

# Analysis and Development of Emergency Management Information System for Railway Systems in Taiwan

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**ABSTRACT:** Railway is one of the most efficient, convenient, and comfortable ways with maximum mobility to meet people. Railway accidents or disasters often cause delays and service interruptions, resulting in operational and other loss. Despite many railway systems in Taiwan having a variety of monitoring systems for natural disasters, they still need an efficient platform for the emergency management of disasters and accidents since time and efficiency are the keys to emergency management. This study aims to fill in this gap by developing an emergency management information system for Railway Systems in Taiwan, i.e. “Railway Emergency Management Information System”, to support railway emergency management center and its sub-divisions in resource management, communication, messaging, and information sharing among different groups. The system includes many features that will improve communications between emergency management center and the mobile emergency management center to facilitate the progress of the disaster control units and dispatching at the disaster site. The study’s information system has been designated by local railway administration as the core system and starts trial since February 2012. Information requirement analysis, framework and design of the aforementioned information system will be discussed in this paper. It is hoped that the present study’s information system research will help improve the emergency response of railway administration and provide safer rail transport service for the passengers.

**KEYWORDS:** railway system, emergency management, information system

## 1. INTRODUCTION

Railway is one of the most efficient methods in land transportations. It satisfies the need for maximum mobility while also provides convenience and comfort. Railway has the greatest passenger capacity of all modes of transportation in the world. Of the 236 countries and regions in the world, 144 offer railway service (Wikipedia, 2012). Since 1891, railroad systems have already been built in Taiwan by the then governor Liu Ming-chuan to provide important passenger and freight services.

Railway operation needs to combine the collective effort and expertise from the transportation, maintenance, mechanical, and electric services, etc. As a result, railway operating organization is divided based on their specialized fields into transportation, civil engineering, mechanical, and electrical engineering departments. Railway accidents often cause train delays and service disruption whereas passengers may be affected, and their loss of time and money is difficult to estimate. Moreover, Taiwan is situated on the typhoon path in the western Pacific. The island was

formed by the pressures from both the Eurasian Plate and Philippine Sea Plate. Therefore, the frequent yearly typhoons and earthquakes also cause constant natural disasters such as floods, debris flows, etc., which pose unpredictable threats to railway facilities and safety. Therefore, as we become more dependent on the railway system, the soundness of its safety designs becomes more critical.

Taking into consideration the adverse events happened to railway systems worldwide (Wiki, 2012), the operating units, including facility management, maintenance, mitigation, recovery, and emergency response, etc., are very important issues in operational management. When responding to natural disasters, accidents and incidents, many railway systems in Taiwan have installed environmental monitoring and early warning systems that are tailored to their own needs (Ministry of Transportation and Communications, 2010). In addition to the installation of monitoring and early warning systems, coordinated mobilization is still necessary to respond to emergencies. Because time and efficiency are the most critical factors, a railway emergency management information system, serving as an efficient platform, allows the emergency response center and operating/maintenance units to exchange information. Management, command, and progress information can thus be instantly shared among the different units. This can effectively improve management's timeliness and strengthen railway's ability to respond (Idom Ingeniería Y Consultoría and China Academy of Railway Sciences, 2010).

This study aims to fill in this gap by developing an emergency management information system for railway systems in Taiwan, the so-called "Railway Emergency Management Information System" (REMIS), to support railway emergency management center and its sub-divisions in resource management, communication, messaging, and

information sharing among different groups. Information modeling, requirement analysis, framework and design of the aforementioned information system will be discussed in this paper. It is hoped that the present study's information system research will help improve the emergency response of railway administration and provide safer rail transport service for the passengers.

## 2. RAILWAY EMERGENCY MANAGEMENT STUDY AND ANALYSIS

### 2.1 Railway Hazard Analysis

Railway hazards include natural disasters (typhoons, floods, and earthquakes, etc.), operational hazards (signals, communication, equipment, brake, and power supply malfunctioning), system hazards (machine wear-and-tears, roadbed subsidence, etc.), man-made hazards (accidents, sabotage), etc. Different hazards have different ranges and levels of effect. Therefore, the methodologies adopted in emergency management and response as well as the manpower and resources required will be different. Hazards need to be classified based on their type and cause in order to appropriately handle the various characteristics. Table 1 describes the types of operational hazards based on the Railway Act and Railway Operation Regulations approved by the Authority in Taiwan (Ministry of Transportation, 2012).

Table1 Hazard Types in Railway Operation Regulation

| No. | Operational Hazard Type       |
|-----|-------------------------------|
| 1   | Train/vehicle collision       |
| 2   | Train/vehicle flipping over   |
| 3   | Train/vehicle catching fire   |
| 4   | Train/vehicle derailment      |
| 5   | Train separation              |
| 6   | Train entering the wrong rail |

|    |                            |
|----|----------------------------|
| 7  | Runaway vehicle            |
| 8  | Collision with buffer stop |
| 9  | Occlusion error            |
| 10 | Vehicle malfunctioning     |
| 11 | Route malfunctioning       |
| 12 | Tramline malfunctioning    |
| 13 | Signal malfunctioning      |
| 14 | Obstacle to train          |
| 15 | Parking outside the signal |
| 16 | Train delay                |
| 17 | Casualty                   |

Although the Railway Operation Regulations set forth 17 types of hazards, the actual recorded hazards may change due to different characteristics of railroad systems. In Taiwan, agencies such as the Taiwan Railway Administration, Taiwan High Speed Rail, Taipei Metro Rapid Transit, Kaohsiung Metro Rapid Transit, Forest Railway, and Sugar Railway have formulated their own standard operating procedures (SOP), forms, and notification process for emergency preparedness and response. For examples, Taiwan Railway Administration has established SOP for the emergency centers and task force based on the results of hazard classification and cause analysis of TRA. They include vehicle side collision, flipping over, fire, signal malfunctioning, etc. To help with the analysis, similar hazards are re-organized into one type. Each category is further classified into more detailed categories based on the causes and responsibility. The result is a 5-tier classification, including general hazard category, hazard category, hazard cause, triggering event, and triggering event analysis. (J.C. Jong et al, 2011) The structure is shown as Figure 1.

Each “hazard cause” in Figure 1 is further classified into “triggering event” and “triggering event analysis”. Except certain minor categories (ie. casualty), “triggering event” is classified into “human error”, “equipment factor”, and “external

factor”. Each category is then further described in the “triggering event analysis” such as classifying “human error” into “driver’s negligence” or “maintenance negligence”, etc. The outcome of railway hazard analysis will be used for database design.

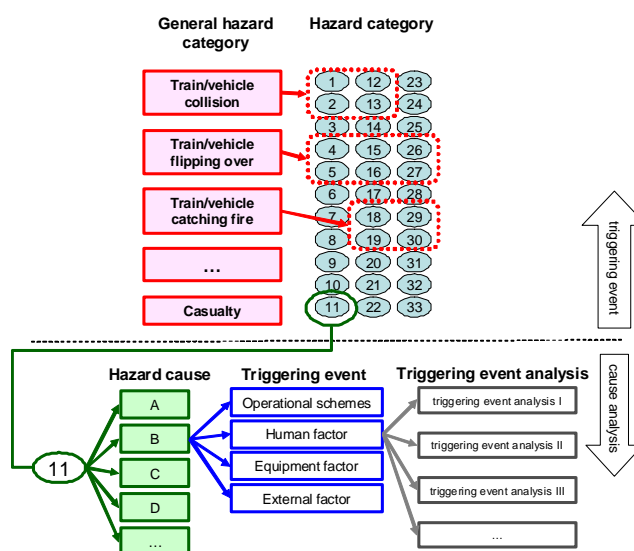


Figure 1. Railway Hazard Classification and Cause Analysis

## 2.2 Railway Emergency Response

Both domestic and foreign railway systems have different approaches to management, depending on the extent of the emergency. When the severity is “normal” or “incident”, limited impact on traffic operation is seen and the situation is controlled through internal safety management measures. On the other hand, when the severity is elevated to “accident” or “crisis”, the situation is unpredictable or unknown, possibly endangering the passengers and disrupting railway operation. At this time, internal and possibly even external resources need to be mobilized to carry out emergency response.

When facing railway accident or incident, the emergency response usually follows the Emergency Management Cycle (Lindell, M., Prater, C., and Perry, R., 2006) that includes 4 phases as illustrated in Figure 2. The phases are linked to each other and noted “the Railway Emergency Management Cycle” that includes:

- (1) Preparedness: Defining the responsibility and authority of each unit, accident or incident classification, and the standard operating procedures for the corresponding response, management, and reporting; strengthening personnel training and prevention/rescue equipment preparation.
- (2) Response: Implementing the various preparatory measures immediately after the incident/disaster has happened, such as reporting the disaster/incident, deploying railway's rescue equipments, deploying police and fire-fighting units, and deploying rescue/medical units, etc.
- (3) Recovery: The priority is to recover the rail services and conduct investigation after the hazard is removed.
- (4) Mitigation: Incorporating the experience gained from the response to safety measures, identifying and reducing hazard categories, and strengthening risk management mechanism to adjust the preparedness.

occurred. They are also required to report in detailed information. Minor train incidents should be compiled in the monthly report. Issues such as who will be providing information regarding the incident, whom should be notified, from whom should assistance and support be expected, the maximum time limit for notification and confirmation, as well as the relevant response measures will be handled based on the standard operating procedures and notification processes as defined by the railway management units. For example, TRA's emergency incident notification flow chart is implemented based on the "Taiwan Railway Administration Emergency Response Notification Form" approved by MoTC (Taiwan Railways Administration, 2010). When a hazardous incident happens, the driver or the dispatcher should notify the station manager on duty, and the manager should contact the regional emergency response team as well as the operation control room and section chief. Eventually, the Managing Director and involved ministries should be notified. All the intermediate officials may also contact the police, fire brigade, and medical units as well as regional emergency operation centers for additional support.

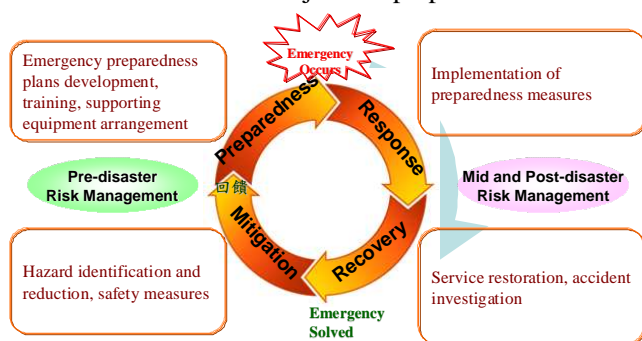


Figure 2. Railway Emergency Management Cycle

Railway's emergency response management information may be used to clarify the operation categories and corresponding information required based on the aforementioned "Railway Emergency Management Cycle" and the incident's chronology.

### 3.3 Railway Emergency Response SOPs

According to Clause 40 in the Railway Act (2012), local, private-owned, and special railroads are required to notify the Ministry of Transportation and Communications (MoTC) in case a major train incident

## 4. RAILWAY EMERGENCY MANAGEMENT INFORMATION SYSTEM REQUIREMENT ANALYSIS

### 4.1 Response and Management Information Requirement Classification

Railway emergency response and management information covers both the periods during disaster incidents and during regular maintenance. It is classified into the followings based on the various levels of emergency response management and incident's chronology in the "Railway Emergency Management Cycle", as shown in Figure 3:

- (1) Preparedness: information that includes emergency response plans, monitoring data

and early warning information, etc.

- (2) Response: information for notification, command and dispatch, response management, follow-ups, and restorations, etc.
- (3) Recovery: assessment information and archival information, etc.
- (4) Mitigation: information regarding the results of railway hazard identification such as potential zones for flooding, rock falling and debris flows.

| Category                 | Contents               |                     |                          |                         |                       |
|--------------------------|------------------------|---------------------|--------------------------|-------------------------|-----------------------|
| Preparedness information | Event monitoring       | Warning information | Notification information | Command & dispatch      | Follow-up information |
| Response information     |                        |                     |                          |                         |                       |
| Recovery information     | Recovery information   |                     | Accident investigation   |                         |                       |
| General information      | Knowledge              | Plans               | Cases                    | SOPs                    | Organization          |
| Dispatch information     | Manpower               | Financial resources | Material resources       | Communication resources | Expert resources      |
|                          | Polices                | Fire brigades       | Hospitals                | Hazards                 |                       |
| Basic information        | Geographic information | Routes              | Facilities               | Agencies                |                       |

Figure 3. Classification of Information on Railway Emergency Management

In addition, the shared information can be further classified as:

- (1) General information: such as response know-hows, planning, precedents, regulations, forms, and organizations, etc.
- (2) Dispatch information: including manpower, resources, financial assistance, communication, police and fire fighters, medical services, experts, and the hazard itself.
- (3) Basic information: including spatial, routes, facilities, and government agencies' information, etc.

#### 4.2 Analysis of Response Management Process

Railway management authorities need different response measures and processes when facing different types of hazardous incidents (i.e. typhoons, earthquakes, storms, railroad accident injuries and deaths, etc.). Some incidents are managed top-down while some others are handled bottom-up. Occasionally, a response is carried out both top-down

and bottom-up. Therefore, this system adds appropriate flexibility to the emergency response process to reduce staff's workload and avoid notification failures.

This system includes 5 operating stages which, in order, are pre-disaster preparedness, event/incident/accident occurrence, and mid-disaster response. Of those, event refers to any irregularity on the entire route, such as fire alarm in the station's hall, railway personnel entering the rail to investigate, mal-functioning switch point signal, etc. When an event occurs, a thorough investigation needs to be conducted to make sure it will not escalate into an incident in order to restore the state of normalcy. If an incident results from such an event, it should be handled according to the corresponding regulation. Possible tasks for railway emergency response and management are given in Table 2.

Table 2. Tasks for Railway Emergency Response and Management

| Pre-Disaster Preparedness                               | Event/incident/accident Occurrence       |  |   | Mid-Disaster Response                       |
|---|--|--|---|---|
|   | Event                                    | Incident                                 | Accident                                  |   |
| 1. Establish comm. network                              | 1. Report operation irregularity         | 1. Report incident                       | 1. Report accident                        | 1. Assemble emergency response team         |
| 2. Record info. on manpower, equipment & resource       | 2. Handle operation irregularity         | 2. Handle incident                       | 2. Handle accident                        | 2. Create response center                   |
| 3. Annual railroad safety exercise                      | 3. Report non-oper. related irregularity | 3. Assign manpower, equipment & resource | 3. Assign manpower, equipment, & resource | 3. Create field command center              |
| 4. Semi-annual disaster prevention exercise at stations | 4. Handle non-oper. related irregularity | 4. Request support                       | 4. Request support                        | 4. Handle disaster and report the situation |
|   | 5. Facility check-ups                    | 5. Support                               | 5. Support                                | 5. Convene meetings for response            |
|   |  | 6. News release                          | 6. News release                           | 6. Assign manpower, equipment & resources   |
|   |  | 7. Estimate repair time                  | 7. Estimate repair time                   | 7. Request support                          |
|   |  |  |   | 8. Support                                  |
|   |  |  |   | 9. News release                             |
|   |  |  |   | 10. Estimate repair time                    |

#### 4.3 The Electronic Notification Process

Railway disaster and incident notification should

include aspects of people, time, and location, such as the number of casualties, location where the incident occurred, and time when the incident took place. In addition, because emergency management is a continuous operation, it should include state information. Such management is illustrated in the ontology model of emergency information as shown in Figure 4.

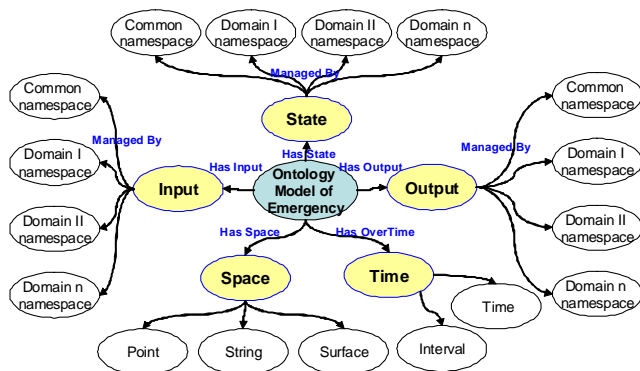


Figure 4. Ontology model of emergency information

To allow the personnel at emergency center to have complete information, smart phones' camera may be used to transmit on-site photos or videos in addition to the conventional communications such as hotline and cell phones or fax. The situation can also be described in detail through e-mail. The electronic notification process is carried out via the 5 channels of e-mail, phone, fax, text message, and web pages.

#### 4.4 Decision-Making Requirements Analysis

One of the objectives of developing railway emergency management information system is to provide assistance to decision-making. The following focuses on typhoon responses that include the most complicated emergency response and management measures to analyze the information needs in decision-making.

After issuing sea typhoon warning, the priorities should be understanding typhoon's movement, damage forecast, the condition of various levels of response centers, and re-disaster preparation. When typhoon approaches, the warning should be upgraded to land warning. Dynamic monitoring that collects information on rainfall volumes, water regime, railway

traffic condition, etc. and early warning actions (i.e. estimating debris-flow warning zones, estimating flooding warning zones, laying out warning zones, damage forecast, releasing information on train suspension/route change) as well as emergency response actions (i.e. bridge block, assisting passengers in flood-prone sections, etc.) and damage report (road disruption, flooding...) should be carried out ; When disaster continues, actively collecting data, rescue, and post-disaster recovery should be the top priorities, as summarized in Table 3.

Table 3. Information Requirements Analysis for Decision-Making: A Typhoon Emergency Management Example

| Phase                | Actions                                | Information Requirements   |
|----------------------|--|--|
| Sea typhoon warning  | Typhoon movement and damage prediction | <ol style="list-style-type: none"> <li>1. Typhoon movement and rainfall analyses</li> <li>2. Historical case analysis</li> <li>3. Prediction of hazard locations and types in the sea warning zone</li> <li>4. Possible impact on railway's recent major activities</li> <li>5. Possible impact on railway's major constructions</li> <li>6. Identifying gaps in flood protection</li> <li>7. Possible impact from unrepaired areas of previous disasters</li> </ol> |
|                      | Preparedness                           | <ol style="list-style-type: none"> <li>1. State of emergency centers at all levels</li> <li>2. Communication test</li> <li>3. Manpower and equipments</li> <li>4. Vehicle preparation for transportation, construction, mechanical, and electrical departments</li> <li>5. Passenger evacuation and settlement</li> <li>6. Temporary construction reinforcement</li> </ol>   |
| Land Typhoon Warning | Data collection via dynamic monitoring | Rainfall volumes, water regime, railroad conditions  |



|                 |                            |   |
|-----------------|----------------------------|---|
|                 | Early warning actions      | 1. Debris-flow warning zone estimation<br>2. Flood warning zone estimation<br>3. Warning zone establishment<br>4. Disaster scale forecast<br>5. Releasing information on suspended or re-routed trains  |
|                 | Emergency response actions | Bridge blocks, assisting passengers in flood-prone sections, visual communications between the headquarter and the regional, local, and field command centers   |
|                 | Compiling information      | 1. Road disruptions<br>2. Flood damage<br>3. Damage on slopes<br>4. Casualty<br>5. Damaged routes<br>6. Property damage<br>7. Active information gathering<br>8. Continuing situation assessment  |
| During Disaster | Rescue efforts             | 1. Confirming disaster area<br>2. Damage assessment<br>3. Dispatching construction, mechanical, and electrical personnel and vehicles<br>4. The estimated times for construction, mechanical, and electrical restorations<br>5. Dispatching police, fire-fighting, and medical support units<br>6. Dispatching relief supplies<br>7. Emergency placement of passengers<br>8. Releasing public information |
|                 | Follow-up efforts          | Post-disaster restoration measures<br>Planning post-disaster restoration progress   |

#### 4.5 Applicable Targets and Units

The targets and users of railway emergency management information system need to be based on the current organization and administrative units and complemented by the regulation of emergency response task force. This system plans to classify the regulations for the system's targets and users into the two phases of preparedness and emergency response for different users.

The preparedness phase is to be used by task assigners, resource managers and managerial staff,

members of general control room, station personnel, and related railway personnel (transportation service, maintenance, mechanics, power, and electrical personnel).

In addition to the above users, additional users such as members of emergency centers and task forces, external emergency center under the MoTC and Emergency Operation Centers of central and regional governments and, Committee of Disaster Management, Railway Police Bureau, municipal emergency 119 call centers, etc. are included during emergency response phase.

### 5. RAILWAY EMERGENCY MANAGEMENT INFORMATION SYSTEM DESIGN AND DEVELOPMENT

The railway emergency management information system consists of many modules including data construction, resource management, investigation and notification, query and display modules that provide functions for data creation, query, modification as well as display for emergency information management.

The data construction module targets the preparedness phase. It provides functions such as task assignment as well as manpower, equipment, and resource management, etc. The task assignment function mainly provides emergency assignment and personnel data inquiry, addition, deletion, and editing. In addition, it provides the conditions of the on-duty personnel and allows setting the organization of emergency response task forces. This includes: type, title, and duty for the task forces. Titles and contents in the organization framework can be queried by selecting from the drop-down menu as in Figure 5.



Figure 5. Emergency Response Task Force Maintenance Screenshot

The resource management module includes: resource assignment which involves resources' management, location, state of assignment, and distribution records. This function provides query, addition, deletion, and editing functions to resources data as well as resource assignment data. It also offers query function to the storage location for prevention resources. Figure 6 displays the maintenance screenshot for resource information by selecting the intended resource safekeeping agency, then selecting the resource category, and finally pressing the Query button to display the basic resource information for that query.



Figure 6. Prevention and Rescue Resource Management Screenshot

The investigation and notification module focuses on the needs of reporting, damage notification and confirmation reply of the event/incident/accident and provides relevant functions. Damage notification function provides the damage information uploading function, including: the time and place of the hazard, notifying personnel, his location, state of damage, damage type, and live video and audio. When the personnel-in-charge is reporting the event/incident/accident, spatial information provided by Google Map will be helpful for locating and understanding the hazard as shown in Figure 7.



Figure 7. Damage Notification Screenshot

Further, railway system may encounter irregularity at any time. After such an irregularity, it is necessary to record all resulting consequences, appoint specific managing units, and report the management's results, etc. Traffic accident report will be made and submitted to the relevant councils for review, improvement, or follow-up after the incident is over. The irregularity management screenshot is shown in Figure 8.



Figure 8. Irregularity Notification Screenshot

When the emergency information and videos are submitted to the emergency center, graphical display showing geographic information will be beneficial for the directors and managerial staff to quickly grasp and understand the situation when facing overwhelming information. For instance, hazards are pinpointed and shown on Google Maps. Icons and colorful zones are used for identifying hazard's severity and impact area, respectively. Selection through hyperlinks further provides the windows for emergency information and videos. Therefore, the query and display module is tailored toward the need to support decision-making process. By incorporating Google Maps development to present various spatial layers, damage statistics, videos and images, as well as released relevant



information, the system can choose to display GIS layer on Google Maps based on the selection tree on the left-hand side of windows. By clicking on relevant icons on Google Maps to pop out messages, the user may acquire more information about the hazards, including the locations, times, situations, rescue equipments, numbers of people affected, actions taken, the estimated time to solution, as well as the unit, official title, name, and cell phone number of the field commanders of various disasters, such as seen in Figure 9.

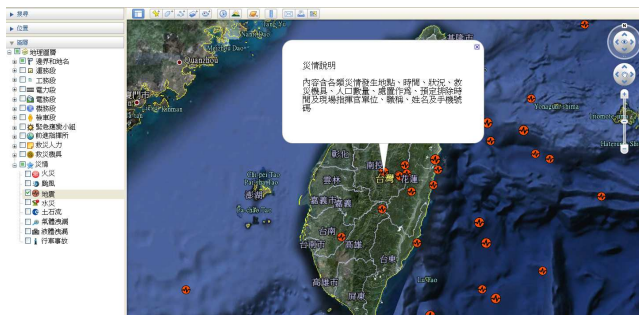


Figure 9. Query and Display Module Screenshot

## 6. CONCLUSION AND RECOMMENDATION

Railway is an important public transportation system. When disaster strikes, the timeliness of emergency response is critical. On the other hand, response management needs to coordinate many units' operations. Communications and the ability to fully grasp the situation are very important. Therefore, this study focuses on the disaster prevention/rescue demands. It also compiles and analyzes the needs in railway's emergency response management when confronted by disasters to design and develops the so-called "Railway Emergency Management Information System". The main objective is to assist the exchange and gathering of emergency information among personnel involved in rescue. This includes the pre-disaster assembling of emergency response task force, preparation of relevant resources, the damage notification and investigation in every stricken areas, and damage presentation, etc. These will serve as a reference for decision-making in emergency response.

Many emergency management information systems

both in Taiwan and abroad tend to emphasize grasping information on mid-disaster response. However, most other information management systems in railway systems focus on the daily management. This leads to a gap between these two types of systems, and users may not be familiar with much of the functionality in either type of systems. In addition, the information provided by many response information systems to the decision-making management level is very limited. It lacks helpful information for command and decision-making. Consequently, this study's railway emergency management information system combines the utilization of regular management with that of emergency information management. It also meets the operating needs for decision-making, and its features are summarized as follows:

- (1) The main functionality designs combine Google Maps (Earth) to consolidate the spatial data both during disasters and non-disaster periods. This aims to provide railway management units, emergency response task forces, and involved divisions with functions such as general inquiry, browsing, statistical calculations, and analysis, etc.
- (2) It targets regional emergency center and provides event, incident and accident management notifications as well as follow-ups tracking and inquiry functions.
- (3) It provides standard data exchange formats such as XML or KML for future integration with external information systems.
- (4) It ensures the timeliness of emergency management information, a common portal for the system, and shared platform and database. It also automatically carries out response notification as well as immediate display of spatial information, damage inquiry, and management notification via internet, e-mail, short messages and fax.

- (5) Because disasters are uncertain, post-disaster recovery and disaster prevention still need to constantly re-examine and adjust system's functions to meet practical demands. Therefore, this system adopts loose-coupling framework for the development of web-based information system to maintain system's flexibility.
- (6) To preserve the connectedness and integration in emergency response management, the system focuses on the coordinated operations of the emergency response task forces and allows support units from the police, fire department, and medical service to fully grasp the available resources. It also provides the mid-disaster automatic notification function.
- (7) This system's functionality design will be combined with railway management units' current information systems to avoid redundant functions. Besides providing automatic information generation, it eliminates the user-learning obstacles as well as the likelihood of becoming an information silo.
- (8) It follows all existing regulations for railway management units.

Although the study's railway emergency management information system is based on the various demands in railway emergency response management, the functionality designed and developed will be given to railway management units for trial use. The system's functions will then be adjusted based on their suggestions. Considering that railway emergency management involves the consolidation of many systems and external users, data, and systems, it must be implemented in due order and not rushed. It should further improve the various function designs and case information to overcome the broad and mercurial effects of disaster incidents.

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