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Efficient Management of Construction Process Using RFID+PMIS System: A Case Study

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Abstract: Present construction site has been changing taller, larger, and more complex. Because of these reasons, materials, labours and equipment have also been increasing gradually. Therefore, the importance of sharing information among the participants is one of the pivotal aspects to success construction project. Radio frequency identification (RFID) technology is one of the most efficient equipment and it has also been widely applied in various areas. Application RFID in construction site could bring benefits rather than established methods for controlling, monitoring, and saving of time objects. Quick and correct information capture and retrieval is essential to support project manager's performance. Project management information system (PMIS) is a suitable system to solve quick delivery data and correct monitor of process. This provides participants with project planning, organizing and controlling by acquired information. Therefore, this research demonstrates the novel technology of the RFID+PMIS. Finally, two real case studies were performed in terms of human resource (HR) and ready mixed concrete (RMC), to prove the new technology's capability, is RFID+PMIS in on-site. From the case studies, RFID+PMIS system was proven in terms of effectiveness rather than current method.

Keywords: Radio frequency identification, project management information system, arbour attendance management, ready mixed concreter.

1 Introduction

The recent project performance in the construction industry showed there needs to be efficient control to achieve a better visibility and traceability because materials, labour and equipment have increased and are complicated. The current approach for controlling and managing a project system is unreliable and ineffective for information sharing among the participants [1], because traditionally this approach has been based on a project manager's experience and done manually through sending paper documents back and forth [1–3]. These approaches are too difficult to solve systematic optimization approaches such as integrated problems, and are not considered practical in real-world construction applications. Also, limitations in data transferring among project participants and the classic database have an effect on lower data quality, longer service process times, and ineffective capturing of information of data. Consequently, not only time and space gaps occur but also this influences duplication of information. In order to solve this problem, the application of a barcode system in the construction industry began in the 1990s by construction firms [4–6]. The barcode system is one of the ways to identify the tools, materials, and location of labour and has been used for a long time in the construction field. Although the barcode system has brought convenience and availability in identifying the position of objects in real-time, it also has limitations that have a short read range and durability especially when they are dirtied or scratched. The main advantage of aspect radio frequency identification (RFID) is that it provides a long distance read range and a huge storage capacity, compared with barcodes. Additionally, it can be utilized for more effective sharing of information combined with project management information system (PMIS). This RFID+PMIS system can be improved and changed to more efficient planning, and control of construction projects require more systematic and logical methods in the construction industry. Therefore, this research develops RFID+PMIS based labour attendant management and logistics delivery of ready mix concrete

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(RMC) by case study. After an improvement of smooth information flow and practical aspects are confirmed, this research tries to evaluate the reliability and feasibility of this system, to compare with the established system.

2 Theoretical Background

The application of RFID is anticipated to be one of the novel technologies for tracking labours, tools, and materials [2,4,6–9]. Unlike barcodes, RFID can withstand harsh conditions and can be read through most materials [5,7,10]. Currently, RFID in the construction site has been implemented more than before, due to its reliability and improvement of the inventory management such as concrete operation, productivity analysis, labour management, structural steel members, location of buried assets, construction tool tracking, and pipe spool tracking tracking [4,9,11–14]. Many previous studies have showed that RFID could help improve the collection and sharing of information in the supply chain process as well [7,10,15–17] since Jaselskis et al. [18] provided a description of RFID.

The PMIS is a system tool and technique, and used in the construction sectors to delivery information. Project managers use the techniques and tools to collect, combine, and distribute information through electronic and manual means [19]. The most important principle of the RFID +PMIS system is its data transferring between RFID and PMIS. Attached to the chip is the antenna, whose purpose is to absorb RF waves from the reader's signal and to send and receive data [20]. The antenna is also known as the coupling mechanism [21]. In electronics, coupling refers to the transfer of energy from one medium to another [20]. The transfer of energy is in the form of magnetic field, which is the way the tag and reader communicate. In the correct environment and proximity to an RFID tag reader, these antennas can collect enough energy to power the tag's other components without a battery [21]. Based on the type and intended use of the tag, the antenna may have many different shapes and sizes [21]. The larger antenna, the more energy it can collect and then send back out. Larger antennas therefore, have higher read ranges although not as high as those of active tags. Antenna shape is also important to the performance of the tag. The tag can simultaneously communicate storage and transfer locations information with the unit en route [18]. It comes with the invoice and contains the information to a construction site.

3 RFID in General

RFID is the novel technology part of automatic identification and composed of a reader and a tag. The concept of RFID working process is simple in that it uses radio frequency (RF) waves instead of light waves between a reader and a tag. The technology of RFID connects objects to the internet and databases, so it can be tracked or identified, and associated project managers and engineers can share data as seen in Fig. 3.1. The main characteristic of RFID can be possible to recognize without direct contact to the equipment. In addition, RFID can be possible to recognize and check anytime while moving or keeping. Furthermore, it can be possible to confirm a number of people in a short time due to RFID's rapid speed of cognition and low level of errors. Moreover, this can be used semi permanently because it is reusable [20]. Another advantage is the relatively large data storage capacity, which is currently up to 128 kilobytes (KB), allowing for storing additional information beyond identification information on the tag [12]. Today RFID can be classified into three types such as active, passive and semi-active system, and it is utilized according to various frequencies.

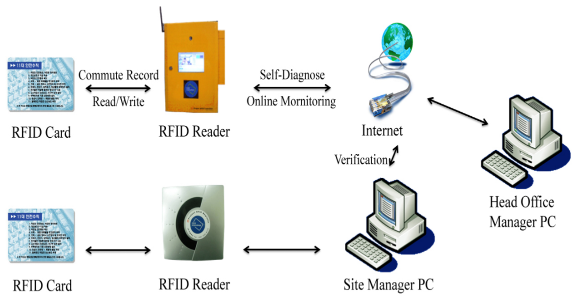

Fig. 3.1 RFID communication

3.1 RFID Tag Types

The most atomic element of RFID is a tag. The tag contains an antenna and a small microchip [1]. The small microchip is comprised of a microprocessor, memory, and a transponder, and its purpose is to transmit the unique identifier of tag and responsible for implementing the correct transmission algorithm. This algorithm ensures the proper time slot of the tag's transmission and causes the tag to transmit at random intervals [21].

There are varieties of RFID tags available, known as the active, passive, and semi-active tags. The active tags can operate with battery power, which has up to 10 years in life span. Furthermore, active tags have a large memory capacity from 32 to 128KB, which comparison to a relatively smaller memory capacity of passive RFID devices that currently vary from 128 to 256 bytes [4]. However, passive tags have a long life period which is 20 years or more because it does not require a battery to operate it. The power of passive tags is provided by the

Table 3.1 RFID frequency

	125-135 kHz	13.56 MHz	400-960 MHz	2.45-5.8 GHz
Availability	>30 years	>10 years	>3 years	>10 years
Bulk reading	Limited	Up to 50 tags/sec	Up to 150 tags/sec	-
Reading distance	˜ 0-100 cm	˜ 0-50 cm	˜ 100-500 cm	˜ 0-500 meters
Data transmission rate	Low	Medium	Fast	Very fast
Interference resistance	High	High frequency	Depends on environment	Susceptible to electronic noise

RF wave created. Today, passive tags are applied in majority of the construction industry due to it being cheaper and made smaller than active tags. A semi-active tag is the type which combines characteristics of the active tag and the passive tag. This tag only uses the battery when energized and then the battery power is returned to sleep mode. However, this tag has a short read range when compared with an active tag. If the tag has a temperature or chemical sensor, the battery can power it, and it operates exactly the same as an active tag [21].

3.2 RFID Frequency

The RFID frequency is classified in four different kinds as shown in Table 3.1. The most common frequency is the low frequency. It works 125 KHz-135 KHz, normally utilized for access control and asset tracking [22]. The high frequency that is used in active tags has 0.5m read range and utilizes 13.56MHz. In addition, high frequency is commonly applied when a medium data is required [22, 23]. The Ultra-High frequency which operates from 400MHz to 960MHz is used when long read range, from 1 to 5m, is required [23]. The last frequency band which is called Microwave frequency can detect a tag from 0 to 500m using an active tag, uses 2.45GHz to 5.8GHz of frequency band [23].

4 Development of the RFID+PMIS System

The RFID+PMIS system has been developed using Microsoft.Net and SQL server. Process data is collected by RFID readers and then synchronized to PMIS server automatically. The objectives of these two implementations are to improve the efficiency of the technical and practical feasibility of RFID application in the construction industry. The PMIS is intended to store information essential to the effective planning, organizing, directing, and controlling of a project, as well as provide a repository of information to be used to keep stakeholders informed about the project's status [24]. This PMIS contains diverse information in terms of guide and background of project such as code management, schedule, user information, and check in/out of labour etc. Automatic acquisition of data requires the construction manager to develop an integrated software system part and interface system part.

The software system part is used by RFID. The status information generated during the whole process is acquired using the RFID components by the internet. The interface using system part is developed in a web environment. The PMIS is connected to the internet server and can recognize each reader using its IP address. Information data from all readers is saved in the database server, and should be available and easy to obtain, preferably by computers. Thus the status of the process can be checked anywhere at any time using PMIS. The system composition is designed as shown in Fig. 4.1. The PMIS should update the process data and allow for head officers, site managers, and subcontractors to access the data through the internet. They monitor the process of the target anywhere at any time by visual inspection, and make decisions on delivery interval as well. By contrast, the PMIS generates a variety of information data. The PMIS is a combination of different technologies that should be tested on a construction site to verify its effectiveness.

5 Case Study

According to a recent report that labour expense takes possession, on average, over 40% of the whole cost [25]. In addition, it is known that up to 70% of the overall construction cost is direct costs relating to material, manpower, and machinery [26]. The purpose of the case study was to test the applicability of the PMIS in real-world for monitoring and controlling with RFID technology. Therefore, this case study describes RFID+PMIS system applications focusing on labour attendant and RMC process management. In this research, 914 MHz RFID tags with of passive type were chosen and the tag is a plain plastic RFID card that can be used as a clip. Site engineers can directly access the PMIS server from anywhere at any time if they can access the internet using PCs, PDAs, and mobile phones. The decision was based on reviews of technological feasibility, and field testing.

5.1 Labour Attendant Management Process

Suggestion procedure in this study is shown Fig. 5.2. The instruments of information collection used were RFID

Fig. 4.1 Screen compositions of PMIS

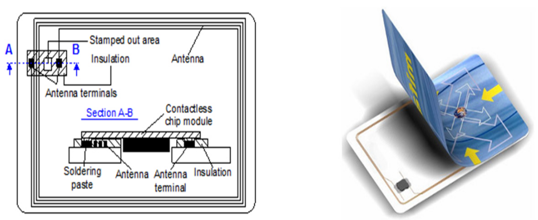

Fig. 5.1 Plain plastic RFID card

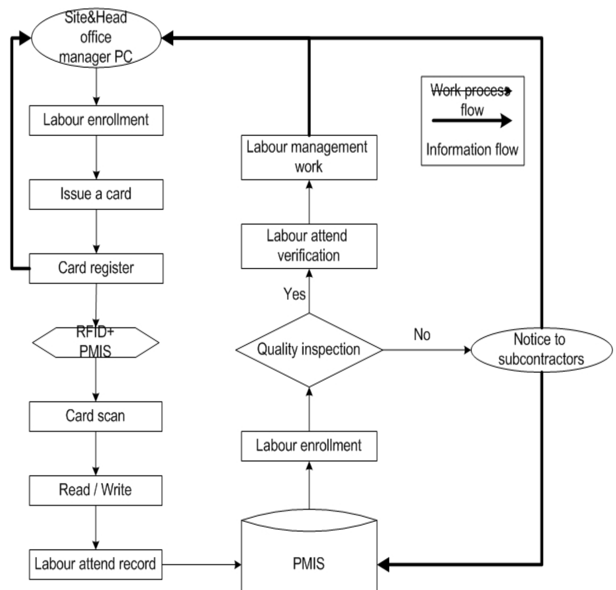

Fig. 5.2 Labour attendant management flow

tag, RFID reader, and PMIS. RFID tag was attached to a personal ID card and RFID reader was located on the gate. Firstly, to collect information of labour, the site manager registered personal information (step 2), then issued an RFID ID card of applicable labour from the site manager's PC. After being issued an RFID ID card individually (step 3), each labourer transferred their attendance time through the scanning of card, scanning in when they were in attendance (step 5). After that labourers were sent to go construction activity after a safety toolbox meeting. Finally, subsequent to daily work, the closing time of labourer was also gathered through scanning the personal ID card. Collected attendance time information and construction activity of labourers were combined on the site manager's PC automatically using the PMIS. This constituted part of a variety of information which is required for labour management (step 6).

5.2 Ready Mixed Concrete Management Process

At each step of the RMC truck process, the tag data was read successfully to generate the associated all of information of process steps. After checking the status of the order, RMC trucks departed from the plant to the construction site with an invoice. When RMC trucks arrived at the construction site, the RFID invoices that come with the RMC trucks were read by using a

Fig. 5.3 Procedure of labour attendant process

stationary reader installed at the gate (step 8), as shown Fig. 5.5.

The process time of an RMC truck was identified for receipt of truck information at the construction site automatically by the RFID tag. The order information, such as information of order number, order date, target date, company, standard, ordering, shipping, returning, pouring, location, and status of receive, as shown in Fig. 5.5., was confirmed on the PMIS screen. The information status of the last column on the PMIS screen associated with logistics and process is used to change its process status from 'not received' to 'received' when the process information was registered automatically. As soon as the update of the PMIS was confirmed, the information of the RMC truck was synchronized to the PMIS server, changing the status of the corresponding information to show 'received'.

5.3 Monitor Method of PMIS

The PMIS provided the detailed information required for monitoring and control using RFID tag data. When completed a labourer's attendance, a daily report of labour attendance is accumulated automatically in real-time. Additionally, collected data via RFID ID card scanning is processed automatically for various methods; special day, term of attendance, and present condition of attendance through the PMIS system. Fig. 5.6 shows different kinds of PMIS processing such as company, month, and type of occupation respectively. The received information of each RMC truck is reflected to the PMIS server by synchronization with a PC. Fig. 5.7 shows information is extracted and stored by date, standard, location, and company in a PMIS database server. This measurement provides fountainhead data which can grasp productivity of construction activity and the resulting quantity.

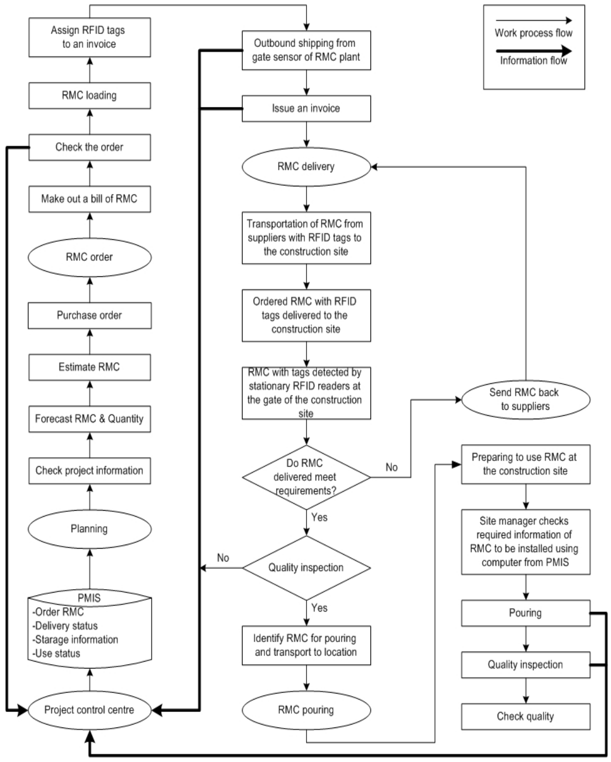

Fig. 5.4 RMC process flow

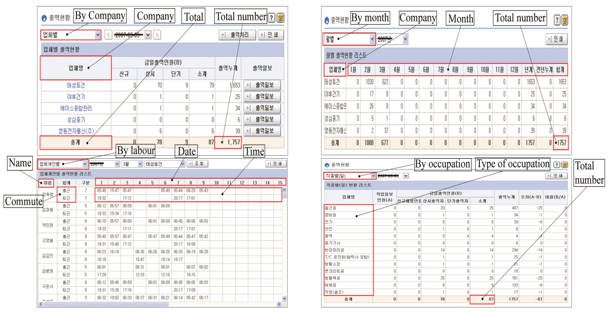

Fig. 5.6 Labourer present condition screens of PMIS

6 Result and Discussion

The test results indicate that the application RFID+PMIS system in the construction site in South Korea has brought magnificent effects. Firstly, this system proved possible to rigorous and accurate access control of the labour attendance record system. In 'K' apartment's concrete work in 'P' construction company case, RFID+PMIS system found difference aspect comparison with work daily report which was reported 70 workers, and 40 workers on RFID. Therefore 'P' company could already perceive construction delay caused by insufficiency of 30 workers through the accuracy of data.

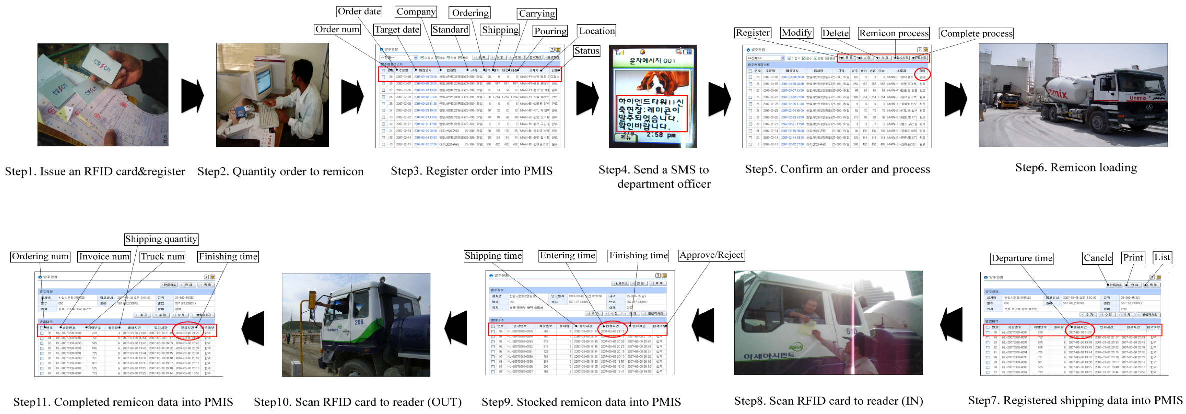

Fig. 5.5 Procedure of RMC process

For this reason, RFID+PMIS system led to an increase of labour productivity and utilized for preliminary data of productivity analysis. Secondly, it is an indication of the efficiency of the concrete pouring operation. A longer waiting time can adversely affect quality, but it also implies that the pouring work can be conducted without interruption. Also, in the RMC process case, five minutes of time saving effect was confirmed averagely per one RMC truck rather than conventional process without frame work. The time saving reduction parts were classified three different sectors which are the part of waiting time for the entrance and exit time checking by field representative, and the part of waiting time for the pouring location checking. Therefore the construction site which needs 300 m^3 pouring (50 RMC trucks) per day can be reduced a total of 250 minutes. Moreover, this time saving is related to the labour cost saving. Normally, five labourers are necessary per one RMC truck in the pouring stage, and labour cost per person was surveyed 10,000 won (£5) per an hour, thus, total 50,000 won (£25) of labour cost was spent per an hour. Therefore, in the construction site which needs 300 m^3 pouring (50 RMC trucks) per day, it is possible to reduce total 208,000 won (£104) of labour costs and in the night work case, total 312,000 won (£156) of labour costs can be saved due to the 50% of labour cost that is increased. This night work labour cost saving is similar with the cost of one RMC truck (24 N/m^2) that is 360,000 won (£180). Additionally, the above mentioned result is only surveyed in terms of RMC truck process thus, enhancement effect of time, equipment and a waste of an element saving will be increased in a real world construction site because more kinds of logistic vehicles are entering and waiting time is increased.

7 Conclusion and Recommendations

This research proposed the RFID+PMIS system integrated environment for the labour attendant management and logistics of the RMC truck process in a construction project. This system has been automatically implemented and has shown process information about the overall status information. In addition, results show that this new approach along with the implemented PMIS contributes to improving control, meeting project deadlines, and exact information of monitoring. Therefore, RFID+PMIS system is expected to attract other construction application sectors, quality, safety, and progress management as well. This research expects that more advanced communication and identification technology to handle the material flow will be utilized as the construction project management in the future becomes more intelligent. However, there was a problem during the initial preparation of RFID+PMIS system implementation which were short in understanding in terms of using it among the participants. Accordingly, participants are required continued monitoring and educating. Additionally, the above mentioned result has fluctuations which depend on the size of field, work duration, and a number of workers. Therefore, in the large scale work place case, the width of productivity, efficiency and saving cost are increased while in a smaller scale case, the effect is reduced due to the part of initial cost of RFID+PMIS system which occurs. Further studies are recommended so that this focus can lead to a serious problem in the assurance of compatibility and standardization among tags and readers of different frequencies in the future when the majority of work items adopt RFID technology for their logistics and process management. This RFID can be combined with biometric information such as fingerprints, iris scanning, and facial recognition. This proposed system is hardly new in other areas such as border control, but in construction it is yet to be widely introduced (Lu et al. 2010). The developed system will be necessary to accelerate technological development associated to tag performance for more applications in construction.

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