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Smart-tracking Systems Development with QR-Code and 4D-BIM for Progress Monitoring of a Steel-plant Blast-furnace Revamping Project in Korea

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Abstract: Blast furnace revamping in steel industry is one of the most important work to complete the complicated equipment within a short period of time based on the interfaces of various types of work. P company has planned to build a Smart Tracking System based on the wireless tag system with the aim of complying with the construction period and reducing costs, ahead of the revamping of blast furnace scheduled for construction in February next year. It combines the detailed design data with the wireless recognition technology to grasp the stage status of design, storage and installation. Then, it graphically displays the location information of each member in relation to the plan and the actual status in connection with Building Information Modeling (BIM) 4D Simulation. QR Code is used as a wireless tag in order to check the receiving status of core equipment considering the characteristics of each item. Then, DB in server system is built, status information is input. By implementing BIM 4D Simulation data using DELMIA, the information on location and status is provided. As a feature of the S/W function, a function for confirming the items will be added to the cellular phone screen in order to improve the accuracy of tagging of the items. Accuracy also increases by simultaneous processing of storage and location tagging. The most significant effect of building this system is to minimize errors in construction by preventing erroneous operation of members. This system will be very useful for overall project management because the information about the position and progress of each critical item can be visualized in real time. It could be eventually lead to cost reduction of project management.

Key words: wireless tracking system, blast furnace revamping, BIM 4D

1. INTRODUCTION

It is expected that the loss due to the increase of the construction period in various projects in Korea arises since the problems of shortening working hours, the aging of construction worker and the shortage of skilled workers. It also applies to the blast furnace revamping project. The steel plant is composed of various sectors such as machinery, electricity, and instrumentation, and is complicatedly entangled with various companies and workers. Therefore, if changes occur in the design and construction process, it takes a lot of time and money to fix and rework. As a solution to this problem, many IT technologies are applied to construction sites. Typically, BIM technology integrates data in the design-procurement-construction-maintenance phase to enhance data consistency. In this study,

BIM technology is linked with the smart tracking system, so that the state of materials can be grasped in real time. It allows workers to be able to check the readiness of the material and adjust the work schedule accordingly. In order to establish the smart tracking system, QR code is assigned to each material and the user of the system inputs the status of the material in the order of unstoring-warehousing-open storage-install-measurement-installation completion. Status of materials is automatically displayed in 3D and 4D models as color so that the manager can easily grasp the current situation. In addition, in open storage status, the user is allowed to enter a location of material so that the material can be easily found in the site. The research method is as follows. First, existing management system is analyzed in recent research. In order to take into consideration the specificity of the revamping project of blast furnace, wireless system is built based on the requirements of related experts. Some functions of the 3D experience of Dassault Systemes are modified to visualize the information collected by the wireless system. A pilot test is performed on the developed contents, and a smart tracking system is applied to a part of the site after correcting the problem through the pilot test.

2. ANALYSIS OF EXISTING SYSTEMS

QR code is a widely used technology from manufacturing, distribution, and logistics to marketing. The order information can be converted into QR codes and used for ordering and inspection work. QR codes can be attached to product labels to collect sales information and used for inventory management. By establishing a distribution history system, consumers can quickly look up the history of their purchases through QR codes. In this way, QR code helps users to know the information about the product or order without mistake [1]. These characteristics of QR code show that it can be used in construction management. QR code contains information about worker and work procedure so that the workers can quickly inquire related information. The information on the worker includes the company to which the worker belongs, whether the safety training is completed, and the scope of the approved work. Such data can be attached to the operator's helmet in the form of a QR code so that the user can inquire related information immediately when it is needed. With regard to work procedures, it is also possible to improve the user's convenience by attaching a QR code which allows the user to access the online work procedure on-site without having to carry the relevant documents with each work [2]. From the viewpoint of logistics management, it is easy to find a case where RFID is applied mainly in a construction site [3]. However, RFID has a disadvantage in that the price of each tag is high and must be read through a specific device. On the other hand, the tag cost of QR code is cheaper than RFID tag and it can be utilized on the smart phone which many workers already have [1]. Therefore, this study aims to suggest a method to utilize QR code for material tracking system of revamping project.

3. BLAST-FURNACE SMART TRACKING SYSTEM

3.1. System configuration and development architecture

The overall structure of the system presented in this study is shown in Figure 1. First, in a wireless system, a QR code is attached to an item to be managed. It is distributed to the supplier and attached to the item at the time of shipment. The smartphone scans the QR code attached to each item and accesses the website where the user can enter the status of the item. The status of the item means the preparation state of the item divided into the stages of unstoring-warehousing-open storage-install-measurement-installation completion. The user selects the status of the item on the website. Then, the status data of the item is stored in the interface table DB.

The BIM platform reflects the status data received through the wireless system in 3D and 4D information. The BIM platform DB is an existing DB that contains 3D and 4D information about the revamping project. In this DB, the 3D model and 4D data are handled through CATIA and DELMIA of Dassault Systemes, respectively. In this research, 3D and 4D information is utilized to visualize the status data obtained through the wireless system in color and to quickly grasp the supply situation of the item. Therefore, the status data of the interface table is updated to the BIM platform DB. Some functions of CATIA and DELMIA are modified to display status data in color.

To operate the system in this process, the interface table must have the tag data and the 3D data of the

items to be managed. This is because the status data input by the user should be matched with the tag data and the 3D data of the item whose status is changed should be transmitted to the BIM platform DB. To do so, the tag data must be assigned to the 3D model at the time of 3D model production, and this must be transmitted to the interface table. However, in this project, Matching 3D data and tag data are carried out additionally in consideration of the introduction of smart tracking system during the project ongoing.

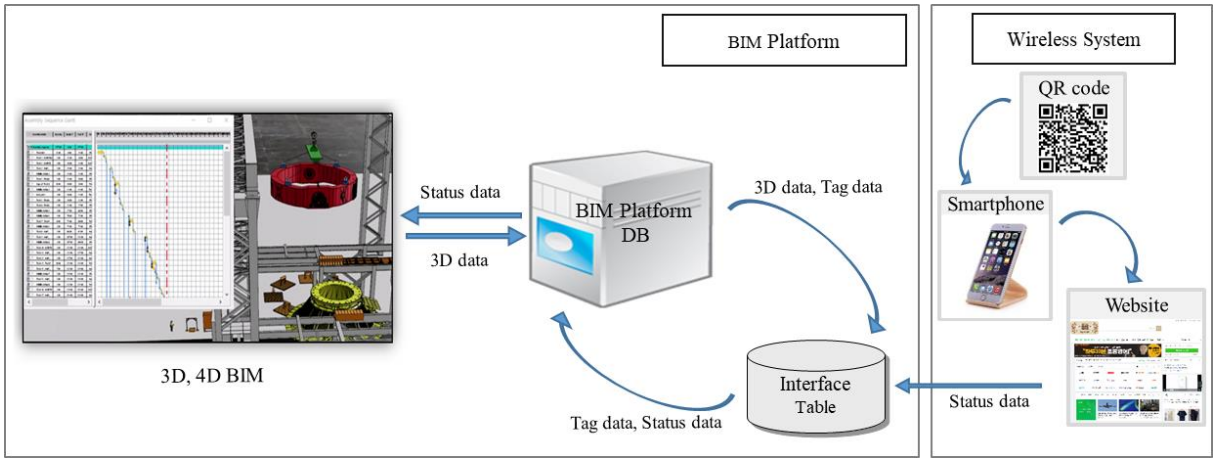


Figure 1. System configuration

3.2. Development of the wireless system

The development of the wireless system proceeds as shown in Figure 2. First, in the requirements collection and analysis, the user of the system and the material management process reflecting the characteristics of the revamping project are determined. Based on this process, the configuration of the screen of website to be accessed by the user is determined. In the data modeling stage, the entities to be managed and the relationship between entities based on the user's requirement is established, and the attributes and the format of them are defined.

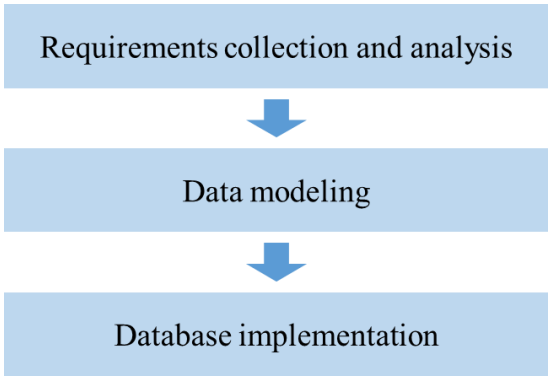


Figure 2. Wireless system development procedure

3.2.1. Requirements collection and analysis

The main user of the system to be developed is P company which manages the revamping project, and the contractor who performs the project. The main page of website designed to reflect these requirements is shown in Figure 3.

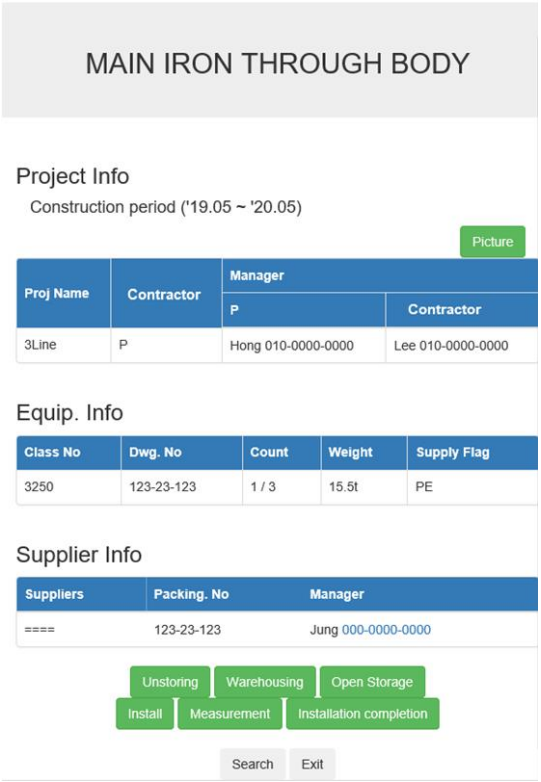
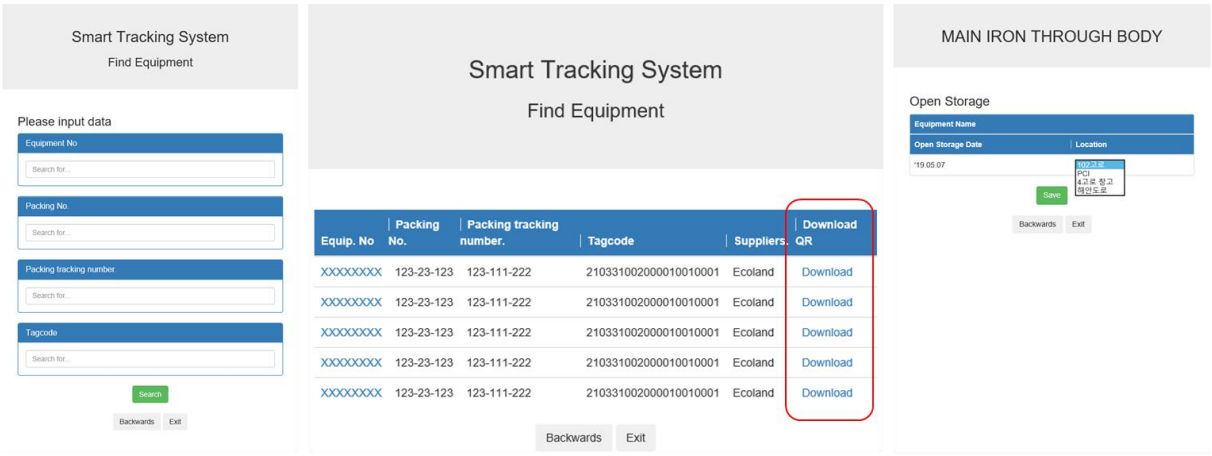


Figure 3. Main page of website

The main page is accessed immediately when the user scans the QR code. Therefore, the main page includes information about the item to which the QR code is attached and information about the supplier. the picture function enables the supplier to retrieve the picture of the item to be uploaded by the supplier. The contact information of representatives of P company and the supplier of each item is included in the page so that the user can immediately contact them when necessary. At the bottom of the page, the statuses for the item input by the user are listed. Considering the user's work process, this is divided into 6 statuses (unstoring-warehousing-open storage-install-measurement-installation completion) in total. Unstoring means the time when the supplier starts the transportation. Therefore, entering the unstoring status and uploading of the picture of the item are functions that the supplier connects to the system and uses. After the items arrive at the site where the revamping project is performed, the item becomes a warehousing state. Open storage refers to a status in which items are stored in a designated place before installation. Install means that the item is placed in where the item should be located. When the inspection is performed, the item becomes the measurement status and when all the work is finally completed, the item becomes the installation completion status.

Some processes are added to the main page based on the requirements to improve user convenience and prevent errors. First, the search function is added so that the main page can be accessed without the QR code. This corresponds to Figure 4 (a). If the QR code attached to the item is located in a place that is difficult to scan or is damaged, the user can access the main page by inputting tag code or item name manually. This function is also needed to download the QR code that the supplier attaches to the item, as shown in Figure 4 (b). In the open storage status, the user can further input the location of the item, thereby preventing the item from being lost in the site. The page for entering the location is shown in Figure 4 (c).



(a) Search function (b) Search result (c) Entering location page

Figure 4. Additional functions

3.2.2. Data modeling

The data and its format required to configure the database are defined based on the pages in requirements collection and analysis. First, the necessary data are listed in Table 1. Project information is about the revamping project. The contact number is used to reach the person in charge of P company and contractor. Equipment information is about the individual item to be managed to which the QR code is attached. The packing tracking number and the drawing number are listed so that the user can check other reference documents. The information such as count, weight, and picture of item help the user to check whether the item matches the order in the process of confirming the item. Status information includes the status of each item and the date to show its past history.

Table 1. Required data list

Division	Data	
Project information	Project period	Contact number of P company
	Project name	Contact number of contractor
	Contractor	
Equipment information	Item name	Count
	Picture of item	Weight
	Packing tracking number	Supply flag
	Tag code	Supplier name
	Class number	Packing number
	Drawing number	Contact number of supplier
Status information	Unstoring date	Install status
	Unstroring status	Installation location
	Warehousing date	Measurement date
	Warehousing status	Measurement status
	Open storage date	Installation completion date
	Storage location	Installation completion status
	Install date	Install status

The main entities derived from the above data are project, equipment and contractor. For security reasons, the user entity is added as the range of the user is limited. Figure 5 shows the structure of attribute and relationship according to entity.

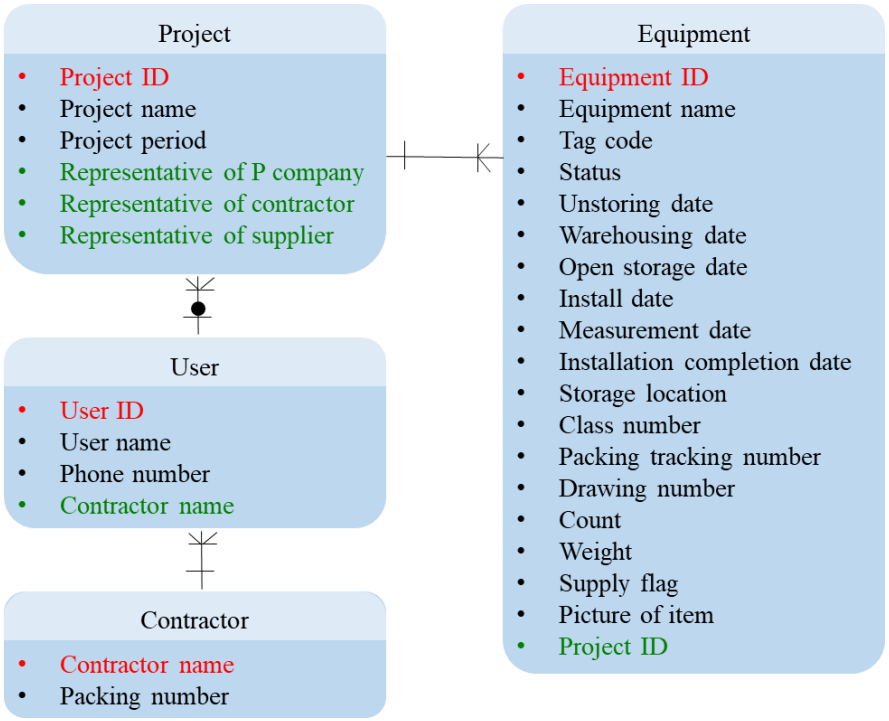


Figure 5. E-R diagram

The red attribute means the primary key, and the green attribute means the foreign key. The interface table is implemented based on E-R diagram of Figure 5.

3.3. Visualization of item status using BIM

Status information about the items collected in the interface table through the wireless system is periodically uploaded to the existing BIM platform DB. The BIM platform DB contains the 3D model and the process order of the facilities that are subject to the revamping project. This platform is based on the 3D experience of the Dassault Systeme. Based on 3D experience, various applications of Dassault Systeme such as CATIA, DELMIA and ENOVIA are utilized. In this study, smart tracking system are integrated with 3D and 4D data so that users can grasp information about several items easily. Therefore, it is necessary to change the status information uploaded to BIM platform DB into color. To do this, the B.I essential functions supported by the 3D experience application are utilized. B.I essentials is an abbreviation for business intelligence essentials, which helps users to identify important information easily [4]. B.I essential function allows 3D model to be displayed in pre-specified colors according to each stage of unstoring-warehousing-open storage-install-measurement-installation completion. In order to connect the status information of each item and the 3D model, the tag data used for specifying the item in the smart tracking system and the 3D model of the item in the BIM platform DB should be connected. The recommended process is to generate tag code according to the agreed numbering rule when creating the 3D model and give it the 3D model in advance. This is because tag codes can be assigned to many 3D model objects without looking for items to manage. However, since the revamping project was carried out prior to the research, assigning the tag code to the inherent code of the 3D model is performed. A list of 3D models is extracted first and the tag data is linked to the list by experts. The list is imported into the interface table as a final step. Experts who are familiar with the equipment is necessary to perform this task in order to specify a 3D model.

4. PILOT TEST AND ON-SITE APPLICATION

In order to verify the developed contents through the above process and collect points to be improved, a pilot test is performed by a unit test method. Based on the results of pilot tests, wireless systems and visualization are improved. The issues to be considered for the system to be applied in the site are also examined in advance.

4.1. Pilot tests

For the pilot test, a smartphone, PC used typically and a license for 3D experience were needed. To be used as a test target, facility completed in 3D modeling were separated into 13 parts arbitrarily. Tag codes and status scenario were assigned to each of 13 parts. The pilot test verified whether each function in the webpage works properly, whether it was easy to use on both smartphones and PCs and whether the color of the 3D model changed according to the status information. Table 2 is the check list used in the pilot test.

Table 2. Check list

Division	Description
Wireless system	Connection via QR code
	Direct connection not through QR code
	Check of Item search result
	Entering status information according to scenario and check of result
	Functionality of main page
Visualization	Display of status information of items in 3D model
	Check of location information of item in 3D model
	Display of status information of items in 4D model

As a result of the pilot test, it is confirmed that the functions that were originally intended in the wireless system operated correctly. Visualization of status information also performed well for applications in 3D experience. But some drawbacks were pointed out. First, all of the buttons for entering status information are activated. For example, when the item is in the warehousing status, the unstoring button is unnecessary. Therefore, unnecessary button should be disabled to prevent users from making errors. It was also pointed out that information indicating the current status of the item did not exist in the main page. In order to know the current status and location of the item, the user must press the status button. So, a table will be added to show the relevant information directly on the main page.

4.2. On-site applications

After resolving the problems that raised through the pilot test, the on-site application proceeds. In on-site application, hundreds of items are targeted unlike the pilot test which targets 13 items. The smart tracking system is first applied partially to find out the problem of enlargement application in advance. The on-site application will be done through the following process. First, the item to be managed is selected from all the items of the revamping project. When it comes to item to be managed, it is required to set the level of detail of the item. When an item is managed either in an excessively small unit or a large unit, it is difficult for the user to grasp the current situation of each item. The QR code is distributed to the supplier of the item to be managed and a tag containing the QR code is attached to each item. In this case, the attachment method should be selected in such a manner that it can be maintained for a management period in consideration of characteristics such as the size, usage method and the surrounding environment of each item. Typically, a tag printed on paper is used because of a price advantage but for items placed in an extreme environment, the QR code marked by laser on the aluminum plate is used to prevent the tag from being dropped or damaged. Suppliers scan these tags at

the time of shipment and update the status of the items. Experts who have sufficient knowledge about each item connect 3D model to the tag data of the target items.

5. CONCLUSIONS AND FUTURE RESEARCH

The purpose of this study is to reduce the cost due to decrease of construction worker productivity and shortened working hours by introducing smart construction technology. The pilot test is completed so far and on-site application is in process. End users of smart tracking system showed positive response in the pilot test. It is targeted that application of the smart tracking system will be gradually introduced throughout the project until next year.

Projects for revamping blast furnaces tend to be repeated periodically and smart construction technology that is used recently has a trend to be standardized and packaged. The smart tracking system is also developed to be used in future projects. In the case of the 3D experience platform of Dassault Systeme for utilizing BIM information, however, paying a license fee is required. Therefore, introducing the system for small and medium-sized companies may be less cost-effective than large companies.

Since the system developed in this study constitutes a part of Advanced Work Package(AWP), it can be the basis for future project management techniques such as linkage with schedule or Earned Value Management System (EVMS).

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