

Development of a Safety Management System for Small Construction Projects Using Smart Wearables and Applications

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Abstract

In recent years, there have been growing social demands for safety in South Korea. However, the number of deaths due to industrial accidents remains high. Industrial accidents are the most common in the construction industry. Therefore, this study seeks to suggest a method of developing applications for safety management for small construction projects using smart wearable. The purpose of smart wearables that can be used in construction projects is divided into behavior analysis, physiological analysis and cognitive analysis. In addition, a server is required to gather and analyze the collected data. The server is divided into servers connected to the networks of public institutions and construction sites. Communications with computer servers, smart-phones and smart wearables are done via wireless networks.

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Keywords : safety management system, small building construction, safety management, smart wearable, application

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1. Introduction

In recent years, there have been growing social demands for safety in South Korea. However, the number of deaths due to industrial accidents remains high. Industrial accidents are the most common in the construction industry. Furthermore, the death toll from accidents is highest in small-scale construction projects[1]. Nevertheless, the establishment of safety-related regulations is predominantly based on large construction projects and often excludes small construction projects. One of the most desirable methods to prevent accidents in construction work is institutional improvement[2, 3]. However, this method require a lot of time and effort as there are many considerations, such as construction conditions and financial status. Meanwhile, advances in IT technology are helping to solve problems arising from construction projects[4, 5]. Therefore, this study seeks to suggest a method of developing applications for safety management for small

construction projects using smart wearables.

2. Problems in safety management for small construction projects

2.1 Classification of construction projects by scale

Table 1 shows the classification of construction projects by scale. In accordance with Article 55, Paragraph 2 of the Labor Standards Act, the construction sites are classified into the following based on the number of regular workers at the sites: petty-scale, small-scale, medium-scale and large-scale workplaces. When these criteria for classification by scale are converted into the average monthly wages of workers(2,314,036 Won) and labor input ratios(28%) notified by the Ministry of Employment and Labor in 2005 and applied to the construction sector, construction projects worth less than 12 billion won are not obliged to appoint safety managers.

Table 1. Classification by Construction Scale

Scale	Full-time worker	Construction amount (unit: a million won)
Minimum	n<5	n<300
Small	5 ≤ n<30	300 ≤ n<2,000
Medium	30 ≤ n<300	2,000 ≤ n<12,000
Large	n ≥ 300	n ≥ 12,000

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2.2 Status of disasters by construction scale

Table 2 summarizes the current status of disasters by scale[6]. In 2017 and 2018, the number of accidents and deaths at construction sites was lowest in construction projects worth 12 billion won or more, with the exception of unclassifiable construction projects. However, it was largest in small-scale construction sites with construction costs of less than 300 million won. Meanwhile, the number of accidents and deaths in the construction projects worth less than 12 billion won with no obligation to appoint the safety managers accounted for about 86% of the total in 2017 and about 81% in 2018.

Table 2. Disaster status by construction amount

Construction amount (unit: a million won)	2017		2018	
	Casualty(%)	Dead(%)	Casualty(%)	Dead(%)
Unclassified	197(1.7)	5(1.9)	215(1.8)	9(3.8)
n<300	4,377(38.0)	87(32.8)	4,130(35.2)	79(33.6)
300 ≤ n < 2,000	3,353(29.1)	62(23.4)	3,181(27.1)	42(17.9)
2,000 ≤ n < 12,000	2,190(19.0)	62(23.4)	2,250(19.2)	45(19.1)
n ≥ 12,000	1,398(12.1)	49(18.5)	1,969(16.8)	60(25.5)
Total	11,515	265	11,745	235

2.3 Difficulties in the safety management of small-scale construction projects

In Korea, construction safety management is planned based on the Construction Technology Promotion Act and the Industrial Safety & Health Act. The safety management plan is established for the purpose of protecting against accidents by stipulating activities related to construction site safety, such as the appointment of a professional safety manager, safety checks and safety education.

Table 3. Analysis of safety management problems in small construction projects

Classification	Details
Problems in safety management systems	Non-appointment of permanently stationed safety managers, Non-preparation of safety management plans
Lack of safety education	Operation of formal safety education, Decline in education standards of educational institutions, Absence of dedicated safety education facilities
Insufficient management	Insufficient guidance and legal checks of supervisory agencies(Ministry of Labor, Korea Occupational Safety & Health Agency, disaster prevention organizations, etc.), Insufficient roles on legal responsibility and safety consciousness of managers and workers
Poor construction environment	Short construction period, low construction costs

However, this is mainly focused on large construction

projects; small construction projects are often excluded in most cases. Therefore, safety management cannot be done on a systematic basis. Table 3 shows problems in safety management for small construction projects[7].

3. Composition of safety management application contents for small construction projects

In order to establish the functions required for safety management applications for small construction projects, this study analyzed the safety management system and safety management plan of a large construction company in Korea[7]. The support functions of the small construction safety management application established based on the analysis results are summarized in Table 4.

Table 4. Support functions of safety management application

Classification	Details
Construction outline	Detailed management of construction information through on-site inquiry about construction site location, start date of construction work, expected completion date, companies related to construction and general manager of safety management
	Management of personal information of operators in the process, such as workers, representatives and company names
Safety information	Inquiry and viewing of contents regarding legal regulations and guidelines related to safety management
	Registration of factors affecting the safety of managers and management of worker actions
	Management of work progress on the day and report in the event of safety-related accidents
Safety education	Education of details concerning the understanding of construction methods on the day prior to the commencement of construction work, detailed construction procedures according to drawings and precautions, etc.
	Education to raise safety awareness among construction workers through educational materials focused on accident cases related to safety & health and disasters
Emergency countermeasures	Formation of a systematic safety management organization by stipulating actions and measures in case of emergency
	Establishment of a network of emergency contacts, such as persons concerned, including contractors, designers, owners, field managers, as well as hospitals, fire departments, police stations and the Korea Occupational Safety & Health Agency
Automatic notification systems	Awakening of workers' safety awareness through automatic notifications of safety-related contents during work
	Notification of real-time risk information for workers with the use of smart wearable devices Realization of disaster prevention through proactive removal of accident risk factors

The functions of the application should be able to solve problems and compensate for the defects of the small construction safety management derived earlier.

The items of construction outline that support functions such as the inquiry and management of construction sites and workers' personal information can support the site management of institutions related to safety management. The safety information items to manage safety management guidelines, regulations, and other matters pointed out, can compensate for the defects in systems. The safety education items for raising safety awareness in the workplace can address the problems of existing safety education. With the support of safety management using smart wearables and applications, it is possible to reduce safety management costs and improve poor construction environments at a low construction cost. In addition, the use of automatic notification systems, such as the detection of real-time hazards through safety messages and smart wearables, makes it possible to call workers' attention and eliminate causes of accidents, thereby helping to create safer construction environments.

4. Safety management support measures using smart wearables and applications

The main purpose of small construction safety management applications using smart wearables is to create a safe working environment for construction workers. Table 5 shows smart wearable sensors and devices that can be used in construction projects[8]. The purpose of utilization is divided into worker behavior analysis, physiological analysis and cognitive analysis. The behavior analysis sensor is used to analyze body movement patterns and thus prevent accidents, such as slippages or falls. The physiological analysis sensor

analyzes human physiological responses and determines whether to continue work based on the workers' health and psychological status. The cognitive analysis sensor is utilized for identifying and eliminating the causes of accidents through an analysis of the movement of workers' eyes or EEG patterns.

Table 5. Smart wearable sensors and devices that can be used in construction projects

Purpose	Smart Wearable Sensor	Smart Wearable Device
Behavioral Analysis	IMU (Inertial Measurement Unit) Sensor	Smart helmets, smart watches and bands, safety shoes, etc
	Positional Tracking Sensor	Smart Helmet, Smart Necklace, etc.
	Pressure Sensor	Smart Shoes
Physiological Analysis	PPG (Photo-electric pulse Plethysmo Graph) Sensor	smart watches and bands
	Skin Temperature Sensor GSR (Galvanic Skin Resistance) Sensor	
	Piezo-resistive Sensor	Smart Clothes
Cognitive Analysis	Eye Tracking Sensor	Smart Glasses
	EEG(Electroencephalogram) Sensor	Smart helmets

The data of the application presented in this study is managed through servers connected to the networks of public institutions and construction sites. The public institution manages data related to safety, such as construction sites and worker information generation, safety-related laws and regulations, and provision updates. The information delivery of smart wearables and applications are shown in Figure 1. The hardware

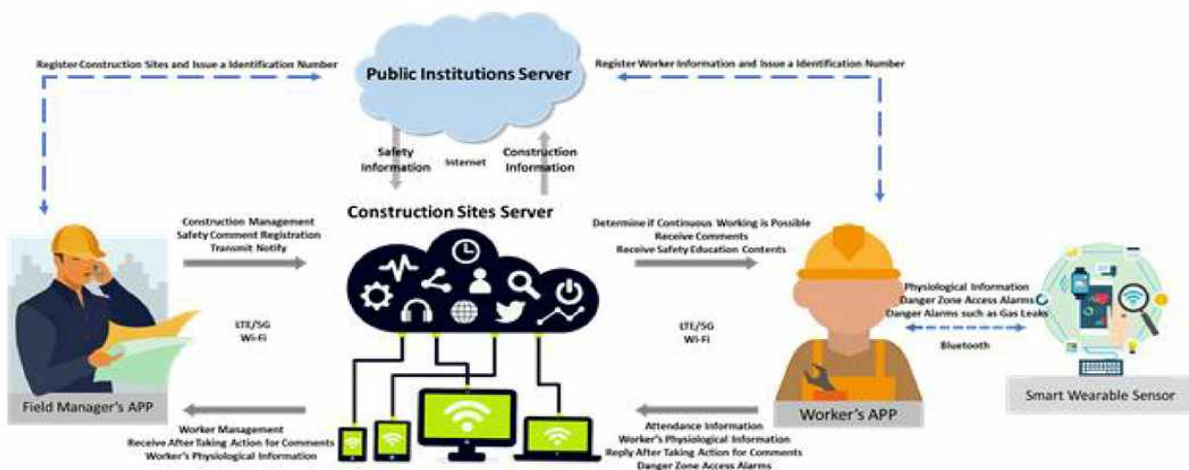


Figure 1. Information delivery of smart wearables and applications

of the safety management system consists of a computer server, a smartphone and a smart wearable. The exchange of information in the system is done via wireless networks, such as a mobile network, Wi-Fi and Bluetooth. The application user is informed about risk information collected through smart wearables in real time. The risk information is delivered to the user via alarm notification. The manager checks the notification, decides whether to continue operation and then notifies the decision to the worker.

5. Conclusion

In the construction sector, construction management systems and applications have been introduced to support safety management on a more systematic basis. However, the construction safety management systems using applications has only been utilized by large construction companies that can develop their own systems. In this regard, this study proposed a method of developing applications so as to support safety management for small construction projects using smart wearables. The major research findings are as follows.

1) The problems were caused by inadequate systems, lack of safety education, insufficient management and poor construction environments.

2) The application is used to support functions, such as a construction outline, safety information, safety education, emergency countermeasures and real-time automatic notifications. The information collected through smart wearables is analyzed on the server to determine risks in real time and deliver into the application user.

3) The purpose of smart wearables that can be used in construction projects is divided into behavior analysis, physiological analysis and cognitive analysis. In addition, a server is required to gather and analyze the collected data. The server is divided into servers connected to the networks of public institutions and construction sites. Communications with computer servers, smartphones and smart wearables are done via wireless networks.

The application functions presented in this study are expected to support professional and systematic safety management. It is also expected that IT technology will help to create a safer and more productive construction environment for construction projects.

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