling. The RFID tag is able to replace existing passive tags. Each scaffold, in turn, can be identified as an object, and finally it can be linked to its VDC model for more effective communication. The project managers would thus benefit from this system in regards to their managerial needs. The following sections describe the prototype of this developed system with an actual case study.

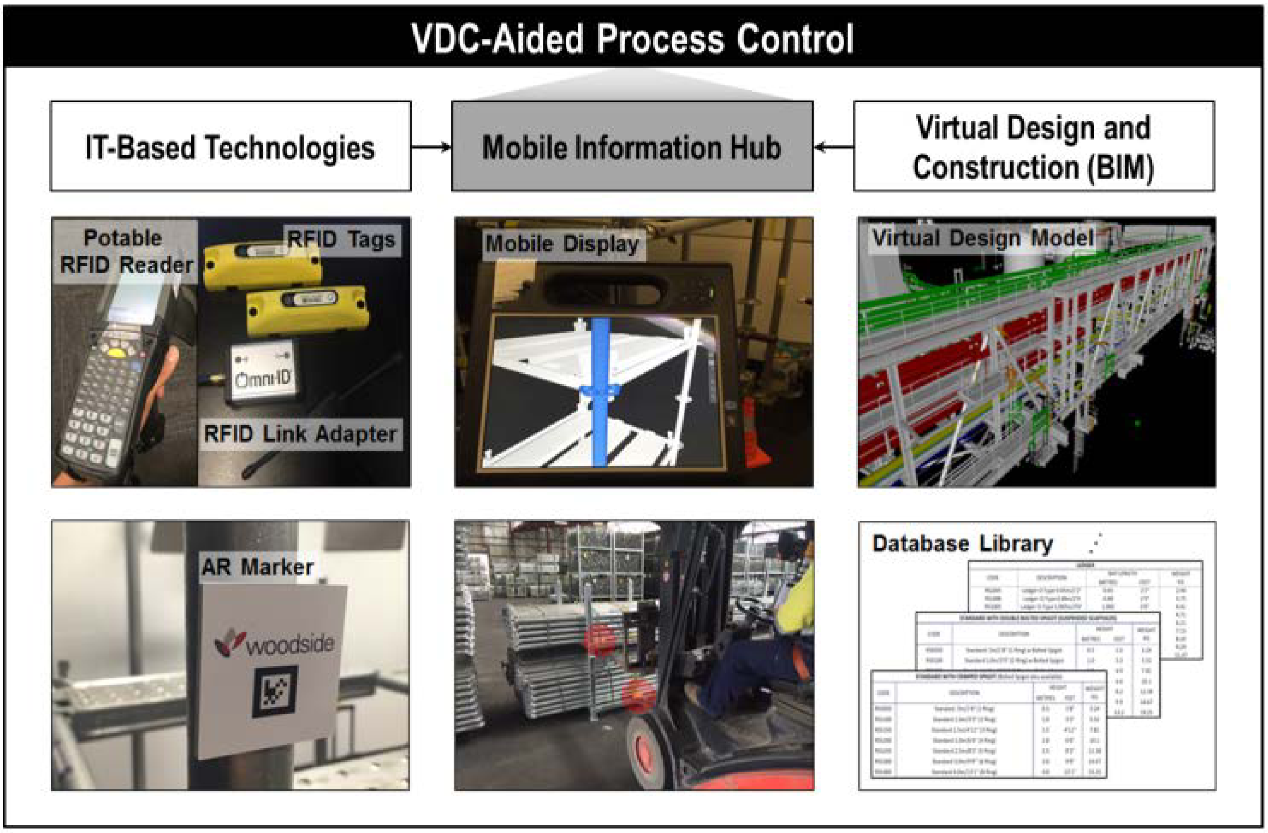

Fig. 2 Framework of the VDC-Aided Supporting System [18]

IV. Field Study: Scaffolding Operation in LNG Mage Project

A. Project Description

The case study presented in this paper is a scaffolding supply chain in a mega project; the LNG on-shore facilities in Darwin NT, Australia. Named the 'Ichthys' project, it includes a huge range of construction including scaffolding works. The works are mostly for the facility's maintenance and new construction for plants. As a temporary structure, the scaffolding requires a wide range of information in order to achieve a high efficiency of the supply chain.

TABLE 1 Procedures of the Ichthys On-Shore LNG Project Scaffolding

Procedures	Work Tasks
(1) Request	End-User Request; JKC Approval; Request Received; Create Request (SMP)
(2) Scope	Determine Scaffold Structure; Decision Criterion; Standard Structure; Modified Standard Structure; New Bespoke Structure; Supervisor Verification
(3) Work-pack	Plan; Scaffold Structure; Materials; Logistics; Build; Invoice
(4) Execute	Erect; Dismantle; Inspect; Maintain

Table 1 summarizes typical procedures of the scaffolding task: (1) Request; (2) Scope; (3) Work-pack; and (4) Execute. The goal of the mock-up system is to develop a mobile information provider to improve the current procedures, especially focusing on (3) Work-pack, where the logistics of scaffold resources is arranged.

B. Testing the RFID-based Mobile Information Hub

This section presents two applications of the system. The initial version of the system: 'Mobile Information Hub' was implemented by the use of the Radio Frequency Identification (RFID) technology and a mobile Personal Computer (PC). Figure 3-(a) shows the first stage of the scaffolding management mobile PC. As shown in the figure, the information hub provides essential information according to the procedures studied in Table 1.

A detected RFID tag was linked to the mobile and tracked along the supply chain providing essential information regarding its logistics such as Safety, Design, Work-packs and Location. The first step of the system is to select the date/time and name of work crews. The next step is the detection to identify the delivered bunches of scaffolds before launching the execution. At this stage, critical information can be distributed as needed for each work-pack. Accordingly, the inspector examines the material resources in relation to the specification by use of the RFID reader and database. Finally, the logistics can be confirmed before the erection starts. Simultaneously, Figure 3-(b) presents an example to show how the information is visually distributed in the site office. The detected information is integrated with VDC models to provide a more effective source for communication.

(A) MOBILE INFORMATION PROVIDER

(B) CONSTRUCTION OFFICE PORTAL

Fig. 3 PROTOTYPE OF THE MOBILE INFORMATION HUB FOR THE SCAFFOLDING MANAGEMENT

Figure 4 shows an on-line information hub, the Productivity monitoring system. The figure includes logistics information of thirteen work-packs including ten erection and three dismantlement works. The logistics information covers area; request number; user information; workforce; cost; and process flow. The RFID-oriented resource control enables the monitoring of the productivities of work-packs in real-time. It can be distributed by both the mobile and on-site displays. The most important contribution of the on-line hub is the accessibility of the information, which manifests as a real-time information provider in a feed-forward mode.

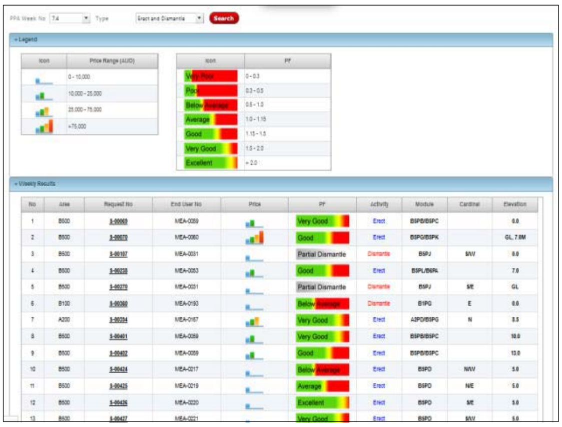

Fig. 4 PRODUCTIVITY DASHBOARD BASED ON THE WORK-PACK

V. SUMMARY AND CONCLUSION

Construction projects require large quantities of resources for their successful execution. Accordingly, managing relevant information is a critical issue in construction management. This paper presents a technology-based information system: called Virtual Design and Construction (VDC)-aided system. It was developed on the principles of several traditional methods such as Lean thinking, Total Quality Management (TQM), and Supply Chain Management (SCM). This system fundamentally depends on the Radio Frequency Identification (RFID), and its detected data linked to virtual models. A field study in this paper cover the scaffolding needs within Australian energy plant facilities. The system's potential was demonstrated via its preliminary application to the actual cases. This system would therefore be beneficial to construction managers in dealing with complicated information regarding project resources.

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