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Real-Time Low-Carbon Prediction in Ready-Mixed Concrete Production Process for Smart Manufacturing

Byeongseop Kim, Jongpil Jeong*

Department of Smart Factory Convergence, Sungkyunkwan University, Suwon, Gyeonggi-do, 16419, Republic of Korea

Abstract

The key to global warming is greenhouse gas emissions. Since 2015, the Republic of Korea has implemented a carbon emission rights system to encourage companies to voluntarily reduce carbon emissions. Not long ago, the government declared carbon neutrality by 2050. However, in order for the carbon emission rights system to function as a greenhouse gas reduction, it takes half a year to calculate carbon emissions, and small and medium-sized enterprises (SMEs) that are not only large in resources and manpower for calculation should be left to consulting companies. It costs millions to tens of millions of won to calculate once. This paper provides a carbon emission response solution for ready-mixed concrete (Remicon) companies. Greenhouse gases emitted from various factories are calculated in real time using IoT equipment. The calculated greenhouse gas emissions are visualized and shown. Therefore, companies can plan to reduce greenhouse gas emissions based on data and make predictions about when to certify low carbon certification. This project targeted one of the building material industrial groups. In the future, it can be expanded to the entire region-based society, including individuals and families, which are the minimum units. This allows the government to check national-based carbon emissions in real time and determine policies based on data. Finally, it is intended to change people’s consciousness by visualizing the degree of contribution to the phenomenon of global warming through real-time carbon emissions.

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1. Introduction

Global warming is getting worse day by day. As time goes by, record heat waves, droughts, and forest fires are occurring throughout the world. The abnormal climate phenomenon caused by global warming can no longer be delayed due to the immediate problem. It is a problem that must be solved immediately for the survival of mankind.

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government declared carbon neutrality by 2050. However, in order for the carbon emission rights system to function as a greenhouse gas reduction, it takes half a year to calculate carbon emissions, and small and medium-sized enterprises (SMEs) that are not only large in resources and manpower for calculation should be left to consulting companies. It costs millions to tens of millions of won to calculate once.

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The environmental performance labeling system is a government-led certification system that has been operated under the supervision of the Ministry of Environment since 2001 and provides quantitative information on the environment [1]. Carbon grade labeling and low carbon product certification are systems that respond to climate change by inducing eco-friendly product production and consumer consumption of low carbon products by disclosing greenhouse gas emission information of products (including services).

For low-carbon certified companies, not only government-level additional points and rewards from public institutions, but also low-carbon certified items are given priority bargaining rights when publicly bidding by the Public Procurement Service, so many companies are striving to obtain low-carbon certification. Although low-carbon certification can be obtained using the existing ez-EPD certification program to obtain environmental performance mark certification, it is difficult for SMEs to handle the time and cost incurred in manually entering the program for a certain period of time. Furthermore, even if the program is used, the biggest problem in carbon performance labeling and low carbon certification is the consulting cost to obtain low carbon certification. Not only do they have to pay more than 10 million won per item, but they also have accumulated data performance for at least three months, which is very inefficient and uncertain in terms of time and cost. It is an unfavorable situation for SMEs that have difficulty in forming environmental evaluation departments and dedicated operating personnel.

Companies without environmental departments or employees have to check the possibility of low-carbon certification through consulting, so they are spending a large amount of money. The prediction program provides a system that calculates carbon emissions in real time, and reduces the burden of having to spend money to obtain environmental performance labels and low carbon certification per item without a separate environmental representative.

Air pollution is caused by the presence of particulate matter, hazardous substances, and biological molecules in the Earth’s atmosphere [2]. It adversely affects living organisms such as humans, animals, and food crops, and can also damage architecture and the natural environment. It is incomplete if the concentration of harmful airborne particulate matter such as allergies, cardiovascular disease, and lung disease is not known. Therefore, to address this problem, it is used with sensors that detect carbon monoxide, carbon dioxide, temperature, humidity, and atmospheric pressure using arduino to monitor particulate matter [3]. It is a good platform to interface with many devices at the same time.

Internet of Things and cloud computing are the latest technologies. The Internet of Things is a concept or paradigm in which devices detect, identify, process, and communicate with each other without human interference [4]. Cloud computing is the practice of consuming resources from remote servers such as storage, virtual machines, applications, and utilities hosted on the Internet rather than building and maintaining infrastructure for in-house computing. The Internet of Things becomes very powerful when it is integrated with cloud computing. IoT cloud systems provide a view of accessing IoT resources and functions from a defined API and configuring and operating them in the cloud [5]. Data stored in the cloud can be retrieved at any time and can be analyzed in a better way, leading to solutions that control air pollution to some extent. Through a data transmission system through a test bed construction, a web browser was established to verify applicability to actual domains and determine whether low carbon certification can be obtained based on a database that has real-time motorized the GWP.

The composition of the paper is as follows. Section 1 consists of the carbon emission measurement system of the remicon manufacturer, Section 2 consists of the remicon manufacturing process, EMS and IoT Applications, Section
3 consists of low-carbon prediction techniques based on real-time carbon emissions, Section 4 is implementation and results, and Section 5 is conclusion.

2. Related Work

2.1. Manufacturing process of Remicon

Remicon is produced by measuring concrete components, cement, aggregates, and water accurately according to a specified mixing ratio at a facility called Banging Plant, which is a specialized concrete production plant in accordance with the manufacturing method and quality inspection prescribed in Korean Standard (KS) F 4009. It means concrete that is not yet hardened and transported to the construction site using a truck mixer or an agitator truck after manufacturing [6, 7].

Remicon is limited to sales rights within 90 minutes for Remicon trucks and 60 minutes for dump trucks after production. Due to the limited time, the Remicon product forms a market area of this product within 90 minutes, so it has strong characteristics of a local industry, and various raw materials are transported to a factory, and then transported to a construction site within a limited time.

2.2. Energy Management System

Energy Management System (EMS) is defined as an integrated energy solution for visualization and optimization of energy flow and use for commercial buildings, businesses (factory), housing, social infrastructure (power grid, transportation network, etc.) [8, 9]. EMS is classified as HEMS (Home EMS) for housing only, BEMS (Building EMS) for building only, FEMS (Factory EMS) for factory only, and CEMS (City/Community) for region only, and has functions to monitor energy flows such as gas and power and control facilities and devices. In Korea, through the IT-based ESCO pilot project promoted by the Ministry of Industry in 2011, the Energy Management Corporation has expanded its construction and operation by applying it to factories [10]. In particular, FEMS is a factory energy management system that monitors and controls energy supply, use, and operation status for power distribution, air conditioning, and lighting as well as production line facilities in the factory [11]. These systems include monitoring functions that collect and display values from facilities, process management, performance management, control functions, analysis functions and associated databases, existing Enterprise Resource Planning (ERP), and Manufacturing Execution Systems (MES). The energy management system should be able to propose production process methods and energy policies that reduce energy by analyzing the energy usage using the collected data. In particular, based on ICT which is the keyword of the 4th revolution, the company is introducing an active IT-based energy management system that provides optimal energy patterns that are the final goals [12, 13].

2.3. IoT Applications

Recently, IoT has emerged as a strong field. It leads to a tremendous amount of research activities and businesses of venture capitalists and tech giants. Some precautions among the leading applications include smart grids, smart cities, and smart wearables. Devices and Smart Home Almost all different IoT applications include some kind of sensor and transducer. It is usually attached to the microcontroller along with wired or wireless. Transferring wirelessly to a local database or remote Take advantage of the cloud that converts raw data into useful information. The research and development activities include the manufacturing technology of smart objects or devices, appropriate wireless technology, development boards, network protocol design, applications, and so on. In the context of our project, we investigated recent research achieved in the development. The Air Quality Monitoring System (AQMS) based on the IEEE / ISO / IEC 21451 standard has been published, and concentrations of CO, CO₂, SO₂ and NO₂ have been measured using electrochemical and infrared sensors. The result is stored in the data server [11].

A comparative study of smart sensors, objects, devices, and IoT objects has been published. The authors also explained the definitions and concepts of IoT in various ways. Differences and similarities between smart objects and smart objects in IoT are expressed in tabular form [12]. Monitor environmental parameters with current measurement sensors and gas sensors (infrared) using microcontrollers. The sensor nodes are set in different areas for real-time
monitoring of the environment [14]. They provide information on air quality affected by various factors such as pollutants and toxic gases. It analyzes air pollution from various perspectives, such as weather data, pollutants, and traffic data. The system helps people recognize the impact of their activities on air quality deterioration. We presented a system that monitors environmental parameters and models and manipulates microclimate in urban areas. The system is implemented for efficient urban infrastructure adaptation after analyzing urban microclimate [15]. In the framework for urban environmental monitoring, parameters such as carbon monoxide, carbon dioxide, temperature and pressure are implanted into the system via raspberry pie [15]. We present a system that measures and collects data from water quality and air quality parameters, and the results are displayed on the IBM Watson IoT platform [16].

3. Low Carbon Certification Based on Real-Time Carbon Emissions

This study aims to establish a data management platform in the remicon manufacturing process that can store various types of data generated through the IoT service provision procedure.

3.1. System Architecture

The product line of environmental performance certification is classified as production goods, durable goods, non-durable goods, and service energy-use durable goods, and building materials, including Remicon, are classified as production goods [17]. Remicon products have guidelines for preparing products that use energy in the stage of use to calculate environmental performance and define the system boundaries of products as shown in Figure 1.

Fig. 1. Carbon Emission Calculation Architecture.

3.2. Prediction Workflow

It can be defined as a configuration for a program for collecting data from pre-manufacturing, manufacturing, and disposal stages of the product to calculate carbon emissions for Remicon. In the pre-manufacturing stage, performance on raw materials or energy sources required to make each raw material will occur in real time. Likewise, in the manufacturing step of the local layer, manufacturing, energy source, and disposal data generated in the manufacturing step of the Remicon will be generated and accumulated in the production management system operated by the local end by the internal computer network. Such real-time occurrence data is collected in the central server in charge of
the overall data, and the figures are calculated in real time by the evaluation platform through the data necessary for calculating the environmental performance mark. Figure 2 illustrates this system workflow.

4. Experiment and Implementation

4.1. System Configuration

Sensing in the actual process is modeled and implemented as a test bed, and the collected data is transmitted to the server by operating and sensing in the test bed with Arduino. After that, data was provided so that it could be checked in real time through a web page or application tailored to the user interface. Google Cloud Platform was used for stable server operation. It is using DB and Compute Engine functions on Google Cloud Platform. Figure 3 is an overall flowchart of Arduino, Server, DB, and prediction programs.

As shown in Figure 4, the DB was constructed using MySQL. DB includes manufacturing data for Remicon by workplace, weather, and raw material transportation information. Currently, it is operated using Google Cloud Platform SQL, and mainly performs database input and output through the Node.js server program and the implemented DB input program. It runs Python programs such as prediction programs through Python-Shell provided by Node.js, and provides DB input/output, communication with Arduino, and web services. In the case of the server program, it was implemented by dividing it into a frontend server and a backend server. A backend server was created using Node.js Express, and a frontend server was created using Node.js and React.js. The frontend server is responsible for
sending web pages when they are called, and the backend server is responsible for DB management, Python program execution, and communication with Arduino.

![Flowchart of Prediction Programs](image)

Fig. 4. Flowchart of Prediction Programs.

The program is set according to the required calculation method of carbon emission per unit production through the Easy Environmental Product Declaration (ezEPD) certification program provided by the Korea Institute of Environment and Industry, and outputs Global Warming Potential (GWP) for a specific period of time using Remicon manufacturing information and raw material information stored in DB. Figure 5 shows the result screen of the GWP interwar calculation programming through the execution result of the calculation program.

![GWP Calculation Results](image)

Fig. 5. GWP Calculation Results.

4.2. Prediction and Results

In this paper, we predict when low-carbon certification can be obtained by deriving the GWP for the product through actual data collection through test bed construction. The real-time data collection experiment through the test-bed of the Remicon manufacturing process, which was constructed in Section 3, was successfully collected as shown in Figure 6, and the data obtained in real-time were transmitted to the server, stored in DB, and displayed in UI.

As shown in Figure 6, data collected in real time is continuously accumulated in the cloud server for a certain period, and GWP for each set period can be calculated according to the manager’s environment setting on the implementation UI screen, and the result value is determined as shown in Figure 7.

The system was used to collect data from the pre-manufacturing stage to the disposal stage of products, and the central server was used to actively change the acquisition of passive certification by manpower, and it was an opportunity to understand how changes in production materials or processes affect carbon emissions.
This study attempted to derive an applicable plan by reviewing the applicability of IoT-related technologies in the current domestic environmental performance certification. Air pollution is the biggest environmental problem in the world today. Air pollution has adverse effects on human health, climate, and ecosystems. Due to the emission of toxic gas by the manufacturing industry, the concentration of harmful gases and particulate matter in the atmosphere is increasing. In this regard, Korea operates an environmental performance labeling system that quantitatively displays
the environmental impact on products and services, and operates a certification system to spread a market-led low-carbon consumption culture by disclosing carbon emission information and certifying low-carbon products. Recently, an Internet of Things system that supports human activities based on various types of actual data has attracted attention in various fields and collects and uses data generated in the manufacturing step, but the domestic environmental certification system does not professionally use the data.

5. Conclusion

In this paper, we propose a system for collecting production information using IoT sensing data used by Arduino in the manufacturing process of Remicon and a platform for deriving a low carbon certification point for products using the data. The proposed platform clarified the reliability and real-time nature of the measured data for the system and showed the efficiency in calculating the corresponding carbon emissions in the proposed platform.

In the future, research on how to introduce distributed excursions through the introduction of edge computing through data generated in manufacturing industries will be conducted to expand the scope of application of the program and review the application by industry group at the government level.

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