DEVELOPMENT OF MOBILE APPLICATION BASED RFID AND BIM FOR DEFECT MANAGEMENT ON CONSTRUCTION FIELD

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ABSTRACT: Recently, defect management have been considered as one of the major issues for more large-sized and complicated in domestic construction industry. However, the defect management have not been performed systematically because of special manpower, excessive amount of documents, 2D based inspection work, unclear traditional checklists, complicated work process and difficulty in communicating construction information. Therefore, the construction field manager could not performed the quality inspection and defect management work on time as well as the reliability of recorded quality and defect factors was decreased. The primary objective of this study is develop a Construction Defect Management Application CDMA) using a mobile (smartphone). The application can be sharing a huge information and communication technology based on RFID (Radio-Frequency Identification), BIM (Building Information Modeling) which enables field mangers to efficiently gather the information of defection in construction on-site.

Keywords: Defect management; RFID; Application; BIM; Building Information Modeling

1. INTRODUCTION

The definition of construction defect is: any deficiency in the design or construction of a building, or in the materials used in construction, or in locating or preparing the construction site that results in the building not performing in a manner that is reasonably expected by the consumers. Under this definition, a construction defect is the result of an improper act or failure to act of an architect, engineer, developer, contractor, subcontractor, material supplier or manufacturer or other party involved in furnishing the labor and materials for constructing facilities. The defect information can be categorized into two basic concepts: general defects and specific defects.

A general defect refers to the general comments about a space without referring to particular building elements or objects. A specific defect usually refers to faulty details of a particular building element or object [1].

However, current defect management processes do not satisfy user's demands for building quality and defect information feedback. In addition, quality inspection and defect management have not been performed effectively because of insufficient field mangers, special manpower, and excessive amount of documents, unclear traditional checklists, complicated work processes and difficulty in communicating construction information. Therefore, the construction field manager could not perform quality inspections and defect management work on time. In addition to this, the reliability and quality of recorded defect factors decreased

The primary objective of this study is develop a Construction Defect Management Application CDMA) using a mobile device (smartphone). The application can utilize information and communication technology based on RFID (Radio-Frequency Identification) and BIM (Building Information Modeling) which enable field mangers to efficiently gather information on defects in construction, on-site.

It is anticipated that effective use of the proposed application would be able to improve communication and information sharing among the related participants and systematically accumulate data (3R, Reuse/Reduce/Recycle) that might be used in similar construction project.

The application collects defect data at construction field in real-time, and controls the transmission and receiving of defect data on-site or site office. In addition, it is possible to access a repository of data in real-time for seamless information acquisition and quick decision making for corrective actions when defects are found.

2. LITERATURE REVIEW

2.1 Defect Management

The main purpose of defect management is to check and/or prevent defects as a part of project quality management. In construction, managers identify defects and record them with information of drawings or documents such as checklists and punch lists. Then upon returning to the office, the collected defect data is re-

documented into a computer system. Once a defect is identified in the field, they discuss with the subcontractors and make an order to take action. After the worker finishes the rework, the manager re-checks the work and then confirms the rectification of defects.

Defect management at construction sites is carried out by field manager, Sub-contractor, and worker. Currently, the field manager is the main participant who leads the defect management. In general, defect management tasks are conducted through existing 2D drawings or specifications. In the meantime, various methods, processes and material information are examined.

However, a considerable amount of time is actually being spent in sharing and managing defect information, which are generated in the construction phase, in real time. With the existing methods of defect management, field manager cannot timely confirm changes in defects that may occur during construction processes. Thus, the field manager has no choice but to go back to office and check the changes in person. Consequently, the field manager's workload increases and also, quality and defect management tasks come to be simply performed in the extemporaneous manner. As a result, if a defect occurs, its locus of responsibility becomes unclear. Currently, defect management at construction sites lacks the proper establishment of existing defect-related information databases, particularly in terms of similar defects. So, a feedback system for the prevention is not prepared yet. Therefore, to manage defects properly, database should be established and the information about the defect that has already occurred should be reused or recycled. Additionally, CDMa that can reduce defects must be developed.

2.2 Various Technologies for System Configuration

(1) RFID Technology

Purposes of CDMa are: to accumulate and recycle a wide range of information about defects, to analyze the information, to discover the cause of the defects, and to prevent and reduce the defects through on-site management. In order to manage the field where defects occur, one must deliver information - which is useful for defect prevention - to field manager in the right place at the right time. It is needed that field manager receives defect information anywhere so that this field manager can judge whether or not reconstruction or subsequent work would be performed due to the defects. For this, CDMa needs to get accurate location information telling where the field manager is situated as well as which defect(s) the field manager needs to know.

Since the use of mobile devices such as tablet pc and smartphones has been increased recently, the location information of the user can be provided with use of the GPS sensor mounted inside the devices. Yet, when the GPS sensor is applied to the construction industry, high definition location measurement is available only in outdoor, not in the indoor places. For this reason, in indoor environments, accurate location information of the user or building materials cannot be provided. Compared to this, RFID Technology is a measurement technique using RF (Radio Frequency) signals which are based on wireless network. Presently, various high definition techniques for location measurement including UWB (Ultra Wide Band), WLAN, RFID and so on are being studied to compensate for the disadvantages of GPS. Among these techniques, RFID can build infrastructure at a lower cost than the other techniques mentioned above [5].

(2) Building Information Modeling

Building Information Modeling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition (NBIS). BIM enables a virtual information 3D model to be handed from the project team (architect, structural and building services engineers, field manage, etc.) to the main contractor and subcontractors and then on to the owner or operator.

Recent BIM-related studies have been performed for the introduction and development of BIM. Along with these, there are also the research with the following themes – the introduction and revitalization of BIM, the possibility of applying BIM to each construction sector[6], and the development of the systems using BIM and its process[7]. However, there is still little research to improve defect management at construction site using BIM.

(3) **Defect Management using Mobile Tool**

At the moment, the mobile devices including smartphones possess excellent portability through their small size and lightweight. Also, the devices have a variety of functions like high definition cameras for photos and videos, WiFi wireless Internet support system, email managing program and schedule managing program. That is to say, the single equipment integrates several functions that have been operated by several different equipments separately. If the single equipment can be used at construction sites too, many limitations can be overcome. At the past construction sites, there were imitations to carrying tools (e.g. PDA, UMPC, Tablet PC and etc.) which are utilized for management and collection of information about occurrences on sites. Also, the working environment of the construction sites was not fully considered in the past.

In fact, research on defect management using application in smartphones is currently insufficient. Also, research on defect management, which utilizes latest technologies including PDA, RFID and Laser Scanner, are being steadily progressed. These studies, however, are not aimed at prevention of defects, but focusing on the after action that will be taken after a defects' occurence.

In this regard, this study aims at developing Construction Defect Management Application (CDMa) that can manage defect information more accurately and efficiently with use of Mobile-based RFID and BIM techniques; in order to improve the working method for defect management rather than other numerous tasks of

the construction phase, which are carried out by different project participants.

3. Defect Management Process using Smart Phone App

3.1 System Process

The defect management system is designed for quick completion of information recording (from the point when a defect occurs), completion of action taking and completion of action approvals among workers. The information about the defects is stored in the project DB so as to be used in the management tasks. This information can be reused for the project's defect management tasks or, utilized in education for defect prevention. Figure 1. shows the process of the defect management system. The contents of each step of the process are as the following.

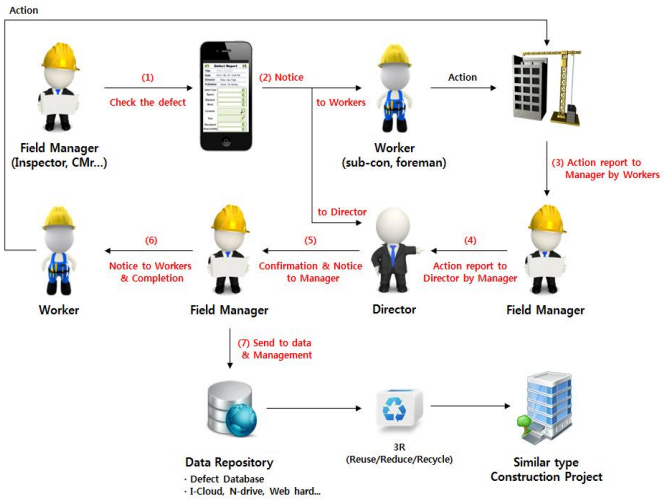

Figure 1. Comparison of Main Features between Mixed-use and Single-use Projects

① As discovering a defect, the field manager is to record defect information by making use of the application.

② The stored information is to be sent to both the director and worker. When the user is recording defect information, he or she can select multiple recipients who relate to the defect, such as a responsible worker.

③ The worker is to carry out a task upon a defect, after checking the defect information that is sent by the manager. Then, the worker is to record and restore the contents dealing with solutions to his or her received information about defects. The worker is to retransmit those contents to the manager.

④ The manager is to review and approve the contents about solutions to defect information, which is sent by worker. On the one hand, if there is a problem with the solutions provided by the worker, the manager is to attach an order to rework to the received information and then, he or she is to retransmit it to the worker. On the other hand, if there is no problem, manager is to select 'confirm' or 'approve', to save the relevant information and to transmit it to director.

⑤ Director is to check and approve the defect information that is sent by manager.

⑥ Manager is to send the completely approved defect information in the form of an alarming message to worker.

⑦ Defect information includes records of defect occurrence, details about task performance and review details. This is stored in a DB during the period of project execution.

⑧ The reports on defects, which are stored in the project DB, can be reused for other defect management tasks of projects that may be carried out later. Thus, the occurrence of the same type of defects can be prevented.

3.2 System Constitution

This study suggests a mobile-based construction defect management system, which is divided into three categories – the initial screen, the input of defect information and the transmission/reception of defect information. With this system, it is possible to share information about defects and the solutions in real time between working participants. Also, it is possible to improve the inefficient aspects of the existing defect management tasks that are considered earlier in this paper. Figure 2. shows components of defect management system. Each item's detail are represented as follows.

Figure 2. Components of Defect Management System

(1) Initial Screen

The initial screen consists of four components – Apps Play, Initial Screen, Login Screen and Project Information Selection. The initial screen is designed for tasks of selecting/confirming tasks on the project list, which is already conducted or, tasks of registering/deleting a new project or selected project. Login information consists of several options like employee number and password. Also, project information consists of the options like basic information on selected project, report writing and list of defect management status. Figure 3. shows the components on the initial screen of defect management system.

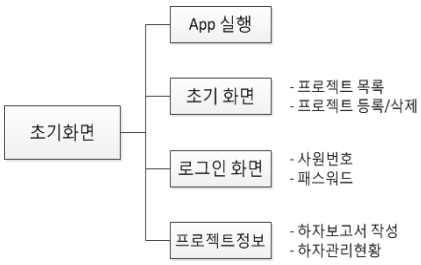

Figure 3. Components of Initial Screen

(2) Input of Defect Information

The input of defect information consists of three components – varied defect information, image information and recipient/director setting. First, as for the defect information, the user can select specific information according to the relevant content, while categorizing the information by defect type, construction type, space and location. The image information includes information on 3D BIM Image, Picture and Drawing that deal with location information, that is, one of key technologies of this system. Also, the recipient and the director are differentiated with each other depending on whether there is a defect or not. When sending a message, multiple recipients can be selected at once. Both the recipient and the director are all participants in a business. Depending on the type of defect or the construction type, messages can be selected for/transmitted to the subjects who are involved in the tasks. Through this, disputes that may occur due to defects can be prevented in advance. Figure 4. shows the classification system of input of defect information.

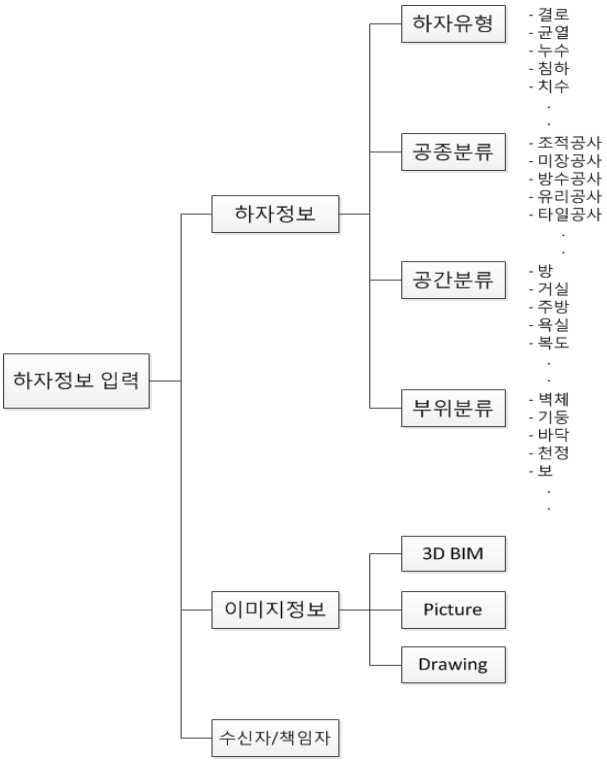

Figure 4. Components of Input of Defect Information

(3) Transmission/Reception of Defect Information

The transmission/reception of defect information consists of information transmission, information reception and defect management status. Through the information transmission, when a defect occurs, it is possible to check whether or not the information is delivered rapidly and accurately. Moreover, through the information reception, it is possible to make a report on whether or not business actors properly receive information about defects. The after action can be also reported through the information reception. With these kinds of reports, the received information can be retransmitted to manager and approved by the manager. The defect management status is designed for confirming both a list of the input defect information as well as the defect information's progress details. Figure 5. shows the classification system of transmission/reception of defect information..

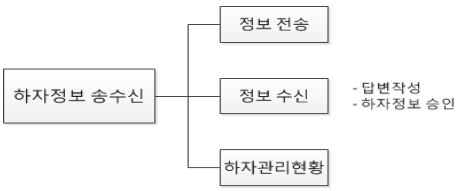

Figure 5. Components of Transmission/Reception of Defect Information

4. Smart Phone Apps System and Utilization

4.1 Initial Screen

After running the App on smartphones, the initial screen, as the screen displaying access to a project, is needed to show the project that the user wants to record. After running the App, the manager is to select the project among the several projects which are displayed on the screen. On the initial screen, with the project code created along with the establishment of project DB, it is possible to register the project and then, delete the completed project from the list. When one selects a project and accesses it, the login screen is displayed. If the employee number and password are input on the login screen, it is possible to log in to the project through the approval process of the web system. When the login procedure is completed, the selection screen displaying basic information of the project, defect report writing and defect management status is output. To input the information of the defect which occurred, defect report writing must be selected. Figure6. shows the initial screen.

Figure 5. Initial Screen

4.2 Input of Defect Information

After defect report writing is selected, the screen will move to another screen to record defect information. Based on the login information, the project (which is selected on the initial screen), and the employee number/password, the writer's information and the writing date are all automatically entered. The user is to input the title of the defect and to check the input details on writing date, writer and manager.

The first step is to select detail items on defect type, space categorization and construction type categorization. These detail items are to be used for searching the defect information stored or, the items are directly used as a tool for saving the information in DB. Then, select an item of attachment to choose defect information as well as the relevant data. On the following screen, items for selection are displayed and can be attached. The pictures and relevant drawings that are saved in project DB can be attached.

The second step involves selecting RFID+BIM item and attaching BIM model including the user's location information Especially, with the item and model, values of x-coordinates and y-coordinates that describe the user's location can be output. Here, smartphones, the user's RFID tags or receiver can be used for the output procedure. Consequently, the user's or the occurring defect's location can be identified in real time. The displayed coordinates are to be sent to the main server and the coordinates can be represented through BIM model. Thus, the location information of the defects, which occur through 3D BIM model, can be determined.

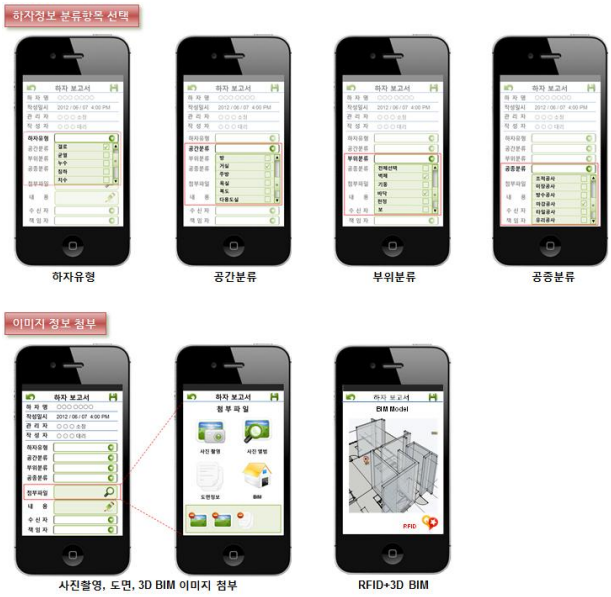

Figure 6. Input of Defect Information

Finally, input the solutions to the defects and identify the type of the defects or the reason. Then, choose a proper worker who will be in charge of managing the defect information. At this time, select additional business actor(s) that can be held responsible for the solutions to defects. Afterward, all the input details can be saved.

Figure 7. Input of Defect Information

4.3 Transmission/Reception of Defect Information

It is possible to save defect information and check the stored details using this system. If there is an error in the input information, the error can be modified. If there is no error, just transfer the defect report to the selected relevant subjects. At the time when the transfer is completed, the screen that enables the user to create a new report and determine defect management status simultaneously is provided.

The worker who confirms the defect information is to perform the task according to the solution provided by manager. After completing the task, the worker is to input the details of the solution on the report writing screen. The worker also has to attach pictures and send them. The manager who receives the defect report is to review it. If there is an error, the manager is to order to rework to the worker. If there is no error, the manager is to select the approval completion and at the same time, he or she sends it to director. Through final approval by the director, the defect report is to be saved in the main DB. With this defect report, it is possible to identify a series of management measures including solutions, confirmations, reviews and approvals that are displayed on the defect management status screen. Furthermore, when project will be conducted in the future, this report can be utilized as a material for education and assistance in the defect manager's management tasks. As a result, it can be useful for the prevention of accidents in projects which will be carried out in the future.

Figure 8. Transmission/Reception of Defect Information

5. CONCLUSIONS

Recently, various construction tasks have become more integrated and combined. As such, there has been a lot of research and development attempting to merge a variety of IT technologies, in order to improve work efficiency and to satisfy user's requirements. In particular, in order to increase the satisfaction of facility users, studies that are aimed at preventing defects especially in the construction phase have been carried out. However, the results of recent research seemingly cannot be applied to actual construction sites. This may be due to their complicated nature, which makes them impractical to actual construction sites.

As a result, field manager's workloads continuously increase. Furthermore, there are other problems such as poor communication, increasing defect occurrence rates and increases of claims.

Therefore, this study suggests a conceptual model of Construction Defect Management Application (CDMa), which utilizes Mobile-based RFID and BIM technology, in order to improve efficiency, accuracy and promptness of defect management tasks in existing construction sites. In the earlier part, this paper already discussed the efficiency, accuracy and promptness of defect management tasks.

The main research results of this study are discussed as follows:

1) From the point when a defect occurs, information can be rapidly shared between working subjects on a task. With this information sharing, CDMa is able to share information in real time, in terms of defect reason, type, solution, report and approval. Through such a series of processes, the defect information can be stored. Also, the information can be reused in follow-up projects so as to become helpful in addressing the problems encountered in existing defect management tasks.

2) CDMa can input/output not only the text information about the defect's type, the construction type, the space and the part, but also information on location, 3D BIM image, picture and drawing that are particularly gained through RFID. With the functions of CDMa, field managers can record defect information more quickly and accurately than with the existing checklists, punch-lists and work schedules, with which the recording process can be long and repetitive.

Additionally, on the system, recipients and directors who are the working leaders in defect-related tasks can choose to output the information into a form of report. With this, it is possible to prevent claims or disputes in advance, which may result from defects.

3) The defect management system suggested in this research can share defect information in real time between the workers at construction sites (field manager, sub-contractor and worker). Also, it is possible to minimize time wasted at work, by reducing inefficient document writing and unnecessary fieldwork.

This study is aimed at improving the existing inefficient defect management process through Mobile-based CDMa. To develop an appropriate application, research is currently being performed in cooperation with a mobile application-making expert. Thus, it is required to liaise with domestic and international construction sites in which this defect management system will be applicable in the future. Through the liaison, it will be possible to address the systems current limitations and to validate it's applicability. In addition to this, user satisfaction, system practicality and system effectiveness will be considered. The system under development is expected to be applicable for use on actual construction sites.

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