A REAL-TIME PMIS BASED INDUSTRIAL CONSTRUCTION PROJECT MANAGEMENT SYSTEM

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ABSTRACT: As amount of information in construction industry is growing, the role of information system in project management is becoming increasingly important. With the emerging IT application to the advancing construction industry, construction project management system with advanced technology has been progressed vigorously to improve construction productivity and management efficiency. Recently, a web-based Project Management Information System (PMIS) is developed to support decision-making process by efficiently managing project related information generated from various discipline. Many firms are in the process of developing the PMIS system or already have been applied the system to various projects. However, PMIS is still in its early stage of development to be applied at industrial plant construction projects that process management is significantly emphasized for the successful execution of the project. With the complexity of the industrial plant projects, the industry practitioners need to be able to visualize the construction schedule information to manage the project efficiently. This study suggests methodologies for improving PMIS specialized for industrial plant piping construction projects to estimate the baseline schedule and performance measurement more accurately by developing a framework for the piping construction projects. By using this developed system, the researchers expect that piping construction projects will be more efficiently managed on a real-time basis through measuring progress of piping at each and every state of progress milestone and provide management with opportunities to forecast the level of efforts required to execute the remaining work scope in a timely manner

Keywords: PMIS, 4D system, Plant piping construction, real-time progress tracking, Project milestone

1. INTRODUCTION

Despite recent global economic depression, contract amounts by the Korean construction companies awarded from overseas industrial plant construction projects have been increased constantly for the past decade. This increase is partially due to the expansion of energy generating plant facilities projects in the Middle East and other developing countries. Also the Korean firms' competitiveness has been well recognized in the international construction markets through continuous development in technology.

Industrial plant projects are complex facilities in that construction packages include various engineering disciplines such as civil, structural, architectural, mechanical, electrical, and automation. Also, current trend of the project sizes are getting larger in terms of their sizes and budget. To meet their increasingly complicated requirements, these industrial plant projects tend to be contracted in the form of EPC (engineering, procurement, construction) delivery method, that a single entity performs E-P-C process. With the EPC contract method in place, construction process is usually fast tracked so the construction can incorporate the imminent changes in design. It is obvious that the fast tracking reduces project durations and improves flexibility of construction process. However, the weakness of the fast track method is the higher level of difficulty for predicting the final cost of project execution and contractors are forced to carry a high risk of having undefined scope of works in the early stage of contract. With the enhanced complexity of the projects, managing project scope, cost, and schedule becomes one of the most important factors for the project success for owners and contractors. Thus, the level of accuracy to measure project progress and predict the level of efforts to perform the remaining work scope at any given time of project execution is the key element for the successful project execution. .

To overcome these difficulties in measuring of construction process and predicting of remaining work scope, project management are emphasized throughout the entire process of the construction.

Development and application of PMIS has been accelerated to encompass management requirements in all steps of construction project execution geared toward efficient project information sharing and management. PMIS is used to increase the efficiency of design, procurement, construction and project management by integrating the information technology (IT) and it brought huge advancement in construction information management. However, the researchers found a limited application of PMIS in the area of industrial plant construction projects. The aim of this study is developing a PMIS that can be applied to the industrial plant construction projects. Developed PMIS through this research may help industry practitioners to effectively manage project information and by utilizing the information, they can reliably measure construction progress and predict remaining work scope in a highly efficient manner.

2. RESEARCH SCOPE AND METHOD

The scope of this study involves developing a PMIS for piping construction projects that usually takes approximately 30~40% of the budget in the industrial plant construction projects. First the researchers developed the PMIS that is applicable to the industrial piping projects. The factors that affect construction difficulty in the every stage of construction are identified. Then the PMIS can incorporate those factors by employing difficulty factors to each unit of piping. Once the progress of piping construction also can be quantified and visualized by the 4D modeling techniques incorporated into the PMIS.

Figure 1 shows the procedure of PMIS development. Firstly related literature was reviewed in the area of development and application of PMIS, performance and progress tracking of piping construction, and the 4D-based progress tracking techniques. Also, a case study project has been selected to test developed PMIS. Development of the PMIS was performed through the collaboration with a professional construction IT firm. The developed PMIS was tested to the cast study project for validation. .

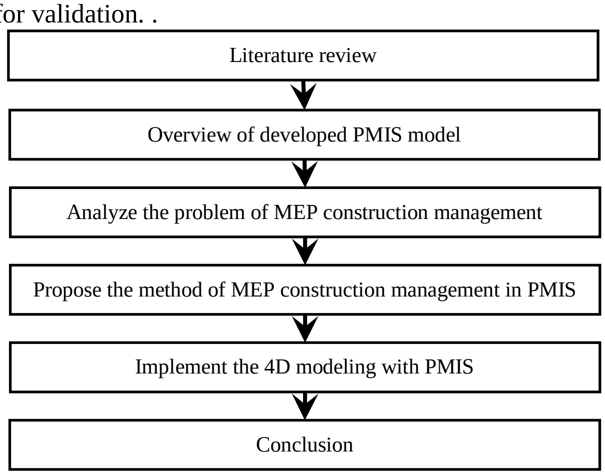

Figure 1. Procedure of study

3. Literature Review

3.1 Performance measurement in construction

In the construction industry, the accurate measure of performance is one of the key elements to the successful execution of the projects. In terms of contract payment methods under the fast tracked process, cost reimbursable contracts are generally employed in pursuit of installing the lines with incomplete design or acquiring flexibility to the design changes. Earned Value Management System (EVMS) is a proven method to measure the progress and performance. EVMS is a performance based management system that measures performance compared to the plan based upon process-cost integrated management standard.

Many research showed that the growth of revenue was directly related to the productivity improvement as shown in Table 1. Son (2003) measured, analyzed, and proposed a method to improve construction productivity. Park (2003) analyzed correlation between the factors that lower construction productivity and the waste factors with relation to lean construction principles to present the possibility of adopting lean construction. Kim (2008) provided a new approach in assessing the wide variety of project performance and proposed a system by validating through industry survey on project practitioners. Table 1 shows major subjects of those studies.

Table 1. Study about Performance measurement

Author	Title
Son, Jeong-Wook (2003)	A Study on Construction Productivity Measurement Method
Park, Joo-Hyun (2003)	The Study on Correlation Between Factors Decreasing Construction Productivity and Waste Factors With Relation To Lean Construction
Cha, Hee-Sung (2008)	Developing Measurement System for Key Performance Indicators on Building Construction Projects

3.2 Visualization of construction process by using RFID Technology

Information is need to understand the construction process easily for manage the progress and materials considering complicated situation of variety workers, equipment, materials in the field of construction. For the study in this field, Kang (2006, 2008) developed an improved methodology and 4D tool to organize 4D object for construction schedule management and progress control and a new management technology to control schedule information by each WBS level.

In recent years, the research has been conducting that apply the newest technology such as RFID, and related studies are as follow. Koo(2009) proposed a consistent and systemized approach for decision making in adopting RFID technology in a construction project to support construction logistics and progress management. And Oh(2010) suggested that the construction material management system be developed using RFID according to the information flow and various properties of materials. Table 2 shows major subjects of those studies. But the analysis was found to be insignificant that applied RFID technology in the plant industrial construction which is only applies to logistics management process in part of construction such as steel structure construction or precast concrete construction restrictively.

Table 2. Study about visualization of construction process

Author	Title
Kang, Leen-Seok (2006)	Improvement of Construction Scheduling and Progress Control Functions in 4D CAD System
Kang, Leen-Seok (2008)	Development of Major Functions of Visualization System for Construction Schedule Data in Plant Project
Koo, Do-Hyung (2009)	A Decision Making Support Model of Work Item-based Adaptation Strategy for RFID-based Construction Logistics and Progress Management
Oh, Kun-Soo (2010)	A Study on the Development of Construction Material Management System using RFID

3.3 PMIS development and Application

To perform the work effectively in a timely manner for the project team, the necessary information should be provided quickly and accurately for the timely decision making. This construction information that encompass overall process of construction process must be organized The PMIS is system that handles the massive information effectively with the help of IT. As the complexity of construction projects has been elevated, the usage of the IT based project management system becomes a key factor to control a large volume of information and archive the information for the project operation and maintenance.

Thus PMIS is recognized as a new form of project database system that the client, supervisors, contractors, and subcontractors share the variety construction information at the various levels to promote better communication. This system leads to effective management and work efficiency. As mentioned above, the PMIS is a system to share the massive information for efficiency work process among the project members. Even though no standard form of PMIS to meet the user requirements, some essential elements are required such as project management, contract management, user management, material code management, manufacturing factory management, and material management.

Yu (2004) identified the factors for successful implementation of construction project management information system, especially focused on the characteristics of construction management tasks. Park (2005) suggested a method to establish a PMIS for a SOC Project. Efficiency of the developed system was evaluated and items to be improved were identified. Na (2010) provided a framework that is capable of operating PMIS efficiently under an e-business environment, by providing a method to establish a work breakdown structure (WBS) and an EVM-PMIS integration model. Table 3 shows major subjects of those studies. As many research has been performed to optimize the application of PMIS, most existing research has limitation to be applied to the industrial plant construction projects.

Table 3. Study about PMIS

Author	Title
Yu, Jung-Ho (2004)	Success factor for implementing construction project management information
Park, Hyung-Keun (2005)	A case study on developing and applying web-based PMIS to SOC project
Na, Kwang-Tae (2010)	The establishment of an activity-based EVM-PMIS integration model

4. DEVELOPMENT OF PMIS FOR INDUSTRIAL PLANT PROJECTS

4.1 Overview of developed PMIS model

The way of establishing a PMIS may vary depending on its purpose and usage.. If a company establishes the PMIS, generally it reflects their management systems and administrative procedures. Also it can be integrated with other information systems the company operates. In this study, a PMIS that is specifically aimed to be used in the industrial plant construction has been developed in collaboration with a professional IT firm. The system consists of 19 system modules including user management, project management, logistics information management, material management, status management, quality management and the rest.

Figure 2 shows the concept of process in the PMIS that is combined with RFID (Radio Frequency Identification) technology. Once 2D-based drawing sets were completed, each object has to be mapped when they are modeled in the 3D format. The material ID represents each individual component registered in the model with the unique properties. After 3D modeling and registering is completed, the RFID tags have to be attached to each component before they are delivered to the construction site. The component with the tag attached gets unique number and is tracked at each step by recognizing the unique numbering system.

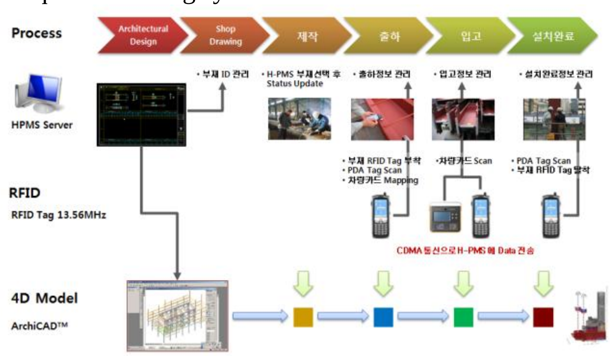

Figure 2. PMIS concept of process

4.2 PMIS configuration

As shown in Figure 3, PMIS is divided into system administrator functions and logistics management functions. System administrator functions are composed of project management, supplier management, user management, material code management. Logistics management functions are composed of material product plant and on-site logistics management. Each module consists of 3~4 sub-modules. The information that entered through the sub-modules is aggregated into upper level module and combined to be recorded in each database. Users can lookup various types of information from the database. The researchers developed a module that takes construction difficulty into account as shown in the Figure 3. The module was built in conjunction with the status management module, which manages the progress of construction. Construction difficulty factors are defined as factors that affect constructability such as location of pipe spool or work space between each pipe spool. Applying difficulty factors improves the accuracy when measuring construction progress and predicting the remaining work scope

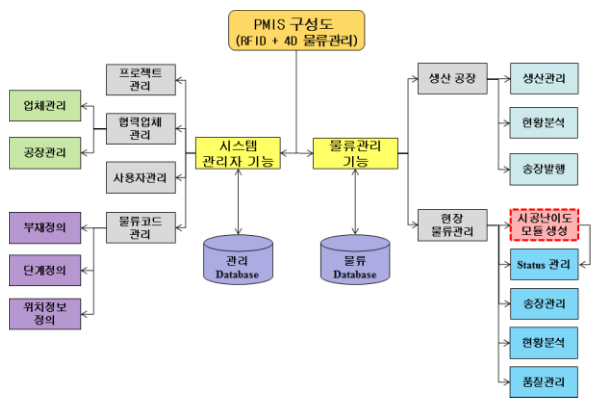

Figure 3. PMIS configuration

5. MEP PROCESS MANAGEMENT IN PMIS

5.1 Measure of plant productivity with EVMS method

EVMS (Earned Value Management System) is a performance-based management system that a project is managed by measuring performance in conjunction with budget. First set the WBS (Work Breakdown Structure) classified into hierarchical units of the project which are facilities, work area, and type to measure the construction progress and performance. It could be classified by type of pipe materials in the plant construction. Distribute the time of need for each materials that classified on WBS, and calculate the number of days for piping construction.

5.2 Analysis of MEP construction management issues

The accuracy of progress measurement depends on the capability to capture various levels of effort that is required to install each component for the plant piping construction. Also, the method of tracking the progress is still manually performed in most practices. Estimation of the initial budget and duration is typically performed based on physical characteristics of materials such as pipe type, diameter, and length with no regard to the constructability changes by construction sequence. In other words, the initial estimate does not reflect the reality of construction sequence because it does not consider the other factors such as location of pipe spool or distance between pipes that affect the constructability beside physical characteristics of material. The factors that affect constructability for each type of materials must be identified and considered to improve the accuracy of performance measurement and prediction of remaining work scope.

5.3 MEP construction management in PMIS

5.3.1 Management method of plant construction

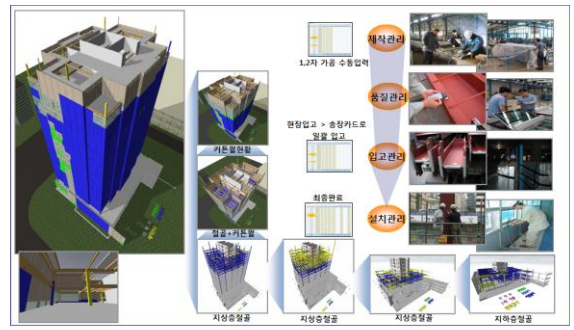

Figure 4. Overall flow of PMIS

To manage the construction information with PMIS, in 3D modeling first 3D models are developed based on the 2D drawings. In the 3D modeling, each component has to be synchronized by material ID's by mapping the material ID's from the 2D drawing. While 3D modeling work is in progress, the components of the model need to be registered in the PMIS by using registration menu on PMIS. The components can simply be selected from the materials library. The materials that were ordered from the registered list in the PMIS are manufactured from the factory and the date for each step of progress is entered in the PMIS. After material production is completed, the RFID tags are attached to each component and a unique tag numbers are assigned.

Before shipping the materials to the construction site, the statement of account and invoice are made. Each invoice card includes every tag numbers that were loaded in the shipping truck. Truck drivers keep the statement of account and invoice card to be read by a card reading machine at the entrance of construction site so dates information can be entered in the PMIS automatically. When materials are installed, the tag is read again with a PDA device so the PMIS recognizes the date of installation. Through each step described above, construction progress information is managed by PMIS and the construction progress is automatically measured. Figure 4 shows the overall flow of the process.

5.3.2 Process management of steel structure, curtain wall, precast concrete panels, and MEP construction

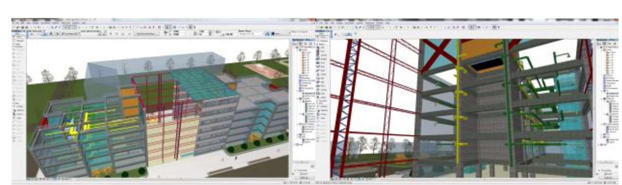

Figure 5. 3D model of case study project

In this study, the researchers developed a case study project with a 3D model from a virtual building to implement the PMIS for process management as shown in figure 5. This virtual building consists of steel structure, curtain wall, precast concrete, MEP types that typically has factory-product and on-site install process.

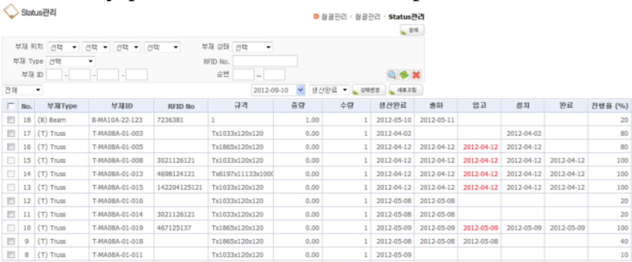

Figure 6. Process management screen of steel structure, curtain wall, precast concrete

Figure 6 shows the screenshot of managing the construction process information to measure of progress. Material ID represents the type of material and location of installation. Basically steel structure, curtain wall, precast concrete construction has simple steps as production, shipping, installation and complete.

Table 4. Process management screen of MEP 1

No.	Item Type	부재 ID	Line ID	RFID No.
4	P	P-MA05A-F1204-120400-79-5	120400-79	9468122134
3	P	P-MA05A-F1204-120400-79-6	120400-79	9468122135
2	P	P-MA05A-F1204-120400-81-5	120400-81	9468122136
1	p	P-MA05A-F1204-120400-81-6	120400-81	9468122137

As table 4 shows Process management screen 1, MEP construction include more information in material ID unlike other materials. For example, letter P, MA05A, F1204, 120400, and 79-5 indicate a type of material, location, P&ID (Piping & Instrumentation Diagram) number, ISO number, and drawing number of the line, respectively.

Table 5. Process management screen of MEP 2

Size	Pipe Spec	LM	Est. Hour	Diff. Factor	Equiv. Hour
6.60	A1	4	2	1.5	3
6.60	A1	2	1	2	2
1.00	A1	2	1	2	2
1.00	A1	3	5	1.5	7.5

As seem in table 5, the PMIS also includes pipe size, pipe spec, pipe length, and estimate time for managing the construction progress of each material. The estimate hours are calculated based on the Korean standard mechanical equipment cost data. Estimating work hours tends to have a fairly large range of error, because it is calculated by the physical characteristics of materials only.

Thus this study suggest to reduce the error range of prediction of remaining work scope by measuring the exact time of construction progress with construction difficulty factor module that has been developed through this study. Difficulty factor is a quantitative number that considers the factors to take the constructability issue into account at the early stage of project or in the process of construction. Then equivalent hours are calculated by multiplying difficulty factor to estimate hour. Those are the factors to be considered to calculate the difficulty factor as follows.

1) Material constructability due to interference each other
2) Inadequate of management and director
3) Procurement of wrong equipment or materials
4) Failure of equipment
5) Work permit delays
6) Wrong work flow
7) Reworks
8) Operation interrupted frequently
9) Process or design changes
10) Accidents

Table 6. Process management screen of MEP 3

출하	Receive	Fabricate	Weld	Hydro	Punch	진행율 (%)	Earned Value(H)
2012-04-02	2012-04-02	2012-04-02	2012-04-02			60%	1.8
2012-04-02						0	0
2012-04-02						0	0
2012-05-09	2012-05-09	2012-05-09	2012-05-09	2012-05-09	2012-05-09	100%	7.5

Table 6 shows the screenshot of managing the piping construction process. Piping construction process has steps of production, shipping, receiving, fabricating, welding, hydro testing, and punch-list. Each step is a gate to get a partial credit to earn progress. Once all processes are completed, each line is considered 100% complete, and give the weight factor to measure the progress for each step. To measure the progress for each step, each milestone for progress steps is defined by selecting each step as shown in figure 7. The weight factors for each step of process are then entered. In this example, receiving each component from the site takes 10%, fabricating is 20%, welding is 30%, hydro testing is 20%, and punch listing takes 20% as seen in figure 7. For example, if a pipe line is processed through welding, 60% of the progress can be calculated.

So it is possible to get earned hours by identifying each step of process and calculate with equivalent earned hours. Also it is possible to improve the accuracy of prediction of remaining work scope by measuring actual progress of construction with PMIS that developed it this study.

Figure 7. Regulate the step and weight factor of process

5.4 Implementation of 4D modeling based on PMIS

By developing a 3D model of a building, it is possible to visualize the MEP system such as mechanical equipment, electronic, piping, and HVAC in the building and analyze the construction difficulty. In addition, the interference between each material and activity can be verified. Interference between each component results in changing the position of a component inevitably. And interference between activities may occur by a large number of tasks working form limited space in the building or industrial plant construction. Especially in the plant construction that various activities for piping and equipment installation are performed in the crawlspace, it is the key factor to setting work priorities for efficient process management.

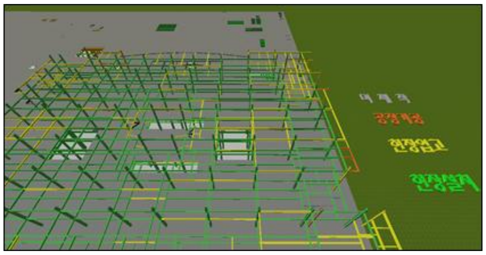

Figure 8. Implementation of 4D modeling

The other advantage of managing the process information through 3D modeling in PMIS is that it provides capability to check the construction process visually. In other word, the construction process is confirmed through the 4D modeling by adding information of construction process in the 3D model. Figure 8 shows the 4D modeling that assigns unique color for each step of progress to provide a visual representation of the status. As shown in the figure, each step is given a different color: if a component is not manufactured the color is gray, produced in the factory is orange, received is yellow and installed is green, so it is possible to know the state of construction process by changing colors.

6. CONCLUSION

This study aims to suggest the method to improve the accuracy of predicting remaining work scope by measure the construction progress accurately in the plant piping construction. First, the researchers developed a PMIS in collaboration with professional IT firm to measure the construction progress and predict the remaining work scope by manage the construction information. The PMIS that was developed in this study included a construction difficulty module which considers constructability to manage the construction process more efficiently.

The PMIS is divided into the system administrator functions and the logistics management functions. System administrator functions are composed of project management, supplier management, user management, code management and logistics management functions are composed of material product plant, on-site logistics management. Each module consist of 3~4 sub-modules. Construction information through the material production, fabrication and construction complete could be managed using RFID technology based on PMIS. Also it is possible to visualize the process of construction by given a unique color for each step of construction process. Future research project scope includes evaluating and analyzing the reliability of PMIS by quantifying the construction difficulty factors and applying them to the industrial plant construction projects.

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