A WEB CONSTRUCTION FAILURE INFORMATION SYSTEM USING CASE-BASED REASONING IN KOREA

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ABSTRACT
The purpose of this study is to develop a web-based failure information system for construction practitioners using case-based reasoning techniques, which can systematically accumulate, manage, and share valuable failure information. The system developed in this study can continuously accumulate and search data in the form of text, photographs and video clips and receive real-time information based on case reasoning. The web-based construction failure information system is composed of a construction code administration module, a failure case registration module, an index module and a reasoning module. In doing so, a relational case database technique was utilized to manage efficiently and effectively the failure case information classified into work condition, failure circumstance and causes, and countermeasure. Also a web programming technique was adopted to manage texts and photographs or u-tube of each case. The prototype system was validated with real failure cases occurred in the Korean construction industry. Through the validation process, which included examination by a number of construction practitioners, the system has demonstrated a promising result, indicating that it can be utilized as a valuable proactive tool to prevent future failures by searching similar past failure cases.

Keywords: Case-based reasoning, Construction failure, Construction failure information system, Web

1. INTRODUCTION

Advanced foreign nations are continuing with their studies on failure information in order to reduce occurrence of construction failures and putting efforts to collect and accumulate related information. Particularly in 1982, ASCE established Technical Council on Forensic Engineering (TCFE) to develop a guideline for failure investigation and has been conducting researches to find the means to provide failure information to construction practitioners. Occupational Safety and Health Administration (OSHA) investigates and manages failure cases on its own (Jeon, 2004). However, construction failure information in Korea exists as documents such as reports and case studies, and it is difficult to accumulate information because the format of information collection is not systematic. This fact leads to deficiency of sharing failure information and communication tools, also causes the important factors (technical factor, managerial factor) which is suggested by Whittington (1992) and Andi (2005).

Therefore, for construction practitioners to accurately understand information about construction failures and establish measures to prevent same failures in the future, an efficient failure information system is needed. Such a system must be constructed based on a well-structured format which includes contents like the cause, type and circumstance of failure. This system should also allow easy accumulation and management of failure information and be able to efficiently search through past failure cases. In addition, learning effects can be maximized by providing visual data using photographs and movie clips instead of limiting to simple text information during failure case education.\(^\text{10}\)

\(^{10}\) Lee (2003) argued that education with photographs and movie clips is advantageous for cognition of information by providing interesting and lively environment to users.
Accordingly, this study attempts to construct a web-based construction failure information system (W-CFIS) using a failure information classification system and case deduction technique performed in existing studies to search and inquire failure cases and offer photographs and movie clips in addition to text information, thereby realizing an effective education on construction failures.

2. THEORY REVIEW

2.1 Definition of Construction failure

The definition of construction failure differs according to every researcher. Table 1 summarizes the definition of construction failure given by researchers.

<table>
<thead>
<tr>
<th>Researcher</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leonards</td>
<td>An unacceptable difference between expected and observed performance</td>
</tr>
<tr>
<td>(1982)</td>
<td></td>
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<tr>
<td>Hohns</td>
<td>(1) The act of falling short, being deficient, or lacking</td>
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<tr>
<td>(1985)</td>
<td>(2) unattainment or nonsuccess</td>
</tr>
<tr>
<td></td>
<td>(3) nonperformance, neglect, omission</td>
</tr>
<tr>
<td></td>
<td>(4) bankruptcy</td>
</tr>
<tr>
<td></td>
<td>(5) loss of vigor or strength</td>
</tr>
<tr>
<td>Janney</td>
<td>(1) structural failure: the reduction of capability of structural system or component to such a degree that it cannot perform safely its intended purpose</td>
</tr>
<tr>
<td>(1986)</td>
<td>(2) construction failure: a failure that occurs during construction and they are considered to be either a collapse, or distress, of a structural system</td>
</tr>
<tr>
<td>Kaminetzky</td>
<td>A human act: omission of occurrence or performance; lack of success; nonperformance; insufficiency; loss of strength; and cessation of proper functioning or performance</td>
</tr>
<tr>
<td>(1991)</td>
<td></td>
</tr>
<tr>
<td>Jeon</td>
<td>Not only structural failure and defect, but also safety problem, depreciation of performance, and potential defect which are caused by failure and defect</td>
</tr>
<tr>
<td>(2004)</td>
<td></td>
</tr>
</tbody>
</table>

The early researches had focussed on required performance of buildings and subdivided it into construction, structural, and managerial issues. Recently, it has expanded to include structural collapse, safety, performance, and defects. This study defines the technical and management factor as failure causes. In addition, occurred failure cases are classified into 4 types (facility, element, work, and situation) to reasoning easily and prevent potential failure.

2.2 Construction Failure Information Classification and Data Type

A systematic information classification system is required to efficiently accumulate and manage construction failure information. Looking into construction failure classification systems proposed in existing studies, American Society of Civil Engineers (ASCE) suggested a classification system by classifying failure cases into the time of failure occurrence, type and source through its ‘Guidelines for Failure Investigation’. Park (2003) classified failure into general information about facilities, failure status information, cause and countermeasure. Also, Jeon (2005) considered properties of construction failure information and classified failures into facilities, parts, stage, type, cause and lesson. Construction failure information should include the circumstance at site, failure circumstance, cause and countermeasure.

Therefore in this study, failure information is classified into work condition, failure circumstance, cause and countermeasured with consideration on practical utility, as shown in Table 2. This classification will be utilized in the web-based construction failure information system to input and offer failure data as codes, photographs and movie clips. The cause and countermeasure for failures can be inputted and managed using texts.
Table 2: Construction Failure Classification

<table>
<thead>
<tr>
<th>Primary Factors</th>
<th>Secondary Factors</th>
<th>Tertiary Factors</th>
<th>Data Type</th>
</tr>
</thead>
</table>
| Construction Work Situation | - Type of Facility | · Residential/Commercial Facility  
· Public Facility  
· Heavy Industry Facility | |
| | - Type of Elemental | · Ground and Underground  
· Civil Structure  
· Structure Finishing Part | |
| | - Type of Work | · General Article and Cost  
· Temporary Work(indirectness)  
· Temporary Work(directness) | |
| | - Type of Structure | · Shear Wall Structure  
· Core Structure  
· Rahmen Structure | |
| Construction Failure Situation | - Phase that a Failure is Occurred | · Planning/ Design  
· Execution  
· Maintenance | |
| | - Type of Occurred | · Latent Failure  
· Functional Failure  
· Failure on Safety | |
| | - Failure Damage Pattern | · Partial Collapse  
· Total Collapse  
· Functional Defect | |
| Factor causing Failure | - Technical Factors | · String | Text |
| | - Site Management Factors | |
| | - Organizational Factors | |
| Construction Failure Preventive Measure | - Technical Measure | · String | - Text |
| | - Site Management Measure | - Photograph |
| | - Organizational Measure | - U-tube |

(1) Construction Work Situation
Failures occur in various forms depending on the properties of construction projects, and it is necessary to closely investigate work conditions for examination of the cause. Thus, in an effort to understand the properties of construction projects, work condition is classified into facility type, part, construction type and structure type. In addition, a database is constructed to provide photographs and movie clips related to work conditions and to allow detailed examination of conditions.

(2) Construction Failure Situation
Since the failure situation can become important information in establishing preventive measures against the cause and result of construction failures, details must be delivered effectively. Construction failure can occur in all stages of construction including planning, design, construction and maintenance. The size of damage and future countermeasures differ greatly according to the stage in which failure occurs. It is also possible to establish countermeasures against construction failures that occur repetitively by analyzing the form and type of failures and connecting them with work situation. Failure situation is therefore classified more clearly into stage of occurrence, form and type. Photographs and movie clips are provided as failure data to efficiently deliver failure situation.

(3) Factor Causing Failure
Construction failure is caused by many factors, and such factors are mutually correlated. In particular, Kim (2005) examined construction failure mechanism and classified the cause of failures into indirect and direct causes through correlation analysis on construction failure causes. Direct cause is technical cause and indirect cause includes organizational cause and site cause. The web-based construction failure information system in this study will apply this classification.

(4) Construction Failure Preventive Measure
Construction failure measures are taken to prevent same failure from occurring again in the future, by synthesizing the details of (1), (2) and (3) above. Especially, preventive measures should be
established after understanding and analyzing the cause of failure. Failure measure is classified into technical measure, site measure and organizational measure. Data on preventive measures are inputted and provided in texts, photographs and video clips so that detailed measures can be prepared.

2.3 Application of Case Based Reasoning

Case Based Reasoning (CBR) is the method in which similar past cases are reviewed in order to solve new problems. CBR is applied to system developed in this study. The process of system is that information of work situation, failure situation, failure causes, and preventive measures is first saved into case data base, then it is second saved into index database to deduce similar case. This process allows measuring degree of similarity and grasps the accuracy of reasoning.

![Figure 1: Process of Case Based Reasoning](image)

3. SYSTEM DESIGN AND DEVELOPMENT

3.1 Concept of Web-Based Construction Failure Information System

Construction failure information at Korean construction sites is being created in broad and diverse forms, but such information is being accumulated and managed in a non-systematic format and exists only as text. Long lengths of time and high costs are being spent on sharing and learning of construction failure information.

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2) refer and adjustment “Continuous Improvement Model of Construction Process using Construction Failure Information(Jeon, 2005)”
However, with recent development of IT, large amounts of data can be inputted and outputted efficiently using computers without limitations on time and space. Data can be inquired and used on a real-time basis through the web-based internet. If construction failure information system is constructed based on the web, various failures at construction sites can be estimated and prevented in advance. Figure 2 is a conceptual model of the construction failure information system. Construction failures that occurred in preceding projects were analyzed through a well-structured classification system for utilization in future projects.

3.2 System Module and Case Reasoning Method

Construction failure information systems can continuously accumulate and search data in the form of text, photograph and video clip and receive real-time information based on case reasoning. For this, web-based construction failure information system is composed of a construction code administration module, failure case registration module, index module and reasoning module as shown in Figure 3.
1) Construction Code Administration Module
Authorities for construction code administration module are granted to the system administrator and managed based on the information classification system suggested in this study. Also, the module allows registration and management of information on new facilities, construction types and parts by granting new codes.

(2) Registration Module
The registration module can systematically input and manage failure cases according to work condition, failure situation, cause and countermeasure. Related expert or administrator can input details on the failure as a text with photographs and video clips.

(3) Index Module
The construction failure information system administrator needs to review, select and register data for accurate delivery of failure information. Therefore, the index module allows reasoning on failure cases demanded by users by creating a database of failure cases that were verified to have high utility.

(4) Reasoning Module
The reasoning module is the core module of the construction failure information system which provides information to search and view similar past cases and establish preventive measures against similar construction failures. If the reasoning is to be based on keywords included in failure cases, the module must be made so that it does not perform reasoning on unnecessary words. In the case of the Korean language, unnecessary words are excluded from the reasoning using word analyzer during indexing work. As illustrated in Figure 4, the reasoning module of construction failure information system performs its reasoning based on text. However, the module is believed to allow more detailed learning of failure cases by users if past failure cases registered in the database are provided together with photographs and video clips.

4. CASE STUDY
To verify the prototype of web-based construction failure information system constructed in this study, actual construction failure cases of Korean construction sites recorded in the database are examined.
4.1 Case Summary

As mentioned in 3.2, the failure case index is primarily classified as code into case name, type of facility, location and type of structure. Failure situation was divided into construction failure situation, factor causing failure and construction failure preventive measure. As described in 2.2, cause and preventive measure were segmented into technical factors, site management factors and organizational factors to allow users to more easily understand and search factors in the wanted field.

The target case is a failure case of pipe installation on the masonry walls of a gymnasium. Piping and masonry construction were conducted at similar time period, and pipes were imported to the masonry walls. In general, pipes are supposed to be separated from masonry walls. Importation in masonry walls is expected to create cracks in the walls and bring a high potential of risk.

Table 3: Investigation Result of Construction Failure Case

<table>
<thead>
<tr>
<th>Case Name</th>
<th>Type of Facility</th>
<th>Type of Elemental</th>
<th>Type of Work</th>
<th>Type of Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe Installation Failure in Masonry Wall</td>
<td>Health, Religion and Recreation</td>
<td>Basic Structure(wall)</td>
<td>Masonry Work</td>
<td>Masonry Structure</td>
</tr>
</tbody>
</table>

Table 3 briefly shows information related to this case. Type of facility is primarily a health/resting/religious facility and secondarily an exercise facility. Type of structure is primarily a basic structure and secondarily a masonry wall. Also, construction type is masonry construction, and the structure form was classified as masonry. Causes of failure were lack of design standards, insufficient supervision, inappropriate organizational structure and unsmooth communication within organization for organizational cause, insufficient design knowledge and indifferent supervisor for site management cause, and design error and lack of cooperation with the constructor for technical cause.

4.2 Case Registration and Reasoning

(1) Registration

As Figure 5 shows, case registration is classified into construction work condition, failure situation, cause and countermeasure. Since type of facility, part, type of construction and structure format are encoded, users can select the code that corresponds to the wanted case. Photographs and video clips can also be uploaded as attachments.
The outline describes details on work conditions. Failure situation, cause and countermeasure on such details are prepared in relation to each other to allow users to understand complex causes of construction failure based on organizational/site/technical perspectives. In addition, uploaded photographs are outputted on the screen as thumbnails and expanded as a pop-up screen upon clicking by users. Video clips provided as web streaming service can help users better understand failure cases.

(2) Reasoning
Case reasoning can be done by clicking on the top-down menu or direct input of a keyword by users on type of facility, construction type and other information made into code, as shown in Figure 6.
Figure 7 shows the case reasoned through word analyzer. Search result outputs simple title and few keywords on the reasoned case with the degree of similarity.

![Keyword Reasoning]

Once the user clicks on a case name given in the search list, detailed information on the case shows up. As in Figure 8, a brief list of visual data can be seen on the bottom of the screen with text information. Here, photographs and video clips can be viewed as pop-up windows if the user clicks on the visual data. Secondary reasoning on similar cases can be performed on the selected keyword by linking the search module with the previously selected keyword.

![Figures 8: Snapshot of Result Ouput]

4.3 Expected Effect

To predict expected effect of the prototype, this study executed interview to 10 people(8 beside an executive director of major general contractor and president of medium construction firm) who are working in construction part over 10 years about satisfaction of prototype. The factors of satisfaction measurement refer to Delon, Goodhue, Ives for analyzing quality of system and information which are influence on satisfaction. The analyzing item and result is following.

<table>
<thead>
<tr>
<th>Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Availability of System Approach</td>
</tr>
<tr>
<td>Intuition of System Interface</td>
</tr>
<tr>
<td>Availability of System Usage(Inspection and Uploading of Information)</td>
</tr>
<tr>
<td>Definitude of Information Classification System</td>
</tr>
<tr>
<td>Update of the Latest Information(New Technology and Construction Method)</td>
</tr>
<tr>
<td>Availability of Information Feedback</td>
</tr>
</tbody>
</table>
As a result, by using the Web Construction Failure Information System, items are accessible, useful, and interview feedback indicated high satisfaction with the system. In particular, the systematic system, which have information classification system and it differs from excel and existing self-developed system, has very high satisfaction. According to well-appraised item, respondents' evaluation of this system has indicated value as a method of preventing failures and as an education tool. However, respondents pointed out that the system interface is difficult and the inadequate accumulation of data could be improved. Thus, after correcting the system interface and inspiring recognition participants of construction part to accumulate failure data, the prototype developed in this study has expected effect as followings.

1) Present the standard of systematic construction failure information storage system
2) Predict construction failure through analyzing of the past failure cases
3) Present the effective task process for preventing construction failure
4) Use as educational tool for participants of construction part

5. CONCLUSION

The purpose of this study was to construct a web-based construction failure information system for use as a learning tool in accumulating and managing diverse construction failures occurring in Korea and preventing them. The prototype of web-based construction failure information system developed in this study can systematically manage information using a coded classification system and providing video clips and photographs with text information, showing the possibility of an effective education. Therefore, if an institution is established to administer construction failure cases based on such system and accumulated failure information is used as a tool for understanding and education, the image of construction industry will improve and the system will contribute to development of overall industries.

However, the prototype developed in this study is limited by small number of data and unsmooth access of video information. Such limitations should be supplemented. In addition, in order to put a large amount of failure information into a database, construction practitioners, administrators and workers should not conceal their construction failure experiences and instead try to make improvements using failure cases as valuable lessons.

REFERENCES


Chang, N. C. (2002), Study on the development of the construction failure information system, MS thesis, The Graduate School of Construction Engineering, Chung-Ang University.


The Technical Council on Forensic Engineering of ASCE (1989), Guidelines for Failure Investigation, ASCE.

