A Systemic Approach to Disaster Management

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***ABSTRACT*:** Several natural disasters that have occurred over the last 35 years world-wide have highlighted the need to improve radically the safety performance of organizations. A *systemic* approach has been adopted to construct a model for a disaster management system. It has been applied to the case of natural disasters, although the approach is general. The essential purpose has been not merely to identify functions but to create a "structure" for a Systemic Disaster Management System (SDMS), within which necessary "process" or action takes place. The SDMS model aims to help to maintain risk within an acceptable range in an organization's operations in a coherent way. The model is proposed as a *sufficient* structure for an effective disaster management system. It has a fundamentally *preventive* potentiality in that if all the sub-systems and connections are present and working effectively, the probability of a failure should be less than otherwise. The model consists of the following fundamental characteristics:

{a} a recursive structure (i.e. 'layered'),
{b} a structural organization which consists of a 'basic unit' in which it is necessary to achieve five Functions associated with systems 1 to 5, and
{c} four principles of organization,

It is hoped that this approach will lead not only to more effective management of natural disasters, but also to more effective management of technological disasters.

KEYWORDS: disaster management system, risk, systemic.

1. INTRODUCTION

Throughout history, natural disasters have exacted a heavy toll of death and suffering and are increasing worldwide. During the past 34 years they have claimed about four million lives worldwide, adversely affected the lives of at least a billion more people, and resulted in property damage exceeding $50 billion (Guha-Sapir and Lechat 1986b; National Research Council (NRC) 1987; International 1998; Office 2001). Projections based on available data suggest that, in the U.S. alone, the costs of natural disasters between 1995 and 2010 will approach $100 billion and the loss of 5,000 lives.

Natural disasters have included earthquakes in Turkey, Greece, and Taiwan in 1999 (Centers for Disease Control and Prevention (CDC) 1993; Kunii et al. 1995; Tanaka 1996; Oda, et al. 1997; Tatemachi 1997) and El Salvador and India (2001), a series of devastating hurricanes in the Caribbean in 1998 (including Hurricanes Mitch and Georges), severe flooding in Mozambique (2000 and 2001), Venezuela (1999), and California in 1998 (CDC 1993a,b,c; Chartoff and Gren 1997), Tornadoes in Oklahoma and Texas (1999), global adverse weather conditions related to the El Niño 1998, and the volcanic eruption of Mount Soufriere on the island of Montserrat (1997).

On 26 December 2004 the biggest earthqauke for 40 years occurred between the Australian and Eurasian plates in the Indian Ocean (BBC, 2005). The quake triggered a *tsunami;* i.e. a series of large waves that spread thousands of kilometers over several hours. As a consequence of the tsunami, the coastal areas like the Sri Lankan tourist resort of Kalutara, had no early warning of the approaching tsunami (BBC, 2005). It is believed that several waves of the tsunami came at intervals of between five and 40 minutes. For example, in Kalutara the water reached at least 1 Km inland, causing widespread destruction and death. The disaster left at least 165,000 people dead, more than half a million more injured and up to 5 million others in need of basic services and at risk of deadly epidemics in a dozen Indian Ocean countries.

The most recent disasters such as Hurricanes Katrina and Rita show how vulnerable the United States is to disasters. It is believed that destruction caused by Hurricain Rita largely spared Houston and reflooding occurred only in some areas of New Orleans (Barret, 2005). As Rita neared the Texas coastline, some three million residents got in their cars and made a run for it. Among the results: a 100-mile-long traffic jam outside Houston, hundreds of motorists stranded when their gas ran out, and a deeply peeved public. On the other hand, Katrina caused an estimated $35 to $60 billion in damage and resulted in at least 1000 deaths (Barret, 2005).

Two more natural disasters have occurred in 2005 and have had devastating effects; the hurricane Stan which hit Central America countries and the second, an earthquake that occurred in Pakistan administered Kashmir (BBC 2005). Hurricane Stan left ten of thousands of people homeless. For example, in Mexico where tens of thousands people were moved from their homes, several oil rigs located in the Gulf of Mexico were evacuated and 17 people are confirmed death. The worst hit country was Guatemala, where entire villages have been wiped out by landslides and flash floods, and hundreds of people have been killed. More than 90,000 people are living in shelters, and water and electricity have been cut in the affected areas. The confirmed death toll is 652. Four people were killed in Honduras. Some 300 people were flooded and seventy people are known to have died in El Salvador. In addition to this, more than 50,000 others have been taken to hundreds of shelters throughout the country, as rescue efforts continue. Almost 3,000 were affected by storms that destroyed hundreds of homes and the confirmed death toll is ten in Nicaragua.

Heavy rainfall and new floods prompted by Stan added to the woes of hundreds of communities, mostly along the Pacific Coast of Costa Rica, which had undergone heavy destruction as a result of Hurricane Rita. More than 500 people were taken to temporary shelters. The confirmed death toll is two.

On 8 October 2005 an earthquake of magnitud 7.6 (according to government officials) struck close to Muzaffarabad in Pakistan administered kashmir. The disaster caused 75,000 deaths, at least 60,000 injured and up to three million left homeless by the devastating South Asia earthquake (Freeman, 2005, & BBC, 2005).

The above disasters have shown that the existing ‘disaster management systems’ were inadequate to deal with such disasters. There is a need for a systemic approach. Systemic means to see events as products of the working of a system. A system can be defined as any entity, conceptual or physical, which consists of inter-dependent parts. Given the above ‘failure’ may be seen as the product of a system and, within that, see death/injury/property loss etc. as results of the working of systems.

1.1 Objectives

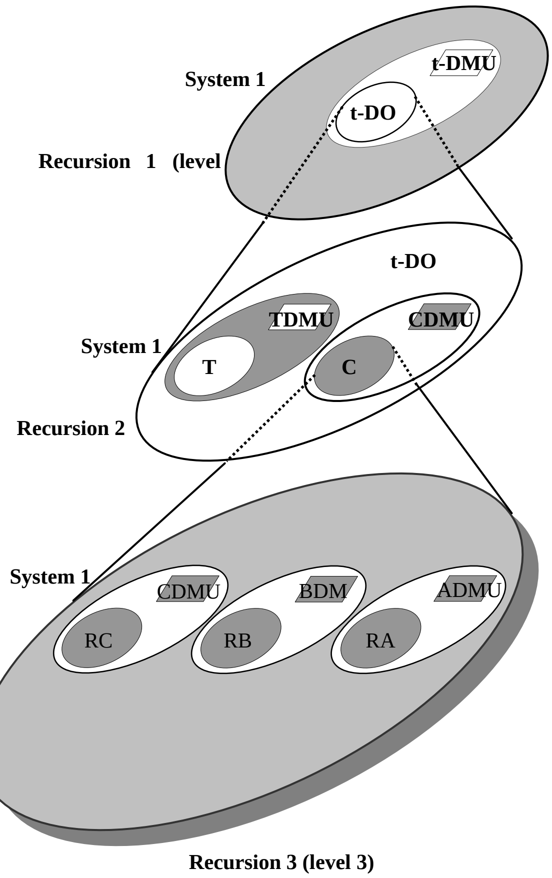
This paper proposes a systemic disaster management system (SDMS) model, which aims to maintain risk within an acceptable range in an organization's operations in relation to a disaster management. The model is proposed as a *sufficient* structure for an effective disaster management system. It has a fundamentally *preventive* potentiality in that if all the sub-systems and connections are present and working effectively, the probability of a failure should be less than otherwise.
It is hoped that this approach will lead not only to more effective management of natural disasters, but also to more effective management of man-made disasters.

2. A SYSTEMIC DISASTER MANAGEMENT SYSTEM (SDMS) MODEL

The Systemic Disaster Management System (SDMS) model is intended to maintain risk within an acceptable range in an organization's operations in relation to disaster management. The model is proposed as a *sufficient* structure for an effective disaster management system. It has a fundamentally *preventive* potentiality in that if all the sub-systems and connections are present and working effectively the probability of a failure should be less than otherwise.
The SDMS model consists of the following fundamental characteristics:

{1} a recursive structure (i.e. 'layered'),
{2} a structural organization which consists of a 'basic unit' in which it is necessary to achieve five functions associated with systems 1 to 5,
{3} four principles of organization,

A full account of the above characteristics of the model is described elsewhere (Santos-Reyes & Beard, 2001). A brief description of {1} and {2} will be given in the subsequent paragraphs.



t-DMU=total Disaster Management Unit
t-DO= total Disaster Operations
CDMU= Chiapas Disaster Management Unit
C= Chiapas
TDMU= Tabasco Disaster Management Unit
T= Tabasco
ADMU= A-Disaster Management Unit
RA= Region-A
BDMU= B-Disaster Management Unit
RB= Region-B
CDMU= C-Disaster Management Unit
RC= Region-C

Fig. Recursive structure of the SDMS

2.1 Recursive Structure of the SDMS Model

Recursion may be regarded as a 'level', which has other levels below or above it. Fig. 1 is intended to show three levels of recursion for the disaster management system for the case of Mexico. The 'total Disaster Operations' (t-DO) may be taken to be the highest level of the system of interest and is shown at level one or recursion 1. The t-DO is represented as an elliptical symbol and contains two basic elements: (1) a 'management unit' represented by a parallelogram symbol and (2) the 'operations', managed by (1), indicated as an inner elliptical symbol (the line that connects (1) & (2) indicates interdependence between them).

At this level, the total Disaster Management Unit (t-DMU) is concerned with the designing of prevention measures in order to prevent deaths/injuries of citizens of the whole country; i.e. Mexicans. The t-DO is where all these policies, procedures concerning prevention are implemented, for example, training on evacuation from public buildings, homes, schools, hospitals, etc.

As described in Santos-Reyes & Beard, 2001, the fundamental de-composition of the t-DO may be carried out in different ways. In particular, it was pointed out that de-composition might be on a basis of geography or function. In the present study effectively, a de-composition on a basis of geography has been assumed. 'Chiapas' and 'Tabasco' operations have been identified as the basic sub-systems of the t-DO and they are shown at recursion 2 in Fig. 1. 'Chiapas & Tabasco' are states located at the South East of Mexico (It should be noted that the de-composition of t-DO at the present case is illustrative only; i.e in a real case t-DO may be de-composed into more States or regions, etc.). Usually these states are severely hit when hurricanes occur. It must be pointed out that each of the above sub-systems can be de-composed into further sub-systems depending on our level of interest. For example, 'Region-A (RA)', 'Region-B (RB)' and 'Region-C (RC) Operations' are shown as sub-systems of 'Chiapas' operations at level 3. Similarly, 'Tabasco' can, in principle, be de-composed into Regions but this is not shown in Fig. 1.

The 'Total environment' (the elliptical symbol shown on the left hand part of Fig. 2) is not part of the system of interest but it may influence it, for example via economic and political drivers and of course the natural disasters; therefore it is important to consider them.

The SDMS model as shown in Figs 1&2 are intended to manage natural disasters. These Figs will be used as the basis for the description of the model.

2.2 Structural Organization of the SDMS Model

The SDMS model has a 'basic unit' in which it is necessary to achieve five functions associated with systems 1 to 5. Systems 2 to 5 facilitate the function of system 1, as well as ensuring the continuous adaptation of the disaster management system as a whole. The five functions are the following: formulation of the Disaster Policy, Disaster Development, Disaster Functional, Disaster Coordination, and Disaster Policy Implementation. Referring to Fig. 2:

2.2.1 System 1: Disaster *Policy Implementation*

System 1 implements disaster prevention policies in the total disaster operations (t-DO); i.e., to the whole country, Mexico. How system 1 might be 'broken down' further is a key question; for example, system 1 might be de-composed on a basis of geography or functions. For the purpose of the present study system 1 was de-composed on a basis of geography; i.e. 'Chiapas & Tabasco' (these are two states located at the South East of Mexico. They usually are severely hit by Hurricanes) and this is shown in Figs. 1&3.

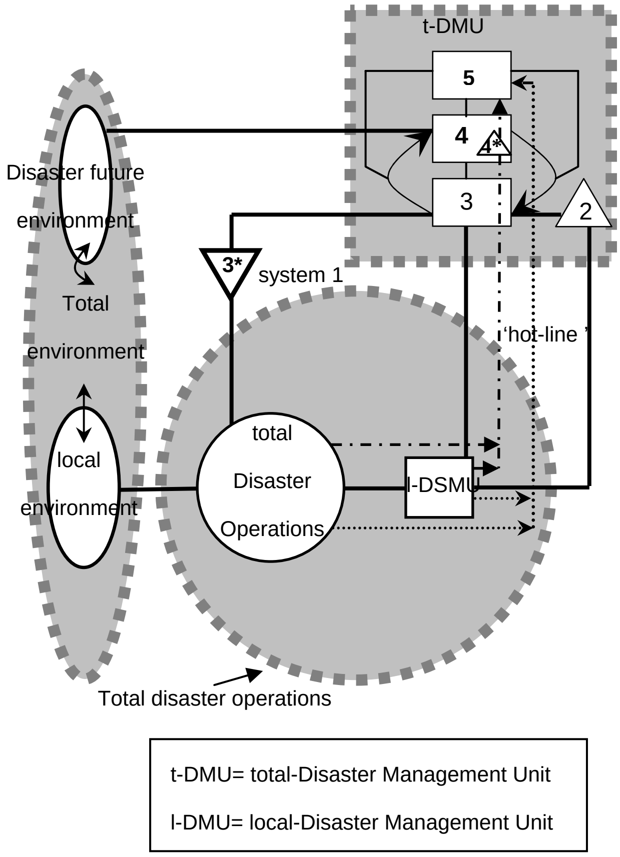


Fig. 2 A SDMS Model

2.2.2 System 2: *Disaster Co-ordination*

System 2 co-ordinates the activities of the operations of system 1 in relation to the SDMS's total environment (this will be discussed further in a later section). System 2, along with system 1, implements the disaster prevention plans received from system 3. It informs system 3 about routine information on the performance of the operations of system 1. To achieve the plans of system 3 and the needs of system 1, system 2 gathers and manages the information of system 1's operations. There are other organizations within the total environment that may create some conflicting situations in the operation of system 1. An example of co-ordination activity could be the evacuation of towns, cities, etc. Other example could be the co-ordination of all those activities related to humanitarian aid to the affected areas.

2.2.3 System 3: *Disaster Functional*

System 3 is directly responsible for maintaining risk within an acceptable range in system 1, and ensures that system 1 implements the organization's disaster prevention policies. It achieves its function on a day-to-day basis according to the plans received from system 4. System 3 requests from systems 1, 2, and 3* information about the performance of system 1 to formulate its disaster prevention plans and to communicate future needs to system 4. It is also responsible for allocating the necessary resources to system 1 to accomplish the organization's disaster prevention plans. Allocation of resources for the training of personnel who will help to evacuate people from the affected areas due to a natural disaster; such as an earthquake or hurricane, etc. is an example of the function of system 3.

System 3*: *Disaster Audit*

System 3* is part of system 3 and its function is to conduct audits sporadically into the operations of system 1. System 3* intervenes in the operations of system 1 according to the plans received from system 3. System 3 needs to ensure that the reports received from system 1 reflect not only the current status of the operations of system 1, but are also aligned with the overall objectives of the organization. The audit activities should be sporadic (i.e. unannounced) and they should be implemented under common agreement between system 3* and system 1. The revisions of the adequacy and the functioning of the engineering services and fixed installations that may be used in case of a natural disaster (e.g. shelters, electricity supply systems, water supply systems, etc.) are examples of the action of system 3*.

2.2.4 System 4: *Disaster Development*

System 4 is concerned with disaster related research and development (R&D) for the continual adaptation of the disaster management system as a whole. By considering strengths, weaknesses, threats and opportunities, system 4 can suggest changes to the organization's disaster prevention policies. This function may be regarded as a part of effective disaster planning. Firstly, system 4 deals with the policy received from system 5. Secondly, it senses all relevant threats and opportunities from the total physical and socio-economic environment of the organization, including 'disaster future environment' (this is explained in more detail in a later section). Thirdly, system 4 deals with all relevant needs of system 1's performance and its potential future. Finally, it deals with the confidential or special information communicated by system 4*.

Research on new technologies in relation to Early Warning Systems (EWS) may be part of the functions of system 4. Another example of could be the promotion on further research regarding the prediction of when an earthquake is going to happen by employing the concepts of Fractals, etc.

System 4*: *Disaster Confidential Reporting system*

System 4* is part of system 4 and is concerned with confidential reports or causes of concern from any person, about any aspects, some of which may require the direct and immediate intervention of system 5.

An example of system 4* may be a confidential report regarded to looting of shops, private houses, hospitals, schools, universities, banks, etc.

2.2.5 System 5: *Disaster Policy*

System 5 is responsible for deliberating disaster prevention policies and for making normative decisions. According to alternative plans received from system 4, system 5 considers and chooses feasible alternatives, which aim to maintain the risk within an acceptable range throughout the life cycle of the total disaster operations (t-DO). It also monitors the interaction of system 3 and system 4, as represented by the lines that show the loop between systems 3 and 4 as shown in Fig. 2. An example of system 5's policies is to address the prevention of injuries/deaths from natural disasters. These policies should also promote the culture of prevention throughout the organization and amongst the people, local governments, etc.

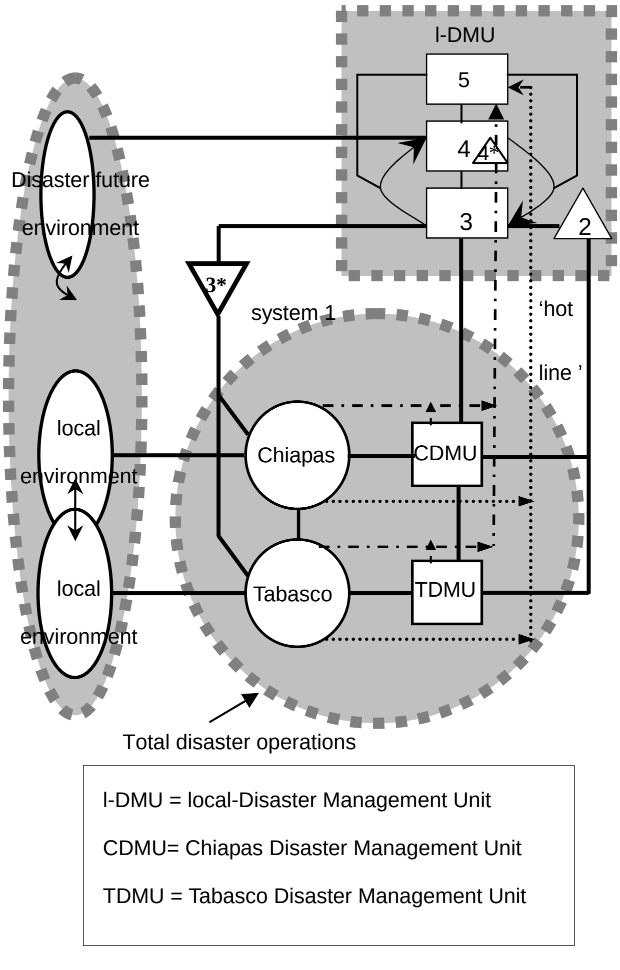


Fig. 3 Recursions 1&2 in the format of the SDMS

Fig. 2 shows, at one level of recursion only, the SDMS model that is intended to manage natural disasters in Mexico (Figs. 2&3 should be seen in the context of Fig. 1). The top right hand side broken line square box is the total Disaster Management Unit (t-DMU) at recursion 1. The broken line circle represents the total Disaster Operations (t-DO). However, the 'basic unit' may be replicated for every operation of system 1 as implied in Fig. 3.

The organizational structure of the SDMS is shown as interacting in a defined way with its environment through system 1's operations, and through system 4, as illustrated in Fig. 2&3. 'Environment' may be understood as being those circumstances to which the SDMS response is necessary. 'Environment' lies outside the SDMS but interacts with it; it is the source of circumstances that threaten the SDMS, for example earthquakes, tornadoes, hurricanes, tsunamis. System 4 deals with both 'total environment' represented as an elliptical broken line symbol and the 'disaster future environment' embedded into the total environment as shown in Fig. 2. The 'future disaster environment' is concerned with threats and opportunities for the future development of disaster prevention. For example, the search for better technologies of the prediction of when an earthquake will occur is an example of the activity of 'future environment'.

Whenever a line appears in Figs. 2&3 representing the SDMS model, it represents a channel of communication, except for the lines that connect the balancing loop that connects systems 4 and 3.
Fig. 2 shows a dashed line directly from system 1 to system 5, representing a direct communication or 'hot-line' for use in exceptional circumstances; e.g. during an emergency. Also shown on Fig. 2 is a line with an arrow from system 1 to system 4* and system 5, representing a safety confidential reporting system. Both channels, the 'hot-line' and the confidential reporting system, represent 'initially' one-way communication channels but they may become two way communication channels between systems 1 and 5 and 1 and 4* respectively.

3. CONCLUSION

A systemic disaster management (SDMS) model has been proposed. The objective of the SDMS model is to maintain risk within an acceptable range. It is hoped that this approach will help to manage natural disasters more effectively.

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REFERENCES

Barrett, J. 2005. Newsweek, URL:http://newsweek.com (September 26, 2005).

BBC, Tsunami disaster. 2005. URL:http://news.bbc.co.uk/go/pr/fr/-/1/hi/world/asia-pacific/4136289.stm

BBC,http://news.bbc.co.uk/go/pr/fr/-/1/hi/world/americas/4326084.stm (Published: 2005/10/10 11:51:05 GMT).

BBC,http://news.bbc.co.uk/1/hi/world/south_asia/4322624.stm (15/112005).

Centers for Disease Control and Prevention (CDC). 1993a. Flood-related mortality—Missouri, 1993. *MMW*R, 42, 836–838.

Centers for Disease Control and Prevention (CDC). 1993b. Morbidity surveillance following the Midwest flood—Missouri, 1993. *MMW*R, 42, 797–798.

Centers for Disease Control and Prevention (CDC). 1993c. Public health consequences of a flood disaster—Iowa, 1993. *MMW*R, 42, 653–656.

Chartoff, S. E., and Gren, J. M. 1997. Survey of Iowa emergency medical services on the effects of the 1993 floods. *J. Prehosp. & Disaster Med*., 12, 210–214.

Freeman, S. A generation has been lost. *Times*

Online(www.thetimes.co.uk), October 10, 2005

GuhaSapir, D., and Lechat, M. F. 1986b. Reducing the impact of natural disasters: Why aren't we better prepared? *Health Policy and Plng.*, 1, 118.

Hagman, G. 1984. *Prevention better than cure*. Swedish Red Cross, Stockholm.

International Decade for Natural Disaster Reduction (IDNDR) Secretariat. 1998. *The international decade for natural disaster reduction: Action plan for 1998–1999 Geneva*. United Nations Office for the Coordination of Humanitarian Assistance.

Kunii, O., Akagi, M., and Kita, E. 1995. Health consequences and medical and public health response to the Great HanshinAwaji Earth-quake in Japan: A case study in disaster planning. *Medicine and Global Surviva*l, 2, 32–45.

National Research Council (NRC). 1987. *Confronting natural disasters: An international decade for natural disaster reductio*n, National Academy Press, Washington, D.C. Nations, New York.

Oda, Y., et al. 1997. Crush syndrome sustained in the 1995 Kobe, Japan earthquake; treatment and outcome. *Ann. Emerg. Med.*, 30, 507–512.

Office of U.S. Foreign Disaster Assistance. 1999. *Disaster history: Significant data on major disasters worldwide, 1900–present*. Agency for International Development, Washington, D.C.

Santos-Reyes, J., and Beard, A. N. 2001. A Systemic Approach to Fire Safety Management. *Fire Safety Journal*. 36, 359-390.

Tanaka, K. (1996). ‘‘The Kobe earthquake: The system response. A disaster report from Japan.’’ *Eur. J. Emerg. Med.*, 3, 263–69. Oda, Y., et al. (1997).

Tatemachi, K. 1997. Acute diseases during and after the Great Han-shin- Awaji earthquake. *Proc., WHO Symp. Earthquakes and People's Health*, 48–52.

United Nations (UN) General Assembly. 1988. *International decade for natural disaster reduction: Report of the Secretary General. 43rd session, agenda item 86. A/43/723. 18 October 1988*. United
World Health Organization (WHO). 1980.

World Health Organization (WHO). 1980. Emergency care in natural disasters: Views of an international seminar. *WHO Chron.*, 34, 96.