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# Implementation of AI-Based Chemical Dispersion Prediction and Safety Management Information System

Jin-Kwon KIM<sup>1</sup>

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## Abstract

**Purpose:** This study proposes an implementation framework for an intelligent safety management information system that integrates public big data and AI to preemptively respond to hazardous chemical leakage accidents in industrial complexes. The research aims to bridge the gap between technical analytics and managerial practice, establishing a new paradigm for intelligent disaster management within the framework of sustainable corporate governance. **Research design, data and methodology:** The research design utilizes public APIs from the Korea Meteorological Administration to collect multivariate time-series data. The methodology employs the Long Short-Term Memory (LSTM) algorithm to predict dynamic pollutant dispersion paths. A key methodological distinction lies in the standardization of complex predictive data into a unified 'Environmental Risk Index (ERI)' and the automation of real-time response processes through user-centered UI/UX design. **Results:** The findings demonstrate that the proposed system provides management with objective, data-driven evidence for high-stakes decision-making through risk quantification. Furthermore, it offers a cost-effective ESG management model for small and medium-sized enterprises (SMEs) by leveraging public data infrastructure instead of costly proprietary sensors, proving its practical efficiency in resource-limited environments. **Conclusions:** This system functions as a strategic information asset that significantly enhances organizational resilience and ensures industrial site safety. The study concludes that the integration of AI-driven predictive models into managerial information systems is essential for proactive risk control and sustainable corporate governance, providing a robust strategic mechanism for modern industrial safety.

**Keywords :** Environmental Risk Index (ERI), Decision Support System, ESG Management

**JEL Classification Code :** C45, D81, M15, Q56

## 1. Introduction

Hazardous chemical spill accidents at industrial sites lead to more than just human casualties; they result in the erosion of corporate brand value, substantial legal penalties, and a loss of community trust. Hanna & Britter. (2002) emphasized the importance of dispersion modeling, which serves as a core tool for quantifying non-financial risks from a management perspective. Particularly, accidents in

national industrial complexes can disrupt entire supply chains; therefore, real-time monitoring frameworks proposed by Kim et al. (2021) are essential for establishing Business Continuity Planning (BCP).

The introduction of AI technology is shifting the paradigm of managerial decision-making from reactive to proactive. The predictive power of deep learning, when integrated with real-time field data, empowers decision-makers to optimize the allocation of safety management resources while minimizing

<sup>1</sup> First Author Adjunct professor, Department of Business Management, Tech University of Korea. Korea. Email: [kjk66kr@tukorea.ac.kr](mailto:kjk66kr@tukorea.ac.kr).

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operational uncertainties. (Zheng et al, 2015; Cha & Kang, 2018)

For such technical achievements to translate into corporate value, the role of Decision Support Systems (DSS) is paramount. When integrated with user-centered design, these systems function as intelligent management information systems that facilitate rapid managerial judgment during crises and mitigate broader social costs. (Turban et al, 2011; Kim et al, 2022).

This study aims to propose a plan for implementing an information system that integrates engineering prediction technology into a managerial risk management framework.

## 2. Literature Review

### 2.1. Characteristics of Chemical Dispersion and Modeling

The atmospheric dispersion of hazardous chemicals leaked from industrial sites involves a complex mechanism determined by the physicochemical properties of the pollutant source and surrounding meteorological conditions. Gases or particulate matter released into the atmosphere undergo dilution and dispersion through processes of turbulence and advection. (Hanna & Britter, 2002).

Wind direction determines the movement path of the substance, while wind speed directly affects the dilution rate and arrival time. Furthermore, atmospheric stability serves as a critical variable regulating the intensity of vertical dispersion.

Deterministic models such as the Gaussian Plume Model or ALOHA have been predominantly used for chemical accident response. However, these models have limitations in reflecting terrain complexity or abrupt meteorological changes in real-time and tend to exhibit increased uncertainty in output values even with minor errors in input data. (Hanna & Britter, 2002). The structural density of national industrial complexes complicates the accurate forecasting of pollutant paths due to aerodynamic wake effects and micro-scale wind field fluctuations. This necessitates the adoption of advanced data-driven models that can synchronize with real-time IoT sensors to capture and predict evolving dispersion dynamics.

### 2.2. Environmental Big Data and IoT Monitoring Framework

With the advancement of Information and Communication Technology (ICT), environmental pollution management has evolved from a past reactive approach to a

real-time preventive framework that integrates IoT sensor networks with public big data.

IoT-based integrated safety management systems monitor industrial sites through AI-enhanced CCTV and provide workers and managers with real-time access to multivariate sensor data. This integration drastically improves initial response speeds to accidents and facilitates the proactive prevention of industrial safety incidents. IoT-based monitoring holds significant value as a data source for identifying localized meteorological conditions and subtle changes in chemical substances in real-time.

Public environmental datasets serve as a critical instrument for addressing the surveillance limitations of private business sites. National air pollution monitoring network data offers superior credibility; thus, incorporating this information into big data analytics is imperative for a comprehensive assessment of regional environmental risks. (Lee et al., 2022)

The time-series data collected via public APIs serves as a fundamental training dataset for AI models to learn past pollution patterns and predict future risks. Therefore, to implement an efficient safety management information system, it is imperative to design a data governance framework that organically integrates and analyzes individual on-site IoT data with public environmental big data.

### 2.3. Deep Learning-Based Time-Series Forecasting: LSTM

The perspective of Management Information Systems (MIS), predictive models function as strategic assets for optimizing organizational resource allocation and risk management. The analytical superiority of deep learning technologies in a big data environment can significantly enhance the quality of decision-making in both corporate and public sectors. (Zheng et al., 2015). Particularly for time-series data, such as chemical emission levels and meteorological conditions that fluctuate over time, it is crucial to precisely analyze the influence of past patterns on future risks.

While traditional statistical models have limitations in capturing non-linearity and long-term correlations in data, the Long Short-Term Memory (LSTM) network adopted in this study enables the learning of long-term dependencies by resolving the vanishing gradient problem, a critical drawback of conventional RNNs. (Park et al, 2021).

This allows the information system to move beyond simple monitoring of current states to preemptively predicting uncertain future environmental changes, thereby supporting managers in Evidence-based Decision Making.

The LSTM-based predictive model holds substantial academic and practical value as an intelligent decision-

support tool that maximizes the efficiency of safety management at industrial sites and minimizes economic losses and social costs caused by disasters.

## 2.4. DMIS and Decision Support

Disaster Management Information Systems (DMIS) serve as pivotal tools that integrate vast amounts of data generated throughout the disaster lifecycle to provide meaningful insights to managers. Information systems function as Decision Support Systems (DSS) integrated with analytical models, rather than mere data repositories, they can offer optimal solutions in unstructured disaster scenarios. (Turban et al., 2011). Given that industrial chemical accidents are characterized by extreme time-criticality, enhancing the speed of information dissemination and readability through an intuitive User Interface (UI) serves as a decisive determinant of system success.

The value of a system is evidenced not only by its technical completeness but also by its practical utilization and performance within the organization. System quality and information quality significantly enhance user satisfaction, which ultimately translates into improved overall organizational performance. (DeLone & McLean., 2003).

The system proposed in this study also aims to secure the trust of decision-makers by providing high-quality predictive information through AI and to generate practical outcomes by reducing accident response costs. Consequently, an intelligent safety management information system serves as a strategic mechanism for fulfilling CSR and fostering a sustainable operational environment.

## 3. Research Methods and Materials

### 3.1. Research Framework and System Architecture

This study aims to implement an intelligent information system for responding to chemical accidents in industrial complexes by integrating public big data and deep learning algorithms. The system design is based on the standard architecture of Decision Support Systems (DSS) proposed by Turban et al. (2011) structured into a three-tier hierarchy: Data Acquisition, Preprocessing & Analysis, and Information Service Provision.

First, the Data Layer facilitates the real-time acquisition of atmospheric and chemical datasets via public APIs provided by national big data platforms. The objective is to secure the integrity of the system's input values by capitalizing on the superior credibility and temporal resolution of national observation networks. Second, the Analysis Layer trains an LSTM model based on the collected time-series data to predict pollutant dispersion

paths and calculate risk indices. Third, the Service Layer visualizes the analyzed information and transmits it to manager dashboards and worker alert systems.

This layered architecture focuses on automating data flows to minimize human error and ensure rapid decision-making during incident responses.

### 3.2. Data Collection and Preprocessing

To ensure the performance of the proposed system, a dataset is constructed by integrating verified air pollution data from the Automated Surface Observing System API from the Korea Meteorological Administration. The collected items include atmospheric concentrations of hazardous chemicals and key independent variables for dispersion: wind direction, wind speed, temperature, and humidity. Constructing a multivariate dataset that considers the correlation between meteorological variables and pollutants is essential for enhancing predictive precision in industrial complexes.

The collected data undergoes a preprocessing stage to eliminate outliers and missing values that impede analytical accuracy. Specifically, abnormal values caused by sensor errors are smoothed using the Moving Average Filtering technique suggested by Zhang et al. (2019), and Min-Max Normalization is performed to prevent distortion arising from scale differences between variables.

The Environmental Risk Index (ERI) proposed in this study is calculated through a weighted linear combination model that integrates physical pollutant concentrations with managerial and human impact variables. The mathematical formulation is as follows:

$$ERI = (C_n \cdot W_c) + (R_l \cdot W_r) + (P_h \cdot W_p)$$

where  $C_n$  represents the normalized pollutant concentration,  $R_l$  denotes the legal compliance risk, and  $P_h$  signifies the potential for human casualties. Each weight ( $W_c=0.4$ ,  $W_r=0.3$ ,  $W_p=0.3$ ) was determined through a Delphi survey involving 10 environmental safety experts, ensuring the objectivity and academic rigor of the index.

Reflecting the characteristics of time-series data, a Sliding Window technique is applied where data from the past N-hours predicts the subsequent 1-hour.

This systematic preprocessing follows the data quality management principles emphasized by Brownlee (2018) for optimizing machine learning model performance, thereby securing the analytical reliability of the system.

### 3.3. Implementation of Prediction Model and Risk

## Index Calculation

The LSTM architecture proposed by Hochreiter & Schmidhuber (1997) is adopted as the analytical engine to transform industrial uncertainties into manageable risks. From a MIS perspective, the LSTM model functions as a Proactive Risk Management tool that visualizes future crisis scenarios by extracting meaningful patterns from unstructured and vast environmental time-series data. By learning long-term dependencies, the model identifies substantial threat signals requiring organizational response, rather than being overwhelmed by short-term numerical fluctuations.

To support rapid managerial decision-making, the complex concentration data predicted by AI is standardized into an 'Environmental Risk Index (ERI).

Applying a risk assessment model within a management context, this index is calculated by integrating simple pollutant concentrations with weighted factors for legal compliance risks and potential human resource damages. This enables executives to make high-stakes decisions—such as emergency shutdowns or evacuation orders—based on objective evidence. Such quantification of risk realizes the practical value of analytics emphasized by Davenport (2014) and demonstrates that information technology is a strategic asset directly linked to organizational resilience.

### 3.4. System UI/UX Design and Service Process

The ultimate success of an intelligent information system transcends technical accuracy; it depends on how efficiently the provided information is delivered to users to trigger actual response actions. The system interface proposed in this study adheres to user-centered design principles, specifically engineered to minimize cognitive load during disaster scenarios.

The manager's dashboard integrates with Geographic Information Systems (GIS) to visualize AI-predicted pollutant dispersion ranges and applies a color-coded visual alerting system based on the calculated Environmental Risk Index (ERI), enabling decision-makers to instantly identify crisis levels.

The service process focuses on shortening the 'lead time' from accident detection to the issuance of response instructions. When a danger signal exceeding the threshold is identified by the AI analysis server, the system automatically transmits push notifications to the smart devices of workers in relevant processes, providing optimal evacuation routes and material-specific emergency response manuals (MSDS).

The efficacy of an intelligent information system is determined not only by its accuracy but also by its ability to catalyze user action through effective communication. Our

proposed interface applies user-centered design principles to minimize cognitive load in disaster situations, effectively bridging the gap between data provision and immediate response. (DeLone & McLean (2003). This UI/UX design functions as a strategic touchpoint that bridges the gap between technical analytical results and practical response actions in the management field.

## 4. Results

This study originated from the critical awareness that safety management in industrial complexes should no longer be confined to mere administrative procedures or reactive measures.

To validate the practical efficacy of the system, usability testing was conducted with a focus group of eight safety administrators from national industrial complexes. The empirical results demonstrated a 32% improvement in decision-making response time compared to traditional text-based reporting methods. Furthermore, the system achieved an average score of 4.4 on a 5-point Likert scale for visual legibility. These findings confirm that the intuitive UI/UX design effectively minimizes cognitive load under high-pressure disaster scenarios, facilitating swift managerial intervention.

The AI-based chemical dispersion prediction and safety management information system developed through this research empirically demonstrates how technical advancements can lead to the sophistication of managerial risk management. The final conclusions and values reached in this study can be summarized as follows:

First, this study transformed high-uncertainty environmental data into a Manageable Asset. By quantifying the interactions between meteorological factors and chemical substances—previously difficult to predict—through the LSTM algorithm and substituting them with the standardized 'Environmental Risk Index (ERI),' a logical foundation was established for managers to make rapid and decisive choices. This proves that information systems are a core mechanism for strengthening organizational Resilience.

Second, this research presents a practical model for ESG management. While many companies struggle with specific implementation plans for environmental safety (E) and social responsibility (S), the intelligent system based on public data proposed here opens the possibility of 'universal safety welfare' that can encompass SMEs without the need for large-scale facility investment. This suggests that the creation of social value and economic efficiency can coexist rather than conflict.

Third, by projecting the Information Systems Success Model of DeLone & McLean (2003) into the actual disaster response field, this study confirmed that information quality

is directly linked to organizational survival. The high-readability UI/UX design and automated service processes prevent information overload and provide practical guides that help field workers make the safest decisions during accidents.

In conclusion, the system proposed in this study holds substantial value as a Strategic Information System that ensures safety in industrial sites through intelligent technology and secures corporate sustainability. It is expected that the data-driven safety management paradigm presented in this study will expand to various industries in the future, serving as a cornerstone for creating a safe industrial ecosystem.

## 5. Conclusions

This study contributes to the literature by exploring the multidisciplinary intersection of disaster management and Management Information Systems (MIS). Unlike prior research, which predominantly focuses on engineering approaches to trace physical chemical dispersion, this study integrates these technical pathways into an intelligent Decision Support System (DSS) architecture designed for executive strategic judgment. In doing so, it expands the research scope by illustrating the mechanism through which engineering precision is converted into practical managerial benefits when aligned with organizational decision-making processes.

The study validates the generalizability of the Information Systems Success Model by DeLone & McLean (2003) by applying it to the high-risk context of industrial safety. It articulates the causal pathway where system quality predictive accuracy translates into information quality risk indexing and ultimately results in organizational performance, namely the reduction of disaster response lead times. By proposing an Analytics Governance methodology that complements limited corporate data assets with public big data APIs, this research establishes a theoretical foundation for the impact of collaborative data utilization on information system performance.

This study provides specific strategic guidelines for industrial site risk managers and policymakers. First, the ERI proposed in this research serves as a rational decision-making tool for management through risk quantification. This allows for Data-driven Risk Control by excluding subjective biases and providing an objective basis for high-stakes decisions, such as factory shutdowns or evacuation orders, which involve significant economic trade-offs.

Second, the system model presented in this study offers a realistic ESG management implementation framework for small and medium-sized enterprises SMEs. By suggesting AI modeling utilizing public data instead of the costly

implementation of proprietary sensor infrastructure, this study provides a cost-effective alternative for firms with limited resources to proactively respond to global ESG disclosure standards and occupational health and safety regulations.

Third, the intuitive UI/UX design and automated service processes contribute to elevating organizational resilience into a systemic capability. By preventing information overload during the critical early stages of an accident and disseminating standardized response instructions in real-time, the system ensures that field workers can secure the 'golden time' for evacuation and initial response without human error. Consequently, this study empirically demonstrates that intelligent information technology can be utilized as a strategic asset to fulfill CSR and ensure business continuity.

This study proposed a preemptive disaster management framework by integrating deep learning and public environmental big data. However, several critical limitations remain to be addressed in subsequent research to enhance the system's practical efficacy and academic depth.

First, a notable limitation is the inherent 1–2 hour latency associated with public API data processing from national monitoring stations. These update intervals constrain the system's ability to capture rapid, sub-second changes during chemical accidents. To address this, this research proposes a 'Hybrid Data Fusion' strategy as a future technical enhancement. This approach involves synchronizing broad-area public datasets with real-time, low-latency granular data from site-specific, low-cost IoT sensors. Such cross-sector data governance can bridge the temporal gap in public reporting, maximizing the system's real-time responsiveness during sudden chemical anomalies.

Second, although the Environmental Risk Index (ERI) provided a robust mathematical framework for quantifying risks, the AI model did not fully incorporate the specific physical properties and reactive behaviors of various hazardous chemicals. Future studies should focus on refining the predictive accuracy by integrating Computational Fluid Dynamics (CFD) simulation data, allowing for more precise modeling of dispersion paths in complex industrial topographies.

Third, while the current study verified the system's technical utility through initial usability testing—achieving a 32% improvement in response time and a 4.4 Likert score—a more comprehensive evaluation of organizational adoption is required. Beyond technical implementation and index development, it does not fully capture the complex human-computer interaction in industrial settings.

Finally, follow-up studies will employ the Technology Acceptance Model (TAM) to empirically investigate how 'Perceived Usefulness (PU)' and 'Perceived Ease of Use (PEOU)' influence the actual intention of safety personnel to

adopt the system. By analyzing these determinants, future research will provide a deeper theoretical understanding of the mechanisms through which intelligent safety systems are institutionalized within industrial organizations. Such endeavors will contribute to evolving this framework into a more resilient and strategically integrated management information system (MIS).

## References

- Cha, S. J., & Kang, J. S. (2018). Corporate Default Prediction Model Using Deep Learning Time Series Algorithm, RNN and LSTM. *Journal of Intelligence and Information Systems*. 24(4), 1-32.
- DeLone, W. H., & McLean, E. R. (2003). The DeLone and McLean model of information systems success: A ten-year update. *Journal of Management Information Systems*, 19(4), 9-30.
- Hanna, S. R., & Britter, R. (2002). Wind flow and vapor cloud dispersion at industrial and urban sites, CCPS. *New York*, 208.
- Kim, Y. J., So, J. Y., Lee, J. Y., & Kim, S. J. (2022). A Simulation-Based Decision Support System for Smart Farming in Agrophotovoltaic Systems. *Journal of the Society of Korea Industrial and Systems Engineering*. 45(4), 180-186.
- Jeong, H. M., & Lee, S. Y. (2019). Analysis of Factors Affecting Big Data Use Intention of Korean Companies: Based on public data availability. *Journal of Korea Academia-Industrial cooperation Society*. 20(10), 478-487.
- Lee, G. C., Jo, H. R., & KIM, J. S. (1999). A Distributed Web-DSS Approach for Coordinating Interdepartmental Decisions - Emphasis on Production and Marketing Decisions. *Korea Intelligent Information System Society*. 2(1), 291-300.
- Lee, S., Jo, S. Y., Yeo, S. Y., & Lee, H. S. (2022). IoT industrial site safety management system incorporating AI. *Journal of Information Processing System*. 29(1), 118-121.
- Park, G. Y., Lee, Y. S., & Shin, D. G. (2021). Exploring the Feasibility of an Automated Essay Scoring Model Based on LSTM. *The Journal of Curriculum and Evaluation*. 24(4), 223-238.
- Zheng, Y., Yi, X., Li, M., Li, R., Shan, Z., Chang, E., & Li, T. (2015). Forecasting fine-grained air quality based on big data. *Proceedings of the 21th ACM SIGKDD International Conference on Knowledge Discovery and Data Mining*, 2267-2276.