CONSTRUCTION MATERIAL MANAGEMENT USING SMART MOBILE COMPUTING

Kwang-Pyo Lee[1], Hyun-Soo Lee[2] and Moonseo Park[3]

[1] PhD Candidate, Seoul National University, Seoul, Korea
[2] Professor, Seoul National University, Seoul, Korea
[3] Associate Professor, Seoul National University, Seoul, Korea
Correspond to leekp86@hotmail.com

ABSTRACT: As construction works have become larger and more complex, improving productivity by introducing Information Technology (IT) is pursued and more effective construction management is needed in construction industry. In this circumstance, many different kinds of project management system is being introduced, and various IT technologies are applied such as Personal Digital Assistant (PDA), Bar Code, Radio Frequency Identification (RFID), Web Camera, and so on. However, these kinds of technologies might cause re-processing of information and ineffectiveness of project because of lack of real time information processing technology or separation between construction sites and management offices. Meanwhile, these technologies rather decrease the construction productivity except for the data saving and database function.

Therefore, this research aims to develop Application that can be applied efficiently for construction material management, by understanding problems of former management system with questionnaires and extracting functions with analysis of requirements. In virtue of the construction material management Application which will be developed in this study, it will be possible to input information automatically, to process and check material information in real time, and to identify the location of necessary material. Then, the problem of separation between construction sites and management offices are solved, and as a result, more efficient management of materials in construction sites will become possible. At the same time, this study will investigate the possibility and applicability of new IT device, Smart Phone to construction sites.

Key Words: Smart Mobile Application, Construction Material Management, Global Positioning System, Real time networking, QR code

1. INTRODUCTION

As construction works have become larger and more complex, improving productivity by introducing Information Technology (IT) is pursued and more effective construction management is needed in construction industry (Ugwu O.O. 2004). In this circumstance, many different kinds of project management system is being introduced, and various IT technologies are applied such as Personal Digital Assistant (PDA), Bar Code, Radio Frequency Identification (RFID), Web Camera, and so on (Bowden S. 2005). However, these kinds of technologies might cause re-processing of information because of lack of real time information processing technology or separation between construction sites and management offices that these technologies rather decrease the construction productivity except for the data saving and database function (Chen Y. 2008).

Meanwhile, next to small lap top such as netbooks, smaller portable device 'Smart Phone' has introduced in various fields and it is possible for anyone to extend their working area and handle their works with no limitations on time and place. Beyond the function of mere phone, Smart Phones have strengths in Global Positioning System (GPS), Google Map, QR code, and various sensing function that it is possible real time communication, real time networking, real time positioning, and automatic data input (Apple Korea, 2010).

This study will suggest more efficient way of construction management by applying Smart Phone with various Information Technology functions. At the same time, it will select parts of management in which Smart Phones can be applied better. Especially, construction material management is managed inefficiently with existing Project Management System because various data items exist and it is complex management process. This problem is related to the past problems such as lack of real time information processing technology or separation between construction sites and management offices. By solving those problems with development of construction material management Application based on Smart Phone, material information is to be managed more efficiently. In addition, by applying the developed

Application to construction sites, this study will identify the applicability of Smart Phones to construction sites.

The research process and methodology of this study is like below.

(1) Analysis of precedent studies.
-Review of existing literature.
-Analysis of Smart Mobile functions.
-Analysis of construction material characteristics and management Process.

(2) Analysis of requirements and drawing functions.
-Understanding drawbacks of existing Project Management System based on survey in construction sites experts.
-Understanding applicability of Smart Phone on construction sites.
- Analysis of requirements to solve problems.

(3) Developing Application for construction material management and evaluating its applicability.
-Drawing functions based on analysis of requirements.
-Realization of construction material management Application and User Interface based on the functions drawn.
-Suggestions on new material management process using construction material management Application.
-Drawing considerations for applying Smart Phones to construction sites more efficiently and suggesting alternatives through analysis on characteristics of construction sites and functions of Smart Phones.

2. PRELIMINARY STUDIES

2.1 Review of Existing Literature

Recently, construction sites pursue more efficient management system by relating construction sites and management offices with application of Smart Mobile Device. For this, locally and abroad, various studies are being done on application of smart mobile device to construction sites. There is a study in which three Smart Phone Applications are selected and practicability of Application program is analyzed by studying people who use Smart Phones and those who don't (Verkasalo Hannu 2010) and a study of drawing directivity of more improved Smart Phones in the future by comparing and analyzing various Smart Phones and understanding their characteristics (Changyung Fu 2009). And as a study to real application to construction sites by practical development, a study of developing Application for construction equipments management and construction safety guideline by analyzing function, performance and reliability of users (Irizarry J and Gill T 2009).

Looking into existing studies, they are usually focused on understanding basic facts before application or improving level of each smart mobile device. Since they don't reflect the characteristics of construction sites enough, development and application of Application for

real using is insignificant now, and real application to construction sites is not accomplished yet.

2.2 Smart Mobile Device

Smart Phone can be defined as a mobile unit that enable to use various services by adding functions of PC to cell phones and connecting phone network and computer network. It is similar to PDA phone but has different form. PDA phone loads Windows CE for PDA among Windows of Microsoft and enables to use telephone calls and internet network by installation of Phone Module. On the other hand, Smart Phone is a cell phone to which PC function is added. It optimizes UI for Applications to become easily used, and maximize internet acceptability regardless of place using 3G network and Wi-Fi network. Also, Smart Phone has various sensors such as microphone(sound) sensor, illumination(light) sensor, contact sensor, pressure sensor, temperature sensor, infrared light sensor, acceleration sensor, gyro sensor, motion sensor, earth magnetic field sensor, touch sensor, bio sensor, and so on. Those sensors are used to collect data, and the data is realized as factor technologies such as touch recognition, speech recognition, vision recognition, augmented reality, motion recognition, haptics, context awareness, health management, and so on. Then, finally establishment of Application software become available.

Here, interface means a physical media or software program that transmits information between two systems, and it enables the communication between object and object or machine and human. In virtue of this, Smart Phones recently secure applicability on various fields with functions such as e-mail, web browsing, fax, banking and game. Also, compared to past Personal Digital Assistant (PDA), it has strong portability and shows more developed form of communication tool not for only work but for life. For this reason, this study is to extract more effective management way by applying Smart Phone to construction sites to check real time information and handle works.

2.3 Analysis of Construction Material Management Process

At the current material management situation in construction sites, the manager orders material in appropriate supply time and the material arrive at the construction sites on time. When the material arrive, quality test is conducted at first to check whether the material is appropriate to the requirements, and if there is no defect, the material is carried into construction sites. In this process, the manager should check material information such as dates, standard, volume, aggregate, total demand, unit, the name of company, date of order, order quantity, estimated date of arrival, estimated time or quality. The material information is then managed using documents or pictures. This is re-input in office to be saved as database. Also, the material information is required when the material is carried into the construction sites or it is managed. For this, the manager goes back to

management office to search and check the material information. This is a problem from the separation between construction sites and management office. It causes the delay of work and loss of material. In this study, this problem will be efficiently solved by introducing Smart Phone into construction sites.
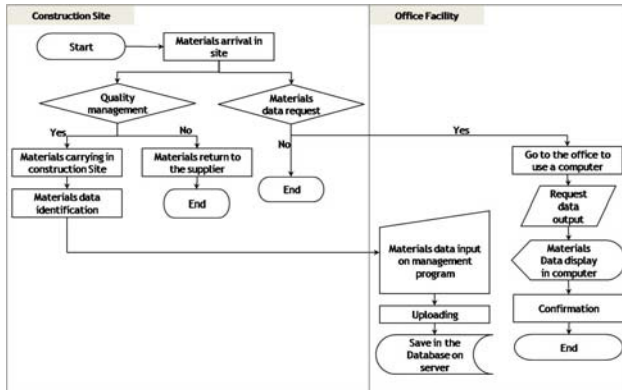

Figure 1. Existing Material Management Process

3. REQUIREMENTS ANALYSIS AND DRAWING FUNCTIONS

This study is to search problems of existing IT technologies and Devices that was applied to construction sites by survey on large domestic construction experts, understand the applicability of Smart Phone, analyze requirements, and draw realization functions.

3.1 Conducting a Survey

We visited Kajewul Newtown in Korea in which D Construction and S Construction Company as well as other companies are processing construction work. There, we conducted survey and interview on applicability of Smart Phone with construction managers, chief managers, and architects. Among 50 surveys, we obtained 42 answers.

Table 1 . Survey Outline

Company	D Construction, S Construction
Target Construction Site	Kajewul NewTown, Seodaemun-gu, Seoul, korea
Subjects	Total 42 people (11 architects, 10 section chiefs, 13 construction credit managers, 6 department heads, 2 chief managers) average age 35.88, average experience 9.62 yrs
Period	2010.11.10 ~ 2010.11.12

The survey items were general demographic information, background and problems of existing IT technology, expected improvements of construction sites with introducing smart phones, and drawing part of construction management in which Smart Phone Applications can be applied.

First of all, on the background of IT introduction to construction sites and utilization status, work efficiency is the highest factor among company policy, work efficiency, management practicability, and personal aid. And this shows that IT technology basically aims the efficiency of work management. However, IT technology generates problems such as complexity of using process, problems of modifying style and form, inconvenience in data saving, complex work process, and inconvenience in searching documents or data, redundancy with prior works, and so on. Especially, interview and survey showed that the redundancy between prior works is the most severe problem, which appeared from the separation between construction sites and management offices.

Next, we examined the applicability of Smart Phones to construction sites, and material management is the best part in which Smart Phones can be applied the most efficiently. Those are managed the most inefficiently now because of the prior problems. And this is solved using the smart phone function like real time networking and automatically data collection.

Lastly, when Smart Phones are applied to construction sites, some advantages are expected. That is overcoming the limit of time and place, effective communication, real time management through networking, decreasing the redundancy, and sharing of information.

3.2 Analysis of requirements

Construction material management requires a lot of input information since it has high relation between other management parts such as quality control or scheduling control. This is connected to the problem of separation between construction sites and management offices, and generates the problem of re-input of material information. Also, most of the construction sites have working process delay problems because of impossibility of real time information identifying.

Based on this, the requirements to actualize material management Application with Smart Phone on construction sites were analyzed. From this analysis, the requirements were automatic input of material information, real time identification of information, and real time positioning of materials

4. DEVELOPING A MATERIAL MANAGEMENT APPLICATION

According to the results above, construction material management Application with Smart Phone will be developed. First, the functions will be drawn based on the requirement analysis, and by actualization of each functions, the Application will be developed finally. At the same time, new construction material management process will be suggested based on Application. Considerations and alternatives to more effectively apply Smart Phone to construction sites will be derived by analyzing the characteristics of construction sites and Smart Phone. <Figure 2> shows the system architecture of construction site material management Application that will be developed through this study.
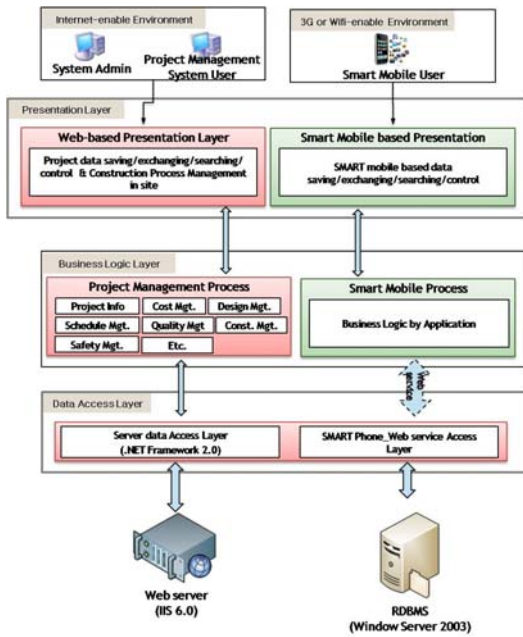
Figure 2 . Construction Material Management Application Architecture

4.1 Drawing functions

4.1.1 Real time automatic input function

The real time automatic input of construction material information is a function that lets information that manager input to manage the materials such as dates, standard, volume, aggregate, total demand, unit, the name of company, date of order, order quantity, estimated date of arrival, estimated time or quality be uploaded to Project Management System Server without a limit on time and place. This will improve the inefficient working process that the material manager handles the material-related works in construction sites and goes back to the management office to re-input and save the material information. The real time automatic input of construction material information is realized with QR code that is a kind of Automated Data Collection(ADC) technology provided by Smart Phone and Wireless Networking technology using 3G or Wi-Fi network.

QR code is a mobile code of Japanese mobile communication machines. It stands for Quick Response code and two dimensional barcode that are developed by Denso in 1994. QR code can be saved in cell phones easily only by taken pictures with cell phone camera, and it is possible to check it again. Especially Smart Phone has inconvenient process of information input because of its characteristics of cell phones, so it might be easy to read information with applying QR code.

This is a kind of ADC technology, and <table 2> shows the comparison with Radio Frequency Identification that is used in construction sites now. Compared to QR code, RFID has its strengths in terms of fast recognition speed, possibility to accept information from many tags at the same time, and recyclability of tags. However, the price of tag is still expensive, and it might be impossible to recognize according to the

characteristics of attached objects (metal, liquid). Also, it should be considered that there might be frequency interference between reader and reader or tag and tag when they are close to each other. In addition, if tags are not recycled, it can cause environmental pollution. Compared to this, QR code has economical benefit and can avoid data confusion by reading information individually. Also, in terms of interference or environmental problems, it is more advantageous than RFID. Therefore, this study will apply QR code considering the characteristics above and adaptability with Smart Phone.

Table 2 . Analyzing QR code and RFID

	QR code	RFID
Tag price	cheap	130-250 won
Recognition method	optical	electrical
Recognition speed	about 4 sec	about 0.01-0.1 sec
Recognition distance	about 57cm	about 27m
Number of recognition	Recognizing one at one time	Recognizing number of tags at the same time
Recognition rate	about 95%	about 99.9%
Built-in cell phone reader	possible	possible
penetration	impossible	possible(except for metal)
copy	possible	impossible
Code scalability	limited	impossible
managing level	Product Level	Item Level

Data obtained from QR code is saved automatically to project management server using Real-time Networking using 3G network or Wi-Fi network. <Figure 3> shows the data flow when real time input of construction material data is applied based on QR code and real-time networking. First, material suppliers save the information of supplying material to QR code, attach it to material, and send to construction sites. When the material arrives, the managers test the quality of materials, and receive the material information through Smart Phone. This information is saved to project management system server, and it is possible to check that information in management offices.
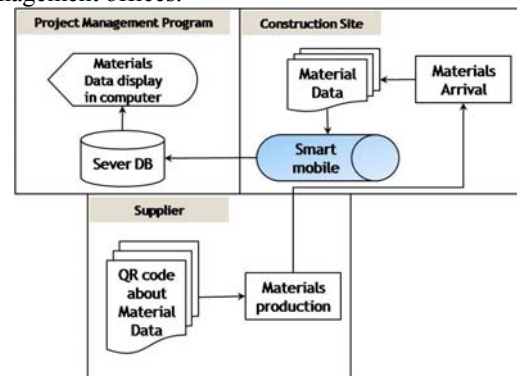

Figure 3 . Real-time Automatic Input Function

4.1.2 Real time identification of material information

As well as the problem of material information re-input because of separation between construction sites and management offices, there can be inefficiency not to identify the material information real time when it is necessary on the process of construction material works in site. Real time identification of material information can solve this problem. It allows material information to be identified real time using Smart Phone.

First, the required information is derived. Since User Interface of Smart Phone is limited to 3.3~5 inches, it is impossible to identify all the material information using Smart Phone. Actually, the required material information is limited in construction sites. Now, the material data like standard, volume, aggregate, total demand, unit, the name of company, date of order, order quantity, estimated date of arrival, estimated time or quality is saved to Project Management System Server. Among this information, the required information in construction sites is derived from server and identified.

From the interview with material manger in construction site, it is appeared that more frequently used data is the name of company, standard, order quantity, and estimated arrival time. The construction material management Application will make it possible to check that information in real time.

4.1.3 Real time positioning tracking of material

Last, we are to try real time positioning of material based on Global positioning System and Naver map (Naver 2010) provided from Smart Phone. When the material arrival is delayed, it causes the loss of material or delay of construction period. For this reason, materials like ready-mixed concrete or steel frame need to be managed more actively, and for this, the real time positioning for material will be provided.

<Figure 4> shows the information flow for real time positioning. The deliverer possesses Smart Phone, and using GPS in it, he transmits his real time location to the server. The location information of deliverer is appeared through mapping with coordinate of Naver map. Manager can check the real time location of deliverer using Smart Phone, estimate the arrival time, and prepare for the delay of materials.
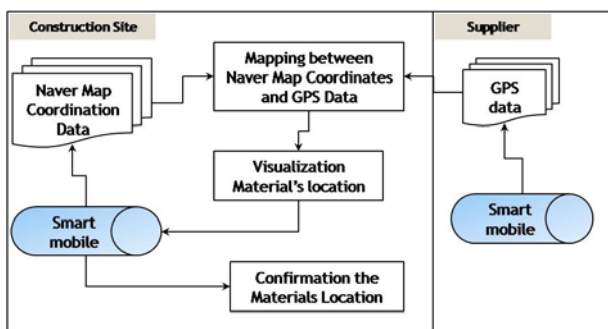

Figure 4 . Real-time Positioning Tracking Function

4.2 Realization of construction material management Application

Based on the functions above, the construction material management Application will be realized finally. <Figure 5> is the final composition map to develop Application, and it consists of system set-up, searching, input, applying, and identification. System set-up is a function to establish basic environment. It sets up environment such as log-in, project information download, as well as material information list. Searching function is to search material according to the kinds of work type or materials, and select certain materials. Input function is to read and save real time material information using QR code. Applying function is to identify the location of material based on using Smart Phone. Identification function is to derive and check certain required information among saved material information from input function.
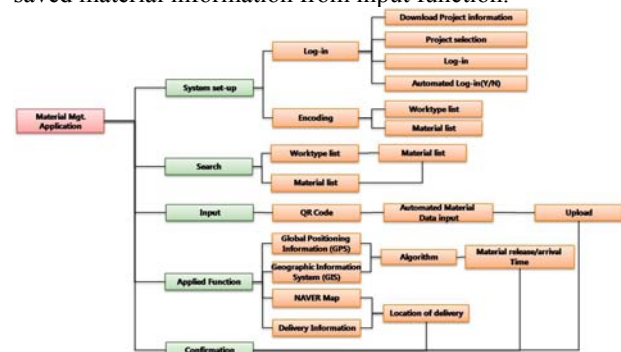

Figure 5 . Composition Map to Develop Application

<Figure 6> shows the User Interface of Application that will be developed in this study. Each screen stands for the automatic input function, real time identification of material information, and real time positioning of material which is presented above.

Figure 6 . User Interface (UI)

4.3 New material management framework

In chapter 2.3, existing construction material management process was analyzed. Under the existing management process, works are repeated in the part of material information input because of the separation between construction sites and management offices. In addition, when information is required during material-related works, it is problematic that workers should go back to offices to process it. Because of this, information processing and management system becomes inefficient.
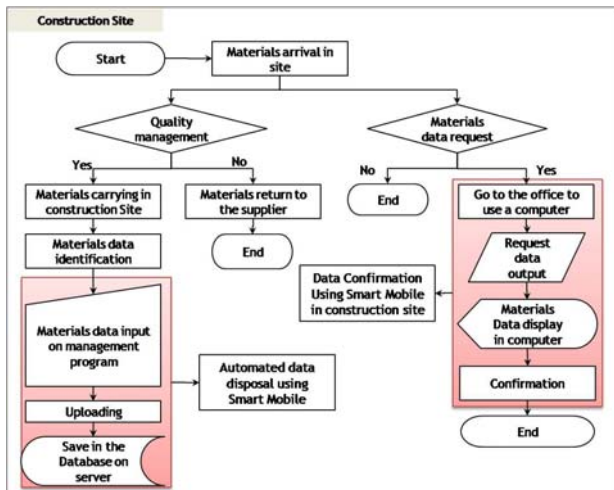
Figure 7 . Material Management Process Using Smartphone

Meanwhile, when the construction material management Application based on Smart Phone is practically used in construction sites, the process is like what is shown in <Figure 7>. The prior problem of repetition in material information input can be solved as information is input, uploaded and saved automatically in construction sites in virtue of the material information automatic input system using QR code. Next, the problem that a worker should go back to office to check information, it can be possible to check it in construction sites by drawing information from project management system server using 3G or Wi-Fi network. Like this, the construction material management system will enable more efficient material management by real time processing works in construction sites.

4.4 Analysis on characteristics of construction sites and considerations of smart phone application

To apply and practically use Smart Phone in construction sites, it is required to develop methods to input and search data effectively in regard of characteristics of construction sites and Smart Phone. It is required to analyze the working environment of construction sites and working patterns of worker and examine information of multimedia and sensors. Then, by optimizing and combining them, it becomes possible to derive convenient way of operation and aid tools for searching and using necessary information.

4.4.1 Characteristics of Smart Phone

Examining the characteristics of Smart Phone, there are problems that it is hard to identify much information at the same time because the size of User Interface is limited to 3.3~5 inches. Also, since the touch screen is not resistive but capacitive, if it is not touched directly with human skin, there can be a mal-functioning. Last, battery has its limit. Since various technologies are intensively combined, battery is consumed a lot with multitasking. Also, in case of some Smart Phones, battery replacement is impossible, so it is necessary to recharge battery constantly. To apply Smart Phone to construction sites

effectively, the problems above should be solved. <Table 3> illustrates the details of each consideration.

Table 3 . Analyzing the Smartphone Characteristic

Consideration	Details
Screen Size	User Interface is limited to 3.3~5 inches. Though it is larger compared to past cell phones, it is still inconvenient to check details or building drawings clearly.
Touch Screen	Recent Smart Phone OS is based on capacitive touch screen instead of resistive. As a result, it has problems on operation when it is not touched directly with finger.
Battery Limit	Battery of Smart Phone is consumed fast, and even battery cannot be replaced in case of some Smart Phone. Therefore, constant recharge is necessary.

4.4.2 Analysis of Construction Sites Characteristics

Examining the characteristics of construction sites, there are limits from working environment; malfunctioning of touch screen because of wearing globes, communication problems due to the noise in construction sites, weather problems from outdoor environment, problems of increased safety risk on applying Smart Phone while working, readability of Smart Phone, and etc.

Table 4 . Analyzing the Construction Site Characteristic

Consideration	Details
Wearing Globes	When a worker try to apply Smart Phone during outdoor works, it is impossible to operate it with wearing globes since the OS uses capacitive touch screen.
Weather factor	Since most of the construction works are done outdoor, weather factors can give influences. As a result, when using Smart Phone in rain or snow, it might cause malfunction or has limit on work effectively.
Increasing Safety Risk	When using Smart Phone during works, a worker becomes in a defenseless state, which can cause increasing risk of safety accidents. Lack of concentration or increasing safety risk due to Smart Phone must be solved.
Decreasing Readability due to Outdoor Environmental factor	To use Smart Phone while working outdoors during daytime, brightness should be modified to increase readability. However, there is limit, and battery is too much consumed when increasing brightness too much.

First of all, it is general to wear globes in construction sites, which cause problems on effectively using capacitive touch screen. Also, if there occurs noise due to various works or equipments, recording, phone conversations, or checking phone calls and messages can

be delayed that incurs ineffective communication. Besides of this, construction works are influenced by weather because most of the works are done outdoors. Therefore, Smart Phone can be mal-functioned in rain or snow, and readability problem can be caused from outdoor works during daytime. Lastly, when operating Smart Phone, workers become in defenseless state. This situation can lead to safety accident because of lack of concentration. These problems are factors that hinder the using of Smart Phone in construction sites, so it is necessary to prepare for alternatives toward them.

4.4.3 Driving considerations and suggesting alternatives

Analyzing characteristics of Smart Phone and construction sites, the considerations like 4.4.1 and 4.4.2 were derived. Alternatives for these items will be derived and then Smart Phone can be applied to construction sites effectively.

Table 5 . Considerations and Suggesting Alternatives

Functions applied	Improvements	Satisfaction rate	Etc.
Multi-touch gesture interface using touch sensor	Problem of readability due to the size of screen	90%	improved and applied
Applying capacitive touch pen	Touch screen	85%	supplied and applied
	Wearing Globes (subcontractor)		
Using voice recognition and recording function	Touch screen	80%	applying own function
	Wearing Globes (subcontractor)		
Simple touch function by encoding	Weather factor	95%	improved and applied
	Increasing safety risk		
Using extra battery	Battery limit	70%	supplied and applied
	Outdoor environmental factor(decreasing readability)		

The problem of readability due to screen size and weather factors will be solved with screen enlarging or reducing screen by applying multi touch gesture interface through touch sensor. Next, for the inefficiency of using touch screen with wearing globes in construction sites, providing capacitive touch pen can be helpful to operate works effective. At the same time, if it is inconvenient to use touch pad for data processing or input, data will be saved with voice recognition and recording function. Meanwhile, the mal-function and increasing safety risk from weather factors can be solved by minimizing the times and processing time of touch with encoding input data. For battery limit, extra battery can be a solution.

Smart Phone is a state of the art IT Device that was introduced recently, so it is not yet developed or applied to fit with the characteristics of construction sites. Therefore, this study suggests applying it with capacity touch pen, extra battery and encoding of Application functions.

5. CONCLUSION

This study understood the applicability of new Information Technology Device, Smart Phone, based on survey and interview. At the same time, it derived some problems of using existing IT technologies. Based on this, requirements were analyzed, and functions were derived to develop construction material management Application. Finally, it suggested new material management process in construction sites. To develop the material management Application in this study, Automated Data Collection based on QR code, Wireless Networking based on 3G and Wi-Fi, Global Positioning System, as well as various sensors and Map are applied.

The construction material management Application in this study is to solve inefficient material management situation due to repetition of work from separation between construction sites and management offices as well as impossibility to check information during works in site. To solve these problems, automated input function of material information with QR code and real time identifying function of material information based on real time networking is developed. At the same time, using GPS and Map function of Smart Phone, real time material positioning function is derived. This enables to input material information in real time when materials are stocked, and also to check material information during works in construction sites. Also, material that has importance in terms of time can track the location in real time, so it becomes possible to prepare for the delay of material.

Comparing with existing Tablet PC, or Personal Digital Assistant, Smart Phone has more portability and convenience thanks to its characteristics as a phone. This can play an important role to be applied to construction sites, and that is why construction industry gives positive consideration and promotes its application to construction sites. Besides, with the material management Application in this study will contribute to understand the applicability of Smart Phone, and finally to make more efficient management activity is possible. This study suggested construction material management Application based on Smart Phone. To extend the range of using this, some further research is necessary. First of all, more practical development should be conducted, and then, corrections of its practical use in construction sites should be understood. Also, efficiency, convenience, and practicality should be also checked.

ACKNOWLEDGEMENT

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