International Journal of
Geo-Information

Review

Measure of Utilizing Space Database Information for Improvement of Efficient Disaster Management (Focusing on Nuclear Power Plant Accidents)

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Abstract: The damage caused by disasters is increasing worldwide, with hundreds of thousands of deaths due to the occurrence of complex large-scale disasters such as the 2010 Haiti earthquake and the 2004 Indian tsunami. South Korea has also experienced human casualties and damage to property caused by large-scale disasters in the past 10 years. Accordingly, a disaster-appropriate response measure is needed. Thus, we conducted this study to present a measure of utilizing spatial database and image information to improve the efficiency of disaster management that is operated based on the country's existing national disaster management system. We present an efficient disaster response measure that differs from the existing collection-, reporting-, and propagation-oriented operating methods of disaster information through the use of spatial database and image-based information that can be combined with mandatory information with regard to nuclear power plant accidents. Thus, this study contributes to deriving a system that could collect and provide information rapidly at the time of disaster by defining the attribute and spatial information required at the time of disaster during nuclear power plant accidents and by deriving available systems and providing institutions.

Keywords: disaster management; spatial database; image information; national disaster management information system

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Citation: Lee, B.; Kang, A.; Ham, S. Measure of Utilizing Space Database Information for Improvement of Efficient Disaster Management (Focusing on Nuclear Power Plant Accidents). *ISPRS Int. J. Geo-Inf.* **2022**, *11*, 438. https://doi.org/10.3390/ijgi11080438

Academic Editors: Wolfgang Kainz and Godwin Yeboah

Received: 20 May 2022
Accepted: 27 July 2022
Published: 2 August 2022

1. Introduction

The damage caused by disasters is increasing worldwide, with hundreds of thousands of deaths due to the occurrence of complex large-scale disasters such as the 2011 Fukushima nuclear disaster [1,2], the 2010 Haiti earthquake [3,4], and the 2004 Indian tsunami [5]. South Korea has also experienced human casualties and property damage caused by large-scale disasters in the past 10 years, such as typhoon Mitag [6] in 2009, the hydrofluoric acid spill accident in Gumi [7] in 2013, and the collapse of the Mauna Ocean Resort gymnasium [8] and sinking of the motor vessel Sewol [9] in 2014. Such damage is aggravated due to poor disaster response. Thus, a disaster-appropriate response measure is needed, and a response system optimized according to the characteristics of disasters (disaster occurrence pattern, progress characteristics, and roles of response organizations) must be developed [10].

South Korea's disaster management was systematized through legislation in 2004, and risk management manuals are prepared and operated according to Article 34 (5) (Preparation and Operation of Risk Management Manuals in Disaster Field) of the Framework Act on the Management of Disaster and Safety and the National Crisis Management Basic Guidelines. On the basis of the functions and roles specified in the standard manual for risk management, working-level manuals for risk response are put in place to specify the measures and procedures required to respond to real disasters. Finally, manuals for actions at the scene containing the procedures of action measures of organizations that directly perform the mission in disaster fields are put in place. These manuals for action are prepared for each disaster type by every ministry, agency, and local government, resulting in more than 5300 manuals in total [11]. Despite the sheer number of these manuals, current disaster management has not advanced considerably from the operation method of simply collecting, reporting, and propagating disaster information.

A system should be developed to recognize disaster situations rapidly and collect and express field situation information quickly and scientifically in emergencies for the "problem-solving contingent response" in accordance with the new disaster environment and current demand on foremost citizen safety to solve this problem [12]. This system [13] is developed in this research [14,15] on the basis of multichannel image information, such as information from satellites and drones on-site, disaster information from the national disaster management system (NDMS), and spatial data from the locations of disasters.

Thus, the current spatial database status required for each disaster type is identified, and the image information required for disaster management is mapped in this research as part of the "study on the development of recognition of continuous disaster situations and risk monitoring technology utilizing multichannel image information such as satellites and drones". Through this process, we aim to implement an effective disaster response measure that departs from the existing collection-, reporting-, and propagation-oriented operating methods.

The scope of this study targets the 41 disaster types extracted from the standard manual for risk management, which is operated according to Articles 3 (1) and 34 (5) of the Framework Act on the Management of Disaster and Safety. The current spatial database status analysis targets the national spatial data infrastructure (NSDI) portal (nsdi.go.kr) [16] and open data portal (data.go.kr (Accessed on 15 January 2021)) [17], and the national land information platform (map.ngii.go.kr(Accessed on 15 January 2021)) [18] for spatial databases in addition to the NDMS (National Disaster Management System) and mandatory information derived during four stages of disaster response (disaster occurrence—report reception and recognition; situation propagation/reporting and initial action; central accident management headquarter operation—search and rescue; management and recovery). With a focus on nuclear power plant accidents, we aim to provide a measure of utilizing spatial database and image-based information, which can be combined with mandatory information in the measure that applies the spatial data disaster management.

The present paper is organized as follows.

In Section 2, the types and mandatory information of disasters are derived through a literature review. In addition, a spatial data platform that provides spatial data which can be combined with mandatory information is investigated. The measure of performing disaster management using the spatial database is presented in Section 3. Finally, the contributions and limitations of this study are discussed with the conclusions in Section 4.

2. Literature Review

In this section, the types and mandatory information of disasters are derived through a literature review. The mandatory information required for each disaster type is derived, and a spatial data platform that provides spatial data which can be combined with mandatory information is investigated.

2.1. Disaster Type

A disaster is a sudden and massive accident that breaks down the organization and functions in a specific community or society. It is a series of events that could damage lives, properties, living means, and social infrastructure and facilities; such damage cannot be overcome without external help and lies outside the scope that can be handled within normal capabilities [19].

The government of Korea has enacted the Framework Act on the Management of Disaster and Safety to protect citizens' lives and properties from various disasters. The disaster management system in Korea was systematized when the Framework Act was established in March 2004. Currently, Korea classifies disasters according to Article 3

(1) of the Framework Act on the Management of Disaster and Safety as follows: "Natural disasters refer to disasters caused by typhoons, floods, downpours, strong winds, winds and waves, tidal waves, heavy snowfall, lightning, droughts, earthquakes, sandy dust, hypertrophy, ebb and flow, volcanic activity, crashes or collisions of natural space objects (such as asteroids and meteoroids), and other natural phenomena equivalent thereto." Social accidents refer to (1) damage that exceeds the scale prescribed by the Presidential Decree and is caused by fires; collapse; explosions; traffic accidents, including aviation and marine accidents; chemical, biological, and radioactive accidents; and environmental pollution incidents; (2) damage caused by the paralysis of national backbone systems, such as energy, communication, transportation, finance, medical treatment, and water supply (hereinafter referred to as "national backbone systems"); and (3) damage caused by the spread of infectious diseases under the Infectious Disease Control and Prevention Act or contagious animal diseases under the Act on the Prevention of Contagious Animal Diseases.

Furthermore, risk management manuals are prepared and operated according to Article 34 (5) (Preparation and Operation of Risk Management Manuals in Disaster Field) of the Framework Act on the Management of Disaster and Safety. The standard manual for risk management is "a document stipulating the disaster management system for and the duties and roles of related agencies in disasters requiring the management at a national level, which shall be the guidelines for preparing working-level manuals for risk response and shall be prepared by the head of each disaster management supervision agency," and a working-level manual for risk response is "a document stipulating the measures and procedures necessary for responding to actual disasters in accordance with the functions and roles stipulated in the standard manual for risk management, which shall be prepared by the head of each disaster management supervision agency and the head of the related agency." Finally, a manual for actions at the scene is "a document stipulating in detail the procedures for actions to be taken by an agency that directly performs its duties at a disaster scene, which shall be prepared by the head of an agency designated by the head of the agency that has prepared working-level manuals for risk response." Thus, the current manuals were prepared for each disaster type by every ministry, agency, and local government, resulting in more than 5300 available manuals [11]. Table 1 summarizes the risk management manual types.

Table 1. Risk management manual types.

Manual	Preparation Institution	Main Contents
Standard manual for risk management	Disaster management agency(central ministry and agency)	Disaster management system and missions and roles per organization
Working-level manual for risk response	Supervision and related organizations	Stipulated measures and procedures necessary for responding to actual disasters
Manual for actions at scene	Organization designated by the head of the preparation institution of the working-level manual	Procedures of actions taken by the organization that performs the mission at disaster scenes

The Ministry of Public Administration and Security rewrote the standard manual for risk management in October 2018 to meet citizens' considerable interest in disaster management and preemptively manage disasters.

This modification strengthened the field operability of the manual for risk management by reflecting the reinforced disaster management system and manual-related regulation improvements after the Moon Jae-in government was established. In particular, heat and cold waves were added to the manual for risk management as new disaster types.

Disasters are divided into natural disasters and social accidents and addressed according to the revised standard manual. The four stages of disaster response are disaster occurrence, initial response, and management and recovery. The first stage involves report reception and recognition. The second stage includes situation information propagation, reporting, and initial response. Disaster situation information is disseminated among ministries and agencies, support requests are submitted, and professional medical staff who can be inputted to the scene are requested. The third stage involves identifying accident scales and searching for and rescuing victims (including patient transfer). The final stage includes managing disasters and recovering from the damage. There are 41 disaster types operated in the standard manual by supervision agencies, as presented in Table 2.

Table 2. Forty-one disaster types and supervision agencies.

Field	Disaster Type	Supervision Agency
Natural disaster (13)	Storm and flood	Ministry of Public Administration and Security
	Earthquake/tsunami	
	Large-scale volcanic eruption	
	Red tide	Ministry of Maritime Affairs and Fisheries
	Drought	Joint ministries and agencies
	Ebb and flow	Ministry of Maritime Affairs and Fisheries
	Cosmic radio noise	Ministry of Science and ICT
	Algal bloom	Ministry of Environment
	Landslide	Korea Forest Service
	Lightning	Ministry of Public Administration and Security
	Cold wave	Ministry of Public Administration and Security
	Heat wave	Ministry of Public Administration and Security
	Crash or collision of a natural space object	Ministry of Science and ICT
Social accidents (28)	Wildfire	Korea Forest Service
	Hazardous chemical spill	The Ministry of Environment
	Large-scale water contamination	
	Large-scale marine pollution	Ministry of Maritime Affairs and Fisheries
	Utility tunnel	Ministry of Public Administration and Security/Ministry of Land, Infrastructure and Transport
	Dam collapse	Ministry of Trade, Industry and Energy/Ministry of Land, Infrastructure and Transport
	Large-scale subway accident	Ministry of Land, Infrastructure and Transport
	High-speed railway accident	
Social accidents (28)	Large-scale fire in densely crowded facility	National Fire Agency
	Radioactive leakage from neighboring nations	Nuclear Safety and Security Commission
	Ship accident at sea	Ministry of Maritime Affairs and Fisheries
	Large-scale human accident in workplace	Ministry of Employment and Labor
	Collapse of densely crowded facility	Ministry of Land, Infrastructure and Transport
	Disaster and accident in correctional facility	Ministry of Justice
	Domestic animal disease	Ministry of Agriculture and Forestry
	Infectious disease	Ministry of Health and Welfare
	Area of information and communication	Ministry of Science and ICT
	Finance computer	Financial Services Commission
	Nuclear safety area	Nuclear Safety and Security Commission/Ministry of Commerce, Industry and Energy
	Power area	

Table 2. *Cont.*

Field	Disaster Type	Supervision Agency
Social accidents (28)	Oil supply area	Ministry of Health and Welfare
	Health care area	Ministry of Health and Welfare
	Drinking water area	Ministry of Environment
	Freight transportation by land	Ministry of Land, Infrastructure and Transport
	Global Positioning System (GPS) radio interference	Ministry of Science and ICT
	Excursion ship and ferry accident	Korea Coast Guard
	Concert hall safety accident	Ministry of Culture, Sports and Tourism
	Fine dust particles	Ministry of Environment

2.2. Mandatory Information of Disasters

The government specifies the golden hour for each type of natural disaster and social accident, such as earthquake, fire, and vessel sinking accidents. It is necessary to have mandatory information of situation awareness for each disaster type to develop a response system at the scene. Through such a system, special rescue teams can arrive at disaster scenes within 30 min for land accidents and 1 h for marine accidents in accordance with firefighters and the Korea Coast Guard. The golden hours for some disaster types are summarized in Table 3.

Table 3. Golden hours for some disaster types.

Disaster Type	Golden Hour	Note
Earthquake	48 h	Rapid increase in death probability of persons buried due to collapse
Fire	5 min	Quick expansion of fire combustion speed and damage area
Wildfire	30 min	Required arrival time of fire extinguishing helicopter
Ship sinking accident	20 min	Ship sinking start time
Oil ship sinking accident	30 min	Prevention of marine pollution incident
Aircraft accident	90 s	Explosion within 90 s after emergency landing

Response activities that are essential immediately after disaster occurrence are established by priority to have an initial scene-focusing response and minimize the damage spread. Information should be gathered through an analysis of mandatory components for response activities (detailed information, resources, prerequisites for activity to occur, etc.). Thus, the government developed and is operating the NDMS to ensure the mandatory information required for disaster management.

2.3. Current Status of Spatial Database Platform

The spatial data in Korea were developed in 1995 and have since been managed by the government to achieve quantitative expansion, thereby significantly contributing to administration efficiency. Although problems occur during the process, such as a lack of interlink utilization systems and duplicate implementation of spatial data systems by the central and local governments, data are developed and managed to utilize spatial data and a three-layer system. In such a system, spatial data production, collection, and service are provided through the basic plan of the national spatial data policy, thereby supporting spatial data utilization for citizens.

2.3.1. Data Development and Management to Utilize Spatial Data

To utilize all national land information as spatial data, the Ministry of Land, Infrastructure and Transport develops base data, such as fundamental spatial data and national points of interest (POIs). Considering the spatial data characteristics consisting of geometric and attribute information, the fundamental spatial data are characterized by geometric information, whereas national POIs are characterized by simple attribute information.

The fundamental spatial data can be the location reference or reference data of other information as the important geometric information used in various fields, which can be defined as spatial data that can be referenced to produce, manage, and utilize other spatial data. The items in the fundamental spatial data are designated according to the National Spatial Data Act as follows: the configuration of grounds, coastlines, administrative boundaries, road or railroad boundaries, river boundaries, land registration, spatial data of artificial structures, control points, place names, orthoimages, digital elevation model, spatial data three-dimensional (3D) model, and indoor spatial data. That is, the fundamental spatial data are regarded as mandatory spatial data that are linked with various attributes and utilized in not only administration but also disaster management, welfare, and industries. Thus, they are priority information in selecting utilizable spatial data.

The 23 items of the fundamental spatial data are collected and distributed through a physical infrastructure called the National Geospatial Program (NGP). The project division of the NGP requests data from organizations and collects and manages these data (Table 4).

Table 4. Current status of update system of fundamental spatial data.

Item	Responsible Institution	Update Period	Management System
Legal-status neighborhood, cadastre of land Spatial data 3D model Indoor spatial data	Ministry of Land, Infrastructure and Transport	Frequently	Korea Land Information System (KLIS)
Administrative neighborhood, road name address	Ministry of Public Administration and Security	Frequently	Korea Address Information System (KAIS)
Statistical district	Statistics Korea	Every year	Census spatial statistics DB
Railway boundary, railway centerline Road boundary, road centerline Stream boundary, stream centerline Lakes, buildings, DEM Place name, cadastral control point Orthoimage	National Geographic Information Institute	Every two years (or frequently)	Digital map management system National land spatial imagery information system National place name management system National control point issuance system
Coastline, submarine topography Marine borderline	Korea Hydrographic and Oceanographic Agency	Every two years (or every year)	Total Oceanographic Information System
Catchment boundary	Han River Flood Control Office	If needed	National water resource management Total information system

The national POI is POI information managed by the National Geographic Information Institute; it consists of the location, address, name, business name, and building name of the points collected from the Ministry of Land, Infrastructure and Transport; Small Enterprise and Market Service; Ministry of Public Administration and Security; and other institutions. The number of POIs has been rising since 2014. As of 2017, information has been collected from the continuous digital topographic map and 83 layers around the nation (Ministry of Land, Infrastructure and Transport), national business name information (Small Enterprise and Market Service), national licensing information (Ministry of Public Administration and Security and local government-held data), and other hospital and education institution information, which are managed by pre-processing and processing. National POIs are provided through the national land information platform, which is operated by the National Geographic Information Institute, and its link is supplied in the NSDI and open data portals.

2.3.2. Three-Layer System of National Spatial Data: Production, Collection (Distribution), and Service

National spatial data are managed and operated via a three-layer system (production, collection (distribution), and service) to raise the reliability and efficiency of spatial data through an interlink utilization between data and to prevent spatial data duplication (Figure 1).

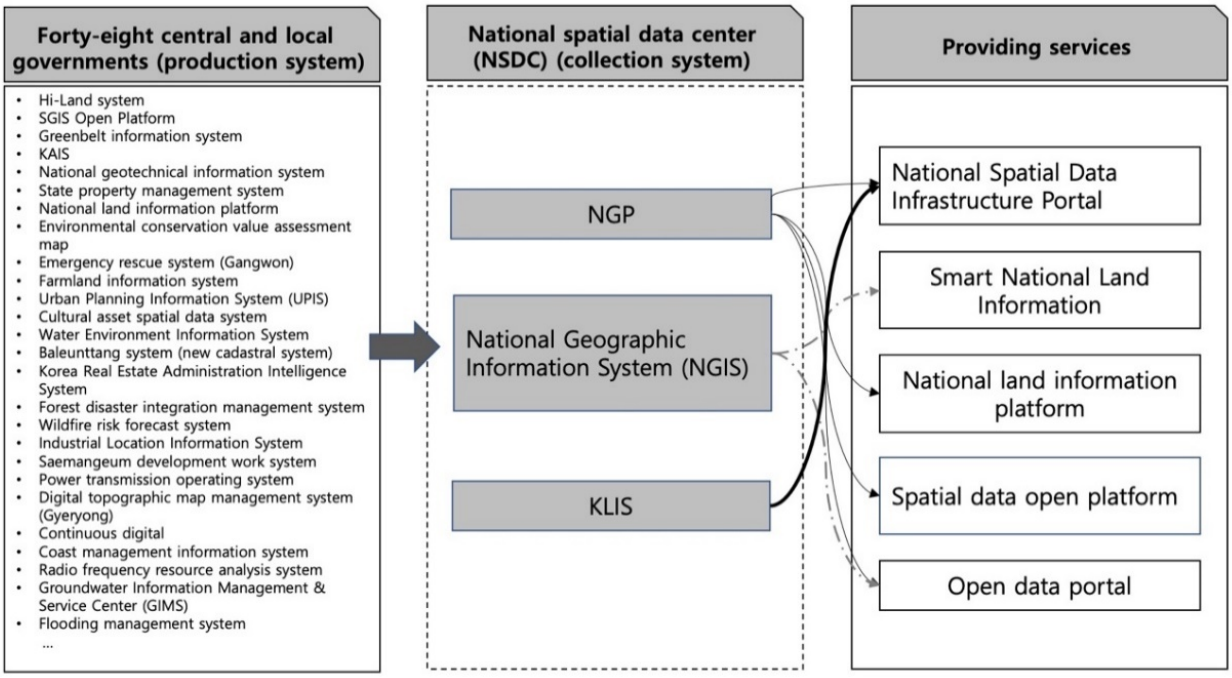

Figure 1. Three-layer system of spatial data: production, collection (distribution), and service.

Spatial data are developed through a system that manages national land, seas, cities, environment, and disasters. There are two available systems: one manages specific topic data through the combination of spatial and attribute data, and the other develops and manages spatial data, such as continuous digital maps, digital topographic maps, control points, and images (Table 5).

The spatial data production system is connected with the interlink integration systems, namely, the NGP (National Geospatial Program) and the NGIS (National Geographic Information System). The NGP was developed by the Ministry of Land, Infrastructure and Transport and the Ministry of Public Administration and Security to secure the infrastructure of spatial data implemented for each organization and utilize spatial data for administrative work in City/Do and Si/Gun/Gu. The NGIS is an information collection system where systems that manage national land information are linked; these systems include the digital topographic management system of local governments, the Korea Real Estate Administration Intelligence System, and the farmland information system.

The Ministry of Land, Infrastructure and Transport supplies data from the NGP (National Geospatial Program), NGIS (National Geographic Information System), and KLIS (Korea Land Information System) as administration and services for citizens while operating the NSDC (National Scientific Data Center). A total of 33 layers, including an individual cadastral map and integrated building information out of 484 spatial layers managed by the NSDC, are classified as publicly inaccessible data, which are not supplied through the site (as of October 2019). National spatial data services are provided through the

Ministry of Land, Infrastructure and Transport and the National Geographic Information Institute (Table 6).

Table 5. Spatial data production system.

Information System	Operation Institution	Information System	Operation Institution
UPIS (Urban Planning Information System)	Ministry of Land, Infrastructure and Transport Local governments	National POIs	National Geographic Information Institute
Management system for integrated underground facilities		National base maps	
Digital topographic maps	National Geographic Information Institute Local governments	Fundamental spatial data	
Integrated control points		Continuous digital maps	
Aerial photographs		Coastal basic maps	
3D spatial data	Ministry of Land, Infrastructure and Transport	Inaccessible system	
Greenbelt management information system		High-definition road maps	
Spatial object registration no.		Orthoimages	
Korea Real Estate Administration Intelligence System		Place names	
Cadastral maps of North Korea		Aerial photograph DB after liberation	
Indoor spatial data		National geotechnical information system	Korea Institute of Construction Technology
Integrated GIS database		Professional construction support system DB	
Cadastral resurvey administration system		Defense property spatial data system	Land and Geospatial Informatix Corporation
Transaction of soil and rock open portal recycle system		Road register information system	
Land transaction permit area database		Road name, address, basic maps	
KLIS (Korea Land Information System)		Forest soil digital maps	
National water resource management Total information system		Cadastral control points	
River Information Management Geographic Information System	Han River Flood Control Office	Water resource DB	Korea Water Resources Corporation
Flood risk maps		Underground water information system	
Real estate transaction management system	Korea Appraisal Board	Architecture administration system	Korea Land and Housing Corporation
House Price Information System		Happy City 3D spatial data system	

The NSDI portal provides spatial data from organizations that manage data and topics for citizens to easily utilize them. The data can be downloaded directly or through an application programming interface. It is truly a so-called representative site of the NSDI.

Through the smart national land information, real estate information can be searched conveniently using mobile terminals (smartphones and tablets) at any time and from anywhere. The smart national land information is a mobile system where the real estate information of the current location can be queried on the basis of spatial data, such as cadastral maps and aerial photos, using the location information (GPS). In the spatial data open platform, spatial data collected by the NSDC (National Scientific Data Center) are checked and downloaded over a 3D platform (VWorld) [20]. The platform provides metadata and ensures the convenience and reliability of spatial data utilization.

Table 6. Comparison of national spatial data providing services (in terms of data provision).

Service Name	Operating Party	Site	File Open to the Public	File Supply Method	
				Download	API
NSDI portal	Ministry of Land, Infrastructure and Transport	nsdi.go.kr	possible	possible	possible
Smart national land information	Ministry of Land, Infrastructure and Transport	m.nsdis.go.kr	impossible	Impossible	impossible
Spatial data open platform	Ministry of Land, Infrastructure and Transport	vworld.kr	possible	impossible	possible
National land information platform	National Geographic Information Institute	map.ngii.go.kr	possible	possible	possible

The national land information platform, which is run by the National Geographic Information Institute, enables searching digital topographic maps, continuous digital topographic maps, fundamental spatial data, aerial photographs, and national control points, which can be directly downloaded by citizens.

3. Measure to Apply Spatial Database to Disaster Management

Currently, 41 types of disasters are managed by the standard manual for risk management [21]. The mandatory information is defined, and disaster stages are divided into four (disaster occurrence, initial response, and management and recovery) for accident response by disaster type according to the standard manual for risk management. In this section, mandatory information is derived for each stage with a focus on nuclear power plant accidents out of the 41 disasters. Spatial data that can be combined with the derived mandatory information are derived.

3.1. Derivation of Mandatory Information by Disaster Type

Mandatory information for each stage of disaster (occurrence, response, and recovery) is needed to respond to disasters effectively. The standard manual specifies the mandatory information to respond to disasters. In this study, mandatory information is explained with a focus on nuclear power plant accidents as a disaster type. Accident information, corrective actions taken immediately after leakage, nuclear power plant information, and weather, sea, and marine information at the time of accident are required in the disaster occurrence stage. Initial responses take place through information such as recognition of accident type, initial correction actions taken, and weather. The initial response stage is divided into the (1) situation propagation, reporting, and initial substage and the (2) central accident management headquarter operation substage. The situation propagation and the reporting and initial substages need disaster situation propagation among related ministries and agencies, securing rescue teams, evacuation and relief information, and possible secondary damage occurrence and preventive information, thereby establishing a collaboration and reporting system among ministries and agencies. In the central accident management headquarter operation substage, earnest rescue and response are conducted through the accident scale, search/rescue and disaster prevention work, weather conditions during radioactivity prevention work, lifeline, and dangerous facility information. Finally, the damage scale in the affected area is calculated, and recovery information is collected in the recovery stage. Table 7 summarizes the mandatory information for each accident response stage.

For nuclear power plant accidents, accident information, such as radiation leakage, can be acquired through the nationwide environmental radiation monitoring information, and weather is mandatory information. Information is needed about appropriate protective gear, life saving, radiation therapy, decontamination-specialized hospitals, number of doctors, and road section with the shortest transfer time. Nearby fish farm and coast information is monitored through ferry master information to prevent secondary damage in surrounding areas. In the central accident management headquarter operation substage, station and train operation information is required for lifeline information. In addition, the location information of facilities, including any sewage treatment facility near the affected nuclear power plant, is required. This disaster-related information is acquired through the NDMS along with the information collected at the scene.

3.2. Derivation of Fusible Spatial Database by Mandatory Disaster Information

The aforementioned mandatory disaster information stage largely consists of attribute information. Determining the disaster situation at the scene with this attribute information has limitations. Abstract spatial data combination is an effective method of supporting decision making and delivering accurate information.

The spatial database that can be utilized in nuclear power plant accidents was analyzed with 983 types of the latest data list in 2019, which was provided through the NSDI portal. Nine types of spatial databases were found by the analysis. First, the spatial information provided by the National Geographic Information Institute was investigated as follows. A digital topographic map was used to locate rivers, fish farms, railways, and airports required to prevent secondary damage. The national POIs in the national land information platform can be linked with hospital information, the number of doctors, the nearest operable helicopter, and aircraft information. The land use map was then used to calculate the radiation leakage and contamination area.

Purpose region information, such as coastal management, nuclear power, and restricted area information, can be acquired from the NGIS (National Geographic Information System) and then used. Coastal erosion information and natural coast management diagrams and maps can be obtained through the link with the Ministry of Maritime Affairs and Fisheries. Finally, the road section information is derived from the KAIS in the Ministry of Public Administration and Security or from the UPIS (Urban Planning Information System) in the Ministry of Land, Infrastructure and Transport. Table 8 summarizes these spatial data.

3.3. Measure to Combine and Utilize Image-Based Spatial Database

The abstract spatial database at the scene and image information that delivers the situation of the actual scene are essential for improving the efficiency of disaster management. The range of disaster damage in a nuclear power plant accident is wide and has a large number of possible human casualties. Thus, appropriate image information for each mandatory information is required. For weather information, a geostationary meteorological satellite that has a resolution level of 500 m to 1 km and can be applicable to a wide area is useful. For radiation-induced human casualties and radiation leakage, real-time image information collected at the scene through multiple drones and ground sensors will effectively convey the urgent situation at the scene. Radiation leakage and contamination area information, which are required during disaster occurrence and recovery, can be acquired from high-resolution (1–3 m level) synthetic aperture radar (SAR), very-small-sized satellites (10 m), or multispectral satellites, as summarized in Table 9.

Table 7. Mandatory information for each stage of accident response (e.g., nuclear power plant accidents).

Accident Response Stage		Mandatory Information		Disaster Information
Main Stage	**Substage**	**Comprehensive Information**	**Detailed Information**	
Disaster occurrence stage		Accident information	Radiation-induced human casualty information, radiation-induced nuclear leakage and leaked amount, etc.	Nationwide environmental radiation monitoring information
		Corrective actions executed immediately after leakage and nuclear power plant information	-	-
		Weather/sea/marine information at the time of accident	Wave height, tidal current, turbidity, wind direction/speed, water temperature, water depth, etc.	Meteorological information
Initial response stage	Situation propagation, reporting, and initial substage	Propagation of disaster situation information among related ministries	-	-
		Securing rescue teams	Information of appropriate protective gear, radiation therapy, decontamination-specialized hospital information, proximity routes for traffic and transfer	Disaster material and equipment, hospital information and number of doctors, road section information
		Evacuation/ relief information	-	-
		Possible secondary damage occurrence/ prevention information	Nearby ditch and river location information, nearby fish farm distribution, nearby coastal region information	Ferry master information
	Central accident management headquarter operation substage	Accident scale information	-	-
		Search/rescue and disaster prevention work information	Nearest operable helicopter and aircraft information	-
		Weather information during radioactivity prevention work	-	-
		Lifeline information	Railway, train, and airport information and location, etc.	Station and train information
		Dangerous facility information	Nearby nuclear power, gas, oil facility location	Sewage treatment facility
Management and recovery stage		Management/recovery meteorological information	-	-
		Management/recovery	-	-

Table 8. Example of combination of spatial data with disaster information (e.g., nuclear power plant accidents).

Accident Response Stage		Mandatory Information	Data Source: Institutions	
Main Stage	Substage		Disaster Information	Spatial DB
Disaster occurrence	Accident information	Radiation-induced human casualty information, radiation leakage nuclide and leaked amount, etc.	Nationwide environmental radiation monitoring information: Korea Institute of Nuclear Safety	-
		Radiation leakage and contamination area	-	Land use map (1/25,000): National Geographic Information Institute
	Weather/sea/marine information at the time of accident	Wave height, tidal current, turbidity, wind direction/speed, water temperature, water depth, etc.	Meteorological information: Korea Meteorological Administration	-
Initial response: propagation, reporting, and initial substage	Securing rescue teams	Appropriate protective gear information	Disaster material and equipment: Korea Environment Corporation, Ministry of Public Administration and Security	-
		Radiation therapy, decontamination-specialized hospital information	Hospital information, number of doctors: Korea Fire Safety Association	POI: National Geographic Information Institute
		Proximity route information for traffic and transfer	Road section information: Korea Expressway Corporation	Road (status): Ministry of Land, Infrastructure and Transport (UPIS)
	Possible secondary damage occurrence/prevention information	Nearby ditch and river location information	-	Digital topographic map (Stream): National Geographic Information Institute
		Nearby fish farm distribution	Ferry master information: Ministry of Maritime Affairs and Fisheries	Digital topographic map (fish farms): National Geographic Information Institute
		Nearby coastal region information		Purpose region information (coast control), coastal erosion information, natural coast management diagram and map, etc.: Ministry of Land, Infrastructure and Transport/Ministry of Maritime Affairs and Fisheries
Initial response: Central accident management headquarter operation stage	Search/rescue and disaster prevention work information	Nearest operable helicopter and aircraft information	-	POI: National Geographic Information Institute
	Lifeline information	Railway, train, and airport information and location, etc.	Station and train information: Korean Railroad Corporation	Digital topographic map (railway, airport): National Geographic Information Institute

Table 8. *Cont.*

Accident Response Stage		Mandatory Information	Data Source: Institutions	
Main Stage	Substage		Disaster Information	Spatial DB
Initial response: Central accident management headquarter operation stage	Dangerous facility information	Nearby nuclear power, gas, oil facility location	Sewage treatment facility: Korea Infrastructure Safety Authority	Purpose region information (nuclear power, restricted area): Ministry of Land, Infrastructure and Transport (NGIS)
Management andP recovery stage	Management/recovery	Contamination degree (soil, air)	-	Land use map (1/25,000): National Geographic Information Institute

Table 9. Measure of combination of image-based spatial data (e.g., nuclear power plant accidents).

Accident Response Stage	Mandatory Information	Disaster Information	Image Information
		Data Source: Institution	
Disaster occurrence	Radiation-induced human casualty information, radiation leakage nuclide and leaked amount, etc.	Nationwide environmental radiation monitoring information: Korea Institute of Nuclear Safety	Multiple drone and ground sensors, fixed CCTV, smart devices
	Radiation leakage and contamination area	-	SAR satellite, very-small-sized satellite, multispectral satellite
	Weather conditions	Meteorological information: Korea Meteorological Administration	Geostationary meteorological satellite
	Wave height, tidal current, turbidity, wind direction/speed, water temperature, water depth, etc.		
Initial response: propagation, reporting, and initial substage	Proximity route information for traffic and transfer	Road section information: Korea Expressway Corporation	SAR satellite
	Nearby ditch and river location information	-	
	Nearby fish farm distribution	Ferry master information: Ministry of Maritime Affairs and Fisheries	
	Nearby coastal region information		
Initial response: Central accident management headquarter operation substage	Railway, train, and airport information and location, etc.	Station and train information: Korean Railroad Corporation	SAR satellite
	Nearby nuclear power, gas, oil facility location	Sewage treatment facility: Korea Infrastructure Safety Authority	
Management and recovery stage	Management/recovery	Contamination degree (soil, air)	SAR satellite, very-small-sized satellite, multispectral satellite

Disaster information is currently collected and serviced by the NDMS in the Ministry of Public Administration and Security, and the spatial database is collected and linked in the NGP (National Geospatial Program). However, these various pieces of information are managed separately among ministries and agencies. Thus, accessing the systems that provide information and determining whether the linked data are updated could hinder the rapid information collection at the time of urgent disaster occurrence. In this regard, linkage with open API services in the national administration network and acquisition of updated information and utilization in disaster information would effectively prevent duplicate implementation of systems, thereby guaranteeing the quality and up-to-dateness of information.

4. Conclusions

In this study, we aimed to provide a measure of utilizing spatial database and image information that is based on existing national disaster management information to improve the efficiency of disaster management. To achieve this goal, we first investigated 41 disaster types operated on the basis of the required standard manual and mandatory information. Mandatory information required at the time of accident response for each disaster type was defined through this investigation. Second, we examined and extracted image information and the spatial database required for disaster management by analyzing multichannel image information and the spatial database status obtained from satellites and drones. Finally, the spatial database and image information that can be applied to nuclear power plant accidents were matched, and a measure to utilize them is proposed.

To utilize spatial database and image information with a focus on nuclear power plant accidents, we derived a spatial database that can be linked with 10 items from the information required to respond to nuclear power plant accidents and six items that can utilize image information obtained from satellite and drone images. Although the disaster information is collected and serviced by the NDMS in the Ministry of Public Administration and Security, this information is text-based attribute information. Thus, it is more effective in providing realistic and visualized up-to-date information by fusing spatial database and location information via satellite images.

Since the spatial database is generated by collecting spatial information from various institutions in the NGP (National Geospatial Program) of the Ministry of Land, Infrastructure and Transport, it can be utilized, but the quality control (such as update frequency and up-to-dateness of information) is required essentially to acquire and use on-site information.

Thus, this study contributes to deriving a system that could collect and provide information rapidly at the time of disaster by defining the attribute and spatial information required at the time of disaster during nuclear power plant accidents and by deriving available systems and providing institutions.

However, this study is limited in that we derived only the required information list and systems and did not implement them with real data. In future work, the current research should be verified by overlapping analyses of an actual spatial database and image information for all disaster types to practically test the supply of scene situation information rapidly and scientifically in the event of an emergency situation.

Author Contributions: Conceptualization, Aetti Kang; funding acquisition, Bomi Lee; writing—original draft, Bomi Lee; writing—review and editing, Sungil Ham. All authors have read and agreed to the published version of the manuscript.

Funding: This research was supported by the Research Grant of Jeonju University in 2021.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study: in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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