

# Resource Management System for Crisis Response & Management

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## ABSTRACT

Crisis response and management is a critical duty of authorities worldwide to ensure the wellbeing and safety of their citizens and the sustenance and function of society. One of the core components of crisis response is the management of various resources that support the emergency response operations. In this paper, the design of an emergency resource management system is presented, which is developed to utilise geographic information system (GIS), internet of things (IoT), and cloud technologies for precise and real-time inventory management as well as dynamic and adaptive resource dispatching services.

## Keywords

Resource Management, Emergency Response, GIS, IoT, Cloud computing

## INTRODUCTION

An indispensable element of crisis response and management is emergency resources that can be assigned to incident operations (Liu, Shaw and Brewster, 2013). As information and communication technologies (ICT) is increasingly embraced for emergency and crisis management tools, upgrade from conventional practise of managing emergency assets has become one of the core requirements for establishing an integrated command & control platform.

A number of characteristics of emergency resources contribute to the challenges of building an effective and efficient resource management system (Chen, Sharman, Rao and Upadhyaya, 2008; Hick, Hanfling and Cantrill, 2012; Sheu, 2007). Firstly, the notion of resource in the context of emergency and crisis management is of intrinsic variety and complexity. For instance, physical assets such as equipment and materials, human task forces, as well as capabilities to perform certain tasks such as transport and communication can all be considered emergency resources. Secondly, locations of emergency resources can span across vast geographic areas, making it a compulsory task to support a distributed paradigm in inventorying and maintenance. Thirdly, the intrinsic dynamics of requirement for resource maintenance and emergency logistics must be taken into account. Therefore the system needs to facilitate the management of up-to-date information of resource administered across different agencies and organisations as well as integrate with real-time situational awareness.

Taking into account the aforementioned considerations, we have devised an emergency resource management

system for crisis response and management, and its high level design is presented in this paper. The system incorporates a cloud platform which provides users with distributed, ubiquitous and pervasive access to virtual resource database and resource management functions for both normal and emergency scenarios (Doukas, Pliakas and Maglogiannis, 2010). The remainder of the paper is structured as follows: firstly the overall architecture of the system design is illustrated, and then the cloud-based data and service platform is described; subsequently the routine resource administration in normal mode and emergency resource dispatching and coordination in crisis scenarios are described and illustrated with screenshots of implemented system for several projects (with hypothetical data and maps due to confidentiality agreement); finally the conclusion is provided with some summarising remarks.

## SYSTEM DESIGN

### Architecture

An overview of the system architecture is provided in Figure 1. The asset layer consists of virtual representation of physical resource entities, such as equipment and materials attached with radio frequency identification (RFID) tags, barcode labels, or field vehicles or specialised/critical resources attached with global positioning system (GPS) locators, human resource identifiers, capability codes and so forth. The data layer provides central hosting and maintenance of asset information and other relevant data required for resource management, and applications hosted in the function layer provide resource management functions for both normal and crisis mode. Both the data and function layers are implemented using a cloud approach, facilitating access to system services via various type of front-end user terminals, depending on specific site facility and nature of missions.

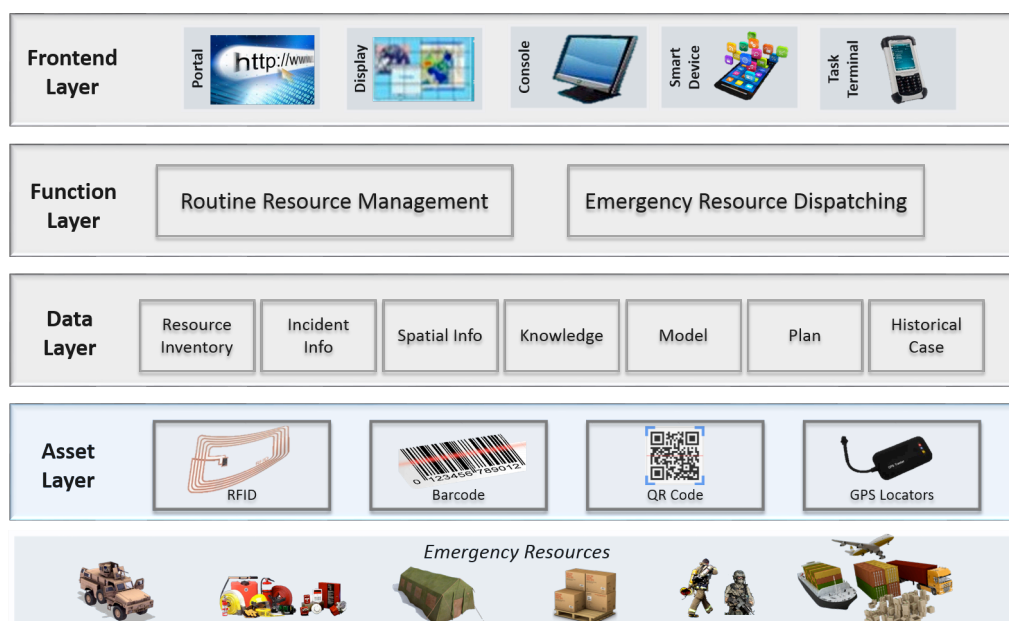


Figure 1 Overall system architecture

### Cloud Platform

The incorporated cloud platform illustrated in Figure 2 consists of data repository and resource management services in the cloud, which provides reduced complexity for implementation and operation as well as improved interoperability and reliability of the system.

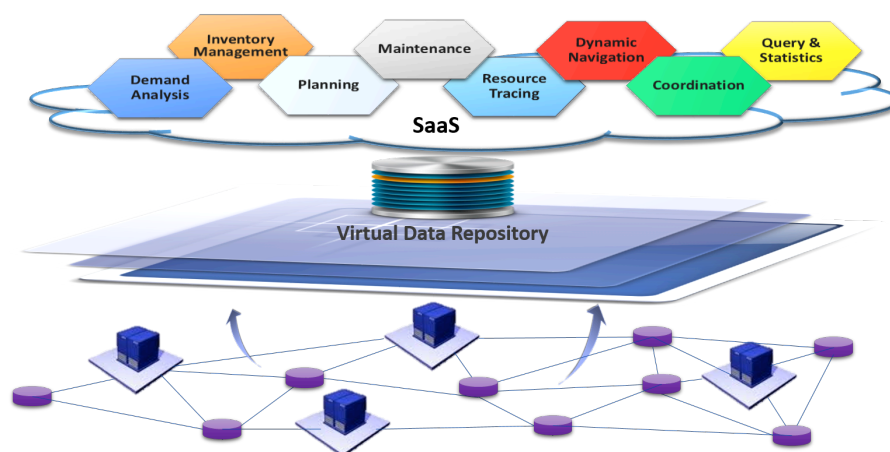


Figure 2 Cloud platform

The cloud-based data repository enables users across geospatial areas and agencies to access a single resource data warehouse created from virtualisation of underlying databases that are physically separate in a distributed manner. As a result, the system is capable of hosting potentially massive datasets generated from huge amount of resource entities in the asset layer. In the meantime, the cloud repository facilitates the synchronisation of up-to-date resource information whilst retaining the existing physical topology in the interest of cost effectiveness and operational reliability.

The resource management cloud services provide applications for both the routine management of resources in normal scenarios and the dispatching and coordination of resource during emergency and crisis response operations. The software-as-a-service (SaaS) paradigm is employed in delivering the resource management services which results in several advantages (Doukas, et al., 2010; Li, Li, Khan and Ghani, 2011): applications can be accessed through browser-based thin client which minimises the potential issues of incompatible software and technologies; it also enables ubiquitous, pervasive and device-agnostic resource management services that support different types of front-end terminals; furthermore, individual user site is exempt from the complexity of installing and maintaining application servers, and help reduce the total cost of ownership for emergency and crisis management authorities.

It is noted that whilst a cloud-based solution is desirable for areas/sites/nations with inadequate or limited resources to locally maintain various ICT infrastructure, it does on the other hand entails Internet connectivity to access system functions, which may be unavailable/unstable due to a diverse array of factors. Therefore it is advised that backup measures should be in place when normal connection fails, such as a combination of communication means (2G/3G/4G, satellite communication), failover applications on servers locally managed on premise, support for offline mode where the system may be operated without active Internet and resume information synchronisation when connection recovers.

## ROUTINE RESOURCE MANAGEMENT

The management of resources in normal mode, i.e. when there is no imminent or present crisis incident, mainly focus on the maintenance of resource inventory and providing support for basic functionality such as data query, statistical analysis for administrative and planning purposes.

### Inventory Management

This function supports the centralised management of resource entries in the data repository, which serves as the foundation upon which the entire system is built. Resources are specified utilising a set of standardised descriptors with respect to the following attributes as shown in Table 1.

Attribute	Content	Example
Location	Current position of resources	1) Identifier of current warehouse 2) Identifier of last registered checkpoint 3) Coordinates reported by GPS locator
Availability	Indicator of resource availability	1) Remaining (unallocated) quantity in storage 2) (If unavailable) Expected available time
Category	Applicable purpose of resources	1) Transportation 2) Communication 3) Sheltering and housing 4) Firefighting 5) Search & Rescue
Capability & Capacity	Key specification of resources	1) Max. load of emergency vehicles 2) Data rate of satellite communication terminal 3) Max. accommodation capability of tents 4) Rating of fire extinguishers 5) Cone-shape volume of life detector
Owner	Current responsible entity	1) Property right holding agencies 2) (If in transit) Responsible agencies/individual of current storage position
Timestamp	Time of last significant resource record operation	1) Data & time of inventory entry creation 2) Data & time of most recent record update 3) (Obsolete entries) Date & time of entry removal

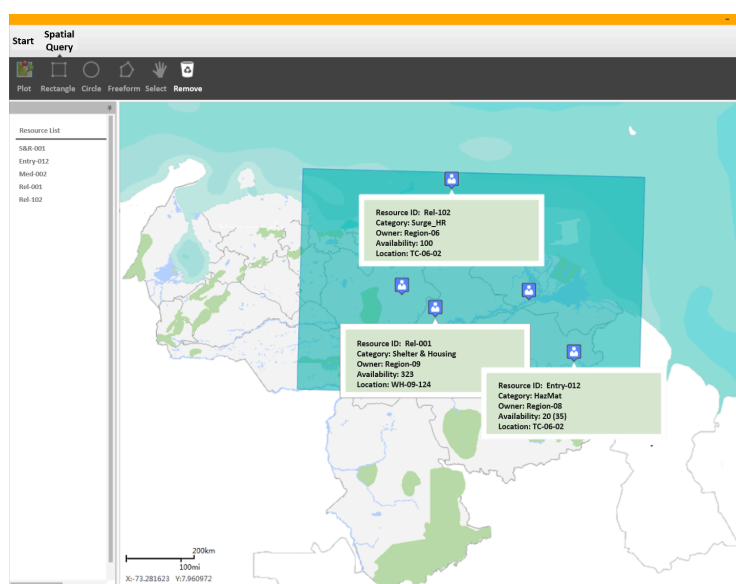
**Table 1 Inventory entry attributes and examples**

### Query & Statistics

This function provides the conditional search of resource. Different types of conditions are supported, including simple search terms of certain resource attributes as well as compound search terms based on combination of multiple attributes for more precise queries.

As illustrated in Figure 3, Geographic information system (GIS) is also integrated to provide advanced functionality:

- Geospatial query: apply user-defined search conditions in areas drawn on GIS map, providing intuitive visualisation of emergency resources matching the desired attributes in the specified areas or close proximity.
- Geospatial statistics: statistical analysis of query results, such as the shipping trace of vaccines and the percentage of different sizes of shelter tents, can be generated as thematic map layers, and overlaid onto the basemap to facilitate procurement and logistic planning and decision-making.



**Figure 3** Example of geospatial resource query

## Planning

This function enables users to construct scenarios for common emergency types and associate them with templates of corresponding resources demand in terms of type, quantity, capability, collaborating agencies, thematic maps containing locations of and dispatching routes from/to main resource warehouses/hubs, and so forth. Because of the diverse characteristics of individual emergency and crisis incidents, planning of emergency resource using this scenario-based approach facilitates task-oriented resource preparation and rapid mobilisation.

## Maintenance

This function facilitates the maintenance of emergency resources to verify that the inventory data are up-to-date and ensure the availability and usability of emergency equipment and materials. Conditions of resources in storage are routinely checked and maintained to ensure rapid deployment in emergencies. The system is integrated with dedicated maintenance handsets devised to support fast counting via reading RFID tags, precise condition report with per item granularity using barcode/RFID and wireless communication capability. Maintenance tasks are created based on these reports and assigned to maintenance personnel based on their location, availability and skills. The position and status of target resource, planned dispatching route, as well as nearby maintenance facilities are also visualised on GIS maps and communicated as part of task descriptions.

## EMERGENCY RESOURCE DISPATCHING

In emergency and crisis circumstances, the focus of resource management is on determining what resources are needed, where and how many of the required resources are available, and how they can be timely and safely delivered to the scene.

## Demand Analysis & Matching

The requirements of emergency resources are analysed based on historical cases and the estimates of crisis impacts. Key factors of current incident such as time, location, season, category, etc. are extracted to construct feature matrix, which is in turn compared with that of past cases to identify situational similarity. And the resource dispatched and utilised in the past cases is used as the baseline for determining types and quantity of demanded resources. Based on the impact of the current incident such as casualty, facility damage, weather, etc. obtained through predictive modelling or situation updates and the specific of environment, social-economic

index and population density of the affected areas, the resource demand is adjusted from the baseline.

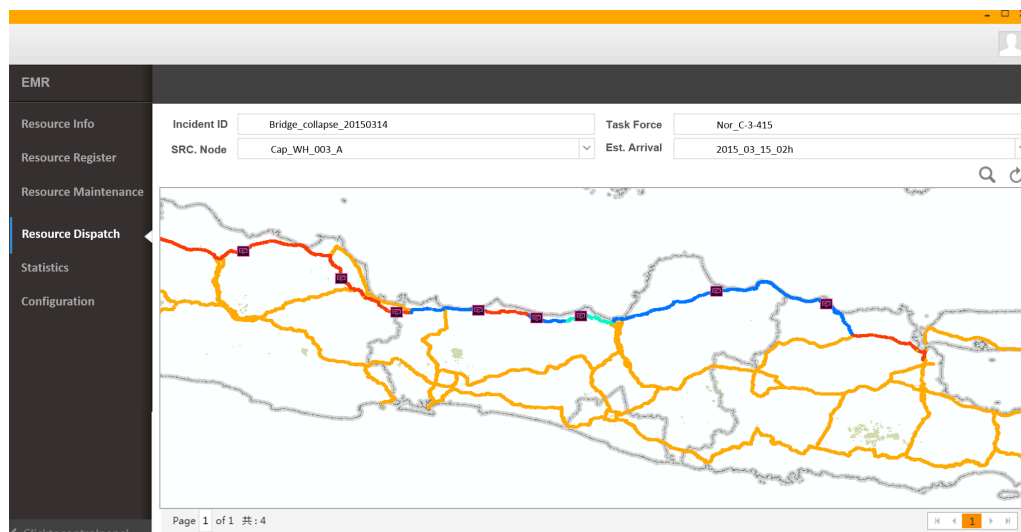
The results of demand analysis are compared with attributes in the inventory, and the matching resource is located through combined criteria of capability, availability, quantity, location and so on. The outcome of demand analysis and resource matching are stored in the case database for future reference.

### Critical Resource Tracing

Supported by barcode and RFID tags, the entire logistic cycle of critical resources is tracked. At each point of significance such as entering and exiting warehouse, loading and unloading from freight, and passing checkpoint of control area, digital records are automatically generated and logged with detailed information such as location, time, material/equipment quantity, status, responsible task force, and so on. Resource administrators and commanding authorities can retrieve the real-time traces of critical resource both in storage and in transit which facilitates decision-making for emergency and crisis response operation.

### Dynamic Navigation

For each resource dispatching task, the system generates a dispatching plan according to the characteristics of incident, nature of resources and current situation, including suggested routes, transfer vehicle types, estimated arrival time, supporting resource required (food/water, specialised tools, etc.), as illustrated with the hypothetical example in Figure 4.



**Figure 4 Example of resource dispatching navigation interface**

Field forces designated to resources transfer are equipped with GPS devices enabling their locations to be tracked in real-time. And as the system constantly monitors the ongoing situation such as transport network conditions, accessibility to operation sites, and natural environment, the navigation for dispatching is adjusted dynamically for optimal efficiency and safety and transmitted to the field forces.

### Dispatching Coordination

This function facilitates the coordination of emergency resource dispatching missions involving multiple parties such as the commanding centre, field dispatching forces, and collaborative agencies. To this end, a GIS-based tool called common operational picture (COP) is devised which consists of a basemap covering the entire dispatching routes and other site of significance to the operation via overlays of thematic layers. Collaborating participants are able to communicate via COP in text, audio, video, as well as marking and plotting of dispatching-related information. The state of COP is synchronized among all participants to provide a united situational awareness and operation coordination. An example of COP in a hypothetical operation is shown in Figure 5.

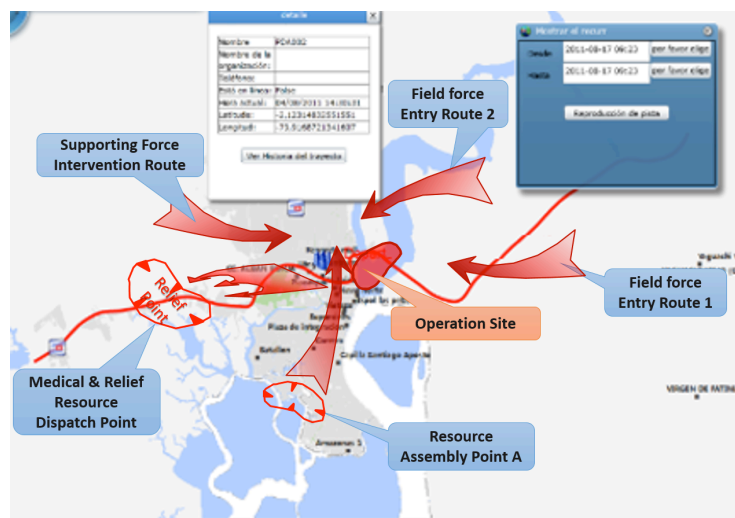


Figure 5 Example of COP

## CONCLUSION

In this paper, the design of the emergency resource management system developed for crisis response and management was presented. The architecture of the system was depicted and main services in both normal and emergency modes were described. The system design incorporates geographic information system (GIS), cloud computing and Internet of Things (IoT) technologies to support real-time and ubiquitous awareness of various emergency resources as well as the dynamic dispatching based on evolving crisis situation. The system is intrinsically incident-agnostic and has been implemented in several projects for the response and management of various types of crisis such as natural disasters, public security, accidents and catastrophes, and so forth.

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