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# Earth Information System (EIS) for the Reuse of Resources between Construction Sites

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## Abstract

Surplus resources such as earth and rocks are wasted at many construction sites by not being reused at other sites, which increases costs and creates environmental problems. This material could be reused if information on the surplus resources and needs of each construction site were shared. A Web-based earth information system (EIS) has been developed in Korea with the aim of reducing the cost of public work projects to enable real-time sharing of the required resource information among construction sites. This study evaluated the effectiveness of EIS by analyzing whether it could support resource-sharing activities among construction projects and whether these activities could reduce both the waste of resources and the cost of construction. The viability in EIS was examined from a high level system perspective. EIS was reported to cut costs by disposing of surplus resources to other sites through resource transactions. However, an analysis of the actual shared volume of earth and rocks showed that the registered volume was not updated in real time. The problems identified are compared to the conceptual model of EIS, and some improvements are suggested.

**Keywords:** resource reuse; information technology; Internet; system analysis; sustainable construction

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## 1. Introduction

Surplus resources such as earth and rocks at construction sites are often wasted. Some sites export surplus earth and rocks to remote landfills, while others develop borrow pits or buy earth and rocks for their backfill needs.

As Fig.1. shows, when a surplus exists between the excavation and backfill of earth and rocks at a site, the surplus volume is often wasted, and when a gap exists, a difficulty may arise in obtaining the required volume. The information on the volumes for excavation and backfill is maintained only as a project record for a construction site and is not shared among different projects. This type of need is not shared because most participants in the construction industry take these circumstances for granted. They assume that the lack of reuse is due to the location of the construction site and the uncertainty of resource planning during the design and engineering process.

We propose an information technology (IT) solution to this resource-wasting problem. It is based on the

idea that surplus earth and rocks could be reused if the information regarding the surplus resources and needs of each construction site were shared. Since IT has been recognized as one of the enablers or facilitators for achieving construction business innovation and integration (Jaafari 2001), the use of information infrastructure has led to effective information transfer, regardless of the physical separation and type of hardware. Business activities and transactions can be performed over the Internet (Zhang and Tiong 2003), and geographical information systems (GIS) are used for the management of spatial information (Li *et al.* 2003). Moreover, wireless network access through widespread mobile phone networks has been growing. Applying these technologies at construction work sites has extended the opportunities to communicate and share resource information beyond the immediate location of the site.

Based on this concept, a Web-based earth information system (EIS) has been developed, which enables real-time sharing of information on required resources among construction sites. This study evaluated the effectiveness of EIS by analyzing whether it could support resource-sharing activities among construction projects and whether this resource sharing reduced the waste of resources and unnecessary construction costs.

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### Current Earth and Rocks Information Management

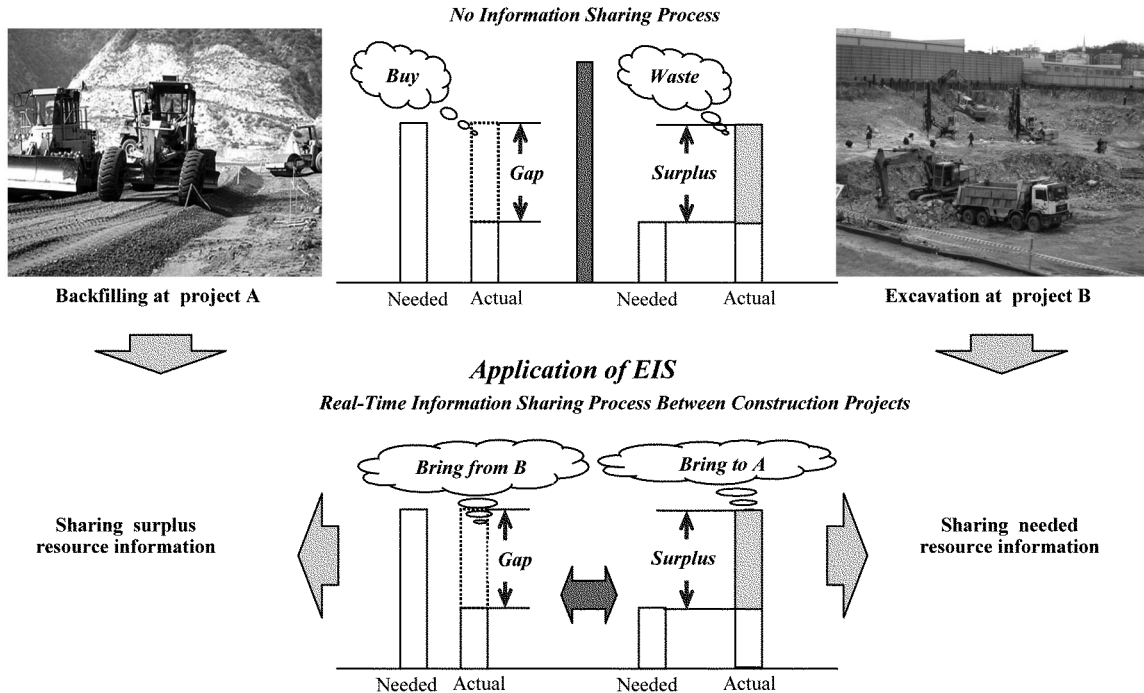


Fig.1. Current Status of Earth and Rocks Resources, and the Need for EIS

## 2. EIS (Earth Information System)

### 2.1 Viability of EIS

The development of EIS was supported by the Korean government as a part of its effort to reduce the cost of public projects. However, to promote the widespread use of EIS among participants, it is necessary to ensure its viability and sustainability.

A preliminary study had examined the viability of EIS using a causal loop, as shown in Fig.2.

Causal loop diagrams are basic cognitive mapping techniques that provide a method of capturing multiple

cause-and-effect relationships (Morecroft and Sterman 1994, Peña-Mora *et al.* 1997).

This diagram was developed to assess whether EIS was viable and operationally sustainable.

The reuse of surplus earth and rocks will reduce the waste of resources and provide opportunities to reduce project costs, thereby increasing the benefits to construction companies.

The systematic information management of earth and rocks is one of the key factors for the successful application of EIS. It is not only a primary strategy to

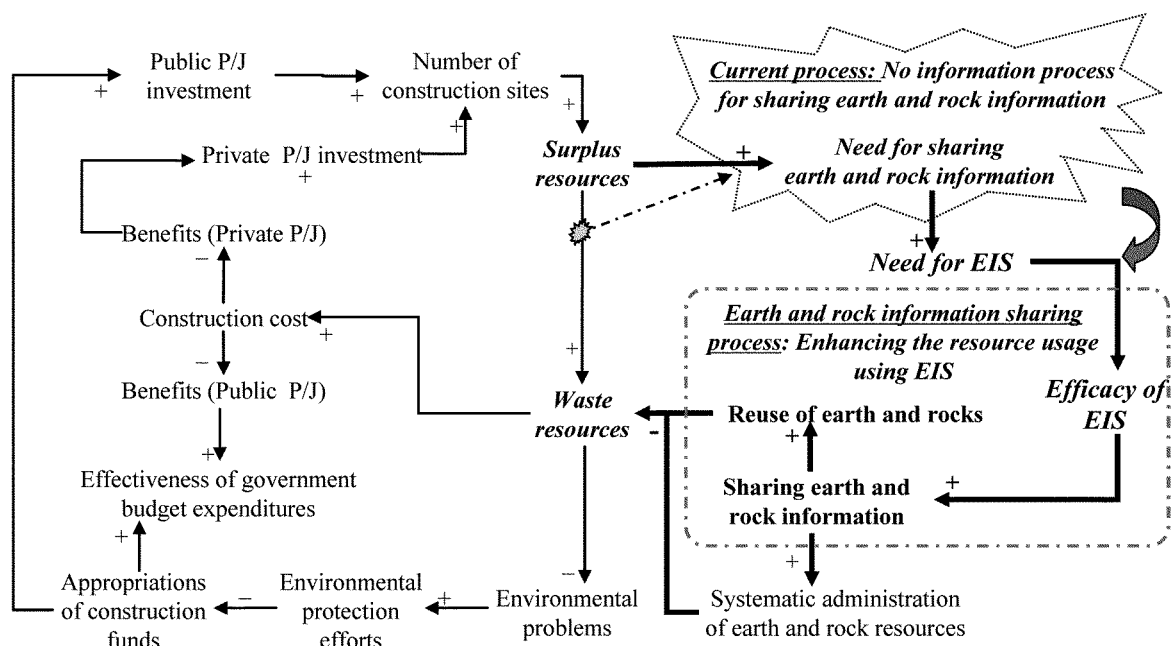


Fig.2. Viability of the EIS

promote EIS for improving information sharing about earth and rocks, but it also enables the government to monitor the current nationwide status of earth and rocks, allowing the systematic administration of this resource.

EIS was used on public projects to validate its effectiveness. Privately controlled projects could be induced to use EIS if they could search and share the data generated by public works, and cost reductions in public projects may lead to an improved efficiency in government budgeting and expenditures. This reuse of resources can also reduce environmental problems without the need to introduce environmental protection efforts for construction sites.

### 2.2 A conceptual model of EIS

Effective implementation of an information system requires careful consideration of the interrelated components needed to form the system. This includes hardware, software, people, structure, operating procedures, politics, and culture (Laudon and Laudon

1994, Vickers 1999).

In general, it is desirable and necessary to apply advanced IT to encourage the industry to use resources more efficiently. In particular, it is important to develop a resource information sharing system to revolutionize the resource reuse process among construction sites. Based on this vision, a conceptual model of EIS was created, and is shown in Fig.3.

EIS can enhance the effectiveness of earth use by transferring the surplus resources and needs of each construction site into the shared information system.

The operational activities of EIS were designed around three subsystems: input, search, and statistical report, supplemented by other functions to facilitate user-friendliness.

The input subsystem allows an owner agency to enter the basic project information and related earth or rock information. This could include such information as site location, earth or rock type, designed or scheduled volume of excavation or backfill, and plans

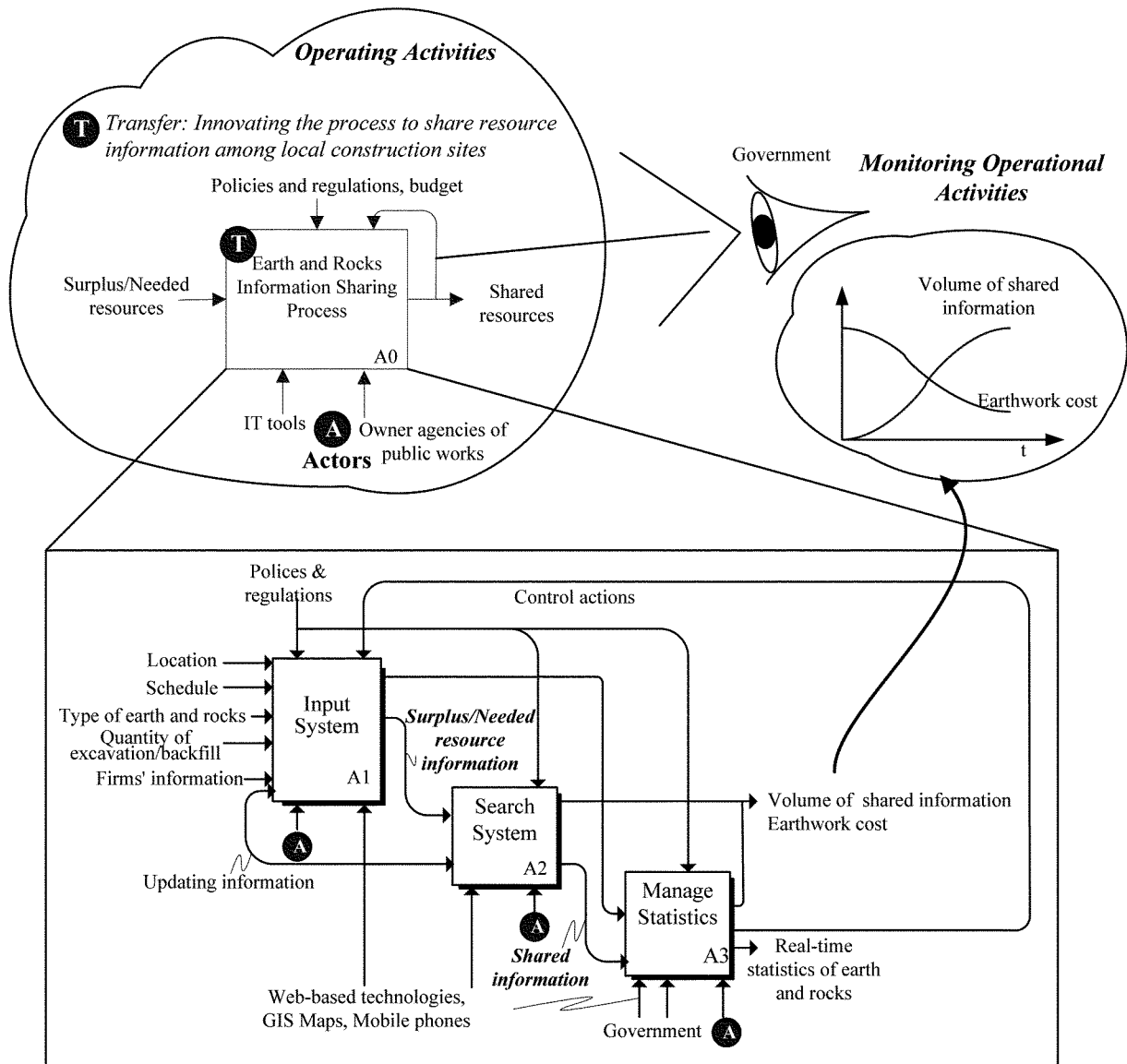


Fig.3. A Conceptual Model of the EIS

for delivery to other sites.

The earth information search system enables users to find earth and rock information by the administrative zone such as city, county, and district using a simple mouse click.

The earth information statistics system provides real-time statistics for the volume of excavation or backfill and identifies the state of information sharing. This subsystem allows a government agency to view the real-time statistics of the earth resources throughout the country.

The scope of earth and rock information management includes not only the construction phases but also the design and engineering phase. Therefore, EIS will be able to manage earth and rock resources until the completion of the delivery and issue, predicting the demand from other project designs, and tracking the resource movement to the construction phases. Fig.4. shows the system use and data processing by project phase.

The design of EIS allows users to acquire earth and rock information regardless of time and space constraints. Web-based technologies and mobile communications permit the system to be used in the field. The GIS function is used to enter location

information by clicking on GIS MAP objects and pointing to the location information, and mobile phone text messages (short message service, SMS) can be used without accessing the Internet. If the user enters the location information using the GIS, the SMS automatically sends the information in accordance with the conditions contained in the database.

The main users of EIS who perform information-sharing activities are the owner agencies of public works. Owner agencies have both the responsibility and authority to register all the information that is relevant to a project. After the owner agency registers a project, the project participants such as designers, contractors, and supervisors are able to search the detailed information on surplus or required resources.

As owner of the EIS, the government must create the regulations required to run it successfully, and constantly monitor the volume of shared resources and reduction in environmental waste. EIS is slated for introduction by legislation through the Korean Regulations for Construction Industry and its Enforcement Decree. In addition, the use of earth and rocks generated in public works will mandate the application of EIS.

EIS development was completed in December 2004.

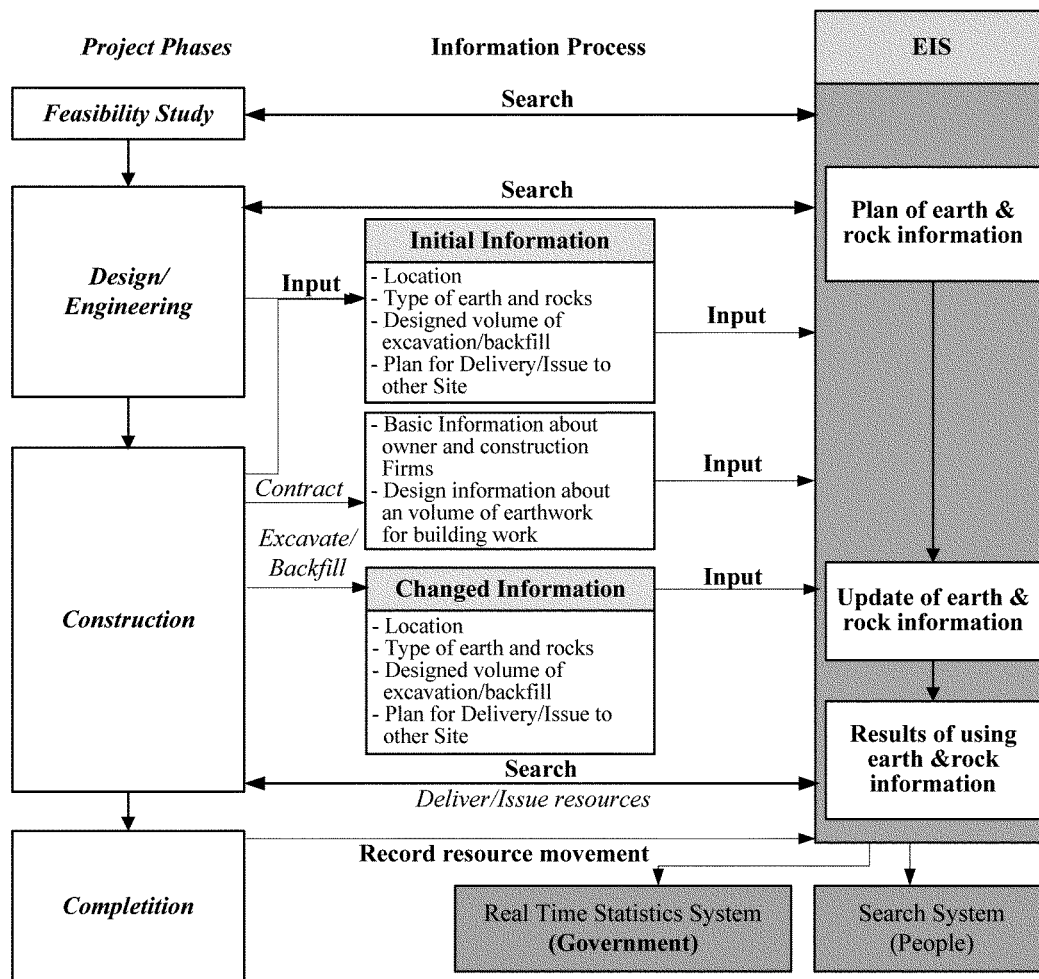


Fig.4. System Use and Data Processing

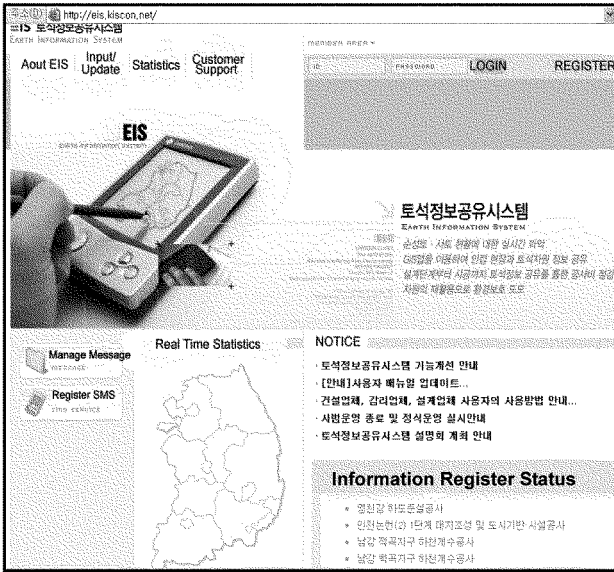


Fig.5. Main Menu of the EIS\*

\* Since EIS is used only in Korea, the language of the Web site is Korean. In this paper, however, we have translated the main terms into English.

Fig.5. shows the main menu of the system available to users on the Internet at <http://eis.kiscon.net>.

Internal testing occurred in January and February 2005. A further pilot trail took place in May 2005 with 27 public owner agencies. Since June 1, 2005, EIS has been fully open to public construction projects.

### 3. Evaluation of the EIS

#### 3.1 Framework of the analysis

To conduct validity testing according to Fig.2, it is understood that once the effectiveness of the EIS was validated, information sharing about earth and rock resources would increase. This would lead to more opportunities to share resources and reduce construction costs. Based on this assumption, the

analysis criteria were established as shown in Table 1.

First, the effectiveness of the EIS was evaluated by conducting a survey of EIS users. The questionnaire was composed of questions related to the need for the EIS, the usefulness of its functions (Mahmood and Jeanette 1985) and its ease of use (Srinivasan 1985).

Second, the actual state of sharing resources using the EIS was assessed by investigating the information registered in the system and interviewing those in charge of system operations and management (O&M). The sharing status was based on the number of projects registered and updated in the EIS, and the volume of excavation or backfill. The O&M manager was interviewed to analyze how the process was controlled to guarantee accuracy (Bailey and Sammy 1983, Miller and Doyle 1987, Srinivasan 1985, Whyte *et al.* 1997), relevance (Bailey and Sammy 1983, Mahmood and Jeanette 1985, Miller and Doyle 1987, Srinivasan 1985), and timeliness (Bailey and Sammy 1983, Miller and Doyle 1987, Srinivasan 1985) of the registered information.

Finally, benefits of the EIS were verified by calculating the reduced disposal cost of wasted resources identified through resource transactions.

#### 3.2 Analysis results

##### (1) Effectiveness of the EIS

After the EIS was implemented, a survey was conducted to investigate the present status of sharing earth and rocks, and verify the need for and usefulness of using the system. During June 2005, 86 private construction firms and 93 publicly owned agencies responded to this survey.

##### ▪ Need for the EIS:

As shown in Table 2., the majority hoped to share information (Q1), agreed with implementing the EIS (Q2), and were willing to use the EIS (Q3).

##### ▪ Usefulness of the EIS:

Construction firms and agencies expected the

Table 1. Analysis Criteria

Criteria	Variables	Analysis methods
Effectiveness of the EIS	<ul style="list-style-type: none"> <li>▪ Need for the EIS</li> <li>▪ Usefulness of the EIS</li> <li>▪ Ease of use</li> </ul>	Survey of EIS users
Status of shared resources	<ul style="list-style-type: none"> <li>▪ Volume of excavation/backfill</li> <li>▪ Number of construction projects</li> <li>▪ Volume of shared resources</li> <li>▪ Updated information</li> </ul>	Analysis of the resource information registered in the EIS
	<ul style="list-style-type: none"> <li>▪ Accuracy (Use of the system is easy in terms of sharing resources)</li> <li>▪ Relevance (The system can provide sufficient information to share resources)</li> <li>▪ Timeliness (The system can provide up-to-date information on time)</li> </ul>	Interview with the EIS O&M manager
Benefits of the EIS	<ul style="list-style-type: none"> <li>▪ Benefits from the reduced disposal cost of wasted resources</li> </ul>	Survey of the transaction cases

application of the EIS to keep costs down (Q4); the responses showed an average savings of about 4.4% in earthwork costs. They also supported increased transparency of public works (Q5).

▪ Ease of use:

During August 2005, an online survey was also conducted of the 112 users who had registered in the EIS. Of these, 85% responded that the system was easy to use in terms of sharing earth and rock resources. However, the other 15% found this difficult. The system details are under constant revision to increase usability. The EIS O&M support staff have been responding to a daily average of 10 queries by e-mail or phone. A further 122 question and answer messages have been registered on the EIS bulletin board.

**(2) Status of shared resources**

The periods of registering new data and the cycle of updating the old data were examined to clarify the

statistics of EIS use. For the sake of accuracy, the analysis covered only the data entered after June 2005 when the system was declared operational.

Table 3. lists the registered users and the volume of resources.

On August 10, 2 months after the EIS was opened to public construction projects, 988 users and 1,134 projects were registered in the EIS database. The number of registered users increased to 1,868 after 1 year.

In August 2005, 134 million m<sup>3</sup> of excavation and 183 million m<sup>3</sup> of backfill were registered from 42.5% of the current public work projects. In addition, 17 million m<sup>3</sup> of excavation and 20 million m<sup>3</sup> of backfill were reported as being shared. A year later, 121 million m<sup>3</sup> of shared earth and rock resources were registered in the EIS database. By August 2007, this figure was 70 million m<sup>3</sup>.

Table 2. Survey Results on the Need and Usefulness of EIS

Variables	Questions & Answers; Contractors' responses (%); Owners' responses (%)	□ Contractors □ Owners
Need for the EIS	Q1. Are you sharing information on excavation/backfilling with other agencies (or firms)? ① <b>Hope to share information, but it is very difficult;</b> <b>C: 50 (58%), O: 52 (56%)</b> ② Sharing information, but few agencies (firms) are involved and utilization is not efficient; C: 20 (23%), O: 20 (22%) ③ Sharing and using information partially with acquainted agencies (firms); C: 8 (9%), O: 7 (8%) ④ Sharing and using information well with agencies (firms) at nearby construction sites; C: 8 (9%), O: 14 (15%)	
	Q2. What is your opinion on implementing an earth and rock information system (EIS) to provide an information sharing ability? ① <b>Strongly agree; C: 32 (37%), O: 43 (46%)</b> ② <b>Agree; C: 33 (38%), O: 28 (30%)</b> ③ Disagree; C: 21 (24%), O: 16 (17%) ④ Strongly disagree; C: 0 (0%), O: 6 (6%)	
	Q3. If the EIS is implemented, what would your firm's usage level be? ① <b>High willingness to use; C: 13 (15%), O: 20 (22%)</b> ② <b>Willingness to use; C: 66 (77%), O: 62 (67%)</b> ③ Would not use; C: 5 (6%), O: 10 (11%) ④ Would not use because no related earth and rock works exist; C: 2 (2%), O: 1 (1%)	
	Q4. What cost reduction can be expected from the application of the EIS? ① <b>Strongly cost-effective (10% of earthwork cost);</b> <b>C: 9 (10%), O: 8 (9%)</b> ② <b>Cost-effective (5% of earthwork cost); C: 38 (44%), O: 48 (52%)</b> ③ <b>Marginally cost-effective (1% of earthwork cost);</b> <b>C: 27 (31%), O: 26 (28%)</b> ④ No effect; C: 12 (14%), O: 11 (12%)	
Usefulness of the EIS	Q5. Do you agree with supplying earth and rock information generated from public works via the Internet to increase the transparency of public works? ① <b>Strongly agree; C: 20 (23%), O: 24 (26%)</b> ② <b>Agree; C: 63 (73%), O: 64 (69%)</b> ③ Disagree; C: 3 (3%), O: 1 (1%) ④ Strongly disagree; C: 0 (0%), O: 4 (4%)	

Table 3. Statistics of EIS Use

	Number of users	Volume of resources (million m <sup>3</sup> )		
		Excavation	Backfill	Shared
Aug. 2005	988	134	183	37
Aug. 2006	1,868	230	315	121
Aug. 2007	3,062	117	258	70

### (3) Benefits of the EIS

In July 2007, a survey was conducted to investigate the benefits of transactions from confirmed business relationships between construction sites using the EIS. Table 4. shows 11 such transactions. In the case of the transaction between Project A and Project I, Project A responded that the benefit amounted to \$77 K by reducing disposal cost of 20,000 m<sup>3</sup> of excavated material. Project I saved \$229 K by accepting the sand from Project A. Thus, a 20,000 m<sup>3</sup> resource transaction produced a total direct benefit of \$307 K to both parties. Project A also responded that its benefits would have been \$382 K if Project H could have accepted all 53,092 m<sup>3</sup> produced. For all 11 transactions involving 570,808 m<sup>3</sup> of surplus resource dispersed to other construction sites, the total benefit was reported to be \$3,919 K.

### 3.3 Problems and improvements in the EIS

The analysis of the actual shared volume demonstrates that the quantity of the earth and rocks registered in the EIS database was not updated in real time. In total, 2,351 individual data records of earth and rock information for the 1,136 construction projects are registered in the system. Of these, 1,176 were entered after June 2005. Approximately 10% (110) were confirmed to have been delivered or issued to other construction sites, while the remaining 90% (1,066) had no records for such a delivery or issue. The reason that no record for delivery or issue were

entered is that no clear delivery or issue plans were implemented in the design phase, or the users did not enter or update the information when the delivery or issue actually occurred.

When we examined the database on October 18, 2006, we found 599 records in which the delivery or issue plans were not entered after a prearranged date, that is, cases in which the earth and rocks were in short supply at the start of an earthworks project. The number represented 55% of all the records. That is, at least 55% of the earth information was registered in the design phase but the corresponding delivery or issue plans were not updated on a timely basis.

Based on this analysis, the following problems became apparent in the sharing of earth and rock information using the EIS. First, the volume of resources entered in a project design phase was not updated as construction progressed. Second, the volume of shared resources was not changed even after a change occurred in the available volume due to the sharing of resources. These problems are due to the lack of an updating procedure for making changes in the EIS process in the EIS conceptual model.

The following improvements were suggested to record and track the changes to EIS data. The first problem can be solved by forcing the input of the changes as construction progresses. The second problem can be solved by establishing regulations that force all earth and rock information to be shared in the EIS.

## 4. Conclusions

An increase in sustainable construction has occurred worldwide. Sustainable construction is a strategy aimed at encouraging the industry to use resources more efficiently, limit the environmental impact of its activities, and produce buildings and infrastructure that benefit everyone (Myers 2004).

Table 4. Transaction Cases

Case	Transaction source			Transaction destination			Transaction totals		
	Project	Type of resource	Benefits (\$ K)	Project	Type of resource	Benefits (\$ K)	Type of earth and rock	Volume of transaction (m <sup>3</sup> )	Benefits (\$ K)
1	A	Excavation	77	I	Backfill	229	Sand	20,000	307
2	B	Backfill	56	J	Excavation	118	Sand	34,554	174
3	A	Excavation	305	H	Backfill	330	Sand	53,092	635
4	C	Backfill	54	K	Excavation	15	Sand	14,543	69
5	D	Excavation	100	L	Backfill	80	Sand	17,841	180
6	E	Backfill	249	M	Excavation	459	Blasting rock	210,000	708
7	F	Excavation	106	N	Backfill	0	Sand	44,778	106
8	G	Excavation	418	O	Backfill	47	Sand	46,000	465
9	G	Excavation	273	O	Backfill	30	Sand	30,000	303
10	G	Excavation	546	O	Backfill	61	Sand	60,000	607
11	H	Backfill	177	P	Excavation	188	Sand	40,000	365
Total			2,360			1,558		570,808	3,918



This study presented the need of applying advanced IT to encourage the construction industry to use resources more effectively. To this end, this study evaluated the effectiveness of a system that could support resource-sharing activities among construction projects to reduce construction costs. A conceptual model of EIS was developed with regard to the viability based on the efficiency and cost-effectiveness.

The implementation of EIS provides the following benefits: an opportunity for cost reduction, improved environmental protection by supporting the timely supply of earth and rocks from neighboring districts, the collection of real-time or periodic statistics to enable knowing the status of excavation and backfill in the country, and efficient government budget expenditure by ensuring the efficiency of construction and the reuse of resources. From the user survey results, application of the EIS is expected to achieve an average cost reduction of 4.4% in earthworks projects.

However, the analysis of the actual volume of the shared earth and rocks demonstrated that the volume registered in the EIS was not updated in real time due to the lack of an updating procedure for making changes in the EIS process. Some process improvements have been suggested to record and track changes. To maintain the EIS as a sustainable operation, future research will be carried out on the required maintenance efforts such as monitoring user participation, updating system requirements, and providing publicity and education programs.

### Acknowledgment

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