Service-oriented architecture of environmental information systems to forecast the impacts of natural disasters in South Korea

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Abstract

Purpose – While high-quality information is critical in decision-making for environmental issues and assessing the impact of natural disasters, there is a significant lack of research on how environmental information systems (EISs) can be integrated through service-oriented architecture (SOA). The purpose of this paper is to investigate the EISs in South Korea and to propose an SOA to improve the quality of EISs.
Design/methodology/approach – This study follows the design science research methodology proposed by Peffers *et al.* (2007). A pilot test was conducted with Environmental Impact Assessment Support System (EIASS) end users based on the modified DeLone and McLean's IS success model to discern the moderating effect of SOA readiness.
Findings – This study proposed a new SOA for the South Korea EIASS; the work processes among EIASS, nationwide EISs and local EISs are also analyzed. Conceptual and hardware SOA for the EIASS were presented. The finding shows that SOA readiness has a significant moderating effect for EIASS end user benefits.
Practical implications – Supply chain managers can exploit GIS-based environmental information, which can be provided by the new EIASS architecture, to estimate the risk of a natural disaster within the geographical region of their supply chain.
Originality/value – This is one of the few studies in the EIS literature that propose an SOA to improve the quality of EIS. In addition, the study remodeled DeLone and McLean's IS success model to assess the proposed SOA for EAISS and found that the new SOA would be useful for end users.

Keywords Service-oriented architecture, Environmental impact assessment, Environmental information systems, IS success, Natural disaster

Paper type Conceptual paper

1. Introduction

Rapid industrialization and population growth have aggravated environmental problems such as the depletion of resources, global warming, destruction of the natural environment, and an increase in natural disasters, thus giving rise to concerns about the loss of nature's self-purification capacity (Song, 2004). Over the last decade, substantial attention has been given to sustainable development and the risk of natural disasters. This interest is the result of growing concerns over human abuse of natural environments. Few can deny that thoughtless development has increased the risk of natural disasters. It is possible to minimize the potential natural disaster risk by assessing the environmental impact of such development. Finding solutions to environmental problems is strongly dependent on the quality of the available environmental information.

A Center for Research on the Epidemiology of Disasters (CRED) report (Guha-Sapir *et al.*, 2016) indicated that the number of natural disasters dramatically increased between 1996 and 2006, and more people are being affected by these disasters. The amount of global

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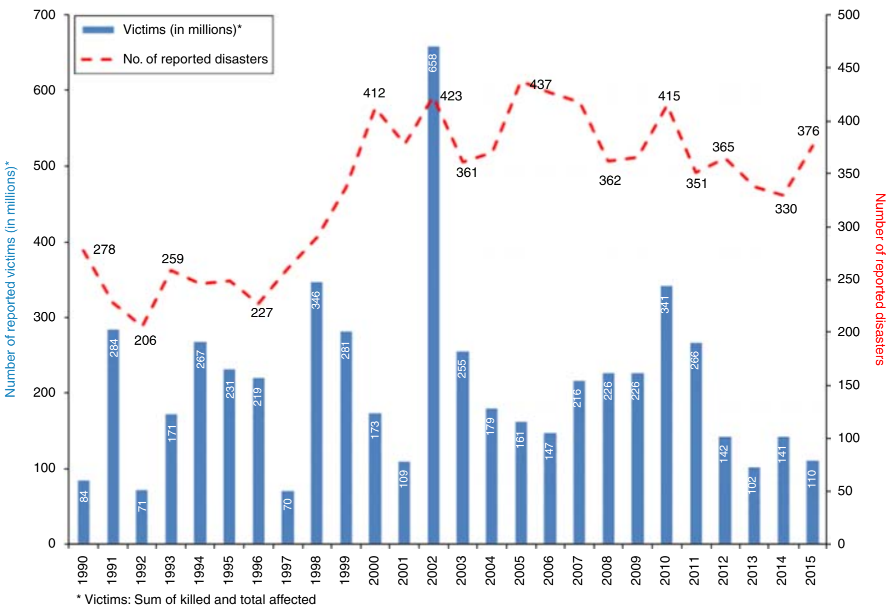
economic damage caused by natural or humanitarian disasters has also increased steadily (Guha-Sapir *et al.*, 2016). Figure 1 shows the number of reported natural disasters and the number of reported victims around the world from 1990 to 2015.

During the 1980s, there was an average of about 180 disasters per year. In the 1990s, that average increased to around 300 per year. From 2000 to 2007, the number was around 460 disasters per year, which is a dramatic increase. An increase of this magnitude can be explicated by global warming and thoughtless development (Guha-Sapir *et al.*, 2016). In 2016, 342 disasters triggered by natural hazards were registered by CRED, and a declining trend in the annual number of disasters since 2005 has been observed.

The early 2000s witnessed increasing interest in sustainable development and environmental disaster management in supply chain management (SCM) (Kleindorfer and Saad, 2005). The interest in sustainable development results from growing concerns over the abuse of natural environments. It is important to manage supply chain risks that can result from natural disasters, acts of war and terrorism, and other reasons (Chopra and Sodhi, 2004). Companies and organizations should proactively respond to and manage their supply chain risk to avoid disruptions. To mitigate the risk of disruptions, organizations should develop risk-management strategies that minimize potential risk and reduce environmental uncertainty.

Emergency management or disaster management is the discipline of both avoiding and dealing with risks (Haddow *et al.*, 2013). Emergency management is a continuous process, with the related activities typically classified in four phases, i.e. preparedness, response, recovery and mitigation, based on the comprehensive emergency management concept proposed in the 1978 report of the National Governors' Association Emergency Preparedness Project.

Figure 2 (Verisk Maplecroft, 2017) shows global climate change vulnerability. Note that several regions are in extremely risky status. Protection of the environment has become one



Source: Guha-Sapir *et al.* (2016)

Figure 1.
Number of reported natural disasters per year around the world

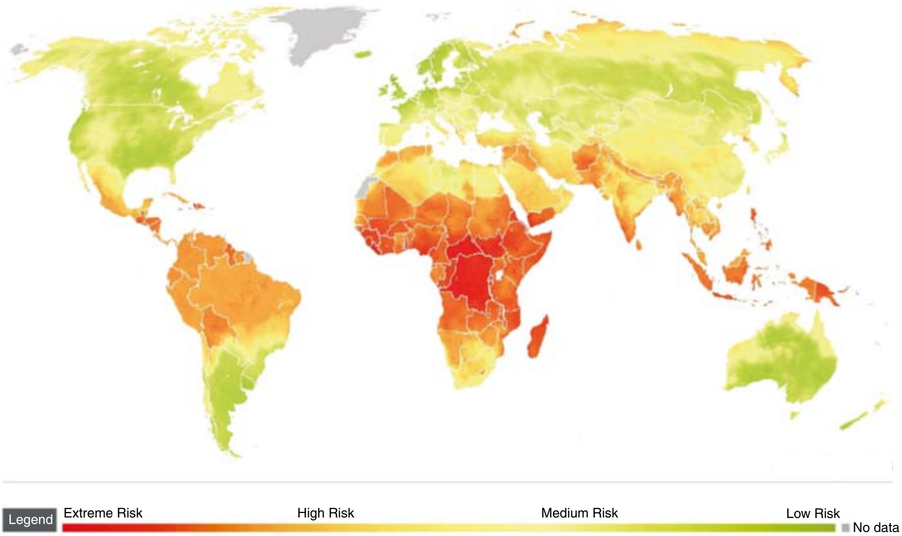


Figure 2. World climate change vulnerability index 2017

Source: Verisk Maplecroft (2017)

of the greatest challenges facing industrialized societies. It is clear that the many problems in environmental protection and environmental planning can only be solved if grounded in comprehensive and reliable information (Patig and Rautenstrauch, 2001). Environmental problem-solving is, therefore, mainly an information-processing activity, handling a wide range of environmental data.

Information systems (ISs) have great potential for reducing environmental disasters and improving the environmental quality. Solutions to environmental problems are strongly dependent on the quality of the information sources. Consequently, information is a critical factor in making decisions on environmental issues (Patig and Rautenstrauch, 2001; Horsburgh *et al.*, 2011). This information is important as a basis for making decisions in regard to actions in environmental protection as well as for gaining knowledge in environmental research.

While IS communities agree that obtaining high-quality data is a critical factor in researching environmental issues and assessing the impact of natural disasters (Watson *et al.*, 2010), there is a lack of research on the influence of information integration of an environmental information system (EIS) for sustainable development and the impact of natural disasters.

Due to the complex nature of environmental data, EIS requires state-of-the-art computer technology. Because the environment is a broad-ranging and multidisciplinary subject, an effective EIS necessarily requires the active participation of multiple institutions and organizations from different environmental subject areas.

The study is motivated by two main research questions:

RQ1. How can South Korea EIS be enhanced by an service-oriented architecture (SOA)?

RQ2. How does EIS help South Korea to assess the impact of natural disasters?

Thus, the objective of this paper is to investigate the EISs in South Korean and to propose an SOA to improve the quality of EIS. Also, an application of EIS to forecast natural disasters will be examined.

This paper is structured as follows. The next section reviews prior research in EISs and environmental impact assessment (EIA) in Korea. In Section 3, we describe SOA in EISs and propose an SOA for the Korean Environmental Impact Assessment Support System (EIASS).

In Section 4, we develop a conceptual model for assessing the SOA for Korean EIASS and conduct a pilot test with actual system users. In Section 5, we discuss practical implications and limitations in the paper. Then, we conclude this paper and point out directions for future research.

2. Literature review

2.1 Literature for environmental information systems

Usländer (2005) argued that there has been no standard syntactical and semantic integration technology across organizational borders up until now. This hinders the efficient development of integrated views and services. The author suggests that a multitude of legacy systems have to be migrated into an integrated thematic IS, with a common approach for the meta-, master, measurement and spatial data. Vijay *et al.* (2009) studied the ways in which EISs are providing environmental information to decision-makers, policy planners, scientists and engineers, research workers, etc., thus ensuring the integration of data collection, collation, storage, retrieval and dissemination to all concerned. In his study, environmental data have typically been collected, evaluated, catalogued and stored in a large number of disciplinary categories, often by scientists studying particular disciplines (e.g. geology, biology) or based on Xu's (2001) research by agencies with mandates to collect and track certain types of data (e.g. census data, toxic release inventory).

Granell *et al.* (2010) proposed an EIS using a service-based architecture in the framework of the European Union-funded Available WAter Resource project. Service design principles and strategies for enhancing service integration were discussed in their study. Mineter *et al.* (2003) pointed out the need for a new generation of environmental applications, shifting from centralized, desktop applications toward the provision of distributed geospatial services and components. The authors foresaw the use of emerging technologies, e.g. web service (Curbera *et al.*, 2002; Alonso *et al.*, 2004) and grids (Foster *et al.*, 2001) and emphasized the need for software modularity and reuse by means of structuring applications as a set of connected services.

Fang *et al.* (2014) introduced a novel integrated IS that combines the Internet of Things (IoT), cloud computing, geoinformatics and e-science for environmental monitoring and management with a case study of regional climate change and its ecological responses. Their research provides a prototype application for environmental monitoring and management. Castell *et al.* (2015) introduced mobile technologies on the citizens' observatory in the areas of air quality as an environmental health monitoring system and environmental health knowledge base. Their mobile application, Citi-Sense-MOB, provides citizens and authorities with information on transport, CO_2 emissions, and air quality. According to their research, Citi-Sense-MOB has the potential to significantly improve data coverage by the provision of near-real-time high-resolution data over urban areas. Cherradi *et al.* (2017) proposed a planning aid system to reduce the risks of transporting hazardous material using a micro-services-based architecture on a cloud environment. The authors expect the micro-service-based architecture to help organizations to produce effective plans to reduce the risks of transporting hazardous materials in urban areas. Braun *et al.* (2018) presented a lightweight framework that allows web components to access data services via standard interfaces. The proposed web component framework (W2C) was evaluated with environmental applications.

Over the past decade, several studies have been conducted on EISs. However, none of the studies have tried to integrate local and nationwide EIS using SOA and investigate how to forecast the impact of natural disasters using EIS.

2.2 Environmental impact assessment (EIA) in Korea

The EIA was originally tailored to restructure the rules and values related to environmental protection through interdisciplinary work. The EIA has developed into a decision-making tool for the implementation of projects that present a potentially significant environmental impact (Bond *et al.*, 2010). The EIA originated almost four decades ago in the USA through the enactment of the National Environmental Policy Act (NEPA, 1969) (www.nepa.gov/nepa/regs/nepa/nepaeqia.htm). In South Korea, the EIA was introduced through the Environment Preservation Act in 1977 and was later strengthened in a new EIA Act, passed in 1993. The EIA Act mandates that the EIA test urban development projects, industrial site buildings, and energy development. All projects subject to the EIA must be approved through a public hearing (Ministry of Environment, 2004; Ministry of Environment, 2017a, b).

The destruction of ecosystems and environmental pollution has been increasing, and *ex-post* facto measures alone are insufficient solutions. The environmental impact assessment system (EIAS) was introduced as a preliminary preventive policy measure to ensure that environmental factors are considered in the initial stages of setting up a development plan. The EIAS was devised as a measure for estimating and analyzing the negative effects of a development project on the natural environment, so such effects can be reduced when the plans for that project are established and to provide a method to support decision-making activities. The EIAS is now an important asset for preventing environmental conditions from becoming worse and for achieving "environmentally and socially sustainable development," as it considers environmental as well as economic and technical aspects of establishing and implementing a development project.

Over the past 25 years, since its introduction, the EIA in South Korea has served as an effective program for protecting the environment while increasing awareness of environmentally friendly development to developers and institutions as well as promoting the importance of environmental conservation to the public. In the early 1980s, only those projects led by the public sector such as administrative authorities and government-invested organizations were subject to the EIA, and the number of projects under the EIA system was relatively low. However, the scope of assessment projects was expanded to include the private sector; further, the overall number of EIAs conducted also increased. As of 2003, the EIA was performed on a total of 2,623 projects. Table I shows the number of projects completing consultation in the EIA from 1982 to 2003, and the projects number dramatically increased after 2001.

However, apart from such achievements, the EIA in South Korea has come under criticism for systematic and operational problems, calling it a measure that further validates development activities rather than being a measure for environmental conservation (Song, 2004).

The EIA in South Korea has been perceived as a key element in upholding the principle of prior considerations, a guiding principle in environmental law. In other words, while the EIA recognizes the necessity of development, it reviews the impact of a development project on the environment in advance and provides guidance in establishing a development plan

Table I. Number of projects completing consultation in EIA

Project group	Total	1982-1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Total	2,623	996	149	115	161	151	151	155	154	121	117	168	185
Urban development	461	201	21	17	27	6	18	25	23	16	19	24	31
Development of energy	328	244	4	11	22	15	12	3	3	3	2	2	7
Formation of industrial complexes	269	145	14	18	20	16	12	8	7	5	7	11	6
Construction of roads	591	39	47	29	42	40	39	64	61	57	50	60	63
Development of gymnastic facilities	152	104	4	3	–	–	7	6	6	5	4	5	8
Others	822	263	59	37	50	44	63	49	54	35	35	66	70

Source: Ministry of Environment (2004) that minimizes its negative impact on the environment. It is recognized as an environmental management measure that enables sustainable development by harmonizing development and conservation (Jeong, 2000).

The EIAS in South Korea played a crucial role in shifting policymaking from that of the previous model, which focused on project efficiency and economics, to an environmental-friendly development model and changed mindsets among development executors, thus raising awareness of preserving the environment, i.e. environmental aspects have been taken into account when initiating development projects since the introduction of the EIA. The objective of EIA is to promote environmentally sound and sustainable development. It also aims to maintain and create a healthy environment by identifying objective measures for win-win solutions as well as for blocking and preventing possible environmental destruction and pollution associated with various development programs (Song, 2004).

As shown in Table II, 63 project types in a total of 17 areas are subject to the EIA in South Korea. These are mostly large projects that are likely to have a significant impact on the environment.

Group	Type and size of projects
Urban development (10)	Urban planning, land organization, housing development, urban renewal, school: 300,000 m^2 Distribution complex, passenger and cargo terminal: 200,000 m^2 Car parking (200,000 m^2), wastewater treatment (100,000 m^2/day), market (150,000 m^2)
Formation of industrial location and industrial complexes (6)	National industrial complex, local industrial complex, industrial complex of rural area, small and medium industry area, free export zone: 150,000 m^2
Development of energy (6)	Power development, electricity facilities: 10,000 kw Mining industry (300,000 m^2), submarine mining industry, oil pipeline and oil storage (100,000 kl)
Construction of harbors (4)	Fishing port, harbor facilities, new harbor: 300 m, 10,000 m^2 Dredge: 100,000 m^2
Construction of roads (3)	Road: new road: 4 km, extension: 10 km
Development of water resources (2)	Dam, reservoir: 2M m^2
Construction of railroads (including urban railroads)	Railroad, city railroad, high-speed railroad: 1 km Cable railway: 2 km
Construction of airports (1)	Airport (runaway: 500 m)
Utilization and development of rivers (1)	River works: 10 km
Reclamation works and forester land clearing works (2)	Filling-up (300,000 m^2), reclamation (1M m^2)
Development complexes of tourist (6)	Tourist industry, resort, hot spring: 300,000 m^2 Park, resort: 100,000, urban park: 250,000 m^2
Development of gymnastic facilities (5)	Gymnastic facilities, cycling race, racecourse: 250,000 m^2 Youth discipline facilities and district: 300,000 m^2
Development of mountainous areas (2)	Public cemetery (250,000 m^2), grassland (300,000 m^2), transforming (200,000 m^2)
Development of designated regions (2)	Urban planning and development for balanced development of districts
Installation of waste and excreta disposal facilities (2)	Night-soil treatment (100 kl/day), waste landfill (300,000 m^2)
Construction of military facilities (3)	National defense facilities (330,000 m^2), navy base installations (100,000 m^2), military air base (runaway: 500 m)
Excavation works (4)	River (50,000 m^2), forest (100,000 m^2), coastal quartz sand, coastal sand (250,000 m^2)

Source: Ministry of Environment (2004)

Table II. Type and size of projects subject to EIA in Korea

The current EIA assessment categories and items are comprised of 23 items in three categories, as shown in Table III.

2.3 Procedures for an environmental impact assessment

The EIA process in South Korea is composed of three stages: commencement, where a preliminary assessment statement is drafted and displayed, announced, or presented to local residents to collect their opinion; a finalized assessment statement, which is submitted after consulting with the ministry of environment, and collecting the opinions of local residents for approval of the project by the authority concerned; and the validation of compliance with consultation details and a survey of the post-impact assessment. The detailed procedures are described in Figure 3 (overview of EIA procedures).

It is clear that the EIA cannot achieve the original vision set out in the world's first legislation, adopted in 1970, unless a learning-organization approach is taken, whereby the critical role of informal knowledge is recognized, informal knowledge is properly managed by EIA teams to engender a common understanding of sustainable development goals, and interdisciplinary and transdisciplinary working practices are adopted (Bond *et al.*, 2010).

2.4 Environmental information systems (EISs) in South Korea

The official name of the IS that supports EIA projects in South Korea is the Environmental Impact Assessment Supporting System (EIASS). All of the files and database content are written in Korean. This system is now working at http://eiass.go.kr.

The Korea Ministry of Environment and Korea Environment Institute started to build the Web-based system for the construction of a comprehensive information database of EIAs in Korea, funded by the National Information Agency. The purpose of building this system was to create a computerized database of the information from past EIA projects, such as the text of environmental impact statements and various research data for EIA, and to provide this database to the public, government officials and project developers, so they can use past EIA data to help estimate the feasibility and environmental impacts of future development projects.

In this system, more than 3,000 past environmental impact statements and EIA agreement results, which are scanned and converted to PDF files with bookmarks, are included, along with project outlines, details of environmental protection near project sites, and various environmental quality measurement results that were extracted from the PDF files of EISs and converted into a database format.

This database can be searched in a geographical information system (GIS)-based graphic user interface. Developers spend quite a lot of time completing EIS during project planning. Using this system, the authors would expect that having an active reference to past EIA information would lead to a reduction in the time it takes to complete an environmental impact statement and assist in creating an effective balance between environmental preservation and development. In the GIS DB, spatial information is built for project sites,

Categories	Environmental items
Natural environment	Atmospheric environment, topography and geology, flora and fauna, marine environment, hydrology
Ambient environment	Land use, air quality, water quality, soil, solid wastes, noise and vibration, odor, electric wave, shading, landscape, sanitation and health
Socioeconomic environment	Population, residence, local industry, public facilities, education, traffic, cultural asset

Table III.
Items and categories stipulated in EIA

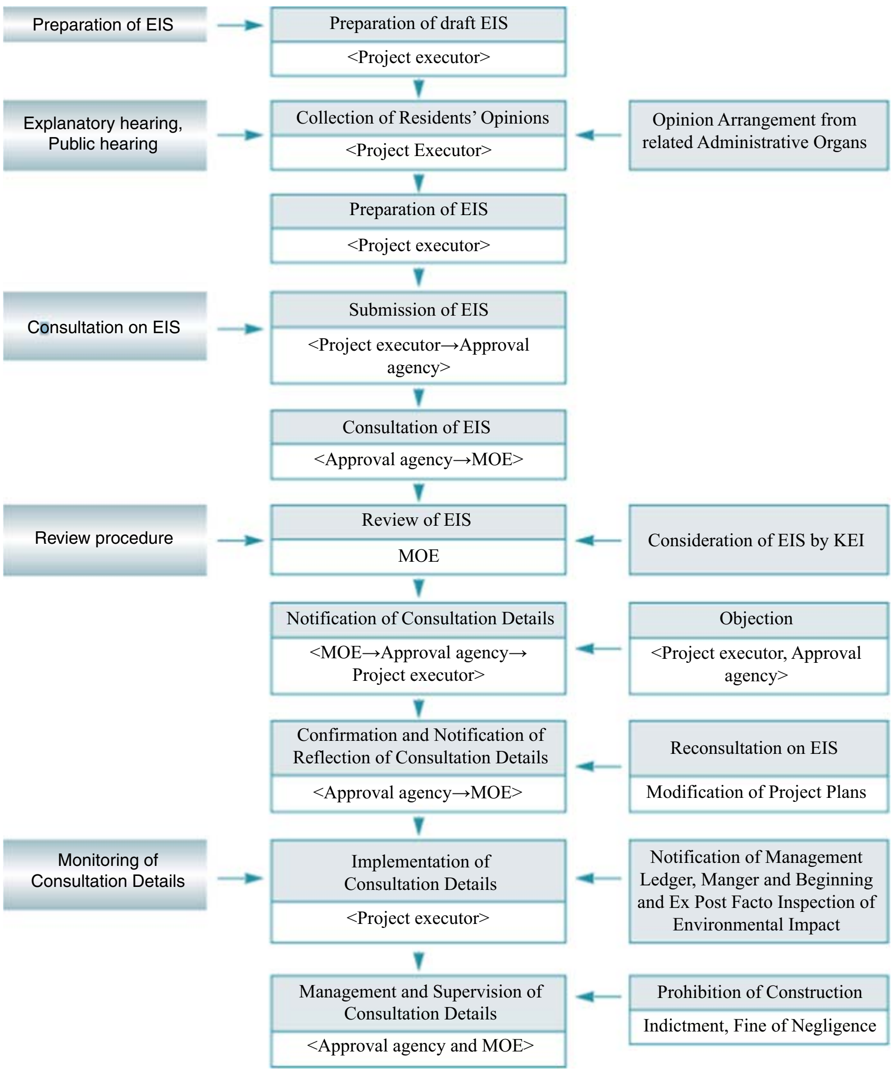


Figure 3.
Procedures of EIA

from measured points and investigation ranges that are among the items in the EIA statement, and attribute information is built.

Figure 4 depicts an overview of the EIASS system, which is based on various solutions and services, to provide prior EIA information and full EIA statements. The main users of an EIASS system are mostly public, consultation agencies, EIA statement publication agencies, and EIA statement reviewers. Through the web-based portal, the EIASS system delivers diverse services to users.

Spatial information for EIA projects is stored in a GIS DB. Spatial information is built for project sites; measured points and investigation ranges are among the items in an EIA statement; and attribute information is built, so that a geographic information system may provide project overview information and environmental quality measurement information.

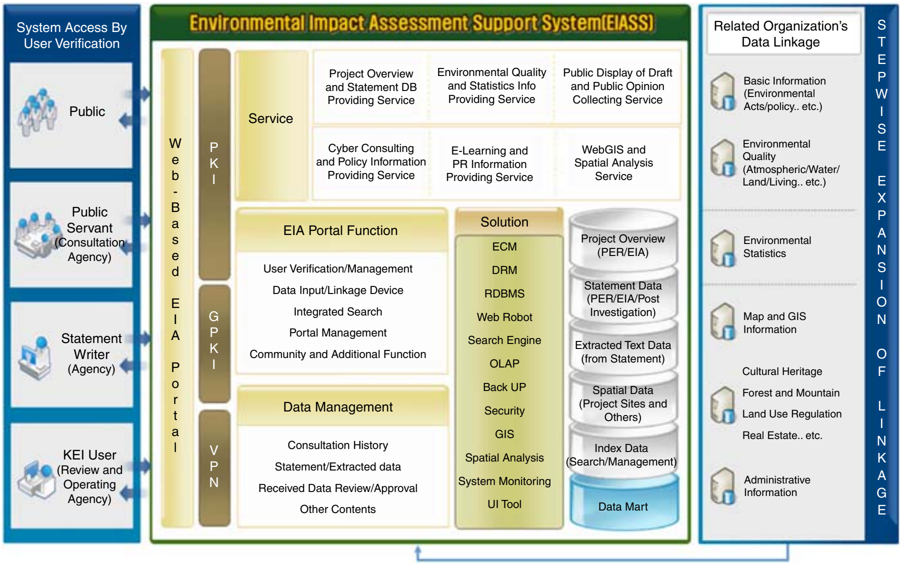


Figure 4.
EIASS system overview

Using a digital topographic map of 1:5,000 or 1:25,000 as a base map, depending on a scale of an image constructed in the EIA statement, an extracted image is matched to the digital topographic map (warping), and a project site, an investigation area and an investigation point are built through vectorizing.

Figure 5 shows an example of a geographical DB and Web-GIS system in EAISS.

2.5 Other EISs in South Korea

In South Korea, there are 23 different national and regional EISs. Each system has its own topic area (e.g. forest, heritage, underwater, air quality, foreshore, stream, landslide). Tables IV and V list nationwide EISs and local EISs in Korea. The governance of the nationwide EISs and the local EISs is decentralized and distributed to multiple responsible bodies and local governments. Therefore, system quality, service quality and data quality in each system are highly diverse. Also, budgets for local EISs are limited, so the main focus of the local EIS is to collect and monitor environmental data by sensors. The local EIS does not provide a user-friendly interface, and its public access is inconvenient.

Environmental research and problems are interdisciplinary (Bond *et al.*, 2010). In this case, an interdisciplinary approach is understood to be a means of integrating several natural and social sciences. The reference to interdisciplinarity is clear and is not to be confused with multi- or transdisciplinarity, which are sometimes mentioned in the context of impact assessment. To better support an EIA project, EIASS should integrate scattered information from over 23 different EISs. How can we enhance EIASS to interoperate with other EISs? One possible answer might be using an SOA to integrate distributed EISs.

3. System design using SOA

3.1 Service-oriented architecture in environmental information systems

SOA is a computer system architecture paradigm that views complex software systems as an interconnected collection of distributed computational components. Each component has a defined Web service interface that allows it to be loosely coupled with client applications. The service-oriented paradigm presents an attractive way of modeling the multidisciplinary

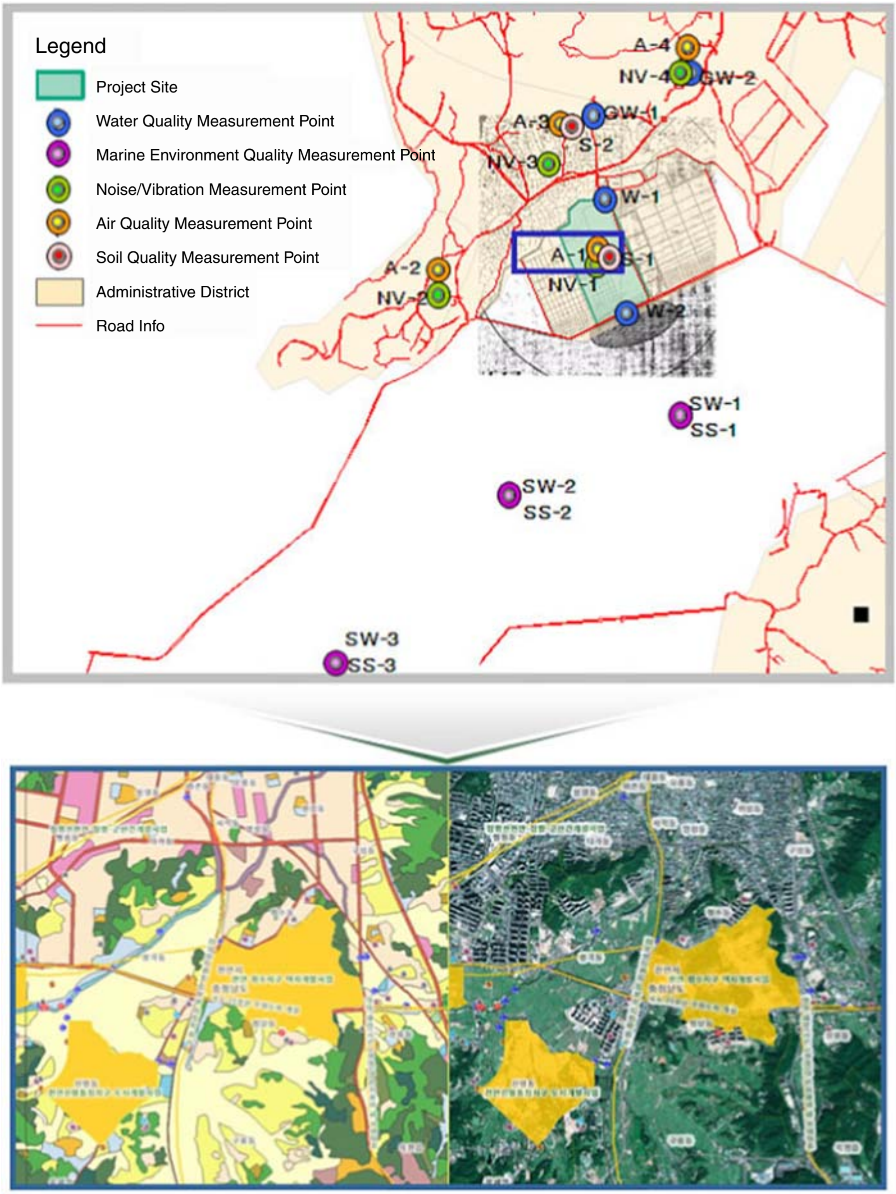


Figure 5.
Example of geographical DB and web-GIS system

EIS because it allows a diverse community of scientists and engineers to work independently on components of a larger modeling system (Goodall *et al.*, 2011).

Recently, attention has focused on SOAs as a means of building environmental decision-support systems (Mineter *et al.*, 2003; Granell *et al.*, 2010; Goodall *et al.*, 2011; Horsburgh *et al.*, 2009). In service-oriented computing, a software system is viewed as a collection of independent components or services that are loosely coupled and are able to exchange data with one another over a computer network (Curbera *et al.*, 2002;

System	Responsible body	Objective	Main contents
KLIS (Korea land information system)	Ministry of Public Administration/ Ministry of Land	Integrate two different land use information	Title deeds, specific use area
LURIS (land use regulation information service – luris.mltm.go.kr)	Ministry of Land	Provide regulation information for specific use area	Six land use information guide, detail limitation 6,400
Costal management information system (www.coast.kr)	Ministry of Land	Manage the spatial resource of coastal areas more efficiently and in sustainable manners through collecting database	Costal information map
Korea tidal flat information system (www.tidalflat.go.kr)	Ministry of Land	Support systematic the Korea tidal flat information	Marine reserve tidal map
Water management information system (www.wamis.go.kr)	Ministry of Land	Providing service including water resources information scientifically collected, created, and processed for water-related organization	Hydro/meteorology, basin, river, dam, groundwater, water use, etc. (300 items)
Environmental conservation value assessment map	Ministry of Environment	To assess the environmental value information of the country comprehensively and scientifically	Natural environment (14) water environment (11) others (31)
Ecological map	Ministry of Environment	Development ecological map	
Environmental GIS (http://egis.me.go.kr)	Ministry of Environment	Provide GIS DB	
Ground water information (http://sgis.or.kr)	Ministry of Environment	Provide integrated water ground information	
National noise information center (www.noiseinfo.or.kr/)	Ministry of Environment	To provide the information about the current operation status on the measurement of the environmental noise (automatic, manual), aircraft noise, railway noise, road vibration nationwide, and to use the information on minimizing the noise through the service of the measuring noise in the country	
AirKorea (www.airkorea.or.kr)	Ministry of Environment	Overall grasp of the real-time air-quality data across the country	PM-10, O_3, CO, SO_2, NO_2
Korea soil information system (http://asis.rda.go.kr)	Rural Development Administration	Characteristics of soil	

Table IV.
Nationwide EISs in South Korea

		Environment information	Major contents	Website
Seoul	Statistics	Population, traffic	Statistics of population, traffic	gis.seoul.go.kr
	Air quality	Measurement of air quality	O_3, SO_2, NO_2, CO, PM10	air.seoul.go.kr
	Water quality	Measurement of water quality	PH, DO, BOD, SS, COD, T-N, T-P	env.seoul.go.kr
Busan	Air quality	Measurement of air quality	O_3, SO_2, NO_2, CO, PM10	www.bihe.re.kr
	Water quality	Measurement of water quality	PH, DO, BOD, SS, COD, T-N, T-P	
Daegu	Air quality	Measurement of air quality	O_3, SO_2, NO_2, CO, PM10	air.daegu.go.kr
	Water quality	Measurement of water quality	Cd, As, CN, Hg, Pb, Cr+6, PCB, ABS	www.dgwater.go.kr

Table V.
Local EISs in South Korea

Huhns and Singh, 2005). Service orientation is a core concept behind distributed computing, where the internet is not only used for delivering information from machines to humans, but also between machines themselves (Huhns and Singh, 2005; Foster *et al.*, 2001). Service-oriented science, which refers to scientific research enabled by distributed networks of inter-operating services, was coined by Foster *et al.* (2001). The concept of service orientation shares much in common with component-based modeling, as described by Argent (2004). Each service acts as a component that is an autonomous entity capable of responding to requests instantiated by outside entities. The primary distinction between service-oriented computing and component-based modeling is that service orientation implies distributed components interoperating over a network (Huhns and Singh, 2005). This distinction carries important design and use implications, which are discussed in this paper.

Previous work in applying web services within the water resource community has focused primarily on exposing historical databases (Goodall *et al.*, 2011), integrating water data across heterogeneous data providers (Horsburgh *et al.*, 2009), or on data processing workflows using web services (Granell *et al.*, 2010).

3.2 Service-oriented architecture for EIASS

The interdisciplinary environmental tasks require integration of environmental information drawing from multiple decentralized EISs that usually cover a thematic domain (e.g. air, water and land). EIASS is an IS that deals with geospatial data and services. It allows the user to store, query, and process environmental information and visualize it in thematic maps, diagrams, and reports. Thus, EIASS is associated with heterogeneous sensors and/or environmental systems that cover a thematic domain. From an IS perspective, local and nationwide EISs are autonomous modules with a high level of inner cohesion. They only provide a limited view to end users. Information integration can be implemented by a loose coupling of EIS. SOA would be the best approach for these requirements. The SOA approach enables the sharing of geospatial data and services as well as their composition to higher-level integration across heterogeneous systems in a loosely coupled but controlled manner.

In this study, we propose a new architecture for EIASS using SOA. Figure 6 presents the business process among EIASS, nationwide EISs and local EISs. By identifying the business process, we can see how the system could be connected. Also, because processes are the basic elements of the services, the process diagram can identify service requirements. The local EIS system stores environmental sensor and monitor data, which should be transferred to the national EIS system through Web services. The national EIS system provides only thematic data because the responsible body of each thematic system varies. The EIASS system will integrate all thematic systems and provide all dimensions of environmental information to diverse users.

Figure 7 presents the conceptual system architecture of the integrated EIASS using SOA principles. The EIASS integrates a set of modules, including client components, services, interfaces and databases. All the thematic nationwide EIAs are loosely coupled with EIASS through this architecture. The proposed architecture consists of four layers: EIASS portal layer, interface layer, services layer and data layer. Components and services in each layer perform similar tasks. The components belonging to the EIASS portal layer contain two layers: presentation layer and application layer. The presentation layer handles the user interface, user experiences, and data visualization. The application layer contains service client, forecasting logic, and general-purpose modules. The EIASS portal module plays the role of a one-stop portal as a gateway to facilitate connection to other remote services. The EIASS portal controller plays a central role in the architecture managing interactions between the presentation layer's and application layer's module. The general-purpose module contains functions present in most current web applications. The service client module in the EIASS portal layer allows users to communicate with service instances at the service layer.

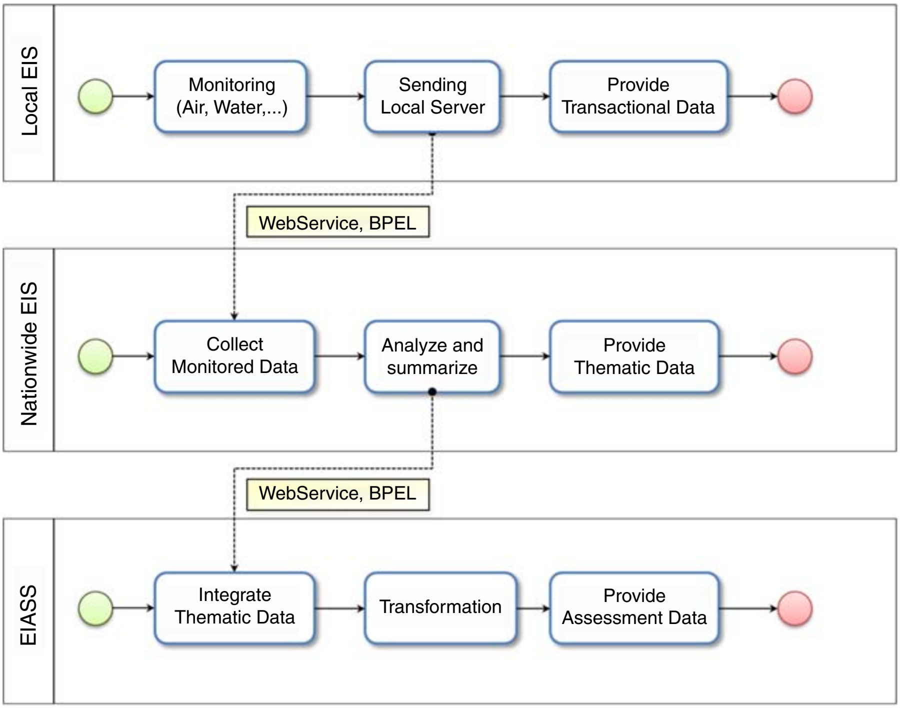


Figure 6.
Work process among EIASS, nationwide EISs and local EISs

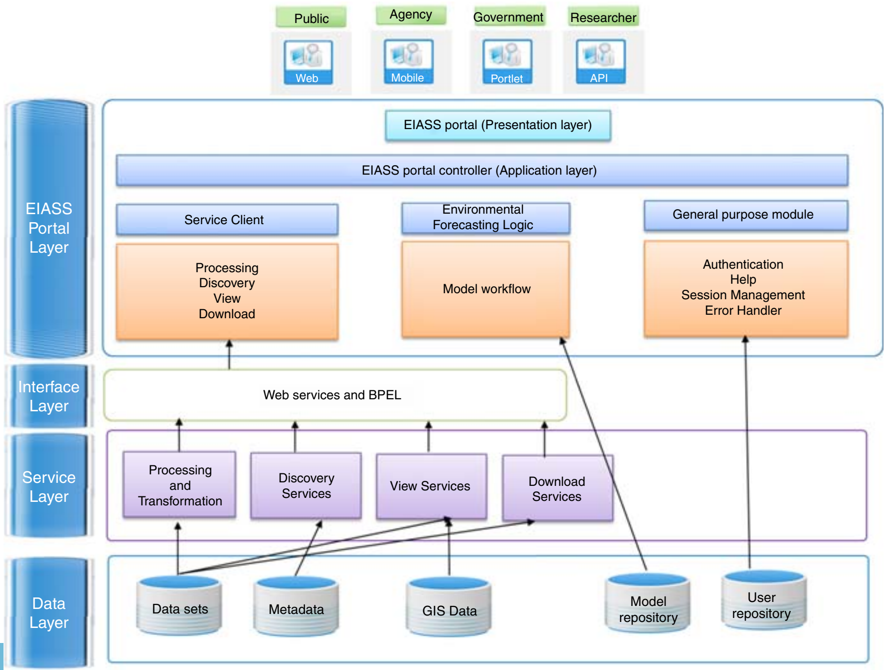


Figure 7.
Conceptual system architecture for the integrated EIASS

The service layer comprises a variety of distributed service instances (transformation, discovery, view and download). Service interoperability is achieved by the interface layer. Interfaces are critical in SOA because they indicate how to interact with available services from heterogeneous systems. The data layer contains databases, data repositories and metadata registries.

Figure 8 shows the hardware architecture for integrated EIASS. Each thematic nationwide EIA will connect to the service repository through web service or business process execution language, and end users will use multiple devices to access the service repository.

4. User benefits of SOA architecture for EIASS

4.1 DeLone and McLean's IS success

To assess the value of the proposed EIASS SOA architecture, the perspective of end users is crucial because the main objective of the EIASS is to disseminate EIA information to the public. We refined DeLone and McLean's IS success model to examine the moderating effect of SOA readiness to EIASS user benefits. DeLone and McLean's (2003) IS success (D&M IS success) model provides a useful lens through which we can understand the effect of SOA implementation for the EAISS system success in a more integrative manner. The IS success model in Figure 9 can be interpreted as follows: an IS system can be evaluated based on three quality dimensions, i.e. information quality, system quality and service quality.

4.2 Research model and hypotheses

Building on DeLone and McLean, we have modified the D&M IS success model to elucidate how individual users assess the EIASS system success with SOA implementation. Figure 10 shows that the conceptual model consists of six constructs. By taking into account the characteristics of EAISS systems, the framework explicates how the two quality constructs moderated by SOA implementation affect user satisfaction and intention to use. In addition, the framework posits that extended use and satisfaction will influence individual benefits.

In this study, the SOA readiness refers to the level of the SOA implementation for the EIASS. We elaborated the SOA readiness using Arsanjani and Holley (2005)'s SOA

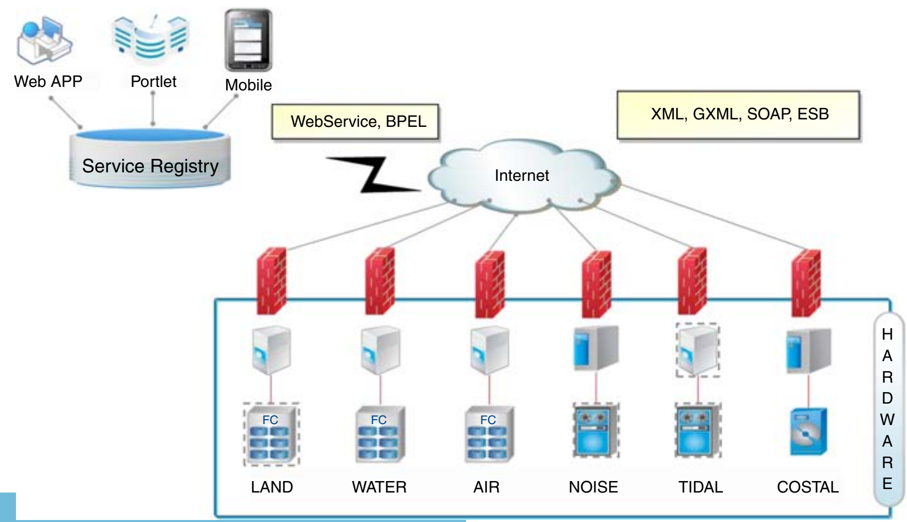


Figure 8. Hardware architecture for integrated EIASS

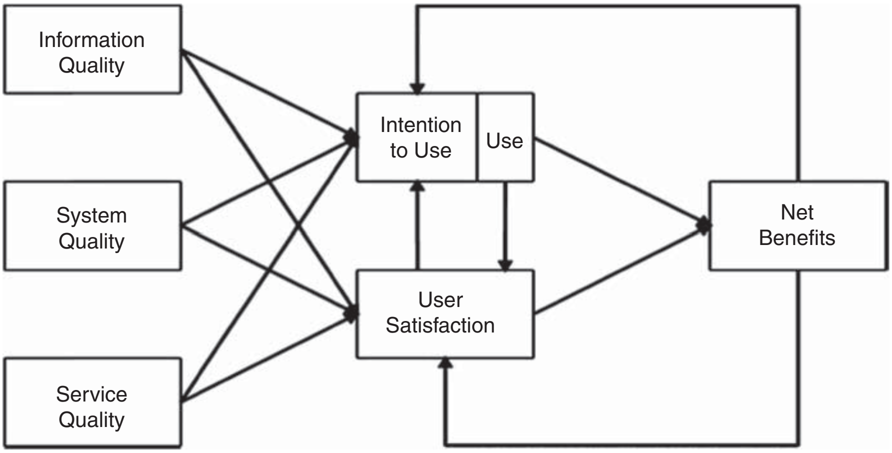


Figure 9.
DeLone and McLean (2003) updated IS success model

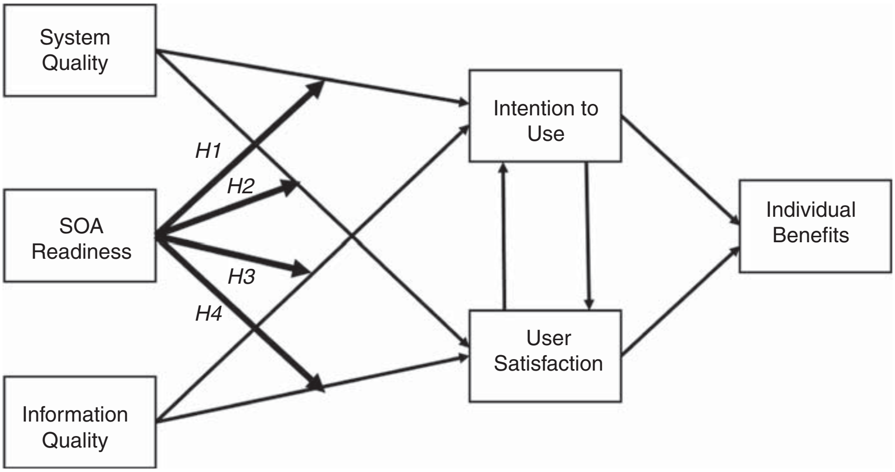


Figure 10.
Conceptual model

maturity model. The maturity model has four levels: Level 1 – implementing basic web services; Level 2 – SOA integration; Level 3 – enterprise-wide SOA adoption; Level 4 – on-demand business transformation. Figure 10 represents the research model. There are two quality-related constructs (system quality and information quality) and three constructs in regard to individual use and benefits. On top of these constructs, in this study we examine the moderating effect of SOA readiness on the effect of both system quality and information quality on user intention, along with user satisfaction. Because our focus is on the value of SOA readiness in EIASS, we only hypothesize the moderating effects of SOA readiness on the IS success constructs.

System quality is the level of IS performance, which includes system-related dimensions and task-related dimensions (Hsu *et al.*, 2015). Prior studies adopted the DeLone and McLean model to show the positive relationship between system quality and user intention, along with user satisfaction. Because SOA can integrate disperse systems and provide better system performance, SOA readiness can positively moderate the relationship between system quality and individual use and satisfaction on the EAISS. Thus, we provide the following hypotheses:

H1. SOA readiness enhances the relationship between system quality and individual intention to use the EAISS.

H2. SOA readiness enhances the relationship between system quality and user satisfaction.

The information quality refers to the quality of information that EAISS provides, which includes the accuracy of information, completeness of information, consistency of information, uniqueness of information and timeliness of information, helpfulness and relevancy. The higher level of information quality leads to higher levels of an individual's intention to use EAISS and satisfaction on the system. One of the distinct characteristics of SOA is to integrate information, i.e. SOA implementation integrates system as well as information across different EIS systems with EAISS. Therefore, the SOA readiness positively affects the relationship between information quality and an individual's intention to use systems and his/her satisfaction:

H3. SOA readiness enhances the relationship between information quality and individual intention to use the EAISS.

H4. SOA readiness enhances the relationship between information quality and user satisfaction.

4.3 Data collection and analysis

To test the proposed conceptual model, a survey questionnaire was designed to collect data on each of the model constructs. Questionnaire items were reviewed for content validity by two EIASS system developers and two power users. To pilot test, the survey was conducted with 38 system users. The 38 survey questionnaire participants consisted of local/national civil servants, EIA consulting agents and GIS system developers. In this sample, most respondents have more two years of IT education background at the college level, and the average year of EIASS system usage is 3.5. A short description of SOA for EIASS was given to survey participants.

All research constructs included in this study had multi-item scales derived from the relevant literature. Each item in the survey employed a five-point Likert scale. Discriminant validity measures the extent to which different constructs diverge from one another. In Table VI, the diagonal elements represent the square root of average variance extracted (AVE), providing a measure of the variance shared between a construct and its indicators. The square root of AVE is required to be larger than the correlations between constructs to meet the criteria for discriminant validity. The constructs used in the model meet the criteria.

	Mean	SD	System quality	Information quality	SOA readiness	Intention to use	Satisfaction	Individual benefits
System quality	3.52	0.60	0.75					
Information quality	3.30	0.65	0.55	0.77				
SOA readiness	3.47	0.59	0.31	0.42	0.92			
Intention to use	3.40	0.55	0.33	0.18	0.29	0.88		
Satisfaction	3.38	0.54	0.40	0.27	0.53	0.29	0.92	
Individual benefits	3.59	0.64	0.53	0.57	0.44	0.23	0.33	0.89

Table VI. Results of the measurement model

We used AMOS V18.0 as the analytical software to evaluate the pilot. The results of the structural model validate the moderating effect of SOA readiness. We find that the moderating effect of SOA readiness to system quality and information quality is statistically significant, and end user benefits would be increased by the proposed SOA architecture in Section 3.

5. Discussion and implications

The debilitating effects of natural disasters have led to an awareness of business issues relating to SCM network risk. Natural disasters disrupt the global economy far beyond local damage, as the effects trickle through supply chains causing uncertainty and chaos. An effective supply chain continuity plan should be created as part of a disaster plan by an SCM manager. Most SCM managers know that supply chain disruptions are serious and costly. However, it is difficult to prepare or estimate a supply chain disruption by natural disaster because only limited environmental information is available; further, this information is typically scattered among multiple systems. Possessing high-quality information is a critical decision-making factor for environmental issues and assessing the impact of natural disasters. SCM managers can exploit high-quality integrated environmental information, which the EIASS provides, to estimate the risk of a natural disaster within the geographical region of a supply chain.

The US National Research Council (2007) proposes a simplified four-phase model for an emergency management cycle, i.e. preparedness, response, recovery and mitigation. The activities in each phase can be improved by the EIASS connected to the local and nationwide EISs. For example, if SCM managers examine the environmental sensor data and geological vulnerability report for their supply chain route with EIASS, it is possible to change their SCM plan and avoid SCM disruption. Without an SOA approach, current EIASS cannot provide sufficient information to decision makers and stakeholders.

In this paper, we introduced the EIASS in South Korea, which is currently used as a reliable information resource for estimating potential environmental disasters; we also proposed an SOA approach to improve its quality. EIASS provides historical information about EIA projects and supports a geographical DB with a Web-GIS system. All information in the EIASS is publicly available. The EIASS system facilitates user search behaviors with a powerful web-GIS system and geographical DB. Without the EAISS, it would be difficult to obtain high-quality and integrated environmental information for a specific area or route.

The motivation for this work was to design a web-service-based architecture to integrate the solo phenomenon in South Korea EISs. Such an integrated model does not currently exist, yet is needed to achieve a national infrastructure for efficient decision-making about sustainability policies and mitigating the impact of natural disasters. We explored current local and nationwide EISs in South Korea and their data sets. The EIASS can act as an environmental information portal that provides historical EIA information to evaluate the potential risk of a natural disaster in an SCM by integrating all of South Korea's local and nationwide EISs. Therefore, we propose an SOA design for EIASS. While a complete solution to the challenges of integrated EIS with an SOA in South Korea is beyond the scope of this paper, our intention is to begin a dialog on SOAs in EIS in order to address the importance of an integrated view in environmental decision-making to mitigate the impact of natural disasters. A large part of this effort is focused on identifying both the benefits and challenges of service orientation.

The possible disadvantages of a web-services approach for environmental modeling are related to the loosely coupled, web-based architecture of services that can result in performance, reliability and security issues. Performance challenges in using web services for EIASS primarily relate to tightly coupled process interactions that may require large data transfers, particularly when initializing and parameterizing the environment domain, or from computational tasks with long computing times. In addition to performance issues, the reliability of services can also be a disadvantage in service-oriented modeling approaches. There is the possibility of remote servers becoming temporarily unavailable, thereby disrupting all client applications dependent on that service. Finally, security must be considered to prohibit unauthorized users and to track the overuse and abuse of services. Many of these issues are addressed by existing technologies such as grid infrastructures (Foster *et al.*, 2001), which can be used to enhance the applicability of SOAs for modeling. Furthermore, adoption of the IoT and emerging wireless networking technology in EIASS applications would be considered as future research topics.

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Appendix

Variable	Item
System quality	I find the EIASS easy to use
	I find it easy to get what I want in the EIASS
	The EIASS is flexible to interact with
	I find it easy to learn EIASS
Information quality	The information generated by the EIASS is correct
	The information generated by the EIASS is useful
	The EIASS generates information in a timely manner
	I trust the information output of the EIASS
SOA readiness	The EIASS enable to access the local EISs
	The EIASS enable to access the nationwide EISs
	The EIASS enable to compile information from external systems
	The EIASS enable to integrate information from heterogeneous systems
Intention to Use	Using the EIASS enables me accomplish tasks more quickly
	Using the EIASS has improved my job performance
	Using the EIASS has made my job easier
	I find the EIASS useful in my job
User satisfaction	I am satisfied with the functions of the EIASS
	The EIASS has eased my work processes
	I am generally satisfied with EIASS
Individual benefits	The EIASS will help overcome the limitations of the paper-based process
	Using the HIS will improve the EIA process
	The EIASS facilitates easy access to relevant information
	The EIASS will enhance communication efficiency
	The EIASS use will improve an efficiency of decision making

Table AI. Survey items

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