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Additional Information

# *Improving Emergency Plans Management with SAGA*

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## **Abstract**

In the Information Technology age, Emergency Plans remain as islands of information. The knowledge about emergency preparedness and response included in plans is not easily accessible to practitioners who want to create new plans or to improve the existing ones. Additionally, recent studies demonstrate that practitioners claim for the existence of curated resources related to emergency management that, somehow, become the authorized source of knowledge for planning and responding to emergencies. Something similar happens to the administrative management of plans. Currently, it is a mere activity of document management, that still lacks/requires ad-hoc processes for auditing and evaluating plans. However, the Information Technology is mature enough to provide new solutions to plan development and management.

In this paper, we present SAGA, a framework that supports the full lifecycle of an emergency plan management. SAGA provides all the actors involved in plan management a number of tools to support/for supporting all the stages of the plan lifecycle. It is intended to be instantiated in systems promoted by civil defense agencies, providing administrative support to plan management; additionally, editing tools for plan designers and tools for analysis and improvement of such plans by organizations are provided. Plan enactment facilities in emergency response are also integrated.

### **Keywords**

Emergency Management, Emergency Plans Management, Architecture, Information System.

## ***1 Introduction and motivation***

Emergency Management is among the most interdisciplinary communities of practice in the world. Researchers and practitioners of many diverse disciplines (from medical teams to computer scientists, from psychologists to rescue corps, and many others) join efforts to provide a holistic solution to the problem of analyzing, designing and enacting the adequate responses to a large variety of natural and man-made disasters. Solutions belong to both methodological and technological dimensions. The former include, among many others, frameworks for emergency management at the local, regional or even national levels; such frameworks provide the Emergency Management community with a common terminology, establish the requirements for responses and define the way incidents should be handled. Examples of such frameworks are the National Incident Management System (NIMS) at the USA, the

UK's Resilience initiative or the Spanish Self-Protection Rule<sup>1</sup>. To support the development of the different initiatives, a number of tools have been developed. The nature of tools varies from one country to another, ranging from a number of basic guidelines to IT-based environments with different levels of sophistication.

On the technological side, research and development in emergency management information systems have grown significantly during the last decade. On one hand, advances in hardware, especially the advent of a myriad of smart mobile devices, have brought forth solutions that allow the delivery of information between response teams and command control rooms to be faster and richer than with previous systems [1]. Moreover, the situation awareness has significantly improved thanks to sensor networks which capture huge amounts of data that are crucial to improve early alerting systems and, thus, minimize damages [2]. Software technology, meanwhile, has evolved towards more intelligent applications that are able to process large amounts of data coming from the sensor networks, run on different mobile platforms, and retrieve information from large collections of documents. A special mention is deserved by the family of social applications, which have demonstrated to be a new interaction paradigm with special influence in the organization of volunteering during emergency responses [3].

In such a technology-enhanced universe, some islands are left in emergency management where innovation is still to arrive. Among them, the development of the *Emergency Plan* -the tangible result of the planning stage- is of particular relevance, since emergency plans are the essential building blocks of

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<sup>1</sup> *Norma Básica de Autoprotección*

every response. And, as such, one would expect the launch of emergency planning tools which allowed building better plans. Nevertheless, we will show that such tools are still to come.

Despite the sophistication of multimedia and hypermedia authoring tools, emergency plans are stored in traditional document-like files. Although the expressive power of process languages has been successfully exploited for decades in Business Process Improvement, the operational aspects of responses are specified as natural language descriptions, hampering the definition, enactment and post-mortem audit of drills and actual responses. Additionally, instead of using Digital Library technology to support plan preservation and dissemination, emergency management related information is scattered among (too) many sources, whose trustworthiness is not always acceptable [4]. As a consequence, large amounts of knowledge included in emergency plans are difficult, if not impossible, to reuse in order to build a coherent corpus of plans.

The knowledge relevant for emergency management and response can be of different nature, as pointed out by Diniz et al [5]. The experience and background of emergency responders constitute the so-called *Previous Personal Knowledge*. In general, a good *Previous Personal Knowledge* reduces the time needed to make decisions, since autonomy of responders gets enforced. However, it is difficult to transfer it to plans since it is tacit, highly personal and hard to formalize [6]. As a complement to *Previous Personal Knowledge*, explicit knowledge is originated in some information sources, and may belong to two categories: on one hand, the *Previous Formal Knowledge* is generated in advance, as a result of the prevention activities, and does not change during the development of the emergency; on the other hand, the *Current Contextual Knowledge* is composed of all the information which cannot be compiled in advance because it is mostly generated during the development of the emergency, and may even change during the emergency evolution.

One of the main challenges of the emergency management community is to formalize as much knowledge as possible, so that a number of authorized knowledge sources may serve as a reference for emergency planners. Most of it would go to emergency plans in the form of text, images, maps, and other kinds of interrelated objects. But not all the required Previous Formal Knowledge should be included in plans. Rather, plans contain references to other resources such as laws, technical documentation about infrastructures, and others. Thus, linking plans with/to their associated knowledge resources is a must in modern emergency management environments. But this challenge is far from being overcome as far as planning remains in the word processor age.

It is time to apply new technologies to move toward a new generation of emergency plans that will be easier to develop, audit, maintain, and reuse, as well as more powerful in their support to responses. Facilities like personalized views for different response teams and civilians affected by the emergency, bidirectional multimedia information retrieval and transmission, workflow-like coordination, and others [7] are considered essential in future emergency response environments.

Finally, what is missing is a full lifecycle support for emergency plans including, on one hand, rich media content and, on the other hand, tools for plan definition, dissemination, enactment and analysis. In this paper, we proclaim the need for a new generation of emergency plan management tools, and enumerate the requirements these tools should meet. As an example of last generation tools, we introduce SAGA [8], a framework for the development and management of emergency plans. The SAGA acronym comes from the Spanish name corresponding to Self-protection Management Support System. The intended goal of SAGA is to become a resource provided by civil defense agencies to support the emergency plans lifecycle, including development, audit, simulation, enactment and improvement.

This paper is structured as follows. Section 2 includes a survey of how emergency plans are managed in nine countries around the world. Based on/Following the study of these countries, in section 3 we enumerate the basic requirements for emergency plan management improvement; specifically, we describe the requirements the plan management process must have according to the different stakeholders, from authorities to citizens. Then, in section 4 we introduce SAGA, a framework for the improvement of plan management processes. We outline the SAGA architecture, and explain how processes can be improved using the SAGA facilities for plan editing, enacting, and disseminating, among others. Finally, in section 5 we summarize the work made and outline our current and future work on the system.

## ***2 A survey of emergency plan management***

One of the goals of our research in the development of emergency plan management tools was to discover similar initiatives in the world. With this aim, we visited the websites of the Civil Defense agencies in nine countries around the Globe looking for initiatives to i) rule emergency plan development and maintenance, ii) provide official support to planners in the form of resources of different types, and iii) increase the IT-sophistication of such resources, if any. Surprisingly, we did not find any case where all three features were met.

### ***2.1 Canada***

The Public Safety Canada office [9] rules all the aspects related to Emergency Management. Dependent on the Government of Canada, PSC promotes a coordinated, nation-wide approach with the aim of defining a uniform structure for the management of emergencies. Specifically, a number of guidelines on how to develop an emergency management plan are accessible to federal institutions in cooperation with the Provinces, Territories and other entities. The legal framework is provided by the

Emergency Management Act [10] and the Federal Policy for Emergency Management [11]. The latter includes explicit statements (sections 7.x) about the obligation of federal institutions to build emergency management plans. To ensure uniformity in plan design, some methodological guidance plus an Emergency Plan Template are provided at the Emergency Management Planning Guide 2010–2011 [12]. Emergency planners in an organization must then use the template to create the corresponding document into the organization. No tool support is provided for the planning stage.

## **2.2 Germany**

The Federal Office of Civil Protection and Disaster Assistance [13] coordinates the emergency management initiatives, which are mostly within the remit of the Länders. The efforts are getting more and more aligned with the European directives regarding public safety, and a specific implementation has been developed according to the structure of the Federal State. Though some general guidelines and manuals have been issued to drive civil protection in the country, no support to planning was found in the Website of the BBK.

## **2.3 India**

The creation of the National Disaster Management Authority [14] and the State Disaster Management Authorities were prescribed in the Disaster Management Act issued by the Indian Government in 2005. The purpose of the agencies is ‘to implement a holistic and integrated approach to Disaster Management in India’. The National Institute of Disaster Management [15] is the institution in charge of developing training programs, knowledge and community building initiatives. The NIDM is leading a number of emergency related research projects in cooperation with research institutions from India and worldwide.



In a way similar to the USA, an Incident Response System [16] has been developed which includes all the guidelines defined to create a coordinated response to incidents. The organizational structure, as well as the mechanisms for emergency response are defined in the IRS. Documental support to responses is provided as a number of different forms, but no concept of Emergency Plan as the outcome of a preparedness activity is included; moreover, planning is seen as an activity that starts once an incident has occurred.

## ***2.4 New Zealand***

The Ministry of Civil Defense and Emergency Management [17] is the organization in charge of all aspects of emergency management in New Zealand. All the Government's initiatives related to Civil Defense are implemented as part of the National CDEM Plan, which construction is supported by the Guide to the National CDEM Plan; its latest version comes from 2006, and has been reviewed in 2009 [18]. The emergency management philosophy is based on the '4R' model, which includes four cyclic activities, namely reduction, readiness, response and recovery. Planning is part of the readiness activity; however, neither plan structure nor templates are provided. Rather, the notion of plan stands for large scale initiatives related to specific hazards (e.g. the National Health Emergency Plan) or specific response forces (e.g. the Police Emergency Plan).

## ***2.5 South Africa***

The Disaster Management Act (DM Act) [19] established a model for disaster risk management best practices. This law makes provision for emergency preparedness, response and recovery, and the participation of volunteers as a collaborative process between all levels of the government, civil society and the private sector. The National Disaster Management Centre (NDMC) [20] is responsible for implementing the DM Act and providing an integrated and coordinated emergency management policy (at the national, provincial and municipal levels). All materials have been developed as guidelines,

templates and other documents for the implementation of disaster risk management in municipalities and provinces and are grouped by key performance areas (KPAs) each one with a specific objective (KPA1: Integrated Institutional Capacity for Disaster Risk Management; KPA2: Disaster Risk Assessment; KPA3: Disaster Risk Reduction; KPA4: Response and Recovery). In order to achieve these objectives, three enablers are defined: Information Management and Communication; Education, Training, Public Awareness and Research; and, Funding Arrangements for Disaster Risk Management. The National Disaster Management Framework (NDMF) [21] groups and organizes all the information, guides, monitoring and evaluation instruments so that the organizations may be implementing the DM Act. In this context, every centre or organization should have an emergency plan. In the law [22], the essential contents are indicated, as well as their validation process by NDMC to coordinate all levels, and their administrative registry. However, we have not found specific templates or tool support to facilitate the elaboration of emergency plans by the emergency planners.

## **2.6 Spain**

The Spanish Law on Self-Protection [23] prescribes the basic guidelines for emergency plan development and management in public service organizations. Essentially, the law prescribes the obligation of organizations to create and maintain an emergency plan, whose content is defined in a plan template included as an appendix to the Law. In some specific cases, the emergency plan must be e through additional parts related to particular types of organizations (also defined in the Law). Eventually, two or more individual emergency plans can be merged into a larger one (e.g. in the case of shopping centers).

To improve plan management and provide plan visibility, the Law prescribes that the Civil Defense Agency must set up an administrative registry of emergency plans, where all these plans will be submitted and kept for further administrative and/or operational use. Moreover, to support the

elaboration of emergency plans, the Civil Defense Agency will create and maintain a repository of emergency-related resources accessible by planners, so that reusable plan pieces can be retrieved when needed. Finally, mechanisms for auditing emergency plans and plan maintenance will be defined and implemented; also, the civil defense authorities will establish certification mechanisms to guarantee that emergency plans are compliant with regulations.

## ***2.7 United Kingdom***

The Civil Contingencies Act 2004 [24] is the basic law which regulates disaster and emergency management in the United Kingdom. This law defines the legal background for emergency preparedness and response, defining the obligation for certain organizations to be prepared for different kinds of emergencies, and establishing the additional powers of the government for urgent response in the case of a large scale emergency.

To complete the basic guidelines defined by this law, the Cabinet Office in the United Kingdom has promoted the “UK Resilience” initiative [25]. The UK Resilience site acts as a centralised repository for civil protection practitioners to improve emergency preparedness. In this repository, information can be found about emergency management and planning as diverse as basic guidelines to communicate risks, emergency plans development, laws or emergency training courses [26]. Regarding to planning activities, chapter 5 of the Emergency Preparedness section [27] focuses on emergency plans development, exercising and reviewing. In spite of the efforts of the government to improve emergency preparedness, no automatic tool support for plans development is provided.

## ***2.8 United States of America***

The Federal Emergency Management Agency (FEMA) [28], which is part of the U.S. Department of Homeland Security, rules every aspect of the emergency management in the USA. The main

responsibility of FEMA is to coordinate the preparedness, planning, mitigation, response and recovery at all levels (governmental and nongovernmental). Specifically, the National Incident Management System (NIMS) [29] guides all organizations to prevent, respond to, recover from, and mitigate the effects of any incident. The components are: preparedness, communication and information management, resource management, command and management. Different guidelines, standards, procedures and protocols are developed collaboratively for every component. The National Integration Centre (NIC) is in charge of the management and maintenance for all aspects of NIMS. The coordination between departments, agencies, organizations at every level (local, state and federal) is their main responsibility. On the other hand, the National Response Framework [30] provides the structure and mechanisms for national-level policy related to incident management.

Emergency Planning is considered a critical element of effective response. The national preparedness guidelines [31] collect a set of templates and guidelines to elaborate the Emergency Plan. For instance in [32] a template is provided to elaborate the Emergency Plan in organizations or in [33] to elaborate a familiar emergency plan; however, we have found no tool support to facilitate the elaboration of emergency plans by the emergency planner. On the other hand, there is not a public emergency plan repository to consult other plans during the development and improvement process of a new emergency plan.

## ***2.9 Japan***

Japan is a disaster-prone country since it is situated along the circum-Pacific seismic belt. For this reason, numerous laws regulate disaster management in this country since the end of the XIX century. The Disaster Countermeasures Basic Act (enacted in 1962) [34] is the law which provides the basic foundation for the formulation of disaster management measures in Japan. This law states that the Central Disaster Prevention Council is the organization on charge of formulating and implementing a

Basic Plan for Disaster Prevention. This document, which is reviewed every year, is the master plan and the basis for disaster reduction activities in Japan, and clarifies the duties assigned to the different governmental, public, or local institutions. Based on this plan, specific plans shall be defined such as the Disaster Management Operation Plan (made by every designated government organization and designated public corporation) or the Local Disaster Management Plan (made by every prefectural and municipal disaster management council).

Although there exist numerous documents and guidelines for emergency management planning (disaster countermeasures are regulated by more than 50 different laws), neither specific template nor tool support is provided for planners.

## ***2.10 Discussion***

After reviewing policies in different countries, we see that the last decade has been crucial in the advance of civil defense and emergency management: regulations in most countries are less than 10 years old. Moreover, there is no uniformity in the way civil defense is organized. Differences arise about the global philosophy (all-hazard vs. specific hazard approaches), the structuring of the emergency lifecycle (different number and type of stages), the implementation of policies (nationwide vs. state driven policy), and the standardization of emergency plans (only a few of the studied countries provide a plan template). The most surprising finding is, however, that even if they are recent activities, the main tool used to build plans is a text editor, with disregard of notorious technological advances whose application would produce richer and better managed plans.

## ***3 Requirements for a solution***

Planning is just a part of the emergency plan management. To reach a global solution, a wider viewpoint is required. There are several stakeholders other than planners that participate in the plan management process and, hence, should be considered. Table 1 summarizes the following discussion.

### ***3.1 Planners***

Planners are, by far, the community with the strongest needs regarding plan development. In 2008, Turoff and Hiltz published the results of a detailed study about the sources of information used by health related emergency management practitioners and researchers, as well as their informational needs [4]. The report pointed out that the Web is, by far, the most used information source, and that most of the people that participated in the study pointed at the difficulty of finding the information they want as the most critical problem. Among the causes, the huge amount of information available and the lack of organization of such information were mentioned.

One of the main conclusions of the report was the acknowledgement that library science principles and tools would play a crucial role in organizing and making available vast amounts of information, especially in the case of the gray literature, which includes numerous materials considered crucial to practitioners. The idea of a “professional library” as a mediator between organizations suggests that a new role is joining the community. Thus, the idea of a plan digital library arises as a key building block in the architecture of every plan management system.

Some practitioners have moved towards social networks as a means to disseminate and share knowledge. However, issues such as indexing and abstracting are tasks that require a level of expertise not granted by current social network systems, since they require skills in information organization typical of librarians.

### **3.2 Authority**

By *Authority* we mean a Civil Defense Agency that issues laws and rules establishing emergency management policies at the national, regional or local level. These rules often include the obligation of elaborating emergency plans and the specification (at some level of abstraction) of their structure and content. Given the diversity of organizations and associated plans, providing emergency plan authoring tools is considered a must. Using them, planners in a specific domain share a common plan template that they can customize to their particular case. If the tool provides the right structuring mechanisms, content reuse becomes affordable since plans share also a common terminology.

Plan visibility should be granted via a public registry of plans that would act as a repository for a number of administrative workflows such as plan validation, organization of drills, or plan registration and validation, defined and enacted under the control of the Authority. The registry would act as a digital library where planners could look for similar plans, or reuse plan fragments (such as legal texts, or technical descriptions of emergency equipment, to name just two of them) that could be directly inserted into new plans. Within the library, plans would be described by some metadata. And the library would accept plans in any media, not only the text-based ones.

### **3.3 Organization**

Organizations are the institutions obliged by law to elaborate an emergency plan. The framework support to organizations includes access to all legal and technical documents regarding emergency management, mechanisms to upload plans to the registry, access to the plan evaluation results, and guidance in the organization of drills. Also, bridges between organizations and emergency response forces must be implemented in order to streamline responses in case of incidents.

Another finding of the Turoff & Hiltz's report is the nature of plans as islands of knowledge: plans are not only isolated from knowledge sources, but also from other plans. Organizations usually build their own plans, whose disclosure is often restricted due to reasons ranging from confidentiality to just reluctance to others taking profit of their time and money investment. Doing so, planning as a discipline is losing what perhaps is the most valuable source of reference for new plans design: the ability to examine already existing plans to inspire new ones, or just to compare a new plan with others for its evaluation. Community-level knowledge reuse will definitely represent an enhancement of planning practices. Again, the plan digital library may help extending the visibility of plans.

### ***3.4 Command & Control***

Staff at Command and Control (C&C) needs a comprehensive view of the emergency development, that is, to have access to all the knowledge required to make decisions which will result in actions transmitted to the different teams. As mentioned in section **¡Error! No se encuentra el origen de la referencia.**, knowledge comes from different sources. To the formal knowledge stored in plans, contextual knowledge must be collected in-place from different sources which include both responders and affected people. Sometimes, contextual information may override parts of the plan content (e.g. in case of a building partial collapse, some of the building evacuation routes may be unusable), but in other cases comparing both the formal and contextual descriptions may be useful. Thus, visualization tools allowing a selective dissemination of information are required.

The overall choreography of the response defined in the plan must be enacted with the participation of the C&C. In order to take a full log of the response actions performed for their further analysis and evaluation, a process engine will be of great help. The engine will also help in ensuring that the action plan is executed as it was defined. However some flexibility is required to react to unforeseen changes in



the development of the emergency; hence, flexible process definition and enactment tools bring the expressiveness needed to handle on the fly action plan variants [35].

### ***3.5 Response Teams***

The availability of mobile computing technology has brought forth tools for responders that will improve their situational awareness and communication with C&C. A large number of projects are being developed to provide responders with timely and context-aware information about the area they are assigned to work in (see e.g. a list of the European Union initiatives at [36]). Contextual information management allows the access to important data such as the number of affected persons in a building, their health profile, or even their current frame of mind. This may help responders to better prioritize the response actions.

The C&C staff's situational awareness can also be improved thanks to the fresh, in-place information sent out by responders' devices, which become intelligent sensors able to provide decision makers with all the information their users consider relevant at some point. An exhaustive tracking of all the information traffic may result in plan improvements at the later analysis of a response.

### ***3.6 Affected citizens***

Affected citizens are, by far, the most ignored community in the planning process. Despite the plan is obviously built to preserve their lives and properties, little effort has been done to provide them with useful tools to help them during emergencies. As a matter of fact, evacuation plans depicted in a DIN A3, A4 or even A5 poster stuck on a station wall or the back of a hotel room door are the sole companion of individuals caught in an emergency. This situation needs to be significantly improved since current technology allows going much further. Building infrastructures to support personal safety assistants that

guide not only those that some authors called the “Walking Wounded”, but every person having a smartphone, will improve the overall results of responses in terms of rescue.

### ***3.7 Citizens***

Emergency plans are designed in a professional way by experts. However, it is frequent that individuals react differently when affected by an incident. Panic, rushes or “follow the crowd” reactions may result sometimes in an undesired behavior. But sometimes, differential behavior may be beneficial. It is likely that individuals who inhabit a location on a daily basis will develop an instinctive response to emergency situations based on their daily interactions with the environment. These reactions are usually not taken into account during an emergency plan design. Thus, potentially valuable information for emergency plans is being left out. This information is tacitly available from the individuals that might be involved in the emergency, and should therefore be gathered from them. Thus, engaging these individuals in the emergency planning process may help to generate better emergency plans [37].

### ***3.8 Other requirements***

Besides the above stakeholder-specific requirements, there are some features of a global plan management framework that are not tied to a specific actor in the process:

*Extensibility and Interoperability.* Typically, safety enforcing laws include emergency plan templates to be used by emergency plan designers [23, 38]. In some cases, a basic template is defined for each organization, and additional domain specific templates are defined to be plugged into the basic one in cases like nuclear plants, airports, and a number of strategic infrastructures. Such extensions must be seamlessly integrated in the basic template. Similarly, sometimes two or more emergency plans may be merged into a higher level one; this is the case of large shopping centers including different buildings with their own plans. This can be better achieved following a component-based approach to plan

development, where the document that constitutes a plan arises as the result of the composition of a number of fragments corresponding to the different sections of the plan.

*Process awareness.* At the core of an emergency plan are the activities to be performed by the different response teams to mitigate the effects of an incident. Such activities are not isolated; rather, they are part of an overall choreography where different roles are played by individuals or teams, under the direction of decision makers at the control room. At the USA, the National Response Framework is defined in terms of roles, activities, and other related concepts [30]. However, no specific language is provided to define the process. A formal definition of the process that such choreography defines is mandatory to lead response one step further, and has several advantages: first, a process definition language sets a common terminology for every emergency plan; second, the formal semantics of the language and the existence of execution environments facilitate the analysis of the emergency plans, the definition of scenarios for teams training and, most important, the execution of the process during the response (providing coordination, data flow, efficiency, logging, etc.).

*Tool support.* The above requirements are hard to fulfill without tool support. Such tools should be provided by the Authority, giving organizations the means to develop emergency plans according to the regulations, giving planners reuse-based plan editing tools, providing citizens with new safety enforcement utilities, and allowing civil defense agencies the definition and enactment of emergency plans for actual responses or for plan analysis activities.

## ***4 An overview of the SAGA Framework***

We have worked for years in the development of IT solutions for the different issues mentioned along the paper. As a result, we have developed SAGA, a suite of tools for emergency plan management. SAGA was first introduced in [8] and, to the best of our knowledge, is the first framework that integrates

a suite of tools supporting the different stages of the emergency plan lifecycle (creation, audit, simulation, etc.). Although it was inspired by the Spanish law on civil defense, the functional requirements that motivated its development are general enough to define some generic functional blocks like Plan Edition, Plan Management, Plan Audit and improvement, etc., which can be customized for every different country and policy.

Figure 1 shows the main architectural components of SAGA. In the following paragraphs, we briefly describe the different SAGA components, relating them to the requirements enumerated in section 3. The Plan Generation System (PGS) is an implementation of the Document Product Lines (DPL) approach to the case of emergency plans [39]. DPL allows developing documents in contexts of high content variability and high degree of reuse, as it is the case of plan design and development. The PGS includes a plan fragment repository where planners can search materials to reuse, and where every new plan component is added to during the edition process. This way, a rich collection of planning resources is incrementally built with the cooperation of all the PGS users and the Authority staff.

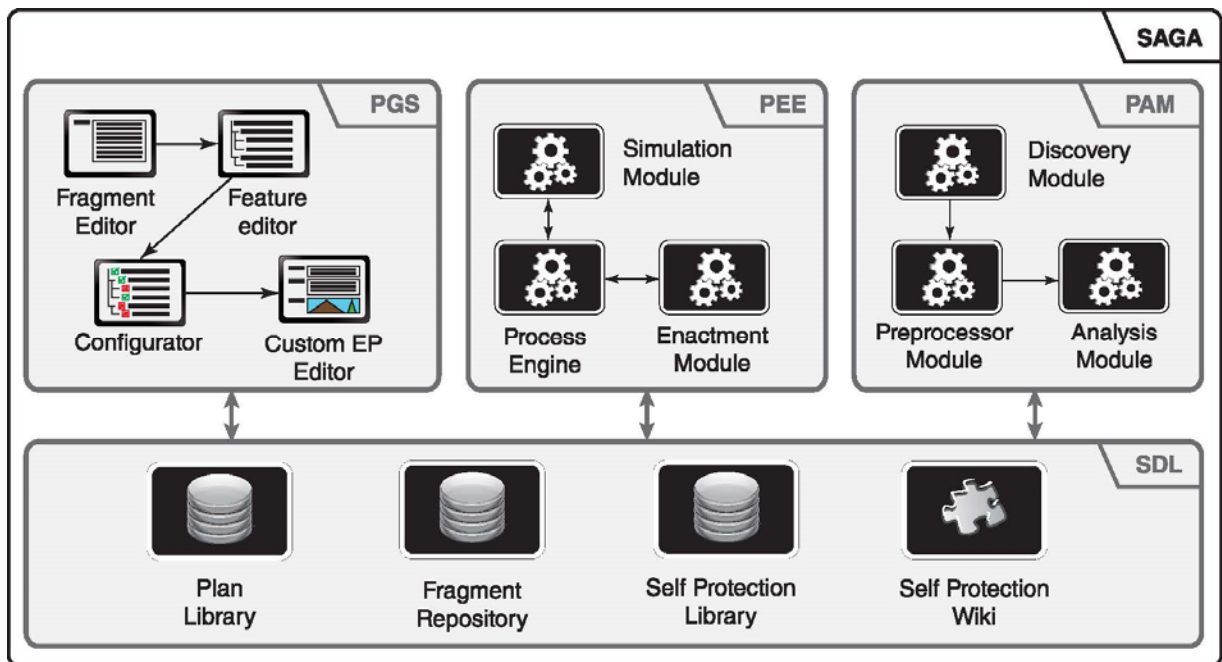


Figure 1 Architecture of SAGA

At the core of SAGA, the SAGA Digital Library (SDL) acts as the main knowledge resource. It is composed of several repositories: first, the Plan Library holds the collection of emergency plans that organizations submit to the system to comply with their obligation; second, the Fragment Repository holds the document components that are (re)used during the plan development by means of the Plan Generation System. Third, the Self-Protection Library is a collection of documents that might help emergency plan designers in their tasks; legal documents, technical information about safety equipment, or sample emergency plans may be part of the collection. Other components may be included in the SAGA Digital Library; an example in Figure 1 is the Self-Protection Wiki, a collaborative space where practitioners can share experiences and knowledge about emergency plan development and use. The Wiki is not available in the current SAGA implementation, but it could be added without significant effort.

Finally, we have two modules related to emergency plans execution. On one hand, the Plan Execution Engine (PEE) allows the enactment of plans for audit, simulations or actual responses under certain circumstances; on the other hand, the Plan Analysis Module (PAM) is intended to perform plan analyses and suggest improvements to plan authors following different techniques.

Table 1 summarizes the requirements of the different stakeholders for a plan management support system like SAGA. For each stakeholder and requirement, we cite the SGA module that fulfills the requirement. Notice that the Plan Execution Engine is by far the most complex component since it must provide plan executability, support interaction between the different response participants, and context management. The SAGA features will be most effective when the full plan development lifecycle is

<b>Stakeholder</b>	<b>Activities</b>	<b>SAGA Module</b>
Authority	Define & enact management workflows	– Plan generation System – Plan Execution Engine
	Define plan templates	– Plan generation System
	Own a plan registry	– SAGA Digital Library
	Validate plans	– Plan Analysis Module
	Define drill schedule	– Not supported
Organization	Access to emergency management legislation	– SAGA Digital Library/Self Protection Library
	Obtain customized plan templates	– Plan generation System
	Register plans	– SAGA Digital Library/Plan Library
	Comply with validation activities	– Plan Analysis Module
Planners	Tools for editing plans from templates	– Plan generation System
	Tools for content reuse	– Plan generation System
	Use of rich content authoring tools (beyond the word processor)	– Plan generation System

Command & Control	Access to specific plans	– SAGA Digital Library/Plan Library
	Access to other formal knowledge	– SAGA Digital Library/Self Protection Library
	Merging context with formal knowledge	– Plan Execution Engine
	Enact plans	– Plan Execution Engine
	Interaction with response teams	– Plan Execution Engine
Response Teams	Customized action plans	– Plan generation System
	Context capture	– Plan Execution Engine
	Context retrieval	– Plan Execution Engine
	Access to formal knowledge	– SAGA Digital Library/Self Protection Library
Affected citizens	Customized, context-aware evacuation plans	– Plan generation System
	Emotion-sensitive interface	– Plan Execution Engine
Citizens	Access to plans	– SAGA Digital Library/plan Library
	Provide feedback on plans via public participation processes	– SAGA Digital Library/Wiki

Table 1 SAGA components fulfilling the stakeholders' requirements performed within the SAGA framework. However, we cannot neglect the large amount of existing

plans which were not created with SAGA that could be also managed through the system. A brief discussion about both types of plans follows.

#### ***4.1 Improving plans using SAGA***

Creating an emergency plan may be easy. Creating a good plan, however, is not. Similarly, auditing a plan is difficult, and sometimes tedious. Thus, practitioners invest large amounts of time and resources to create useful plans, as well as auditors at civil defense agencies do to analyze them.

In many cases, new plans are built from scratch, without any reference provided by knowledge sources (as pointed out in Turoff and Hiltz's report). Among the sources desired by practitioners, some of them claim that accessing to previously developed plans would be of great help in order to have some

guidance, especially when those plans have been recognized as valuable by evaluation agencies. However, as mentioned earlier in this paper, plan isolation is usual, making this desire unviable.

SAGA is a first attempt to reduce such isolation. Its existence and deployment in an emergency management community would provide several ways to improve planning, as we describe below.

#### ***4.1.1 Improving SAGA-born plans***

A high number of improvements in a plan are derived from its comparison with other similar plans. Comparing SAGA-born plans (that is, plans created with the SAGA's Plan Generation System) is straightforward. Since a canonical plan structure is used in the PGS, the comparison can be done element-by-element, resulting in a list of differences provided to planners.

Additionally, plans created with the SAGA PGS can benefit from the content reuse provided by the framework. The availability of plan components stored in the Fragment Repository would help planners to save time in the elaboration of new plans. Any new content is automatically added to the Fragment Repository, becoming available for future plans. If the fragment collection has been curated to ensure quality of contents, an important part of the overall plan quality will be granted.

#### ***4.1.2 Improving other plans***

Making the PL accessible to planners would allow them to consult existing plans to get an idea of how others have planned similar emergency responses. The disclosure could be partial in case of confidentiality requirements by applying some view mechanism at the library level. The comparison may be done manually, although some tool for helping planners to find similarities and differences among their plan and others would be very welcome.



Trying to use SAGA to compare a plan not created with SAGA gets more complicated. A SAGA-compliant version of the plan to be compared must be created in order to use the different techniques implemented by the Plan Analysis Module (see section 3.4). Such a version is produced by *plan slicing*, that is, by decomposing the plan into the different fragments following the feature model used in the specific product line. A full description of the process is out of the scope of this paper, but we give an overview in the following example, where we use SAGA to compare a SAGA-born plan with another one not created with SAGA.

## ***5 Conclusions and further work***

Emergency plans are key drivers of responses to incidents. As such, Civil Defense agencies define mechanisms for the management of emergency plans, including content specifications and administrative processes. In a highly normative context, tool support from authorities would be expected in order to standardize formats, unify analysis criteria, and make plan development easier. Similarly, administrative tools for plan management would ease the authorities' work. However, such tools hardly often go beyond the definition of forms or the granting of access to some mapping applications. As a result, heterogeneity in emergency plan design and lack of interoperability of the management tools are usual.

A full lifecycle approach to emergency plan management is still to come. In this paper, we have introduced SAGA, a framework designed to provide support to all the stages of emergency plan development and use. SAGA covers the administrative aspects of emergency plan management; it also provides support for emergency plan designers via a reuse-enforcing development environment. Access to information relevant to practitioners is provided by the SAGA Digital Library, which consists of different repositories holding plans, plan fragments and other resources. SAGA also provides support to

team training and emergency plan improvement via scenario-based simulations, and facilities for actual emergency plan enactment during emergencies.

Despite its Spanish law based origin, we have engineered SAGA in a way that makes it adaptable to different settings. Thus, it could be used in different countries to support their specific plan management policies. For those countries where a law exists, all the management processes could be implemented within the Digital Library. In other cases, having SAGA available may represent an opportunity for authority to develop a more systematic management of emergency plans.

As for future work, we want to exploit the extensible nature of SAGA to design and develop new components. Of particular interest is the availability of tools for emergency plan improvement that complement the simulation-based tests. At the present stage, comparative improvement of plans is supported via the SAGA Plan Analysis Module. We are also exploring the possibility of incorporating a module for emergency plan evaluation based on the Cross-Impact Analysis technique [40] where some events will be related to the domain, while others will be directly tied to the process model we use to describe the procedures of a particular emergency plan (e.g. delays in the completion of some tasks or resource allocation conflicts can result in changes in the process to avoid them). Other lines for future work are related to the incorporation of citizens as actors in the process, providing a personalized and context-aware view of emergency plans to be accessed through people's mobile devices that will help them feel safer and find evacuation guidance, among other advantages.

Finally, the analysis performed on the emergency plan management policies in different countries provides the ground for defining and developing a framework for the assessment of the maturity of plan management policies in organizations, following ideas initially developed in [41].

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### REFERENCES

- [1] T. Catarci, M. de Leoni, A. Marrella, M. Mecella, A. Russo, R. Steinmann, M. Bortenschlager, WORKPAD: Process Management and Geo-Collaboration Help Disaster Response, *International Journal of Information Systems for Crisis Response and Management (IJISCRAM)*, 3 (2011) 32-49.
- [2] A. Galton, M. Worboys, An Ontology of Information for Emergency Management, in: *Proceedings of the 8th International Conference on Information Systems for Crisis Response and Management (ISCRAM 2011)*, Lisbon, Portugal, 2011.
- [3] C.M. White, *Social Media, Crisis Communication, and Emergency Management*, CRC Press, 2012.
- [4] M. Turoff, S.R. Hiltz, Information Seeking Behavior and Viewpoints of Emergency Preparedness and Management Professionals Concerned with Health and Medicine, Report to the National Library of Medicine, in: *Information Seeking Behavior and Viewpoints of Emergency Preparedness and Management Professionals Concerned with Health and Medicine, Report to the National Library of Medicine*, 2008.
- [5] V.B. Diniz, M.R.S. Borges, J.O. Gomes, J.H. Canós, Encyclopedia of Decision Making and Decision Support Technologies, in: F.A.P. Humphreys (Ed.), Frédéric Adam; Patrick Humphreys IGI Global, London, 2008, pp. 184-191.
- [6] I. Nonaka, H. Takeuchi, *The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation*, Oxford University Press, USA, 1995.
- [7] J.H. Canos, G. Alonso, J. Jaen, A multimedia approach to the efficient implementation and use of emergency plans, *IEEE Multimedia*, 11 (2004) 106-110.
- [8] J.H. Canós, A. Gómez, M.C. Penadés, M.R.S. Borges, SAGA: an Integrated Architecture for the Management of Advanced Emergency Plans, in: L. Rothkrantz, J. Ristvej, Z. Franco (Eds.) *Proceedings of the 9th International Conference on Information Systems for Crisis Response and Management (ISCRAM 2012)*, Vancouver, Canada, 2012.
- [9] Public Safety Canada, <http://www.publicsafety.gc.ca>, 2012. Last accessed on Oct. 2012.
- [10] Emergency Management Act (S.C. 2007, c. 15), <http://laws-lois.justice.gc.ca/eng/acts/E-4.56/>, 2007. Last accessed on Oct. 2012.
- [11] Federal Policy for Emergency Management, <http://www.publicsafety.gc.ca/prg/em/fpem-eng.aspx>, 2009. Last accessed on Oct. 2012.
- [12] Emergency Management Planning Guide 2010–2011, <http://www.publicsafety.gc.ca/prg/em/emp/emp-2010-11-eng.aspx>, 2010. Last accessed on Oct. 2012.
- [13] Federal Office of Civil Protection and Disaster Assistance, [http://www.bbk.bund.de/EN/FederalOffice/federaloffice\\_node.html](http://www.bbk.bund.de/EN/FederalOffice/federaloffice_node.html), 2012. Last accessed on Oct. 2012.
- [14] National Disaster Management Authority, <http://ndma.gov.in>, 2012. Last accessed on Oct. 2012.

- [15] National Institute of Disaster Management, <http://nidm.gov.in>, 2012. Last accessed on Oct. 2012.
- [16] National Disaster Management Guidelines - Incident Response System, [http://nidm.gov.in/PDF/guidelines/Incident\\_Response\\_System.pdf](http://nidm.gov.in/PDF/guidelines/Incident_Response_System.pdf), 2010. Last accessed on Oct. 2012.
- [17] Ministry of Civil Defense and Emergency Management, <http://www.civildefence.govt.nz>, 2012. Last accessed on Oct. 2012.
- [18] The Guide to the National Civil Defence Emergency Management Plan, [http://www.civildefence.govt.nz/memwebsite.nsf/Files/The-Guide-2009-revision/\\$file/The-Guide-v1.2-complete-web.pdf](http://www.civildefence.govt.nz/memwebsite.nsf/Files/The-Guide-2009-revision/$file/The-Guide-v1.2-complete-web.pdf), 2009. Last accessed on Oct. 2012.
- [19] Disaster Management Act, 2002; Act No. 57, 2002, <http://www.info.gov.za/view/DownloadFileAction?id=68094>, 2003. Last accessed on Oct. 2012.
- [20] NDMC Home Page, <http://www.ndmc.gov.za>, 2012. Last accessed on Oct. 2012.
- [21] South African National Disaster Management Framework, <http://www.ndmc.gov.za/Documents/Framework.aspx>, 2012. Last accessed on Oct. 2012.
- [22] Disaster Management Regulations: Disaster Management Act, 2002 (Act No. 57 of 2002); No. 27991, <http://www.info.gov.za/view/DownloadFileAction?id=61447>, 2005. Last accessed on Oct. 2012.
- [23] Norma Básica de Autoprotección (Spain's Self-protection Law), <http://www.boe.es/boe/dias/2007/03/24/pdfs/A12841-12850.pdf>, 2007. Last accessed on Oct. 2012.
- [24] Civil Contingencies Act 2004, <http://www.legislation.gov.uk/ukpga/2004/36/contents>, 2004. Last accessed on Oct. 2012.
- [25] UK Resilience, <http://www.cabinetoffice.gov.uk/ukresilience>, 2012. Last accessed on Oct. 2012.
- [26] Emergency Planning College, <http://www.epcollege.com>, 2012. Last accessed on Oct. 2012.
- [27] Emergency Preparedness, [http://www.cabinetoffice.gov.uk/sites/default/files/resources/Emergency\\_Preparedness\\_chapter5\\_amends\\_2111\\_2011.pdf](http://www.cabinetoffice.gov.uk/sites/default/files/resources/Emergency_Preparedness_chapter5_amends_2111_2011.pdf), 2011. Last accessed on Oct. 2012.
- [28] FEMA Home Page, <http://www.fema.gov/>, 2012. Last accessed on Oct. 2012.
- [29] National Incident Management System, <http://www.fema.gov/national-incident-management-system>, 2012. Last accessed on Oct. 2012.
- [30] National Response Framework, <http://www.fema.gov/national-response-framework>, 2012. Last accessed on Oct. 2012.
- [31] National Preparedness Guidelines, <http://www.dhs.gov/national-preparedness-guidelines>, 2012. Last accessed on Oct. 2012.
- [32] Emergency Response Plan, <http://www.ready.gov/sites/default/files/documents/files/EmergencyResponsePlan.pdf>, 2012. Last accessed on Oct. 2012.
- [33] Make a Plan, <http://www.ready.gov/make-a-plan>, 2012. Last accessed on Oct. 2012.
- [34] Disaster Countermeasures Basic Act (Act No. 223), [http://cordis.europa.eu/fp7/security/fp7-project-leaflets\\_en.html](http://cordis.europa.eu/fp7/security/fp7-project-leaflets_en.html), 1962. Last accessed on Oct. 2012.
- [35] M. Llavador, P. Letelier, M.C. Penadés, J.H. Canós, M.R.S. Borges, C. Solís, Precise yet Flexible Specification of Emergency Resolution Procedures, in: B.V. de Walle, M. Turoff (Eds.) Proceedings of the 3th International Conference on Information Systems for Crisis Response and Management (ISCRAM 2006), Newark (NJ), USA, 2006.
- [36] FP7 Security Research project leaflets, 2012. Last accessed on Oct. 2012.
- [37] M.C. Penades, M. Borges, A. Vivacqua, J.H. Canos, C. Solis, Collaborative refinement of emergency plans through public engagement, in: Collaborative Computing: Networking, Applications and Worksharing (CollaborateCom), 2011 7th International Conference on, 2011, pp. 524-527.
- [38] FEMA Planning & Templates, <http://www.fema.gov/planning-templates>, 2012. Last accessed on Oct. 2012.
- [39] M.C. Penadés, J.H. Canós, M.R.S. Borges, M. Llavador, Document product lines: variability-driven document generation, in: Proceedings of the 10th ACM symposium on Document engineering, ACM, New York, NY, USA, 2010, pp. 203-206.
- [40] M. Turoff, V. Bañuls, Major Extensions to Cross-Impact Analysis, in: Proceedings of the 8th International Conference on Information Systems for Crisis Response and Management (ISCRAM 2011), Lisbon, Portugal, 2011.

[41] R. Santos, M.S. Borges, J. Canós, J. Gomes, The Assessment of Information Technology Maturity in Emergency Response Organizations, *Group Decis Negot*, 20 (2011) 593-613.