International Journal of Architectural, Civil and Construction Sciences
ISSN: 2415-1734
Vol:7, No:2, 2013

Emergency Response Plan Establishment and Computerization through the Analysis of the Disasters Occurring on Long-Span Bridges by Type

Sungnam Hong, Sun-Kyu Park, Dooyong Cho, and Jinwoong Choi

***Abstract*—**In this paper, a strategy for long-span bridge disaster response was developed, divided into risk analysis, business impact analysis, and emergency response plan. At the risk analysis stage, the critical risk was estimated. The critical risk was "car accident."The critical process by critical-risk classification was assessed at the business impact analysis stage. The critical process was the task related to the road conditions and traffic safety. Based on the results of the precedent analysis, an emergency response plan was established. By making the order of the standard operating procedures clear, an effective plan for dealing with disaster was formulated. Finally, a prototype software was developed based on the research findings. This study laid the foundation of an information-technology-based disaster response guideline and is significant in that it computerized the disaster response plan to improve the plan's accessibility.

***Keywords*—**Emergency response; Long-span bridge; Disaster management; Standard operating procedure; Ubiquitous.

I. Introduction

THE Seohae Bridge disaster that occurred in 2006 is recognized as the worst traffic accident that has occurred ever since all the sections of Seohae Highway were opened. A 25-ton truck was speeding on the foggy highway, with a poor field of vision, and hit a 1-ton truck, triggering a series of road accidents. The firefighters and rescue workers had difficulty accessing the site due to the thick fog and entangled vehicles, causing many casualties.

A car accident is a randomly developing, unintended event in time and space[1]. In the case of a car accident on a long-span bridge, both the bridge users and the administrators suffer major losses unless swift responses are made, because the bypass options for vehicles are limited. Moreover, as highway bridges are designed for high-speed driving, the risk of suffering serious damage is also high. The estimated loss from the Seohae Bridge disaster was about 4 billion Korean won [2]. In an attempt to reduce such losses, studies on swift response based on information technology (IT) have been actively conducted.

In this study, methods for swift and efficient emergency responses as part of the management organization of long-span bridges were explored, including the establishment of an emergency response plan, the computerization of such plan, and the development of an emergency response flowchart.

II. Research Background

A. Literature Review

In the study on an optimal disaster reduction plan for early disaster responses conducted by Lee et al. (2010), ideas on a disaster reduction activities plan and its implementation to maintain the business continuity of the South Korean companies were suggested, and alternatives for maintaining business continuity were explored by establishing an early response system[3]. In addition, the guideline for accident preparedness and business continuity planning, which was adopted as a disaster management standard in South Korea, was analyzed, an implementation guideline that can be easily applied to the South Korean companies was suggested, and a method of establishing disaster reduction activities and the use of IT by companies were investigated. In particular, a model for risk assessment, for influence analysis, and for the establishment of a prevention plan as well as a response and management plan as part of the planning phase of the five-phase guideline for accident preparedness and business continuity planning, was suggested. Moreover, methods for facilitating local-disaster reduction activities were suggested, and the use of IT, which is necessary for enhancing the level of disaster response, was also suggested.

According to the study conducted by Kim et al. (2008) on the standardization of the temporary restoration of railway accidents and on the development of standard operating procedures (SOPs), standards for the temporary restoration of railway accidents and for SOPs were suggested[4]. The railway accidents in South Korea and abroad were analyzed and classified. In addition, the railway accident types were determined, and methods of preparing SOPs were suggested using temporary restoration scenarios.

In the study conducted by Park et al. (2008) on the introduction of an activity action diagram and on the establishment of a computerized action plan by emergency responders in railway accidents, situational activities based on emergency response scenarios were suggested using the existing classifications and data of railway accidents by type,

Sungnam Hong(Ph.D, Research Professor) is with the Department of Civil and Environmental Engineering, Sungkyunkwan University, Suwon, Korea, (e-mail : cama77@skku.edu).

Sun-Kyu Park(Ph.D, Professor) is with the Department of Civil and Environmental Engineering, Sungkyunkwan University, Suwon, Korea, (e-mail : skpark@skku.edu)

Dooyong Cho(Ph.D, Professor) is with the Dev. of Technoloy Education, Chungnam National University, Daejeon, Korea, (**Co-corresponding author**, phone : 82-42-821-5693; e-mail : dooyoungcho@cnu.ac.kr).

Jinwoong Choi(M.E, Ph.D Student) is with the Department of Civil and Environmental Engineering, Sungkyunkwan University, Suwon, Korea, (**Corresponding author**, phone : 82-31-290-7530; fax : 82-31-290-7949; e-mail : cjw85@skku.edu).

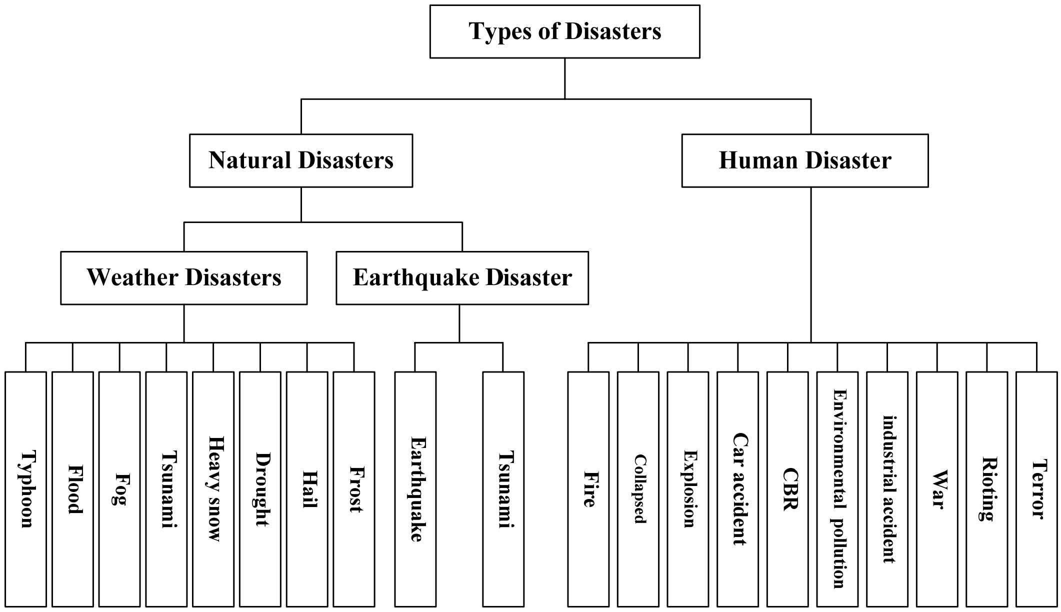

Fig. 1 Risk recognition and designation

and actions within the category of the activity were also suggested[5]. Finally, computerization was done for easy access to the study results.

In the study on emergency responses to electric-rail-car fires in tunnels conducted by Kim et al. (2008), SOPs and practice for engine drivers were suggested[6]. Swift and accurate emergency responses of engine drivers in the case of electric-rail-car tunnel fires were explored to minimize the damage arising there from.

B. Theoretical Backgroud

1) Risk Analysis

JIS Q 2001, the standard risk management system of Japan, defines a risk as "a combination of the certainty and result of an event" or "a combination of the occurrence probability and result of an event" [7]. In other words, a risk can be described as the product of the probability and result of an event or the product of the level of occurrence certainty of an event and of the damage that can be caused by such event[8].

Risk analysis is an analysis of the effects of a risk on an organization. It consists of the steps of risk recognition, designation, and assessment.

2) Business Impact Analysis

Business impact analysis is an analysis of the effects of the critical risk calculated from risk analysis on the current business operations. It consists of the steps of process recognition and designation, process estimation, and process assessment.

3) Standard Operating Procedure

Standard operating procedure (SOP) is a written guideline that reflects what is expected of and required from the staff of an organization as they carry out disaster responses. The SOP defines the detailed items of the operation, describes the functions of the administration and disaster response, and consists of various methods according to the needs and preferences of the organization. A system consisting of a training program, staff briefing, practice, and training can be prepared and included in the written SOP. In addition, the understanding of the required tasks can be enhanced by using the SOP, and the recognition of the potential problems can be boosted.

III. Disaster Analysis by Type, and Emergency Response Plan Establishment

A. Risk analysis

1) Risk Recognition and Designation

Risk recognition and designation refers to the process of finding out an organization's risks. Different organizations have different risks. The types of disasters for an organization operating long-span bridges can be summarized as Fig. 1.

2) Risk Estimation

The risk matrix method described in JIS Q 2001 is currently the most widely used qualitative method (a type of order determination) [8]. As such, the method was used for risk analysis in this study, and a survey was conducted for risk estimation, targeting specialists in this field. Two variables — occurrence probability and influence of the survey — were given weights on a scale of 1 to 4 (4: very high; 3: high; 2: average;1: low). The results of the survey are as Table I.

TABLE I
RESULTS OF THE RISK SURVEY

Risk	Occurrence Probability	Influence	Probability*Influence
Typhoon	2.33	2.67	6.22
Flood	3.33	2.67	8.89
Fog	3.00	2.67	8.00
Tidal wave	1.00	3.00	3.00
Snowstorm	2.00	3.33	6.67
Drought	2.00	1.67	3.33
Hail	1.67	2.33	3.89
Freezing damage	1.33	3.33	4.44
Earthquake	1.00	4.00	4.00
Fire	2.33	3.33	7.78
Collapse	1.00	4.00	4.00
Explosion	1.33	3.67	4.89
Car accident	4.00	3.33	13.33
Chemical/biological/ radiological accident	1.00	2.67	2.67
Environmental contamination	1.67	1.33	2.22
Industrial disaster	2.67	1.00	2.67
War	1.00	4.00	4.00
Riot	1.00	2.67	2.67
Terror	1.00	3.67	3.67

3) Risk Assessment

After assessing the results of the risk estimation, the probability and influence of the risks were distributed on a two-dimensional table. Based on the distribution table, the risks were prioritized. The critical risks had higher probabilities and influences than the non-critical risks.

As shown in Fig. 2, as a result of the risk analysis, "car accident" was assessed as a critical risk, followed by "typhoon and flood," "fog," "fire," and "snowstorm," in descending order.

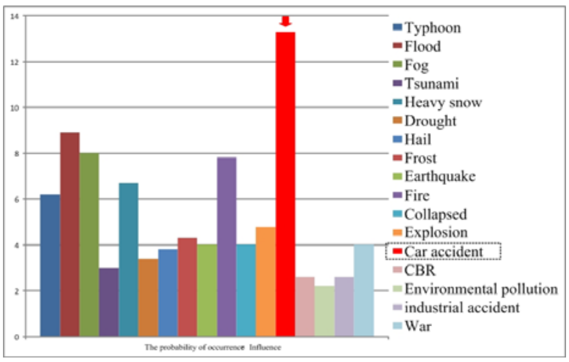

Fig. 2 Results of the risk analysis

B. Business Impact Analysis

1) Process Recognition and Designation

To analyze the operation process of organizations in charge of long-span bridges, the upper-level functions are defined and then dissolved to lower-level functions until the lowest level is defined. Each function is usually divided into two or more lower levels[8]. The regular duties of the organization in charge of long-span bridges are as Table II.

TABLE II
PROCESS RECOGNITION AND DESIGNATION

Upper-Level Function	Lower-Level Function		Lowest-Level Function
Management	General affairs	1	Customer management and satisfaction
		2	Call center and CRM business
		3	Public relations
	Accounting	4	Business planning, coordination, and budget administration
		5	Accounting and settlement, tax payment
		6	Financial administration, liquid assets administration
	Contracts	7	Construction projects, service contract and procurement
		8	Feasibility study for and basic design of construction projects
	Land administration	9	Compensation for land acquisition, land acquisition
		10	Administration of lands, including national property and undecided lands
Sales	Branch management	11	Road operation system and branch management
		12	Toll collection and Hi-pass management
		13	Toll road ticket and receipt management
	Rest area management	14	Rest area management
		15	Rest area upgrading management
Structure	Structures Facilities	16	Structures maintenance
		17	Establishment of structures maintenance criteria and management
	Electric appliances	18	Communication structures management and maintenance
		19	Establishment of criteria for electric-facilities construction and management
	Monitoring	20	Disaster response management
		21	Monitoring of road status
Road	Pavement	22	Pavement design, construction, and management
		23	Road maintenance planning and management
	Landscaping	24	Landscaping design, construction, and management
		25	Establishment of criteria for landscaping project and management
Traffic safety	Safety equipment	26	Equipment management
		27	Installation and maintenance of traffic safety facilities
	Communication	28	Traffic demand forecast and policy establishment
		29	VMS management
	Patrol	30	Patrol team management
		31	Cracking down on overloaded and restricted vehicles
	Situation room management	32	Safety plan establishment and implementation supervision
		33	Situation room management

2) Process Estimation

To investigate the effects of "car accident," a critical risk, on the duties of an organization, a survey was conducted using a qualitative method that was the same as the previous risk estimation. The influences of the emergence levels and risks were estimated using two variables. The influences were classified as "direct influence,""indirect influence,""influence outside the organization," or "no influence", and "1," "2/3," "1/3," and "0"weights were given to them, respectively[8].

TABLE III
RESULTS OF THE DUTY INFLUENCE SURVEY

Lowest Function	Emergence Level	Influence	Emergence Level*Influence
1	3.67	0.33	1.22
2	4	0.33	1.33
3	3.67	0.67	2.44
4	1.67	0	0
5	1.67	0	0
6	1.67	0	0
7	1	0	0
8	1	0	0
9	1	0	0
10	1	0	0
11	3.33	0.67	2.22
12	4	2	8
13	2.33	0	0
14	2.7	0.67	1.78
15	1.33	0	0
16	2.33	0.67	1.56
17	1	0	0
18	2.33	0.67	1.56
19	1	0	0
20	4	2	8
21	4	2	8
22	2.33	0.67	1.56
23	1.33	0.67	0.89
24	2	0.67	1.33
25	1	0	0
26	4	2	8
27	4	3	12
28	4	2	8
29	4	1	4
30	4	2	8
31	2.7	0.67	1.78
32	3.67	1	3.67
33	4	1	4

3) Process Assessment

A process with a higher emergence level and a higher influence is considered a more critical process. The details are the same as those of risk assessment, so further description is omitted. As a result of the business impact analysis, "installation of traffic safety facilities and maintenance" was assessed as a critical risk process in the event of a car accident.

C. Establishment of an Emergency Response Plan

1) Establishment of an SOP

In the event of a car accident, the SOPs of the relevant department, of the manager-in-charge, and on the action plan are shown in Table IV. The manuals of Korea Highway Corporation, a highway management organization, were used as references, but the duties were further divided and were separated by title.

TABLE IV
SOPS IN THE EVENT OF A CAR ACCIDENT

Section		SOP
Branch restoration team leader		Disaster response team management
		Reception of situations
		Termination of emergency responses
Branch restoration team assistant leader		Reception and reporting of situations
		Direction of emergency response
		Direction of site management
Procurement and mobilization team	Team leader	Management of materials/equipment
		Reception and reporting of situations
		Towing
		Site clearance
	Team member	Reporting of situations
		Emergency response materials/equipment check
		Confirmation of the necessity of emergency response materials/equipment
		Request for assistance with emergency response materials/equipment
		Procurement of emergency response materials/equipment
		Restoration and situation room team support
		Temporary road blocking
		Establishment of access control line
		Removal of access control line
		Request for towing equipment
Restoration and situation room team	Team leader	Response to site situations
		Reception and reporting of situations
		Vehicle towing
		Emergency road restoration
		Site clearance
	Team member	Situation reporting
		Confirmation of the outbreak of fire
		Firefighting
		Emergency measures for casualties and evacuation
		Identification of casualties
		Contacting health care centers and victims' families
		Confirmation of the necessity of an emergency medical tent
		Establishment and management of the emergency medical tent
		Emergency medical tent removal
		Confirmation of the necessity of towing
		Vehicle towing
		Confirmation of the possibility of emergence restoration
		Emergency road restoration
		Seaport restoration
		Removal of underground utilities
Safety and communication team	Team leader	Reception and reporting of situations
		Use of the emergency contact network
		Management of bypass road
		Site clearance

Team member	Reporting of situations
	Sensor detection
	CCTV confirmation
	Patrol team confirmation
	Emergency contacting and calls
	Interagency contacting
	Request for access control to branch
	Establishment of bypass road
	Removal of bypass road
	Bypass road guide using VMS
	Installation of bypass road sign
	Removal of bypass road sign
	Notification of emergency clearance using VMS
	Notifying each team of emergency clearance

2) Flowchart Development

A flowchart of emergency responses in the event of a car accident was prepared by classifying the SOPs by job title, according to the situation flow, as follow Fig. 3.

IV. Prototype Software Development

A. System Overview

A prototype software was developed based on the precedent studies. Upon the completion of the inputting of the organization's emergency response plans, the functions (e.g., drills), individual duties in emergency situations, and direction support were inputted. The details of the system are as follows:

1) Disaster Response Order

With a disaster response order, the disaster responses start according to the flowchart. The Fig. 4 shows the disaster response order.

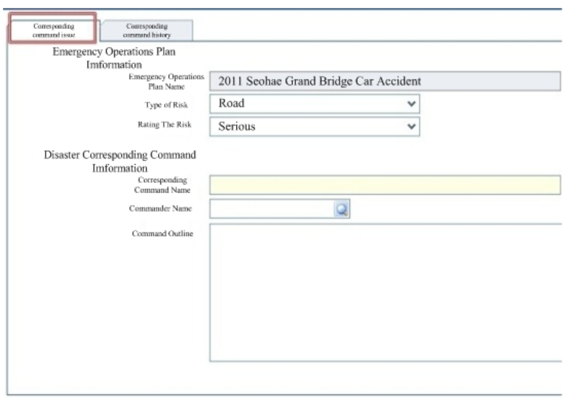

Fig. 4 Disaster response order

2) "My Page"

When a disaster response order is placed, an individual SOP and the relevant information are provided to every person in charge through "My page," as the emergency responses progress. Fig. 5 and 6 show what a safety team member will see after logging on. Fig. 5 shows a situation requiring a "sensor detection" SOP while Fig. 6 shows a situation requiring a follow-up "CCTV confirmation" SOP.

Fig. 5 "My page"

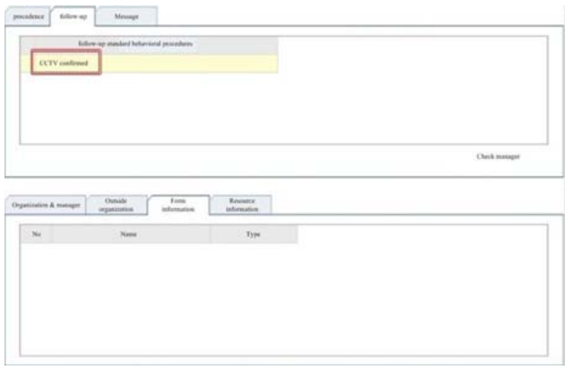

Fig. 6 "My page" (follow-up SOP)

International Journal of Architectural, Civil and Construction Sciences
ISSN: 2415-1734
Vol:7, No:2, 2013

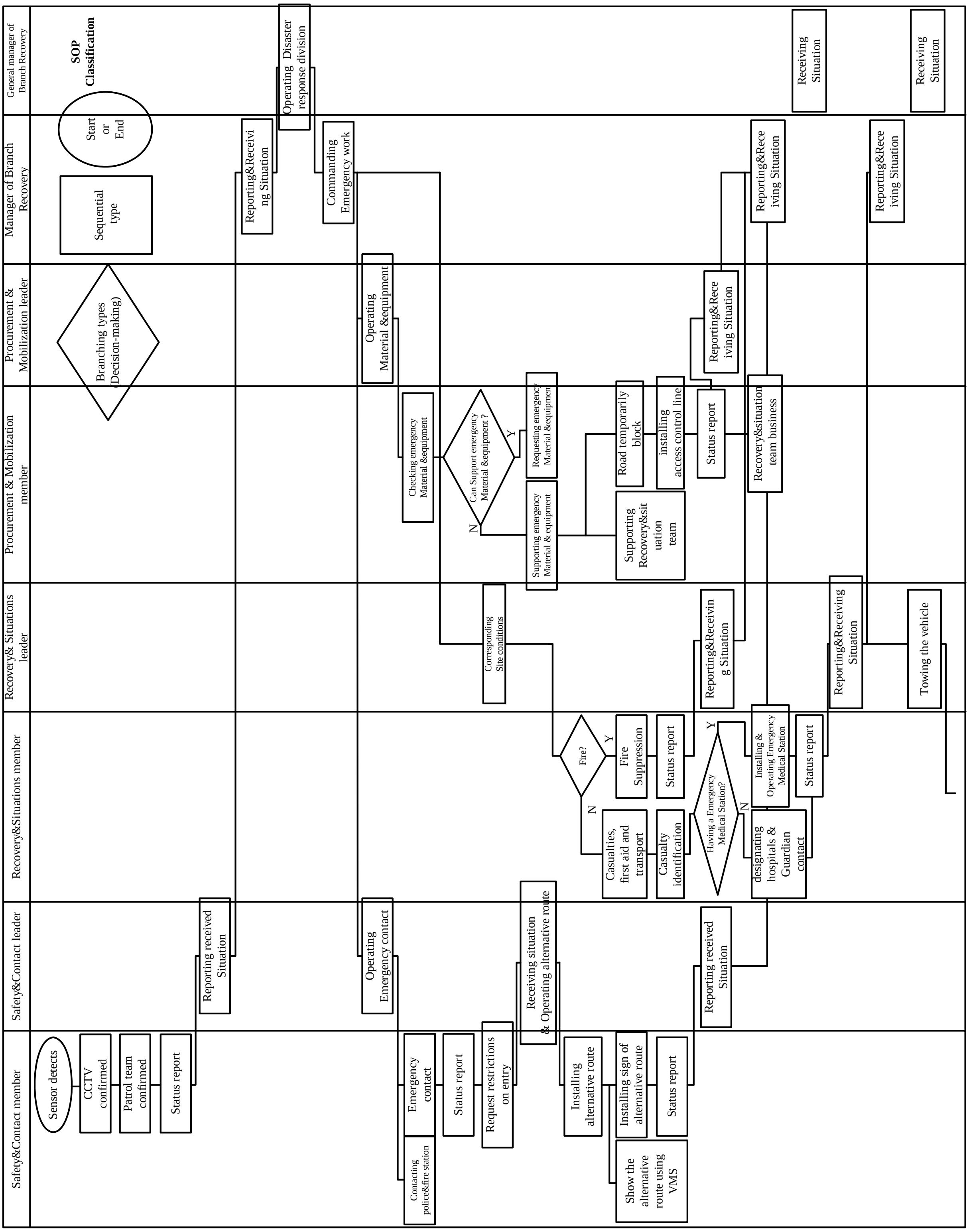

Fig 3 Flowchart of emergency responses in the event of a car accident(continued)

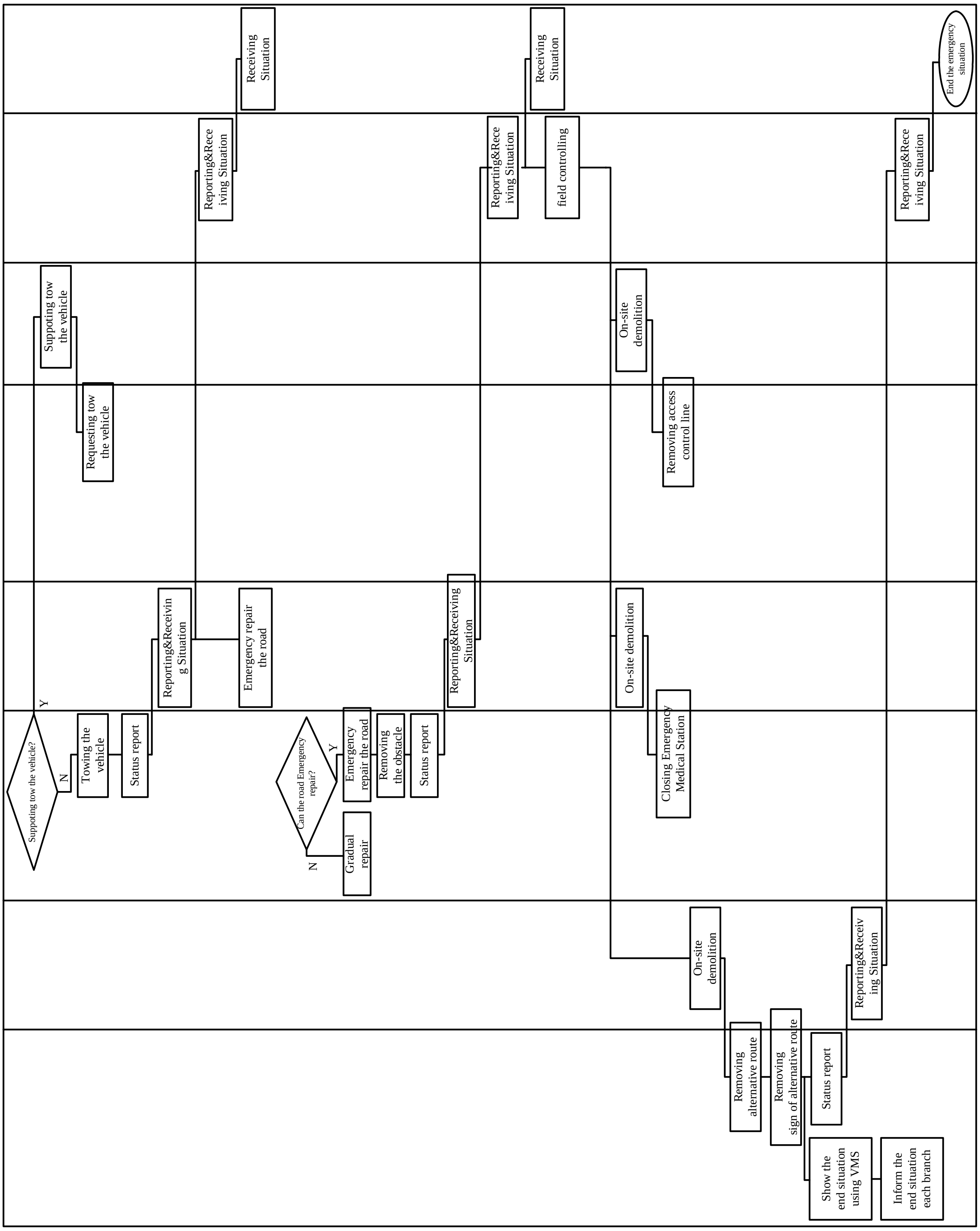

Fig 3 Flowchart of emergency responses in the event of a car accident

3) Situation Monitoring

Through situation monitoring, the current status of the emergency response can be confirmed. The current status of the emergency response is shown through the emergency response progress rate (the ratio of the completed SOP against the total SOP) and the accomplishment rate. It can be used as a reference for establishing future drill strategies. In real-world situations, efficient directions for responses at the sites can be achieved through a clear understanding of the situation.

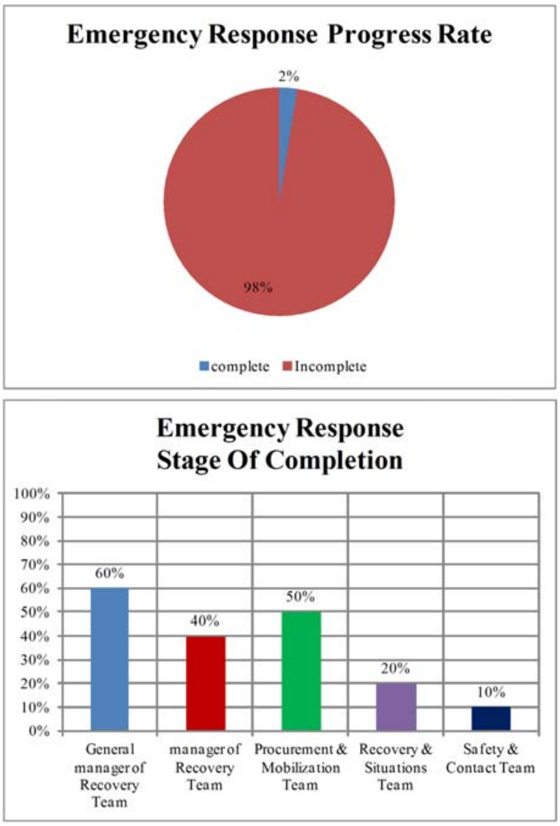

Fig. 7 Situation monitoring

V. Conclusion

In this paper, plans for effective responses to disasters occurring on long-span bridges are suggested.

Through risk analysis, “car accident” was estimated to be the priority risk on long-span bridges. Through business impact analysis on the organization in charge of long-span bridges in the event of a car accident, the priority restoration duties were estimated to be “situational understanding of roads” and “traffic safety.”Through risk and business impact analysis, effective procedures were drawn, and based on these, an emergency response plan for swift responses in the event of a car accident was established. Regarding the SOPs (detailed action guidelines), the types of SOPs were described, and a flowchart specifying the individual duties by job title, with the lapse of time, was established. Finally, a prototype software for the computerization of the emergency response plan was developed based on the results of this study.

The precedent studies focused on the development of scenarios for establishing emergency response plans and procedures, and the target of such studies was limited to railway accidents. In comparison, an emergency response plan for disasters resulting in significant losses on long-span bridges was suggested in this study. As a disaster estimation method, qualitative analysis was conducted to enhance the objectivity in this study. Business impact analysis was conducted to establish an efficient emergency response plan. Moreover, a prototype software was developed based on the results of this study, to maximize the effects of the disaster responses or drills.

The prototype software suggested in this study has excellent accessibility to information and can be applied to training and education as well as to real-world situations. Accordingly, the prototype software will contribute to the swift responses of the organization in charge of long-span bridges, and can reduce the socioeconomic loss caused by accidents.

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