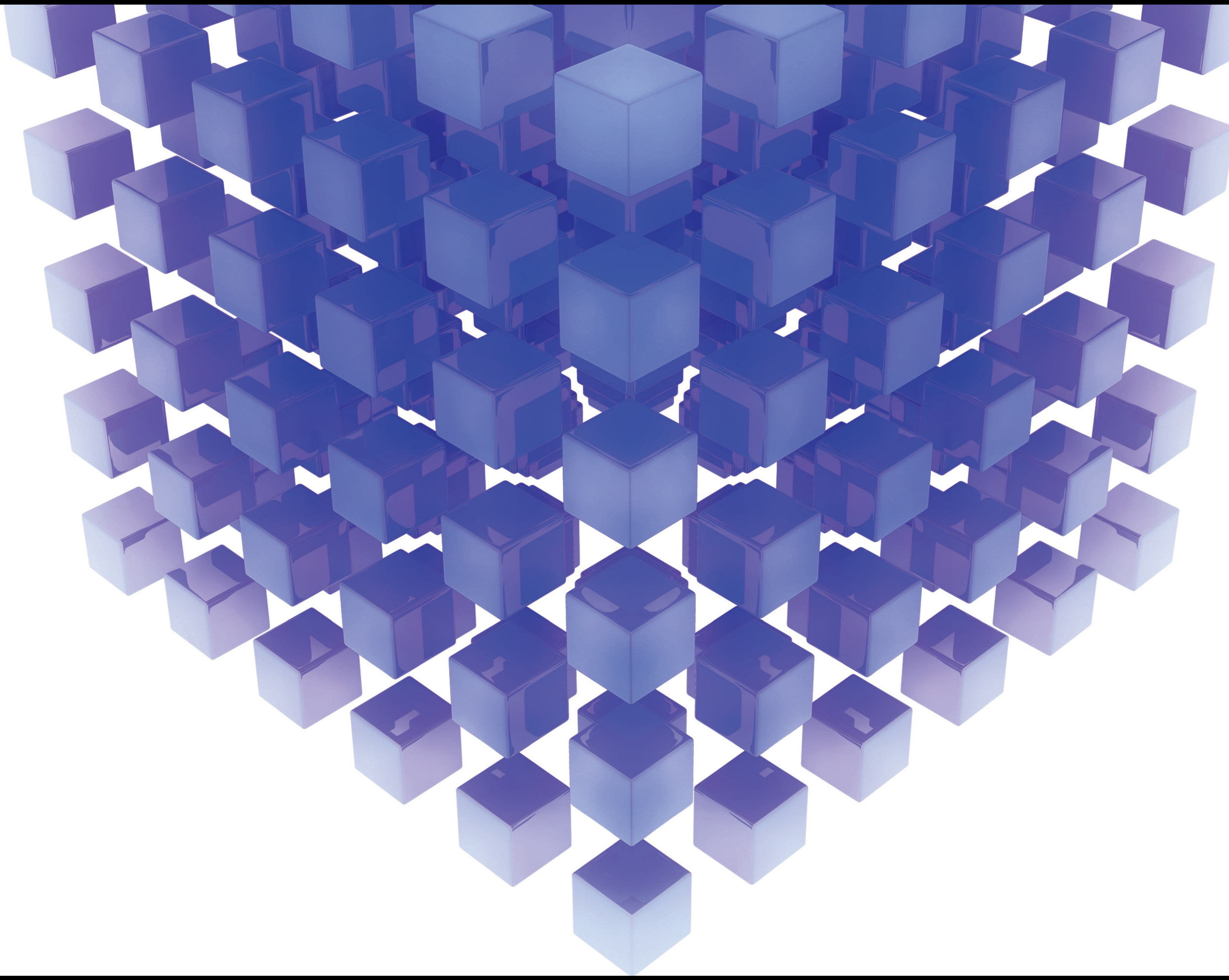
Mathematical Problems in Engineering

Smart Processing Instruments, Management, and System Sustainability

Lead Guest Editor: Sanghyuk Lee
Guest Editors: Dohyeong Kim and Eunmi Lee



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Contents

Hindawi
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Research Article

Internet of Things in the Bathroom: Smart Health-Monitoring Bidet System

Sung-Phil Heo [1] and Suyong Jeong [2]

[1]*Department of Information and Communication Engineering, Gangneung-Wonju National University, Gangneun 26403, Republic of Korea*
[2]*Department of Nursing, College of Health and Welfare, Gangneung-Wonju National University, Gangneun 26403, Republic of Korea*

Correspondence should be addressed to Suyong Jeong; mulyong930@gwnu.ac.kr

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The Internet of things (IoT) helps our everyday lives such as by monitoring objects and tracking behaviors in various settings, but studies on enhancing the bathroom experience are rare. This article describes full details about development and implementation of a smart health-monitoring bidet based on our study published previously in the conference. A smart bidet system is designed to monitor the users' health through several contact-type sensors, such as pressure, oxygen, and thermometer. The system is equipped with a built-in artificial intelligence software platform and is designed to detect anal and spinal diseases. The attached sensors normally operate under waterproof conditions: we tested their performances under X6 international protection marking conditions. These devices were designed to operate properly even in extremely waterproof conditions. The temperature, pressure, and oxygen sensors of the bidet system had error rates of about 4.1, 0.6, and 1.1 percent, respectively.

1. Introduction

When it comes to confusing and ever-changing terminology, nothing really comes close to digital technology. From dongles to routers, smart hubs to podcasts, the technology world certainly has no shortage of jargon. However, one phrase might just be worth knowing, that is, IoT. It is certainly one of the more unusual turns of phrase, but WLAN (wireless local area network) or WPAN (wireless personal area network) enabled products could end up in every home in the world, by monitoring objects and tracking behaviors in various settings. However, studies on enhancing the bathroom experience are rare. Based on our previous publication in the conference proceedings [1], this article describes the development and implementation of a smart health-monitoring bidet with full details including additional and new contents we did not report earlier.

Bidets are used to clean and maintain the perianal area of a toilet seat. They are generally attached to the seat's heating and cooling components [2]. The first bidet system was introduced in France in the seventeenth centuries [3]. Today, these electronic devices are used for various purposes, such as cleaning, heating, and drying [4]. The seat is attached to an electric powered nozzle that is designed to clean both male and female anus areas [5]. Electronic bidets are usually equipped with a mechanical or two-pronged mechanical nozzle on one or both sides of the toilet [6, 7].

In basic bidets, a high-pressure water jet is utilized to clean the anus and genital areas. However, in recent models, the jets can also function autonomously. The latest energy-saving technology for electronic bidets is a device that automatically warms up once a user approaches it [8].

Several patents about electronic bidets have been registered. One of these includes a system that uses an internal camera to locate and identify the users' lower body orifices; afterwards, an electronic bidet can automatically adjust the settings based on the user's weight and orifice location. It can also detect the exact size of the water droplets and adjust the temperature and pressure [9]. Another electronic bidet has a remote controller that is powered by a series of microforce sensors [10]. However, these bidets have not yet applied with the Internet of Things.

The IoT has the potential to improve the efficiency and effectiveness of healthcare systems by helping prevent and manage chronic diseases of the aging population [11], and the IoT is a network of devices that are connected through machine-to-machine (M2M) communications. This technology enables the exchange of data and enables the collection of big data and automation within a wide range of industries. In addition, conventional bidets are being substituted with electronic bidets that use various sensors and a remote controller to provide additional convenience. The electronic bidet manufacturer Novita recently collaborated with LGU + to control bidet functions via smartphone [12]. However, this bidet cannot receive biometric information or big data; in fact, the various types of biometric information acquired from the sensors are not stored in a memory but only displayed once and then disappear. By combining existing conventional electronic bidets with IoT technology, the collected biometric information can be potentially applied to the health care field [13]. IoT provides the opportunity to develop smart wearable applications in health sectors and to grow the existing wireless capabilities (i.e., mobile devices, interactive sensors, and actuators) [14].

The early prediction of diseases can help prolong people's lives by allowing timely treatments. Within this context and goal, we developed an electronic bidet that can be easily accessed in everyday life and predict possible early-stage diseases. This new type of bidet (i.e., "medical bidet") has integrated IoT sensing technologies and various types of sensors (i.e., pressure, oxygen, and thermometer sensors). In this paper, we describe the application of the medical bidet to smart health care: it collects and analyzes personal biometric information in a nonrecognition and nonrestraint way, within the daily-used space of the bathroom. Section 2 describes the construction of several sensors that can be fitted in the smart health-monitoring bidet toilet seat. Section 3 shows the results obtained from the sensors under waterproof International Protection Marking (IP) X6 conditions. Section 4 presents the concluding remarks.

2. Materials and Methods

Figure 1 shows a schema of our smart health-monitoring bidet end-to-end architecture. A smart health-monitoring bidet uses various sensors (pressure, oxygen, and thermometer) to detect potential and actual early-stage diseases. The raw data collected from these sensors were automatically processed by our dedicated software. There have six pressure sensors at lower side of the toilet seat, and these can be used to calculate resistance variance by measuring the difference between the force-sensing resistor layer and the active spot [15]. Pressure sensors can also be used to diagnose spinal deformities and guide users to correct their body posture. Oxygen sensors can be used to measure the amount of hemoglobin (Hb) in the blood for checking physiological data, instead of using the photodiode method [16, 17]. Thermometer sensors can be used to monitor the body temperature, a vital sign that can also be combined with additional information to evaluate user's health status [18]. The biological information collected through these various sensors can be transferred to the network system through communication channels (Bluetooth or Wi-Fi).

2.1. Pressure Sensor Module. Sitting for long periods of time can lead to improper posture and worsen the conditions of the spine [19]. This issue can be prevented by using pressure sensors positioned on the lower part of the toilet seat (Figure 2(a)), which could help avoid spine deformation by stimulating posture correction.

Figure 2(b) shows the possible sensor detection positions: they operate based on algorithms that describe center-of-gravity movements within nine virtual blocks to determine posture deviations. The calculation of the center-of-gravity position in a two-dimensional space (coordinates Xi and Yi) (Figure 2(b)) is described by the following equations and is shown in Table 1.

$$CoPx = \frac{\sum_{i=1}^{4} F_i X_i}{\sum_{i=1}^{4} F_i}, \quad (1)$$

$$CoPy = \frac{\sum_{i=1}^{4} F_i Y_i}{\sum_{i=1}^{4} F}. \quad (2)$$

The pressure sensor measurements are based on changes in the resistance values derived from the pressure force in the corresponding contact area between the active area and the force-sensing resistor layer. The real-time resistance information is then transformed into an analog voltage output. The analog voltage data obtained from the pressure sensor are transferred to a 10 bit analog-to-digital converter (ADC) through Bluetooth, using a universal asynchronous receiver transmitter (UART). Finally, these data are stored in a smartphone application. Figure 3 shows a block diagram of the module used by the pressure sensors: the sensor signal needs to be amplified by the operational amplifier and then converted into a digital signal by the ADC. Finally, the weight data are transferred to a smartphone through Bluetooth, in combination with date, time, and position data.

2.2. Oxygen Sensor Module. Oxygen sensors were utilized to assess oxygen saturation, which offers a value of the Hb amount [16]. The oxygen sensor measures Hb bonded with oxygen; in fact, when Hb is not attached to oxygen, it has a different wavelength [20]. Two different light-emitting diode (LED) wavelengths (660 nm and 940 nm) were used because a 660 nm LED has a much higher absorption coefficient ratio than a 940-nm LED does [21]. The oxygen saturation level at various absorption coefficient ratios could be estimated from the ratio between the pulsatory motions, applying the Beer–Lamber law [22].

Figure 4 shows a schematic diagram of the oxygen sensor module. The pulse oximetry circuit (MAX30120, Maxim Integrated, San Jose, CA, USA) was used to scan the oxygen saturation data, which were then processed through software algorithms. The measurement module circuit in the bidet

FIGURE 1: Smart health-monitoring bidet end-to-end architecture.

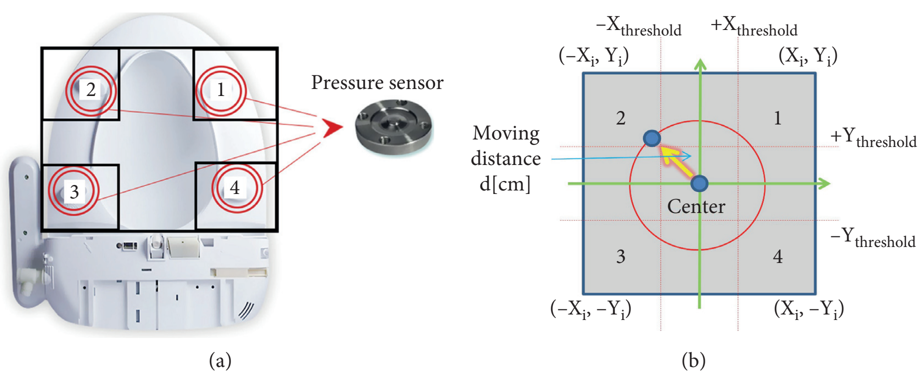


FIGURE 2: Pressure sensor system. (a) position of four numbers; (b) the pressure sensors can detect positions within the nine virtual blocks defined by the dashed red lines.

TABLE 1: Center-of-gravity movements within the virtual blocks.

Block	CoPx	CoPy
1	$CoPx < -X_{\text{threshold}}$	$CoPy > Y_{\text{threshold}}$
2	$\lvert CoPx\rvert < X_{\text{threshold}}$	$CoPy > Y_{\text{threshold}}$
3	$CoPx < X_{\text{threshold}}$	$CoPy > Y_{\text{threshold}}$
4	$CoPx < X_{\text{threshold}}$	$\lvert CoPy\rvert < Y_{\text{threshold}}$
6	$CoPx < X_{\text{threshold}}$	$\lvert CoPy\rvert < Y_{\text{threshold}}$
7	$CoPx < X_{\text{threshold}}$	$CoPy < -Y_{\text{threshold}}$
8	$\lvert CoPx\rvert < X_{\text{threshold}}$	$CoPy < -Y_{\text{threshold}}$
9	$CoPx < X_{\text{threshold}}$	$CoPy < -Y_{\text{threshold}}$
5	Default	Default

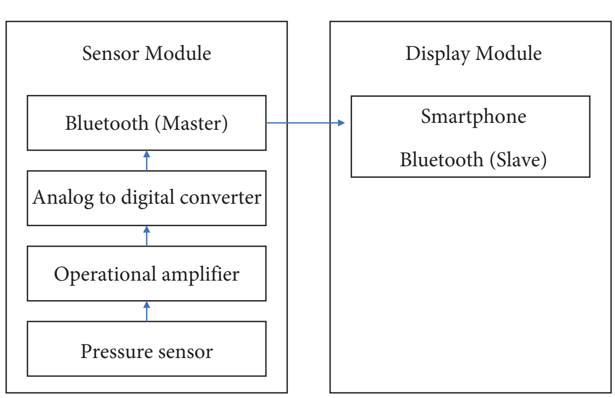


FIGURE 3: Schematic diagram of the pressure sensor and display modules.

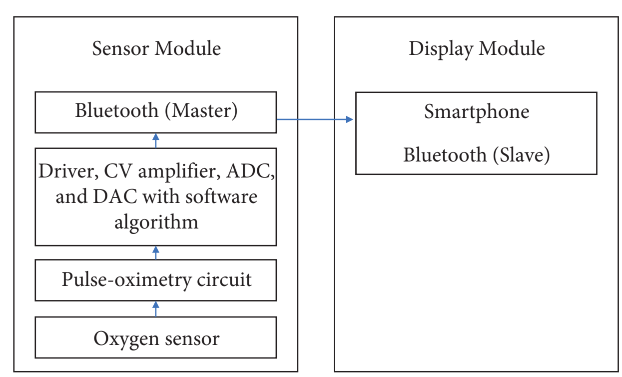


FIGURE 4: Schematic diagram of the oxygen sensor system.

control board was designed to measure oxygen saturation. Moreover, the driver circuit within was designed to convert the voltage level to the current level and control the intensity of the light using the LED driver board. Furthermore, a differential current-voltage (CV) amplifier was needed: the received signal was converted by aligning the human finger into infrared (IR) and red LED current using an ADC and a DAC (digital to analog converter). A microcontroller was used to change the current controlled by the DAC (i.e., the LED current). A low pass filter was also utilized to remove unwanted ambient noise signals [23]. Next, measured physiological signals were transferred to a smartphone application through Bluetooth. Finally, the signals reflected from the LED lights and the blood oxygen saturation (SpO2) data were converted by first-in-first-out (FIFO) algorithms and sent to the smartphone [24].

2.3. Thermometer Sensor Module. A thermometer sensor measures the body temperature; then, raw data were processed through our designed algorithm. The body temperature is a physiological index of vital signs and supplementary information related to women's health, such as menstruation, ovulation, and gestational period [25]. The thermometer sensor was attached to the top of the bidet cover, as shown in Figure 5.

2.4. Communication Module. The data collected by the devices were transmitted to a smartphone using Bluetooth communication protocol. The goal was to detect potential diseases and monitor physiological symptoms (fever and scoliosis) [26].

The developed smart health-monitoring bidet system employed an STM32F103RCT6 microcontroller unit (MCU). This MCU contained an ARM Cortex-M3 32 bit RISC core (operating at 72 MHz), embedded memories, and extensive input/output and peripheral ranges connected to two advanced peripheral buses (APBs) [27]. This component can offer three 12 bit ADCs and four 16 bit timers with two pulse width modulation (PWM), with both standard and advanced communication interfaces [28]. UART0 and UARAT1 were used as debug and Bluetooth ports, respectively, for interworking with the smartphone. In order to obtain valid physiological signals from the sensors (thermometer, oxygen, and pressure sensors), we adopted a communication method suitable for the sensor characteristics and connected it to the MCU: the MCU was designed to communicate with one temperature sensor through a system management bus (SMB), with four pressure sensors through a serial peripheral interface (SPI), and with one oxygen sensor through an interintegrated circuit (IIC). The DC input and output voltages in the low-power mode were 5 V and 1.8 V, respectively, while they were equal to 3.3 V in the high-performance mode.

Bluetooth is a wireless technology that enables devices to connect to each other over short distances [29]. The communication module, shown in Figure 6, is an integral part of the smart health-monitoring bidet. It enables the user to control the bidet's sensors through a smartphone [30].

The data obtained from various sensors were transmitted to the device ID and to the MCU in the HEXA format. The data obtained by the sensors were treated in the following way. First, the sensor which provided these data was identified by the MCU based on its ID: "0×00" indicates a pressure sensor, "0×01" a thermometer sensor, and "0×02" an oxygen sensor. Then, the data are transmitted from the MCU to a smartphone through Bluetooth and converted into a decimal number that can be displayed by the user. The sensor data format has a header (indicating the start of the text [STX]), a tail (indicating the end of text [ETX]), and a space used to delimit or separate between different series of sensor data. The typical sensor data structure format and an example of thermometer sensor data format (for a temperature of 35.6°C) are shown in Figure 7.

Figure 5: Smart health-monitoring bidet cover with the thermometer sensor.

3. Results and Discussion

3.1. Pressure Sensor Module. Figure 8 shows the positions of the four pressure sensors and their wiring connectors connected to a device for accuracy check purposes.

The weight data and the correspondent error difference, calculated by each pressure sensor (at positions 1, 3, 7, and 9, as shown in Figure 2(a)), were considered to evaluate the pressure sensor capabilities. Table 2 shows the error rates of four pressure sensors in different weight settings. The measurements were conducted using push-pull gauges in a digital force gauge machine for weights between 10 and 50 kg (in 10 kg interval steps). The average error of the four pressure sensors was within 4.1%, which is a very low percentage of errors for the pressure sensor attached at the bottom of the bidet.

3.2. Oxygen Sensor Module. The diode-emitting red infrared light in the oxygen sensor, attached to the left side of the bidet, was used to determine the accuracy of performance by targeting 10 times the same skin portion (Figure 9(a)); then, the average measurement value was calculated as shown in Figure 9(b). A set of 10 repetitive measurements was conducted every minute. Within 3 minutes, the accuracy of the oxygen sensor had reached 100%. The value and the average accuracy differed by 0.6%.

3.3. Thermometer Sensor Module. Body temperature as a vital sign was obtained using the thermometer sensor. The accuracy performance of the thermometer sensor embedded at the top section of the bidet toilet seat was checked 10 times (Figure 10(a)). The average accuracy was then calculated as

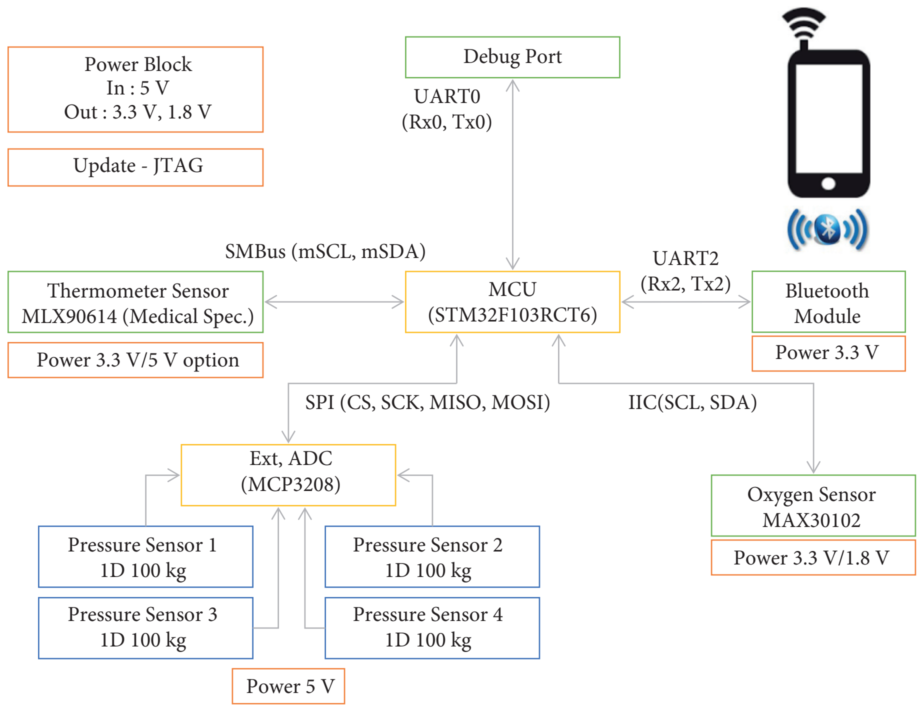
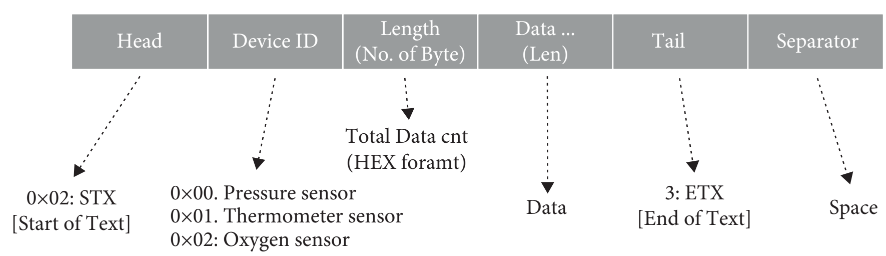


Figure 6: Block diagram of the smart health-monitoring bidet system communication channel.



(a)

Head	Device ID	Len	Data[0]					Tail	Separator
STX	Thermometer sensor	1	3	6	.	5	SP	ETX	SP
0×02	0×01	0×01	0×31	0×36	0×2E	0×35	0×20	0×03	0×20

(b)

Figure 7: (a) Sensor data structure format. (b) Example of thermometer sensor data format for a temperature of 35.6°C (body temperature).

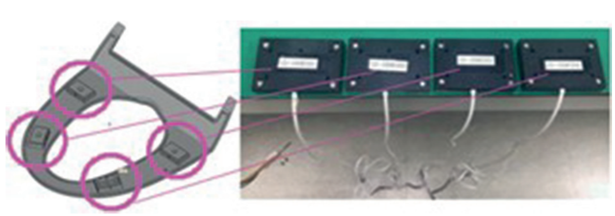


Figure 8: Positions of the pressure sensors (on the lower side of the bidet toilet seat) and their wiring connections.

shown in Figure 10(b). After 3 minutes, the average temperature was 32.39°C, corresponding to the average body temperature difference of 0.35°C (1.06%).

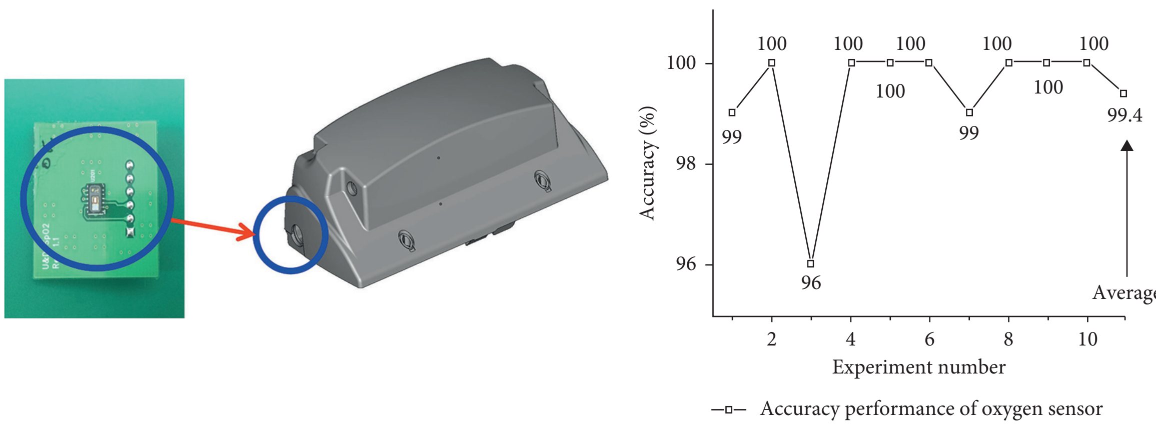
3.4. Smart Health-Monitoring Bidet System. Figure 11 shows the Bluetooth terminal installed on a smartphone, the main MCU, the embedded MCU, as well as all interfaces of the thermometer, oxygen, and pressure sensors. The measurement data obtained from each pressure, oxygen, and thermometer sensor were converted into weight, SpO2, and temperature data, respectively. Then, these data were sent to a smartphone by Bluetooth and saved in a phone application.

Figures 12(a) and 12(b) show the 3D models of the thermometer and pressure sensors, situated on the lower side of the smart health-monitoring bidet toilet seat. Figure 12(c) shows the sensors attached to the bidet system.

Table 2: Percentage and average errors of each sensor for different measurements.

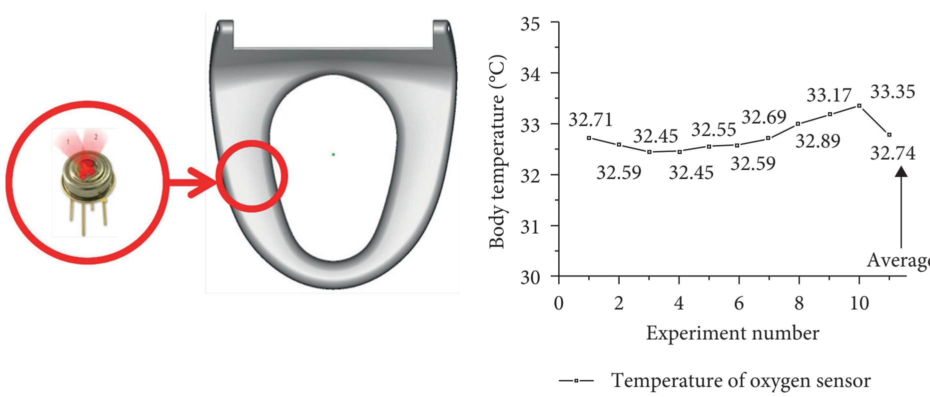
	Error (%) for 10 kg	Error (%) for 20 kg	Error (%) for 30 kg	Error (%) for 40 kg	Error (%) for 50 kg	Average error (%)
Sensor 1	7.780	4.600	2.480	0.625	0.488	3.195
Sensor 3	6.620	0.180	1.967	4.650	6.704	4.024
Sensor 7	4.420	4.420	0.880	0.005	1.952	2.335
Sensor 9	0.130	1.640	1.207	0.130	4.006	1.423

*The sensor numbers (1, 3, 7, and 9) refer to the positions of the pressure sensors. The percentage and average errors were calculated considering weights of 10, 20, 30, 40, and 50 kg.



(a) (b)

Figure 9: (a) Oxygen sensor and its position on the smart health-monitoring bidet. (b) Accuracy performance test of the oxygen sensor attached to the left side of the smart health-monitoring bidet.



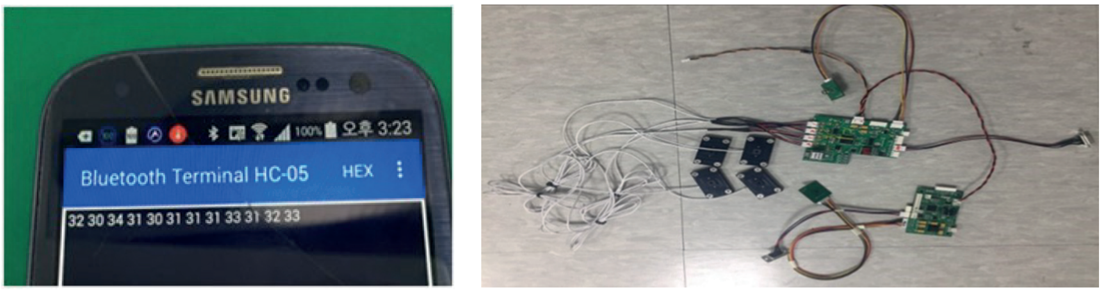
(a) (b)

Figure 10: (a) The thermometer sensor and its position on the smart health-monitoring bidet. (b) Accuracy performance test of the thermometer sensor.

The toilet seat of the bidet system is always used in the presence of water; hence, it is essential to make the system waterproof in order to protect the sensors and the MCU.

Because the smart health-monitoring bidet needs to work properly in the presence of water, its waterproof capability was experimentally tested. The smart health-monitoring bidet, equipped with thermometer, pressure, and oxygen sensors, achieved an IPX6 waterproof rating: all the sensors were functional after being sprayed with water from all directions for 3 minutes. Figure 13 shows the experiment conducted to verify the waterproof capability of the smart health-monitoring bidet. Therefore, the performances of the pressure, thermometer, and oxygen sensor functions were checked after 3 minutes of water spray to prove the IPX6 capability of the developed smart health-monitoring bidet.

3.5. Application Software. The goal of this project was to develop an application that can receive and send data using wireless communication (Figure 14). It could collect bio-



(a) (b)

FIGURE 11: (a) Bluetooth terminal installed on a smartphone. (b) Entire interfaces of the smart health-monitoring bidet system, including the main and embedded MCUs, as well as the thermometer, oxygen, and pressure sensors.

(a) (b) (c)

FIGURE 12: (a) Thermometer sensors on the lower side of the smart health-monitoring bidet toilet seat. (b) Pressure and oxygen sensors on the top and to the back of the toilet seat. (c) Photograph of the bidet with all the sensors attached.

FIGURE 13: Experiment conducted to verify the waterproof capability of the smart health-monitoring bidet system.

signals related to a disease and relay them to a mobile device. It could also provide information on the severity of the disease that can be inferred. In the future, all bio-signals collected by a device will be stored in a server and used to build big data. This will be extended to an artificial intelligence software technology that collects and informs users about their health.

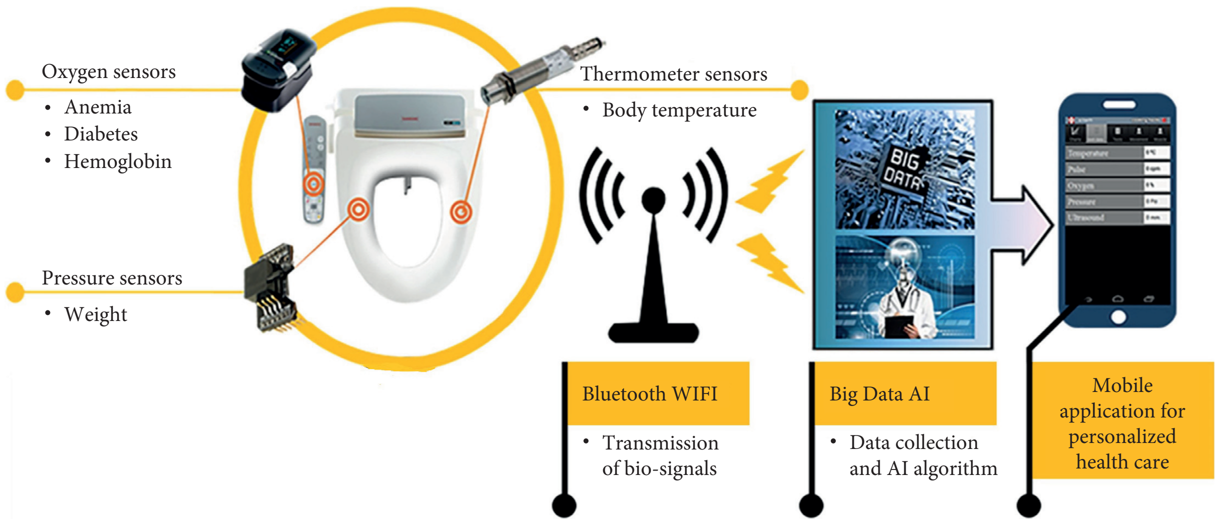


Figure 14: Mobile application for the smart health-monitoring bidet system.

4. Conclusions

This paper proposed a smart health-monitoring bidet system that uses various contact sensors such as thermometer, pressure, and oxygen. The performance of these sensors was tested under IPX6 conditions. The pressure, oxygen, and thermometer sensors revealed error rates of approximately 4.1%, 0.6%, and 1.1%, respectively, indicating excellent precision. The data collected by these sensors were then transferred to a smartphone application using Bluetooth communication protocol. Our smart health-monitoring bidet system can monitor various physiological data that can detect health problems.

Currently, solutions using the IoT are changing the world significantly. It has become very clear that more IoT devices will appear, which are developed to facilitate routine processes by assisting mankind in a vast range of actions. The smart bathroom is among recent IoT solutions that are very soon to be implemented. In this paper, we have calculated various health indicators by measuring and analyzing bio-signals in a nonconstrained, unrecognized environment through a health-monitoring bidet using contact sensors, noncontact sensors, wireless communication, and artificial intelligence software technology. Further studies will be needed that develop this smart bidet system into a Clinical Decision Support System (CDSS) for patients with health problems and conduct research to test the clinical effectiveness of the system.

Data Availability

The data that support the findings of this study are available from the first author (spheo@gwnu.ac.kr) upon reasonable request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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Research Article

Distribution of the Emergency Supplies in the COVID-19 Pandemic: A Cloud Computing Based Approach

Jixiao Wu and Yinghui Wang

Department of Economics and Management, Shijiazhuang Tiedao University, Shijiazhuang 050043, China

Correspondence should be addressed to Yinghui Wang; wang112111@163.com

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The containment of the COVID-19 pandemic was significantly affected by the unbalanced distribution of emergency supplies, low coordinated transport efficiency, high costs, and the inability of nonprofit organizations to handle the emergency supplies efficiently. Based on the COVID-19 experience, in this paper, we build a cloud platform for emergency supplies distribution to reduce the asymmetry of emergency logistics information, reduce the costs, and improve the efficiency of emergency supplies distribution. Our proposed method uses a genetic algorithm with the monarch scheme to optimize the urban emergency supplies distribution. The numerical results and sensitivity analysis for a sample network indicate that using the proposed platform the integrated cost in different cities are reduced by 29.01%, 28.67%, and 22.73%, the required time in different cities are reduced by 22.98%, 26.59%, and 36.65%. The results suggest that the proposed method reduces the integrated cost and transportation time and finds the optimal distribution path.

1. Introduction

The outbreak of COVID-19 at the beginning of 2020 resulted in a significant increase in demand for emergency supplies worldwide. This unprecedented situation severely affected the coordination of demand and supply due to inaccurate decision-making and inefficient distribution of emergency supplies. With the exponential increase in the number of confirmed COVID-19 patients, the existing emergency system became quickly ineffective. This resulted in the shortage of vital emergency supplies in some affected regions, caused significant pressure on the emergency workers, and further aggravated the difficulty of containing the spread of the COVID-19 epidemic.

The emergency services in the epidemic are defined by the National Disaster Medical System (NDMS) as the set of urgent healthcare or medical services required in response to significant/catastrophic incidents, such as natural disasters, significant outbreaks of infectious diseases, and bioterrorist attacks [1]. Although epidemics inevitably happen, their spread can be effectively contained by building an effective emergency logistics system. This paper proposes a cloud computing-based platform to incorporate Big Data, informatization, and intelligence to address the emergency supplies distribution problem in the affected regions. Our objective is to optimize the distribution of emergency supplies to accelerate epidemic relief. Our approach is to integrate the supply and demand information of the emergency supplies on the cloud platform. This reduces the opacity of this information in the emergency logistics services, the asymmetry of supply and demand cat egories, and the uncertainty of distribution. Using the cloud platform, the Big Data, including the emergency supplies, demand points, distribution vehicles and supply, and demand information of different emergency supplies, are processed. The cloud platform then uses these data to optimize the connection of each node in the emergency logistics network while effectively reducing the cost of emergency logistics. This approach enables efficient and intelligent emergency supplies distribution.

Emergency logistics is referred to the logistics service that responds to disasters (e.g., H1N1 influenza, SARS virus, Ebola virus, earthquake, and terrorist attack) [1]. To optimize the distribution of the supplies within the required time-frame in the emergency logistics, various technologies are used, for example, system dynamics [2], heuristic algorithm [3–7], and Internet of Things technology [8]. In the existing works, the optimization of emergency logistics is mainly focused on time [9–11] and cost [6, 12–15]. However, the distribution of supplies for COVID-19 is different from the traditional emergency logistics and has unique features [16]. We incorporate the unique features of the disaster demand points in COVID-19 [16] and adopt a genetic algorithm to optimize the emergency supplies distribution subject to time constraints.

With the development of information technology, information technology has been widely used to improve the logistics process, realizing the logistics informatization from the network to the client. For instance, logistics alliances [17], hyper-network theory [18], and other methods are adopted to combine emergency supply chains to optimize logistics services. Such techniques are based on constructing a comprehensive emergency supplies distribution platform to solve the multipath problem in logistics networks [18–21]. Big Data plays an essential role in the auxiliary resource scheduling and prevention decision-making of the epidemic. Furthermore, the application of intelligent logistics systems effectively improves the resilience of cities in responding to epidemics [22–24]. Therefore, establishing a unified transporting and coordination mechanism for the emergency supply chain eliminates the imbalance in the supply of supplies and satisfies the demand for medical treatments [25]. New technologies such as blockchain are also used in designing efficient emergency supply chains. For instance, blockchain technology is used to build an information management model of supply for targeted donation and epidemic prevention supplies, which shows that using blockchain technology improves the performance of emergency logistics in terms of information transparency, credibility, efficiency, and fairness. Furthermore, it enables efficient coordination of emergency supplies supply [26]. The aforementioned research provides significant supporting evidence that the combination of emergency logistics with advanced information technologies, such as blockchain and cloud computing platforms, plays a pivotal role in the efficient design of such systems. Nevertheless, the current literature has not thoroughly investigated the model build and function design of logistics informatization. The build of logistics information platforms in emergency disasters (especially the COVID-19 epidemic) is still rare. So we have combined the supplies demand features of COVID-19 to build an emergency logistics cloud platform.

Furthermore, in some existing works, a combination of cloud computing and logistics is used to an intelligent logistics system based on logistics informatization [27]. Furthermore, in Govindan et al.'s study [23], the benefits of integrating Big Data and cloud technology into the logistics supply chain are investigated. The build of the emergency logistics cloud platform can rely on government departments [28]. The risks associated with network security, user acceptance, information technology updates, and data sharing in the logistics information platforms are managed by devising a ladder risk management mechanism and optimizes the logistics cloud platform's data sharing and information security capabilities [29]. Also, in Lijia's study [30], considering the automatic matching based on the cloud technology functions formulated the optimal dynamic coordination among the users as a multiobjective optimization problem. It is also shown by Fu et al. [31] that cloud technology can optimize the distribution efficiency of the emergency logistics network. Nevertheless, the existing works seldom combine the cloud platform with emergency logistics and rarely realize the efficiency improvement of emergency supplies distribution through the cloud platform. To strengthen the range of the cloud platform and improve the distribution efficiency of emergency supplies, we combine the cloud platform with emergency logistics, design an emergency logistics cloud platform in COVID-19, and improve the functions of the cloud platform.

Recently, some technologies are used in a wide range of intelligent management applications for sustainability, but these methods are rarely used in human space networks for public health. Based on the previous research, the objective of this paper is to optimize the urban emergency supplies distribution plan by the cloud platform. This paper's contributions are as follows. (1) We build a cloud platform to solve the inefficiency of the supply distribution, low distribution efficiency, and high transaction costs caused by information asymmetry in emergency logistics. (2) The proposed cloud platform optimizes the urban emergency supplies distribution routes, ensures the timeliness of emergency supplies, and reduces the cost of emergency supplies.

2. Emergency Supplies Distribution Design Based on a Cloud Platform

According to the "*Trust Report: Cloud Computing in China*" jointly released by Alibaba Cloud, IEEE China, and Alibaba Research Institute in 2018, more than 70% of companies have transferred more than half of their businesses to a cloud computing platform. The report also points out that about 43% of companies transferred all their businesses to a cloud computing platform. This report concludes that using cloud computing platforms has become a norm that the Chinese business community has accepted. Based on the existing research on Big Data and informatization in emergency logistics [32–34], we built a cloud computing platform for emergency supplies distribution in the epidemic. Compared with the supply distribution model built in the existing literature, this research adopts the cloud computing platform to handle multiple supply and demand information. We then formulate the optimal supplies distribution plan according to the demand for supplies in different epidemic areas. Big Data and cloud computing have been applied to general logistics in intelligent logistics, solving optimization problems, supply chain management, transportation path planning, and supplies distribution [35]. The supply distribution model based on the cloud platform relies on cloud computing, Big Data technology, communication facilities, and various servers and network facilities. The cloud platforms also have unified technical standards, system settings, and protocol specifications [30]. With the Internet as the key, the cloud platform integrates subsystems to form intelligent and complex decision-making systems with various functions and modules [30]. The proposed emergency supplies distribution cloud platform (see Figure 1) comprises an emergency logistics system, a vehicle distribution system, an emergency supplies system, and a core module. In the following, we explain the module's functions and elaborate on the data relationship and transmission routes between them.

The emergency logistics system connects the supply requirements of each node to the cloud platform and penetrates each link of the transport. The vehicle distribution system also optimizes the cloud platform supplies distribution model in terms of the information and service flows. The system also integrates the logistics, capital, and information flow involved in the entire supply chain into the emergency supplies distribution cloud platform. Internet of Things is also used to monitor logistics and transport in real-time. The emergency supplies system combines the emergency supplies provided by various suppliers with the cloud platform to strengthen the supervision of emergency supplies by nonprofit organizations. The core module is composed of 4 parts: communication layer, isolation layer, cloud computing, and Big Data. This module quickly integrates the supply-demand information of the emergency logistics cloud platform and feedback to each node in time and effectively [36]. This results in inefficient operation of the logistics network, reasonable distribution of the supplies, and optimizing the logistics costs.

The core module of the cloud platform consists of four parts: communication layer, isolation layer, cloud computing, and Big Data. The communication layer uses the wired communication based on optical cable, metal wire, and wireless communication to transmit the data information of the vehicles, supplies demand, and supplies inventory provided by each node. The isolation layer is to ensure data security. The isolation method mainly comprises network isolation with firewalls between internal and external source networks and data isolation with encryption technology [37]. Cloud computing is then used to store a massive amount of data, which are also classified and analyzed. The processing of big data includes performing secondary mining on the data to filter out the critical information, processing the filtered critical information through intelligent algorithms, and combining the actual demand information to analyze the optimal supply distribution method. The decision information is then transmitted to the nodes through the communication layer and fed back to the actual logistics transport process.

Based on the aforementioned framework and combined with the epidemic prevention requirements of COVID-19, this paper builds an emergency supplies distribution auxiliary system in COVID-19 based on the existing GuangDong Platform for Common GeoSptial Information Services (http://guangdong.tianditu.gov.cn/). The functional structure of the system is shown in Figure 2. It includes a public service system, epidemic prevention and control system, mobile service system, postepidemic decision auxiliary system, departmental coordination system, emergency supplies management system, shared exchange system, and interface services with other systems [38]. The system can be quickly built based on the services provided by the GuangDong Platform for Common GeoSptial Information Services.

The collaboration model between the emergency supplies distribution system and the auxiliary system based on the cloud platform in the COVID-19 is shown in Figure 3.

The system design and key technologies of emergency supplies distribution on the cloud platform are as follows.

2.1. Unified Data Management and Sharing Service. Based on the unified data management provided by the cloud platform and hierarchical sharing services for emergency demand, the hierarchical management of epidemic prevention and control can be quickly realized. It can complete hierarchical prevention and control management at the city, district, and town levels.

2.2. Place Name and Address Matching Service. Based on the place name and address matching service provided by the cloud platform, the rapid mapping of various types of epidemic data is realized, and the epidemic prevention and control map is formed promptly.

2.3. Intelligent Algorithm Service. Through intelligent algorithms combined with urban population data, the distribution of floating populations in high-risk areas can also be analyzed. This facilitates targeted epidemic prevention and control. The intelligent algorithm service of the cloud platform is mainly reflected in the following aspects:

(i) Build a distributed spatiotemporal big data storage engine, which uses NoSQL and SQL combination and is compatible with HBase, Hadoop, and PostgreSQL to realize the organization and management of large-scale heterogeneous spatiotemporal data.
(ii) Establish a distributed spatiotemporal Big Data index, support multiple indexes, such as R-Tree and GeoHash, which used distributed GIS algorithm and combined with Spark cluster to provide large-scale distributed memory computing.
(iii) Integrate GPU/CPU large-scale parallel computing to provide high-performance Web-based GIS computing services.

2.4. Public Service Platform. The public service platform can help the construction of an emergency logistics system. For example, Guangdong Province has met the demand of different departments and people for data by building the GuangDong Platform for Common GeoSptial Information Services, realized various demands from "zero-code" construction to complex secondary development.

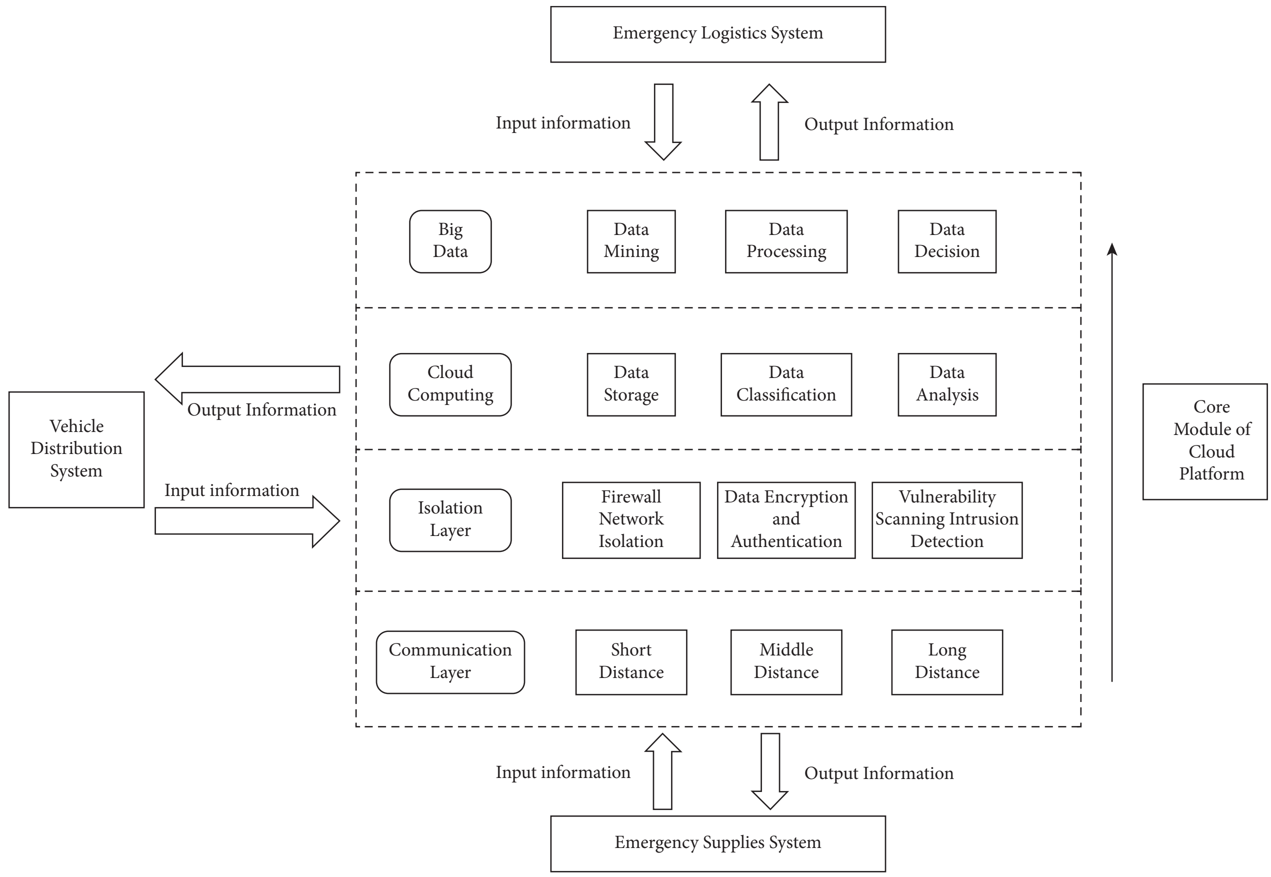

Figure 1: The framework of the emergency supplies distribution of the proposed cloud platform.

2.5. Meet Multilevel Demands. The construction of the emergency logistics system should consider the use of CDC, hospitals, medical institutions, and other government departments and consider the use of the public.

The special distribution centers should handle the distribution of emergency supplies. The transport reserve system is different from the general supplies for the supply of emergency supplies in terms of financing, reserve, and transport [39]. To clarify the modelling boundaries, this research obtains emergency supplies supply information and classifies the demand information through the cloud platform, focusing on emergency supplies distribution. The emergency supplies distribution steps of the cloud platform can be briefly summarized as follows: publish supplies demand data at various demand points ⟶ collect the emergency supplies from suppliers and distribution centers in various places ⟶ supplies reserve and distribution plan ⟶ intelligent cloud decision-making for supplies sorting, vehicle management, and path selection ⟶ supplies distribution at each demand point. The detailed flowchart of the proposed emergency supplies distribution is presented in Figure 4. The cloud platform is mainly responsible for the information flow part, and the logistics part is handed over to the relevant emergency personnel.

3. Methods

The emergency supplies are demanded during the incident, and after a major epidemic, the emergency supplies reserved in the city become low. Hence, the reserves are not sufficient for the long-term needs of the city's emergency. Note that the demand of each demand point in the epidemic and their urgency might be different. Therefore, it is essential to reasonably plan the supply distribution to fluctuation emergency supplies' demands. The existing supply chain of emergency supplies is generally a 3-level distribution network of "supplies, supplier-distribution centers, and demand points" as shown in Figure 5. However, such patterns require more data and excessively make unrealistic assumptions on time spent in the parts [40].

The traditional distribution model of emergency supplies has complicated processes and insufficient information communication between nodes. This is also prone to a lot of additional costs. The distribution model of emergency supplies based on the cloud platform (as shown in Figure 6) can optimize the "$i * j$" routes between the suppliers, i, and the demand points j to "$i + j$" routes by the cloud platform, which greatly simplifies the distribution process. Sufficient sharing of information resources enabled by the cloud platform enables the supplier to fully understand the

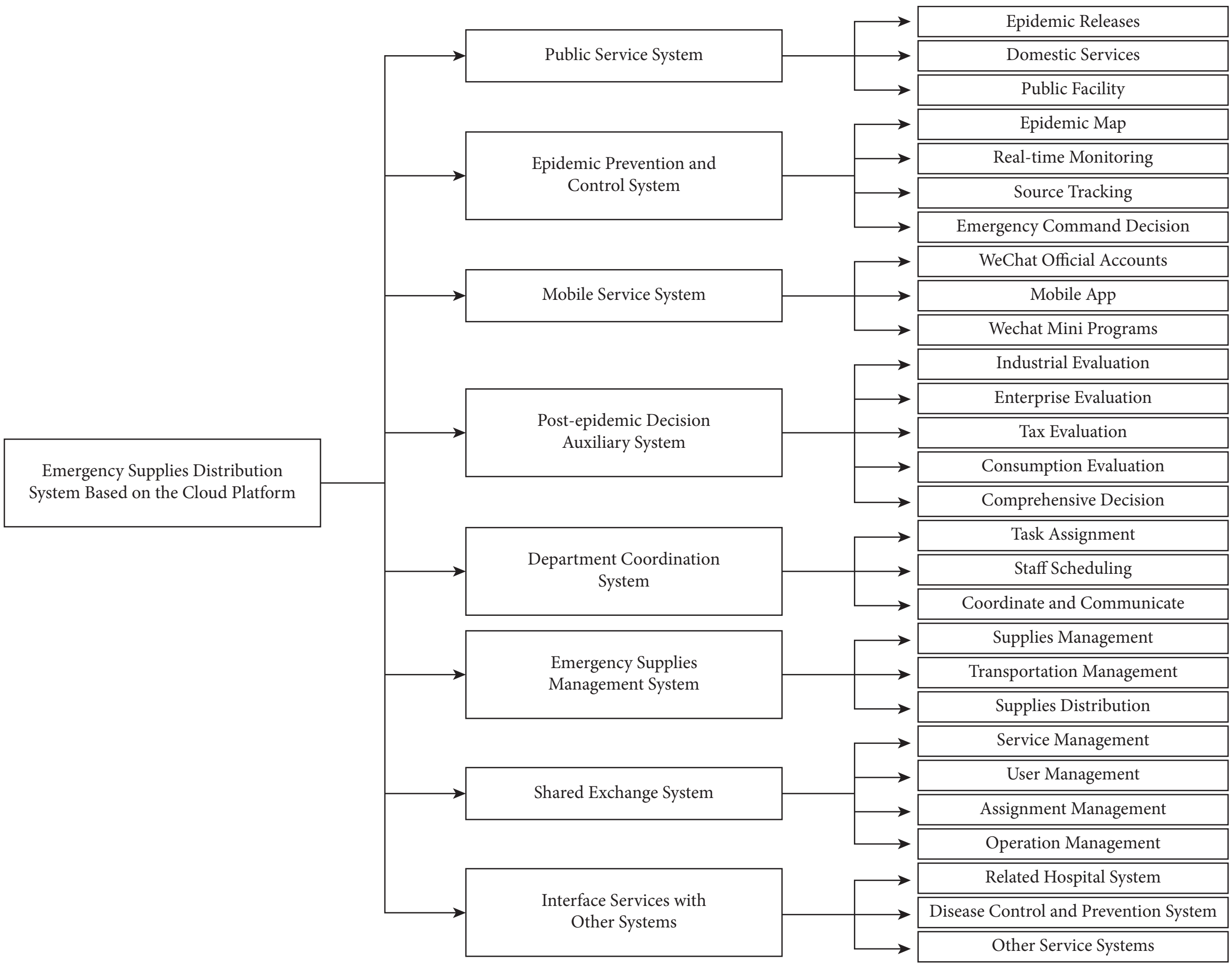

Figure 2: The functions of the emergency supplies distribution system based on the cloud platform.

supplies demand of the demand point, which makes it unnecessary for the vehicles to transit through the distribution center as in the traditional model, hence can directly complete the supplies distribution from the supplier to the demand point. To optimize the distribution model, the time, and the cost of the overall emergency logistics network, it is necessary to reasonably plan the distribution route and the position of each node to minimize the sum of the costs and time of all routes. Furthermore, it is necessary to consider route optimization and establish a cloud platform emergency supplies distribution model to achieve optimal supplies distribution.

Concerning the actual scenario of emergency supplies distribution in COVID-19, the following assumptions are made in combination with the characteristics of the cloud platform:

(1) In the process of emergency supplies distribution, a vehicle can only transport one kind of supplies at a time.

(2) The transaction cost does not incur in the distribution of emergency supplies based on the cloud platform.

(3) The cloud platform in this paper is led by the state. Hence, the node does not need to consider the construction cost of the cloud platform.

3.1. Parameter Setting. The relevant parameters and decision variables of the emergency supplies distribution model are presented in Table 1.

3.2. System Model. Based on the aforementioned model, the cost of the emergency supplies distribution model in the epidemic is

$$\operatorname{Min} C = H + \sum_{i\in V}\sum_{j\in V}\sum_{n\in N}\sum_{k\in K} C_l x_{ijkn} + \sum_{i\in V}\sum_{j\in V}\sum_{n\in N}\sum_{k\in K} c_{ijk} x_{ijkn}\left(d_{in}^{2} + d_{jn}^{3}\right), \quad (1)$$

$$\operatorname{Min} C' = \sum_{i\in V}\sum_{j\in V}\sum_{n\in N}\sum_{k\in K} C_l a_{ijk}^{p} + \sum_{i\in V}\sum_{j\in V}\sum_{k\in K} c_{ijk} a_{ijk}^{p} d_{ij}^{1}, \quad (2)$$

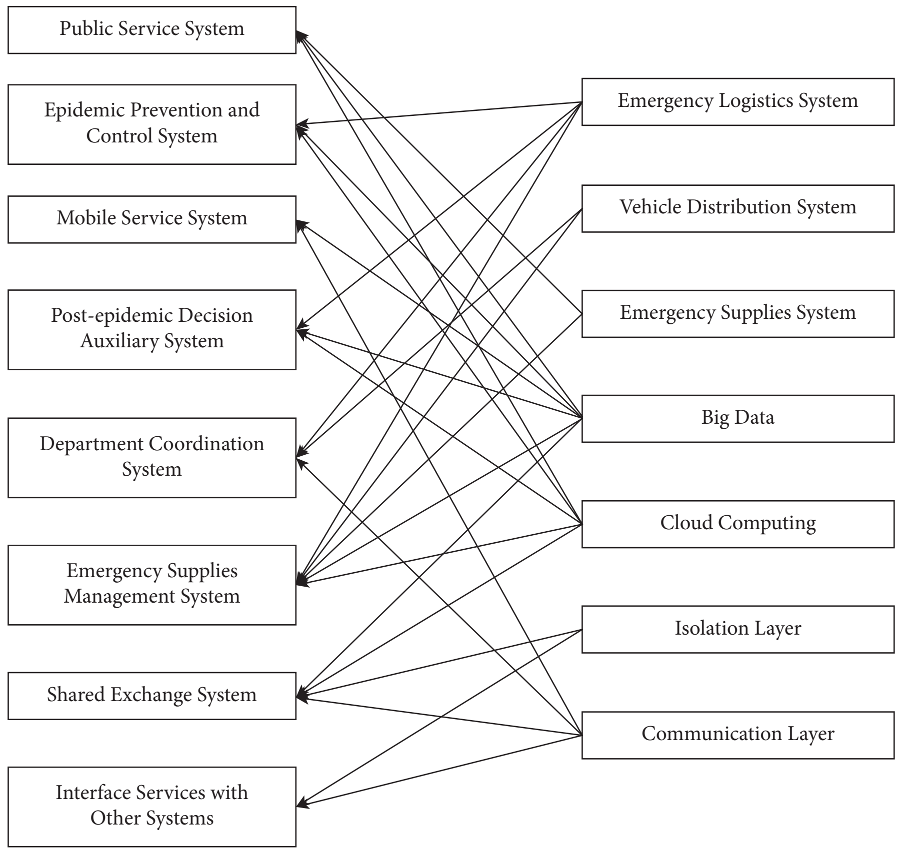

Figure 3: The collaboration model between emergency systems.

$$\text{Min}\, T = \sum_{i\in V}\sum_{j\in V}\sum_{n\in N}\sum_{k\in K} T_l x_{ijkn} + \sum_{i\in V}\sum_{j\in V}\sum_{n\in N}\sum_{k\in K} x_{ijkn}\frac{d_{in}^2 + d_{jn}^3}{v}, \tag{3}$$

$$MinT' = \sum_{i\in V}\sum_{j\in V}\sum_{n\in N}\sum_{k\in K} T_l a_{ijk}^p + \sum_{i\in V}\sum_{j\in V}\sum_{k\in K} a_{ijk}^p \frac{d_{ij}^1}{v} \tag{4}$$

The objective function in equation (1) represents the minimum integrated cost of the traditional emergency supplies distribution, including the transaction cost in the distribution of emergency supplies, the loading and unloading cost, and the transportation cost. Equation (2) also represents the minimum integrated cost of emergency supplies distribution based on the cloud platform, including the loading and unloading costs and transportation costs. Equations (3) and (4) are the minimum time in the traditional and cloud platform models, respectively, including the loading and unloading and transportation time. We also have the following constraints:

$$\sum_{i\in N\cup I}\sum_{n\in N}\sum_{k\in K} x_{ijkn} = a_{ijk}^p, \forall j \in J, \forall p \in P, \tag{5}$$

$$\sum_{i\in N\cup J}\sum_{n\in N}\sum_{k\in K} x_{ijkn} = a_{ijk}^p, \forall j \in J, \forall p \in P, \tag{6}$$

$$\sum_{i\in N}\sum_{n\in N}\sum_{k\in K} x_{ijkn} = 1, \forall j \in J, \forall p \in P, \tag{7}$$

$$\sum_{j\in N}\sum_{n\in N}\sum_{k\in K} x_{ijkn} = 1, \forall i \in I, \forall p \in P, \tag{8}$$

$$\sum_{i\in N}\sum_{k\in K} a_{ijk}^p = 1, \forall j \in J, \forall p \in P, \tag{9}$$

$$\sum_{j\in N}\sum_{k\in K} a_{ijk}^p = 1, \forall j \in J, \forall p \in P, \tag{10}$$

where equations (5) and (6) ensure that if the distribution center n is selected to serve the point pair p, there must be a vehicle to transport emergency supplies; otherwise, no distribution center is selected. Equations (7) and (8) indicate that the emergency supplies from supplier i to demand point j must be solely transported through the distribution center n. Equations (9) and (10) also ensure that only one path can be selected for transportation at a time in the traditional model. We further need to make sure the following:

$$\sum_{i\in I} D_i = \sum_{j\in J} S_j, \tag{11}$$

$$\sum_{p\in P} a_{ijk}^p d^p \le q_{ijkn} x_{ijkn}, \forall i \in V, \forall j \in V, \forall k \in K, \forall n \in N, \tag{12}$$

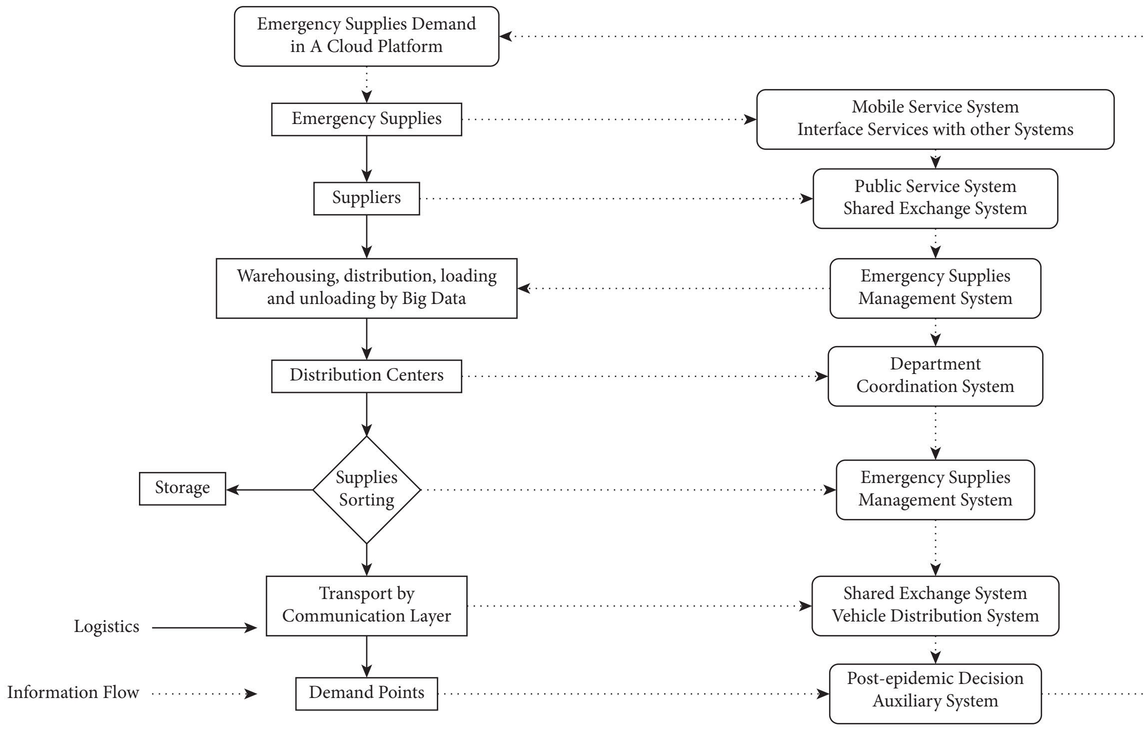

Figure 4: The emergency supplies distribution process is based on the proposed cloud platform.

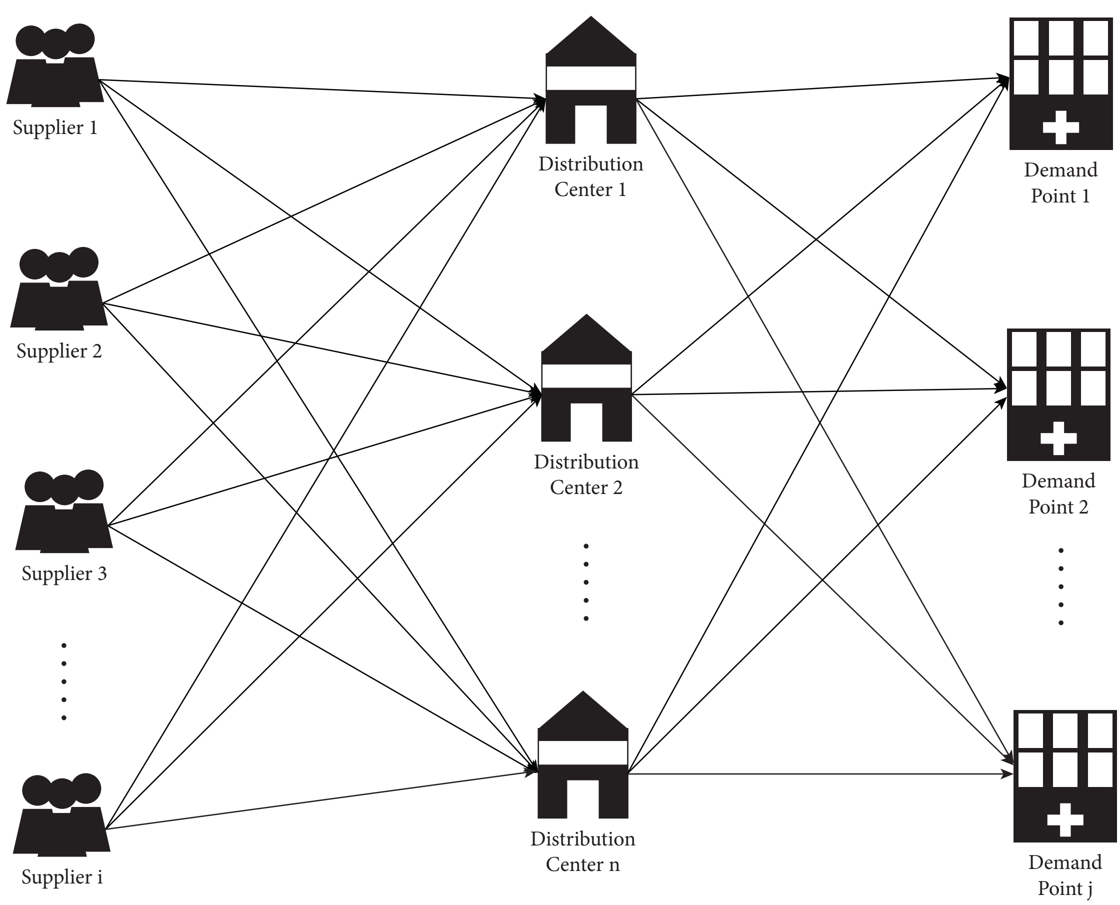

Figure 5: The traditional distribution model of emergency supplies in the epidemic.

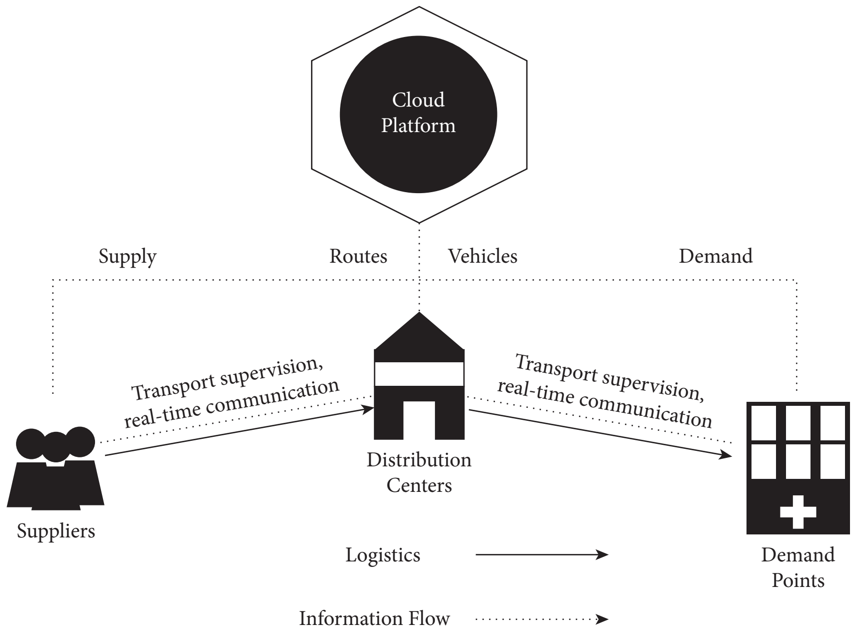

Figure 6: The distribution model of emergency supplies in the epidemic based on the cloud platform.

Table 1: Parameters, sets, and decision variables.

Symbol	Description
d_{ij}^1	The distance from the supplier i to the demand point j (km)
d_{in}^2	The distance from the supplier i to the distribution center n (km)
d_{jn}^3	The distance from the demand point j to the distribution center n (km)
q_{ijkn}	The unit transportation capacity of the vehicle k from the supplier i to the demand point j through the distribution center n (tons)
c_{ijk}	The cost of per vehicle per unit distance (yuan/km)
v	Vehicle speed (km/h)
I	The set including suppliers indexed by i, $I = \{0, 1, 2,..., i\}$
J	The set including demand points indexed by j, $J = \{0, 1, 2,..., j\}$
P	The set including supply and demand point pairs from supplier i to the demand point j
N	The set including distribution centers indexed by n, $N = \{0, 1, 2,..., n\}$
K	The set including the transport vehicles indexed by k, $K = \{1,2,..., k\}$
G_n	Maximum load of the distribution center n (tons)
T_l	The loading and unloading time (h)
C_l	The loading and unloading cost (yuan)
D_i	The set including emergency supplies provided by the supplier i
Q_k	Maximum load of transport vehicles (tons)
S_j	The set including emergency supplies received by demand point j
C	The comprehensive cost of emergency supplies distribution of the cloud platform (yuan)
d^P	The number of emergency supplies between the point pair p in the period, pP
H	The transaction cost between nodes without cloud platform service (yuan) $V = IJN$
x_{ijkn} {0,1}	If the vehicle k from the supplier i to the demand point j through the distribution center n, then $x_{ijkn} = 1$, otherwise $x_{ijkn} = 0$
y {0,1}	If the cloud platform service is not opened, then $y = 1$, otherwise $y = 0$
a_{ijk}^P {0,1}	If the supplier i to the demand point j is transported by the vehicle k and serves the point pair p, then $a_{pijk} = 1$, otherwise $a_{pijk} = 0$

$$\sum_{p\in P} a_{ijk}^p q_{ijkn} \le W_n y, \forall n \in N, \tag{13}$$

$$q_{ijkn} \ge 0, \forall i \in V, \forall j \in V, \forall k \in K, \tag{14}$$

$$\sum_{j\in J} q_{ijkn} \le D_i, \forall i \in I, \tag{15}$$

$$\sum_{i\in I} q_{ijkn} \le S_j, \forall j \in J, \tag{16}$$

$$a_{ijk}^p \in \{0,1\}, \forall i \in V, \forall j \in V, \forall k \in K, \forall p \in P, \tag{17}$$

$$x_{ijkn} \in \{0,1\}, \forall i \in V, \forall j \in V, \forall n \in V, \forall k \in K. \tag{18}$$

In the aforementioned equations, equation (11) ensures that the number of emergency supplies provided by all suppliers is the same as all demand points received it. Equation (12) enforces the transportation capacity constraint, which requires that the distribution center n selected for the transport path between the point pair p must be active. Equation (13) also enforces the transportation capacity of the distribution center n. Equations (14) to (16) also apply the transportation capacity constraints between the points, where equations (17) to (18) are the decision variables related to the emergency supplies distribution model.

3.3. Algorithm Design. The distribution of emergency supplies in the epidemic based on cloud platforms extends the traditional logistics transport problem. Furthermore, the emergency supplies distribution model in this paper involves multiple distribution centers and multiple demand points. Therefore, it is necessary to adopt an intelligent optimization algorithm to solve the problem. Here, we propose using the genetic algorithm. The steps of the genetic algorithm in this research are as follows:

Step 1: *Population Initialization*. Number each demand point, randomly arrange and generate chromosomes, and reserve them in a matrix to form the initial population.

Step 2: *Calculate Fitness*. Calculate the transport distance of each chromosome in the initial population. Then add the supply requirements of each demand point and the upper limit of the vehicle load into the fitness calculation to find the shortest average time and route. Set the number of iterations $g = 1$.

Step 3: *Selecting the Chromosome*. Select the chromosome with the lowest fitness in this generation as the father's chromosome, and leave the ascending chromosomes as the mother's chromosome.

Step 4: *Cross-Variation*. Using the monarch scheme, the chromosome with the highest fitness value is selected as the monarch chromosome. It is then placed in the odd-numbered position of the entire population and forms a pair with the even-numbered position of the latter one. The number of crossover points is then determined according to the crossover probability ($P_c = 0.8$), and the population is randomly selected according to the variation probability P_m ($P_m = 0.3$) after the cross-operation [41]. The next generation of chromosomes is then generated.

The algorithm calculates the fitness of the population individuals after cross-variation. The minimum fitness of the generation g and the corresponding individual value are recorded. Then it is checked whether the number of iterations exceeds the maximum allowed iterations, G. If so, the cycle is stopped, otherwise $g = g + 1$, and it returns to Step 4 to re-execute the monarch plan [41–44]. The flowchart of the algorithm is shown in Figure 7.

4. Experimental and Data Analysis

To optimize the distribution of emergency supplies, we use MATLAB-generated data using the actual coordinate distribution on the map. We also modify some of the parameters of the sample city for sensitivity analysis and then analyze the stability of the supplies distribution path. In these models, a distribution center n, undertakes the transportation task from multiple suppliers i to demand points j. When the vehicle is transported in the traditional model, the supplies are loaded once at the supplier, then loaded and unloaded once at the distribution center, and unloaded once at the demand point. The vehicle only needs to load the supplies once at the supplier and unload the supplies at the demand point in the cloud platform model. For brevity, this paper does not consider the fixed opening cost of each point in the emergency logistics network. The points and data in this experiment are based on the Baidu map (https://map.baidu.com/) and the relevant literature [42–45], optimizing the results through MATLAB.

4.1. Emergency Logistics Optimization in the Seriously Affected City Based on the Cloud Platform. The main stations and logistics parks in the seriously affected city are selected as the suppliers. The Red Cross Society and the relevant government departments in the city are selected as the distribution centers. The eight main hospitals in the city are selected as the demand points. The relevant data for each point in the emergency logistics model is presented in Table 2.

Table 3 shows the distance between suppliers, distribution centers, and demand points in the seriously affected city.

This paper assumes that during the opening of each point, the emergency supplies between suppliers and demand points in the seriously affected city are as presented in Table 4.

After the optimization in MATLAB, the integrated cost of the emergency logistics model in the seriously affected city is obtained and shown in Figure 8. The emergency logistics plan is also presented in Table 5. The integrated cost of the emergency logistics in the traditional model is 21,030 yuans, and the integrated time is 17.54; the integrated cost of emergency logistics based on the cloud platform is 14,930 yuans, and the integrated time is 13.51. It means a reduction of 29.01% of the cost and 22.98% of the time using the proposed cloud platform. The distribution path of emergency supplies from suppliers and demand points are also shown in Table 5. For instance, for Demand Point 1, in the traditional emergency logistics model, the supplies it received are provided by Supplier 2 through the 3rd vehicle of Distribution Center 3, Supplier 3 through the 1st vehicle of Distribution Center 1, and also Supplier 4 through the 1st vehicle of distribution Center 3. In the emergency logistics based on the cloud platform, Demand Point 1 can directly receive emergency supplies provided by Suppliers 2, 3, and 4 without transferring through the distribution center. As it is seen, using the proposed cloud platform, emergency supplies

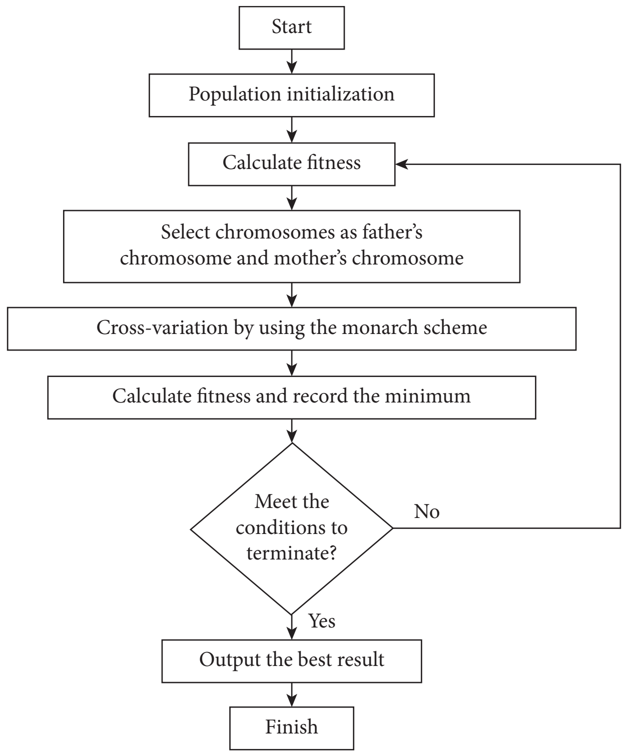

Figure 7: The flowchart of the genetic algorithm for optimization.

can be transported directly from the supplier to the demand point, significantly reducing the transportation process.

4.2. Emergency Logistics Optimization in the General Affected City Based on the Cloud Platform. The main stations and logistics parks in the general affected city are selected as the suppliers. The Red Cross Society and the relevant government departments in the city are selected as the distribution centers. The four main hospitals in the city are selected as the demand points. The relevant data for each point in the emergency logistics model is presented in Table 6.

Table 7 shows the distance between suppliers, distribution centers, and demand points in the general affected city.

This paper assumes that during the opening of each point, the emergency supplies between suppliers and demand points in the general affected city are as presented in Table 8.

After the optimization in MATLAB, the integrated cost of the emergency logistics model in the general affected city as shown in Figure 9 and the emergency logistics plan in the general affected city as shown in Table 9. The integrated cost of the emergency logistics in the traditional model is 11,670 yuans, and the integrated time is 10.20; the integrated cost of emergency logistics based on the cloud platform is 9,070 yuans, and the integrated time is 7.49. It means a reduction of 28.67% of the cost and 26.59% of the time using the proposed cloud platform. The distribution path of emergency supplies from suppliers and demand points in the general affected city is shown in Table 9.

4.3. Emergency Logistics Optimization in the Minor Affected City Based on the Cloud Platform. The main stations and logistics parks in the minor affected city are selected as the suppliers. The Red Cross Society and relevant government departments in the city are selected as the distribution centers. The two main hospitals in the city are selected as the demand points. The relevant data for each point in the emergency logistics model is presented in Table 10.

Table 11 shows the distance between suppliers, distribution centers, and demand points in the minor affected city.

This paper assumes that during the opening of each point, the emergency supplies between suppliers and demand points in the minor affected city are as presented in Table 12.

After the optimization in MATLAB, the integrated cost of the emergency logistics model in the minor affected city as shown in Figure 10, and the emergency logistics plan in the minor affected city as shown in Table 13. The integrated cost of the emergency logistics in the traditional model is 4,840 yuans, and the integrated time is 3.15; the integrated cost of emergency logistics based on the cloud platform is 3,740 yuans, and the integrated time is 1.99. It means a reduction of 22.73% of the cost and 36.65% of the time using the proposed cloud platform. The distribution path of emergency supplies from suppliers and demand points in the minor affected city is shown in Table 13.

The aforementioned cases show that the cloud platform has played a critical role in reducing the cost and time of emergency supplies distribution. With the city's emergency

Table 2: Relevant points and parameters in the seriously affected city.

Parameter	Symbol	Value	Parameter	Symbol	Value
Maximum load of transport vehicles	Q_k	100t	Number of transport vehicles in the distribution center	K	3
Vehicle speed	v	60	Emergency supplies received by Demand Point 1	S_1	120t
Maximum load of Distribution Center 1	G_1	200t	Emergency supplies received by Demand Point 2	S_2	160t
Maximum load of Distribution Center 2	G_2	220t	Emergency supplies received by Demand Point 3	S_3	155t
Maximum load of Distribution Center 3	G_3	170t	Emergency supplies received by Demand Point 4	S_4	135t
Maximum load of Distribution Center 4	G_4	150t	Emergency supplies received by Demand Point 5	S_5	110t
Maximum load of Distribution Center 5	G_5	180t	Emergency supplies received by Demand Point 6	S_6	95t
Emergency supplies provided by Supplier 1	D_1	180t	Emergency supplies received by Demand Point 7	S_7	140t
Emergency supplies provided by Supplier 2	D_2	220t	Emergency supplies received by Demand Point 8	S_8	120t
Emergency supplies provided by Supplier 3	D_3	140t	Emergency supplies provided by Supplier 5	D_5	150t
Emergency supplies provided by Supplier 4	D_4	160t	The loading and unloading time	Tl	0.5
The loading and unloading cost	C_l	100 yuan	The transaction cost in traditional model	H	300 yuan
The cost of per vehicle per unit distance	c_{ijkn}	7 yuan/t $*$ km			

Table 3: Distance of each point in the seriously affected city.

	Distribution Center 1	Distribution Center 2	Distribution Center 3	Distribution Center 4	Distribution Center 5
Supplier 1	12.3	17.1	13.5	16.2	15.1
Supplier 2	6.5	15.3	4.7	14.2	6.8
Supplier 3	16.5	7.7	17.5	6.4	15.4
Supplier 4	36.6	53.9	63.6	51.4	40.2
Supplier 5	25.3	37.1	44.7	39.3	30.2
Demand Point 1	34.3	33.2	32.8	28.5	32.2
Demand Point 2	18.7	29.3	18.8	29.8	19.6
Demand Point 3	15.5	5.8	16.7	4.5	15.2
Demand Point 4	13.9	7.1	12.3	5.5	11.3
Demand Point 5	6.3	15.2	4.3	13.9	7.8
Demand Point 6	3.9	14.4	3.3	13.3	6.3
Demand Point 7	5.6	18.4	5	15.6	5.7
Demand Point 8	4.4	16.9	3.9	15.5	5.2

Table 4: Emergency supplies between suppliers and demand points in the seriously affected city.

	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5
Demand Point 1	0	80	100	70	0
Demand Point 2	80	50	0	0	30
Demand Point 3	70	0	70	0	40
Demand Point 4	0	40	60	30	0
Demand Point 5	60	50	0	40	20
Demand Point 6	0	30	50	30	30
Demand Point 7	90	0	60	20	0
Demand Point 8	60	60	0	70	0

levels, the cloud platform has a bigger effect on cost optimization.

4.4. Sensitivity Analysis. Different levels of urban emergency logistics have different integrated cost and distribution paths due to different factors, such as supplies demand and transportation capacity constraints. With the level of emergency increased, the demand for emergency supplies and the cost of transportation increased. It is seen that the unit transportation cost c_{ijkn} and the loading and unloading cost C_l have significant impacts on the supplies distribution. To further verify the impact of these factors on the emergency logistics based on the cloud platform, this paper

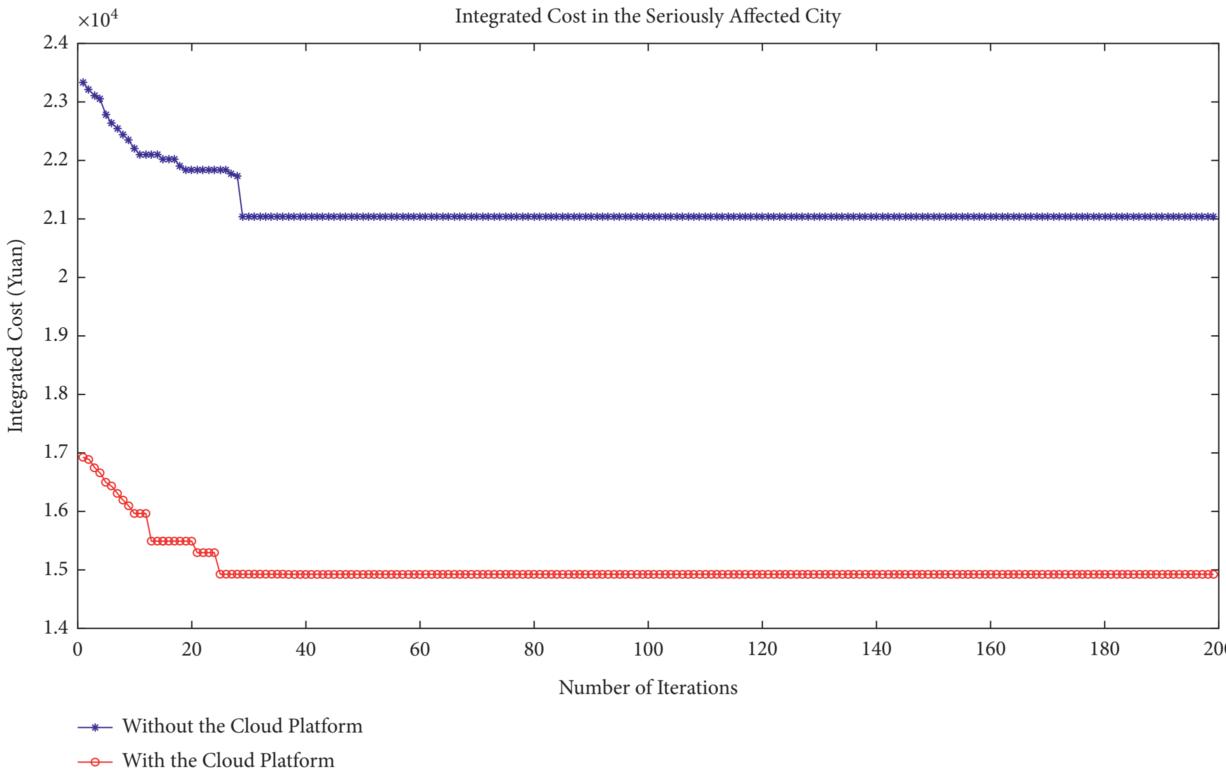

FIGURE 8: Integrated costs in the seriously affected city.

TABLE 5: The distribution path of emergency supplies in the seriously affected city.

Without the cloud platform			With the cloud platform		
Supplier	Demand Point	Distribution path	Supplier	Demand Point	Distribution path
2	1	2⟶3⟶1 (1)	2	1	2⟶1
3	1	3⟶1⟶1 (3)	3	1	3⟶1
4	1	4⟶3⟶1 (1)	4	1	4⟶1
1	2	1⟶4⟶2 (3)	1	2	1⟶2
2	2	2⟶3⟶2 (1)	2	2	2⟶2
5	2	5⟶4⟶2 (1)	5	2	5⟶2
1	3	1⟶4⟶3 (1)	1	3	1⟶3
3	3	3⟶4⟶3 (2)	3	3	3⟶3
5	3	5⟶1⟶3 (2)	5	3	5⟶3
2	4	2⟶1⟶4 (3)	2	4	2⟶4
3	4	3⟶4⟶4 (3)	3	4	3⟶4
4	4	4⟶5⟶4 (2)	4	4	4⟶4
1	5	1⟶4⟶5 (3)	1	5	1⟶5
2	5	2⟶5⟶5 (2)	2	5	2⟶5
4	5	4⟶3⟶5 (2)	4	5	4⟶5
5	5	5⟶5⟶5 (2)	5	5	5⟶5
2	6	2⟶3⟶6 (3)	2	6	2⟶6
3	6	3⟶3⟶6 (2)	3	6	3⟶6
4	6	4⟶1⟶6 (2)	4	6	4⟶6
5	6	5⟶1⟶6 (3)	5	6	5⟶6
1	7	1⟶1⟶7 (3)	1	7	1⟶7
3	7	3⟶3⟶7 (3)	3	7	3⟶7
4	7	4⟶3⟶7 (2)	4	7	4⟶7
1	8	1⟶3⟶8 (1)	1	8	1⟶8
2	8	2⟶2⟶8 (3)	2	8	2⟶8
4	8	4⟶5⟶8 (2)	4	8	4⟶8

Table 6: Relevant points and parameters in the general affected city.

Parameter	Symbol	Value	Parameter	Symbol	Value
Maximum load of transport vehicles	Q_k	100t	Number of transport vehicles in the distribution center	K	3
Maximum load of Distribution Center 1	G_1	170t	Vehicle speed	v	60
Maximum load of Distribution Center 2	G_2	150t	Emergency supplies received by Demand Point 1	S_1	120t
Maximum load of Distribution Center 3	G_3	180t	Emergency supplies received by Demand Point 2	S_2	110t
Emergency supplies provided by Supplier 1	D_1	110t	Emergency supplies received by Demand Point 3	S_3	100t
Emergency supplies provided by Supplier 2	D_2	130t	Emergency supplies received by Demand Point 4	S_4	130t
Emergency supplies provided by Supplier 3	D_3	90t	The loading and unloading cost	C_l	100 yuan
Emergency supplies provided by Supplier 4	D_4	100t	The loading and unloading time	Tl	0.5
The cost of per vehicle per unit distance	c_{ijkn}	7 yuan/ t * km	The transaction cost in traditional model	H	300 yuan

Table 7: Distance of each point in the general affected city.

	Distribution Center 1	Distribution Center 2	Distribution Center 3
Supplier 1	44.8	15.2	14.7
Supplier 2	35.5	5.1	5.5
Supplier 3	90.3	65.2	50.3
Supplier 4	38.9	22.2	19.9
Demand Point 1	48.6	8.4	9.5
Demand Point 2	36	9.1	8.8
Demand Point 3	33.3	9.6	7.7
Demand Point 4	44.4	8.2	7.3

Table 8: Emergency supplies between suppliers and demand points in the general affected city.

	Supplier 1	Supplier 2	Supplier 3	Supplier 4
Demand Point 1	0	100	0	80
Demand Point 2	90	0	120	130
Demand Point 3	130	100	80	0
Demand Point 4	0	0	110	70

changes the value of c_{ijkn} and C_l, keeping the other parameters unchanged. We then explore the impact of these parameters on the integrated cost to investigate the stability of emergency logistics. The final results are presented in Table 14.

The sensitivity analysis of different parameters in Table 6 suggests the following:

(1) Given a limited amount of time, with the intensification of emergency levels (or increasing the number of demand points), the impact of the unit transportation cost of the emergency logistics is decreased. In contrast, the impact of the loading and unloading cost of emergency logistics is increased.

(2) The cloud platform can play a good role in optimizing the integrated cost of emergency logistics; the effect increases with the increasing emergency levels.

(3) Although the integrated cost of the emergency logistics fluctuates by the changes in parameters, the distribution path and the integrated time have not changed. This confirms that the distribution model is stable and can optimize the distribution path of the emergency supplies.

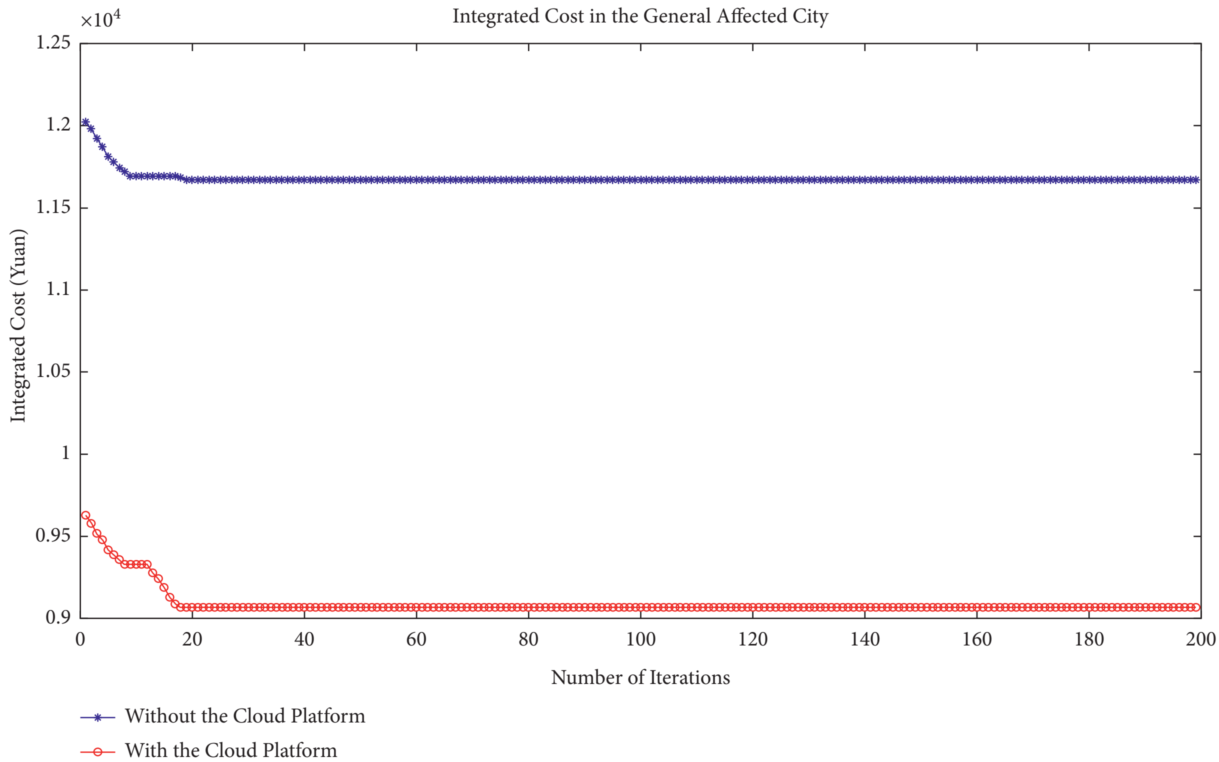

FIGURE 9: Integrated cost in the general affected city.

TABLE 9: The distribution path of emergency supplies in the general affected city.

Without the cloud platform			With the cloud platform		
Supplier	Demand point	Distribution path	Supplier	Demand point	Distribution path
2	1	2⟶1⟶1 (3)	2	1	2⟶1
4	1	4⟶3⟶1 (3)	4	1	4⟶1
1	2	1⟶2⟶2 (1)	1	2	1⟶2
3	2	3⟶2⟶2 (2)	3	2	3⟶2
4	2	4⟶3⟶2 (3)	4	2	4⟶2
1	3	1⟶3⟶3 (3)	1	3	1⟶3
2	3	2⟶3⟶3 (1)	2	3	2⟶3
3	3	3⟶2⟶3 (3)	3	3	3⟶3
3	4	3⟶3⟶4 (2)	3	4	4⟶4
4	4	4⟶1⟶4 (1)	4	4	4⟶4

TABLE 10: Relevant points and parameters in the minor affected city.

Parameter	Symbol	Value	Parameter	Symbol	Value
Maximum load of transport vehicles	Q_k	100t	Number of transport vehicles in the distribution center	K	3
Maximum load of Distribution Center 1	G_1	100t	Vehicle speed	v	60
Maximum load of Distribution Center 2	G_2	100t	Emergency supplies received by Demand Point 1	S_1	90t
Emergency supplies provided by Supplier 1	D_1	70t	Emergency supplies received by Demand Point 2	S_2	110t
Emergency supplies provided by Supplier 2	D_2	70t	Emergency supplies provided by Supplier 3	D_3	60t
The loading and unloading cost	Cl	100 yuan	The loading and unloading time	Tl	0.5
The cost of per vehicle per unit distance	c_{ijkn}	7 yuan/t ∗ km	The transaction cost in traditional model	H	300 yuan

Table 11: Distance of each point in the minor affected city.

	Distribution Center 1	Distribution Center 2
Supplier 1	11.1	8.2
Supplier 2	23.2	27.1
Supplier 3	9.3	12.3
Demand Point 1	2.8	2.8
Demand Point 2	1.9	3.7

Table 12: Emergency supplies between suppliers and demand points in the minor affected city.

	Supplier 1	Supplier 2	Supplier 3
Demand Point 1	100	0	120
Demand Point 2	90	110	0

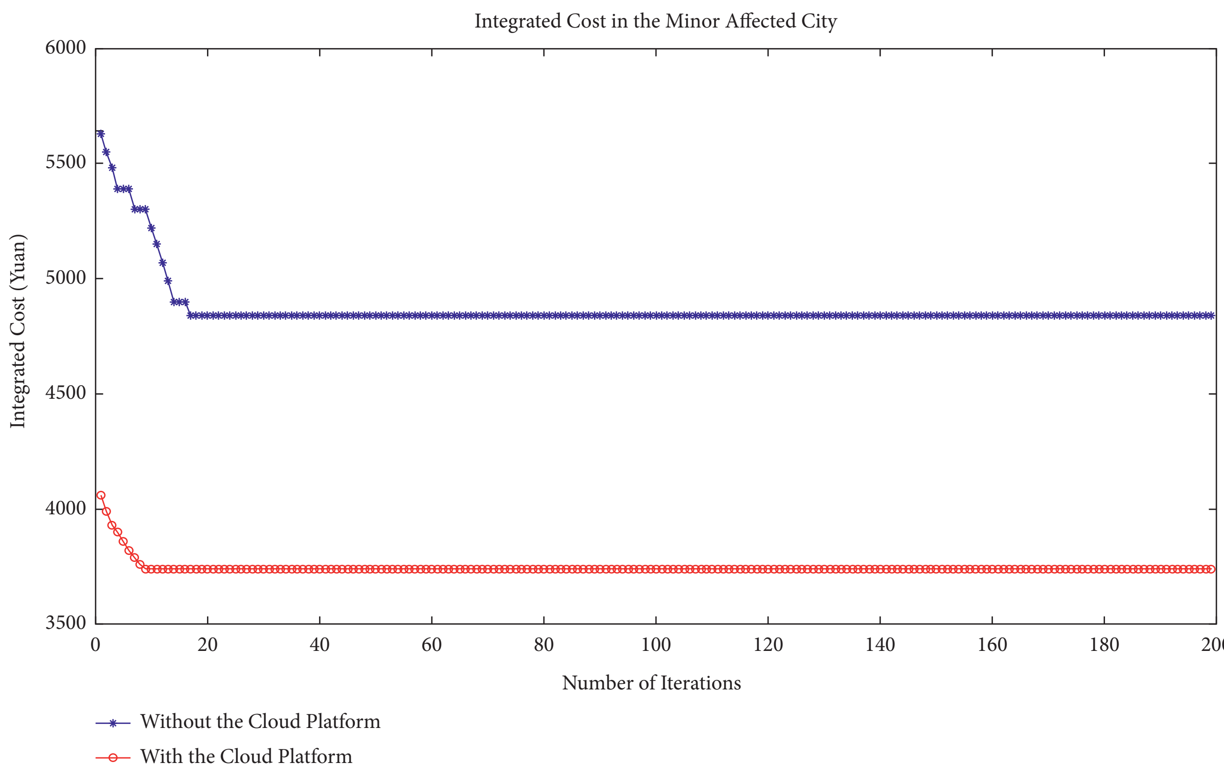

Figure 10: Integrated cost in the minor affected city.

Table 13: The distribution path of emergency supplies in the minor affected city.

Without the cloud platform			With the cloud platform		
Supplier	Demand point	Distribution path	Supplier	Demand point	Distribution path
1	1	1⟶1⟶1 (4)	1	1	1⟶1
3	1	3⟶1⟶1 (1)	2	1	2⟶1
1	2	1⟶1⟶2 (2)	2	2	2⟶2
2	2	2⟶2⟶2 (2)	3	2	3⟶2

Table 14: Sensitivity analysis of emergency logistics supplies distribution.

	Symbol	Value	Seriously affected city		General affected city		Minor affected city	
			Cost (yuan)	Degree of change	Cost (yuan)	Degree of change	Cost (yuan)	Degree of change
Without the cloud platform	c_{ijkn}	3.5	16,165	−23.13%	8135	−30.29%	3370	−30.37%
		7	21,030	—	11,670	—	4840	—
		14	30,760	+46.27%	18,740	+60.58%	7780	+60.74%
	C_l	50	15,830	−24.73%	9670	−17.14%	4040	−16.53%
		100	21,030	—	11,670	—	4840	—
		200	31,430	+49.45%	15,670	+34.28%	6440	+33.06%
With the cloud platform	c_{ijkn}	3.5	10,065	−32.59%	5535	−38.97%	2270	−39.30%
		7	14,930	—	9070	—	3740	—
		14	24,660	+65.17%	16,140	+77.95%	6680	+78.61%
	C_l	50	12,330	−17.41%	8070	−11.03%	3340	−10.70%
		100	14,930	—	9070	—	3740	—
		200	20,130	+34.83%	11,070	+22.05%	4540	+21.39%

5. Conclusion and Future Works

The logistics industry plays a vital role in the distribution of emergency supplies. In this paper, we devised a cloud platform for emergency supplies distribution. By establishing an urban emergency supplies distribution path optimization model, our proposed platform optimizes the supplies distribution routes in the epidemic and reduces emergency logistics costs and time.

Although this research has optimized the distribution mode and costs of emergency supplies based on cloud platforms in the epidemic, the results of this research can be extended in the following directions:

(1) Further investigation of multiobjective optimization to achieve the optimal cost and the shortest time for the emergency supplies distribution based on the cloud platform.

(2) Considering the situation of reverse logistics in emergency logistics and optimizing the emergency supplies distribution model from a general perspective.

(3) Considering cross-regional/countries distribution of emergency supplies based on a cloud platform.

(4) At present, there are not many academic studies on the accuracy of cloud platforms supplies distribution [46–48]. In the future, new experimental results will be combined to prove the accuracy and effectiveness of the cloud platform.

Data Availability

The data that support the findings of this study are available from the correspondence author (wang112111@163.com) upon reasonable request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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Research Article

Role of Technology in Sustainable Gambling: Policy Effects of Electronic Card System and Limit Setting

Junhwi Park[1], **SeongRak Choi**[2], **Dohyeong Kim**[3], **Denise Boots**[3], **and Chang Kil Lee**[4]

[1]*Crime Prevention and Treatment Research Division, Korean Institute of Criminology and Justice, Seoul 6764, Republic of Korea*
[2]*Department of Business Management, Dongyang Mirae University, Seoul 8221, Republic of Korea*
[3]*School of Economic, Policy and Policy Sciences, University of Texas at Dallas, Richardson, TX 75080, USA*
[4]*Department of Urban Policy and Administration, Incheon National University, Incheon 220212, Republic of Korea*

Correspondence should be addressed to Chang Kil Lee; leechangkil@yahoo.com

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With the rapid expansion of the gambling industry in Asian markets over the past decade, South Korea has implemented policies seeking to expand entertainment gambling while simultaneously seeking to reduce possible harms from problem gambling. In 2016, the mandatory electronic players' card (EPC) system was adopted into specific Korean horse and cycling venues to discourage problem gambling behaviors since it prohibits large bets, while permitting other venues to autonomously operate EPC systems. This study compares preliminary data from mandatory versus autonomous venues to explore how EPC systems impact gambling behaviors, revenues, and policies. Overall, electronic cards were more widely adopted in mandatory venues for horse betting and in autonomous venues for cycling betting. Analyses indicate that larger bets were placed at both horse- and cycle-betting venues with autonomous card registration versus mandatory venues. While the EPC system mitigated problem gambling behaviors in horse betting, this impact was not observed for cycle betting. Such differences indicate that users across different types of sport betting exhibit somewhat distinct characteristics and behaviors in using electronic cards, which could shed light on the sustainable gambling strategy of adopting technology-driven EPC systems in sport betting not only in South Korea but also elsewhere around the world.

1. Introduction

There has been a rapid expansion of the transnational casino industry into Asian markets over the past decade [1]. Asia has become the most dominant regional market shaping the gambling industry, with a compounded expansion rate of roughly 20 percent between 2011 and 2015 and a global market share estimated at roughly 45% by 2015 [2, 3]. Forecasts regarding the Asian Pacific region continue to point to growth and expansion in the region, with Macau, Australia, and Singapore leading as the top three gambling destinations, respectively [2]. An exception to the explosive Asian growth model comes when looking at South Korea; while an established gambling economy, competition from Macau and Japan has been projected to negatively impact gambling revenues in Korea, leaving this nation with flat or slightly lower revenues when compared to other Asian countries [2]. At the same time, the increasing middle class of Mainland China and change in attitudes toward gambling have resulted in competitive markets rising across Asia to attract tax dollars and revenues, with Korea seeking to attract its share of casino tourism revenues with the adoption of more liberalized legalized gambling policies [4].

Toward this end, and in keeping with worldwide trends expanding gaming in Asian markets, Korea has implemented gradual regulations since the late 2000s by executing a multistep plan by the Korean National Gambling Control Commission (hereinafter the "NGCC"). These initiatives, collectively known as the National Master Plan, represent a public policy response under a responsible gaming framework which seeks to expand entertainment gambling while simultaneously addressing possible harms to individuals, families, and communities that come from excessive and irresponsible gambling [5]. At the same time, these policies reflect the Korean government's efforts to positively reshape and shift attitudes toward legalized gambling from one perceived as a "vice" to one that perpetuates the "entertainment" and "fun" of recreational gambling [6]. This dramatic shift in Korean government policies that seek to reframe gambling as a procommunity and recreational activity reflects the more proliberalization Reno Model emulated by other countries such as Singapore, the United States, Australia, and Macau [7, 8].

In 2010, the first stage of the National Master Plan piloted electronic players' card (EPC) systems which was supposed to launch a small number of gambling venues across horse, bicycle, and motorboat racing, casinos, and sports betting sites (e.g., Sports Toto) [9]. Very few individual gamblers actually opted into the card program, and the NGCC reported serious inconveniences for those individuals who tried to use the system. In July of 2012, the NGCC launched a second pilot program after considering feedback from industry stakeholders and experts, with 10% of all horse- and cycling-racing venues implementing one of two options: (1) venues completely banning cash bets and (2) venues allowing a certain amount of maximum bet. The second National Master Plan began in 2014 with the goal of increasing the ratio of electronic card users and bets made from the cards.

The introduction of the EPC system in Korea was proposed as a policy to address the social negative side effects of the gambling industry [5]. In addition, it was argued that adopting this system would enhance the integrity and transparency of gambling activities as a form of recreation and fun while helping to curb the potential for gambling addictions to form or be furthered at these betting sites [10]. In theory, the introduction of electronic cards discourages problem gambling behaviors because they prohibit an individual from betting over KRW 100,000 in a single game (with an estimated conversion rate of roughly $1 USD = 1100 KRW). If players are required to bet only by using the electronic card, it is possible to cap a single bet at an amount below KRW 100,000. This adoption of EPC system fundamentally bars any single bet to exceed KRW 100,000 and, hence, it is deemed to improve the efficacy of the regulation on betting amounts and, further, have the benefit of reducing gambling addiction. However, in reality, it is possible to exceed the maximum bet amount by using the EPC for one maximum bet and then placing cash bets for the same race at any venue that allows cash transactions. At casinos, patrons similarly may place two or more bets simultaneously in machines or at tables at the KRW 100,000 maximum amount, thereby bypassing EPC restrictions.

However, significant controversies exist in the empirical literature regarding the impact of the electronic card system on gambling addiction effects and the negative effects derived from the introduction of the electronic card system. If electronic card system is implemented, the revenue would greatly decline, which would harm the business foundation of legal gaming industry and may lead to the decrease in tax revenue [11]. Moreover, the adoption of EPC systems would decrease the privacy of users and further encourage illegal betting due to the maximum caps that players were limited to [12], thereby increasing the side effects such as gambling addiction [13]. Due to such opposing opinions, the NGCC has been continuously delaying the full adoption of the electronic card system in Korea. While relatively more studies have been evaluated on the economic impacts of EPC systems [14] or focused on other types of gambling in Korea, such as casinos [15] and arcade games [16], it appears that there is a lack of support in the literature for the aim of the EPC systems to prevent gambling addiction or enhance customer convenience versus if no EPC system was adopted, for the case of betting on horse and cycle races.

In February of 2016, the Korean government adopted the mandatory use of electronic card into select horse and cycle venues. Hence, while some venues were required to use electronic cards for horse-racing and cycling businesses, others were provided with autonomy—rather than obligation—of choosing to adopt EPC systems. Introducing a mandatory system in specific horsing and bicycling venues while permitting other venues to autonomously operate their businesses with an option of EPC systems in Korea offers researchers an ideal opportunity to explore how EPC systems impact gambling behavior, revenues, and responsible gambling policies. With such selective adoption practices, the Korean government created a natural experiment whereby the policy effects of mandatory adoption of electronic cards can be compared to venues granted the autonomous adoption of electronic cards.

Thus, we aim to evaluate the impacts of the EPC system adopted in specific Korean horse- and bicycling-racing venues on gambling behavior, revenue, and responsible gambling policies. We used the data collected in the project conducted by the authors in 2016 [17] which examined the policy effects of mandatory versus autonomous electronic card systems by comparing measures across horse- and bicycling-racing venues that were required to adopt electronic cards versus other horsing and bicycling venues where adoption of electronic cards was not mandated. The following are the major contributions of this paper:

(i) This paper contributes to the gambling study literature by utilizing government data from the National Gambling Control Commission (NGCC) of Korea as it rolled out an EPC system as both autonomous (voluntary registration) and mandatory (all players must use cards) across select legal horse- and cycle-racing venues

(ii) It is the first study, to our knowledge, to offer an exploratory analysis of empirical data on EPC system from Korea, which highlights the role of technology in sustainable gambling

(iii) It offers a valuable first look into the impact of this launch of selective EPC systems whereby the policy effects of mandatory adoption of electronic cards can be compared to venues granted the autonomous adoption of electronic cards

The rest of the paper is organized as follows. Section 2 describes the data and methodology of the current study, and Section 3 presents the results on the impact of mandatory and voluntary adoption of EPC systems on gambling outcomes in horse- and cycle-betting venues, respectively. Section 4 discusses the implication of the findings and Section 5 concludes the results of this study.

2. Materials and Methods

We aim to make a comparative evaluation on whether there is any difference in gambling behavior and outcomes between mandatory and autonomous policies of operating electronic card system in horse-racing and cycle-racing businesses in South Korea. Mandatory-type venues require the use of electronic cards only when betting at least KRW 50,000 (USD 45 based on a conversion rate of $1 USD = 1110 KRW), while autonomous-type venues permit bets to be placed in cash or through electronic cards in all bet amount ranges. The key variables to be compared between mandatory-type versus autonomous-type venues include the following: (1) average purchase amount per ticket issued, (2) average purchase amount per person, (3) total number of tickets issued per person, and (4) the proportion of tickets in each betting range among the total number of tickets issued.

The data were collected from nine gambling venues (six horse-racing and three cycle-racing) for 20 weeks between February and June 2016. During this period, NGCC designated three horse-racing venues (Incheon, Jung-Gu; Daegu; and Changwon) and one cycle-racing venue (Gunpo) as mandatory and three horse-racing venues (Incheon, Nam-Gu; Seoul; and Busan) and two cycle-racing venues (Cheonan and Uijeongbu) as autonomous. All venues were comparable in terms of total revenue, total number of customers, and tickets issued. More details of the data can be found in the final project report submitted to National Gambling Control Commission by the authors (2016).

3. Results

3.1. Horse Betting. Table 1 summarizes the results of the comparison between mandatory-type venues and autonomous-type venues for horse-betting data in terms of the proportion of cash versus electronic cards among the total number of tickets issued and the total revenue, the average purchase amount per ticket issued and per person, and the proportion of each betting range among the total number of tickets issued.

As shown in Table 1, for both mandatory and autonomous types, cash purchases contributed over 86% of the tickets issued and revenue, but electronic card usage seemed slightly more active in mandatory-type venues than in autonomous-type venues (13.2% versus 10.6% for the number of tickets and 11.3% versus 9.5% for total revenue), with marginal significance ($p < 0.1$). Average betting amount per ticket and per person by cash was statistically significantly higher in autonomous-type venues than in mandatory-type venues (KRW 14,307 versus KRW 12,597 for per ticket betting; KRW 546,038 versus KRW 479,493 for per person betting), but average amount of betting per person by electronic card was statistically indifferent between the two types of venues. The gap in per ticket average betting between cash and electronic card purchases was larger in mandatory-type venues (KRW 1,731 for mandatory versus KRW 1,172 for autonomous), while autonomous-type venues had a larger gap in per person average betting between cash and electronic card purchases (KRW 418,209 for mandatory versus KRW 489,150 for autonomous). In addition, there was no statistical difference in the average number of tickets issued per person between autonomous-type and mandatory-type venues, purchased by either cash or electronic card. Interestingly, only less than 2% of the tickets purchased via electronic cards were priced over KRW 50,000 in mandatory-type venues even if there was no betting limit, while almost 3% of the tickets purchased using electronic cards were priced over KRW 50,000 in autonomous-type venues. Of course, cash betting over that amount, which was only allowed in autonomous-type venues, took about 5% among all tickets purchased by cash.

Overall, as for horse betting, it seems apparent that electronic cards were relatively more used in mandatory-type venues where users betted less not only by electronic cards but also by cash. It is also found that high-price betting over KRW 50,000 occurred more frequently in autonomous-type tenders, particularly when purchased by cash. Despite the fact that the average numbers of tickets issued for each customer were similar in both mandatory-type venues and autonomous-type venues, customers tended to spend more in autonomous-type venues where cash betting was entirely flexible.

3.2. Cycle Betting. Likewise, Table 2 summarizes the results of the comparison between mandatory-type venues and autonomous-type venues for cycle-betting data in terms of the proportion of cash versus electronic cards among the total number of tickets issued and the total revenue, the average purchase amount per ticket issued and per person, and the proportion of each betting range among the total number of tickets issued.

Unlike the horse-betting case, for cycle betting, electronic card usage was significantly more active in autonomous-type venues than in mandatory-type venues (26.3% versus 12.6% for the number of tickets and 12.1% versus 8.4% for total revenue; $p < 0.01$), although cash purchases were dominant as well (73–92%). Similar to the horse-betting case, the average betting amount per ticket and per person by cash was statistically significantly higher in autonomous-type venues than in mandatory-type venues (KRW 30,436 versus KRW 21,594 for per ticket betting; KRW 372,065 versus KRW 278,532 for per person betting), but the opposite was true for the average per ticket betting amount by electronic card (KRW 13,653 for mandatory versus KRW 11,675 for autonomous). Thus, the gap in per ticket or per person average betting between cash and

Table 1: Comparison between mandatory-type and autonomous-type venues in horse betting.

Category			Types		Analysis of difference	
			Mandatory	Autonomous	t-value	Significance level
% of cash/cards among total number of tickets issued		Cash	86.85	89.40	1.508	0.070
		Electronic cards	13.15	10.60	−1.508	
% of cash/cards among total revenue		Cash	88.66	90.54	1.663	0.053
		Electronic cards	11.34	9.46	−1.663	
Avg. betting per ticket issued (KRW)		Cash	12,597	14,307	11.550	0.000
		Electronic cards	10,866	13,135	6.138	0.000
Avg. betting per person (KRW)		Cash	479,493	546,038	7.050	0.000
		Electronic cards	61,284	56,888	−0.697	0.245
Avg. number of tickets issued per person		Cash	38.08	38.19	0.150	0.441
		Electronic cards	5.79	4.55	−1.616	0.057
% of each betting range among total number of tickets issued	Cash	≤ KRW 30,000	90.26	90.16	−0.492	0.313
		> KRW 30,000 ≤ KRW 50,000	9.74	4.70	−27.014	0.000
		> KRW 50,000 ≤ KRW 70,000	0.00	1.26	97.404	0.000
		> KRW 70,000	0.00	3.88	56.254	0.000
	Electronic cards	≤ KRW 30,000	94.82	92.80	−5.404	0.000
		> KRW 30,000 ≤ KRW 50,000	3.47	4.42	4.222	0.000
		> KRW 50,000 ≤ KRW 70,000	0.76	1.27	8.825	0.000
		> KRW 70,000	0.95	1.51	5.233	0.000

electronic card purchases was much larger in autonomous-type venues: KRW 18,761 (autonomous) versus KRW 7,941 (mandatory) for per ticket average betting and KRW 320,466 (autonomous) versus 253,044 (mandatory) for per person average betting. The average number of tickets issued per person was statistically different between autonomous-type and mandatory-type venues for both cash and electronic card purchases. Contrary to the horse-betting case, 4.28% of the tickets purchased via electronic cards were priced over KRW 50,000 in mandatory-type venues, while 2.67% of the tickets purchased using electronic cards were priced over KRW 50,000 in autonomous-type venues. Cash betting over that amount, which was only allowed in autonomous-type venues, took almost 20% among all tickets purchased by cash, which is a lot larger compared to only 5% in the horse-betting case.

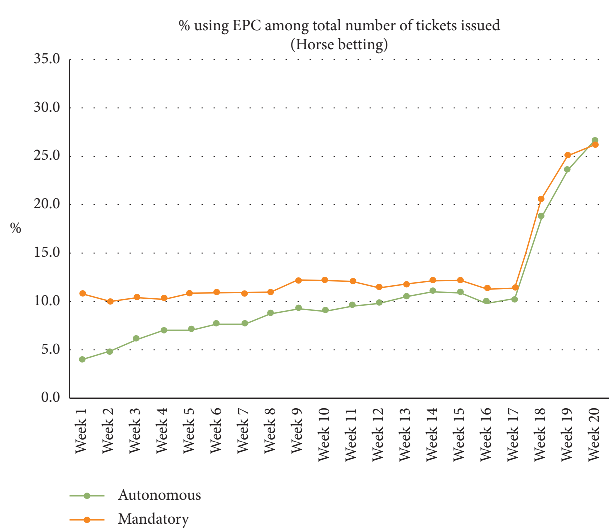
The most noticeable difference for cycle betting in comparison to horse betting is that EPCs were more frequently used in autonomous-type venues, although high-price betting over KRW 50,000 was still prevalent among cash purchases. In addition, compared to autonomous-type venues, a larger number of tickets were issued per person on average when paid by cash, but fewer tickets were issued among card purchases in mandatory-type venues. However, it seems also true for cycle betting that customers tend to spend more in autonomous-type venues, particularly by cash, since no limit was placed on cash betting.

3.3. Weekly Patterns of EPC Usage and Average Betting Amount. Figure 1 shows the weekly trends of EPC usage rate for 20 weeks comparing autonomous-type and mandatory-type venues since the introduction of a mandatory system in specific horsing and bicycling venues in 2016. Interestingly, the EPC usage rate is higher in mandatory-type venues for horse betting, while it is substantially higher in autonomous-type venues for cycle betting throughout the period. Except for the last few weeks, about 10–15% of tickets in mandatory-type venues for both horse and cycle betting were issued as EPC throughout the period, but a substantial difference was found for EPC use in autonomous-type venues between horse betting (5–10%) and cycle betting (20–30%). Such difference implies that EPC adoption is highly dependent upon how each gambling industry promotes the use of EPC, such as marketing, promotion, and advertisement, particularly for autonomous-type venues. It is also noticeable that, in horse-betting sites, the EPC use in autonomous-type venues was lower initially but continuously caught up with that in mandatory-type venues. Both autonomous-type and mandatory-type venues for horse-race betting induced a massive addition of EPC users after the 17th week, due to industry-wide campaigns.

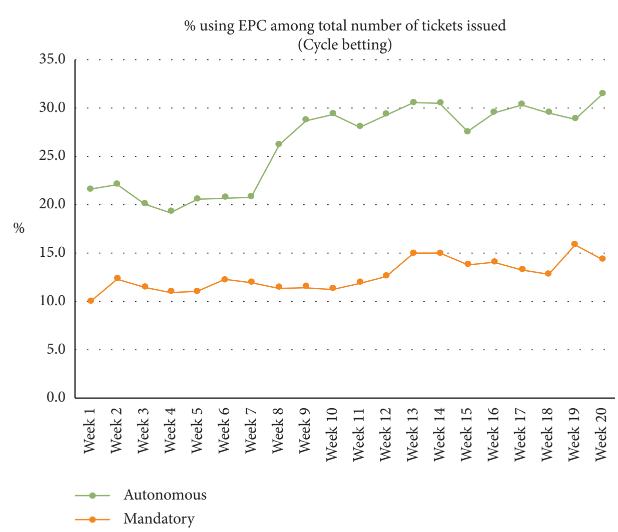
Figure 2 shows whether or not each horse betting gambler's betting pattern has changed over time during the 20-week period in autonomous-type and mandatory-type venues. It appears that the change in their betting

Table 2: Comparison between mandatory-type and autonomous-type venues in cycle betting.

Category			Types: Mandatory	Types: Autonomous	Analysis of difference: t-value	Analysis of difference: Significance level
% of cash/cards among total number of tickets issued		Cash	87.39	73.74	−13.191	0.000
		Electronic cards	12.61	26.26	13.191	0.000
% of cash/cards among total revenue		Cash	91.65	87.88	−5.879	0.000
		Electronic cards	8.35	12.12	5.879	0.000
Avg. betting per ticket issued (KRW)		Cash	21,594	30,436	32.021	0.000
		Electronic cards	13,653	11,675	−5.143	0.000
Avg. betting per person (KRW)		Cash	278,532	372,065	10.898	0.000
		Electronic cards	25,488	51,599	8.769	0.000
Avg. number of tickets issued per person		Cash	12.89	12.23	−2.140	0.019
		Electronic cards	1.86	4.41	10.796	0.000
% of each betting range among total number of tickets issued	Cash	≤ KRW 30,000	72.92	68.04	−6.916	0.000
		> KRW 30,000 ≤ KRW 50,000	27.08	12.27	−23.220	0.000
		> KRW 50,000 ≤ KRW 70,000	0.00	3.41	59.064	0.000
		> KRW 70,000	0.00	16.28	64.451	0.000
	Electronic cards	≤ KRW 30,000	90.83	91.89	1.954	0.029
		> KRW 30,000 ≤ KRW 50,000	4.89	5.44	1.570	0.063
		> KRW 50,000 ≤ KRW 70,000	1.05	0.92	−2.302	0.014
		> KRW 70,000	3.23	1.75	-4.489	0.000



(a)



(b)

Figure 1: Weekly trends of EPC usage rate (autonomous-type versus mandatory-type venues): (a) horse betting; (b) cycle betting.

preferences (cash versus EPC betting) was minimal during the first few months, except that the betting amount by EPC systems continued to increase in autonomous-type venues. However, the cash betting amount significantly dropped after around the 17th week, mostly due to the dramatic increase of the betting amount by EPC. Considering that cash purchases consist of 85–90% of the total tickets issued in both types of venues, a significant reduction effect of the average betting amount per person began to be conspicuous after 3-4 months of implementing the EPC system, in both

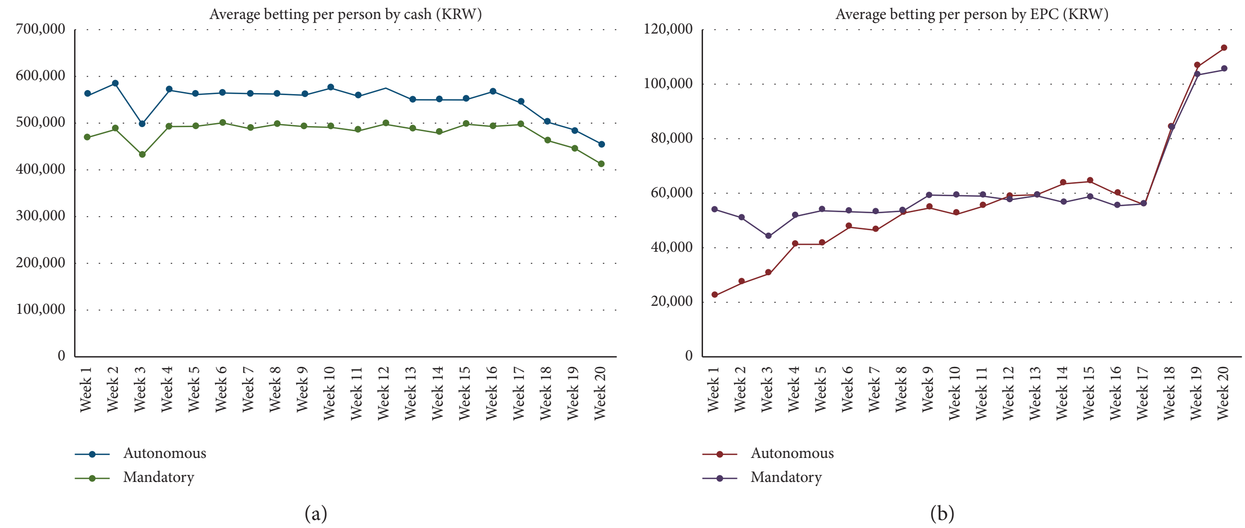


Figure 2: Weekly trends of average betting amount per person in horse betting (cash versus EPC; autonomous-type versus mandatory-type venues): (a) cash betting; (b) EPC betting.

autonomous-type and mandatory-type venues. The findings imply that the potential role of EPC in mitigating problematic gambling behaviors could be marginal in the beginning but could be eventually sizable even in autonomous settings, if the EPC system is constantly and effectively promoted and marketed. However, these temporal patterns were not observed for the cycle-betting data, which may indicate some unique difference in gambling behaviors or EPC operations in the horse- and cycle-betting industry in South Korea.

4. Discussion

This study evaluated the impacts of the electronic players' card (EPC) system adopted in specific Korean horse- and bicycling-racing venues on gambling behavior, revenue, and responsible gambling (RG) policies by comparing the venues with the mandatory versus autonomous adoption of electronic cards. To our knowledge, the present article is the first to examine preliminary data available from the NGCC which include various outcomes of EPC systems in Korea. While RG principles would suggest that EPC systems might discourage problem gambling behaviors regardless of venue type, the findings from this study reveal significant differences between the two types of sports betting. As expected, we found that electronic cards were more widely adopted not only in mandatory-type venues for horse betting but also quite unexpectedly in autonomous-type venues for cycle betting. Such conflicting results might imply that the adoption rate of EPC systems depends on the level of marketing or promotion efforts across the venues rather than the types of EPC systems (mandatory versus autonomous) or sport betting game (horse versus cycle betting).

For both horse betting and cycle betting, it is found that that larger bets were more frequently placed at venues with autonomous card registration compared to mandatory-type venues, mostly due to high-priced cash purchases. The average number of tickets and betting amount per person using EPCs were higher in mandatory-type venues for horse betting than in autonomous-type venues for cycle betting. During the 20-week study period, the EPC use in autonomous venues was lower initially but gradually caught up with that in mandatory-type venues for horse betting, while the EPC use was always higher in autonomous-type venues for cycle betting. Similar to other literatures which suggest that bet limits can have a positive influence on problem gambling behaviors (see Auer et al., 2020), the current results suggest that the continuing operation of EPC system in horse betting may have some positive influence on alleviating problem gambling even on a voluntary basis in autonomous settings. Yet this impact was not observed for cycle betting. Such differences indicate that users across these different types of sports betting exhibit distinct characteristics or gambling behavior in using electronic cards.

There are intriguing policy considerations for the NGCC and the gambling industry in Korea to consider with the implementation of EPC systems across various gambling venue types. For example, some research has shown that, in some countries such as Australia, "overall, it appears that playing with an account card or ticket assists players to gamble more responsibly compared to players using cash" ([18], p. 232). This study may also inform public health professionals and policymakers regarding the potential role of EPC in mitigating negative gambling behaviors, which may contribute to positive policies that reduce the social and economic costs of problem gambling addiction in Korea. Korea's National Master Plan is an ambitious one that is being presented as a blueprint for responsible gaming policies [5]. Yet, this plan has been slower to be adopted than originally designed by the NGCC and has received a significant amount of critique from the Korean gambling industry regarding mandatory enrolment and implementation [9]; this opposition is similar to that derision seen in other areas of the world where cashless payment technologies have been adopted and more industry responsibility has been endorsed (see Nisbett, Jackson, and Christensen, 2016).

Despite the contribution of this study to the literature, several limitations should be noted. First of all, while the study findings show anecdotal evidence to explain differences between the two types of sports betting and the two types of EPC operation (mandatory versus autonomous) observed here, these data do not allow for more advanced statistical testing and modelling. Ideally, more data will be collected, which will allow for control and statistical significance to be tested in regression models. Second, the reduction effect of average betting amounts on EPC use may not be directly related to a decline in problem gambling behavior; this finding could be only a temporary adjustment phenomenon. Lastly, an additional limitation is the small sample size of the data from a total of nine gambling venues collected over 20 weeks, which clearly limits the statistical inferences that can be drawn and the overall generalizability. Accessing additional data from Korea, which allows for more statistically advanced analyses across longer data periods, is a natural next step to determine if the results reported here are consistent beyond the preliminary snapshots currently available. Although future studies should focus on overcoming the present study's limitations, the unique contribution of the current article is that it allows an initial look at the impact of implementing mandatory EPC operations on sites with a naturally occurring experimental design. As such, the results of this pilot study can be used as a foundation for more nuanced discussions regarding the expansions of designing and operating the EPC system as well as the long-term implications of such policies.

5. Conclusions

As Asia continues to dominate the largest gambling market in the world [2], liberal-leaning gambling jurisdictions simultaneously struggle with rebranding the gambling enterprise in the public eye from one of a banned, sinful activity to one that embraces the community and accepts gambling as a harmless, fun entertainment. The incentives to legitimize gambling are considerable, as revenues from tourism and gambling are economically significant. As Korea appears to be adopting a more expansive policy for gambling similar to Macau and Australian Reno/liberal risk model [1], common social perceptions regarding mainstream acceptance, the founding and integration of community-based gambling facilities, and deeply ingrained cultural issues regarding gambling fallacies within Korean and Asian culture are some of the critical topics that must be addressed to ensure responsible gaming practices. Per "responsive regulation" ideals perpetuated in more liberalized/individual risk localities, the mandatory versus autonomous adoption of EPC systems could be viewed as a collaborative relationship between government regulators and the gambling industry in cooperation with community stakeholders [8]. On the other hand, the adoption of more public health focused approaches, such as requiring players to enrol and register cards with betting limits, could also be viewed as an effort toward reducing gambling-related harm, which is more consistent with the public health consumer protection-oriented regulatory scheme [1, 19, 20].

Public health perspectives that inform policy and practice present opportunities for increased consideration and evaluation of the overall well-being of populations impacted by prevention, promotion, and protections that minimize harm [21]. It also emphasizes that responsible gambling could focus on the individual as well as the community with a more holistic view [22]. Toward that end, recent public health focused research suggests that gambling harm is not limited to problem gamblers with clinical levels of addiction but that at-risk gamblers account for a substantial and major proportion of all negative gambling outcomes incurred [23]. Moreover, some scholars argue that a shift toward self-regulation of the gambling industry forces to a public health consumer protection model is ideal for responsible gambling, since it embraces the operator duties to limit harms, endorsing practices such as mandatory precommitment limits and fees imposed on locals who gamble [24]. Without question, such conceptual issues point to the importance of further studying Korea's natural experiments with EPC systems and considering how these mandatory versus voluntary adoptions of EPC systems impact policies, practices, and procedures. It remains to be seen as to what the dominant model will become in Korea. Such considerations are central to reducing harms and ensuring consumer protection while balancing the interests of industry and government ventures.

Questions remain regarding whether the findings of this study would hold up across time, with larger sample sizes, or across gambling venues. Further qualitative inquiries that delve into the thoughts and feelings of Korean gamblers as they adopted EPCs that limit bets would be helpful in better understanding decision-making and the impact of RG tools to support healthy gambling habits. Future studies might seek a mixed-methods approach that would allow for such analyses. While empirical literature has suggested that bet limits (voluntary and mandatory) have beneficial results as part of RG strategies to control problem gambling behaviors in other parts of the world (e.g., Auer and Griffiths, 2021), the data in the present study do not allow for a comprehensive analysis. Are there cultural differences in attitudes toward RG tools and implementation across varying gambling venues? These issues are the ones to pursue in future research as well.

Data Availability

The data that support the findings of this study are available from the first author (krpark@kic.re.kr) upon reasonable request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Acknowledgments

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