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Disaster Management: A Review of Existing Models and Approaches

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Abstract—*These days disaster risk of communities across the globe is increasing in alarming manner. Recent events such as earthquakes, floods, tsunamis, droughts, landslides, avalanches etc. have emphasized the vulnerability of settlements to natural disasters. Urbanization, vulnerable rural livelihoods, the decline of ecosystems are being identified as the major reasons for this increasing disaster risk. This serious crisis has generated a vital need for profound research in the field of disaster management. Natural hazards are dynamic and uncertain processes and disaster management is a very complex and multidisciplinary field which requires interventions of experts from diverse fields. Researchers from all the disaster prone countries are studying the disasters and providing suggestions for disaster risk reduction. Various modeling techniques suggested by researchers give solutions to deal with such complicated situations. Models are representations of real situations. Models are especially effective in resolving issues which are of multi pronged origin and options and when more than one agency is involved in mitigating the same. Many researchers have developed many models in the recent past to deal with the complicated process of disaster management. After studying the extensive research which is being conducted at global level, this paper provides a review of some remarkable approaches and models in the field of disaster management. The purpose of this paper is to provide students, researchers, and responsible personnel with an overview of various models, approaches and frameworks suggested by various experts engaged in the field.*

1. INTROD UCTION

Disaster management is emerging as a major concern for all communities across the globe because of the occurrence of several major natural disasters in the past few years. Globally it has been recorded that the disasters are striking with increasing frequency, causing massive human and economic losses [21]. Disasters like floods, earthquakes, cyclones, landslides, avalanches, droughts, forest fire, etc strike various countries on a regular basis. Also, climate change is expected to increase the frequency and intensity of extreme weather events and give rise to new vulnerabilities with differential spatial and socio-economic impacts on communities. The unprecedented increase is expected to have severe impact on the hydrological cycle and water resources leading to droughts, floods, drinking water shortage, loss of coastal wetlands and mangroves as well as rise in food insecurity and health problems. This serious crisis has generated a vital need for profound research in the field of disaster management. Researchers from all the disaster prone countries are studying the disasters and providing suggestions for disaster risk reduction. Disaster management is a very complex and multidisciplinary field which requires interventions of experts from diverse fields. Various modeling techniques suggested by researchers give solutions to deal with such complicated situations. After studying the extensive research which is being conducted at global level, this paper provides a review of some remarkable approaches and models in the field of disaster management.

2. MODELS FOR DISASTER MANAGEMENT

Models are representations of real situations and can be presented in various types viz. iconic models, analog models, mathematical models, deterministic models, probabilistic models and conceptual models [2]. Satyendra [25] states:

‘Modeling as a technique has been found to be very effective in resolving issues which are of multi pronged origin and options and when more than one agency is involved in mitigating the same. Modeling techniques help in improving the performance of the implementing agencies be it government agencies, public sector organizations or NGOs.’

A comprehensive review of some of the good models and approaches for disaster management is given in the following sections.

3. CATASTROPHE MODELING

Catastrophe models as we know are probabilistic models to estimate the losses caused by any disaster based on risk and vulnerability of any settlement for a foreseeable set of events. The catastrophe models are popularly developed for disasters like earthquakes on account of their unpredictable nature.

3.1. ‘Cat’ model

Grossi *et. al.* [14] gives a model for earthquake risk in China, on the basis of the 1976 great Tangshan earthquake. A fully probabilistic catastrophe loss or ‘Cat’ model is developed in which tens of thousands of potential earthquakes on various

seismic sources are sampled and an annual rate of occurrence is attributed to each one. The authors state:

'Output from the Cat model can be used to determine the probability that many separate locations could be affected within the same earthquake event. It can also determine the technical price for risk, whether for a single property or a whole portfolio of properties across multiple locations. Cat models perform at their optimum when details on a building and its location characteristics are available.'

The model incorporates the exposure, property damage, casualties and economic losses as a result of earthquake. The authors have advised insurance companies aiming at increasing their presence in the residential sector in China to use Cat models to develop a fair and attractive pricing strategy on the basis of Cat model.

Chian [4] identifies a research gap in the existing catastrophe models for earthquake disasters. The author emphasizes the importance of physical science of building damage that is linked to ground-shaking characteristics. He proposes engineering based building damage estimation model based on established theories of seismic wave propagation and structural resonance. The research introduces a damage factor to provide an indication of the relative extent of damage to buildings. Analysis based on the proposed methodology is given for four case studies. Results show that the computed damage factors reasonably reflect the extent of actual damage to buildings that was observed in post-earthquake reconnaissance surveys of those case studies. The model developed by the author can have a promising future as a complementary assessment tool in building damage estimation in catastrophe modeling for earthquakes.

3.2. Earthquake Disaster Risk Index (EDRI)

One important step in the field of disaster risk assessment and management is development of Multidisciplinary Earthquake Risk Index (EDRI) [7]. The author has developed EDRI which facilitates direct comparison of the relative overall earthquake risk of cities worldwide with contributions of various factors in the form of a composite index.

The factors considered in development of EDRI ensures that disaster situation created by an earthquake is a function of physical impact of earthquake, response of the affected city to earthquake and also the relevance of the impact to the city and to world affairs. The easy comprehension of the resultant index would increase the utility of EDRI for public, governments, insurance companies and other potential users. Hence, Gupta *et. al* [15] has commented that 'the EDRI moves one step further from existing practice'.

3.3. GeoHazards International (GHI) Earthquake Lethality Estimation Method

The GeoHazards International has developed the GHI Earthquake Lethality Estimation Method to estimate lethality potential of earthquakes in communities which would reduce earthquake risk particularly for in developing countries [11].

The GHI method was used in Global Earthquake Safety Initiative (GESI) carried out by GeoHazards International along with United Nations Center for Regional Development. The EDRI method served as the starting point of GESI project. The GESI project obtained very interesting results by evaluating the implications of potential earthquakes in important cities of the world. The GHI method appears to have tremendous potential to improve earthquake risk management predominantly in the developing countries [11].

4. ANALYTICAL APPROACHES

Many researchers have taken different approaches for analyzing a disaster situation. Some important approaches given by researchers are mentioned below.

4.1. Pressure and Release Model

An important model designed for peoples vulnerability and their livelihood conditions is 'Disaster Pressure and Release (PAR) Model' given by Blakie *et. al*. [3]. This model has combined human factor to the study of disasters and illustrates how human actions and structures impact disasters. The 'Access model' was developed along with the PAR model. According to this model the key to understanding the way people cope with hazards is the livelihood strategies that people choose. Both these models recognize that the most vulnerable live with constant hazards such as inadequate shelter, dangerous locations, lack of access to food and regular income and poor health – which can become disasters. The strength of PAR / Access models as given by Palakudiyil and Todd [23] is

'They take a wide ranging view of vulnerability, providing a framework for defining the way people live and earn their living, as well as their vulnerability to disaster.'

4.2. Capacities & Vulnerabilities Analysis (CVA)

The framework of Capacities and Vulnerabilities given by Anderson and Woodrow as referred by Twigg *et. al*. [27] is a matrix meant for analyzing people's vulnerabilities and capacities in three broad, interrelated areas: physical/material, social/organizational and motivational/attitudinal (Table 1). CVA is an easy to use, realistic and indicative tool which has wide applications in the field of disaster mitigation.

Table 1: CVA Matrix, (Source: Twigg *et. al.)* [27]

	Vulnerabilities	**Capacities**
Physical / Material: What productive resources, skills and hazards exist?		
Social / Organizational: What the relations and organization among people?		
Motivational / Attitudinal: How does the community view its ability to create change?		

5. DISASTERS AND SUSTAINABLE DEVELOPMENT

Sustainability issues in all aspects of disaster management are major cause of concern these days. Researchers have been trying to integrate endevors of disaster management with sustainable development of the regions.

The impact of coupling Environmental Impact assessment (EIA) and Environment management (EM) with the Disaster Risk reduction activities in a region is emphasized by During [9]. The author mentions that when seeking to identify and mitigate the impact of proposed developments the process is carried out from two distinct perspectives: "before" and "after" implementation with environmental impact assessment and environmental management the main "instruments" on either side. The research explores the theory that coupling these two "instruments" can aid disaster risk reduction and management. The author concludes that there is no simple answer and that further research is needed for implementing these theories.

5.1. Model for Integration of Climate Change Adaptation and Disaster Risk Reduction

Gupta el.al. [16] have given a model for mainstreaming Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA) in developmental planning process at district level. The research study was undertaken in Gorakhpur district which served District Disaster Management Authority (DDMA) to come out with a climate sensitive model District Disaster Management Plan (DDMP) for Gorakhpur District. The model integrates both the scientific methods and social science methods viz. Participatory Assessments and Shared Learning Dialogues (SLD). This leads to improved understanding of three corners: Communication, Coordination and Convergence within organisation, right from planning to implementation level. Such climate-sensitive departmental plans lead to the development of District Disaster Management Plan with inclusion of climate change issue. This new paradigm in planning process suggested in the model, will possibly contribute to state and national planning framework in context of DRR and CCA considering climate change adaptation issue.

5.2. Sustainable Livelihood Approach (SLA)

Sustainable Livelihood Approach (SLA) is given by Department for International Development [8] which states that

'A livelihood comprises the capabilities, assets and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base.'

The SL framework is built around five inter – related factors that determine livelihoods: the *vulnerability context* in which people live their lives; the *livelihood assets* they possess; the *transforming structures and processes* which influence positively and negatively the livelihood strategies available to people; and the *livelihood outcomes* resulting from their interaction.

SLA encompasses a more holistic approach which focuses primarily on vulnerable people's livelihoods. It analyses the multiple factors that affect them and gives appropriate importance to the interrelationship between the various factors that affect people's livelihoods. [23]

5.3. SusTLE Model

Mukherjee [22] has given a SusTLE model which aims at rural and urban settlements of developing countries to break the cycle between damage, reconstruction and other losses from hazards; and to bring a sustainable impact into the settlement through disaster mitigation. The author states that

'The prerequisite of the SusTLE model is the formulation of appropriate multi – stakeholders' decision making body – the neighbourhood management council. This would have representation from community, local government and consultant groups.'

The SusTLE model encompasses very practical aspects in view of effective implementation of disaster mitigation measures in developing countries.

6. DISASTER MANAGEMENT FRAMEWORKS

Kumar [19] has suggested a model and framework for disaster management in India. It gives a systematic and comprehensive structure for disaster risk reduction efforts. The framework developed by the author is given as Fig. 1.

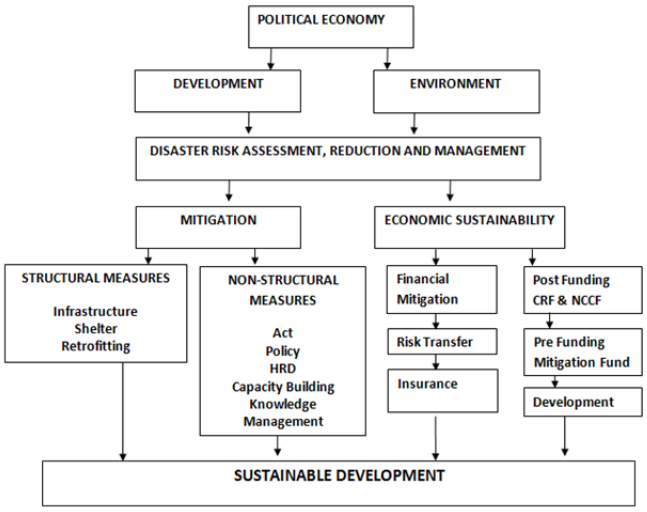

Fig. 1: Framework Model for Disaster Management [19]

United Nations [28] also gives a framework model for disaster risk reduction in sustainable development context. This model though general in format, not only categorizes the risk reduction measures, but also identifies the interlinkage and importance of risk identification and impact assessment through analysis of vulnerability and resource capability.

7. TECHNOLOGICAL INNOVATIONS

7.1 Interactive, Intelligent, Spatial Information System (IISIS)

Comfort et.al. [6] dealt with the crucial issue of coordination in multi-organisational settings in times of disaster. The authors present the concept of complex adaptive systems as a theoretical framework that explains the dynamic processes involved in achieving coordinated action among multiple organisations to manage complex technical operations in environments vulnerable to risk. They argue that coordination may be achieved more easily with the appropriate design of a socio-technical system, that is, a system that supports the exchange of critical information among technical and organisational entities to improve performance in both. The authors present the design and initial findings from a trial demonstration to implement a prototype interactive, intelligent, spatial information system (IISIS) in the Pittsburgh Metropolitan Region. According to the authors:

The IISIS prototype supports five critical functions that practicing disaster managers need to increase efficiency in disaster mitigation and response. These functions are:

1. Reliable, systematic exchange of information within and among organisations with legal responsibility for disaster operations and management.
2. Timely, accurate information to assess known threats to the community.
3. Full transfer of information from one jurisdictional level of operations to the next during disaster operations.
4. Real-time monitoring of threatening conditions, and the timely transfer of information from field units to operations centre and return.
5. Effective reporting of actions from multiple sites of operation, with the timely integration of these

7.2 RADIUS

Risk Assessment Tool for Diagnosis of Urban areas against Seismic disasters (RADIUS) tool was developed for IDNDR (International Decade for Natural Disaster Reduction) by OYO Corporation, Japan and RMSI to enable a city administrator to do quick assessment of earthquake risk to a city. The goal of this tool is to aid users in understanding the seismic hazard and vulnerability of their cities and to guide them in starting preparedness programs against future earthquakes [13].

7.3 HAZUS

HAZUS (Hazards U. S.) is a Geographic Information System (GIS) based earthquake loss estimation tool, developed by the Federal Emergency Management Agency (FEMA) in cooperation with the national Institute of Building Sciences (NIBS). The HAZUS tool provides an approach to quantifying future losses that is national in scope, uniform in application, and comprehensive in its coverage of the built environment. [10]

7.4 RISK.iitb

Recently, a GIS based earthquake risk assessment system (RISK.iitb) suitable for India has been developed at Indian Institute of Technology Bombay. Aditya and Sinha [1] state:

'It is felt that RISK.iitb provides a significant contribution to the field and helps to bridge the varying requirements of scientists, policy makers, executing bodies and public in terms of understanding earthquake risk and its consequences.'

7.5 Emergency Communication

The popularity of online social networking has increased tremendously during past few years. White et.al. [29] explores the possibility of gainfully using such social networks for bringing emergency domain related entities together. The studies investigate whether the social network paradigm can be used to enable individuals and organisations to collaborate in mutually beneficial ways, in all stages of emergency management. A primary survey conducted with this objective shows overwhelming agreement that social networking sites should be considered a viable solution to the problems plaguing information dissemination and communications in the emergency domain.

8. OTHER RESEARCH

Gireesan [12] highlights the significance of empowering the Panchayati Raj Institutions (PRIs) in the process of disaster preparedness and risk reduction. According to the author

PRIs can analyse the hazard, risk, vulnerability and capacity effectively, which is imperative in disaster preparedness and risk reduction. Being close to the people and by virtue of its sheer mandate for local leadership, they have a greater responsibility to take all possible efforts to forecast, prepare and meet any such eventualities. Local knowledge about the resources, facilities and support systems, and the alternative options are crucial in disaster management. In addition, PRIs are in a better position to understand the social vulnerability of the disasters, and to address its differential impacts on children, women, differently abled, the sick and the elderly.

This approach ensures the community participation in all the Disaster Risk reduction activities making it less vulnerable. The author has recommended that the PRIs should have an organizational set up, a disaster management plan for the village and capacity building of its stakeholders. The author

also emphasizes for the involvement of local youth for bringing in new ideas, approaches, strategies and practices in disaster preparedness and risk reduction.

The probabilistic seismic hazard analysis (PSHA) is carried out for various Himalayan regions, which could be used for seismic microzonation of the area and for earthquake engineering [20].

A lot of uncertainties are usually present in spatial data which may have an impact on the quality of outputs. Prasad and Arora [24] have given methods and measures to model uncertainties in spatial data.

In India the recorded strong ground motion data is totally absent or scanty. Hence it becomes imperative to use physical model to represent the ground motion generation and propagation. Hanumantharao and Ramana [17] have generated synthetic bedrock acceleration in the Delhi region from local sources using specific barrier model.

Aditya and Sinha [1] have demonstrated the influence of fault – plane orientation on earthquake scenario development. Loss is estimated for each model building type in terms of number of injuries and fatalities depending on the damage state of the building using procedure described by Sinha and Adarsh [26].

Kumar *et. al.* [18] have adopted a methodology to estimate source parameters namely, seismic moment, stress drop and source radii from digital data of 81 local earthquakes in the western part of Arunachal Himalayas. Cole [5] has stated the basis for performance and protection as

'Disruptions (due to events ranging from potholes to earthquakes) are a constant and unavoidable aspect of development and that all institutions and production activities are structured and adapt overtime so as to balance performance and protection.'

The protection regimes for different systems and magnitudes of disruption are suggested. The optimum levels of protection are determined algebraically using input-output (IO) tables and social accounting matrices (SAMs). A multi sectoral simulation model is used to describe the impacts of disruptions and protection on economic systems. The result of the model shows the important effects of size and frequency of events on costs of protection [5].

9. CONCLUSION

The increasing vulnerability of settlements all over the world is promoting extensive research in the field of disaster management. The paper gives a review of various models, approaches and frameworks developed by experts from various fields in the recent past. The study of all the literature given in the paper will empower the researchers to formulate their own models, approaches or frameworks suitable for their individual research and context.

REFERENCES

[1] Aditya, S. P. and Sinha, R. (2006) 'Influence of Fault-plane Orientation on Earthquake Scenario Development' Paul, D. K. and Sharma, M. L. (Ed) Proceedings of 13th Symposium of Earthquake Engineering, Indian Institute of Technology Roorkee, Roorkee, India December 18-26., 2006, pp 161 - 171.

[2] Anderson, D. R., Sweeney, D. J., Williams, T. A. (2003) 'An Introduction to Management Science: Quantitative Approaches to Decision Making' 10th Edition, Thomson South Western, Thomson Asia Pte Ltd, Singapore.

[3] Blakie, P., Cannon, T., Davis, I. and Wisner, B. (1994), 'At Risk: Natural Hazards, People's Vulnerability and Disasters', Routledge, London

[4] Chian, S. C. (2016) 'A Complementary Engineering- Based Building Damage Estimation for Earthquakes in Catastope Modeling' International Journal of Disaster Risk Science, March 2016, ISSN: 2192-6395 pp. Available: http://www.springer.com/article/10.1007/s13753-016-0078-5

[5] Cole, S. (2004), 'Performance and Protection in an Adaptive Transaction Model', Disaster Prevention and Mitigation, Vol 13, No. 4, pp 280 – 289

[6] Comfort, L.K., Dunn, M. Johnson, D., Skertich, R. and Zagorecki, A. (2004) 'Coordination in Complex systems: increasing efficiency in disaster mitigation and response' International Journal of Emergency Management, Vol 2, Nos 1-2, pp. 62- 80.

[7] Davidson, R. (1996) 'An Urban Earthquake Disaster Risk Index' Doctoral Thesis Stanford University, Stanford, California

[8] DFID (2001) 'Sustainable Livelihoods Guidance Sheets' Department for International Development London, October 2001. Available at http://www.livelihoods.org/info/info_guidancesheets.html

[9] During, B. (2014) 'Benefits of Coupling Environmental Assessment and Environmental Management to Aid Disaster Risk reduction and Management' Journal of Environmental Assessment Policy and management, Vol 16, No. 3, pp. 1450029-1 – 1450029-25.

[10] FEMA (2001) 'HAZUS® 99, Estimated Annualized Earthquake Losses for the United States' Federal Emergency management Agency, United States.

[11] GHI and UNCRD (2001) 'Final Report Global Earthquake Safety Initiative (GESI) Pilot Project' GeoHazards International and United Nations Center for Regional Development, June 2001. Available at http://geohaz.org/contents/publications/gesi-report

[12] Gireesan, K. (2013) 'Disaster Preparedness and Risk Reduction-Significance of Empowering Panchayat Raj Institutions' Disaster and Development, Vol. 7, No. 1 & 2, pp 146-163.

[13] GIS Development (2007) 'Radius: A Simplified Tool for Earthquake Risk Assessment' Available: www.gisdevelopment.net/application/natural_hazards/overview/nho0017.htm

[14] Grossi, P., Re, D. D., and Wang, Z. (2006) 'The 1976 Great Tangshan Earthquake, 30 Year Retrospective', Risk management Solutions, Inc, Newark, USA, Available at http://www.rms.com/publications/1976tangshan.pdf

[15] Gupta, A., Kakhandiki, A., Davidson, R. and Shah, H. C. (1996) 'Multidisciplinary Approach to Urban Earthquake Disaster Risk Assessment and Management' Research Spotlight, The John A Blume Earthquake Engineering Center, Department of Civil Engineering, Stanford University, Stanford, California, Summer Quarter 1996, Issue No. 8 A

[16] Gupta, A.K., Nair, S. S., Wajih, S., and Chopde, S. (2013) 'A Model Integrating Flood Disaster Resilience into Development Plans for Adaptation to Climate Change: A Case Study from Northern India' Disaster and Development, Vol. 7, No. 1 & 2, pp 12-26.

[17] Hanumantharao, C. and Ramana, G. V. (2006) 'Strong Motion Generation from Earthquakes for Delhi from Local Sources' Paul, D. K. and Sharma, M. L. (Ed) Proceedings of 13th Symposium of Earthquake Engineering, Indian Institute of Technology Roorkee, Roorkee, India December 18-26., 2006, pp 116 -123.

[18] Kumar, A., Gupta, S. C., Kumar, A, Sen, A., Jindal, A. K. and Jain, S. (2006), 'Estimation of Source Parameters from Local Earthquakes in Western Part of the Arunachal Lesser Himalaya' Paul, D. K. and Sharma, M. L. (Ed) Proceedings of 13th Symposium of Earthquake Engineering, Indian Institute of Technology Roorkee, Roorkee, India December 18 – 20, 2006, pp 9-17.

[19] Kumar, S. (2010) 'Disaster Management Model and Framework' The Energy Research Institute, Available: http://www.teriin.org/events/docs/smallpdf/Santo3.pdf

[20] Malik, S., Sharma, M. L. and Khandelwal, D. D. (2006) 'Estimation of Spectral Strong Ground Motion for North East India using PSHA' Paul, D. K. and Sharma, M. L. (Ed) Proceedings of 13th Symposium of Earthquake Engineering, Indian Institute of Technology Roorkee, Roorkee, India December 18-26., 2006, pp 137 - 147.

[21] Munich Re and NatCatSERVICE (2014) 'Loss Events Worldwide 2013: 10 Deadliest Events' Munich Re and NatCatService Available at: http://www.munichre.com/en/reinsurance/business/non-life/natcatservice/annual-statistics/index.html

[22] Mukherjee, M. (2005) 'The SusTLE – A Sustainable Approach to Enhance the Contributions of Disaster Mitigation in Settlement Development' International Journal of Emergency Management, Vol. 2, No. 3, 163 – 175

[23] Palakudiyil, T. and Todd, M. (2003), 'Facing up the Storm: How Local Communities can Cope with Disasters: Lessons from Orissa and Gujarat', Christian Aid, London

[24] Prasad, M. S. G. and Arora, M. K. (2006) 'Uncertainties in Spatial Data: Key Inputs to Seismic Hazard Zonation' Paul, D. K. and Sharma, M. L. (Ed) Proceedings of 13th Symposium of Earthquake Engineering, Indian Institute of Technology Roorkee, Roorkee, India December 18-26., 2006, pp 88 - 97.

[25] Satyendra, (2003) Disaster Management in Hills, Concept publishing company, New Delhi, India

[26] Sinha, R. and Adarsh, N. (1999) 'A Postulated Earthquake Damage Scenario for Mumbai', ISET Journal of Earthquake Technology, 36, No. 2-4, pp. 169 – 176.

[27] Twigg, J. and Greig, B. (2001) 'Sustainable Livelihoods and Vulnerability to Disasters' Hazard Research Center, for the Disaster Mitigation Institute (DMI), Disaster Management Working Paper 2/ 2001.

[28] United Nations (2004) **'Living with Risk - A global review of disaster reduction initiatives 2004 version' United Nations International strategy for Disaster Reduction Available:** http://www.unisdr.org/eng/about_isdr/basic_docs/LwR2004.htm

[29] White, C., Plotnick, L., Kushma, J., Hiltz, S. R., and Turoff, M. (2009) 'An online social network for emergency management' International Journal of Emergency management, Vol 6, Nos 3-4, pp. 369-382.