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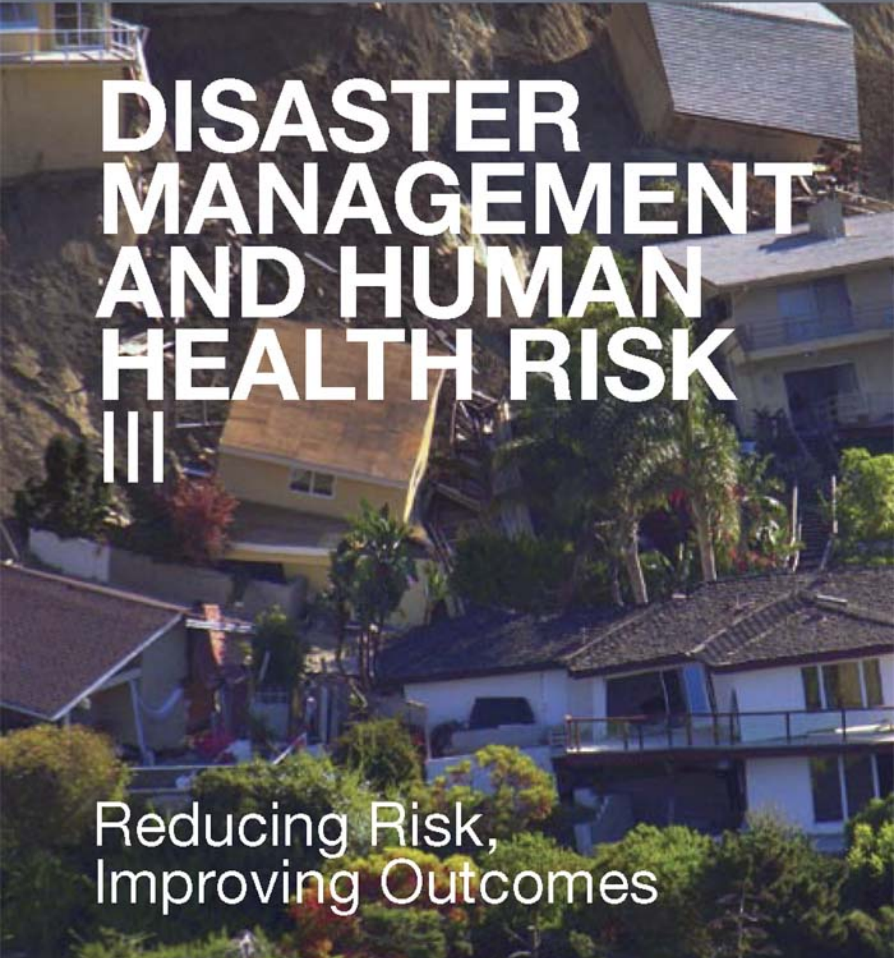

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Disaster Management III

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WIT Transactions on the Built Environment
International Journal of Safety and Security Engineering

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Reducing Risk, Improving Outcomes

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WIT*PRESS* **Southampton, Boston**

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Published by

WIT Press
Ashurst Lodge, Ashurst, Southampton, SO40 7AA, UK
Tel: 44 (0) 238 029 3223; Fax: 44 (0) 238 029 2853
E-Mail: witpress@witpress.com
http://www.witpress.com

For USA, Canada and Mexico

Computational Mechanics Inc
25 Bridge Street, Billerica, MA 01821, USA
Tel: 978 667 5841; Fax: 978 667 7582
E-Mail: infousa@witpress.com
http://www.witpress.com

British Library Cataloguing-in-Publication Data

A Catalogue record for this book is available
from the British Library

ISBN: 978-1-84564-738-4
eISBN: 978-1-84564-739-1
ISSN: 1746-4498 (print)
ISSN: 1743-3509 (online)

The texts of the papers in this volume were set individually by the authors or under their supervision. Only minor corrections to the text may have been carried out by the publisher.

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Printed in Great Britain by Lightning Source, UK.

Preface

This volume contains reviewed contributions presented at the 3rd International Conference on Disaster Management and Human Health: Reducing Risk, Improving Outcomes, held in A Coruña, Spain and organised by the Wessex Institute of Technology, UK. This follows the success of the previous meetings in the New Forest, home of the Wessex Institute (2009) and at the University of Central Florida in Orlando, USA (2011).

This series of conferences originated in the need for academics and practitioners to exchange knowledge and experience in the way to handle the increasing risk of natural and human-made disasters. Recent major earthquakes, tsunamis, hurricanes, floods and other natural phenomena have resulted in huge losses in terms of human life and property destruction. A new range of human-made disasters have afflicted humanity in modern times, terrorist activities have been added to more classical disasters such as those due to the failure of industrial installations for instance.

It is important to understand the nature of these global risk to be able to develop strategies to prepare for these events and develop effective responses in terms of disaster management and the associated human health impacts.

The conference provided a forum for the exchange of information between academics and practitioners, and a venue for presentation of the latest developments. The corresponding volume of the WIT Transactions on the Built Environment containing the papers presented at the meeting has been published in paper and digital format and widely distributed around the world. The papers are also archived in the WIT electronic library (http://library.witpress.com/) where they are available to the international community. Papers presented at Wessex Institute conferences are referenced and regularly appear in notable reviews, publications and databases, including referencing and abstract services.

The Editor is grateful to all contributors for their excellent papers and most especially to the members of the Scientific Advisory Committee who helped with the review process.

Carlos A Brebbia
A Coruña, 2013

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Section 1
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Smart objects and wireless sensor networks for monitoring: sustainable technology in disaster management

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Abstract

Disaster management needs to control significant data in the different phases: conditioning forecast from update in real time of event evolution, emergency plan, and first reconstruction of post event. At same mode, prevention activity consists primarily in the control of important quantities that characterize each event. The aim of paper is to examine two suitable methods of the monitoring for prevention and management of disaster: by means of sensor networks and drone or micro drone unmanned aerial vehicle (UAV). Differently from remote sensing, sensor networks are realized by distributing detection nodes on the territory. Each of two methods, sensor networks and with drone, shows peculiarities: sensor network is suitable for continuous monitoring and for forecasting; the monitoring that uses drones has more benefits in an emergency phase.
Keywords: smart objects, wireless sensor networks, low power, low voltage, unmanned aerial vehicle.

1 Introduction

Disaster represents generally the result of a chain of bad events. Prevention activity consists in the control of important quantities that characterize each event, in order to realize opportune measures against its occurrence.

At same mode, disaster management needs to control significant data in the different phases: conditioning forecast from update in real time of event evolution, emergency plan, and first reconstruction of post event.

WIT Transactions on The Built Environment, Vol 133,
www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/DMAN130011

Disaster risk evaluation understood as forecast of a particular level of loss in terms of life, economic activity disrupted, people injured and so, is a complicated activity. Even the environmental phenomenon simpler is a function of more variables, often aleatory. Associated forecast model analyzes correlations of a selection of those variables and it simulates evolution of phenomenon. There are different software computer programs that realize models at different levels. From simplified version, faster, that uses few variables and produces coarse solutions, to sophisticated version, generally slower, that needs a lot of data inputs. Depending of simulated phenomena, some of these ones are data archived by historical acquisitions; others must be detected in real time. For example, a software simulation on forest fire propagation [1–4] includes historical data, as duration of dry conditions or as orographic slope, together with dynamical data, like speed and direction of wind. In another example, river flood and landslide [5–7], orographical data, climate characteristic of geographical area, profile and sections of rivers and flood plain are historical data, whereas e.g., the pluviometric measures are dynamical data. Both examples point out that all the data are necessary for the software tool is working properly.

Furthermore, real time data assume bigger importance when need monitoring areas of disaster in emergency management activity. In this case, the measure on demand of specific physical parameters and the snapshot observation of the overall effect of an event can modify boundary terms. That is consequence of new updated data: the software simulation evolves to different result and an operative decision is more suitable.

In the phase of the reconstruction, it asks that evaluations are global and detailed, but not necessary real-time. The globality is in order to detect the extension of damaged areas and to count the involved structures. Whereas, the detail represents the damage calculation, that can be estimated for single structure.

The aim of paper is to examine two suitable methods of the monitoring for prevention and management of disaster: by means of sensor networks and drone or micro drone UAV (Unmanned Aerial Vehicle). Differently from remote sensing, sensor networks are realized by distributing detection nodes on the territory. Extension of monitored area can’t be too large if you want to limit node number and cost of full system. Each of two methods, sensor networks and with drone, shows peculiarities: sensor network is suitable for continuous monitoring and for forecasting; the monitoring that uses drones has more benefits in an emergency phase.

2 Wireless sensor networks and smart objects

The meaning of the terms smart objects and wireless sensor networks (WSN) is similar. A wireless sensor network is organized by small nodes that include: sensors (normally no actuators), wireless communication device, microcontroller and power source device. Main characteristic is to operate exclusively with wireless communication radio. Similarly, smart object indicates equipment that includes: one or more sensors/actuators, a tiny microprocessor (usually a microcontroller), a power source, and a communication device. Sensor and actuator allow interacting with the physical environment. The microprocessor /microcontroller elaborates data detected from sensors for storing or sending them. Power source supplies the total energy which is necessary for an efficient work of the node. The communication device enables the node to communicate measures of its sensor the outside, to a control station that collects full data from all the nodes, and receives input from other smart objects. But, unlike wireless sensor network, to implement the network, the communication device can use both technologies: wireless and wire. If the radio communication device is wireless, a more pervasive network can be built. So, smart objects and wireless sensor networks can be considered really network nodes, dedicated to monitoring. But, moreover, the previous definition shows how the smart objects have a greater interaction with the physical world if the devices are among them.

2.1 IP smart objects

Smart objects can use internet as communication middle. In this case its architecture is based on IP (Internet Protocol), and it can use UDP (User Datagram Protocol) or TCP (Transport Control Protocol) as transport protocol. UDP is the simplest protocol. It used, e.g., in a link where the transmitter does not have to wait for a response message by a receiver for confirming correct receipt. At the contrary TCP is a reliable byte stream. Twenty-seven companies founded a worldwide industry alliance to promote the usage of IP standard, open and interoperable, for smart objects. Cisco, Atmel, Arch Rock, Sun Microsystems, etc. have been founding members of this alliance, named IPSO (IP for Smart Object). An activity of IPSO is the production of white papers for divulging tutorial on technologies and use cases. In particular, the alliance spreads general characteristics of low-power technologies, embedded web services, smart cities, etc. Many WSN applications have been developed using internet for showing state and evolution of environmental quantities detected. So, web sites enable to consult and to input data that characterize far areas in the world. In order to develop these applications, it can use one among different operating systems for smart objects, like Contiki, TinyOS, FreeRTOS, that are all open sources. In particular, FreeRTOS has been designed for embedded systems and TinyOS for research into sensor network and smart objects. Furthermore, smart objects system implemented with web services need of lower complexity. Consequently it uses a light architecture model, as REST (Representational State Transfer).

2.2 Non-IP smart objects

The web service isn't the primary purpose of monitoring activities. Moreover, IP architecture is heavyweight in the case of low-power networks. That is, all networks built on the IEEE 802.15.4 standard protocol: a standard radio technology dedicated just for low-power, low-data-rate applications [8]. So, non-IP smart objects technologies are frequently used in the monitoring activities, specifically in the case of low-power, short-range, and low data rate. Proprietary protocol specifications for wireless communication based on IEEE 802.15.4 have been developed, as: ZigBee and Z-Wave. In particular, ZigBee is a network layer on top of the IEEE 802.15.4 standard, which includes PHYsical (PHY) and Message Authentication Code (MAC) layers. Radio frequency bands are in ISM (Industrial, Scientific and Medical) band: 2.4 GHz with 16 channels for global use; 915 MHz with 10 channels for few countries (North America, Australia, etc.), and 868 MHz with one channel for EU countries. The 2.4 GHz radio frequency allows a maximum data rate of 250 Kbits/s. The band 915 MHz permits a data rate of 40 Kbits/s, and for 868 MHz radio frequency the same data rate decreases to 20 Kbits/s. Modulations are Bi-Phase Shift Keying (BPSK) for bands 868 and 915 MHz, and Offset quadrature phase-shift keying (OQPSK) for 2.4 GHz radio frequency. Access mode is the Carrier Sense Multiple Access / Collision Avoidance (CSMA/CA): nodes occur if channel is free before transmission. But when transmission needs a low latency, the GTS (Guaranteed Time Slots) is the access mode.

Companies as: Texas Instruments, Microchip, Digi International, are building RF transceivers that are evolving to higher performances. For example, if you improve the sensitivity of the receiver, the budget of the link increases while always using the same transmitting power. Table 1 compares characteristics of three different radio frequency transceivers, and puts in evidence how area of their applications can be more extensive. Augmentation of link budget is to the detriment of power level, because its consumption increases, but fortunately with less strength if receiver sensitivity was raised. If maximum distance between two nodes can augment, then configurations number with which network can be designed increases too.

Table 1: Technical characteristics of three RF transceivers.

	CC2520	**MRF24J40MA**	**Xbee PRO SE**
Company	Texas Instruments	Microchip	Digi International
Year	2007	2008	2010
Supported protocols	ZigBee	ZigBee, MiWi, MiWi P2P and Proprietary Wireless Networking Protocol	ZigBee
Link budget (line-of-sight)	400 m @ +5 dBm	120 m @ +5 dBm	3200 m @ +17 dBm 1500 m @ +10 dBm
Supply range	1.8V -3.8 V	2.4V - 3.6 V	3V - 3.4 V
Current RX	18.5 mA @ -50 dBm RX	19 mA (typical)	45 mA @ 3.3V
Current TX	25.8 mA @ 0 dBm , 33.6 mA @ +5 dBm , < 1 μA power down	23 mA (typical) 2μA sleep mode	295 mA - 170 mA 3.5μA power down
Receiver sensitivity	-98 dBm	-94 dBm	-102 dBm
RF frequency range	2394 - 2507 MHz	2405-2480 MHz	2405-2480 MHz

From the view point of sustainability, the total cost of a network node has decreased in recent years. Radio frequency transceiver cost is in the range from less than ten to forty Euros, functionally to required performance. The cost of a microcontroller is around a few tens of Euros. Sensors show a variable expense, depending on the type of measurement required, but it is decreasing little by little thanks to the development of MEMS (Micro Electro-Mechanical Systems) and embedded technologies. Many industries-leading supply sensors in the fields as: geo-mechanic, bioscience, flow-dynamic, meteorology, etc. So, you can realize different measurements and monitoring, by coupling sensors like: flow, tilt-meter, pressure, humidity, temperature, CMOS (Complementary Metal-Oxide Semiconductor) image sensors, CCD (Charge-Coupled Device), soil moisture, PH measurement, dissolved oxygen probe, water depth, water level, and so on. Therefore, based on wireless sensor networks or smart objects, the monitoring projects are a challenge whose resolution is currently efficient and in the future will be more convenient.

2.3 Harvesting power supply

In cost evaluation need include the maintenance item. For a sensor network, sites of the nodes should be selected for principally satisfying: area of interest for the measurement, and a radio link satisfying among other connected nodes. The requirement of nearness to public power line cannot limit the choice of location. The feature of low-power pushes to design of a power-supply device for smart object which uses harvesting and scavenging methods [9–12, 14]. Harvesting and scavenging convert power from human activity or limited energy from ambient. A definition considers harvesting the only method of conversion from ambient energy sources that are well characterized and regular. Some energy sources of interest for WSN are: ambient airflow, ambient light, ambient radio frequency, biologic, thermoelectric, and vibrational micro-generators. Performance of each conversion changes in a wide range, depending by type of ambient energy source and method adopted.

For ambient airflow source it can use microelectromechanical turbine which shows at 30 litres/min performance of 1 mW/cm^2.

The available power from ambient light depends from the specific source (sun, incandescent bulb, compact fluorescent bulb, led) and from environmental condition, e.g. mid day with clear sky. Maximum available power is 100 mW/cm^2, if the source is the sun, and 1 mW/cm^2 at 3 m from a compact fluorescent bulb. Conversion efficiency of used technology decreases performance. For example, solar cells show a maximum conversion efficiency of 0.11, if built by using a-Si or Dye-sensitized

The conversion from radio frequency energy uses a device named rectenna. This is a combination of antenna and rectifier [14]. But the radio frequency source doesn't assure sufficient power intensity for WSN nodes in the current technology. A simple example demonstrates this. Efficiency η of rectenna device combines DC power to incident radio frequency, according to eqn (1). The Friis transmission eqn (2) evaluates the received radio frequency power (P_R), when a transmitter at distance R radiates a power P_T. In the eqn (2): G_T and G_R are gains with respect to an isotropic radiator respectively of transmitting antenna and

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receiving antenna, μ is the efficiency of transmitting antenna, and λ is the wavelength of radio frequency.

$$\eta = \frac{P_{DC}}{P_{RF}} < 1 \tag{1}$$

$$P_R = P_T \frac{G_T G_R}{\mu} \left(\frac{\lambda}{4\pi R} \right)^2 \tag{2}$$

In the hypothesis of: isotropic radiators G_T=G_R=1, efficiency μ=1, a relatively short distance R=10, radiated power P_T=1W, and radio frequency f=2.4 GHz, corresponding to λ=0.125 m in free space, the value of maximum incident power is approximately 1μW. This is a value too low. More energy can be harvested if device is hit from radio waves, numerous and outside the frequency band. BioElectrochemical System and in particular microbial fuel cell (MFC) exploits the properties of specific bacteria to produce electrons, by oxidation of organic compounds. An energy production continuous and unlimited has need that the bacteria are nourished, thus ensuring the survival of the bio-film, located at the anode of the cell. This makes these cells particularly interesting in applications devoted to monitoring of rural areas, land where there is plenty of nutritious food for the bacteria.

Thermoelectric conversion is obtained by means of a Carnot cycle. The temperature difference ΔT limits the conversion efficiency. A thermoelectric generator consists of thermopile array. The most common material used to build the thermopiles is Bi_2Te_3, usable in the temperature range 0÷100 °C. These generators produce a power of approximately 30μW @ ΔT=5 °C.

Some vibrational micro-generators use piezoelectric material forming two-layer (on the top and down) bimorph, which are mounted as a cantilever beam. When you bend the beam down, a tension is present in the top layer and compresses the bottom layer. So, piezoelectric effect produces a voltage across each of the layers. The power output is maximized when the natural frequency of cantilever is equal to the driving frequency.

The choice of the harvesting device is made on the basis of the environment in which the system will have to work.

2.4 Applications

In previous articles [15] we described the use of WSNs for monitoring applied to the control of river floods. The WSN node included: PIC32MX360F512L microcontroller, MRF24J40MA IEEE 802.15.4 standard compliant radio frequency transceiver, OV7710 CMOS VGA colour CameraChipTM. Microcontroller and transceiver are Microchip devices. The single-chip video /imaging camera device is an Omnivision image sensor. MRF24J40MA is a PCB module (Printed Circuit Board) that includes an integrated PCB antenna.

The monitoring network included the placement of the sensors along the river at a distance less than the link budget transceiver. From Table 1 it is recognized that this distance is fixed at 120 m, but it is preferred to place the sensors at a distance from each other of 30-40 m. If communication between two nodes fails, and the link to other no-contiguous nodes is on line of sight, this additional communication starts. In order to decrease energetic consumption of each node, a custom protocol has been used for this simplified mesh network.

At present, despite power consumption is greater, new generation of transceivers allows more flexible organization of the network mesh. Solar cells and water flow micro-turbine are suitable harvesting power sources for these network nodes. In the case of reduced production of energy for a period, e.g. solar cells during nocturnal hours, the harvesting device can be hybrid including energy storage in form of capacitor, or thin-film batteries.

In the last period we investigated the potential use of a different source of harvesting, like power supply of WSN communication node. Microbial fuel cell shows attractive qualities, in terms of eco-sustainability, low cost, and no maintenance for many years. MFC generates too low voltage, which must increase to suitable level, if it supplies energy to a WSN node, or smart objects. So, a charge pump must be included into the system design. Efficiency of cell depends from many factors. Mainly from terrain composition that should assure nutritious food for the bacteria. Investigation is in progress to verify how pH influences cell efficiency based on specific bacteria. In parallel an efficient low-power communication design is developing for satisfying the compatibility with limited available power source.

3 Unmanned aerial vehicle

After a disaster, a natural catastrophe, frequently it is necessary to monitor a specific area for evaluating damages or make a more complicate detection. The activity can be dangerous and direct intervention of human operators is slow because of difficulties to move forward. Recent events, such as the earthquake that happened in Italy at Emilia Romagna region, have demonstrated the efficient use of unmanned aerial vehicles (UAV). Drone with a micro-camera onboard has allowed monitoring areas of destroyed buildings. It flew over rubble, and it recorded images, useful for succour activity. If the weight of drone is greater than a threshold, e.g. 20 kg, it must observe the rules of flight control agency, like ENAV, including the communication of flight plan. If so, weight limit should be respected for allowing the flight always. In any case, the present micro-UAVs show a weight below 2 kg, and sufficient autonomy for considering them adapted to monitoring in emergency phase. Furthermore, all devices onboard should be light sufficiently to allow a correct flight and adequate autonomy. Many sensors can be included onboard: VIS and IR image sensors, particulate sensor, and so on. Therefore, monitoring of a restricted area can be carried out by means of platform no expensive, based on micro-UVA. The system also supports emergency teams in their aid activity. At present, the cost of micro-UAV, like basis quadrotor model, with weight less than 1 kg, is smaller than 300÷400 Euros. Normally the basis model includes: motors, telemetry, GPS and landing gear. So, if it adds inexpensive special sensor devices for a customized monitoring with UAV, the full cost will be sustainable.

In perspective the system is open to new useful applications. For example, studies are in progress on the possibility to locate buried and trapped people by using of ground penetrating radar (GPR). In particular, the research is including in the future activity of a working group in European concerted research action COST.

Ground penetrating radar [16] provides information about the different layers of soil and the existence of buried objects. Since GPR is electromagnetic energy and a material in the soil shows a particular electrical conductivity, it is subject to attenuation as it moves through the same material. GPR energy moves with velocity that depends from another characteristic: the dielectric constant. The higher the dielectric, the slower the radar wave moves through the medium. Moreover, a higher difference of dielectric constant between two contiguous materials, results in a stronger reflection. So, when the radar antenna moves along one direction, with a constant velocity, a detected object is shown in the radargram output as a diffraction hyperbola. Figure 1 shows radargram of data recorded by using the SIR-2000 ground penetrating radar system (Geophysical Survey Systems, Inc. (GSSI), North Salem, NH, USA) with a radar frequency of 900 MHz. Horizontal axis of the figure represents the position; vertical axis is the two-way travel time of radar wave. If dielectric constant of material is known, vertical axis can show the depth. In our experiment, a knapsack is buried into a dry sand soil. GPR has detected the object in form of diffraction curve characterized by geometrical parameters.

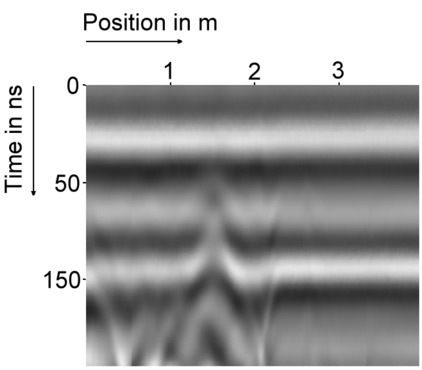

Figure 1: A radar profile recorded at 900 MHz.

4 Conclusions

We examined technologies adoptable for the monitoring that are useful for both activities: risk analysis together with its prevention activity, and disaster management. These new technologies are characterized by: more reduced dimensions than the past (nanometre-scale), and embedded systems more performing The improved characteristics are: light weight of final device, low-voltage, low-power, and low-cost. The decreasing of power supply to lower value, but sufficient to operate the system properly, in all phases of its standard operation, adds freedom degrees to the design of a monitoring system. In the case of WSN and smart objects with wireless radio communication device, the location of a node is not imposed from electricity distribution network. Two features, i.e. low-power and light weight, result in more performing unmanned aerial vehicles that allow the monitoring of areas particularly dangerous. We examined some harvesting sources. And we selected the more suitable of these that should be used for designing smart objects and WSN. For the same reason, despite a relatively short link budget, IEEE 802.15.4 communication standard is the more appreciated. In accordance with these specifics we designed WSN to control risk of river flood. Our next researches will have two different themes: check the sustainable harvesting based on MFC, and investigate more valid setup of a GPR system for locating buried people.

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Development of a spatially explicit vulnerability-resilience model for community level hazard mitigation enhancement

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Abstract

Community vulnerability to coastal hazards can be difficult to analyze at a local level without proper modeling techniques. Societal assets and human populations are dispersed unequally across landscapes, causing vulnerability to vary from one community to another. A common method of quantifying vulnerability has developed in the form of vulnerability indexes, typically conducted at the county scale. These indexes attempt to measure community vulnerability by assessing exposure of traditional vulnerability indicators. Sensitivity and adaptive capacity analyses are excluded from these assessments, creating a less than holistic vulnerability analysis. Traditional vulnerability assessments also neglect the inclusion of place-specific differentially weighted indicators, and the effects of spatial autocorrelation. These limitations make indexes less effective for community level analysis. In response to these challenges, a resilience index that incorporates place, spatial, and scale specific indicators that are more appropriate for community level analysis was developed. The model developed in this research determines varying distributions of vulnerability across the study region using several socioeconomic, spatial and place specific indicators. Spatial statistics (such as spatial autocorrelation techniques) and multivariate techniques (such as factor analysis) were employed to determine the differential influence of each vulnerability and adaptive capacity indicator. The results of the model enable decision makers to target mitigation efforts toward place-specific, differentially weighted indicators that most impact vulnerability at the community level. The model also depicts that traditional vulnerability indicators are differentially impactful at varying spatial scales.
Keywords: vulnerability, resilience, coastal hazards, disaster management.

www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/DMAN130021

1 Introduction

The intersection of natural hazards and human populations results in natural disasters that can cause significant damage to human lives and property. Coastal communities are vulnerable to many natural hazards, including hurricanes, tropical storms, coastal erosion, tsunamis, flooding, and climate change-related hazards influenced by sea-level rise (SLR) [1–4]. To increase the effectiveness of hazard mitigation and comprehensive planning for these and other hazards, it is important to assess vulnerability at the community level so as to provide more detail on local level vulnerability and better target limited mitigation resources. Traditionally, mitigation strategies are chosen and implemented based on perceived mitigation needs, risk tolerance and available funding [5, 6]. These strategies are commonly structural in nature or address the possibility of shaping development patterns, but they often do not consider targeting socioeconomic factors as a way to facilitate recovery while also assisting in resilience enhancement [7–9]. Vulnerability is the potential for loss [10–13]. Vulnerability is a function of exposure, sensitivity, and adaptive capacity. Exposure is the proximity of a community to a hazard, sensitivity is the degree to which a community is affected by a hazard, and adaptive capacity is the ability of the community to adapt and cope with hazard impacts [13, 14]. Resilience is a function of a community's ability to respond to a disaster with minimal help from outside [11, 15, 16]. The understanding of a community's resilience level can aid greatly in post- disaster recovery and estimation of potential losses [16].

Due to uneven distribution of vulnerability indicators within a given area, vulnerability is variable across the landscape including at the sub-county scale. Because societal assets dispersed throughout a community have variable vulnerability to hazards, it is important to identify their differential spatial distribution throughout the community [11, 17]. If reducing local vulnerability is a goal, then hazard mitigation strategies should be targeted at areas within the community with the highest vulnerability. However, many communities often lack the financial resources or expertise to compile hazard analysis on their own, forcing communities to rely on analyses from external consultants or government agencies. External analyses often lack a focus on local hazards, may not adequately consider community nuances, and may not have been conducted at a spatial scale most appropriate for local hazard mitigation [9].

Even though higher spatial resolution for hazard modeling often allows communities to better target mitigation resources, there are several problems associated with conducting spatial analysis at varied spatial scales. Due to data aggregation used in vulnerability and resilience research, it is possible that the reliability of certain analytical methods can be biased based on the way the areal units are defined [18]. For example, the US Census Bureau uses varying levels of spatial aggregation to describe the distribution of the population within the United States. These enumeration units, such as census tracts and blocks, are created based on areas that have mostly homogenous population characteristics, visible boundaries and economic status [19]. This means that the area of each of these blocks will vary based on the population characteristics within them. As

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the level of analysis is aggregated from census block to census tract and upward, the amount of bias increases as well. Aggregation bias creates another reason for the importance of incorporating community scale, locally derived factors, rather than relying solely on nationally collected data when conducting vulnerability assessments. The inclusion of sub-county scale factors is an important component for measuring community vulnerability and resilience because of factor variation inside and across communities within a county [4, 20–22].

This paper presents research conducted through a case study of Sarasota County, Florida that is used to identify and examine place-specific vulnerability indicators for the Spatially Explicit Resilience-Vulnerability (SERV) model. Although Sarasota County serves as a case study for this research, this methodology is applicable to any community or jurisdictional unit, no matter the spatial scale. The second section of the paper provides a brief background on existing limitations of current hazard vulnerability assessments. The methods section briefly discusses the theoretical framework for the SERV model, but predominantly focuses on the identification and classification of mitigation strategies implemented in the county. The results sections details the findings of the analysis as it relates to hazard mitigation decisions. Finally, the discussion and conclusions sections demonstrates the societal relevance of this research as it pertains to a need for multiscalar vulnerability assessments for enhancing community hazard mitigation planning.

2 Background

Mitigation and adaptation policies and plans help reduce coastal community vulnerability to hazard impacts, as well as minimize the cost of recovery from disasters. Hazard mitigation practices include planning, hazard identification and profiling, vulnerability and risk assessments, and implementation of mitigation actions [23–29]. Hazard planning consists of both structural and non-structural actions designed to reduce the potential loss of property or human life in the event of a natural disaster [23, 28–30]. To determine vulnerability to certain hazards, decision makers often conduct vulnerability assessments and incorporate the results into hazard mitigation plans (HMPs). Hazard vulnerability assessments essentially occur at three different levels of evaluation: 1) hazard identification, 2) vulnerability analysis, and 3) risk analysis. Hazard identification defines where the hazard is likely to transpire and calculates the probability of its occurrence. Vulnerability analyses determine which factors cause populations to experience increased or decreased vulnerability to hazards in certain places. Risk analysis calculates probabilities of a hazard occurring and determines probabilities of the levels of damage or injuries that could occur in specific areas [26]. A complete vulnerability assessment includes all three of these levels of hazard assessments. Most vulnerability assessments, however, are often limited to just the hazard identification, the vulnerability analysis, or a combination of both. Vulnerability analyses are included more often than risk assessments, but it is not a common practice for them to be included in mitigation plans. It is also rare for a socioeconomic vulnerability assessment to be present in most HMPs. Hazard assessments generally do not include risk assessments [26]. Risk assessments utilize probabilistic modeling techniques to illustrate the varying probability of occurrence for coastal hazards across a given spatial scale and to provide a greater understanding of not only the extent of the hazard, but where hazards are more likely to occur and which areas might suffer more/less damage [26, 31]. Possession of this information is important for local decision makers and planners if their goal is to efficiently allocate funds for hazard mitigation to areas within the community that contain the highest vulnerability.

For this reason, this research developed the Spatially Explicit Resilience-Vulnerability (SERV) model to help better determine community scale vulnerability and resilience using differentially weighted place-specific, spatial, and temporal vulnerability indicators. The SERV model is a function of exposure, sensitivity, and adaptive capacity, where the components of the model will be determined using the created hazard layers and socioeconomic factors resulting from the vulnerability index. This research uses Sarasota County, Florida as a case study whereby understanding the county's community vulnerability, a measure of community resilience can then be determined using place-specific, spatial and temporal resilience indicators. The results of the analysis are then compared to mitigation strategies that are currently in progress within the county to determine if mitigation is occurring in areas where exposure or vulnerability are highest.

2.1 Study area

Sarasota County, Florida (Fig. 1) lies along the western coast of the Florida peninsula. The county has approximately 35 miles of shoreline and a low average elevation, which makes it susceptible to coastal hazard inundation impacts, such as storm surge inundation and inland precipitation flooding. Much of the county is located at or near sea level, and its highest point of elevation is located further inland in the far north-eastern corner of the county. Low average elevation and central location along the coast makes the county especially vulnerable to coastal hazards and climate change effects such as sea level rise. The county's Comprehensive Emergency Management Plan (CEMP) states that 45% of the county lies within the 100-year floodplain. This increases the county's vulnerability to not only storm surge from hurricanes, but inland precipitation from other coastal storms as well. The county has experienced significant population growth within the last decade and is highly developed along the lower elevations that will likely continue due to the location of current infrastructure and an urban service boundary that essentially limits development to areas more proximal to the coast.

3 Methods

Researchers reviewed the Comprehensive Emergency Management Plan (CEMP) and the county's Unified Local Mitigation Strategy (ULMS) to identify what mitigation strategies are in progress or completed and where they are being implemented within the county. While the CEMP generally describes policies that are in place within the county, location specific mitigation strategies are not explicitly listed. Examples of general mitigation strategies include the mapping of critical and essential infrastructure across the county, identifying Memorandums of Understanding's with other counties and support agencies' responsibilities for disaster relief. In order to determine the location of specific mitigation strategies, the ULMS plan was reviewed. This plan was created in response to the Disaster Mitigation Act of 2000 (DMA 2000), which requires local jurisdictions to prepare and implement a local natural hazard mitigation plan as a condition for receiving mitigation grant funding [29]. DMA Local mitigation plans serve as a guide for decision makers to reduce the effects of natural hazards on local jurisdictions. The Sarasota County ULMS plan specifically identifies hazards and mitigation strategies implemented at the local level within the county. Mitigation strategies that included some spatial reference were georeferenced to map the locations of each strategy.

To determine place-specific, spatial sensitivity and adaptive capacity indicators for Sarasota County, researchers conducted two principal components analyses (PCA), a data-reduction technique that identifies groups of inter-correlated variables, on the two lists of compiled sensitivity and adaptive capacity indicators [32]. The sensitivity variables were aggregated to the census block level and the adaptive capacity variables were aggregated to the census tract level because those were the smallest geographic areal unit of analysis with available data. To determine average level of spatial autocorrelation between the variables, a Moran's I was conducted for each indicator in both indexes. To conduct the PCAs for sensitivity and adaptive capacity researchers used the following parameters: maximum of 20 components, Kaiser Criterion (eigenvalues $\geq$ 1), and a Gamma rotation based on the level of spatial autocorrelation within the datasets to account for spatial autocorrelation. Gamma rotations assign factors to sets of already inter-correlated indicators, which corrects for spatial autocorrelation in the data [33]. Variables that described < 5% of the total population were considered to be non-significant and were either aggregated into a composite variable or were removed from the PCA. Subsequent PCA analyses were conducted using the same parameters to determine the final set of principal components within the sensitivity and adaptive capacity datasets. Sensitivity variables with component loadings $\leq$ -0.45 or $\geq$ 0.45 (to identify weaker variables traditionally found in vulnerability theory) and adaptive capacity variables with component loadings $\leq$ -0.5 or $\geq$ 0.5 are statistically significant to the final index. Block vulnerability scores were calculated using the following static vulnerability equation:

$$V = [E + S] - AC$$ (where V= vulnerability, E= exposure, S= sensitivity and AC= adaptive capacity)

The scores for each of the equation components (exposure, sensitivity and adaptive capacity) are calculated using existing methods and methods developed in this research. Overlay analysis using deterministic inundation extents, including hurricane storm surge, developed in Frazier *et al.* [4] were utilized to determine exposure. Inundation extents also were calculated to include inland precipitation. Sensitivity and adaptive capacity scores were determined by calculating the percentage of each variable within a block. This illustrates which blocks hold the greatest presence of each vulnerability indicator. Researchers assigned directionality to each component loading based on whether the indicator traditionally has a positive or negative influence on vulnerability [20, 27]. Weighted scores were calculated based on the varying influence of each indicator and its factor on sensitivity or adaptive capacity. The final weighted values for each indicator were then summed to create the raw scores for sensitivity and adaptive capacity components. Once the raw scores were determined for each component, the scores were converted to z-scores to prevent any errors that might results from the aggregation of variables. The composite scores were then applied to the vulnerability equation to calculate block level vulnerability scores for Sarasota County, Florida. Once the vulnerability scores were determined, the results were overlayed with georeferenced locations of the current mitigation projects occurring within the county. This was done to determine the relationship of the implementation of mitigation strategies to levels of exposure and vulnerability within the county.

4 Results

The resulting exposure scores were mapped to illustrate areas of exposure from inundation impacts of inland precipitation and sea level rise enhanced storm surge. Fig. 1 symbolizes the distribution of the exposure scoring for a Category 3 storm with 4 inches of inland precipitation.

Results indicate that exposure is greatest along the coast and inland waterways (due to presence of storm surge), but there are also blocks further inland that have high levels of exposure due to inland precipitation. This pattern also indicates that the addition of inland precipitation inundation behaviour to overall hurricane inundation increases the total percentage of exposure.

The results of the sensitivity index PCA also identified the following contributing factors that explain 72.8% of the variance: base population, business and development, traditionally vulnerable populations, critical and medical facilities, low to medium development, income and economic base, and tourism and agriculture. Results indicate that sensitivity is highest in main population zones with areas along the coast predominately containing the highest sensitivity scores. Positive scores indicate higher vulnerability (in red), while negative scores indicate lower vulnerability (in blue). For the adaptive capacity index, the PCA identified the following factors that explain 82.7% of the variance: age and employment, population and utilities, economic base, social services and infrastructure, traditionally vulnerable populations and housing capital, and higher education and equality. The vulnerability scoring results were mapped to illustrate the distribution of community vulnerability within the county (Fig. 2). Positive scores indicate higher vulnerability (in red), while negative scores indicate lower vulnerability (in blue).

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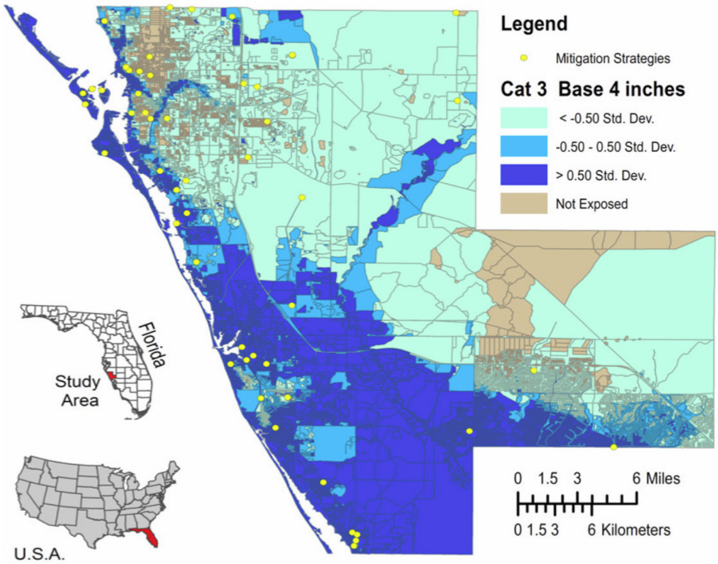

Figure 1: Block exposure scores with mitigation strategies – Category 3 Base 4 inches storm scenario.

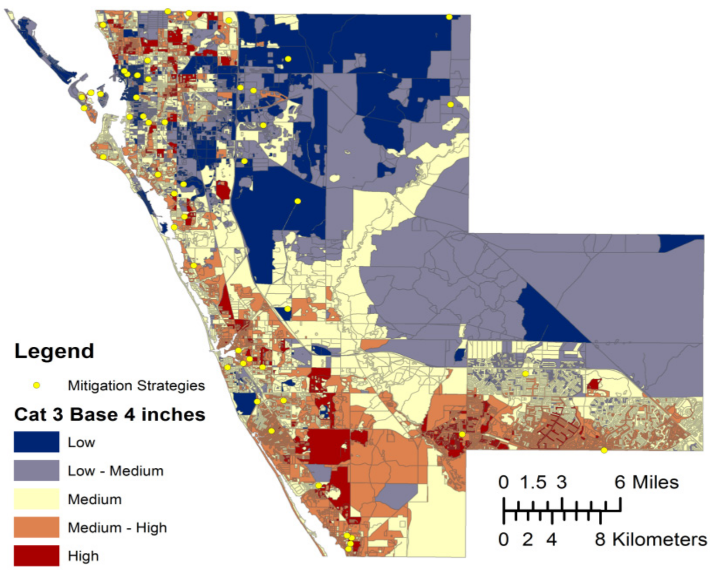

Figure 2: Block vulnerability scores with mitigation strategies – Category 3 Base 4 inches storm scenario.

These results symbolize vulnerability during a Category 3 storm with 4 inches of inland precipitation. The map indicates that communities along the coast and

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in the southern part of the county experience higher vulnerability than the mean. In addition, the vulnerability scores for these areas increase from the mean as exposure increases by storm category. The results of the geospatial analysis of overlayed exposure and vulnerability scoring with the locations of mitigation strategies found in the plan reviews indicate that county mitigation strategies are predominately directed by exposure alone and not based on total vulnerability scores. Results of the plan review also indicate that many of the mitigation strategies within Sarasota County are mostly structural in nature (i.e. relocate fire stations out of floodplain) in areas where exposure to storm surge or inland precipitation is highest.

5 Discussion

Vulnerability assessments that incorporate place specific indicators and consider all three components (exposure, sensitivity and adaptive capacity) provide more holistic information about its assessment. This information can help to determine where short-term disaster mitigation strategies are more cost-effective and serve to better guide the implementation of long-term mitigation and adaptation practices. Local agencies and communities with limited financial resources or expertise to compile hazard analysis often contract out their plan. This often leads to ineffective HMPs that fail to or only marginally enhance local community resilience [29]. Local communities also are usually forced to rely on county, regional, or state level assessments conducted at larger spatial scales that ignore place-specific indicators, which are often too general or unspecific for local level hazard mitigation practices thus hindering the enhancement of local community resilience [9]. Conducting vulnerability analyses at a county scale or higher makes it difficult to place the appropriate amount of emphasis on community level vulnerability indicators, particularly considering the need to consider the spatial relationship of these indicators. Traditional vulnerability assessments only include hazard exposure and do not consider the influence of sensitivity and adaptive capacity on vulnerability [22, 27, 34, 35].

The exposure scoring results indicate that hazard exposure is greatest along the coast and inland waterways as higher elevations impede the ability of storm surge to move further inland. As such, a majority of the implemented county mitigation strategies (predominantly structural in nature) lie along the coast, in areas within the 100-year floodplain and along inland waterways. Inland areas within the 100-year flood plain also experience exacerbated exposure because limited barriers slow inundation flowing further inland. The county's urban service boundary limits development to areas along the coast, where exposure is greatest also contributing to the pattern of mitigation strategies predominantly being in areas where exposure is high. Understanding where exposure is greatest can help local communities to mitigate against further structural losses in the future, but is often done at the expense of mitigation for specifically targeted socioeconomically vulnerable population groups. Socioeconomic factors (such as poverty or age) influence overall vulnerability but mitigation for them is often not specifically assessed or addressed by local communities.

There is often a disconnection between mitigation strategies and overall vulnerability. Some of the mitigation strategies chosen by Sarasota County are located in areas of lower vulnerability, with only a few located in places where vulnerability is considered high. This occurs because these areas have high exposure, but experience lowered sensitivity and higher adaptive capacity. In addition, there are also areas of medium and moderate vulnerability where mitigation strategies (either structural or non-structural) are not being implemented. An issue associated with targeting mitigation to exposed areas is that long-term comprehensive and mitigation planning only considers contemporary hazards. Hazard exposure is likely to change in the future due to climate change enhanced hazards, such as sea level rise or increased storm precipitation. Therefore, targeting mitigation in areas exposed to contemporary hazards in long-range plans might overlook areas where exposure will likely increase as a result of climate change enhanced hazards [4].

The sensitivity scoring results indicate that populated areas along the coast contain the highest sensitivity scores. This might occur because there is a higher population density, larger minority and dependent populations, and a greater amount on infrastructure present in these areas. The adaptive capacity results identify several tracts in the northern and southern part of the county as having lowered adaptive capacity. This could be due to a larger amount of impoverished or dependent populations that have less access to resources. Conversely, several census tracts along the coast and on barrier islands have higher adaptive capacity, despite the higher hazard exposure levels likely due to a greater presence of populations with greater access to resources.

The vulnerability analysis results indicate that areas experiencing high sensitivity and low adaptive capacity have higher vulnerability scores despite their level of exposure. Exposure can indicate areas where greater amounts of damage will occur, but it does not indicate the level of hazard sensitivity of individuals or societal assets. Traditional capital coupled with private insurance, serves to enhance access to resources in many coastal communities thus facilitating post disaster recovery and contributing to lower sensitivity scores. Conversely, impoverished populations, which rely more on social capital and state and federal social programs, are more sensitive to hazard impacts. Thus, simply targeting structural mitigation areas does not necessarily account for or reduce the impact of other indicators on overall vulnerability.

While a majority of the georeferenced mitigation strategies fell within areas exposed to coastal storm inundation hazards, these strategies were not necessarily located in areas where overall vulnerability was greatest. Ten of the 143 listed mitigation strategies in the ULMS plan were non-structural in nature (i.e. public education and outreach and evacuation warning systems) and only two of these strategies were given specific geographic location references. From this, we can conclude that mitigation strategies that target specific vulnerability indicators are not being addressed explicitly within the hazard mitigation planning process. This could occur because decision makers are not aware of socioeconomic marginality in certain areas that can increase vulnerability in part due to the deficiencies in traditional vulnerability assessments. Existing research commonly generalizes vulnerability results to the county level, which does not provide information about what areas within the county are most vulnerable. A more detailed analysis is needed to effectively target mitigation at the sub-county level. It is also possible that socioeconomic factors that can increase vulnerability are not being considered or targeted when mitigation strategies are chosen or implemented at the local level for political, financial or otherwise unlisted reasons. This provides insight as to why the mitigation strategies more coincide with areas of greatest exposure as it is often easier to generate political and financial support for more exposed areas regardless of overall vulnerability. This is likely due to limited knowledge concerning the differential spatial spread of vulnerability indicators across the landscape. This produces general results that can cause mitigation practices to be uniform across the county. Unfortunately, mitigation practices distributed uniformly across a county does not necessarily lead to uniform vulnerability reduction.

6 Conclusions

Vulnerability is variable throughout a community due to a differential distribution of factors that influence vulnerability. Recognizing the uneven distribution of socioeconomic factors and how they intersect with physical hazards is important for effective community-level hazard mitigation and efficient allocation of limited resources. While many existing studies measure vulnerability through vulnerability indexes, they are not conducted at the sub-county level and disregard weighted-place and scale-specific indicators in vulnerability assessments. These issues often lead to incomplete vulnerability assessments and can result in the implementation of uniform mitigation practices across the county. Uniform mitigation practices do not translate to uniform vulnerability reduction and may result in mitigation practices that focus resources on areas that are not as vulnerable.

Including information about the distribution of place-specific, local vulnerability indicators helps planners target non-structural hazard mitigation strategies and response planning to more vulnerable areas. The overlay of current mitigation strategies within Sarasota County and the results of the SERV model illustrate that mitigation strategies are mostly structural in nature and are implemented in more exposed areas, not necessarily areas of high vulnerability. Implementation of mitigation strategies specifically targeted at areas within the community to socioeconomic factors that contribute to overall vulnerability should be addressed if community resilience enhancement is a goal.

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www.witpress.com, ISSN 1743-3509 (on-line)

The use of social media by UK local resilience forums

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Abstract

The power of the public to capture and share real-time information has been utilised effectively in disaster situations, most notably Haiti, and social media has been important for developing new ‘communities of interest’, exemplified by its role during the Arab Spring. The potential methods of harnessing social media in the field of emergency planning, resilience and response (EPRR) are varied and interesting, and range from its use as a means of sending out public information to new ways of generating and using real-time data. Although the UK government have produced various guidance documents for the use of social media, the professional use of such technology in the UKEPRR field is poorly documented and appears sporadic. This paper presents the results of a survey of Local Resilience Forums in the UK on their use and engagement with social media. The findings suggest that the level of application of social media strategies as emergency planning or response tools varied significantly between the LRFs. While over 90% of respondents claimed that their LRF used social media as part of their strategy, most of this use was reactive or passive, rather than proactive and systematic. The various strategies employed seem to be linked most strongly to local expertise and the existence of social media ‘champions’ rather than to the directives and guidance emerging from government. The paper concludes by making policy recommendations concerning requirements for mandatory social media training within the emergency planning professions.
Keywords: social media, crowdmapping, crowdsourcing, emergency planning, resilience, emergency response, local resilience forum.

WIT Transactions on The Built Environment, Vol 133,
www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/DMAN130031

1 Introduction

Social media is a rapidly developing communication tool that has become embedded in society, culture and everyday life (Paslawsky [1]; Proctor [2]; Dufty [3]; Hughes and Palen [4]). Individuals, groups, businesses and organisations use social media to collaborate and share various types of information.

The number of people who now carry a phone or device capable of capturing images and connecting to the internet is growing (Freifeld *et al*. [5]). This makes anybody carrying such a device a potential 'reporter' with a far reaching internet audience. The power to capture information and share it in real time has been demonstrated on many occasions in recent times, during disasters such as Haiti, and in times of political and social change, for example the Arab Spring (Cottle [6]). When governments place bans on live reporting and censor the mainstream media, social media provides a platform where information can still be shared (Doyle *et al*. [7]) and some argue that "the greatest contribution that social media has made to modern democracy is making information available at the touch of a mouse" (AllAfrica.com [8]).

The potential for using social media in the field of EPRR is broad and far reaching, providing opportunities that include assisting during the mitigation, response and recovery phases.

Palen *et al*. [9] point out the significance of photographs taken by eyewitnesses and shared using social media on disaster response. They are no longer seen as personal accounts but as evidence that is often requested by formal disaster response agencies. During emergencies the public actively seek information and the photographic evidence posted on image sharing websites such as FlickR can help people to make sense of the event. The photographic image itself can become a 'community' where people come together to share and comment on the content. Tobias [10] emphasises the power of the eyewitness 'citizen reporter' who will usually be at the scene of an incident long before the traditional media (and even emergency services) arrive. Iconic images such as the photograph taken of the plane ditching in the Hudson River and Tweeted within minutes of the incident were captured by the public and shared to provide information about an incident before emergency services or the media arrive. These 'citizen reporters' are also greater in number and are capable of representing a larger geographical area than traditional media reporters are (Heinzelman and Waters [11]).

The process of taking this information and presenting it geographically has been termed as 'Crowdmapping'. Software has been developed to assist in the process, born from the earlier deployments of Google maps (and others) that were then utilised within the social media community to create a representation of events. The information is often displayed in the form of flags displaying the location of the source onto a map. Software has been created to do this in a more structured and controlled manner, the most discussed in the literature, as it has been utilised in real life situations is Ushahidi [12].

'Crowdmapping' was demonstrated following the incident at the Fukushima Nuclear Power Plant where radiation maps were produced in Japan and the US (Saenz [13]). Similarly, the method was used in Oregon following a large 'boom'. A web developer who heard the 'boom' created a Google Map and asked people to plot on the map what the explosion had sounded like from their location. Within an hour 100 people had placed a pin which were colour coded, depending on the intensity of the noise heard with red being loudest. The police went to the scene concentrating on the area containing the highest concentration of red pins and found the remnants of an exploded pipe bomb (Tobias [10]).

Health organisations have widely used social media as a tool to broadcast public health messages and to educate the public. The Centres for Disease Control and Prevention (CDC) [14] in the USA recognise the potential of social media to "expand reach, foster engagement and increase access to credible, science based health messages". Although social media is widely used for seeking out information relating to health, examples of cases taking full advantage of iterative social media to improve public health are few. A number of exceptions include some epidemiologists who are attempting to use social media monitoring for accessing additional sources of data relating to flu-like illnesses (Corley *et al*. [15] and health professionals at CDC who used the online virtual world, Second Life, to facilitate training on H1N1 virus and to simulate mass prophylaxis sites and distribution of materials following an Anthrax attack (Crowe [16]). Vance *et al*. [17] also discuss the use of Second Life for providing health support and advice to patients.

More conventionally social media could be utilised by health organisations to target specific groups. For example, a forum frequented by parents could be targeted as a community who may benefit from specific health advice relating to child immunisation.

The opportunities offered by social media as a 'two way operational tool' are great, but in the UK EPRR field there is a lack of evidence regarding the use of social media and it seems that there is limited recognition of its potential and poor understanding of the drivers (or barriers) to its greater utilisation.

2 Social media strategies

The success of social media use is dependent on a well-designed strategy. Crowe [16] argues that social media has already impacted on emergency management and therefore it is imperative that emergency planning and response staff utilise the new technology in a proactive way. Lindsay [18] states that while EP communities understand how they can develop strategies to harness social media that they also need to do so with some urgency. St Denis *et al*. [19] point out that as social media use grows in the public domain the pressure on emergency managers to use these communication channels for information distribution is also increasing. It is reasonable to consider that as social media becomes more embedded in society the urgency for the EPRR field to adapt its strategies for communicating with the public will increase.

However, in developing a social media strategy, those responsible may face obstacles within their organisation at the strategic level.

2.1 Organisational 'buy-in'

It has been suggested that the effective utilisation of social media tools are dependent on leadership style (Denyer *et al*. [20]), although Tobias [10] suggests that a lack of organisational buy in could also be due to a lack of confidence in the public generated information. St Denis *et al*. [19] point out that understanding social media strategy adoption is challenging due to its steep learning curve.

Obtaining organisational buy in is also discussed further by Tobias [10] who notes that a group of emergency managers "frequently mention methods for obtaining 'buy in' from those in their organisations who are not familiar with social media". This suggests that persuading the strategists within an organisation to develop social media plans, may be difficult if those making the decision to do so lack the technical knowledge and understanding required for them to appreciate how it might be utilised, and/or are distrustful of the technology.

The UK Home Office have produced Social Media guidance documents such as "Social Media Guidance for Civil Servants" [21] and The Defence Science and Technology Laboratory (DSTL) "Smart Tips for Category 1 Responders using social media in emergency management" [22] while the Cabinet Office will "begin a series of good practice seminars on using social media to interact with users on a rolling basis to December 2013" [23]. However, Proctor [24] suggests that the lack of set standards for emergency responders in the UK, and the consequential variation in the application of social media strategies poses an area of risk.

There appears to be recognition that those responsible for EPRR would benefit from directives to standardise how the community utilise social media, while guidance is appearing in the form of documents and workshops, the uptake may well be variable as it doesn't appear to be a mandatory requirement for Category 1 Responders to follow.

2.2 Types of strategy

Lindsay [18] categorises the current use of social media into two broad categories, a passive approach to disseminate information and receive feedback, with this being the most common approach taken to date by emergency responders and a second approach that involves the systematic use of social media as an emergency management tool.

Proctor [2] points out that the most obvious use of social media in relation to emergency management is to 'warn and inform'. As 60% of the public access the internet every day, social media tools should be used in every communications strategy for warning and informing the public.

Edwards [25] argues that EPRR can no longer just broadcast to individuals and communities and must instead devise strategies that are based on a two way model of communication, listening to what is being said by social media users and then using the communication channel to provide support and improve negatives. The literature appears to demonstrate a consensus that social media strategies need to be developed as a two way communication channel, with consideration as to how information will be received and used, along with how information will be sent.

It should be recognised however, that where some public sector organisational teams have already been 'streamlined', the implementation of a resource intensive strategy may be difficult and achieving organisational 'buy-in' may be more successful by proposing a phased approach to implementation, especially where understanding at the strategic level is an issue.

Crowe [16] found that emergency planning departments are often small, and therefore expecting staff to implement a full scale proactive utilisation of social media may be unrealistic without applying additional resources to the team.

Crowe points out that social media technology is a free resource which 'cuts out the middle man', as public sector organisations budgets are also streamlined this could be viewed as an important benefit (White [26]; Woodcock [27]). Taking this further, Proctor [28] and St Denis *et al*. [19] discuss the potential for a practice involving the recruitment of volunteers to monitor social media during emergencies to form VOST (Virtual Operations Support Team). There is currently a UK project 'UK VOST" (Jennings [29]) that "aims to develop a model of VOST that Category 1 Responders can feel confident in, and that is able to add value to emergency response in the UK". This could potentially address the resource issues that may be faced by many organisations.

2.3 The civil contingencies act

The fields of social media and EPRR are both relatively new and developing arenas, and both are constantly changing to adapt to new emerging technologies and threats and adoption by EPRR organisations varies. In England and Wales, Local Resilience Forums have a statutory requirement under the Civil Contingencies Act 2004 (CCA) which states that Category 1 emergency responders must: "*…establish and maintain effective multi-agency arrangements to respond to major emergencies, to minimise the impact of those emergencies on the public, property and environment, and to satisfy fully the requirements of the Civil Contingencies Act 2004*". Part One of the CCA also specifies that Category 1 responders have a number of duties with regard to civil protection, including to: "*Put in place arrangements to make information available to the public about civil protection matters and maintain arrangements to warn inform and advise the public in the event of an emergency*" "*Co-operate with other local responders to enhance co-ordination and efficiency*" (Civil Contingencies Act 2004 – Part 1 [30]).

The effective use of Social Media as a bi-directional tool has the obvious potential to assist Category 1 responders in their requirement to discharge the above duty to 'warn and inform' the public. This is exemplified by Barbier *et al.* [31] who describe the technology as a facilitator of information sharing, interoperability and collaboration. Social media could therefore potentially offer

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major support for CAT1 duties. However, Crowe [16] points out that social media generated information is unfiltered and not subject to the usual review, change and bias of traditional media channels which normally ensures that the public receive clear and consistent information.

Some organisations with an emergency response role are utilising social media platforms to develop strategies to broadcast their civil protection messages to the public, both in the planning and response phases. Proctor [2] points out that those organisations that additionally monitor social media also benefit from the ability to correct any rumours or contradictory advice that may emerge following the broadcast of a public message. Proctor also argues that social media is "not suitable for broadcasting messages". He discusses that a message could be sent as effectively to the public via a traditional channel such as by radio, allowing the responder to then continue with their response. He states that using social media to simply deliver a health protection message results in a 'flurry' of response and debate that the responder then needs to monitor. Although this is a valid point, particularly where resources are an issue, it should be balanced with the other arguments that point out the value of monitoring the information that is being posted during an incident.

Social media could assist the Category 1 responder in their duty to 'warn and inform' beyond the facility to broadcast a message to a subscribed or selected audience. There is clear evidence that the potential exists for social media to assist during an incident response (Palen *et al.* [9]), and that utilising social media to engage with the public could provide a rapid understanding of a situation as it develops. However, Jaeger *et al.* [32] point out that before, during and after a major disaster, co-ordination of the response is difficult due to the number of individuals and organisations who work together and the interoperability issues that inevitably arise. For example, Barbier *et al.* [31] reported that during the response to the Haiti crisis, government and non-government organisations worked together but difficulties arose in co-ordinating the response due to the lack of a common information system. This problem was addressed in the UK by the development of the National Resilience Extranet (NRE) Collaborate Application to facilitate information sharing between CAT1 organisations. However in order to use the NRE various licenses and training regulations have to be met and it there is a danger that some responders will not have the experience or confidence to use the system in the event of an emergency. In comparison, many of these people will use social media in their day to day life, therefore maintaining an up to date knowledge of the application. While social media cannot match the level of security for information shared via the NRE, the use of social media as a tool to share real-time, un-sensitive information between emergency planners could be considered, in support of their duty under the Civil Contingencies Act to co-operate and collaborate with each other.

2.4 Public expectation

The impact of social media on everyday life has led to the public anticipating that social media channels will be monitored by emergency response staff during an incident and in times of crisis, more and more people are likely to rely on social media to get information, connect with loved ones, seek help and provide assistance (Corbin [33]). In America, a Red Cross survey [34] found that 69% or those surveyed said that emergency responders should be monitoring social media sites in order to direct help as soon as possible and nearly half believe that any request for assistance they made would be already receiving a response. Along with this expectation that someone is 'listening' there is also the assumption that information will be directed to them. Tobias [10] points out that there is an expectation amongst the public that information will be pushed to them immediately and Crowe [16] found that they expect to get more information more quickly than through traditional channels. While the public are now communicating with each other in real time, sharing information socially, it seems that this shift in the way people communicate has changed their expectations with regards to how they receive information from other official channels.

In order to ensure that any information flow between the responding organisation and the public is trusted it is important to foster good relationships prior to any incident. Crowe discusses the long standing issues around trust and the public regarding information received from government representatives and explains that social media creates a higher trust factor for information, as people view and share information within their common network of friends, contacts or organisations. Jaegar *et al.* [32] point out that trust in the sources of information will influence the level of participation and action taken in response. Van Velsen *et al.* [35] concur 'for many, source credibility is an important asset of information usefulness". Barbier *et al.* [31] point out that the level of trust in social media posts could be determined by fellow user feedback, for example the 'thumbs-up' or 'thumbs-down' along with user comments. Kamel Boulos *et al.* [36] reinforces this finding and argues that "reputation and trust, both of emergency management personnel and members of the public that provide the data are equally important".

The public perception of how emergency response teams utilise social media suggests that responders must quickly improve their engagement with social media in order to ensure the health and safety of the public. Consideration should also be given to the actions that responders can undertake to improve the communities' ability to self-respond to an incident and protect life. Inspired by the fact that following the Kobe earthquake 80% of victims were rescued by family and friends, which involved activating existing social ties, Jaeger *et al.* [32] discuss the concept of Community Response Grids as a method for increasing community resilience. Facilitating channels for providing information to the public to aid resident to resident assistance is an important avenue of improving the breadth of reach of any messages conveyed via social media.

3 Survey

Since there is so much potential for the use of social media within the EPRR community, it was considered important to know what policies and practices already existed within Local Resilience Forums and their partners. A questionnaire was distributed to all 38 Local Resilience Forum chairs on the 26th November 2012, with a request that it was cascaded at their discretion to the LRF partners. To ensure anonymity, but to gauge the responses geographically, the respondents were asked to log their LRF by region but not to identify the specific LRF.

There were a total of 63 responses; all were complete and included in the analysis. Due to the anonymity of the responses and the number of LRF in each region, it is impossible to determine exactly how many LRF are represented by this data, although it can be assumed that a maximum of 18 LRF are represented by the respondents. It is not possible to say how many organisations are represented by the responses, however, they are categorised in terms of 'Responder Type' and 'Health'. The responses demonstrated that 75% of the LRFs use social media to communicate with the public, but only 35% use it to communicate with their partner organisations. 40% of those responding for the LRF were less sure about the social media monitoring strategy, with only 20% reporting that it is used.

The LRF responders also reported that the majority (60%) have a strategy for social media use during an incident response, 25% reported that their LRF does not have such a strategy and the remainder were unsure.

Of those using social media during a response, the majority use it to both broadcast and monitor. What isn't clear is the detail of the monitoring strategy. This could be monitoring the responses to their own broadcasts, or monitoring what is being said regarding specific incidents or issues, or even to defer the monitoring and broadcasting back to the individual responding organisation.

Where it was reported that social media isn't presently used by an LRF, 50% answered that they are 'Not Sure' or 'No' when asked if they had plans to implement in the future. The responses received on behalf of partner organisations showed that the majority were not sure how social media was being used. Although it is unreasonable to expect that all staff within an organisation will be aware of the social media activity, it would perhaps be useful to ensure that LRF representatives are aware of any activity to allow them to effectively contribute to any future LRF strategy.

The table below shows the responses submitted for all organisations.

Table 1: Responses on behalf of organisations.

	Yes	**No**	**Not sure**
Incident Response	59%	27%	14%
Monitor	37%	19%	44%
Broadcast	92%	8%	-
Social Media Training Provided	38%	49%	13%
Total	**56.5%**	**25.75%**	**17.75%**

The survey responses suggest that the while most organisations are using social media as a broadcasting tool, far less are also monitoring the responses and providing training for staff. With regard to what defines the organisational social media use, although the majority cited the organisation, a significant number (33%) stated that their strategy is driven by 'local champions or experts'.

While the data collected via the survey identified some interesting patterns, there are several factors that should be taken into consideration when interpreting the results. Firstly the survey was voluntary and therefore not all LRF were represented. The LRF chairs/sub chairs are most often blue light responding organisations, and it appears that some LRF chairs submitted responses on behalf of the LRF themselves (without disseminating onto colleagues). As such it is likely that the organisational response was not a balanced representation of the partner organisations.

4 Discussion

This study has successfully identified a number of potential opportunities, issues and risks relating to the use of social media by the EPRR health community in England.

Although implementing a full scale social media policy to support EPRR would be a positive development, it is likely to be resource intensive. Realistic and manageable strategies, in line with the available resources need to be developed as poorly developed or unsupported strategies could lead to greater risks to public health and safety and could undermine the reputation of the organisation. Therefore it is recommended that social media strategies should be realistic and allowed to evolve incrementally, particularly where issues surrounding technological understanding are present. One approach could be to use the technology to 'Warn and Inform' in line with the Cat 1 responder duty, while crucially ensuring that the expectations of the public are being met. Measures to address resource issues in more ambitious strategies could involve the use of volunteers as in the VOST project and during the crowdsourcing response to the Haiti earthquake. It could be suggested that an LRF or EPRR organisation could factor monitoring and crowdsourcing into their social media strategy by implementing a similar volunteer team.

The study has evidenced clear benefits and the potential of crowdmapping within EPRR strategy, but the lack of implementation appears to be due to low levels of understanding by those responsible for developing the strategies. Confident use of the technology is important, as it would be risky to rely on the deployment of a system if the skills and knowledge required utilise the technology were not evident in those required to use it.

The resources required to implement a social media strategy lie mainly in the form of 'people' as opposed to purchasing additional physical technology. Many monitoring applications are free and have the potential to improve situational awareness for incident managers during a response. However, embedding these into existing plans will be challenging. The research found that 'social media champions' are responsible for driving approximately a third of the responding LRF strategies, which could reflect a lack of understanding by those involved in strategy development. To provide assurance, social media strategy should not be dependent on the efforts and advice of local champions. These champions are important, but there needs to be a systematic method of cascading that information within organisations. Training is therefore a key issue that needs to be addressed before social media can be used reliably and effectively. It would certainly be a risk to rely on a strategy where those responsible were not competent or confident to follow the plan, equally it would be inefficient to train staff to use a technology that they may not utilise and then forget how to use. This suggests that before a set of mandatory requirements for social media use within LRF can be suggested, the vast majority of the LRF partner organisations must adopt a strategy as part of their EPRR. The directives may come from the 'top down', but for them to be successful the training and day to day use needs to come from the 'bottom up'.

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Earthquake and tsunami recovery efforts in northeastern Japan

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Abstract

The earthquake and tsunami that struck on March 11, 2011, caused extensive structural damage over widespread areas of northeastern Japan, inflicted heavy damage to roads and railways, caused numerous fires, and was responsible for a dam collapse. In response to the disaster, the Japanese National Diet passed the Law to Establish the Reconstruction Agency on December 9, 2011, and the Agency was subsequently inaugurated on February 10, 2012, under the direct leadership of the prime minister [1, 2]. In this paper, on and reconstruction activities implemented in areas struck by the earthquake and tsunami are described, focusing on Shiogama City, which is located in Miyagi Prefecture about 15 km north of Sendai. Although damage to Shiogama City's fishing industry turned out to be slight, nearly 50 people were killed or went missing in the city, and approximately 4,000 houses were completely or partially destroyed by the tsunami. Up to now, recovery and reconstruction plans were rapidly formulated by Japanese central government and Shiogama City officials.
Keywords: earthquake, tsunami, recovery, reconstruction.

1 Introduction

The Great East Japan Earthquake, which occurred off the Pacific coast of northeastern Japan on March 11, 2011, was measured by the US Geological Survey (USGS) moment magnitude scale (M_w) as a magnitude 9.03 undersea mega-thrust event, with the epicenter approximately 70 km east of the Oshika Peninsula which projects southeast into the Pacific Ocean from the coast of Miyagi Prefecture in northeast of the main island of Japan and a hypocenter at an

www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/DMAN130041

underwater depth of approximately 32km. It was the most powerful known earthquake ever to have hit Japan, and one of the five most powerful earthquakes occurring worldwide since modern record keeping began in 1900. The earthquake triggered powerful tsunami waves that reached heights of up to 40.5 m in Miyako, Iwate Prefecture, while waves travelled up to 10 km inland in the Sendai area. The earthquake moved the main island of Japan 2.4 m east and shifted the Earth on its axis by estimates of between 10 and 25 cm. On September 12, 2012, the Japanese National Police Agency confirmed about 15,900 deaths, 6,100 persons injured, and 2,700 persons missing across twenty prefectures. They also reported that about 130,000 buildings had totally collapsed, 254,200 buildings were "half collapsed," and another 700,000 buildings were partially damaged. In response, the Bank of Japan offered ¥15 trillion (US $183 billion) to the banking system on March 14, 2011 in an effort to normalize market conditions. The World Bank has estimated that the economic cost of the disaster at approximately US $235 billion, making it the costliest natural disaster in world history [1].

2 The great East Japan earthquake

Major earthquakes with accompanying large tsunamis previously struck the Sanriku Coast region in 1896 and in 1933. The Great East Japan Earthquake, which was caused by a 5–8 m up-thrust on a 180 km wide stretch of seabed 60 km off the Sanriku Coast, resulted in a major tsunami that inflicted destruction along the Pacific coastline of all Japan's northern islands. Thousands of lives were lost as entire towns were devastated. The tsunami propagated throughout the Pacific Ocean region reaching the entire Pacific coast of North and South America from Alaska to Chile. Warnings were issued and evacuations were carried out in many countries bordering the Pacific, even though the affects were minor. For example, Chile's Pacific coast, which is about 17,000 km away from Japan, was struck by waves 2 m high, compared with an estimated wave height of 38.9 m experienced on the east peninsula of Miyako City in Iwate prefecture. Immediately after the earthquake, the Japan Meteorological Agency (JMA) issued a "major tsunami" warning. This is the most serious warning on its scale, and is defined as a prediction of waves at least three meters high. When it struck, the tsunami inundated a total area of approximately 561 km^2 of Japan. However, a government study conducted in the aftermath of the disaster found that only 58% of people in coastal areas of Iwate, Miyagi, and Fukushima Prefectures heeded the tsunami warnings immediately after the earthquake and began evacuating to higher ground. Of those who decided to evacuate after hearing the warning, only 5% were caught by the tsunami. Of those persons in the affected area who ignored the warning, the tsunami waters hit 49%. Figure 1 shows the Japanese archipelago [3].

Although Japan has invested the equivalence of billions of dollars on anti-tsunami seawalls, which line at least 40% of its 34,751 km coastline and stand up to 12 m high, the tsunami simply washed over the top of many of them, collapsing a number of them in the process. Damaged buildings included 29,500

Figure 1: Japanese archipelago.

structures in Miyagi Prefecture, 12,500 in Iwate Prefecture and 2,400 in Fukushima Prefecture. Three hundred hospitals with 20 beds or more were damaged by the disaster, with 11 being completely destroyed. In addition, the earthquake and tsunami created an estimated 24–25 million tons of rubble and debris, and an estimated 230,000 automobiles and trucks were damaged or destroyed in the disaster. As of the end of May 2011, residents of Iwate, Miyagi, and Fukushima Prefectures had requested deregistration of 15,000 vehicles, indicating that the vehicle owners had written them off as irreparable or unsalvageable. All of Japan's ports were briefly closed after the earthquake, even though those in Tokyo Bay and further south soon reopened. Fifteen ports of Sendai, Shiogama, Souma, Kamaishi, etc. were located in the disaster zone. A total of 319 fishing ports, comprising approximately 10% of Japan's total, were damaged in the disaster. However, most had been restored to operation by April 18, 2012. The tsunami also ruptured the Fujinuma irrigation dam in Sukagawa

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City, Fukushima Prefecture, causing flooding that washed away five homes. After the disaster, 252 dams were inspected and it was discovered that six embankment dams had shallow cracks on their crests. The reservoir of one concrete gravity dam was found to have suffered a small minor slope failure. Currently, however, all those damaged dams are functioning without problems. In the immediate aftermath of the disaster, at least 1.5 million households were reported to have lost access to potable water. According to the Ministry of Economy, Trade and Industry (METI), around 4.4 million households served by

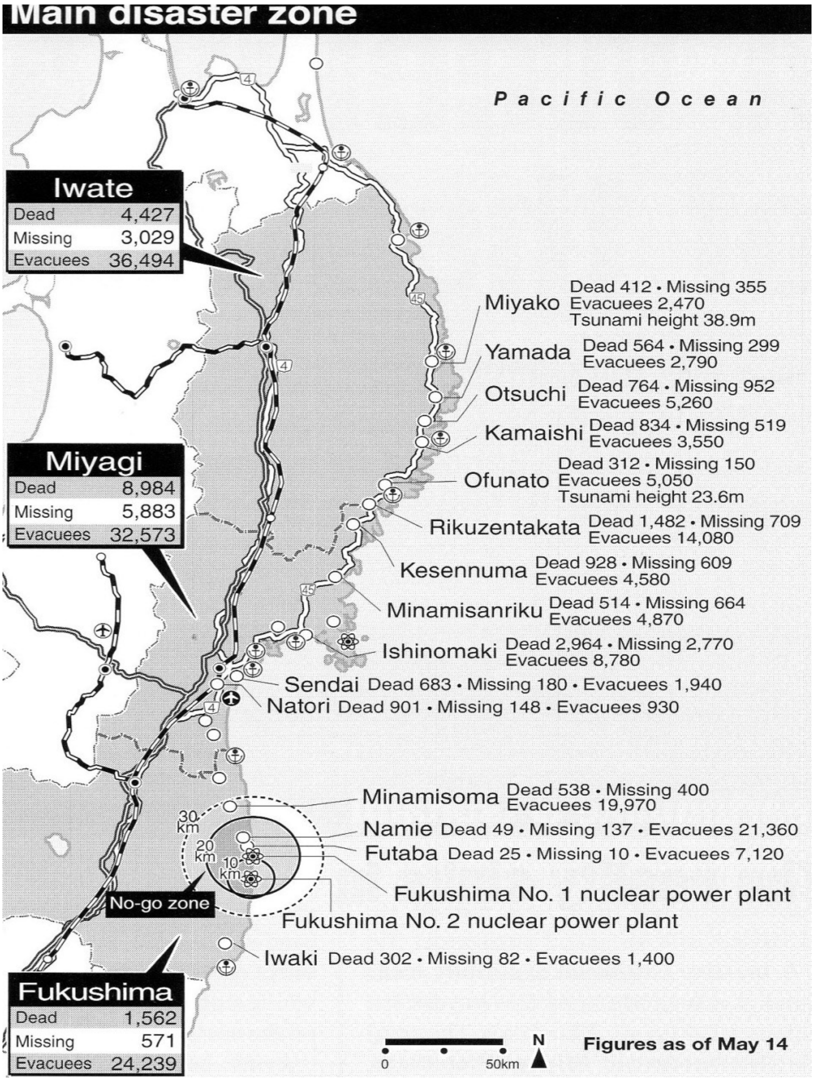

Figure 2: Main disaster zone of Sanriku Coast.

Tohoku Electric Power (TEP) in northeastern Japan were left without electricity. Further south, several nuclear and conventional power plants went offline after the earthquake, reducing the total generating capacity of Tokyo Electric Power Company (TEPCO) by 21 GW, and caused "rolling blackouts," which began on March 14 due to the resulting power shortages. The reactors at the Fukushima No.1 and No.2 Nuclear Power Plants were automatically taken offline when the first earthquake occurred, yet sustained major damage due to the subsequent tsunami. The 30km radius around the nuclear power plants could not be assessed in the immediate aftermath of the earthquake and tsunami. Many sections of the Tohoku Expressway serving northern Japan were damaged as well. As for rail services, the Tohoku Shinkansen line was worst hit, with JR East Railway Co. estimating that 1,100 sections of the line, varying from collapsed station roofs to bent power pylons, required repair. In Tokyo, all railway services were suspended, leaving an estimated 20,000 people stranded at major stations across the city. In the hours after the earthquake, some train services resumed, but most lines serving the Tokyo area did not return to full service until the next day. Various train services around other parts of Japan were also canceled, with JR East suspending all its services nationwide for the remainder of the day. One hour after the earthquake, the resulting tsunami swept over Sendai Airport located on in the eastern part of the city, causing severe damage there [1]. Figure 2 shows the main disaster zone in the Sanriku Coast on May 14, 2011 [4].

3 Shiogama City case study

As previously mentioned, Shiogama City is located in Miyagi Prefecture and is situated on the northeastern Sanriku Coast between the cosmopolitan city of Sendai and Matsushima Bay, which is known as one of the three most famed views in Japan. The city has prospered due to its harbor, which has been a prominent center of maritime trade since the Meiji Era (1868–1912), even though it has more recently evolved into a base for the local and deep-sea fishing industries. Indeed, Shiogama City's harbor boasts the largest unloading point for fresh tuna in Japan, and its other enterprises ensure the city with an abundance of other fresh seafood. In addition to being a popular tourist destination due to its position as one of the doorways to Matsuhima Bay, Shiogama has more sushi restaurants per square kilometer than anywhere else in Japan and leads the nation in the production of steamed fish paste, kneaded fish cakes, as well as other processed fish products. In 2012, the city's population was 56,490, and the number of households was 20,363. Shiogama City covers an area of 17.79 km^2. Figures 2(a) and (b) show overviews of Miyagi Prefecture and Shiogama City [5, 6].

In 2010, 11.4% of the Shiogama City population was under 15 years of age (6,437), 61.1% were citizens 15-64 years of age (34,451), while those citizens aged 65 and older (15,481) accounted to 27.5% of the total. Of the 20,363 total households in the city, 59.6% were nuclear family households (12,115), independent households accounted for approximately 22.1% (4,500), elderly

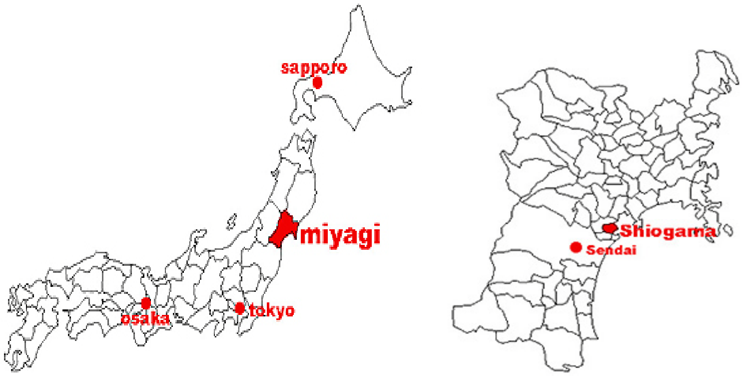

Figure 3: (a): Miyagi Prefecture. (b): Shiogama City.

couple households accounted for 12.5% (2,525) and households consisting of aged persons living alone accounted for 9.8% (1,998) of the total. As for the housing conditions in Shiogama, of the 19,880 total residential units surveyed in 2008, 14,180 were family-owned residences and 5,570 were rental units. In 2009, the city hosted 3,285 offices and employed 23,259 persons broken down as follows: primary industry, eight offices and 131 persons; secondary industries, 552 offices and 5,501 persons; tertiary industries, 2,725 offices and 17,627 persons. Damages resulting from the Great East Japan Earthquake in Shiogama City were as follows: 47 persons deceased due to immediate affects (0.08%), and another 10 persons deceased due to causes related to the disaster (0.02%). Damages resulting from of the tsunami inundation affected 18,718 persons (33.1%), 6,973 households (34.2%), 2,481 offices (75.5%) and 18,596

Figure 4: Flooded areas (shadowed) in Shiogama City.

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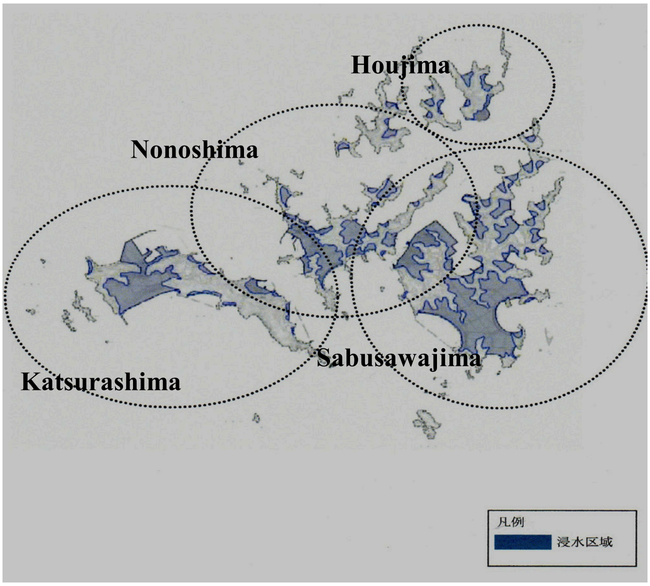

Figure 5: Urato islands of Shiogama City.

employees (80%). The tsunami inundated approximately 27 ha of agricultural land (37%) resulting in extensive damage to cultivated fields. Monetary damages in Shiogama City related to traffic facilities, communication lifelines, housing, education, medicine, etc., were estimated at approximately ¥0.1 billion (US $0.1 million) [7–9]. However, the city suffered slightly less damage than neighboring municipalities (Tagajyou City, Hichirigahama Town, etc.) because nearby offshore islands such as Katsurashima, Nonoshima, Sabusawajima and Houjima of Urato islands absorbed and dissipated much of the tsunami's force. Figure 4 shows an overview of the tsunami flooding in Shiogama City. Figure 5 is offshore islands and shadowed parts are flooding areas.

4 Earthquake disaster reconstruction plans

The Reconstruction Agency is an administrative body of the Cabinet of Japan established on February 2, 2012, to coordinate reconstruction activities related to the Great East Japan Earthquake and the Fukushima Daiichi Nuclear Power Plant disaster [10]. The Reconstruction Agency was established to replace the Reconstruction Headquarters that was created on June 24, 2011, in response to the Great East Japan Earthquake. At its founding, the Reconstruction Agency was headed by then Prime Minister who took direct control of the agency in an effort to strengthen the organization's leadership. Although the Reconstruction Agency is not a Cabinet Office, its authority extends over many other government ministries. The Reconstruction Agency is scheduled to exist for ten years, which was estimated to be the length of time necessary to fully restore the region after the disaster, and is expected to be dissolved on March 3, 2021. Currently, the Agency works out of three regional offices that were established in Iwate, Miyagi, and Fukushima Prefectures, along with two smaller offices, one in Hachinohe, Aomori Prefecture and the other in Mito, Ibaraki Prefecture. The Agency has since forged ties with major Japanese business associations as part of efforts to establish or revive economic activity in regions affected by the earthquake, tsunami, and the nuclear disaster. One such effort is the Reconstruction Design Council, which joins the Reconstruction Agency with the Japan Business Federation, the Japan Association of Corporate Executives, the Japan Chamber of Commerce and Industry, and their affiliated corporations [9]. Furthermore, the Agency also proposed an earthquake disaster reconstruction plan for Shiogama City, which aimed at reestablishing and ensuring safety there. The basic plan calls for

(1) regenerating the local infrastructure and constructing a community spirit that fosters cooperation among diverse support groups,

(2) promoting a citizen-based community where people can resist disasters so that all residents can live in safety,

(3) regenerating and reconstructing basic industries, commerce and infrastructure, including tourism-related enterprises,

(4) other actions as necessary to stimulate the regional economy.

The basic policies of the plan center on the following:

(1) Housing and lifestyle reconstruction, including rehabilitation and reconstruction of damaged/destroyed residences, promoting and maintaining employment, providing economic support to victims, as well as reviving and rebuilding public services.

(2) Improving community safety by enhancing the security and maintainability of the residential environments, reconstructing public facilities, reconstructing and stabilizing city functions and infrastructure, with specific emphasis on areas affected by the tsunami.

(3) Revitalizing commerce and other areas of the economy by rebuilding and reconstructing key industries, rebuilding and revitalizing commercial infrastructure, promoting tourism, and creating a new support system at the national and prefectural level.

(4) Addressing issues related to radioactive fallout. This includes promoting security, dependable civil service, and countermeasures to radioactivity tailored to ensuring safe industrial development.

(5) Reviving of other parts of the district (included offshore islands) that suffered serious damage due to the earthquake and tsunami.

In all areas, rehabilitation support will include repair or reconstruction where necessary including revitalization of basic services, reconstruction and repair of damaged island roadways, medical facilities, administrative services, and industry. To strengthen the nation, it will be necessary for central government agencies to join with prefectural, city, town, and village governments in the affected areas to promote plans of this nature, and provide the human material support required. It will also be necessary to promote cooperation at the citizen and neighborhood association level, as well as within companies and enterprises.

Because of the massive expenses related to reconstruction, financing the recovery is expected to remain an ongoing problem. It will also be important to ensure flexibility and promote good ideas within the framework of the existing systems, set and enforce goals based on clear appraisals of the damages, and conduct period evaluations to ensure proper progress is being made.

5 Considerations

About the time when restoration, the revival from East Japan great earthquake disaster is completed according to the Asahi Newspaper dated March 1, 2013 [11], it was announced in the questionnaire result that the half of the chief of 42 cities, towns and villages in three prefectures where we will be suffered over 6-10 years later. The 6.8 (M_w) Great Hanshin Earthquake, also known as the Kobe Earthquake, occurred on January 17, 1995, in the southern part of Hyogo Prefecture [12]. The focus of the earthquake was located 16 km beneath its epicenter, on the northern end of Awaji Island, approximately 20 km away from the city of Kobe. Approximately 6,434 people lost their lives (final estimate as of December 22, 2005), of which approximately 4,600 were Kobe residents. Among the major cities affected, Kobe, with its population of 1.5 million, was the closest to the epicenter and was hit by the strongest tremors. At that time, it was Japan's second worst earthquake (after the Great Kanto Earthquake of 1923, which claimed 140,000 lives [13]). The Kobe Earthquake caused approximately 10 trillion (US $100 billion) in damage, which amounted to approximately 2.5% of Japan's GDP at the time. Nevertheless, the city of Kobe recovered due to energetic government office and civic activities, and the main economic indicators for the entire region, such as population, manufacturing sector production, tourism, and consumer spending, have all returned to levels that approximate those before the event. However, it should be noted that damage to Kobe City resulted from the earthquake alone, while Shiogama City and other areas affected by the Great East Japan Earthquake also suffered tsunami damage, along with the issue of radioactive fallout from the Fukushima Nuclear Power Plant accidents. Accordingly, the disaster restoration methods and time required for revival in the latter case can be expected to be different. It is necessary to reflect on the historical experiences and lessons learned from Great East Japan Earthquake and Great Hanshin Earthquake disasters in order to contribute to mitigating future damage from domestic and international disasters. It should also be noted that, even though the Great Kanto Earthquake of 1923 [12] and the Great Hanshin Earthquake of 1975 [13] were huge disasters, the Great East Japan Earthquake was significantly different because it paralyzed and depopulated numerous local governments simultaneously. In addition, it marked the first time the Japanese Government faced challenges related to reviving disaster stricken areas in an era experiencing an ongoing population decline. It is also noteworthy that all of these factors were somewhat overshadowed by the nuclear plant accidents. Thus, the degree of difficulty faced by persons and organizations involved in recovery efforts is unprecedented, and ideas that are fundamentally different from those used in past recovery efforts will be required.

It is necessary to consider the implementation of those steps in terms of: prevention, mitigation, evacuation, relocation and sheltering.

6 Conclusions

At present, approximately 360,000 people continue to reside in evacuation shelters set up in the aftermath of the Great East Japan Earthquake. Meanwhile, the population outflow from the stricken area continues, and while public construction efforts are robust and ongoing, numerous people are unable to find hope there. The stricken area has been hit by tsunami many times in the past, and towns in the area that subsist primarily on marine product industries have recovered each time. Despite this, according to the recent public opinion poll, approximately 50% of those residing in the area hope “to move to other locations” in the future. Additionally, since it has been decided that new housing will be constructed on the hilly lands above tsunami danger areas, those who intend to remain in the area can expect to wait another two to three years for house construction, and thus must continue to reside in temporary housing until then. Population levels have decreased in other affected cities, towns and villages along the Sanriku Coast, with most of the departures consisting of persons less than 30 years of age. Aggravating the problem in the depopulated region has been the percentage-wise increase in aged persons, and a shortfall of persons able to provide support for victims. Another shortfall has been in the availability of construction materials necessary for recovery efforts, primarily because of the massive amount of public works underway. The hard power required for the construction of roads, houses, railways, etc. is plentiful, but the soft power required for negotiation of lands or houses is drastically short. It may be difficult that the past life will be revived, but the reconstruction will be premature by the wisdom and the effort of people.

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Section 2
Disaster analysis

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Study on the development of the loss estimation method for urban flood in Korea

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Abstract

Flooding is a major type of disaster in Korea; urban flooding has especially become a serious issue as impermeable parts are increasing in urban areas. Local governments have established structural measures to reduce losses caused by urban floods; however, this can cause financial problems. Therefore, nonstructural measures are needed, and the basic information for the measures has to be clear. It is necessary to establish standards for loss estimation since prevention and recovery are a source of numerous expenditures in national finance. The United States, Japan, and Taiwan have representative methods for loss estimation based on their own databases related to loss information for critical disasters (e.g. earthquakes, storms, and floods). Korea also has some statistical tools – such as Multi-Dimensional Flood Damage Analysis – for national flood control economic analysis; however, there are no systematic loss-estimation tools, mainly because of a lack of available data. In this study, previous research and techniques were reviewed to find adequate tools and frameworks applicable to loss-estimation methods for urban flooding in Korea. The availability of databases related to urban flooding in Korea was then checked.
Keywords: flood, loss estimation, multi-dimensional flood damage analysis.

1 Introduction

In general, a disaster is a natural or man-made hazard resulting in an event of substantial impact that causes significant physical damage, destruction, or loss of life [1]. Furthermore, the Framework Act on the Management of Disasters and Safety [2] defines a disaster as any event that actually causes, or is likely to

WIT Transactions on The Built Environment, Vol 133, © 2013 WIT Press
www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/DMAN130051

cause, any harm to the lives, physical safety, and property of citizens and the state.

There are many kinds of natural disasters, including floods, typhoons, downpours, and tidal waves. Among them, flooding is the most commonly occurring natural disaster in Korea. The frequency and intensity of flooding is rapidly increasing; moreover, flood damage in urban areas has recently become an important issue. The Gangnam flood in July 2011 is a representative event that reflects current urban flooding in Korea.

To reduce flood damage, local governments have established structural and nonstructural measures; however, such measures have to be established based on specific information about expected damage and losses.

Various methods for loss estimation have been developed in Korea. However, they have not been effective in practice [3]. In addition, they do not consider urban systems such as basement structures and drain systems. Therefore, it is necessary to integrate the information that is consistent with damages caused by urban flooding and to develop loss-estimation methods for effective and efficient disaster management.

In this study, previous studies and tools used in other countries were reviewed to find the proper method for estimating loss as a result of urban flooding in Korea. The way to apply loss-estimation methods to urban flooding was then proposed, focusing on the availability of databases in Korea.

2 Loss estimation method

There are various models for loss estimation. HAZUS-MH, developed in the United States, is a representative method for natural disaster loss estimation. HAZUS-MH is a planning tool that estimates damage and losses resulting from multiple natural hazards (e.g. floods, earthquakes, hurricanes). This model produces disaster simulation results based on numerous databases for loss estimation, which includes information on the location and contents of buildings and facilities. It assesses population needs related to emergency management; it also allows users to compare results, including mitigation actions [4].

In addition, there is Taiwan's Haz-Taiwan system and Japan's Disaster Information System (DIS) for earthquake damage. Both have simulated results for earthquake scenarios with databases related to earthquake events. The results from the earthquake modules of both systems can be used to plan and stimulate efforts for seismic hazard mitigation, to prepare for emergency response, and to plan for recovery from an earthquake.

HAZUS-MH, Haz-Taiwan, and DIS have their own databases for operating their systems. The databases of HAZUS-MH in particular were collected and built in 1996 by the Federal Emergency Management Agency (FEMA) through the National Emergency Management Information System (NEMIS). HAZUS-MH can, therefore, evaluate losses by overlapping simulation results on those databases based on GIS.

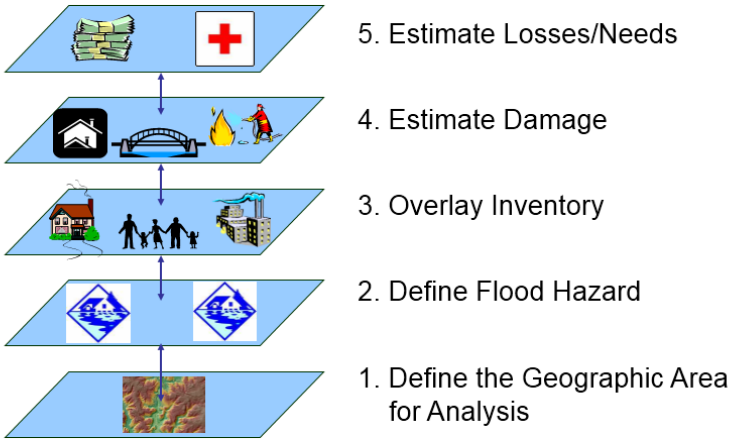

Figure 1: Schematic diagram of HAZUS-MH (USA) for loss estimation [4].

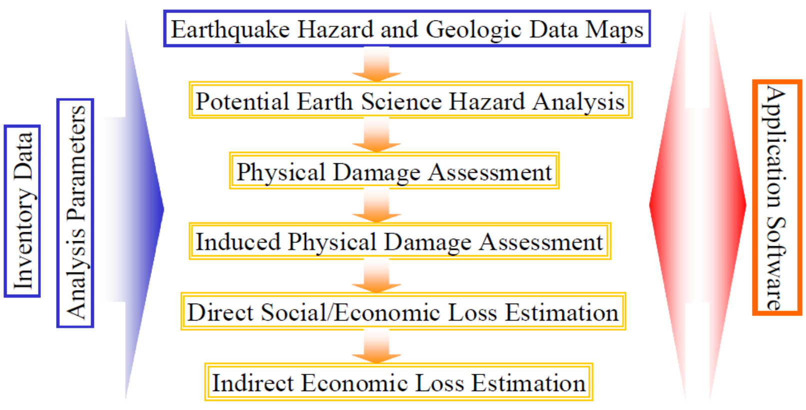

Figure 2: Framework of methodology in Haz-Taiwan [5].

In Korea, the Ministry of Construction and Transportation [6] suggested the Multi-Dimensional Flood Damage Analysis (MD-FDA) system in 2004 for flooding loss estimation. Previous loss-estimation methods relied on the inundation area–damage relationship (a linear model). MD-FDA calculates 100% losses by surveying general properties (buildings, contents in buildings, crops, business types, and assets) in the area. Loss expectation is then estimated according to inundation depth by applying the damage rate. This method can reflect regional characteristics because it uses the disaster annals of each region. In this model, however, it is necessary to prepare detailed flooding maps and recent statistical data for accurate loss estimation. In addition, extensive data has to be built in high spatial resolution, and the database is not combined with GIS.

3 Suggestion for the development of a loss estimation method for urban flood

The most important factor in developing a loss-estimation method is to establish databases, even though a proper module is an essential part. Accurate loss estimation should be based on specific databases.

In the cases of the United States, Japan, and Taiwan, the databases consist of basic facilities (e.g. banks, schools); essential facilities (e.g. police stations, fire stations); transportation; and lifelines (e.g. gas, water, electricity). The databases also include population, land use, and land value, only for loss estimation.

In Korea, however, the database is not sufficient for precise loss estimation. Thus, databases for loss estimation had to be collected from each organization or agency.

Recently, the National Disaster Management System (NDMS) was established to integrate and manage disaster information. This system aggregates 770 kinds of disaster information by networking related organizations and local governments [7].

Table 1: Database of NDMS.

Field	Classification
Prevention and Safety	Safety accident in water, accident location
Fire Service	Hazardous facilities, hazardous accident, fire, rescue and relief operation
Disaster Prevention	Disaster prevention facilities, supplies, damage, restoration, forecast of typhoon
Disaster Situation	Safety accidents, danger index

The NDMS contains diverse information; however, it is only general information, and it needs to be standardized and stereotyped for use in urban flooding loss estimation. Processing techniques for original data and an effective management system for loss estimation are also needed.

The suggested database for urban flooding would be divided into three parts: (1) demographic data, (2) economic and industry data, and (3) property data (as shown in Table 2). Then, appropriate evaluation modules or techniques have to be developed based on the database. The modules have to consider not only property losses, but also socioeconomic losses since indirect socioeconomic losses are an important part of the entire losses owing to urban flooding.

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Table 2: Suggestion of database for loss estimation of urban flood.

Field	Classification
Demographic Data	Population, households
Economic and Industry Data	Total floor area, farmland area, employee
Property Data	Building price, houseware price, crop price, estimated value of industry, deflator

4 Conclusion

For more effective disaster management, it is necessary to build a loss-estimation method for disaster damage. There are a few methods for loss estimation; there is, however, no method just for urban flooding. Such a method is needed to manage the risks posed by urban flooding since it has become a major social problem that causes major damages in Korea.

There are similar methods in the United States, Japan, and Taiwan, and they have their own systematic databases for evaluating damages and losses. In Korea, NDMS, operated by NEMA, collects disaster-related information for disaster-state management. It is, however, inappropriate for loss estimation since most of the data have just the general properties of disaster and damage.

In this study, the method for the development of loss estimation is suggested through research on similar methods and database systems. A systematic and specific database has to be collected and standardized. Evaluation modules or techniques then have to be developed considering available data.

This loss-estimation method can be used by insurers and reinsurers, government agencies, private businesses, the engineering community, and others. For example, government agencies can use loss-estimation results during the period immediately following a disaster to help prioritize the allocation of limited resources. It can also be used by emergency managers for exercises to enhance their response plans, by urban planners to identify high-risk areas to design land-use policies to help mitigate potential losses, and by utilities and public works departments to assess potential infrastructure damage for consideration in their capital improvement plans.

Thus, the database for loss estimation should be managed, and the loss-estimation system has to be established at the national level.

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Relationship of debris flows owing to climate change: Korea's case

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Abstract

The climate change drastically modifies the earth's environment and the landscape is easy to be altered by this global phenomenon. Transforming landscapes which lose their own stability usually results in forms of the ground movements such as landslides. Identifying landslide prone areas, mapping landslides, and evaluating expected risks to people, property, environment, and other resources are, therefore, important issues which are closely related to land use, engineering design work, and emergency planning in order to reduce the impacts by landslides. In this study, we examined the possibilities of identifying unstable areas where landslides would occur. These are based on the statistical evaluation of orientation data representing geomorphological characteristics of the ground surface. Practical applications to recent landslides which occurred in Korea showed the technology we proposed is well delineated the potential susceptibility of landslides before tragic events happened.
Keywords: climate change, precipitation, landslide, debris flow.

1 Introduction

The climate change is the gradual conversion of the current climate by natural and/or anthropogenic causes and drastically modifies the earth's environment and the landscape. Increasing awareness of the socio-economic consequence of the climate change and growing pressure of urbanization on the environment would attract more global attention on landslides disasters including debris flows than ever before. Unexpected precipitation and temperature caused by climate change will accelerate this awareness.

WIT Transactions on The Built Environment, Vol 133,
www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/DMAN130061

In this study, therefore, the status of the climate change observed in the world and Korea is firstly discussed. The circumstances of landslides including debris flows with the climate change is briefly described and a new approach using statistical evaluation of orientation data representing geomorphological characteristics of the ground surface is introduced. Finally, a relationship between consequences of the climate change and debris flows is illustrated.

2 Climate change and its impact

The climate change is the gradual conversion of the current climate by natural and/or anthropogenic causes. It leads the general climate difference including the Greenhouse effect based on the human activities and natural phenomena such as solar activity, shift of earth's axis, and volcanic eruption. More direct effect of the climate change is, however, caused by the human including deforestation, increase of the Greenhouse Gases like CO_2. This trend has become a global issue since the late 1980s.

The major causes of creating the Greenhouse effects are due to the high consumption of mineral and fossil fuels after the Industrial Revolution. The emission of Greenhouse Gases (GHG_S) like CFC_S, CH_4, N_2O and CO_2 is highly increased since the middle 18^{th} century (fig. 1). In 2010, the global averaged mixing ratios of the latter three fractions (CH_4, N_2O and CO_2) reached new highest points (WMO [1]).

Consequences of the climate change usually lead floods, heavy snow, and tsunamis, which are mainly caused by the temperature rise.

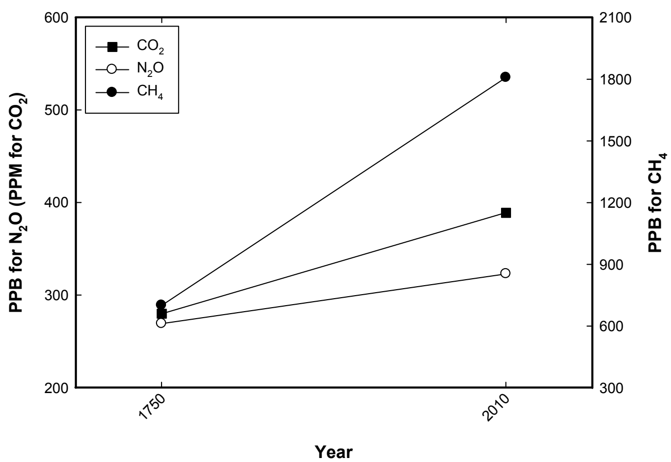

Figure 1: Global abundance and temporal variation of key Greenhouse Gases (Source: WMO [1]).

3 Trend of climate change in Korea

Effects of the climate change on Korea are relatively faster than any other country in the globe and their consequences have increased gradually (NIER [2]). The trend of the climate change observed in Korea is well described in temperature and precipitation.

The annual temperature between 1961 and 1990 increased 0.4°C compared to the value from the past 30 years (1931–1960, fig. 2). The annual precipitation, although it showed a fluctuated behavior, has an increasing tendency in the long term perspective (KMA [3]). For example, the annual precipitation of the last 10 years (1996–2005) is recorded as 1,485.7 mm, which is 10% higher than average precipitation value (fig. 2). The daily number of heavy rainfall (daily precipitation over 80 mm) is also noted as 28 days, which increased 8 days of the current record.

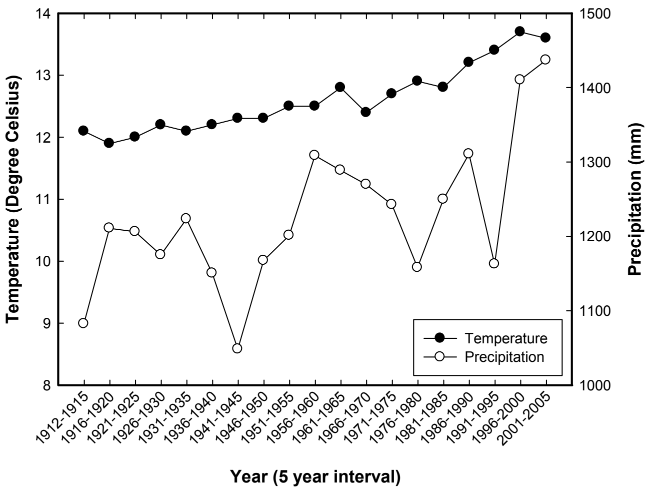

Figure 2: Variation of the annual temperature and precipitation from 1912 to 2005.

The results of the climate change have a strong relationship with water related disasters in Korea such as floods, drought, heavy snow, tsunami, and water-bloom (IPCC [4]). Particularly, the increasing rainfall intensity which is the consequence of decreasing rainfall days followed by the increasing precipitation may cause the frequency of torrential rainfall. This leads slope disasters such as debris flows, which are usually induced by heavy rainfall (fig. 3).

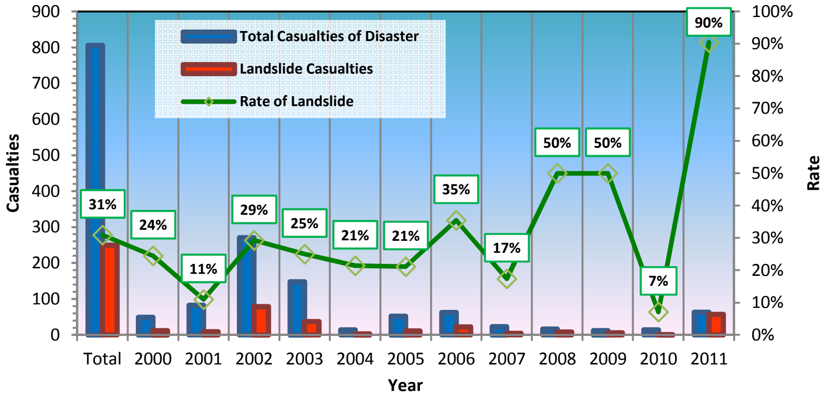

Figure 3: Total casualties of disaster, landslide and its rate, respectively.

4 Debris flow disasters and their consequences

Debris flows, one of the common landslide disasters, are frequently occurred in the world especially rainy season (June to September in Korea). Debris flows are made up of soil, rock, and water. Their flow characteristics depend on the water content, sediment size and/or sorting, and on the dynamic interaction between the solid and fluid phases. The modelling of such an interaction still remains a quite difficult task and the currently available computational models inevitably rely on simplifying assumptions (Pirulli and Sorbino [5]). Therefore, identifying landslide prone areas, mapping landslides, and evaluating expected risks to people, property, environment, and other resources are relatively difficult comparing other landslides disasters such as sliding, falling, etc. In order to reduce the impacts by debris flow, an approach identifying unstable areas where landslides would occur is proposed. It depends on the statistical evaluation of orientation data representing geomorphological characteristics of the ground surface.

4.1 Statistical evaluation of the orientation data

Quantifying the terrain is based on the orientation of planar surfaces that represent the terrain and can be calculated as unit vectors normal to the planar surfaces (Hobson [6]). Strength and dispersion of unit vectors can be used as an indicator of geomorphological features.

Based on the spherical distribution of directional and non-directional data it is shown that typical characteristics of spherical distribution are equivalent to the determination of eigenvalues and eigenvectors especially of a symmetric three by three matrix which comprises direction cosines (Watson [7]). Consider N points of unit mass, (l_i, m_i, n_i), where $i = 1,\ 2,\ \ldots,\ N$ and suppose that $\boldsymbol{u}$ is a true or preferred direction through the centre of the sphere, the moment of inertia I of the set of N points of unit observation data about $\boldsymbol{u}$ can be described as follows (Watson [7]):

$$I = N - \boldsymbol{u}'\boldsymbol{M}\boldsymbol{u} = N - \sum_{j=1}^{3}\sum_{\kappa=1}^{3} u_j M_{j\kappa} u_\kappa \quad (1)$$

where, $\boldsymbol{M}$ is an orientation matrix, a three by three matrix consisting sums of cross products of direction cosines of the unit mass, (l_i, m_i, n_i). It is given by:

$$\boldsymbol{M} = \begin{pmatrix} \sum l_i^2 & \sum l_i m_i & \sum l_i n_i \\ \sum m_i l_i & \sum m_i^2 & \sum m_i n_i \\ \sum n_i l_i & \sum n_i m_i & \sum n_i^2 \end{pmatrix} \quad (2)$$

The eigenvalues of $\boldsymbol{M}$ are calculated from roots of the characteristic equation, $\lambda_i (i = 1,\ 2,\ 3;\ \lambda_1 > \lambda_2 > \lambda_3)$, and corresponding vectors are the eigenvectors, $v_i (i = 1,\ 2,\ 3)$. Three eigenvalues are always positive and add to N while three eigenvectors are always perpendicular to each other (Watson [7]). A normalized form of the eigenvalues can be obtained divided by the number of unit observation points N:

$$S_j = \frac{\lambda_j}{N},\ j = 1,\ 2,\ 3 \quad (3)$$

The evaluation of eigenvalues is especially beneficial when large amounts of field data, either geological or geomorphological, containing the directional characteristic of materials are acquired and compared. Woodcock [8] noted that the eigenvalue analysis would illustrate a relationship between the change of fabric shape and associated strain progression, which Mark [9] provided similar results from till fabrics.

Landslide studies using the characteristics of eigenvalues have been recently developed by Guth [10], McKean and Roering [11], Kasai *et al.* [12]. After Cruden [13] first calculated the axes of cylindrical folds with the eigenvalue technique. They focused on the recognition of topographic information to identify landslide characteristics and their kinematics.

4.2 Overview of the study area in Umyeon Mountain in Korea

The debris flow in the study area at Umyeon Mountain, Seoul, Korea was initiated by heavy rainfall both antecedent and daily rainfall. Saturated ground moved like a flow and hit residences and vehicles under the slope (figs 4 and 5).

The main cause of debris flow in Umyeon Mountain area was rainfall, which classify into the two different ones based on the temporal variation. Firstly, the antecedent rainfall fell two weeks before the landslide event and is recorded as 463.0 mm. It fully saturated ground surface. Second, a heavy daily rainfall amounting 342.5 mm fell into the study area. It took about 74% of antecedent rainfall. The rainfall intensity of the first impacted landslide area was 68.5 mm/hr. Based on the rainfall history, debris flow occurred in the study area was initiated by the high intensity daily rainfall with the help of saturated ground by long-term antecedent rainfall.

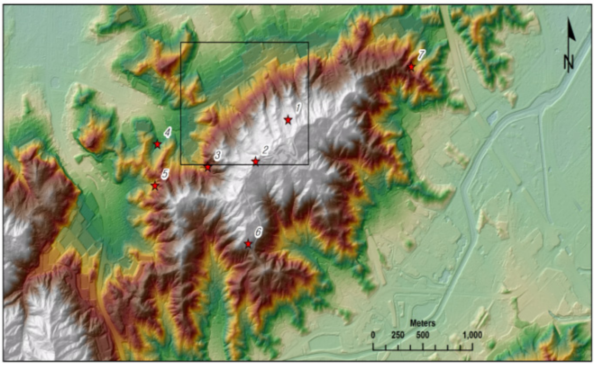

Figure 4: Overview of the study area and debris flow locations (1 and 2: apartments; 3: temple; 4 to 7: residential areas). Area outlined in the figure is shown in Figure 8.

Figure 5: Aerial view of the study area after the debris flow disasters (From locations 1 and 2 in Figure 4).

4.3 Results and discussions

Fig. 6 shows the spatial distribution obtained from planarity value over the study area and representative values are shown in fig. 7. Based on the planarity analysis shown in fig. 6, Low planarity values (less than 5) might represent a

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rough ground surface along the valley of the study area. Result also indicates main valleys, upper mountain areas near the army base, and steep slopes artificially created for residences as very rough areas (Planarity value is less than 3). This covers 5% of the total area (fig. 7). On the other hand, high values of the planarity (over 5) may represent smoother ground surfaces usually representing residence areas including roads and building. Some infrastructures show very high planarity values over 9 and take 2.3% of the study area (fig. 7).

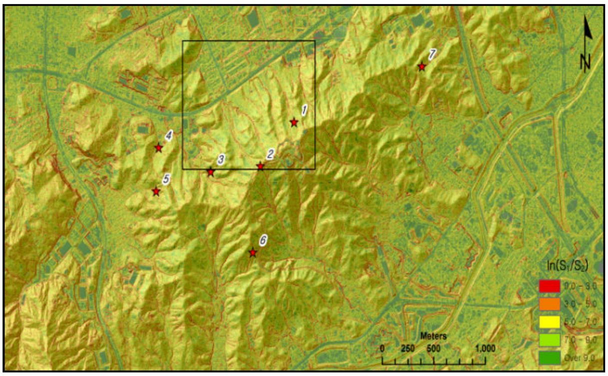

Figure 6: Spatial distribution of planarity values over the study area. Area outlined in the figure is shown in Figure 8.

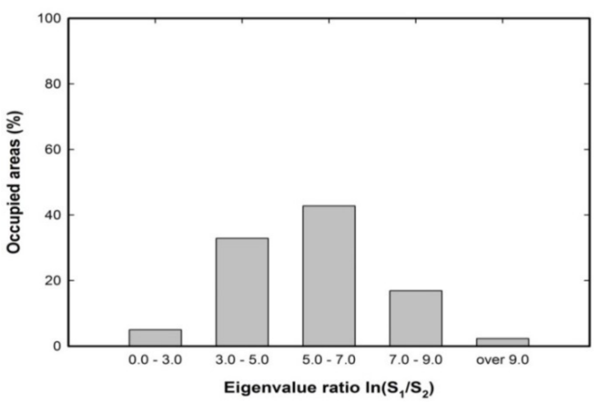

Figure 7: Evaluation of planarity values over the study area.

In this study, statistical evaluation of orientation data well described typical characteristics of geomorphological features on ground surface. These features also provide preliminary information to make the landslide inventory where any landslide related information is absent. Fig. 8 shows a partial distribution of the

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planarity value over the study area, which concentrated on the specific location where the debris flow occurred in 2011. The propagation of the landslide, from initiation to deposition, is relatively wide, it is, therefore, difficult to delineate the exact boundary of the impact due to landslide by using conventional methods.

As shown in fig. 8, a proposed approach based on the analysis of geomorphological features can define the location and boundary of landslide prone areas and may contribute to reduce loss of lives and properties by identifying the movement direction and dispersing border of the future landslides.

Spatial distribution of landslide features would distinguish between stable and unstable domains of the study area and can be used as fundamental elements to achieve landslide hazard assessments with high accuracy.

Figure 8: Distribution of the planarity value and boundary of debris flow occurred in 2011.

5 Relationship between debris flow and climate change

Increases of temperature and precipitation, which are representative indicators of the climate change may affect the initiation of landslides especially flow type slope disasters such as debris flows. The strong correlation between consequences of the climate change and landslides suggests two hypotheses. Firstly, increasing temperature plays an important role in retreating and melting glacier on high mountain areas such as the Himalayas and Alps. Melting water infiltrates into the slopes and decreases the effective stress of soils, which leads to slope failures.

Increased precipitation, whether it is caused by the increased temperature or other factors, also accelerates the frequency of landslide events. Water content within the ground (about one m deep from the ground surface), one of the main causal factors initiating landslides, is identified to gradually increase during summer season. It is, therefore, easy to activate the landslides even in a short period of rainfall.

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Figure 9 well illustrates a relationship between precipitation and landslide events in Korea. The fluctuation of precipitation during 2002 to 2011 indicates relatively upper points in 2002, 2003, 2006, and 2011. These years were reported that high casualties due to landslides. The general trend of temperature during the same period also shows a consistent behavior what precipitation has.

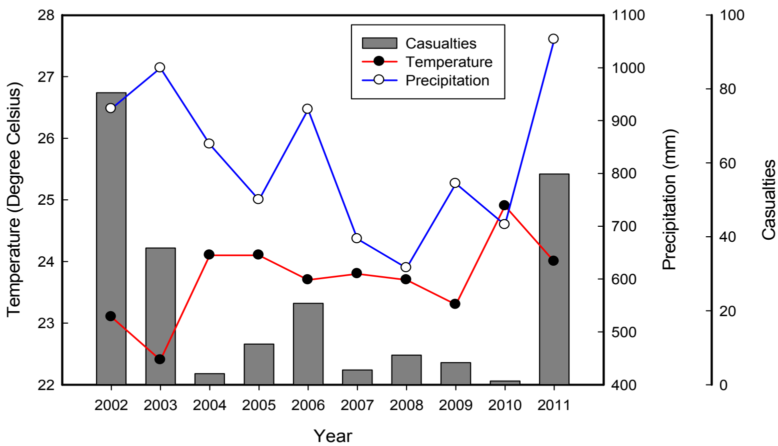

Figure 9: Two key factors of the climate change and casualties of landslide in Korea showing a general trend during 2002-2011.

The climate change may impact all of the hydro-mechanical processes which lead to destabilizing slopes (Laloui *et al.* [14]). Understanding the pattern of the climate change and relating it to the landslide triggering factors will help to estimate the future landslides and reduce the unnecessary casualties and property damages. The advanced methodologies such as remote sensing technologies and real-time monitoring systems will also strengthen the ability to recognize the relationship between them.

6 Conclusions

In this study, we have delineated consequences of climate change and its impact on debris flows, a common landslide in Korea especially summer season. A new approach showing distinct characteristics of geomorphological features on the ground surface is proposed. It provides a guideline between stable and unstable domains of the study area. More physical investigations on specific values which characterize those domains are, however, needed before considering it as a significant parameter in the landslide hazard assessment.

Considering a future tendency of the climate change and its consequences such as modified temperature and precipitation patterns, landslide events will increase and it is the time to develop more reliable technologies to understand physical mechanisms and monitor their behaviors.

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Site-specific soil microzonation for hazard resistant site and land use planning

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Abstract

Over the years, most of the urban complexes in India have undergone a phenomenal growth for various reasons and so has their vulnerability towards different hazards. Microzonation is thus a principal component of pre disaster mitigation efforts. Unless a detailed plot level microzonation is carried out for the city, it is not possible to prescribe detailed development guidelines and planning norms that will take into consideration the vulnerability of that land.

The methodology adopted here is to analyze the results of field reconnaissance surveys and soil borehole details and soil topography surveys, report on the very preliminary stages of the planning of towns/townships /institutional campuses and compare them against the priority index of various types of buildings that these sites constitute in order to have the following:

1. To provide the most appropriate soil conditions for the lifeline structures.
2. To prevent the project from decelerating in doing the above.
3. To reduce the negative effects of defunct urban planning in India because of outdated and ineffective development control regulations.
4. To facilitate the process of microzonation of the cities as a whole.
5. To facilitate strategic long term planning and to add to the pre-disaster mitigation efforts.
6. To help to reduce to a minimum the effects of construction on soil.

The urban planning framework in India has disappointingly not kept pace with the growth of cities, nor with the various changes that have come about in the way that planning is understood. The procedure that the research is trying to accomplish shall help to facilitate disaster mitigation efforts in India. The process involves more analytical work of the reports which is on general reports available for all major projects like strategic long term plans for the towns/townships/institutional campuses. Therefore, there shall not be much of a fiscal issue in doing so. The ultimate goal of the research is to define the

WIT Transactions on The Built Environment, Vol 133,
www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/DMAN130071

principles of site specific microzonation and account the role of an architect/ planner in contributing towards hazard mitigation efforts and strategies.
Keywords: geotechnical, seismic, reconnaissance, microzonation, priority index, architecture, urban planning, townships.

1 An overview

In India, growth of cities is managed by Master Development Plans, usually revised every 10 years. Typically, they determine the city's structural road network, land use zoning pattern, and development control regulations. Being regulatory and policy-oriented in nature, Master Development Plans are often not implemented. Most cities have outdated plans that do not respond to the demands of the real estate market.

Building regulations are intended to ensure the safety of buildings. However, the current development regulation system is irrational, complex, and ineffective—leading to abysmally low levels of compliance as substantial development happens outside the ambit of regulated development. This creates unsafe living conditions and increases vulnerability. Rationalizing and simplifying development control regulations and effective enforcement will improve compliance to regulations.

Over the years, most of the urban complexes in India have undergone a phenomenal growth for various socioeconomic reasons. Thus, the vulnerability of our cities for different hazards has also increased considerably, necessitating a proper hazard evaluation, particularly of the high population density urban center's laying in higher seismic zones. Seismic microzonation, thus, constitutes one of the principal components of pre-disaster mitigation effort.

2 Origination

By and large, the traditional planning framework has not been able to address holistically the issues related to the growth of cities. This is primarily because it has subscribed solely to the "physical growth alone" perspective. Hence, it has not been able to address issues related to safety and disaster mitigation. Factoring in the cost of disaster mitigation in urban and infrastructure planning in vulnerable areas is necessary to reduce the vulnerability of urban.

Areas. A paradigm shift from response to mitigation is urgently needed. These changes should include mitigation into the overall planning context. In a disaster, the survival of social and physical infrastructure systems is critical to the survival of the citizens. Urban infrastructure both physical and social is not designed to withstand hazards in most cities.

The methodology, now broadly accepted, follows a multidisciplinary hierarchical approach, where the sequence of studies aims to generate parameters for source, travel path, ground characteristics and vulnerability, and draw inputs from the disciplines of geology, geophysics, seismology, geotechnical engineering, engineering and seismology.

The most important tool that is used for incorporating hazard consideration in land use zoning is microzonation. Unless a plot level microzonation is carried out for the city, it is not possible to prescribe detailed development guidelines and planning norms that will be taken into consideration the vulnerability of that land.

The local soil conditions have a profound influence on ground response during earthquakes. The recent destructive earthquakes have again demonstrated that the topography, nature of the bedrock and nature and geometry of the depositional soils are the primary factors that influence local modifications to the underlying motion. Based on the results of the geophysical as well as geotechnical investigations and laboratory testing, one or more idealized soil profiles must be selected for the site of interest.

3 Methodology

The methodology adopted here is to analyze the results of field reconnaissance survey, soil borehole details and soil topography surveys report in the very preliminary stages of planning of town/township/institutional campuses and compare it against the priority index of various types of building that these sites will eventually constitute, in order to have the following:

1. To provide the most appropriate soil conditions to the lifeline structures.
2. To reduce the negative effects of the defunct urban planning in India because of outdated and ineffective development control regulations.
3. To facilitate the process of microzonation of the cities.
4. To facilitate strategic long term planning and to add to the pre disaster mitigation efforts.
5. Help to reduce the effects of construction on soil to a minimum.

4 Follow through (a sample implementation): soil microzonation of Arvind Residential Township, Ahmadabad, India

4.1 Introduction to the project

Project name: Arvind Residential Township
Ownership: Arvind mills and textiles ltd.
Projected cost: land cost of 250 cr, with total project cost, for 9 million sq ft at 2000 per square feet, would be app. 1800-2000 cr
Adjacent land use: Arvind factory, Arvind mills, small industrial developments, rest agricultural.
Political authority: Ahmadabad Urban Development Authority.

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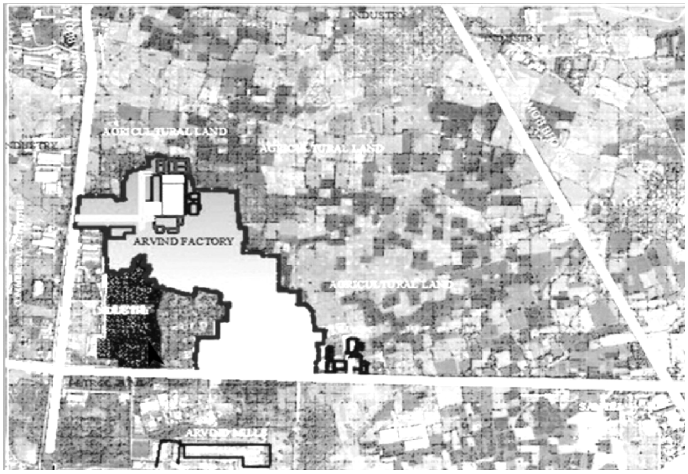

Figure 1: Key plan.

4.2 Project requirements

Low Income Housing: 1 RK, 1 BHK, 1 BHK Study.
Affordable: 2BHK S, 2 BHK M, 2 BHK L, 3 BHK S, 3 BHK L.
Executive Floors, Row House (executive units), Twin Bungalows (premium units), Villas (presidential units).
Amenities: School, Healthcare centre, Clubhouse, Community Centre, Retail Area.

4.3 Priority index values by Ahmadabad Urban Development Authority

With regard to land use zoning different types of buildings and utility services may be grouped under three priorities as indicated below:
Priority 1: Defense installation, industries, public utilities like hospitals, electricity installations, water supply, telephone exchange, aerodromes, railway stations, commercial centers, libraries, other building or installations with contents of high economic value.
Priority 2: Public institutions, Government offices, universities and residential areas.
Priority 3: Parks and play grounds, woodlands, gardens.

4.4 Site details

Plot Area: 134 Acres sq.m.
 Limiting condition for development (bylaws).
>> FSI applicable on the land is 1.2.
>> Max. Ground Coverage permitted is 40%.
>> Plot area reserved for crossover road 10%.
>> Plot area reserved for civic amenities 5%.
>> Open Space: Minimum 5%.

Seismic Details:
Seismic zone: zone 3.
Intensity VI-VIII.
Microzone: Ahmedabad micro zone D.
Accelerations from fault lines:
1. From Cambay fault: 5.6.
2. From Kutch fault: 7.1.
History: the present structures indicate the effects of the 2001 earthquake as intensity VII.

4.5 General investigation of seismicity and soil conditions at Ahmedabad

Ahmadabad and surrounding areas are on the Sabarmati alluvial belt. The city is founded over deep deposits of cohesion less soils. The random distribution of the damage has been recorded from a number of localities scattered on the left and right banks of Sabarmati River. It is evident from the site investigation that the soil is loose up to 3 m depth and exhibits a relatively medium dense condition from 3 m to 15 m depths. The soil is silty sand throughout with a slight variation in the density from shallow to deeper depth. The natural moisture content varies from 8.51% at surface to 10.08% at 15 m depth with a degree of saturation ranging from 38.5% to 51.8%.

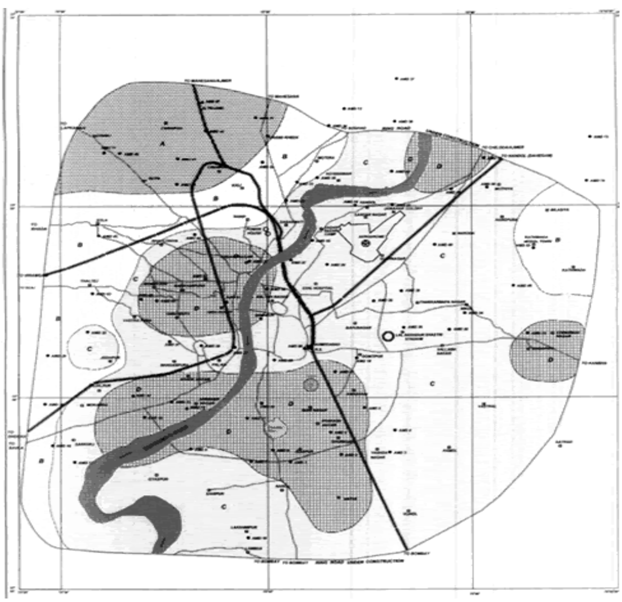

Figure 2: Preliminary seismic hazard map, 1st level of microzonation of Ahmedabad City.

The agglomeration is located in the Cambay graben that is occupied by 400 m thick Quaternary sediments. Though falling in Zone III of the Seismic Zoning Map of India, the city has been severely jolted by the distant Kutch earthquakes of 1819 and 2001. In case of the latter, some 120 taller structures collapsed, from which 718 people lost their lives. This vulnerability of the urban complex under the influence of long period seismic waves, as well as its importance as a rapidly growing commercial centre has necessitated a deeper understanding of the site characteristics on seismic excitation.

Three soil layers, identified based on resistivity survey are – loose topsoil, humid soil, and water saturated (bottom layer). P-wave velocity, as obtained from Hammer Seismic survey, for the three soil layers are – 200–300m/s for topsoil (thickness < 2m), 400 to 600m/s for the middle humid soil (thickness about 10m) and 600- 1500m/s for the bottom layers lying below 12m. Based on the inputs from the present multi-disciplinary studies, the city of Ahmedabad has been demarcated into four seismic hazards micro zones A, B, C, and D.

Microzone D is anticipated to be the most hazardous while micro zone A is the least hazardous zone

GSI suggested carrying out of site-specific studies at each site during the design stage of high-rise buildings, in order to more accurately evaluate the site-specific conditions by planners, designers, and Ahmedabad Urban Development Authority.

4.6 Site reconnaissance survey

A detailed survey of the existing structures on the site was undertaken and also the surface samples were analyzed for basic soil type identification.

4.6.1 Historical significance

Rainfall records for the site: two months of heavy rainfall. Filling activities at the site: yes, sanitary filling, factory waste and frequent soil deposition.
Any previous developments: No.

Presence of fill areas

Type of fill (material): Stones, dry leaves, waste soil.
Extent of spread: 45 m.
Location on the site: near to the factory.
Depth of fill: 2.5 - 4 m approx.

4.6.2 Structure in the site

Location: west, along the main road.
Purpose: Arvind factory.
Area: 7% Existing condition.
>> Cracks: hairline cracks.
>> Surface condition: exposed brick, dilapidated.
>> Ground condition: no vegetation maintained.
>> Corrosion /damp: yes.
>> Condition of doors and windows: barely maintained.

>> Electrical: self generation via on site power plant.
>> Water supply: do.

4.6.3 Structure along the site

Location: left and right side of the site.
Purpose: industrial unit.
Existing condition.
>> Cracks: hairline cracks.
>> Surface condition: fair, due to newer construction.
>> Ground condition: no vegetation around.
>> Corrosion /damp: along the pipelines.
>> Connection to the project: no.
>> Services: 1. Drainage: same as the factory.
2. Electrical: do.
3. Water supply: do.

4.7 Soil test data for the site

Soil test data for the site is shown in Figure 3.

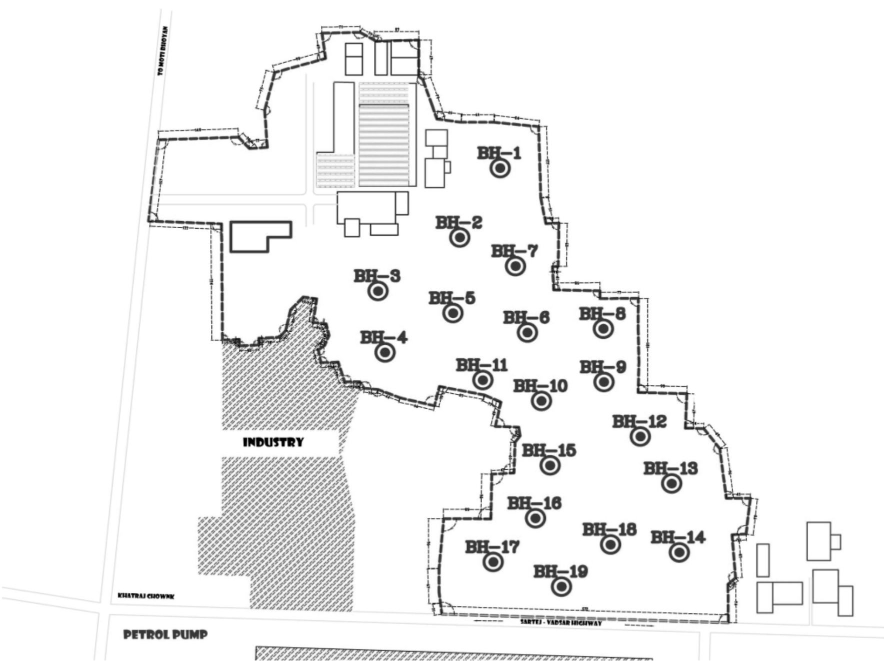

Figure 3: Soil test data for the site.

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4.8 Site zonation according to soil test result and field reconnaissance survey

Site zonation according to the soil test result and field reconnaissance survey is shown in Figure 4.

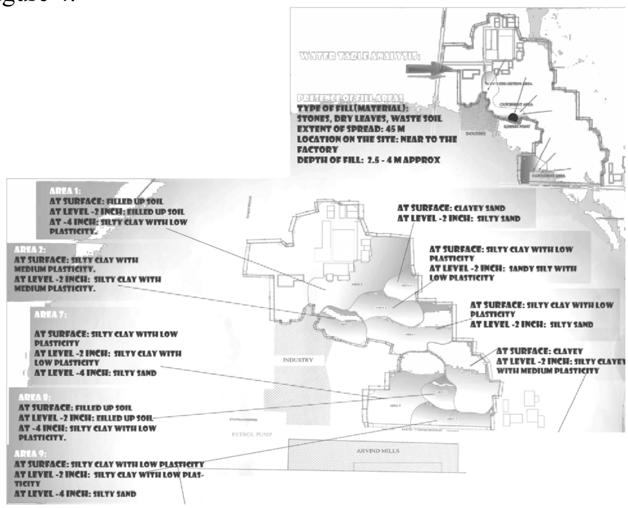

Figure 4: Site zonation according to soil test result and field reconnaissance survey.

4.9 Architectural zoning inferences using the soil analysis and priority index values

Soil specific site plan zoning is shown in Figure 5.

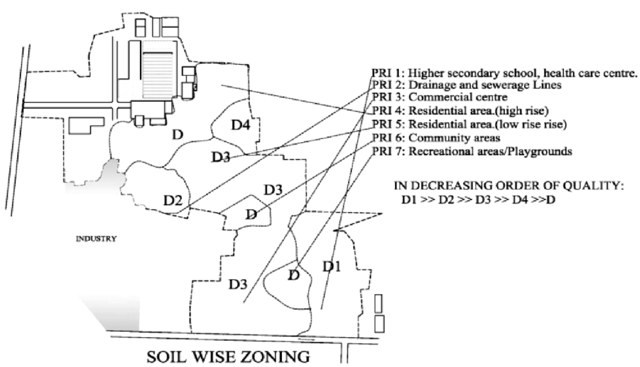

Figure 5: Soil specific site plan zoning.

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Therefore we achieve a zonation based on soil reports, field reconnaissance survey and prioritization

4.10 Summing up of the steps

STEP 1: Field Recognizance Survey
STEP 2: Document and Analysis According To Soil Properties
STEP 3: Studying the Bore Hole Detail Section and Analyzing according to the mechanical properties of the Soil sample.
STEP 4: Prioritize the structures in your design according to their priority index.
STEP 5: Compare the result of step 3 and step 4 in directly propositional manner.

4.11 Details and analysis of the proposed procedure for soil wise zoning

Priority index in Indian building byelaws esp. Ahmadabad Urban Development Authority bye laws categorize the various land uses and type of structure according to their function in decreasing order of Priority in terms of safety and cost analysis.

Field Reconnaissance is an important element in the procedure defined hereby. Subsequent to a review of the available data disclosed by the research described, and prior to the drilling of any exploratory holes, the proposed site should be thoroughly inspected by a geologist and/or a soils engineer. The primary objective of the reconnaissance is to obtain as much surface and subsurface information as possible without drilling exploratory holes or excavating test pits. The types of information to be obtained include accessibility of the site, topography, soil profile, bedrock litho logy and structure, and surface and sub- surface drainage. In determining soil and bedrock information, maximum use should be made of exposures occurring both naturally and as a result of construction.

Consolidation and settlement is one such area that needs attention. In saturated clay when the external pressure is provided, pressure is initially taken by the water then transferred to soil structure. Problematic soils like expansive or collapsible soil may cause high differential movements in structure as a result of settlements. Collapsible soil of value small than 1.0 do not create any problem while those having value more than 20 cause very severe problem. Sanitary landfills too have very less bearing capacity.

The soil activity of a place should become one of the parameter of soil zoning (microzoning of the site). In any moderate or large project having multi land use, the land use which comes under lifelines structure shall be located at a place where the soil is of best quality because of two reasons:

A. The life lines structures should be hazard resistant is all aspects, soil liquefaction, soil seismic activity etc, all should be taken care of.

B. If the soil zoning is not done, maybe in later phases of the project geotechnical reinforcement needs to be done to rectify this neglected aspect in initial stages of design, which in turn would require money and time to scrutinize the problem.

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Soil tests reports which basically comprises borehole sections and details, is required here to be analyzed by the experts and coordinated with the planner/architect so that he can examine them against the priority index value of the proposed structure and design/plan it accordingly.

The myth that the mitigation costs are high prevails over any decision of including such measures in major projects. The reality is that mitigation measures cost can be included for an additional cost of only 2% to 3%. As of today most construction agencies do not consider disaster risk mitigation. It is rather a fact that the problem starts from the planning phase itself. If mitigation measures are taken into consideration it saves the project from getting scrutinized because of the problem that might occur later, thereby also saving the project from wasting money on the problems that arise therein. For example, suppose in a township project, a Lifeline structure (Hospital or a School), because of negligence in terms of hazard mitigation in the planning level, is placed on an expansive soil and while the foundation for the same is done it is found that geotechnical investigation needs to be done to rectify the problem, it will require more energy as well as scrutinize the project thereby increasing the costs tremendously. It thus proves that only if few small steps were added to the planning processes, it would have saved it from the losses. 2% - 3% cost which goes for mitigation measures is thus negligible and in some cases acts as cost effective too. Township integrated development is a newfangled way of development. Researches' have proved them to be useful and sensitive to both local and urban level of environment. If soil sensitive analysis is done in pre-planning stage of all of these upcoming townships it shall help the agencies involved in microzonation act and also ensure a safer environment

Acknowledgements

The present paper would not have been possible without constant help and support from Gensler, Bangalore Office, Birla Institute of Technology, Mersa, India; Indian Institute of Technology, Gandhinagar, India; National Information Centre for Earthquake Engineering, IIT Kanpur, India and Indian Seismological Institute, Gandhinagar, India. Specifically, I would like to thank the following individuals:

Dr. Sudhir K Jain, Director IIT Gandhinagar; Chairperson NICEE, IIT Kanpur.
Dr Amit Prashant, Professor, Civil Engineering, IIT Gandhinagar.
Dr Javed Malik, Professor, Civil Engineering, IIT Gandhinagar.
Vaibhav Shivare, Project Manager, Tata Housing, Gurgaon.
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Identification of microorganisms promoting debris flows caused by eutrophication of hillside ecosystems

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Abstract

A large number of hazards all over the world are caused by debris flows and landslides, and this is especially so every year in Japan. In June 1999, August 2005, July 2010 in the Hiroshima prefecture, and in July 2009 in the Yamaguchi prefecture, there were many hazardous occurrences of large debris flows and landslides owing to torrential downpours. Through the survey made of these hazards it seems that there are two main factors causing the increase of hazards and consequent risks. The two main factors are the contiguity of urbanization of hillsides and the bio-deterioration of mechanical structures of the ground on hillsides caused by eutrophication (nutrient enrichment). The eutrophication promotes microbial activities that deteriorate the mechanical structures of the ground on the hillside slopes. Microorganisms promote the weathering of rocks to soils and cause aggregation of soils by their metabolites. Aggregated structures of soils wet the ground to decrease the resistance to landslides. It seems that microbial activities accelerate the occurrence of debris flows. The eutrophication causes the bio-weathering of the ground. This contribution describes the investigation of the relationships between debris flows and microorganisms activated by eutrophication of hillside ecosystems in order to construct a precise model of occurrence of debris flows. The model may be able to mitigate the hazards. Identification of microorganisms in the subsurface of the hillside was obtained by using a molecular biological technique. It was observed that the values of the eutrophication index (TC and TN) are high in the weathered rock and low in the unweathered rock. Thus weathering of rock can

WIT Transactions on The Built Environment, Vol 133,
www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/DMAN130081

cause the increase of the risk due geological hazards of landslides and debris flows.
Keywords: debris flow, landslide, microorganisms, eutrophication of ground, bio-deterioration of ground, molecular biological technique, DNA, Denaturing Gradient Gel Electrophoresis, DGGE, natural hazard, ecological systems, mechanical deterioration of ground, aggregated structure of soils, weathering.

1 Introduction

A large number of hazards all over the world are caused by debris flows and landslides, and this is especially so every year in Japan. In June 1999, August 2005, July 2010 in the Hiroshima prefecture, and in July 2009 in the Yamaguchi prefecture, there were many hazardous occurrences of large debris flows and landslides owing to torrential downpours. Through the survey made of these hazards it seems that there are two main factors causing the increase of hazards and consequent risks. The one factor is the contiguity of urbanization of hillsides and streams. The other factor is the bio-deterioration of mechanical structures of the ground on hillsides caused by eutrophication (nutrient enrichment) originating in the transition of the ecological systems on the hillsides. These two factors increase the hazards of debris flows several times over. The eutrophication promotes microbial activities that deteriorate the mechanical structures of the ground on the hillside slopes. Microorganisms promote the weathering of rocks to soils and cause aggregation of soils by their metabolites. Aggregated structures of soils wet the ground to decrease the resistance to landslides. It seems that microbial activities accelerate the occurrence of debris flows. This contribution describes the investigation of the relationships between debris flows and microorganisms activated by eutrophication of hillside ecosystems in order to construct a precise scenario model of occurrence of debris flows. The precise scenario model may be able to mitigate the hazards. Identification of microorganisms in the subsurface of the hillside was obtained by using a molecular biological technique.

Historically, a microbial community was investigated by culture-dependent methods. However this way was limited to only identifying isolated strains growing on specific nutrient media. So these data couldn't show exactly the composition of microbial community. Recently, culture-independent approaches have been used increasingly to determine the composition of complex microbial communities. These procedures have enabled the simultaneous characterisation of whole ecosystems and the identification of many species from these sources. The shift from culture-dependent assessment to culture-independent analysis has led to a revolution in microbial ecology. These techniques provide a more sensitive and rapid method than conventional culture dependent analysis with the major benefit of detecting microorganisms which are difficult to culture or uncultivable. Unfortunately, while such approaches possess numerous advantages over culture-based methods, there can still be some limitations. A number of key factors to consider when employing a culture-independent approach are described below. Culture-independent assessment most frequently relies on the analysis of nucleic acids isolated from an entire microbial population. DNA is the focus of analysis in the majority of such studies and provides information with respect to the bacterial diversity and over all microbial history of the environment in question.

From the Denaturing Gradient Gel Electrophoresis (DGGE) analysis it was found that there are many microorganisms in the soft slope composed of the weathered rocks and are not many in the unweathered hard slope composed of weathered rocks. Also, it was observed that the values of the eutrophication index (TC and TN) are high in the soft slope and low in the hard slope. Thus the weathering promoted by eutrophication of hillside ecosystems can cause the increase of the risk due geological hazards of landslides and debris flows.

2 Investigation on bio-deterioration in hillsides slopes

2.1 Investigation sites

The filed investigation on bio-deterioration caused by the eutrophication in the hillsides slopes was conducted in the two sites of hillside slopes in Gokurakuji Hillside near Hiroshima Institute of Technology. The one site is composed of unweathered rock. The other is composed of weathered rock. The investigation subjects are the DGGE analysis, the nutrient (Total Carbon (TN) test and the strength test.

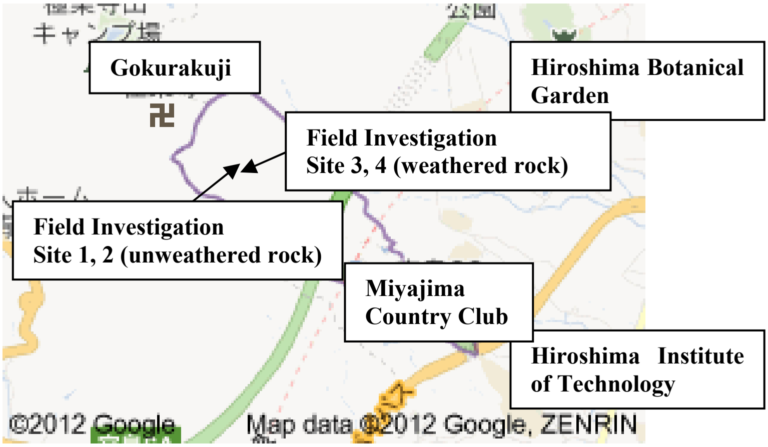

Figure 1: Field investigation sites in Gokurakuji hillside.

2.2 DNA extraction

The rock samples were crushed to pieces with a hammer. 0.5g rock powder was put into a micro centrifuge tube, and 500 µl of Milli-Q water was added. The micro centrifuge tube was vortexed for 5 min. After centrifugation at 12000 rpm for 5 min, the supernatant was transferred to new micro centrifuge tube with

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200 mg of skim milk. After vortexing, microbial DNA was isolated from a mixed solution using an ISOIL for Beads Beating Kit (Nippon Gene, Toyama, Japan), according to the manufacturer's instructions.

2.3 PCR-DGGE analysis

For the DGGE analysis of bacterial communities, the universal bacterial PCR primer set for the 16S rRNA V3 region [341F: 5'-CCTACGGGAGGCAGCAG-3' (*Escherichia coli* positions 341 to 357) and 907R: 5'-CCGTCAATTCMTTTRAGTTT-3' (*E. coli* positions 907 to 926)] was used. The341F primer contained a GC clamp sequence at its 5'end: CGCCCGCCGCGCGCGGCGGGCGGGGCGGGGGCACGGGGGG. Each PCR reaction mixture (50 ml) consisted of 1 μl DNA (approximately10 ng), 5 μl ExTaq buffer (Takara Bio, Siga, Japan), 0.25 mMeach deoxynucleoside triphosphate (Takara Bio), 25 p mol of each primer, and 0.5 units of Ex Taq DNA polymerase (Takara Bio). The amplification program was as follows: an initial denaturing step at 95°C for 5 min, followed by 94°C for 1 min, 64°C for 1 min, and72°C for 3 min. The annealing temperature was subsequently decreased by 1°C/cycle until it reached 56°C, and the annealing temperature of the last 2 cycles was 55°C. The final extension step was 72°C for 10 min.

The D Code system for DGGE (Bio-Rad, Hercules, CA, USA) was used for the bacterial DGGE analysis. For the bacterial samples, 8% gradient poly-acryl amide gels with a denaturing gradient ranging from 30–60% were produced; a 100% denaturant corresponds to 7 M urea and 40% formamide. Electrophoresis was performed at 150 V at 60°C for 6h. After electrophoresis, the gels were stained for 30 min with SYBR Gold (Molecular Probes, Eugene, OR, USA), and the gel image was photographed using Molecular Imager FX (Bio-Rad, Hercules, CA, USA).

2.4 Nutrient test

Total nitrogen (TN) by using C-N analyser was conducted for the unweathered rock and the weathered rock.

2.5 Strength test

The strength test was conducted for the unweathered and the weathered rock by using the Equotip Rebound Hardness Tester and Yamanaka-type Soil Hardness Tester.

3 Results

3.1 PCR-DGGE analysis

The dominant bacterial population concerning of debris flow was investigated by PCR-DGGE, using universal primers, which amplified the V3 region of the 16s rDNA. Results of PCR-DGGE profiles are shown in Figure 2. The bands were considered to represent taxonomical units close to the species level in PCR-DGGE analysis because each of them constitutes a unique DNA-sequence type, which in turn corresponds to a discrete bacterial population. As indicated in Figure 2, the banding patterns of lanes 1–2 differ from those of lanes 3–4. This result shows that the composition of microbial community is different between the unweathered rock and the weathered rock. To clarify the composition of microbial community, clone library analysis and identification of microorganisms are being carried out.

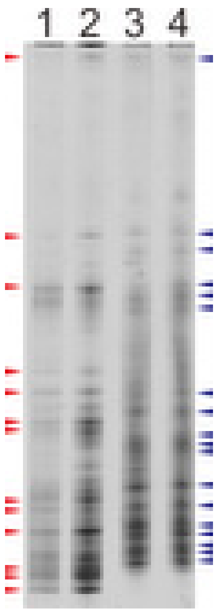

Figure 2: DGGE profile of extracted DNA.

Lanes 1–2: unweathered rock (hard rock); Lanes 3–4: weathered rock (soft rock). The triangles show represented band of DNA. The red triangles show represented the bands of lanes 1 and 2. The blue ones show the bands of lanes 3 and 4.

3.2 Nutrient test

The results of nutrient test are shown in Table 1.

Table 1: Results of nutrient test.

Investigation Site No.	Total Carbon (%)	Total Nitrogen (%)	Remark
1, 2	0.55	0.05	Unweathered rock
3, 4	2.18	0.21	Weathered rock

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3.3 Strength test

The results of the strength test are shown in table 2.

Table 2: Results of strength test.

Investigation Site No.	Ecuotip Rebound Hardness Tester (MPa)	Yamanaka Type Soil Hardness Tester (MPa)	Remark
1, 2	51.25	50.67	Unweathered rock
3, 4	0.97	0.95	Weathered rock

4 Conclusions

Through the results of the investigation on weathering promoted by eutrophication, it may be seen that where many kinds of microorganisms are found, the stability of ground formation is small and there are dangers of occurrence of debris flows. Examinations of total carbon and total nitrogen in the natural hillsides show a similar pattern. It may be well to create a "hazard map" using levels of total carbon (TC) and total nitrogen (TN) in close-to-the-surface samples to forecast future landslides causing debris flows.

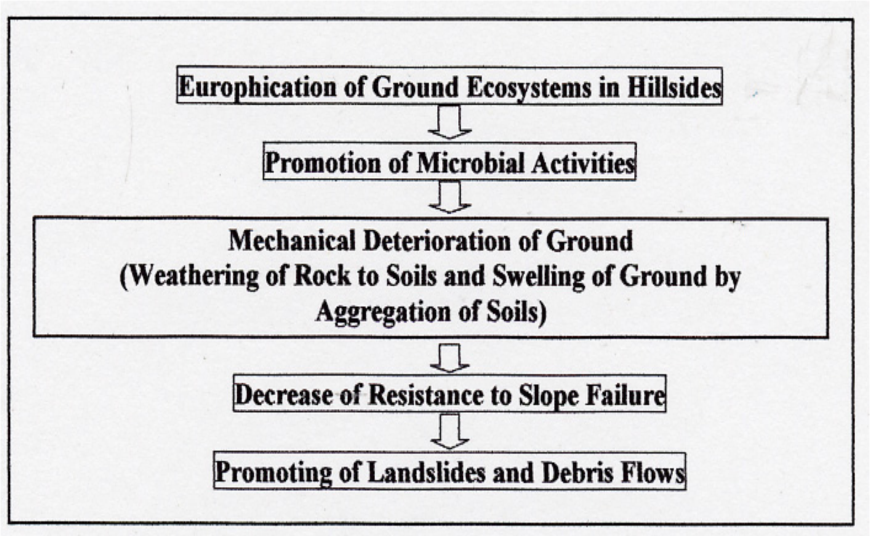

Figure 3: Scenario model of debris flow promoted by mechanical bio-deterioration of ground due to eutrophication of hillside ecosystems

The results of PCR-DGGE analysis show that the compositions of microbial community are different between the unweathered rock and the weathered rock.

Now, we are carrying out the analysis of the existence ration of microorganisms and the identification of microorganisms. We expect that these data will clarify the microorganisms concerning the rock weathering.

This paper is the first attempt to examine the DNA of microorganisms to promote debris flows due to eutrophication of the hillside ecosystems. The continuation of the research may bring a useful technique to make a precise scenario model of debris flows to avoid the risk of the hazards of the debris flows.

At this time, the microbial community was analysed by bacterial primer sets. This data only clarifies a part of complicated microbial community. If we want to know exactly the composition of microbial community, we have to use the various primer sets (ex. fungi, archaea and so on).

Acknowledgement

This work was supported by JSPS KAKENHI (Grant Number 23310129).

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Section 3
Emergency preparedness

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A framework for organisational operational response and strategic decision making for long term flood preparedness in urban areas

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Abstract

Recent years have seen flooding emerge as a significant risk facing United Kingdom (UK) businesses. This paper presents an overview of a framework aimed at improving such organisations' response to and preparedness for floods in urban areas, reducing the disruption and economic loss associated with flooding, and strengthening the flood resilience of the wider economy and society. To achieve these aims an understanding will be gained of business continuity processes and how private and public sector organisations behave and interact in the immediate aftermath of floods. Based on this understanding, agent based modelling and simulation will be used to identify factors which influence organisations' behaviours to flood response and preparedness, and thus determine ways of improving business continuity. Economic analyses will establish the local impacts of flooding in a range of UK urban areas and the cascading effects to the wider economy. Iterations of agent based simulations will enable analyses of how changes in behaviour could influence these impacts and better enable organisational operational response and inform strategic decision making for long term flood preparedness. Thus, practical guidance will be developed to inform organisations how to better adapt to flood risk through more effective business continuity planning, thereby increasing flood resilience.
Keywords: floods, decision making, organisations, response and preparedness.

www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/DMAN130091

1 Introduction

In recent years flooding has emerged as a significant endemic risk facing individuals and organisations across the UK. Indeed, the autumn and early winter of 2000-01 saw the worst flooding in the UK since 1947 and the 2007 floods resulted in the greatest loss of essential services since World War II. Flooding is characterised by high levels of uncertainty, unpredictability and emergence; key elements of hazards symptomatic of a 'risk society' [1, 2]. Hazards such as modern day flooding require novel response and regulation [3], and urgently, given that milder wetter winters and localised extreme weather events are likely to be an ongoing feature of both national and global climate patterns [4–6].

In 2012, the UK's Engineering and Physical Sciences Research Council funded three major projects focussing on innovative solutions to flood risk. This paper presents an overview of a framework for one of those projects aimed at influencing the behaviours of businesses faced with urban flooding and flood risk. The framework aims to enable different types of organisation to enhance their strategic capabilities for both short term event response and longer term preparedness. Thus, organisations will be able to reduce the disruption and economic losses associated with flooding and, as a result, strengthen the flood resilience of both the wider economy and society. To achieve this aim, four integrated and interdisciplinary research goals are being pursued. Firstly, there is a need to achieve a better understanding of business continuity processes and how private and public sector organisations behave and interact with each other in the immediate and longer term aftermath of flood events. Secondly, there is a need to establish how agent based modelling and simulation can be used to improve organisational business continuity by means of representing attributes and simulating behaviours of different types of at-risk UK organisations and the consequences of these for both the short-term response to flooding and longer-term preparedness. Thirdly, there is a need to assess the impacts of flooding on economic systems both within and beyond the immediately affected urban area and explore how changes in organisational behaviour could influence these impacts. Fourthly, there is a need to develop innovative approaches to the promotion of organisational behaviour change and adaptive organisational learning throughout the flood cycle. In pursuing each of these four goals, the research exploits synergies between the academic fields of organisational business continuity management, agent based modelling and simulation, disaster management, emergency planning, flood modelling and prediction, economic modelling and the social/behavioural sciences.

2 Background

It has been estimated that flood damage could account for £10bn to the UK economy in 25 years [7] and that risks relating to precipitation, over the next 30-100 years, will increase by 2 to 4 times across the UK, with some locations experiencing changes beyond this range [8]. A key recommendation emerging from the formal review of the 2007 UK floods was the need to reduce the risk of flooding and its impact [5]. The UK's National Security Strategy [9] discusses the importance of flexibility and resilience to natural and man-made disasters, but also emphasises working in alliances and partnerships to build corporate and community resilience. This can be best understood as part of a paradigm shift in approaches to the management of risk itself. Policy developments in the UK which address risk and resilience are increasingly underpinned by concepts such as communal risk reduction and also, through the involvement of a range of non-state bodies, risk spreading [10]. One powerful stakeholder is the insurance industry. The cost to insurers of the 2007 UK floods alone was £3bn. Insurers have stated that losses on this scale are not sustainable for the insurance industry. Currently, under a pan-industry agreement with government, expiring mid 2013, British insurers are obliged to make insurance cover for flood as widely available as possible and, in effect, insure properties that would otherwise be deemed uninsurable [11]. It is probable that insurance coverage for flood risk will become less available and more expensive after 2013. The impact of this on organisations, and particularly Small and Medium Enterprises (SMEs) and third sector bodies, is significant given that SMEs account for over 50% of UK employment and gross domestic product. However, in light of the paradigm shift outlined, and in the context of the current fiscal crisis, it is unlikely that government will wholly absorb the risk and associated costs. Rather, it is likely that there will be an even greater emphasis upon risk spreading as a means for building resilient cities and communities. Citizens, private sector organisations and public sector bodies will increasingly be obliged to engage in the management of flood risk and the creation of resilience at the local community, regional and national level. Organisational and local resilience are vital interacting components of an overarching strategy for national resilience.

3 Related work

Research on the response to major natural and man-made events has focussed primarily on 'category 1' responders [12]. However, there is a dearth of research on the response of business organisations faced with major disruption caused by flooding. Effective response to disruption through preparedness can mitigate the impact of a major flood event on organisations. This approach forms a cornerstone of business continuity management [13], which is recognised as an important tool for organisational survival in the face of disruption [14, 15]. Effective business continuity can reduce organisational down-time and facilitate a more rapid return to normality thereby lessening the economic impact at the level of the organisation and beyond. Previous reviews have highlighted the role of business continuity as part of any successful flood response [5]. Despite this, in the UK, organisational engagement with business continuity remains low with less take-up by SMEs and third sector organisations relative to larger businesses and public sector bodies [16, 17]. There are indications that a lack of resources and capabilities may account for this lower take-up, however no systematic investigation has yet been undertaken.

Whilst agent based models (ABMs) have provided useful insights into emergency responses to major events [18, 19], their focus to date has been on agents representing individuals exhibiting behaviour intended to mimic emergency responders or members of the public. In flood management, ABMs have been used to model evacuation strategies, albeit without agents representing emergency service personnel [20, 21]. In the response to flood events, there exists scope to develop and utilise ABMs by representing and modelling organisations, rather than individuals, as agents and considering timeframes beyond immediately after the event occurs. ABMs offer an opportunity for using and embedding iterative stakeholder learning and feedback within the modelling process. This can occur through organisation engagement with model outputs from agent based simulations of past or future flood events based on historical data and/or predictions from flood modelling. Indeed, predictions from flood modelling can complement incomplete observed data for specific events [22, 23], postulate future scenarios based on organisation agent behaviour, and provide flooding frequencies [24]. Feedback on behaviour changes, gained from working with stakeholder organisations, can then be fed back into further simulations of the ABM, so improving modelling of the impact of changes in organisations' preparation for and response to flood hazards. In the context of organisational response, organisational agents include SMEs, the emergency services and emergency planning units, local authorities and the Environment Agency.

4 Framework

The framework, presented in Figure 1, aims to iteratively evaluate organisations' response strategies to flooding in order to develop guidelines and recommendations to influence behaviour change enabling them to better prepare for future floods and adapt to flood risk through more effective continuity planning.

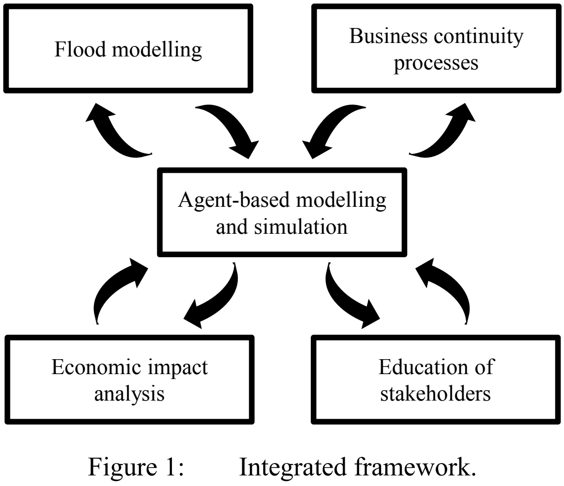

Figure 1: Integrated framework.

This aim will be brought about through the integrated application of flood modelling with agent based modelling and simulation of organisations informed by business continuity processes, analysis of the economic impacts radiating out from directly flood-affected areas, and the education of stakeholders in better preparing for flood events.

4.1 Flood modelling and organisational level agent based modelling and simulation

The focus of this strand of the research is to develop an agent based approach to model and simulate organisational behaviour in the face of flood events. This involves the representation of organisations' attributes and behaviour in terms of their actions and interactions in response to flood events, thus informing strategic decision making for longer term preparedness. A range of private businesses and public organisations will be represented varying in size, sector and operational behaviour. Prior to simulations of organisational behaviour in terms of responding to and preparing for flood events, flood inundation modelling coupled with historical data will be used in a complementary manner to provide detailed information to the ABM regarding which organisation agents are affected. Inundation modelling is necessary to complete what is usually incomplete data from historical records, or where there are no data in cases lacking recent records. The virtual geographical environment component of the ABM, developed using OS MasterMap, is fed information regarding an inundation prediction thus allowing flood events to be modelled in any urban area of the UK, even those areas not yet exposed to flooding. As a result, all organisations in this area directly and indirectly affected by a flood event can be identified. An example geographical area affected by a flood event is shown in Figure 1.

Figure 2: Example geographical area affected by a flood event.

Within the affected geographical area, intelligent agents are used to model the various types of private and public sector organisations with each having different attributes and rules governing their operational behaviour in terms of actions and interactions with other organisations and communities. In addition to the virtual geographic environment illustrated in Figure 1, an agent interaction framework will capture, in simulations of floods events and the aftermath, the interdependent behavioural actions of organisations and their impact. Multiple simulations reflecting varying levels of uncertainties will be performed in two stages to gain an understanding of the dynamic complexity of organisations' interactions in the aftermath of a flood: (a) simulations in the context of their short term and longer term response to flood events thus informing changed behaviour for preparedness; (b) simulations of their short term response with changed behaviour for preparedness measures adopted in light of the simulations in (a) and output from economic modelling to evaluate the effect of such measures and inform the education of stakeholders.

4.2 Business continuity processes

This strand of the research is aimed at gaining an understanding of businesses' response to flood events within a local, regional and national context in the short and longer term in order to generate insights and data on the attributes, dynamic behaviour and interactions of organisations. These insights and data will form the basis of the attributes and rules governing the operational behaviour of private and public businesses represented in the ABM mentioned in *Section 4.1*. To achieve this aim, this research strand will explore the factors which underpin both effective and ineffective organisational response to flooding by identifying what, why and when organisations behave in particular ways in the flood response and preparedness phases. This will involve examining how long it takes organisations to move through the response phase (short term) and preparedness phase (longer term) and regain normal operational functioning so that a better understanding can be gained of what constitutes short term and longer term with respect to effective flood risk. Organisational behaviours are influenced directly and indirectly through interactions with a range of other stakeholders such as the emergency services, local authorities, quasi-governmental agencies, insurers, local community and other organisations, for example across supply and distribution chains. Consequently, it is not possible to generate meaningful insights into these behaviours without contextualizing these actions dynamically within this broader network of actors/agents. By taking this holistic perspective, it is possible to identify what barriers may exist to effective business continuity and where these barriers lie, for example at the micro or meta level. To generate robust and rich data, a multi-method approach is being taken through integrating traditional methods of data collections, such as interviews and focus groups, with data captured from new technology for a number of flood event case studies. Importantly, case studies being considered vary in terms of severity as well as flooding source such as pluvial, fluvial and coastal. As mentioned earlier, data generated will feed into the ABM to enable the simulation of organisational behaviour. Subsequent changes in actions and behaviours will then be interrogated iteratively in the context of the research framework, as well as directly with stakeholders through appropriate means such as follow-up interviews and online forums, blogs and wikis.

4.3 Impact of flooding to urban economy and wider economic systems

The emphasis of this research strand is the economic analysis of the impact of flood events, which is central to identifying economic vulnerabilities and thus where preparedness measures are best applied. Assessments of the economic impact of flood events in urban areas have traditionally focused locally on the initial estimates on the cost of lost assets, referred to as direct damage. These initial estimates are useful in establishing where capital and resources are needed for rebuilding post-event. However, since economies are interlinked geographically, there is a need establish how this direct damage cascades from the local economy throughout the wider economic systems at regional, national and global levels, thus determining the indirect damage. Quantified knowledge on flooding impact will be compiled, including the cost of direct damage and business interruption based on DEFRA's Multi-coloured Manual, into a set of damage functions at an urban area scale. A variant of the adaptive regional input-output (ARIO) model will then be developed to explore the vulnerabilities of urban area economies related to flood damage. This model enables direct damage to be determined using an event accounting matrix, consisting of a set of damage functions. The indirect damage is determined by integrating the local economic datasets and direct damage datasets based on supply constraint environmental input-output analysis. Using the variant ARIO model and output from agent based simulations, economic analyses can be performed regarding the impacts of flooding in a range of UK urban areas leading to specific economic vulnerabilities being identified, which should be the focus of increased preparedness. That is, the identification of business sectors beyond the immediate, or local, impact zone of a flood which are key to the wider economy at a regional and national level.

4.4 Adaptive e-learning and behaviour change in organisations through the flood cycle

This strand of research addresses the need to develop new ways of bridging knowledge gaps between outputs from agent based simulations and the promotion of real and timely behaviour change for resilience among the different stakeholders involved in business contingency planning for floods. As such, a key aspect of this strand is engagement with stakeholders such as businesses, emergency responders and emergency planners, local authorities and the Environment Agency. The development of the ABM mentioned earlier presents opportunities for improving the interface with a broad range of end-users and the tailoring of model outputs to the needs of diverse organisations. Feedback on iterative organisational learning and predicted behavioural changes, after using model outputs from single and/or multiple flood simulations as practical guidance, can then be embedded into the ongoing ABM design process and future simulations. This will improve the underlying assumptions in the modelling that determine the outputs. This research strand is also aimed at developing an e-learning intervention tool that uses new digital technologies to engage end-users with the practical guidance established, and evaluates their use for learning and behavioural change. As smart, future-oriented ubiquitous technologies will be dominant modes of future information engagement, design principles developed will be applicable across diverse flood modelling settings.

5 Conclusions and future work

It is widely acknowledged that the effect of future floods in the UK is expected to be significant in terms of damage, disruption and economic loss. Thus, the need to reduce the risk of flooding and its impact has been identified as key to mitigating this effect. The framework overview presented in this paper relates to ongoing research aimed at addressing the need to reduce the impact of flooding by improving organisations' response to and preparedness for floods in urban areas, reducing the disruption and economic loss associated with flooding, and strengthening the flood resilience of the wider economy and society.

Agent based modelling and simulation coupled with flood modelling provides a means of identifying organisations affected by a flood event in an urban area, investigating the actions and interactions of organisations in terms of their response and preparedness to flood events, and evaluate the implications of strategic policy decisions in the context of changes in behaviour. Key to such an agent based approach is the need to determine and codify how businesses respond to and prepare for flooding at an operational level. Engagement with a variety of businesses will establish the business continuity processes and dynamic behaviours of organisations in flood response and preparedness thus providing data inputs to an ABM. Subsequently, agent based simulations will identify key drivers and barriers to enhance organisational resilience through continuity planning. These simulations will enable the direct and indirect economic impact propagated at a local, regional and national level to be evaluated, leading to improvements in preparedness based on vulnerabilities identified. Further, simulations will facilitate the development of practical guidance to inform enhancements and adaptation in all stakeholders' response and preparedness in the face of flood events, which will be communicated to relevant organisations and communities via relevant risk communication and pedagogical concepts.

Acknowledgement

The authors gratefully acknowledge the funding provided by the UK's EPSRC under grant EP/K012770/1.

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Towards a demand forecast methodology for recurrent disasters

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Abstract

Humanitarian supply chains have received a lot of attention over the last fifteen years, and can now be considered a new research area. But a gap exists between the research work proposals and their applications in the field. One of the main issues is that the demand, in the case of disaster, is hard to assess because of the high-level of uncertainty. Gathering knowledge about future demand is of prime importance to be able to propose models, which are relevant to implement for a real problem. This paper tackles this problematic proposing a four-step methodology for forecast disaster impact, and in this way, the future demand, such as cyclones in the Caribbean or earthquakes along the Pacific Ring of Fire. This approach uses data analysis techniques such as Principal Component Analysis and Multivariate Regression Analysis. An application case on Peruvian earthquake demand is proposed to illustrate the benefits of our approach.
Keywords: forecast, disaster, demand, principal component analysis, multivariate regression analysis.

1 Introduction

Almost every year, losses due to natural disasters are increasing. For instance, the damages from natural disasters in 2011 (US$366 billion and more than 260 million people impacted) reached a level never seen before, with annual average damages for the 2000–2011, around US$100 billion (EM-DAT [1]). In the meantime, the funding of humanitarian operations has been multiplied by thirteen (www.reliefweb.int) over the last decade. All these facts have pushed

WIT Transactions on The Built Environment, Vol 133,
www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/DMAN130101

humanitarian organizations to become more result-oriented. They need to prove to donors that the funds they get are used in the most efficient way. But because of what is at stake, that is to say human lives, they also need to ensure that, whatever the circumstances, those who need their help are rescued quickly and effectively.

Consequently, Humanitarian Supply Chains (HSC) received a lot of attention over the last fifteen years, and can now be considered a new research area. The number of scientific and applicative publications has considerably increased over this period and particularly over the last five years. Reviews in humanitarian logistics and disaster operation management allowed bringing out trends and future research directions dedicated to this area (Altay and Green [2]; Van Wassenhove [3]; Natarajarathinam *et al.* [4]; Charles *et al.* [5]; Peres *et al.* [6]). These authors show that the HSC research projects are mainly based on the development of analytical models followed by case studies and theory. As for research methodologies, mathematical programming is the most frequently used method. But few or no humanitarian organizations go as far as using optimization-based decision-support systems.

This demonstrates that a real gap exists between the research work proposals and their application on the field. To bridge this gap authors proposed some trails among which: (i) Humanitarians naturally evolve in a very hazardous environment and the academic works must consider the uncertainties they face more systematically. For instance, a broad majority of the research works is deterministic and only a few of them propose stochastic approaches; (ii) A consequence of the previous points is that the research work should be more realistic, considering real problems and real data gathering past and future trends (Van Wassenhove [3]; Charles *et al.* [5]). Due to the youth of this academic area, researchers find it difficult to get accurate, and above all, reliable data to support their steps towards improvement (Van Wassenhove [3]; Peres *et al.* [6]); (iii) Future research works should consider the new requirement on efficiency for humanitarian organizations. Productivity and efficiency studies are challenging issues that have gained importance to humanitarian operations because of the donor's pressure on humanitarian organizations to deliver aid to beneficiaries in a cost-effective way (Kovács and Spens [7]).

Furthermore, one of the main issues is forecast disasters' demand. In case of humanitarian crisis, this point is particularly hard to reach regarding the high-level of uncertainty. But without any attempt on that point, too many academic propositions are still purely theoretical. Gathering knowledge about future demand is the prime importance to be able to propose models, which are relevant to implement for a real problem.

This paper tackles this issue by proposing a demand forecast methodology dedicated to the disaster management context. The paper is split up in four parts. The first section will present a brief literature review on demand in humanitarian context. The second section will describe the proposed method and its associated tools. The third section will develop an application case on Peruvian earthquakes' demand. The last section will discuss the limits of the approach and propose some perspectives on this research.

2 Background

In the case of humanitarian organizations, uncertainty reaches a climax. "Natural disaster risk assessment is a typical issue with imprecision, uncertainty and partial truth. The two basic forms of uncertainty related to natural disaster risk assessment are randomness caused by inherent stochastic variability and fuzziness due to macroscopic grade and incomplete knowledge sample" taken from Huang and Shi [8]. The usual methods to deal with uncertainty are to use a stochastic or a robust optimization model. Both need at least some knowledge about the future demand. Stochastic optimization uses probabilities of occurrence whilst robust optimization uses various alternatives, from the most optimists to the worst case scenarios. Stochastic optimization models optimize the random outcome on average. According to Shapiro *et al.* [9], "this is justified when the Law of Large Numbers can be invoked and we are interested in the long-term performance, irrespective of the fluctuations of specific outcome realizations". In our case, the impact of those "fluctuations" plays on human lives and can be devastating. As for robust location problems, according to Snyder in [10], they proved difficult to solve for realistic instances. If a broad majority of the published research works is deterministic, more and more humanitarian researchers now propose stochastic models in order to better consider uncertainty (Martel *et al.* [11]). But stochastic or not, the problem is that since most natural disasters are difficult to foresee, the demand for goods in these disasters also is difficult to manage (Cassidy [12]; Murray [13]). And, even when a crisis occurs, the environment changes so quickly that most of the time information is either not available or not reliable. However, humanitarians could benefit a lot from better visibility on future needs corresponding to future disasters, even it is rough.

Generally, humanitarian practitioners have to make their decision with or without information on the magnitude of the disaster. Disasters are generally characterized by a high-level of uncertainty on both their occurrence and impacts are not easily anticipating (Vitoriano *et al.* [14]). Nevertheless, those on past disasters' information are well known. The EM-DAT database for instance contains essential core data on the occurrence and effects of over 18,000 mass disasters in the world from 1900 to present. The question is how to exploit this information in order to give some visibility to decision-makers and practitioners. Whether the problem concerns occurrence and impact forecasts, the literature review shows that the occurrence dimensions is globally tracked. A lot of work and tools regarding natural disaster prediction (flood, volcano eruption, earthquake, storms so on) have already been developed. Earthquake prediction models for instance try specifying the time, location, and magnitude of a future earthquake with precision (WGCEP [15]). Moreover according to the current thinking, disaster trends are changing. If we refer to EM-DAT [1]; Charles *et al.* [5]; IFRC [16]; IPCC [17], disasters should be more numerous, but of smaller or medium scale in the future. Added to this is the urbanization, which further alters the impact of disasters. The studies of the potential impact of climate change also predict developments in the types of disaster recorded their locations, and their intensities. In practice, analyses of the data from past disasters allow providing valuable information regarding the trends of disasters (localization, intensity, typology and seasonality, so on). The results of Charles *et al.* [5] about African casualties, show that occurrences are not so randomly, they share characteristics such as seasonality, location and targeted-population, so future humanitarian occurrences, though highly uncertain, can be predicted. Other researchers such as Peres *et al.* [6] or Kovács and Spens [7] consider that for small and medium size disasters, future occurrence will be globally similar to previous ones. Regarding this kind of disaster, in Charles [18] for instance has identified by studying the EM-DAT database on a ten-year period that the occurrence and intensity of disasters were globally constant during the decade. But if the occurrence of disasters seems to be managed following this approach, the question of their consequences (number of victims and associated needs) must be examined.

Actually, the impact dimension seems for now not to be really studied in the literature. Disaster impact is defined by UNISDR [19] as, "the potential disaster losses, in lives, health status, livelihoods, assets and services, which could occur to a particular community or a society over some specified future time". In Wisner *et al.* [20] demonstrate in their research that the disaster impact is function of the vulnerability of the concerned area. Vulnerability factor was defined by UNDP [21], as "the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard". While the vulnerability factor is fundamental to explain disaster impact, it cannot be considered sufficient. Many other research works studied in survey proposed by Peres *et al.* [6] or Vitoriano *et al.* [14] insist on the importance of the resilience capability to explain the impact that follows a disaster. Many acceptations can be found in the literature regarding the resilience concept, but it can be defined as the "capacity to resist and to recover after exposition of a system, community or society, to hazards" Peres *et al.* [6]. Inspired on UNESCAP [22] synthesizes the previous information by indicating that disaster impact is a function of both; resilience and vulnerability.

$$Disaster\ Impact = f(Vulnerability, Resilience) \qquad (1)$$

3 Proposition

Our approach concerns the particular case of recurrent disasters such as storms in Caribbean, foods in South-East of Asia or earthquakes in the Andes.

In this research, we made the assumption that the disaster occurrence forecasts are similar to the previous recorded disasters. Consequently, disaster demand forecast will depend only on the future disaster impact assessment. Based on these hypotheses, we propose the following approach to assess future disasters' demand (see Figure 1):

The first step consists of identifying the influencing factors that allow qualifying the vulnerability and resilience level of a potential impacted area. A thorough literature review was done by UNDP [21]; D'Ercole *et al.* [23]; D'Ercole and Metzger [24]; Alinovi *et al.* [25] allows us identifying 58 generic

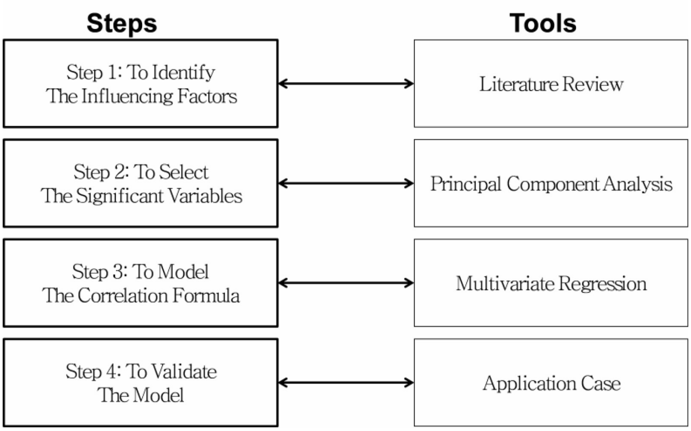

Figure 1: Disaster demand forecast methodology.

factors to characterize the vulnerability and the resilience of the potential impacted area. These include demographics, economic, environmental, health and accessibility indicators. Tables 1 and 2 show this list of indicators. We could remark that all these indicators cannot be applied to all kinds of natural disasters. Some of them are only representative for earthquakes, floods or volcano eruptions for instance.

The second step consists of selecting a subset of significant independent variables among influencing factors identified in Step one. To support this step, we propose to use Principal Component Analysis (ACP) inspired in Saporta [26] and Vargas-Florez *et al.* [27], in order to identify the discriminating variables

Table 1: Generic influencing factors for Vulnerability.

Income and Food Access: Average per person daily income (local currency/person/day); Average per person daily expenditure (local currency / person/day); Household food insecurity access score; Dietary diversity and food frequency score, Dietary energy consumption (Kcal/person/day).
Access to Basic Services: Physical access to health services; Quality score of health services; Quality of educational system; Perception of security; Mobility and transport constraints; Water, electricity and phone networks.
Social Safety Nets: Amount of cash and in-kind assistance (local currency/person/day); Quality evaluation of assistance; Job assistance; Frequency of assistance (number of times assistance received last 6 months); Overall opinion of targeting.
Assets: Housing (number of rooms owned); Housing equipment index (TV, Car, etc.); Tropical livestock unit (TLU) equivalent to 25 K; Land owned (in hectares).
Adaptive Capacity: Diversity of incomes sources; Educational level (household average); Employment ratio (ratio, number of employed divided by household size); Available coping strategies; Food consumption ratio (by expenditure).
Stability: Number of household members that have lost their job; Income change; Expenditure change; Capacity to maintain stability in the future; Net safety dependency (share of transfers on the total income); Education system stability, the Human de Development Index (IDH).

Table 2: Generic influencing factors for Resilience.

Exposure of resources: Zoning by seismic exposition, also inundation zones due to tsunami hazards.
Access to resources: Accessibility of resources in emergency situation.
Functional and vulnerability structures: Structural vulnerability; major bridges, interchanges; Structural function & vulnerability key health facilities.
Access to resources and vulnerability of the population: Access to resources (rate resource / population); Population by age; Population by access to services; Population without access to any services; Average population by households by room; Population without potable water; Population without drainage system; Population without electricity; Households with average people per room; Population living with dirt floors; Population settlements resulting from land's invasion; % Population that are newcomers to the district; % Population with low education; Accessibility due to urban design; Exposure to Hazards.
Vulnerability humanitarian response: Governance humanitarian response system; Quality of system, processes, services and tasks; Maturity and expertise humanitarian institutions; Decision and intervention centers available; Water supply hubs available; Food supply available; Health care available; Energy supply available; Transport, roads and accessibility available; Telecommunications available; Shelters area available; Waste dumps disposable areas available; Economic and finance support; Keep permanent measure system population vulnerability updated; Keep measure system hazard seismic updated; Keep measure system tsunami threat updated; Keep a database robustness and updated base

associated to a given type of disaster. The objective consists of reducing the size of the problem and finding the discriminating variables that will be used in the linear regression in Step three.

The third step consists of modelling the correlation formula that allows assessing the future demand, using a multivariate regression analysis. Actually, for a given disaster's occurrence (earthquake with a magnitude of seven for instance), two different areas would not record the same impact due to their own vulnerability and resilience capabilities. Considering the previous frame we define for each impacted localization at past, the following association:

$$Past\ Disaster\ Impact = f(V_1, V_2, \dots, V_m; R_1, R_2, \dots, R_n) \qquad (2)$$

in which:
$\{V_1, \dots, V_m\}$ are the vulnerability discriminating variables identified during the PCA analysis. $\{R_1, \dots, R_n\}$ are the resilience discriminating variables identified during the PCA analysis.

Based on these equations, we estimate, for a potential impacted localization and for a given period of time *t*, an expected gravity using a multivariate regression model. In words of Sopipan *et al.* [28], if explanatory independent variables have multicollinearity the forecasting calculation can be defined as:

$$Future\ Disaster\ impact = f_{t=1,\dots,T}(X_1, \dots, X_k, \dots, X_{mxn}) \qquad (3)$$

in which:
X_k is independent variable composed of $\{m\ x\ n\}$ values recorded in a given period *t*, from a database which carry a total *T* periods.

The fourth step consists of verifying and validating the relevance of the proposed regression models. To support this step, we propose to make a comparative analysis, in order to measure the deviation between the forecast calculated by the model and the real needs that have been recorded on the field, it defines as *Ratio*. A deviation ratio criterion is proposed:

If 75% < *Ratio* < 100% then the model is considered as "good";
If 50% < *Ratio* < 75% then the model is considered as "doubtful";
If *Ratio* < 50% then the model is considered as "bad".

4 Application case

In this section, we present a numerical application case in order to illustrate the benefits of our contribution regarding the management of earthquake disasters in Peru. Analysis of historical data on Peruvian earthquakes shows clearly that the small and medium size earthquakes' occurrences are globally recurrent in frequency and intensity (Castillo and Alva [29]).

Step 1:
It has made a pre-selection of 12 influencing factors among those 58 generic proposed, relate to vulnerability and resilience influence on earthquake case. The following table shows these:

Table 3: Vulnerability and resilience factors for earthquake disasters.

Vulnerability	Population	IDH	Water [1]	Electricity	Vulnerable walls [2]	Life expectancy birth
	quantity (millon)	ratio	%	%	%	years
Resilience	Illiteracy	Secondary registration	Educative achievement	Family per cápita income	Criminal records	Support logistics
	%	%	%	S/. mes	quantity (mil)	(S/. millon)

[1] Continuous supply services: public network within the housing.
[2] It is considering those houses whose walls are of adobe, thatch or mud.

For each of the 24 Peruvian regions, the values of these 12 factors regarding three representative years (1993, 2000 and 2007) have been gathered from public governmental, NGOs and International organizations databases such as: National Institute of Statistics and Informatics (INEI), Peruvian Ministry of Education (MINEDU) and so on.

Step 2:
Following our methodology, we implemented an ACP on whole vulnerability and resilience data, for instance see Table 4 about resilience. We have to notice that the ACP has gotten 88.69% of data variance. The results can be considered meaningful and can be interpreted. This data analysis allowed identifying correlations between the 12 influencing factors that we retained. For instance the Human Development Index (HDI) is so correlated with life expectancy,

Table 4: Resilience data for 1993, 2000 and 2007 for the 24 Peruvian regions.

Region	Illiteracy			Secondary registration			Educative achievement			Family per cápita income			Criminal records			Support logistics		
	1993	2000	2007	1993	2000	2007	1993	2000	2007	1993	2000	2007	1993	2000	2007	1993	2000	2007
Amazonas	79,5	82,9	88,0	40,8	51,5	78,6	66,6	72,4	84,9	65,8	195,37	204,7	5,23	6,40	0,81	0,0	1,6	0,3
Ancash	78,1	80,8	87,6	65,1	75,1	86,3	73,8	78,9	87,2	87,9	307,27	320,8	7,88	8,20	4,50	0,0	0,0	0,4
Apurímac	63,0	70,4	78,3	43,9	63,7	89,9	56,6	68,2	82,2	52,0	137,49	203,3	1,63	1,56	1,13	0,0	0,0	2,3
Arequipa	92,0	93,6	95,9	82,7	92,4	90,7	88,9	93,2	94,2	149,9	331,33	434,8	16,32	11,07	9,19	0,0	1,6	1,6
Ayacucho	67,2	71,7	71,7	46,9	69,8	69,8	60,4	71,1	71,1	62,9	167,91	167,9	2,26	3,90	2,19	0,0	0,0	0,0
Cajamarca	72,7	77,8	82,9	41,3	51,6	79,6	62,2	69,1	81,8	62,9	198,44	215,7	2,25	3,89	2,29	0,0	0,0	2,9
Cusco	73,8	83,3	86,1	54,5	65,4	87,6	67,3	77,3	86,6	98,6	259,75	262,5	11,57	4,62	4,07	0,0	2,1	2,3
Huancavelica	65,7	72,5	79,9	45,9	61,2	86,7	59,1	68,7	82,2	42,0	142,06	131,9	0,75	2,00	0,02	0,0	0,0	0,0
Huánuco	75,0	77,4	83,4	41,4	55,4	81,7	63,8	70,1	82,8	60,5	191,82	231,6	3,85	4,08	0,99	0,0	0,0	0,3
Ica	94,2	95,7	97,2	87,8	93,4	89,7	92,0	94,9	94,7	125,2	357,79	371,9	7,48	5,77	2,55	0,0	0,0	13,0
Junín	86,3	88,1	92,4	70,2	85,8	86,2	80,9	87,3	90,4	91,4	253,06	278,1	11,86	2,87	1,71	0,0	0,0	2,7
La Libertad	86,2	89,0	91,9	66,0	71,8	82,0	79,5	83,3	88,6	101,3	338,24	381,3	14,81	10,78	9,76	0,0	0,0	0,3
Lambayeque	88,7	89,5	93,5	70,7	75,1	85,3	82,7	84,7	90,8	103,2	343,20	318,4	9,86	9,95	8,47	0,0	0,0	0,6
Lima - Callao	87,1	96,2	98,2	77,7	94,6	89,2	84,0	95,7	95,2	189,7	547,47	552,1	145,90	19,90	67,83	0,0	4,5	2,9
Loreto	88,8	92,0	94,5	47,3	60,5	79,2	75,0	81,5	89,4	99,4	265,28	279,1	6,36	2,90	3,49	0,0	1,8	0,7
Madre de Dios	92,0	92,7	96,8	61,5	85,7	83,3	81,8	90,4	92,3	127,6	327,47	429,8	1,99	5,95	1,39	0,0	0,0	0,2
Moquegua	91,0	92,6	95,3	85,6	91,0	91,1	89,2	92,1	93,9	121,0	412,72	418,2	1,85	5,21	1,44	0,0	0,0	0,6
Pasco	84,6	89,1	91,7	70,5	89,4	85,0	79,9	89,2	89,5	81,2	233,75	222,4	1,12	4,61	0,33	0,0	0,0	0,1
Piura	83,2	86,9	90,8	59,2	70,0	82,4	75,2	81,3	88,0	100,6	209,18	313,8	10,74	5,17	5,52	0,0	2,5	0,6
Puno	77,6	79,5	87,8	65,3	82,4	86,5	73,5	80,5	87,3	55,5	179,72	208,8	7,92	0,83	1,61	0,0	1,6	4,1
San Martín	87,1	89,6	92,3	46,1	56,3	77,7	73,5	78,5	87,4	93,6	220,57	255,4	2,86	2,78	1,34	0,0	1,6	1,3
Tacna	92,5	93,0	96,3	77,3	83,9	89,7	87,4	90,0	94,1	193,8	420,45	410,4	7,06	8,52	1,08	0,0	0,8	0,4
Tumbes	93,3	93,4	96,6	73,4	82,5	85,4	86,7	89,8	92,9	124,9	311,84	412,8	3,92	7,29	1,53	0,0	0,0	0,2
Ucayali	89,9	90,9	95,2	54,1	76,5	80,2	78,0	86,1	90,2	91,2	257,43	313,4	3,39	6,98	2,86	0,0	0,9	0,4

illiteracy, secondary registration, education achievement, income per capita, water and electricity accessibility indexes, meanwhile Criminal Records (CR) is so correlated with population density index, all the cases have $R \geq 0.82$. Furthermore, the three factors should be retained to explain the whole behaviour of the influencing factors regarding disaster impact (*DV*): (i) X_{HDI} for human development index (vulnerability of society); (ii) X_{CR} for criminal records (resilience of society); (iii) X_{VW} for building vulnerability (vulnerability of walls).

Based on these three discriminating variables, we made a second ACP as shown on the factorial plan presented in Figure 2 (more than 90% of data variance).

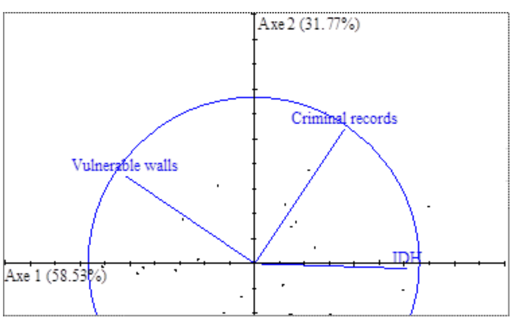

Figure 2: Factorial plan of principal component analysis.

Step 3:
It consists of establishing the regression equation based on the three discriminating variables identifying in previous step that should allow assess potential volume of victims for a given period in a given region. As discussed in section 3, we used a multivariate regression analysis to reach this goal. Our numerical application was based on Peruvian earthquakes recorded in 1993, 1995, 2000 and 2007. For instance for Lima-Callao region its regression equation is:

$$DV_{Lima-Callao} = +184733.8 \times X_{IDH} + 0.468 * X_{CR} - 1485837 \times X_{VW} + 16908.35 \quad (4)$$

Based on all Peruvians regions' equations found, we could assess future disaster impacts for the year 2014 regarding attempted values for X_{HDI}, X_{CR} and X_{VW}. Data for each Peruvian region in 2014 have been sourced through a benchmark step with Chile, which gets very similar characteristics to Peru. The results of the disaster impact forecast for the year 2014 are presented in Table 5.

The approach should be generalized for forecast disaster impacts for a longer time frame. Based on these results, we will be able to establish realistic facility-location model in order to support Peruvian's earthquakes prepositioning inventory strategy.

Table 5: 2014 disaster impact forecasts for the 24 Peruvian regions.

No	Regions	1993	1995	2000	2007	Forecast 2014	Reliable results		Seismic region	
							Yes	No	Yes	No
1	Amazonas	3 333	1 881	4 916	1 161	4982	1			
2	Ancash	1 440	830	2 406	491	3227	1		1	
3	Apurimac	0	812	372	3 815	2037	1			
4	Arequipa	80	4 586	18 022	1 823	-49988				1
5	Ayacucho	610	5 047	1 286	262	38811	1			
6	Cajamarca	8 650	205	7 145	732	-4867		1		
7	Cusco	2 000	2 302	28	11 697	46202	1			
8	Huancavelica	95	1 248	66	44 733	-115138		1		
9	Huanuco	3 877	4 187	54	1 969	1007	1			
10	Ica	0	6 400	10	355 332	416248	1		1	
11	Junin	632	1 218	42	3 267	4643	1			
12	La Libertad	100	5	19	526	-5794		1		1
13	Lambayeque	0	0	11	101	61	1			
14	Lima-Callao	3 282	4 308	213	56 116	127738	1		1	
15	Loreto	392765	2 672	279	2590	488711	1			
16	Madre de Dios	215	1 245	3	134	1699,5	1			
17	Moquegua	50	6 438	13	179	1467,8	1		1	
18	Pasco	183	849	8	724	1776,1	1			
19	Piura	0	2 565	10	1 733	3819,9	1			
20	Puno	1 150	3 007	30	5 335	10224	1			
21	San Martin	12 787	2 304	40	1 865	-342977		1		
22	Tacna	2 350	20	13	20	-8646,8		1		1
23	Tumbes	525	750	5	49	-804,51		1		
24	Ucayali	0	1 628	3	1 609	2225,4	1			
						Total	17	6	4	3
						Equivalence	74%	26%	57%	43%

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Step 4:
In this step, we verify the relevance of our approach by re-calculating the disaster impacts of the year 2014 through our regression equations. For all the regions 74% of the simulated results matched with the real number within a deviation inferior to 10%. On the other hand, for regions that had been submitted to a strong earthquake (as Pisco, in 2007, Chandes and Gilles [30]), the matching rate drops down to 57% within a deviation inferior to 10%.

5 Conclusions and future work

In this paper we have proposed a methodology able for forecast disaster impacts associated to recurrent disasters such as cyclones in Caribbean, earthquakes in Pacific ring of fire, floods in South-East Asia, so on. Our approach is based on two main assumptions. The first one considers that regarding such a disaster, future occurrences can be taken as globally equivalent to the past ones. The second one considers that future disaster impacts will depend on two main factors; vulnerability and resilience.

Based on these hypothesis, our proposal is split up into four steps: (i) Identifying the vulnerability and resilience factors through literature review; (ii) Selecting discriminating variables among these factors through Principal Component Analysis; (ii) Establishing regression equations for a given period of time and a given area, through multivariate regression analysis; (iv) Validating the relevance of the model through standard deviation analysis.

This proposition was applied to the Peruvian earthquakes situation in order to support future strategic thoughts on inventory pre-positioning.

Regarding this work, the next steps will consist in designing a facility-location model that can use such approach to determine the demand. This future model will try to reach a triple goal in terms of disaster management performance: (i) agility for a better responsiveness and effectiveness; (ii) efficiency for a better cost-control; (iii) robustness for a better deployment even if some infrastructures are not available any more.

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Revising a regional disaster management plan using ethnographic data

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Abstract

The present study examined disaster response activities written in a regional disaster management plan of a municipal government in Tokyo. The purpose of this study was to propose a method to improve the plan, formulating a consensual decision making process where municipal officials check and validate their response activities in the plan. During this process, we indicated that response activities in the plan were divided into three categories: 1) general administration, employing standard skills but increased workload, 2) activities unique in a disaster, and 3) activities which are misallocated. We therefore identified which activities should be focused on. The next step was to implement operational simulation training, using ethnographic data obtained from interviews of responders in previous disasters. Acquired operational understanding through the conventions helped officials judge how the disaster management plan should be revised. Consequently, we clarified necessary modifications in the plan. Participants felt that municipal disaster preparedness was enhanced.
Keywords: regional disaster management plan, ethnographic data, disaster response activities, disaster preparedness.

1 Introduction

Municipal disaster management plans are required to be annually reviewed and revised if necessary, according to the Disaster Countermeasures Basic Act of 1961, Articles 42, Japan [1]. A disaster management plan basically consists of 4 parts: general provisions, disaster prevention, disaster response and recovery, and reconstruction. Administrative operational outlines regarding municipal

WIT Transactions on The Built Environment, Vol 133,
www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/DMAN130111

disaster prevention and countermeasures are stipulated in the plan. It is apparent that operational knowledge is required in order to revise plans appropriately. However, disasters do not occur often, and municipal officials normally do not experience response activities. Accordingly, they are often unable to recognize the tasks they must perform until a disaster occurs. It is also anticipated that the plans will be only partially revised, preventing smooth and effective response in future disasters. This problem may cause deficiency in response.

2 Objectives of this study

The present study, as a case study of a municipal government in Tokyo, examined disaster response activities written in a regional disaster management plan. The purpose was to propose a method to enhance disaster response capabilities of municipal officials and to improve the plan, using ethnographic data of municipal responders of past disasters.

3 Review of the literature

In order to examine post-disaster human behaviour after the Great Hanshin-Awaji Earthquake (Shigekawa *et al.* [2]) adopted ethnographic analysis. Using interview data of disaster victims, their residential transition and time phases were identified. The study showed the significance which ethnographic data had for analysing and understanding the response process after the disaster.

Komatsubara *et al.* [3] recognized that ethnographic data contained implicit knowledge of responders. They applied ethnographic interviews of the Niigataken Chuetsu-oki Earthquake in 2007 to visualize procedures of issuing damage certificates. They indicated that consecutive ethnographic interviews helped create an operational manual.

Ethnographic data was utilized by Takemoto *et al.* [4] in an emergency training exercise. They proposed a program to improve competencies of responders, and an ethnographic learning process was practiced. Interview data was used as teaching material to help officials understand governmental responses. They verified that the program using ethnographic data was more effective to improve skills of officials, compared to lectures.

In the present study, the achievements of the previous studies were applied to upgrade a regional disaster management plan. Learned lessons from ethnographic data were utilized for improving the plan, in addition to enhancing response abilities.

4 Countermeasures after the great east Japan earthquake

The Great East Japan Earthquake occurred in Japan on March 11th 2011, causing extensive damage to the Tohoku Pacific coastal areas in the northern part of Japan. As the damage by the disaster was unexpectedly severe, government officials have often been criticized for a damage estimation that is seen as optimistic.

The Fire and Disaster Management Agency notified prefectural governors of "Conducting an emergency inspection of disaster prevention schemes based on regional disaster management plans, etc. (acknowledgement)" in Sho-bo-sai No. 157 in May 2011 [5]. It announced that the Committee for Technical Investigation on Countermeasures for Earthquakes and Tsunamis Based on the Lessons Learned from the "2011 off the Pacific coast of Tohoku Earthquake" would be set up in the Central Disaster Prevention Council. According to the announcement, the basic plan for disaster prevention would be emendated after publishing a report from the committee. This emendation leads to revisions of prefectural disaster management plans. Municipal plans are then required to be revised based on the prefectural emendation.

4.1 Research subject city

The subject city for study is located in the southeast edge of the Tama area of Tokyo. It is a commuter town, a half an hour train ride away from the central Tokyo metropolitan area. The population exceeded 78,000 according to the 2010 census [6].

It is located on the right bank of the Tama River, a first-grade river. Looking at its disaster history, the city experienced a flood in 1974 due to breached levees, and 19 houses were swept away [7]. Since then, it has not experienced a major disaster for approximately 40 years.

4.2 Revising the regional disaster management plan

Municipal governments are the closest administrative organizations to disaster victims, compared to prefectural and national governments. In a response period, municipal officials provide support to citizens. In order to operate appropriately, effective support requires operational knowledge. The same applies to revising a municipal disaster management plan.

The city held a disaster management council in October in 2012. Three topics were discussed there, damage estimation of metropolitan inland earthquakes, outline of revision of a disaster management plan of the Tokyo metropolitan government, and revision of the city plan. It also set up exploratory working conventions for revising the regional disaster management plan.

5 Research methods: exploratory working conventions

The exploratory working conventions were to check and validate the disaster response part of the municipal disaster management plan. They were held twice, on October 19th and November 19th, 2012. There were six teams, corresponding to those of the emergency operations centre of the municipality (Table 1). Thirty-two members in total were assistant managers or had equivalent job titles, selected from each department for the conventions. They are in the position of becoming frontline leaders when a disaster strikes.

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We proposed a method of formulating a consensual decision making process where members check and validate their response activities in the plan. The process was held in the conventions using workshops.

Table 1: Teams in exploratory working conventions.

Teams (Divisions)	Number of members	Operations in disaster response
Administration and general affairs	4	*Total management*, logistics assistance, receiving official from other municipalities, restoration of municipal facilities
Planning and finance	7	Publicity, budget of disaster countermeasures, designation as a disaster of extreme severity, *public donation*
Civil life	4	Burial and cremation, damage certificate, *food etc. supply,* loans to small-and-medium-sized enterprise and agricultural businesses
Welfare and health	5	Secondary evacuation centres, volunteers, reconstruction of life, disposal of dead bodies, medical aid, *measures for people requiring assistance*
Construction and environment	5	Obstacle clearance and restoration, search and rescue, safety check, emergency water supply, *waste treatment*
Education, children and juveniles	7	Emergency childcare, *evacuation centre operation,* emergency education

Operations in italics: examined in the November 19th convention

5.1 October 19th convention

The convention was for approximately three hours and a half with breaks. Four steps were taken in the process.

First, explanation was given regarding an outline of revising the municipal disaster management plan, exploratory working conventions and schedules. Second, a thirty-minute lecture on municipal disaster response was given by a specialist. Third, a brief explanation of working procedures was mentioned. Finally, team members read the plan and recognized their administrative affairs, and the activities were categorized into three with discussion: 1) general administration, employing standard skills but increased workload, 2) activities unique in a disaster, and 3) activities which are misallocated. Output from each team was presented and shared among the other teams at the end.

5.2 November 19th convention

The convention conducted over three hours with breaks was based on a workshop style. A lecture regarding previous ethnographic studies of disasters was given first. Participants recognized the importance of understanding an actual response from the data. After the lecture, they read scripts of interviews taken after the Mid Niigata Prefecture Earthquake and the Great Hanshin Awaji Earthquake. Due to the limitation of time, ethnographic scripts regarding a single responsible activity of each team were selected and provided (Table 1). The participating officials worked together in a team, discussed activities written in the scripts and necessary improvements to the plan.

This process can be regarded as operational simulation training. Acquired operational understanding helped members judge how their administrative duties in the plan should be revised. They clarified important components in the ethnographic data and pointed out improvements.

6 Results and discussion

Response activities in the plan were categorized into three categories. Depending on divisions, the number of activities in each category differed (Fig. 1). It is apparent that many of the response activities appeared after a disaster. Especially in divisions of planning and finance, and construction and environment, the proportion of activities unique in disasters was larger than in other divisions. Government organizations have been targeted for cutbacks in manpower. The imbalance is apparent from the increase of workloads.

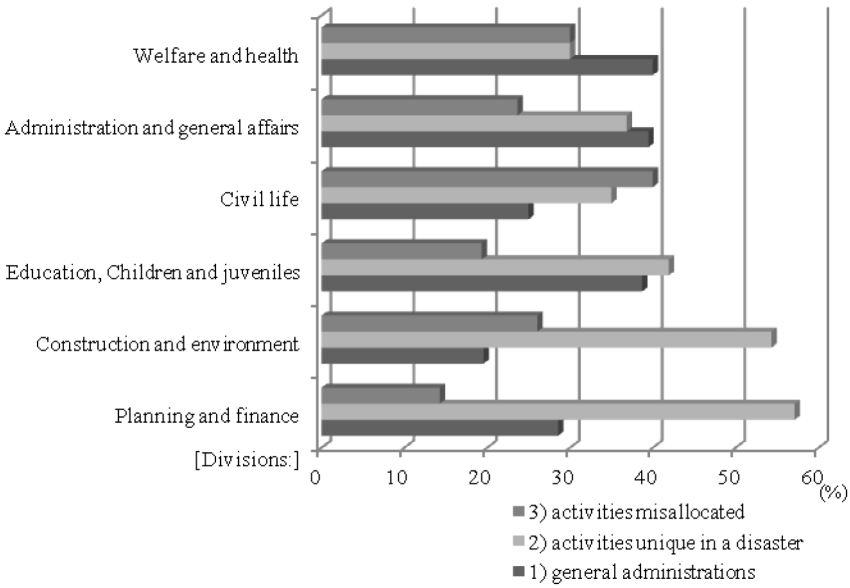

Figure 1: Comparing categorized response activities – number of cards (activities) officials listed.

Officials generally do not conduct activities categorized as 2) and 3). Therefore, both can be considered unique in disasters. The total was the highest in the construction and environment division. With a focus on this division, results of the 2nd convention were examined in the present study.

Considering the percentage of activities categorized as 2), it is obvious that manpower will be in short in a response. Officials in the construction and environment division realized their situation, and countermeasures were discussed by the team: requests for assistance from other divisions, employing retired personnel, and organizing volunteers, etc. Activities often require professional techniques in this division. Pre-disaster arrangement is critical.

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Table 2: Response activities categorized into three (division of construction and environment).

Categorized as	Chapter	Activity
1) general administrations	emergency transport	maintain emergency transport network
		emergency obstacle clearance on road
		debris disposal agreement with Contractors Association
		obstacle clearance in river (small-scale and reached on river bank)
	debris disposal, ensure toilets, and excreta disposal	garbage collection and transport
		excreta transportation system
		maintain manhole toilets
	recover lifeline facilities	recover sewer culvert
	recover public facilities, etc.	emergency responses on roads and bridges
2) activities unique in a disaster	emergency transport	shipping terminal
		select potential locations for emergency temporary landing field
		select emergency obstacle clearance routes
	debris disposal, ensure toilets, and excreta disposal	establish waste stations
		establish temporary waste-collection points
		ensure temporary waste collectors
		arrange cesspool cleaner vehicles
		ensure routes for waste and excreta transport
		ensure domestic water
		formulate a excreta collection plan of temporary toilets
		debris disposal and reuse
		consultation for debris clearance
		contract with debris disposal services
		ensure temporary scrap-yards
		debris disposal
		provide information on debris disposal bearing public expenses
		report debris generation amount to national and prefectural governments
		investigation into soils and stones, bamboo and wood
	recover lifeline facilities	emergency countermeasure in sewage facilities
	recover public facilities, etc.	response to inland water and river
		emergency safety check on public facilities, etc.
	ensure housing and reconstruction	indicate results of emergency safety check
		implement emergency safety check
		investigate into housing damages
		maintain emergency repair ledgers
3) activities misallocated	emergency transport	obstacle clearance in rivers
		ensure transport vehicles, etc.
		transport emergency supplies and manpower, etc.
	debris disposal, ensure toilets, and excreta disposal	stock temporary toilets
		ensure emergency temporary toilets
		ensure equipment and manpower for debris disposal
		separate debris
		disposal of soils and stones, bamboo and wood
	ensure housings and reconstruction	emergency repair of damaged housings
		supply temporary housing
		supply privately-rented housing
		launch temporary housing services

In category 3) activities misallocated, emergency transport of vehicles, supplies, and manpower were found (Table 2). Cooperation with private sectors should be planned. Temporary housing response was also found in this category. Officials considered other divisions should be in charge, while the activity had been conducted by construction related divisions in previous disasters. It is important to set up opportunities for municipal officials to recognize their responsibilities, considering the fact that more than 93% of the members never read the plan before the conventions.

In the division of construction and environment, scripts were provided on emergency debris disposal, including temporary toilets and excreta disposal. Regarding temporary waste-collection, the fact was perceived that river beds cannot be used as collection points (Fig. 2). It is critical to decide collecting

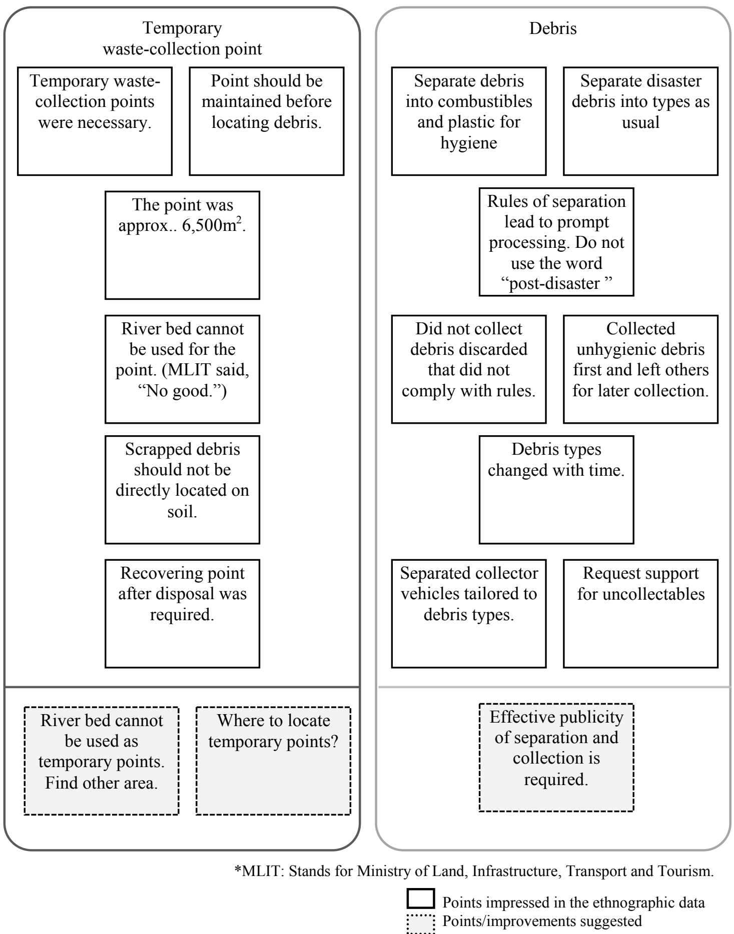

Figure 2: Debris disposal.

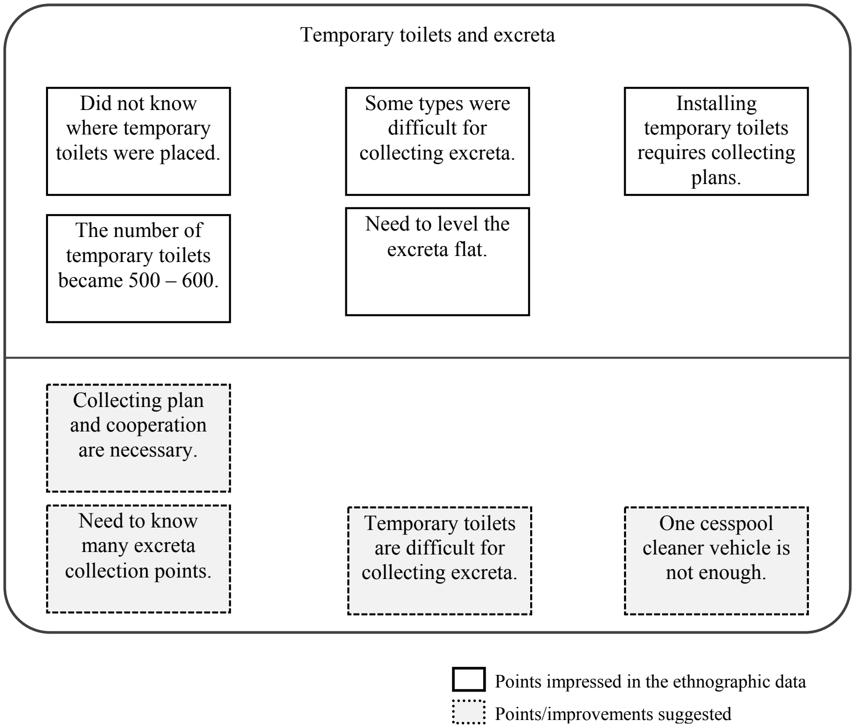

Figure 3: Excreta disposal.

locations in the plan. Candidate sites were discussed. Meanwhile, in debris separation, the importance of publicity was mentioned. Cross organizational discussion is required, which could not be implemented in the convention. Additionally, it was affirmed that normal separation rules for domestic waste should be maintained in disasters.

In the previous disaster, the locations where temporary toilets had been installed were not fully understood. This hindered smooth excreta collection. It was also recognized that the type of temporary toilet employed affected collection. Moreover, the municipality currently owns a single cesspool cleaner vehicle, and any collecting operation will be extremely difficult without taking additional measures. It is critical to prepare a practical and effective excreta disposal plan. Pre-disaster measures should establish plans, including locations and types of temporary toilets, collection points, and cooperation with related organizations in collection, etc.

Other improvements were suggested regarding assistance from unaffected municipalities, a personnel system, cross-organizational coordination, and stock. As for external assistance, aid teams are preferred to be self-contained in a disaster, as a host organization is generally severely damaged and incapable of accepting them. In the ethnographic scripts, an unaffected municipality sent a team, and arranged with disposal facilities before deploying without receiving a request, avoiding placing an additional burden on the affected government. Needs were observed for finding disposal facilities which accommodate the regular separation rules of the city.

Six activities were examined and verified through the conventions. The present study particularized the outputs produced by the division of construction and environment. It is essential to reflect on the improvements indicated through the conventions into the regional disaster management plan. In order to achieve the actual and effective plan, coordination with related divisions should be performed.

7 Conclusion

The present study

1) proposed a method to examine disaster response activities written in a regional disaster management plan of a municipal government. Using ethnographic data of past disasters, present municipal officials pictured the image of a disaster response. Necessary improvements in the plan were discussed and identified.
2) shows that response activities in a regional disaster management plan were divided into three categories: 1) general administration, employing standard skills but increased workload, 2) activities unique in a disaster, and 3) activities which are misallocated. Municipal officials generally do not conduct activities categorized as 2) and 3).
3) indicates that the amount of response activities unique in disasters was prominent, especially in the divisions: construction and environment, and planning and finance. Taking account of recent job cutbacks in municipalities, the imbalance between workload and manpower is apparent.
4) demonstrates that this method helps municipal officials recognize the current situation where organizational structure hinders prompt response. It is crucial to establish opportunities to understand their administrative tasks in disasters and to prepare cross-organizational cooperation and coordination.

Improvements suggested in the present study are important. However, further coordination among divisions and organizations are needed in some cases. Concerning activities categorized as misallocated, conducting inquiries to divisions will be advisable in addition to the proposed method.

This study was also limited in that a convention team worked on a single operational activity. Future studies will target other activities, and will implement operational manuals regarding the activities unique in disasters pointed out in the present study.

Acknowledgements

We thank the municipal officials who cooperated in the present study. This study was funded by the Asahi Glass Foundation. We would like to express our great appreciation for their support. We also wish to acknowledge the support in English provided by John B. Laing, an associate professor of Fuji Tokoha University. We express our sincere gratitude to everyone who cooperated.

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An integrated model of psychological preparedness for threat and impacts of climate change disasters

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Abstract

The reality of unfolding global climate changes and their increasingly evident impacts with respect to the frequency and intensity of natural disasters all over the world gives the matter of psychological preparedness for disasters a compelling currency and relevance. *Psychological preparedness* differs from household or physical preparedness in that what is referred to is an intra-individual and psychological state of awareness, anticipation, and readiness - an internal, primed, capacity to anticipate and manage one's psychological response in an emergency situation. Results of many studies suggest that personality is fundamental to the understanding of resilience and preparedness for disaster.

The aim of the present study was to apply the method of response functions (MRF) for the development of nonlinear integrated model of individual *psychological preparedness* from data and prior knowledge or information on several personality variables: trait anxiety, self-efficacy, dispositional optimism and self-esteem. The proposed model can be applied as effective assessment tool not only for the basic level of psychological preparedness but also for indication of the most important variables for pre-impact intervention.
Keywords: psychological preparedness, integrated model, psychological predictors, method of response functions.

1 Introduction

Natural disasters, such as floods, cyclones, tsunami, droughts, etc. are predicted to increase as a consequence of climate change. The series of disasters that

WIT Transactions on The Built Environment, Vol 133,
www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/DMAN130121

happened just within this millennium – Hurricane Katrina, the tsunami in Indonesia and other countries, earthquakes in Haiti, New Zealand, Chile and Japan, the flooding in Sri Lanka, Pakistan, the Philippines, Australia, China, and Brazil – point out two things: disasters happen everywhere and they happen more frequently. Disasters are complex and uncontrollable events that can elicit a negative emotional response (e.g. stress, fear and anxiety). While such emotions are normal in response to perceived threat, an inability to manage stress can lead to a number of negative outcomes such as: a) cognitive disruption e.g. disorientation and problems with attention and memory, b) poor decision making and judgement, c) maladaptive behaviours e.g. denial and avoidance, and d) negative psychological outcomes post-disaster e.g. post-traumatic stress, depression, and anxiety.

The reality of unfolding global climate changes and their increasingly evident impacts with respect to the frequency and intensity of natural disasters all over the world gives the matter of psychological preparedness for disasters a compelling currency and relevance.

Pre-impact psychological assessment and intervention has been an area of surprising omission in multidisciplinary writings about human response to natural disaster. This is not to say that an extensive literature on human response to natural and man-made hazards does not exist, but much of this discourse relates to either post impact stress and coping issues or organizational preparedness and response (Morrissey and Reser [1]).

Disaster preparedness describes the self-protective or precautionary behaviours that can be harnessed to protect from hazard events threatening one's life and property (Duval and Mulilis [2]; Hobfoll [3]; Paton *et al.* [4]). In the disaster context, *preparedness* is an essential component of all disaster management models and frameworks, but typically focuses exclusively on what *household preparations* and *actions* one should take to protect oneself and family and to prevent or mitigate damage and human and financial costs and loss.

The most widely employed classification of disaster preparedness has three categories:

a) Material Preparedness: The material preparedness includes durable modifications of the household such as fixing tall and heavy furniture or water heater to the wall and possession of various pieces of equipment useful during a disaster such as food and water supplies, fire extinguisher or first aid kit.

b) Planning Activities: The preparedness activities include some arrangements. For example, determining a safe place in the house or identifying a meeting place outside the house.

c) Knowledge and Skills: The third category reflects individual's knowledge and skills about disaster itself and about preparedness methods such as joining a first aid course or reading the materials about preparedness.

Also, disaster researchers have posited many factors that could predict disaster preparedness behaviour. These factors include socio-demographic variables (e.g., age, household income, having school children in the home and level of education), and experiential components (e.g., having been through previous severe past earthquake experience, having relatives who suffered from injury or loss).

Psychological preparedness differs from household or physical preparedness in that what is referred to is an intra-individual and psychological state of awareness, anticipation, and readiness - an internal, primed, capacity to anticipate and manage one's psychological response in an emergency situation. Individual and community psychological preparedness in the natural disaster context has proven to be one of the most effective resilience-conferring strategies available in the context of natural disasters (Reser and Morrissey [5]).

We are aimed to draw the main focus from building codes, fire prevention, evacuation plans, and other important logistical and organizational preparations as well as proactive and resource-based theories of stress and coping and to develop a self-assessment tool that measures psychological resilience and preparedness for a disaster. Understanding psychological factors related to preparedness are central to the efforts to reduce the negative effects of disasters.

A better understanding of one's own and other's psychological response in natural disaster warning situations helps people to feel more confident, more in control and better prepared, both psychologically and in terms of effective emergency planning. Being cooler, calmer and more collected is also a substantial aid to family members and others who may not be as well prepared for what is happening. Psychological preparedness can assist people to think clearly and rationally, which in turn may reduce the risk of serious injury and loss of life (Reser and Morrissey [5]).

Psychological preparedness can play a crucial role in emergency preparedness, in coping with the stress of the unfolding situation, and in limiting acute post-incident distress.

2 Predictors of psychological preparedness

The value and effectiveness of psychological preparedness advice in natural disaster warning situations has received initial and promising empirical support (Morrissey and Reser, 2003), and draws from extensive, evidence-based clinical and health research literatures (e.g., Zeidner and Endler [6]).

Results of many studies suggest that personality is fundamental to the understanding of resilience and preparedness for disaster. A number of models of psychological preparedness exist based predominantly on proactive and resource-based theories of stress and coping, such as the Conservation of Resources Model (Hobfoll [3]), the Warning and Response model (Lindell and Perry [7]), and the Proactive Coping model (Aspinwall and Taylor [8]).

Mulilis and Duval [9] in their "Person Relative to Event Model" examined the self efficacy (beliefs regarding personal capacity to do something) and response efficacy (perceptions of whether personal actions will reduce a problem) as person variables, and severity (estimated degree of destructiveness of a potential earthquake) and probability of occurrence of event (the idea of the time of a potential earthquake) as event variables in predicting earthquake preparedness behaviour.

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These authors have identified how dispositional or personality factors play pivotal roles in this decision making process. It can thus be argued that certain internal traits, values, beliefs, cognitive processes, and defences play a role in how human-environment transactions are managed (Bishop *et al.* [10]; Mulilis *et al.* [11]; Sims and Bauman [12]). Human-environment transactions are often motivated by a need for people to feel that they can exercise control. Consequently, a belief in being able to exercise control has proven to have significant influence on people's hazard resilience. The constructs of locus of control and self-efficacy have thus been implicated as predictors of preparedness (Bauman and Sims [13]; Paton *et al.* [4]; Yates *et al.* [14]).

A great deal of prior research on disaster preparedness has been undertaken, with a number of key influences of preparedness identified (see Becker *et al.* [15] for a review). Key influences include risk perception; preparedness perceptions such as outcome expectancy; critical awareness; optimistic and normalisation biases; self-efficacy; collective efficacy; fatalism; locus of control; previous experience; societal norms; sense of community; community participation, articulation of problems and empowerment; trust; perceived responsibility; responsibility for others; coping style; and resource issues.

These are not the only dispositional characteristics that can be invoked to account for differences in preparedness.

Self-esteem is a favourable or unfavourable attitude toward the self (Rosenberg [16]). It is an individual's sense of his/her value or worth, or the extent to which a person values, approves of, appreciates, prizes, or likes himself/herself (Blascovich and Tomaka [17]). According to (Hobfoll and Lilly [18]), self-esteem, being a robust resource, is resilient to threat of loss. Those who have built a stronger armamentarium of personal, social, economic and other sustaining resources will be better suited to adapt to possible dangers by building on their already durable resource reserves in a proactive fashion (Updegraff and Taylor [19]). Thus, people armed with a robust resource like self-esteem would show greater preparedness before the disaster strikes. Hence, self-esteem, a robust psychological resource (Hobfoll [20]), becomes the motivating factor for preparedness. People prefer to invest resource in impending disaster situations. People having high self-esteem have more sense of worth. They will protect themselves from a self-esteem threatening situation (Loewenstein and Lerner [21]).

Self-efficacy is defined as the perceived ability to organize and execute courses of action to achieve a desired outcome. This concept is shown to influence precautionary behaviour and how well people respond emotionally and behaviourally to stress. Those with positive views of their own efficacy are more likely to try harder to succeed and persist in the face of challenges (Norris [22]).

Self-efficacy reflects the perceptions of personal capacity to do something and outcome efficacy is the measuring of the perceptions of necessary actions in reducing a problem. In the present study, The "Person relative to event" model, using for earthquake preparedness, predicts that increasing levels of threat when resources are appraised as sufficient relative to the magnitude of the threat will increase problem-focused coping (Mulilis and Duval [23]). In the studies (Mulilis and Duval [9]), according to their resources, participants were assigned to groups as clearly sufficient, probably sufficient, and clearly insufficient relative to the magnitude of the threatening event.

Findings showed that, participants in the clearly sufficient resource condition evidenced greater change in preparedness levels than did those in the probably sufficient and clearly insufficient resources condition, and participants in the probably sufficient resource condition evidenced greater change than clearly insufficient condition (Duval and Mulilis [2]). The study of (Paton *et al.* [4]) in disaster preparedness showed that both self-efficacy and outcome efficacy predicted problem-focused behaviour or action coping being linked to earthquake preparedness behaviour.

Dispositional optimism refers to the anticipation that good outcome will occur when confronting major problems (Scheier and Carver [24]). This quality is considered to be a determinant of sustained efforts to deal with problems, as contrasted with turning away and giving up. Individuals that possess this quality are more likely to sustain disaster induced depression than those who do not have it. Optimism has a proven negative relationship to depression and is a strong predictor of the use of problem-focused coping strategies and better cognitive and emotional functioning (Karademas [26]).

Norris identifies optimism, hope, and self-esteem as three concepts necessary to understand resilience; defined as "the process of, capacity for or outcome of successful adaptation after trauma, adversity, or severe stress" (Norris [22]). According to Norris, optimism has been shown to be a key protective factor for disaster.

Optimists and pessimists respond and cope differently with stress. Two forms of coping with stress include problem-focused coping and emotion-focused coping. Problem-focused coping is closely related to optimism and typically shown in situations where people believe something positive can be done about the stressor. This statement agrees with the literature that says optimists are more likely to have stronger problem solving skills (Karademas [26]). Emotion-focused coping is not directly associated but rather is related to pessimism. This form of coping attempts to limit emotional distress and is employed when people feel forced to endure the situation. However, if someone feels that they cannot escape or moderate the stress, they may disengage as a response to the stressor. Problem-focused coping strategies are more concentrated on the actual stressor; while emotion focused coping strategies attempt to deal with the emotions that arise from the stressor (Nes and Segerstrom [27]).

There are multiple theoretical reasons for expecting that the stress inoculation and management components of the psychological preparedness material might be less effective for individuals characterised by moderate to high chronic anxiety (e.g., Gist and Lubin [28]; Lazarus [29]; Watson and Clark [30]).

Potential future disaster can represent a source of anxiety because of their destructive consequences. If this anxiety is present at appropriate level, there is a positive relationship between anxiety and disaster preparedness behaviour. Lazarus [29] stated that, when anxiety is dispositional in character, people tend to appraise any situation as threatening; and those who are high in trait-anxiety scores are more likely to take adaptive adjustments to disaster.

On the other hand, if anxiety reaches an extreme level, it can reduce the likelihood that people will prepare for disasters (Paton *et al.* [4]). According to the study (De Man and Simpson-Housley [31]), high trait anxiety was positively related to the perceived threat. Person "Relative to Event Model" suggested that under conditions in which resources are appraised as insufficient relative to threat, increasing absolute levels of perceived threat and anxiety will decrease problem-focused coping, and so decrease disaster preparedness behaviour (Mulilis and Duval [23]).

It was also the case that the overall level of preparedness for more highly anxious individuals might be expected to be relatively low, possibly reflecting selective avoidance strategies and an escalating experience of anticipatory stress and panic. Previous research has shown that trait anxiety is positively associated with experienced stress in an emergency situation and inversely related to physical preparedness (e.g., De Man and Simpson-Housley [31]; Dooley *et al.* [32]).

Despite the amount of research that has taken place, there are still gaps in our knowledge about the socio-psychological processes related to preparing (Tierney *et al.* [33]).

3 The method of response functions

All the studies of preparedness mentioned above used statistical analysis procedures such as correlation analysis, stepwise linear regression, analysis of variance, discriminant analysis, or similar statistical techniques based on the general linear model or one of its multivariate generalisations. The problem is that such approaches do not yield information about linkages between causes and effects, especially in case of nonlinearity of interactions within system under study. The limitations of such models as exploratory and predictive tools are well known and describe elsewhere (e.g. Maxwell [34]).

Modelling for studying the behaviour of large, complex systems such as psychological phenomena presents considerable difficulties. These difficulties result from the sheer complexity of internal system behaviour arising from dynamic and multidimensional nonlinear interactions. Compounding this complexity is our incapacity to measure internal system states as comprehensively and accurately as we would like, and to perturb system inputs and parameters so that we can observe and understand individual aspects of system's behaviour.

In our study we propose the 'method of response functions' (MRF) as a method of the construction of purposeful, credible integrated models from data and prior knowledge or information. Integration means capturing as much as possible of cause-effect relationships and describing them with an operator of transition, or ''input–output'' function. The data are usually time or spatial series observations of system inputs and outputs, and sometimes of internal states. Data series observations contain "hidden" information on the processes under consideration and one of the main purpose of the proposed method is to ''extract'' and describe these hidden relationships. The method of response functions implies credible models in the sense that they are identifiable, and, hopefully, explains system output behaviour satisfactorily. The theory of the method of response function and its applications has been described in several articles and monograph (Malkina-Pykh and Pykh [35, 36]).

The MRF is an exploratory data analysis technique that attains this aim by condensing large amounts of data into nonlinear regression model that relays important relationships in the most economical manner. The MRF can model nonlinear relationships among variables, can handle nominal or ordinal data, and does not require multivariate normality. This approach allows us to take into account all essential features of psychological systems: complexity, multidimensionality, uncertainty, irreducibility, and so on.

Let us assume the basic definitions of the MRF. By factors we mean the system's properties that directly affect processes or characteristics under study. We designate the factors as a vector $x = (x_1, x_2, \ldots, x_n)$. Then, by ***partial response function*** of the characteristic or the process we mean a function which depends on a single active factor, i.e. the function of a single variable $f_i(x_i)$. In many typical cases, the graph of the partial response function f_i to the variability of the factor x_i is a unimodal or *S*-shape curve. By ***generalised response function*** we mean a function $F(x_1, \ldots, x_n)$ which accounts for all the factors considered and presented as a combination of partial response functions $f_i(x_i)$. A generalised response function can also be determined as an *N*-dimensional geometric figure, or its data matrix equivalent, which gives the levels of an important system response as a function of combinations of levels of the factors to which that system is exposed.

Thus it is necessary to note, that designation of the system's characteristics as factors and responses is entirely determined by statement of a problem.

Now we propose to present the generalised response function in the form

$$F(x_1, \ldots, x_n) = \prod_{i=1}^{n} f_i(\alpha^i, x_i), \tag{1}$$

where n is the number of the factors under study, α^i is a vector of parameters, the values of which we have to determine in the process of identification. Basically, it has been criticised that the multiplicative form represents the independence of the influencing factors. We'll demonstrate later that this problem can be resolved successfully using some specific technique for the evaluation of parameters of the generalised response function $F(x_1, \ldots, x_n)$. We introduce also the additional restriction in the identification procedure:

$$\max_{x_i} f_i(\alpha^i, x_i) = 1 \tag{2}$$

It is evident that standardisation condition (2) gives us a possibility to compare the impact of different factors on the process under study.

The aim of the present study was to apply the method of response functions (MRF) for the development of nonlinear integrated model of individual *psychological preparedness* from data and prior knowledge or information on several personality variables: trait anxiety, self-efficacy, dispositional optimism and self-esteem. These independent variables were used for the construction of the PREP model. The proposed model can be applied as effective assessment tool not only for the basic level of psychological preparedness but also for indication of the most important variables for pre-impact intervention.

4 Integrated model of psychological preparedness

Then the model of psychological preparedness (PREP) is looking as follows:

$$
\begin{aligned}
&PREP_{\mathrm{mod}} = PREP_{norm} \cdot F_{st} \\
&F_{st} = f_1(OPT) \cdot f_2(EST) \cdot f_3(SEF) \cdot f_4(ANX) \\
&f_j(x_j) = \alpha_j \left(\frac{b_j}{c_j + \exp(d_j - \gamma_j \cdot x_j)} \right) \qquad j=1,2,3 \qquad (3) \\
&f_4(ANX) = \alpha_4 (b_4 - c_4(1 - \exp(-d_4 \cdot ANX^{\gamma_4})))
\end{aligned}
$$

where $PREP_{\mathrm{mod}}$, $PREP_{norm}$ are the actual values of psychological preparedness measure resulted from the modified Psychological Preparedness to Disaster Threat Scale (PPDTS) and mean score in the given sample, *OPT* are the scores of dispositional optimism, *EST* are the scores of self-esteem, *SEF* are the scores of self-efficacy *ANX* are the scores of anxiety, F_{st}, f_j are the generalised and partial response functions respectively, $\alpha_j, b_j, c_j, d_j, \gamma_j$ are parameters for evaluation, $j = 1,..,4$.

As function (3) is nonlinear in parameters, the problem of parameter estimation can be solved only by numerical methods. The parameters are determined by minimising the sum of squared differences between estimated data and survey measurements. The corresponding parameters estimation is provided with the module "lsqnonlin" from the program package MATLAB Optimization Toolbox. We enter the coded values because the "natural" measurements of personality variables under study had different ranges that might cause difficulties for the parameter's estimation procedure. All raw scales are linearly converted to a scale from 0 to 10, with a higher score indicating higher levels of personality variables. We identify the parameters by using several initial approximations, until the process converged to a single point and checked the obtained results using the convergence criteria for nonlinear optimisation procedure. Nevertheless, the final solution is selected according to the following guidelines of psychological relevance: (1) the selected parameter

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values should keep the residual errors between model and data as small as possible but not greater than the value of standard error of measurement; (2) parameter estimates should make psychological sense. For example, a reasonable view of the partial response function graphs should be obtained for the variables under study.

Another guideline is the absence of other solutions in the vicinity of the found solution.

5 Future research directions

To be able to provide the identification of parameters of PREP model and its validation we are collecting data on psychological preparedness and its psychological predictors in the sample in Novorossisk, city located on the Black Sea shore in Southern Russia where climate change disasters such as storm wind, flooding and earthquake occur now very often.

Demographic variables include age and gender. Subjects are assessed with the following measures: Self-esteem Scale (Rosenberg [16]), General Self-Efficacy Scale (Schwarzer and Jerusalem [25]), Life Orientation Test (LOT) (Scheier *et al.* [37]), Trait Anxiety Scale of the State-Trait Inventory (STAI) (Spielberger *et al*. [38]).

Disaster preparedness is evaluated with the 14-item preparedness scale based on 18-item Psychological Preparedness to Disaster Threat Scale (PPDTS) (Zulch [39]). Sample instructions and items include, "I am familiar with the severe storm or cyclone preparedness materials available to me", "I know which household preparedness measures are needed to stay safe in a very severe storm or cyclone situation", "In a severe storm or cyclone situation I would be able to cope with my anxiety and fear". Respondents are asked to indicate the extent of preparedness with regard to each item in the scale by checking either 'yes' (score = 3), 'unsure' (score = 2), or 'no' (score = 1).

Russian-validated translations of all measures are used.

6 Conclusions

In the present study we proposed the method of response functions (MRF) for the development of nonlinear integrated model of individual *psychological preparedness* from data and prior knowledge or information on several personality variables: trait anxiety, self-efficacy, dispositional optimism and self-esteem. These independent variables were used for the construction of the PREP model. The proposed model can be applied as effective assessment tool not only for the basic level of psychological preparedness but also for indication of the most important variables for pre-impact intervention.

To be able to provide the identification of PREP model's parameters and its validation, at the moment we are collecting data on psychological preparedness and its psychological predictors in the sample in Novorossisk, city located on the Black Sea shore in Southern Russia where climate change disasters such as storm wind, flooding and earthquake occur now very often.

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Healthcare providers: will they come to work during an influenza pandemic?

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Abstract

The objective of the study was to examine available evidence on healthcare providers' willingness to report to work during a pandemic influenza and on related measures. Limited to scholarly journals, a search in nine databases produced 206 studies, 28 of which met inclusion criteria and were discussed in depth this review. Six studies posed an avian influenza scenario, four studies were conducted during the 2009/2010 global H1N1 pandemic influenza and the remaining 18 studies examined willingness to report to work under a scenario that was related to a pandemic influenza but the type of flu was under-specified. Willingness to report to work varied dramatically among the 28 studies, from a low of 23.1% to a high of 93.1%. Heterogeneous methods employed by researchers make it hard to generalize and draw practical conclusions. Preliminary evidence suggests that physicians may be more willing to report to work than nurses. Given the current state of the literature and the need to estimate workforce availability for preparedness planning, worst case scenario planners may cautiously assume that 1 in 4 healthcare providers will be willing to report to work during a pandemic influenza, not accounting for those who are ill. Because physicians demonstrated higher willingness, the 1 in 4 estimate could be adjusted upward for this provider group.
Keywords: healthcare providers, willingness to report to work, influenza pandemic.

www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/DMAN130131

1 Introduction

The 2009 H1N1 virus produced the first flu pandemic in over 40 years (CDC [1]). Between April 2009 and April 2010 the H1N1virus was responsible for an estimated 43 million to 89 million illnesses, 195,000 and 403,000 hospitalizations, and an estimated 8,870 to 18,300 deaths (CDC [1]). Though underestimated the World Health Organization (2010), published studies suggest that 20–40 percent of populations in various regions of the globe were infected (Chan [2]).

Pandemics have a long-standing history and have been recorded since the 16th century at intervals ranging between 10 and 50 years with varying severity and impact (WHO [3]). Most notable was the severe pandemic of 1918, the Spanish Flu that killed more people than the Great War, known today as World War 1 (Stanford University [4]). Caused by subtype H1N1 the 1918 pandemic was accountable for illness in approximately 20 to 40 percent of the world's population and more than 50 million deaths (USDHHS [5]). The flu was most deadly for those individuals between 20 and 40 years of age (Stanford University [4]). An estimated 28 percent of all Americans contracted the virus resulting in an estimated 675,000 deaths (Stanford University [4]). In many cities, more than half of all families had at least one victim ill with influenza (Barry [6]). Lesser pandemics followed; in1957, the Asian Flu killed approximately 70,000 Americans and the Hong Kong Flu in 1968 pursued with 34,000 deaths (USDHHS [7]).

Differences amongst outbreaks are primarily related to the severity of infection and virulence of the viruses responsible for the outbreak. The 20th and 21st century pandemics share similar characteristics. In each occurrence, approximately 30 percent of the United States population developed the affliction, with half seeking medical care (USDHS [8]). Children under age 18 typically have the highest rate of illness, morbidity and mortality. Geographically each pandemic was rapid and essentially all communities experienced out breaks (USDHS [8]).

If the outbreak is severe, as with the Spanish Flu the impact on society may include a 40 to 50 percent absentee rate among healthcare workers; an overwhelmed healthcare system; interruptions in the functions of societal infrastructure elements such as transportation, supply chains (including medical supplies), water, electricity, financial systems; and the weakening of the overall economy (AHRQ [9]). The national response and contingency plans suggest healthcare workforce shortages may well occur due to illness and mortality among the healthcare providers (OSHA [10]). In addition to illness, unwillingness to report to work during a pandemic outbreak is another factor contributing to healthcare worker shortages.

Emergency preparedness planning is dedicated to finding ways to decrease suffering and minimize the loss of life. Healthcare professionals play a critical role in the disaster response workforce. An effective plan begins with an adequate quantity of healthcare professionals who are able and willing to report to work in a pandemic influenza. Adding to the complexity is the aging healthcare workforce which will impact the number of available personnel physically capable of working in a disaster like environment (NCDMPH [11]). A predicted shortage of 100,000 physicians and 300,000 to 1 million nurses are projected over the next ten years (NCDMPH [11]). In addition, the number of nurses (77%) are 50 year of age or older which will add to the severity of the shortage (NCDMPH [11]).

Present day pandemic threat is linked to an outbreak of avian influenza by the H5N1 strain of the influenza A virus (Homeland Security Council [12]). Transmitted by infected poultry, hundreds of millions of chickens, ducks, turkeys and geese have died or been culled to prevent the spread of the virus (Kilpatrick *et al.* [13]). A total of 608 confirmed human cases, 359 deaths were reported to the World Health Organization (WHO) between January 2003 and August 10, 2012 from a number of countries in Asia, the Near East, Africa, and Europe (WHO [14]). Currently limited to poultry workers the virus has shown an inability to spread from human to human. However, the possibility of mutations over time raises fears and apprehensions that the virus will become communicable between humans with disastrous consequences (USDHHS [5]).

An influenza pandemic will place tremendous burden on the healthcare system. In fact, as in 1918, an influenza pandemic could quickly rise to a level of a catastrophic incident resulting in mass fatalities; placing overwhelming religious, cultural, and emotional problems on local jurisdictions and the family of the victims (USDHHS [7]). Based on these characterises, federal planning estimates suggest the number of people seeking medical care may rise to 50 percent (USDHHS [7]). The demand of intensive care beds and ventilator services may increase by 25% (USDHHS [7]).

For this type of disaster response characterized by a surge of patients with symptoms, three occupational groups of healthcare providers are essential: physicians, nurses, and emergency medical personnel. Emergency and critical care physicians, critical care nurses, and paramedics are of particular importance (NCDMPH [11]). In addition, a multi-disciplinary team of doctors, nurses, pharmacists, respiratory therapists, and other healthcare professionals to maintain a continuum of care. Infrastructure support members, ancillary staff members who provide nutritional and environmental services, maintenance, and medical supplies are also essential to ensure operations (OSHA [10]).

Therefore, an effective response begins with an adequate healthcare workforce ready, able and willing to respond to the surge of patients. Reallocating healthcare professionals from non-acute care facilities, recruiting retired healthcare professionals, reserve or military medical and nursing personnel, and qualified volunteers will be essential to meet the workforce demands (AHRQ [9]).

It is imperative for workforce planning to have accurate data demonstrating healthcare providers' willingness to report to work. But what is known of healthcare professionals' willingness to report to work? Chaffee [15] presents a systematic review of 27 articles published between 1991 and 2007, identifying certain factors influencing the willingness to work. A number of disaster scenarios – weather-related, radiological, nuclear, biological, and chemical –

were examined. Chaffee cites a biological outbreak as a significant barrier to willingness to work referring to one study that reported the lowest willingness to report to work rate that was observed in response to a scenario of a hypothetical pandemic influenza outbreak in New York City. A mere 11 percent of healthcare aides and 37 percent of registered nurses were willing to take care of patients infected with the influenza (Gershon *et al.* [16]). Most participants in the Gershon *et al.* [16] study were female, home healthcare aides, and likely low-wage earners who were concerned about child care if schools were closed and feared for personal and family safety. Chaffee recommends that future researchers enhance their measurement tools in order to build confidence in the data and utilize information for preparedness planning.

While Chaffee's review includes various natural disasters, pandemic influenza was not individually addressed. Even though some studies have attempted to answer the question of how many healthcare providers will report to work during a pandemic influenza event, no systematic review exists. This study seeks to fill this gap by reviewing studies that specifically examined healthcare providers' willingness to report to work during influenza pandemics. Furthermore, what is known of the willingness of the three provider groups – emergency and critical physicians, critical nurses and paramedics – who are best able to provide care in a disaster with surge capacity? Can preparedness planning be enhanced by generalizing the results from the available studies?

2 Method

Nine databases were reviewed for sources: Cinahl (1950 – 2011); CSA Illumina (earliest–2011); Healthcare Reference Center (all); Health Sciences (1879–2011); Health Source (all); Nursing and Allied Health (all); Medline (1992–2011); ProQuest (all); PubMed Central (all); and Google Scholar (1950–2011) in December 2009, followed by additional searches in December 2010 and in May 2011. Keywords for search included willingness to report to work, to respond, to risk one's life and care for patients, to provide clinical services; likelihood of reporting, of working or continuing to work in a pandemic influenza; as well as barriers and strategies to enhance willingness. Article reference lists were manually examined to identify further applicable studies.

All titles and abstracts were reviewed to remove duplicates. A full review of the article was completed if it met inclusion criteria requirements: a study published in a peer-reviewed scholarly journal, study participants are healthcare providers and results are reported on willingness/likelihood to report to work during an influenza pandemic. Articles and abstracts that met the inclusion criteria (n = 206) were thoroughly examined in full text. Scholarly articles that presented original research were further examined utilizing methodology modified from Shi [17]. Then comparative tables were constructed demonstrating response rates, sampling methods and respondent characteristics; operational definitions of dependent variables and author-stated percentage of willingness to report to work; as well as any other significant findings and notes. The quality of the research design was analysed for each of the included studies.

3 Results

3.1 Literature search

A systematic literature review of nine electronic data bases completed in May 2010 revealed 263 records with any of the following keywords Healthcare Providers' (HCPs') willingness to report to work, willingness to respond, likelihood of reporting to work, likelihood of working and likelihood of continuing to work during a pandemic. The process used for identifying 28 studies included in this review is summarized in figure 1. Three relevant qualitative studies were also obtained but their number was too small to conduct a separate review.

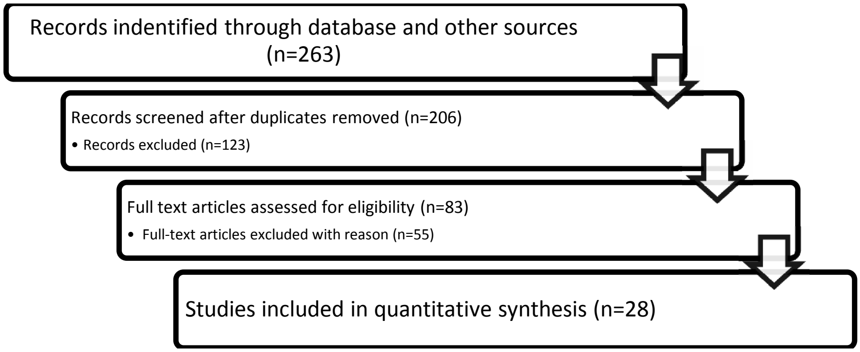

Figure 1: Systematic literature review process.

3.2 Geographic location

Most studies (15 or 53% representing 16,847 study participants) were conducted in the United States and the remaining studies came from Australia, China, Egypt, Japan, Taiwan and the United Kingdom (14,816 study participants). Due to the limited number of studies from the same country, the only possible comparison was US vs. non-US. As shown in table 1, US average willingness to work was 68.65%, as compared to 63.22% in non-US studies.

3.3 Influenza pandemic events

Four studies were completed during the actual H1N1 pandemic global outbreak of 2009/2010 as shown in table 1. In these studies, willingness to report to work varied from 23.10% in Wong *et al.* [21] to 90.10% in Martin [18], M = 63.50. Martin [18] examined factors affecting nurses' ability and willingness to work during an on-going pandemic influenza. This large study included 22,000 nurses who resided in the state of Maine, United States. Similarly, Saleh and Elshaer

[19] conducted their study when the country of Egypt was on the edge of the pandemic. The purpose of the study was to assess the effect of the 2009 H1N1 pandemic on nurses' working behaviour, identify willingness to work, concerns and persuading factors towards working during an actual pandemic. The remaining two studies were conducted in China during the second wave of the same pandemic. Ma *et al.* [20] assessed the knowledge and attitudes of critical care clinicians in ICUs while Wong *et al.* [21] explored the willingness of Hong Kong community nurses to continue to work during the H1N1 pandemic. As can be seen even from this brief description, the researchers focused on different populations (nurses vs. ICU critical care clinicians) and assessed willingness to work at different points of the global outbreak, which may account, at least in part, for an extremely wide range of findings. Nevertheless, the context in which these studies were performed – an unfolding pandemic – elevates the significance of these findings above and beyond the findings from studies that elicited responses to hypothetical scenarios.

Table 1: Author, country of origin, event, sector, respondents, and percent willingness to report.

Study Author/Year	Country	Event	HC Sector	HCP Type	No of Respondents	Percent Willingness
Balicer *et al* 2006 [32]	US	IP	Public Health	Various	308	53.80
Balicer *et al* 2010 [33]	US	IP	Hospital/HCS	Various	3,426	82.50
Barnett *et al* 2010 [34]	US	IP	EMS	EMS	586	93.10
Barnett *et al* 2009 [28]	US	IP	Public Health	Various	1,835	92.00
Basta *et al* 2009 [31]	US	IP	Public Health	Various	2,414	56.20
Cone *et al* 2006 [29]	US	IP	Hospital/HCS	Various	1,711	72.00
Cowden *et al* 2010 [35]	US	IP	Hospital/HCS	Various	778	60.00
Damery *et al* 2009 [36]	UK	IP	Hospital/HCS	Various	1,032	59.30
Daugherty *et al* 2009 [37]	US	IP	Hospital/HCS	Various	256	79.00
Garnett *et al* 2009 [38]	US	IP	Hospital/HCS	Various	2,864	75.60
Gershon *et al* 2010 [16]	US	IP	Home Care	Various	384	27.00
Hope *et al* 2009 [39]	Australia	IP	Hospital/HCS	Nurses	47	47.00
Hope *et al* 2010 [30]	Australia	IP	Hospital/HCS	Various	868	67.00
Imai *et al* 2009 [40]	Japan	IP	Hospital/HCS	Various	7,378	74.50
Irvin *et al* 2008 [22]	US	AI	Hospital/HCS	Various	169	50.00
Ma *et al* 2011 [20]	China	H1N1	Hospital/HCS	Various	695	82.30
Martin 2011 [18]	US	H1N1	Other	Nurses	735	90.10
Martinese *et al* 2009 [23]	Australia	AI	Hospital/HCS	Various	560	64.00
Saleh & Elshaer 2010 [19]	Egypt	H1N1	Hospital/HCS	Various	266	58.50
Schechter 2007 [26]	US	AI	Other	Various	198	79.00
Seale *et al* 2009 [41]	Australia	IP	Hospital/HCS	Various	894	83.30
Shabanowitz *et al* 2009 [24]	US	AI	Hospital/HCS	Various	1,003	79.00
Stuart & Gillespie 2008 [42]	Australia	IP	Hospital/HCS	Various	1,440	67.00
Syret *et al* 2006 [43]	US	IP	Hospital/HCS	Various	180	40.00
Tippett *et al* 2010 [44]	Australia	IP	EMS	EMS	725	56.30
Tzeng *et al* 2006 [25]	Taiwan	AI	Hospital/HCS	Nurses	225	57.00
Wong E *et al* 2010 [21]	China	H1N1	Other	Nurses	401	23.10
Wong T *et al* 2008 [27]	China	AI	Other	Physician	285	82.50

IP = Influenza Pandemic
AI = Avian Influenza

Six of the studies presented a well-defined yet a hypothetical avian influenza scenario. Irvin *et al.* [22] examined the willingness of hospital personnel in a Midwestern US medical center to report to work in an avian influenza and factors influencing their decisions. Martinese *et al.* [23] in Australia examined how an avian or pandemic influenza threat would affect hospital staff members' absenteeism while Shabanowitz *et al.* [24] researched willingness of providers at a US medical center. Tzeng and Yin [25] in Taiwan illustrated factors that contributed to nurses' fear about an avian influenza and willingness to care for infected patients. Schechter [26] determined the ability and willingness of the Medical Reserve Corp volunteers to work in a public health emergency (both influenza pandemic and avian flu). Wong *et al.* [27] examined primary care physicians in outpatient clinics for an avian influenza pandemic. In these studies mean willingness to report to work varied from 50.00% (Irvin *et al.* [22]) to 82.50% (Wong *et al.* [27]), M= 68.58.

In the remaining 18 studies, researchers either examined multiple events (3 studies) or one event called "influenza pandemic" (15 studies). Barnett *et al.* [28] examined four events: weather related, pandemic influenza, dirty bomb radiological terrorism, and anthrax bioterrorism. Cone *et al.* [29] also examined multiple disasters scenarios: earthquakes, ice storms, tornados, flood, fire rescue, hurricane, and biological, chemical, and radiation events. Hope *et al.* [30] similarly examined three scenarios: weather related pandemic, and bioterrorism. The presentation of multiple disparate events made it necessary to limit the description of each event scenario. Fifteen studies – Basta *et al.* [31], Balicer *et al.* [32], Balicer *et al.* [33], Barnettt *et al.* [34], Cowden *et al.* [35], Damery *et al.* [36], Daugherty *et al.* [37], Garnett *et al.* [38], Gershon *et al.* [16], Hope *et al.* [39], Imai *et al.* [40], Seale *et al.* [41], Stuart and Gillespie [42], Syrett *et al.* [43], and Tippett *et al.* [44] – examined willingness to report to work exclusively in an influenza pandemic but scenarios varied dramatically from study to study. For example, Basta *et al.* [31] examined both early and peak pandemic duties to assess willingness to report to work contingent on duties requiring direct face to face contact with infected patients. Peak pandemic with high risk duties of direct face-to-face contacted produced a substantially lower willingness to report to work of 56.2%. Hope *et al.* [30] studied clinical nurse consultants, educations, and managers before and after a four-hour education intervention and four-day influenza pandemic exercise. Syrett *et al.* [43] examined willingness of personnel to respond to a mass causality event with a developing scenario. The scenario was a biological event that was non-transmissible with proven prophylaxis and treatment; then a biological event that was transmissible with only experimental prophylaxis and treatment. Before the severity of the incident was known, providers were twice as willing to report to work. Once identified as transmissible, less than 40% were willing to report to work. For the purposes of this research, percent willing to report to work was reported for the worst-case scenario when multiple pandemic scenarios were presented. Of these 18 studies, willingness to report to work varied from 27.00% (Gershon *et al.* [16]) to 93.10% (Barnett *et al.* [34]), M=65.87. In Gershon *et al.* [16]) only 11% of healthcare aides and 37% of Registered Nurses were willing to take care of influenza patients. Three studies (Balicer *et al.* [33], Barnett *et al.* [28] and Barnett *et al.* [34]), including the study with the highest percent willing workers, utilized the Witte's Extended Parallel Process Model, using a threat-and-efficacy based framework. All three studies examined willingness to report to work if required and also if asked but not required. These studies produced similar results with a relatively small range (82.50% to 93.10%) in providers' willingness.

3.4 Healthcare providers: gender and groups

Participants' gender was reported in 24 studies. The majority of the studied providers were female, 71.21%. Their willinness ranged from 34.10% [34] in study of paramedics and emergency medical technicians to 96.20% [21] in a study of community health nurses. Unfortunately only eight studies presented gender specific data on willingness to report to work.

A total of 204 different provider groups were cited in studies. After duplicates were removed, there were 148 provider groups. Descriptions of professions also varied widely. Nurses' perceptions were studied in 25 studies. Their authors described nurse participants as follows: nurses (9 studies), clinical nurse consultants, clinical nurse specialists, community nurses, early childhood nurses, ER nurses, licensed practical nurses, any nurse, nurse educators and nurse managers, nurse practitioners, nurse unit managers, nursing, nursing administration (2 studies), nursing staff (2 studies), nursing assistants (2 studies), nursing students with a lesser degree nursing credential enrolled in a bachelor degree program. Likewise, 17 different labels applied to physician or doctor groups: attending physicians, doctors (2 studies), dentists (2 studies), ER physicians, general practitioners, hospital doctors, house staff/residents or fellows, interns, consultants, internal Medicine House Staff, MD, DO/PhD, medical registrars, medical staff, medical staff specialists, practitioners, registrars (2 studies), and residents. The category of "other" was noted in 5 studies.

The greatest diversity in provider groups was found in studies of hospitals and healthcare systems. For example, Balicer *et al.* [32] initially listed 18 categories of providers spanning foodservice/linen to hospital staff, clinical staff, physicians and nurses. Categories were then collapsed to clinical and non-clinical staff. Irvin *et al.* [22] collapsed seven provider groups into three categories: doctors, nurses, and other. Several studies referred to general department-based groups, such as administration, maintenance, engineering, community health workers, laboratory services, occupational therapy, pharmacy and telecom to name a few. Finally, some authors used broad classifications of professionals, such as allied health professionals, clinical staff, non-clinical staff, clerical staff, management and supervisors.

In sum, researchers used a broad range of labels and inconsistent groupings to describe healthcare workers. The most widely studied provider groups were nurses and physicians, therefore, we examined their willingness in greater detail.

3.5 Percentage of nurses and physicians willing to report to work

We took a closer look at nurses' and physicians' willingness to report to work during an influenza pandemic but the number of studies was small (13 and 7, respectively). Mean willingness to report to work for physicians was 73.64% (range 66% to 87%) and for nurses was 59.82% (range 23.10% to 90.10%).

Four studies included no other provider group but nurses. Their findings varied widely. In Wong *et al.* [21] 23.10% of community health nurses were willing to work during the pandemic while in Martin [18] 90.10% of nurses were willing to do so. Both studies were completed during H1N1 pandemic influenza. In the remaining nine studies the mean percent of nurses willing to report to work was 63.67% and similar to the mean percent of all providers included in these nine studies (62.28%).

3.6 Methodological differences in measuring willingness

Differences that could possibly affect the study findings included item wording, scale type, scale point labels, use of a midpoint or additional response. In half of the studies, researchers used a variety of Likert-type scales, such as from 1 to 4 and from 1 to 100. Fourteen studies used binary checkboxes with yes vs. no, likely vs. unlikely, willing vs. not willing, or would work/respond/volunteer vs. would not work/respond/volunteer. Variations were noted in the presence of a scale midpoint, which may indicate neutrality, or in offering response options such as "do not know," "unsure/undecided" or "not applicable". Dichotomization methods for splitting those willing and not willing to report to work also varied. Some researchers included neutral or midpoint responses into the unwilling group while others excluded such responses from all subsequent calculations. Therefore, due to the different scaling of responses and dichotomization methods, comparisons and generalizations across studies should be made with great caution. It is possible that these methodological differences explain a great amount of variance in findings across the reviewed studies.

4 Summary

4.1 Summary of evidence

A systematic review of 28 studies on willingness of healthcare providers to report to work during a pandemic influenza was completed. Healthcare provider group definitions varied widely and gender-specific data was limited. Researchers primarily studied nurses and physicians but other provider groups were also included, as well as a grouping of all providers within a specific department.

In most studies, the authors failed to specify willingness to report to work by provider category. Therefore, it is too early to generalize provider-specific findings across available studies. The only exception is the comparison of physicians and nurses, which overall showed higher willingness to report to work among physicians, but even this finding should be interpreted with great caution because the number of studies was small and their methodologies varied widely.

5 Practical implications for planning

5.1 Implications for planning and policy

An influenza pandemic will place an enormous burden on the healthcare system; therefore, pre-pandemic planning is essential to reduce morbidity and mortality. An effective response begins with a healthcare workforce that can respond to the surge of patient and maintain the continuum of care. It is essential to have accurate data demonstrating provider willingness to report to work. Future researchers should make every effort to collect data on first responders, emergency and critical care workers, such as emergency and critical physicians, critical nurses and paramedics, whose availability has a strong effect on disaster response. Planning efforts must also take into consideration the number of providers who may be willing but unable to report to work due to illness; a potential absentee rate that may reach 40–50%.

Overall, the 28 studies demonstrate great variability in results from a low of 23.10% study (of community health nurses) during the 2009 H1N1 pandemic) to a high of 93.10% in the study of EMS providers. Given the current state of the empirical literature, worst case scenario planners may be advised to adopt an estimate of 23% of healthcare providers willing to report to work, which could be further adjusted to account for those who are unable to do so due to being ill. If adjusted to reflect the number of providers inflicted with the influenza virus, the estimated percent of providers who are willing and able to perform their duties may fall below 15%, which would have tremendous implications for workforce planning. Because the worst-case evidence comes from the study of nurses, the estimate of 15% may be adjusted upward for physicians who tend to express higher willingness to report to work than nurses.

Though training exercises are mandated by regulatory agencies and are aimed at enhancing response and mitigating the loss of life, limited data is available on the effectiveness of this training and its role in changing provider willingness to report to work. Therefore, a conservative planning approach will incorporate the worst-case scenario while taking into account the possibility of absenteeism due to illness. Meanwhile training programs and other interventions that enhance willingness to report to work must be implemented. Successful programs must be shared with disaster response, academic, and regulatory communities in order to prioritize funding, education, training, and ultimately improve disaster response.

5.2 Limitations

The absence of healthcare sector information, gender, and worker group limited the ability to draw generalizations on willingness to report to work. The studies were limited to those published in English. Only studies published as of May

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2011 were included in the review. This analysis was limited to studies conducted for the purpose of evaluating willingness to report to work in a pandemic influenza. This review did not explore internal or external incentives, or interventions associated with willingness to report to work.

5.3 Conclusions

Our review showed large variations in healthcare providers' willingness to report to work during a flu pandemic. While it is too early to generalize with confidence, a worst-case scenario planning approach was suggested based on the empirical evidence available to us today. Future researchers are encouraged to include tables that show willingness to report to work by healthcare sector, worker type, and gender. For disaster planning analysis and comparison it is essential that worker types be explained. Cowden *et al.* [35] serves as a model providing a detailed description of occupational categories that would be relevant to many researchers. Future researchers should carefully plan their scenario design and make every effort to study emergency and critical care physicians, critical care nurses and paramedics who are at the frontline of providing care during a pandemic outbreak. Barnett *et al.* [34] and Tippett *et al.* [44] provide excellent examples of EMS providers' willingness to report to work. Finally, research-practitioner collaborations during a real-life influenza pandemic event are perhaps the best opportunities to estimate willingness while minimizing social desirability bias.

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Managing public health expectations: the micro community model of bio-preparedness

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Abstract

The cycle of bio-preparedness is formulaic based on threat assessments, public impact, and resources. Since 2007 the resource allocation for bio-preparedness in the United States has been reduced and has shifted focus based on a changing perception of threat and public vulnerability. These resource reductions have mandated a retraction of government involvement in care and distribution of goods in a bio event. Bio preparedness programs now focus almost exclusively on micro community education including self-care and provisioning during an event.

The United States resource commitment to bio-preparedness planning was extensive after the 2001 Anthrax attacks, which, seen in the light of the 9/11 attacks, created a perception of biological vulnerability. This increased perception of threat and possible public impact led to a commitment of vast resources totaling several trillion US dollars between 2001 and 2006. These resources went primarily to preparedness and monitoring activities, which included a series of biological event exercises named "Bioshield" that revealed some startling shortfalls.

This paper will examine the after action reports of three state wide Bioshield exercises; both the outcomes and their recommendations for bio planning improvements. These results will be compared to the implementation events that took place as a result of the 2009 H1N1 "Swine Flu" response, and the subsequent recommendations and refining of bio-preparedness planning. This paper will also include current bio-planning efforts which implement the exercise and post Swine Flu event recommendations of micro-community self-reliance. The intended definition of a micro community for purposes of paper is

WIT Transactions on The Built Environment, Vol 133,
www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/DMAN130141

a grouping of citizens which share a religious, ethnic, or cultural commonality as a basis for communal organization, preparedness, and resilience.

Keywords: bio-preparedness, Bioshield exercise, micro-community readiness, public health, health policy, Strategic National Stockpile (SNS), vendor managed inventory (VMI).

1 Introduction

Focusing events cause people to shift their attention to a singular problem in an attempt to understand and address a unique situation. This focused attention includes policy makers, elected officials and in the case of disaster, also emergency managers. These sudden and vivid events simulate a greater interest in a problem and often induce a policy change (Cobb and Elder [1], Baumgartner and Jones [2]). Because focusing events are significant in history there is often a rally to change either the response to the event or to mitigate similar events from occurring. This influence can come from the people in the form of mass protests and media attention, and usually call for policy makers to act (Birkland [3]). The actions undertaken by politicians and policy makers usually include changes that require budgetary support, and bio-preparedness is no exception.

2 Bio-preparedness budgets

The contemporary history of bio-preparedness in the United States is benchmarked by several important initiatives. The first initiative is the 1999 creation of the Strategic National Stockpile (SNS), a national repository of pharmaceuticals and critical equipment staged throughout the country and available to any city or state within 12 hours or request. Funded by the US Congress in 1999 the SNS includes the Vendor Managed Inventory (VMI) program of specialized supplies that are also available to any US community within 24 hours. The specialization of the VMI allows for the deployment of specific drugs, often directly from the manufacturer. The VMI response to the 2001 Anthrax attacks included Ciprofloxacin hydrochloride (CIPRO) or ciprofloxacin, a synthetic broad spectrum antimicrobial agent for oral administration, was used both for treatment to those with symptoms and those suspected of exposure (Prior [4]).

Funding for the SNS is a reflection of the overall commitment to the bio-preparedness program. During its creation the SNS had a price tag of only $50 million for fiscal years 1999–2002 (Prior [4]). Following the Anthrax attacks of fall 2001, the funding grew more than ten-fold, reflecting the national priority of bio-preparedness.

The first bio-preparedness focusing event was the 2001 Anthrax attacks, especially potent after the 9/11 terror attacks of the same year. Known as “Amerithrax”, the attack involved weaponized Anthrax delivered via the US Postal Service to several US Senators, ultimately killing 5 people and infecting 17 others (Sarasin [5]).

The Amerithrax attack brought to light vulnerabilities in identifying and treating unique biological weapons. The publics' fears were exacerbated by other recent attacks and the perception of vulnerability was high. After the Amerithrax attack US Congress made bio-preparedness a priority and passed a budget of over $4 billion for FY 2002, as shown in Figure 1. The majority of the funding went to the federal Health and Human Service agency, that subsequently passed down to states and a major metropolitan city through preparedness grants (Franco [6]).

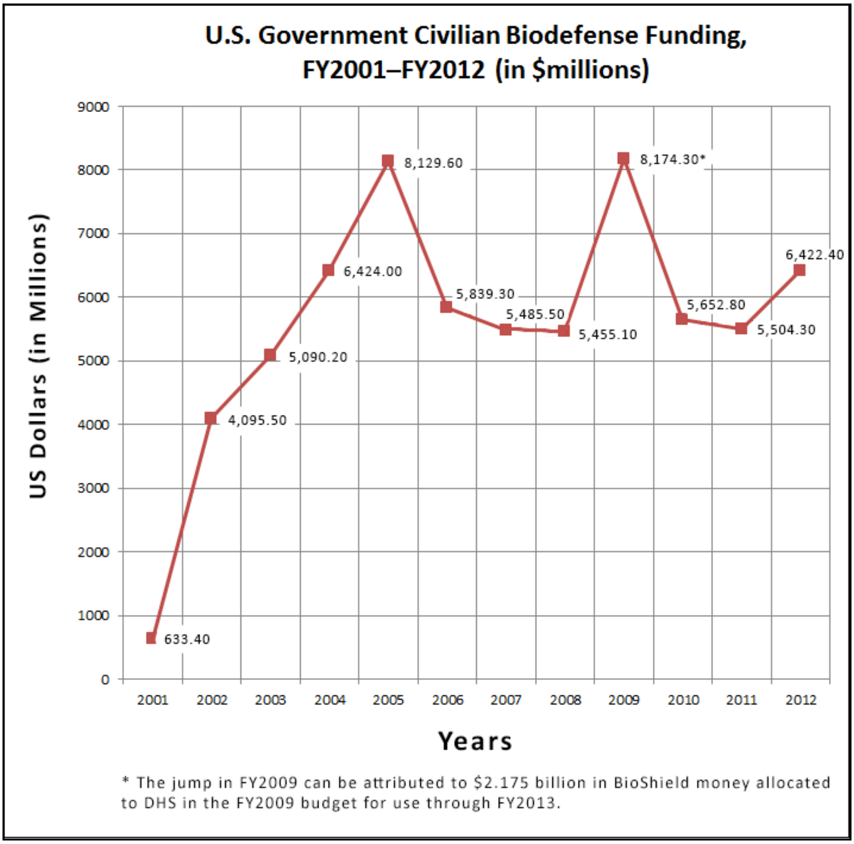

Figure 1: U.S. Government Civilian Biodefense Funding, FY2001-FY2012.

What is most notable about the US bio-preparedness budget is the dramatic decline it makes in the 2005-2006 fiscal year. Specifically,

> "Federal funds for state and local preparedness declined by 38 percent from fiscal year (FY) 2005 to 2012 (adjusted for inflation) – and additional cuts are expected under budget sequestration. From FY2010

> to FY2012, there is a $72 million reduction to Public Health and Emergency Preparedness grants from state, local, territorial, and tribal funds, a $22 million cut to the Academic Centers for Public Health Preparedness and $5 million from the Advanced Practice Centers" (Trust for America's Health [7]).

This dramatic decrease in bio-preparedness support can most likely be attributed to several factors, not the least of which was a global economic downturn. The combined cost from FY2001-2006 was $30.2 billion (Franco [6]) and with no outbreaks or biological attacks during this period it is understandable why the bio-preparedness budget was reduced.

3 State level bio-preparedness

The primary purpose of bio-preparedness money was to strengthen response and distribution capabilities at the state level. This included the distribution of the SNS in a timely and efficient manner once it was received by the states. The bulk of the preparedness money went towards planning and exercising distribution capabilities, specifically the use of Point of Distribution (POD) centres.

Most industrialized countries are required by legislation to conduct disaster exercises that include natural and technological threats (Peterson and Perry [8]). Annual exercises ensure that "potential shortcomings in the plan and training process are identified" (Peterson and Perry [8]). Therefore, these exercises are seen as an important aspect in the process of emergency management. Five core benefits attributed to disaster exercises include:

1. Permitting "inferential testing of the adequacy of a disaster plan";
2. Allowing inferential testing of the "adequacy of training of personnel";
3. Enhancing the visibility of the agencies participating in the exercise with those in the community, and "similarly reassuring the public that emergency authorities are aware of dangers and prepared to take measures to reduce negative impacts";
4. Providing a "hands-on" check of communication equipment, systems, and other materials; and
5. Testing the "viability of the emergency response network relative to the threat exercised" (Peterson and Perry [8]).

Of the various exercises conducted by emergency managers for disaster planning, three of the most commonly used include: tabletop, functional, and full scale (Peterson and Perry [8]). Functional and full scale exercises are considered operations based exercises and are the most accurate for testing a community's response capabilities. The third type of exercise is the tabletop exercise which is used to test plans and operations through discussion before conducting a full scale exercise. All three of these exercises involve simulated, hypothetical man-made or natural disasters in which the participants are asked to respond to the event's demands (Moyer [9]; Peterson and Perry [8]). They are designed to "test and evaluate proposed plans and procedures and resolve questions of coordination and responsibility before implementation of a plan" (Watkins [10]). While familiarizing the participants with the administration of response procedures, these exercises also provide insight for the need of cooperation, resources, and communication during a disaster or emergency situation (Watkins [10]). Full scale exercises are particularly beneficial when trying to implement roles and responsibilities among participating organizations and assess plans, policies, and procedures.

Overall, exercises aid and enhance the participants' "perceptions of response network effectiveness", which is primarily focused on collateral support (Peterson and Perry [8]). These networks between first responders are important because of the decisions, actions, and strategies that will "form the core of any response operation" (Richter, *et al.* [11]). Peterson and Perry's [8] study concluded that exercises have the capability to alter participant perceptions of not only response network effectiveness, but also teamwork, training and equipment adequacy, and job risk.

4 The "Bioshield" initiative

The requirements of bio-preparedness are a "when" not "if" scenario. 15–20 previously unknown diseases have been discovered in the past few decades including HIV/AIDS, Ebola, hepatitis C, Lyme disease, Hantavirus pulmonary syndrome, and Severe Acute Respiratory Syndrome (Graham [12]). New strains of influenza and other newly emerging diseases are likely to spread even more broadly and quickly due to the mobility of the world's population. With influenza as the world's greatest biological challenge and a widely quoted awareness massage reminds us, "The influenza pandemic of 1918-1919 killed more people than World War I (WWI), at somewhere between 20 and 40 million people" (Barry [13]). The Spanish Influenza has been on record as the most devastating epidemic in recorded world history, with far great deaths than in four-years of the Black Death Bubonic Plague from 1347 to 1351.

There are a variety of bio-scenarios, as seen in Table 1, that would warrant individual preparedness over national response. At the small scale contagious event the individual or micro community would self-care, and if necessary lean on the medical infrastructure. At the large scale contagious level the professional medical community would be overwhelmed sheltering in place and individual self-care would be the message (Graham [12]) (Trust for America's Health [7])

From 2002-2006 the Florida Department of Heath undertook a series of "Bioshield" exercises to simulate a variety of bio threats that could occur in the

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state. As with most exercises, the primary areas of weakness included "communication". Other results indicate the inability to distribute and track the distribution of the SNS pharmaceuticals (Florida Department of Health [14]). Specifically, the Bioshield Exercise After Action Report (2006) noted an inability to measure the State's ability to process requests of specific materials

Table 1: From Bio-Preparedness report card (Graham [12]).

LEVEL	BIOLOGICAL EVENT
SMALL-SCALE NON-CONTAGIOUS	• LIMITED EXPOSURE TO PATHOGEN • NO ADDITIONAL EXPOSURES • SMALL NUMBERS OF ILLNESSES AND/OR DEATHS • POTENTIAL FOR MEASURABLE PSYCHOLOGICAL AND SOCIO-ECONOMIC IMPACT
SMALL-SCALE CONTAGIOUS	• LIMITED INITIAL EXPOSURE TO PATHOGEN • SMALL NUMBERS OF ILLNESSES AND/OR DEATHS • PERSON-TO-PERSON TRANSMISSION WITH CONTAGION POTENTIAL • POTENTIAL FOR MEASURABLE PSYCHOLOGICAL AND SOCIO-ECONOMIC IMPACT
LARGE-SCALE NON-CONTAGIOUS	• EXPOSURE IN ONE OR MORE CITIES • ADDITIONAL EXPOSURES POSSIBLE OVER TIME • EPIDEMIC NUMBERS OF ILLNESSES AND/OR DEATHS • SIGNIFICANT PSYCHOLOGICAL AND SOCIO-ECONOMIC IMPACT: CIVIL UNREST
LARGE-SCALE CONTAGIOUS	• EXPOSURE IN ONE OR MORE CITIES • ADDITIONAL EXPOSURES OVER TIME • EPIDEMIC NUMBERS OF ILLNESSES AND/OR DEATHS WITH CONTAGION POTENTIAL • SIGNIFICANT PSYCHOLOGICAL AND SOCIO-ECONOMIC IMPACT: CIVIL UNREST

Table 1: Continued.

LEVEL	BIOLOGICAL EVENT
LARGE-SCALE DRUG RESISTANT	• EXPOSURE IN ONE OR MORE CITIES • ADDITIONAL EXPOSURES OVER TIME • POTENTIALLY UNCONTROLLABLE NUMBER OF ILLNESSES AND/OR DEATHS • MEDICAL COUNTERMEASURES UNAVAILABLE OR INEFFECTIVE • CIVIL AND POLITICAL UNREST IN THE AFFECTED REGION; GLOBAL ECONOMIC IMPACT
GLOBAL CRISIS CONTAGIOUS	• NUMEROUS EXPOSURES IN MULTIPLE LOCATIONS OF HIGHLY CONTAGIOUS, NOVEL PATHOGEN(S) • MEDICAL COUNTERMEASURES UNAVAILABLE • GLOBAL OUTBREAK WITH POTENTIAL FOR MILLIONS OF ILLNESSES AND/ OR DEATHS • BREAKDOWN OF POLITICAL INSTITUTIONS; GLOBAL ECONOMIC DISRUPTION

for distribution in a bioterrorism event, and noted, “The final order that was entered into Tracker (a state wide system used by Florida to monitor resources and requests during emergencies) exceeded the inventory on hand” (Florida Department of Health [14]). The State also self-reported their inability to track and account for the delivery of SNS assets sent to Points of Dispensing (PODs). Staffing was also a concern and because this was the fourth year the Bioshield exercise had been undertaken it is significant to note that in 2006 Florida reported, “Some confusion as to who was assigned primary and alternate responsibilities” (Florida Department of Health [14]).

In 2005 Florida exercised its Point of Distribution (POD) plan for the SNS in Orange Country Florida, home of Disney World. The exercise was deemed a “success” but there were noteworthy results, including the amount of time and resources it would need to operate a POD in a real bio event. The POD Exercise After Action Report indicated that a single POD, staffed with 86 people per shift, could handle 420 people (clients) per hour (Florida Department of Health [15]). The exercise was unable to get a significant number of volunteers so this load of clients was extrapolated as a best case scenario. Given this assumption of throughput, and the population of Orange County at 1.169 million people, it would take 116 days of POD operations if they were open in 24 hour shifts. The exercise did not take into account other acknowledged influencing variables such as reduced staffing due to the bio event, the need for multiple shifts if operating in a 24 hour capacity, and the need for a system of separating the symptomatic clients during POD operations (Florida Department of Health [15]). Other challenges identified by the Florida Department of Health include language barriers between residents or tourists and health personnel, and a large number of undocumented workers within the state, which would inflate the number of the population.

5 Micro community bio-preparedness

Epidemiologists, disaster planners, and virologists agree that influenza pandemics have happened in the past and will happen in the future (Diprose [16]). The philosophy of prudence being mobilized in response to the threat of pandemic influenza is illustrative of the intensification of public health practices that distinguish individual preparedness from the national (Sassen in Diprose [16]). The results of the Florida Bioshield exercises reveal a weakness in the government's ability to effectively distribute pharmaceuticals to a single county, let alone a state of 19 million. It has also become a recognized challenge of all levels of government that beyond the distribution of pharmaceuticals to the populous is the quantity of pharmaceuticals that would have to be produced to meet the needs of a nation of 313 million. In the "Bio-response Report Card" (2011) published by a bi-partisan committee chaired by Senator Bob Graham states, "The nation does not yet have adequate bio-response capability to meet fundamental expectations during a large-scale biological event" (Graham [12]).

Understanding the limitations of government creates a paradigm shift in perceptions and the ability to meet the health and security of individuals in the state. Emerging and dynamic risks change the definitions of 'precaution' (Ewald [17]), 'preparedness' or 'pre-emption' (Derrida [18]). By 2007 the limitations of the state in response to bio-preparedness required policy makers to rethink the individual approach. Combined with a demand to curtail spending, resulting in a reduction of $3 billion between FY2006 to FY 2007, this new approach revealed the individual or micro community bio-preparedness campaign. Individual or micro community bio-preparedness employs the "paradigm of prudence" model (Samimian-Darash [19]) and urges societies and individuals to be in a constant state of readiness about possible high-consequence threats. Whether pertaining to public health or bio-preparedness the paradigm urges that individuals be in a constant state of readiness about possible high-consequence threats or proactive in preparing for the arrival of disasters (Diprose [16]).

The paradigm of prudence and individual preparedness policy initiative in bio-preparedness has led to specific campaigns that "mobilize whole of the nation response planning" (Graham [12]). These whole nation responses include messages of individual levels of care in the event of an outbreak. These specific campaigns of awareness included open messages of state limitations combined with public awareness campaigns of individual preparedness. The official government message from both the Federal Emergency Management Agency (FEMA) and the Centers for Disease Control and Prevention (CDC) include the expectation that individuals "Have any non-prescription drugs and other health supplies on hand, including pain relievers, stomach remedies, cough and cold medicines, fluids with electrolytes, and vitamins" (FEMA [20]). The same public messaging also includes a recommendation that individuals, "get involved in your community as it works to prepare for an influenza pandemic (FEMA [20]).

6 Conclusion

There has been a measurable shift in public awareness of bio-preparedness and prevention in the past decade. The awareness campaigns of sneezing into your elbow, and intense hand washing have changed cultural norms and expectations. The cultural shift can be linked to the paradigm of prudence initiative that emerged as part of changing policy and resources. These policy shifts are related both to limitations of resources, including budgetary restrictions, and the need for improved plans as a result of intense state disaster exercises.

The focus on individual and micro-community preparedness, and the self-expressed limitations of government, has created a public partnership between the state and the individual. This partnership is based on honest expectations and limitations resulting in a new level of responsibility and awareness. In fostering this partnership, a higher awareness of personal preparedness for biological events can be accomplished through continued state and federal funding for education and awareness of not just communities, but also the nation as a whole.

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Risk minimal routes for emergency cars

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Abstract

The computation of an optimal route for a given start and destination in a static transportation network is used in many applications of private route planning. In this work we focus on route planning for emergency cars, such as, for example, police, the fire brigade and ambulance. In the case of private route planning, typical quantities to be minimized are travel time or route length. However, the idea of this paper is to minimize the risk of a travel time exceeding a certain limit. This is inspired by the fact that emergency cars have to reach the destination within a legal time. We consider mainly two approaches. The first approach takes into account relevant information to determine the weight, i.e. the desirability of certain edges of a graph during the minimization procedure. One possible risk factor to be aware of would be a suddenly jammed single-lane road on which the emergency car has no chance to make use of the benefits of the siren for instance. The same holds for full-closure situations and railroad crossings. We present a catalogue of risk factors along with an appropriate algorithm for practical route planning in emergency situations. The second one takes into account a weekly updated set of probe-vehicle data for each minute of the week along with data of current travel times. Comparing those travel-time data allows calculation of the associated risk for traveling certain edges of a route in a road network. We expect our algorithm to be a major advancement especially for destinations that lie outside the typical region travelled weekdays. In this case, automatic route planning naturally goes along with an additional gain of time.
Keywords: route planning, static transportation network, emergency situation.

1 Introduction

The road network is a ‘critical infrastructure’ whose ‘failure or impairment would cause a sustained shortage of supplies, significant disruptions to public

WIT Transactions on The Built Environment, Vol 133,
www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/DMAN130151

order or other dramatic consequences' [1]. For emergency services road network is the backbone of their mobility. Also the individual traffic, the public transport and the commercial transport requires a safe and reliable operation traffic system. But traffic management often only considers a balance between supply and demand. Potential threats and hazards and the resulting damages are not been covered. From the point of view of a critical infrastructure, traffic management must operate a risk management to evaluate the existing threads to prepare appropriate measures. Similarly, emergency services should also note risk factors for route planning in order to get not only fast, but also reliable to their destination. To address this risk evaluation in emergency services and traffic management, this paper presents several points of view of risk in this context of traffic. First, from the view of a single vehicle route planning, we present generalizations of shortest-path problems taking certain risk factors into account. This might for instance be the loss of travel time due to various reasons as traffic jam, a blockade, and narrow single-lane roads with inefficient manoeuvrability and so on. There are certain differences to private route planning with regard to the risk of exceeding a limiting travel time; since emergency cars using their siren have 'rights of way', one can assume constant loss of time when turning whether there is a traffic light or not. Even traffic jams on broader multilane roads are not as limiting for the travel time as for individual drivers since other cars have to form an emergency lane. While its formation on a large Autobahn section for example might be inefficient, it may be practicable on shorter distances as tailbacks at traffic-light crossings. Thus, risk factors might further imply the average number of lanes per kilometer, the length of the route, etc., influencing the algorithmic route choice.

Second, from the view of a traffic management center, we analyze real traffic data from floating cars in order to calculate the risk for a given route on a statistical basis.

2 Advanced routing algorithm for emergency cars

We consider the problem of finding a desirable route for given start and destination points on a road network. Such networks can be considered as a directed graph comprising nodes and edges so that each edge represents a road section. Edges can uniquely be classified by source node u and target node v as $e=(u,v)$. We consider 'static routing', i.e. the route is calculated once before the trip. Usually, static routing algorithms generalize Dijkstra's algorithm, see [2], which finds the optimal path for a graph with non-negative edge path weights. If those weights are given by length, Dijkstra gives the shortest route, while, if the weights are travel times, it provides the fastest route, see [3, 4] for an overview of the various algorithms. In general one associates a weight $T(e)$ with each edge e. The algorithm then finds the minimal sum of weights along a path from its source to destination node.

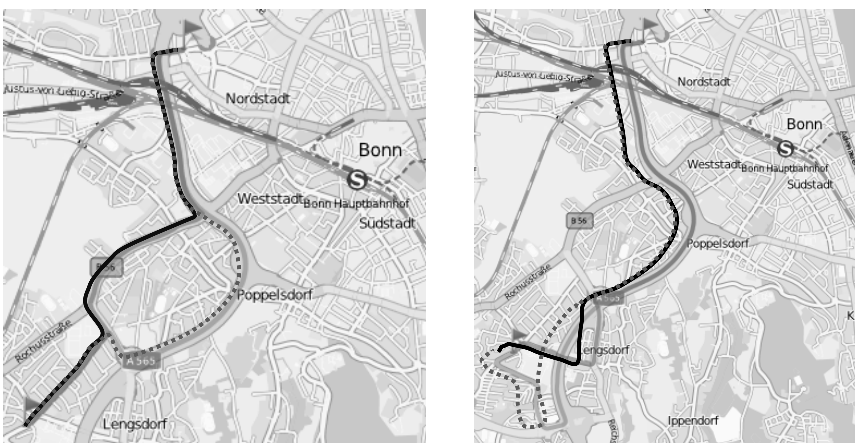
The interest of the present article is in assuming different risk factors as weights along the path. An example: driving on single-lane roads has the risk of being blocked; the more lanes, the easier it becomes to find a gap or even an emergency lane that is formed by other cars and therefore the lower is the risk. Let *n(e)* be the number of lanes on edge *e* and *l(e)* its length. We are aiming to maximize the average number of lanes per kilometer:

$$< n(e) > = \sum_{e' \in route} l(e')n(e') \,/ \sum_{e' \in route} l(e') \qquad (1)$$

Note that this can be achieved by an appropriate telescope sum similarly as it is done in the A* algorithm [5]. In the same way we can find optima for other quantities; for instance the average number of lanes per second is obtained by replacing *l(e)* by the travel time *t(e)* and so on.

Table 1: Different risk factors as average length, travel time and number of lanes per kilometre for driving different routes at a constant amount *a* of the speed limit.

Route	**Extremal property**	***length***	***travel time***	***<n / km>***
Fig. 1a) dotted	Min. time	*5257m*	*4:17 min* for *a=1* *8:00 min* for *a=0.535*	*1,688*
Fig. 1a) black	Min. length	*4551m*	*4:39 min* for *a=1* *8:00 min* for *a=0.577*	*1,715*



a) The dotted route is 'fastest': *T(e) = t(e)* and travels a longer distance on the Autobahn. The black route is 'shortest': *T(e) = l(e)*.

b) The dotted route is Pareto-optimal for lane number and travel time. The black route is the fastest route avoiding low-speed edges, see text.

Figure 1: Route from fire station 1 in Bonn (north) to destination in Bonn-Hardtberg (south).

Along with the risk factor one wants to optimize the travel time simultaneously. Obviously, this is not possible in general. However, as claimed in [6], one can determine a privileged set of paths, the set of Pareto-optimal paths. For the latter paths it is not possible to improve one of the elements

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without worsening the other. Table 1 compares essential quantities of the different routes from Figure 1. Here we assume that the emergency car travels each edge e with some velocity a times $v_{lim}(e)$, with a being a positive real parameter and v_{lim} its speed limit.

In Bonn, emergency cars are constrained to reach their destination within 8 minutes in at least 90% of the cases of emergency. Table 1 shows that the two routes of Figure 1a) lead to the destination if the emergency car can drive at least 54% of the speed limit on the fastest route and 58% of the velocity on the shortest route. Sometimes it is necessary to take into account that emergency cars need time for turning also when making use of the siren in emergency situations. Table 2 shows a possible choice for the angle-dependent turning times. We checked that both, the fastest and the shortest route remain stable under the introduction of turning penalties $2a$ times as large as those in table 2. In general, one might think of a more sophisticated choice of turning penalties, dependent on the turning possibilities or even taking probe-vehicle data into account [7, 8].

Table 2: The table gives one useful choice of weights for turning from edge *e'* to edge *e* depending on the angle in between. Note that the weight can be scaled by some factor to account for different types of turning situations.

Weight / [s]	**Right turn: absolute angle…**	**Left turn: absolute angle…**
0	… smaller than 45°	… smaller than 45°
1	… between 45° and 135°	
2	… exceeding 135°	… between 45° and 135°
3		… exceeding 135°

Table 3: Risk factors as in Table 1 for the routes of Figure 1b) for driving different routes at a constant amount *a* of the speed limit.

Route	**Extremal property**	***length***	***travel time***	***<n / km>***
Fig. 1b) dotted	Pareto-optimal for max. #lanes / km and min. travel time	*6855m*	*5:00 min* for $a=1$ *8:00 min* for $a=0.625$	*1,900*
Fig. 1b) black	Min. time for avoiding roads with speed limits lower than 50 km/h	*5618m*	*4:19 min* for $a=1$ *8:00 min* for $a=0.540$	*1,680*

Up to now we have assumed that emergency cars drive at a constant amount a of the speed limit which is not always the case. In general, this amount will depend on the very edge, see section 4. If possible, an emergency car might even exceed the allowed speed limit. In doing so, the driver is bound in law to make sure that he doesn't endanger other people. This is typically warranted on the Autobahn. If the emergency car drives a times 20km/h faster on the Autobahn and drives all the other edges at *a* $v_{lim}(e)$, one arrives at the darker route in Figure 1b). However the same route can be generated from a hierarchical routing that excludes edges with speed limits of 30 km/h or smaller. If one uses real traffic velocities in the routing algorithm, i.e. aggregated or current data from probe vehicles for each minute of week one often finds this curve as well as the fastest route.

Apart from the risk factors described above, one might think of many more. They can be cast in weight functions of the following form:

$$T(e',e) = p\,t(e) + t(e',e) + (1-p)[r(e) + r(e',e)]. \quad (2)$$

Here *t(e)* and *r(e)* reflect the weights associated with edge *e* while the weights *t(e', e)* and *r(e', e)* are concerned with the transition between the two edges. We distinguish further *t* and *r*, the difference being that *t* enters the real travel time while *r* is a virtual risk value that only manipulates the route finding – not the travel time. The contributions to those four weights are as follows, see [9] for a different analysis:

- *t(e)* is simply given by the edge length and the speed. The speed that enters the routing algorithm is a current speed from probe vehicles if possible. Otherwise historical or theoretical speed values are used.
- *r(e)* might not only contain a *weight for number of lanes* as described above but a *weight for low-speed edges* for example. Those edges might either be congested roads with speed limits of at least 50km/h or roads where 30 km/h are allowed. In the first case there is a risk that the time to form an emergency lane becomes large. In the second case there is a risk that one has a small road that lowers the manoeuvrability of the emergency cars. Especially in pedestrian zones and play streets where the allowed velocity is 10 km/h or less the emergency car cannot afford to drive much faster. For similar reasons as using penalties for low-speed edges one might think of a *weight for street category* from small roads to German motorways. The *current traffic situation* (either free flow, synchronized or congested traffic) can be determined from single-probe vehicle data by comparing the allowed and current speed and may enter with according weights. For concepts of a collective optimal route finding in congested traffic see [10]. Also *roadwork* contributes to the current traffic situation and has to be taken into account. A *weight for architectural separation* of oppositely directed lanes plays an important part especially for high densities and small number of lanes for the situation of emergency-lane formation.
- *t (e', e):* The main contribution to travel-time influencing weights for transition between edges is a *penalty for turning*, see above. Each time where more than a single edge follows the current edge, a delay time for turning is calculated from the angle between the two edges. For the case where more detailed information about traffic lights and their respective phases or even turning times from probe vehicles are known, they are used too.

- *r (e', e)* concerns the following risk factors for the transition between consecutive edges: railroad crossings and other *full-closure situations* that cannot be resolved as well as ferry services for river crossing (as provided in individual routing) have to be displayed by the largest of weights. Beyond that we can include a penalty for the transition onto slower edges (which contain higher risk) in order for the car to stay on a strategic road. Sometimes it is necessary to have the frequent possibility of turning onto an alternative route if the current road is suddenly blocked. So an appropriate quantity to maximize is the *node degree per unit length*.

Finally we stress that the parameter p in equation (1) interpolates between finding the fastest route (for $p=1$) and finding risk-minimal routes for $p=0$.

Note that while the weights $T(e)$, calculated beforehand, depend only on the current edge, the weights $T(e',e)$ in equation (2) depend on the previous edge as well. However the problem can be reduced to finding an optimum for $T(e)$ from the principle of node contraction [1, 2]: Let $e'=(u,v)$ and $e=(v,w)$. Then those two edges can be replaced by a single edge by adding a shortcut $e''=(u,w)$. For example the travel time from u over v to w is replaced by the sum of travel times and an appropriately scaled turning penalty, see table 2; for railroad crossings the resulting edge e'' will have infinite weight and so on. Those data can be preprocessed in order to enhance the performance of the algorithm; however a reasonable compromise with memory space has to be found.

3 Risk assessment for road networks by travel time

For the operation of critical infrastructures the German Federal Ministry of Internal Affairs [11] recommended risk assessment as an appropriate method to assess the threats. But in road-traffic management risk assessment is currently lacking. Therefore, in this chapter an evaluation function for risk in road traffic management is shown, starting at the general formula: Risk = Probability of the occurrence of the threat times the expected loss in case of occurrence. To apply the risk formula for traffic management, a measure of the expected loss has to be defined. Analyzing the potential hazards and their effects in the transportation system, it comes clear that they ultimately have an impact on the travel time of the road users. All types of hazards affect the capacity of the road infrastructure (e.g. landslides) or/and the traffic demand (e.g. escape or evacuation). Both types of influence affect finally the travel time of each road user. Hence it follows, that the 'frequency of the occurrence of a threat' can be expressed as the frequency of a specific travel time. Travel times and there frequencies were measured via

floating car data (FCD) systems, also known as probe vehicle data [12–14]. Floating Cars are vehicles driving in a fleet moving with the flow of traffic, and which are equipped with a technology (e.g. GPS) to self-detect the cars' positions. The vehicles wirelessly transmit their positions and time stamps to a processing system. There, the incoming data is processed to determine traffic

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states. The FCD approach works well, if the number of equipped vehicles is large enough to ensure statistical significance of the measured traffic data [15].

Attention must be paid to the fact, that the travel time is not a loss at all, because every trip has necessarily a minimum travel time to reach the destination; only travel times beyond a limit t_g, to be defined, can be named as a loss (see Figure 2).

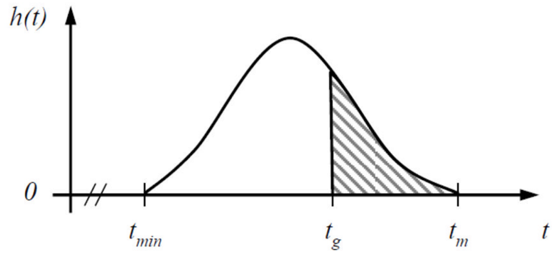

Figure 2: Sketch of the absolute frequency of travel times.

Therefore the risk can be calculated as follows:

$$t_{risk} = \sum_{t \text{ with } t_g \leq t \leq t_m} Prob(t) \cdot t \quad (3)$$

The formula suggests that the driver shall include a time budget of, say, 5 minutes for instance.

4 Results

Following, we present results derived from analysing probe-vehicle data for typical routes between a major fire station in Bonn and a destination in Bonn-Hardtberg (cp. section 2). The data base was recorded between August 2012 and March 2013 using taxi cabs in the region of Bonn as described in section 2. For this study, the probe-vehicle data were aggregated to a 1-hour-interval.

Figure 3 displays frequencies of travel times for the route alternatives introduced in section 2. On the left side, 'cross-hatched' bars indicate the route with a minimal travel time when avoiding streets with speed limits lower than 50 km/h. The underlying grey bars refer to a route with a maximal number of lanes per kilometer. In the picture, the peak values point to the most probable travel time averaged over all working days in the respective time period.

It can be seen that the peak value of the 'cross-hatched' bars is placed at a travel time of 350 to 400 seconds whereas the peak of the grey bars has a value of above 400 seconds. This indicates that in general vehicles on the 'cross-hatched' route reach the destination earlier than the cars on the 'grey' route. This appraisement may change considering the **r**esponse time illustrated by the red vertical line in the figure: The histogram clearly reveals lower frequencies for the 'grey' route for travel times greater than the **r**esponse time of 480 seconds.

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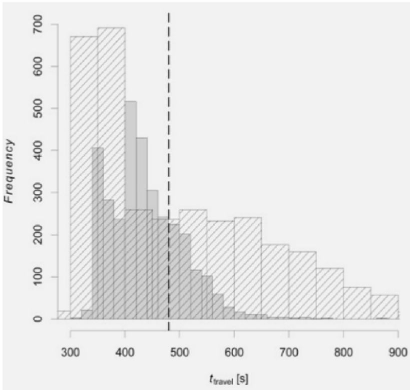
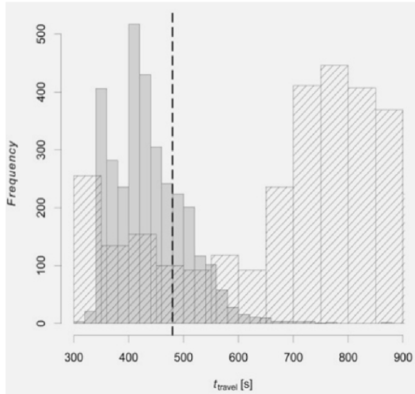


Frequencies of travel times for a route with a maximal number of lanes per kilometre (grey) and a minimal travel time when ignoring speed limits lower than 50 km/h (‘cross-hatched’).



Frequencies of travel times for a route with a maximal number of lanes per kilometre (grey) and the route with the minimal length (cross-hatched’).

Figure 3: Histograms of travel times over all working days for different routes from fire station 1 in Bonn to a destination in Bonn-Hardtberg. The vertical dashed line represents the response time of 8 minutes.

In summary, vehicles are faster on the ‘cross-hatched’ route but also more likely not to reach their destination within the legal limit.

On the right-hand side, Figure 3 compares frequencies of travel times for the route with the minimal length (‘cross-hatched’) and again the route with a maximal number of lanes per kilometer (grey). The ‘cross-hatched’ route has a considerable amount of trips with a total travel time between 300 to 350 seconds. Nevertheless, there are a number of very high travel times in the range from 700 to 900 seconds which exceed the response time by a factor of two. In contrast, the smallest possible travel times of the ‘grey’ route are larger than 300 seconds. As in the figure on the left side, the number of travel times violating the legal limit is much smaller in comparison to the ‘cross-hatched’ route.

Table 4 illustrates these relationships in another way. It presents mean travel times well as the risks of exceeding the response time of 8 minutes defined in section 2. The values in this table are given in seconds.

The table shows that the ‘cross-hatched’ route for the left side of Figure 3 has a high risk for the morning peak hour, whereas in the evening the risk is in the same range as for the ‘grey’ route. For the right side of Figure 3 it can be seen that despite of the possibility of realising the smallest travel times on the ‘cross-hatched’ route the mean travel times as well as the risks are always high for every period of a working day.

Table 4: Mean and risk values of travel times for route alternatives of figure 3 of different periods of the day.

Period		Left side of Figure 3		Right side of Figure 3	
		'cross-hatched'	'grey'	'cross-hatched'	'grey'
08:00 – 09:00	$\bar{t}_{travel}$	571.12	448.59	794.73	448.59
	t_{risk}	434.71	187.01	664.83	187.01
18:00 – 19:00	$\bar{t}_{travel}$	468.26	466.04	819.21	466.04
	t_{risk}	277.53	242.38	717.57	242.38
24 hours	$\bar{t}_{travel}$	443.02	426.19	752.20	426.19
	t_{risk}	291.07	129.20	635.12	129.20

This behaviour might be influenced by several facts: The route for getting minimal travel time when avoiding routes with speed limits lower than 50 km/h ('cross-hatched' route on the left side of Figure 3) has disadvantage for the high traffic volumes of the morning peak hour. During that period higher velocities cannot be reached because of the dense traffic. In contrast, for lower traffic volumes during the day and in the evening, this route performs better in comparison to the 'grey' route.

For the right-hand side of Figure 3 it reveals that vehicles on the 'cross-hatched' route with the shortest absolute length are very much influenced by the timing of the traffic lights at intersections. The very short travel times displayed in Figure 3 can only be reached for periods of weaker traffic in the night or in the early morning. For the relevant periods of the day, Table 4 shows significantly higher travel times and risk compared to the 'grey' route.

Figure 4 presents another relevant factor. Here, the standard deviations of the travel times for all working days of the sample period are plotted for the routes already presented on the right-hand side of Figure 3.

It can be seen that the travel times on the route with the minimal length (grey) are fluctuating heavily. This behaviour is caused by a high number of traffic light controlled intersections. On the one hand, a vehicle might pass these traffic lights during a 'green wave' without any delay. On the other hand, especially for periods of higher traffic volumes over the day a vehicle might be influenced at almost every intersection leading to a broad diversity of possible travel times.

In comparison to the 'grey' route, the travel times of the 'black' route (optimum between lane number average and travel time) have only very small variations. In this case, most parts of the route consist of motorways or roads of a comparable category with at least two lanes per direction. Here, the possibility of being delayed is reduced dramatically.

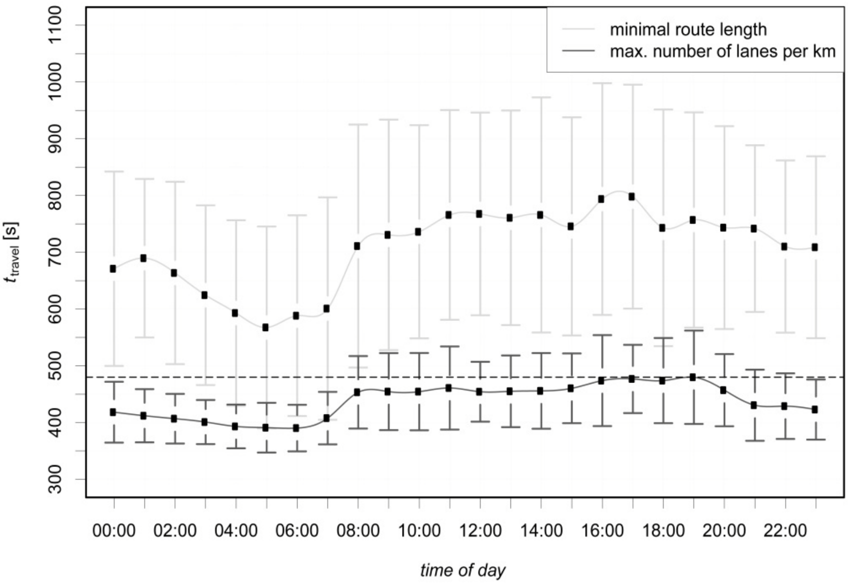


Figure 4: Travel times and their standard deviations for two routes from fire station 1 in Bonn to a destination in Bonn-Hardtberg. One route features an optimum between maximum number of lanes per kilometre route length and minimal travel time (black), the other route has the shortest total length (grey). The horizontal dashed line indicates the response time of 8 minutes.

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Emergency planning and visualization: the case of Miami-Dade County's Emergency Operations Center

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Abstract

Relief efforts for previous disasters such as the 9/11 attacks in New York, hurricane Katrina in New Orleans, and the earthquake in Haiti, illustrate the need for emergency management agencies to have a comprehensive emergency management plan in place. Miami-Dade County's (MDC) Emergency Operating Center (EOC) is one of the leading centers in hurricane emergency management in the U.S., which makes them the ideal starting point for understanding how technology helps them to address the challenges that are unique to them. The goal of this paper is to share with emergency response teams across the globe the tools that the EOC uses to excel in preparedness for disasters. We focus on the way decision-making factors are incorporated into their technology as well as demonstrate how they use Geographical Information System (GIS) driven applications to maximize the effectiveness of their decision makers and response teams.
Keywords: disaster management, emergency management (EM), visualization, preparedness, risk assessment, natural disasters, knowledge management, geographical information systems (GIS).

1 Introduction

Emergency management (EM) is "the managerial function charged with creating the framework within which communities reduce vulnerability to hazards and cope with disasters" (FEMA [1]). It is a closed-loop cycle that is composed of four different phases: Preparedness, Mitigation, Recovery, and Response. Preparedness is the risk assessment of threat likelihood and the planning for

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doi:10.2495/DMAN130161

those threats that pose the highest risk; Responses are the actions taken when the threat is being experienced in order to save lives or prevent property damage; Recovery is the action taken following the experienced threat in order to return to normal; and mitigation is the act of preventing, or minimizing, the risk or damage in an emergency. Although they may seem isolated they each build upon the previous step and feed the subsequent step. Learned information helps project current and future impact of the disaster in its different stages (Jain and McLean [2]). For example, recovery allows the effort to switch from a reactive response to a proactive one for future incidents through mitigation, while steps taken in mitigation minimize the requirements for preparedness.

Local governments are responsible, with limited resources, to cope with disasters through their emergency management agencies. These agencies need to efficiently coordinate the use of personnel, resource inventory, and infrastructure –including roads, evacuation routes, shelters, etc. (Gunes and Kovel [3]). Miami-Dade County has more experience (hence, equipment, training, and planning) with hurricanes than any other county in the United States due to their South Florida location, which is directly in the Atlantic hurricane path. The operations are directed by the Miami-Dade County (MDC) Emergency Operations Center (EOC), which is a center comprised of public, private, and non-profit organizations that is activated by the Mayor's Office of Emergency Management to respond to diverse types of emergencies. The EOC is the core for efforts following a disaster and has six responsibilities: coordination, policy-making, operations management, information gathering, public information, and hosting visitors and allows for interpersonal communication and decision-making (Quarantelli [4] and Kendra and Wachtendorf [5]).

Knowledge management during emergency response and preparation is a very difficult task due to the exponential communication paths $((N \times (N-1))/2)$ developed during coordination. This is why visualization tools are critical in helping emergency planners and responders receive ubiquitous situational awareness and enable real-time response during critical emergency operations. This paper is intended to show how emerging information and communication technologies (ICTs) have helped Miami-Dade County's EOC become a model for the nation in hurricane response with the hope that it stimulates further discussion, which ultimately will result in the improvement of the life-saving processes that all citizens rely on.

The decision making drivers (logistics, resources, knowledge, and politics) and preparedness cycle in Emergency Management present challenges that need to be overcome, such as: risk assessment, timing and uncertainty, data convergence and quality, and resource allocation (for more information see Castellanos *et al.* [6]). The following section discusses how the case study, Miami-Dade County's EOC, has addressed these challenges through their use of technology and visualization tools. The paper covers some of the lessons learned at the EOC and points to some future directions that will aid the emergency management community in preparedness for future events.

2 Miami-Dade County Emergency Operations Center

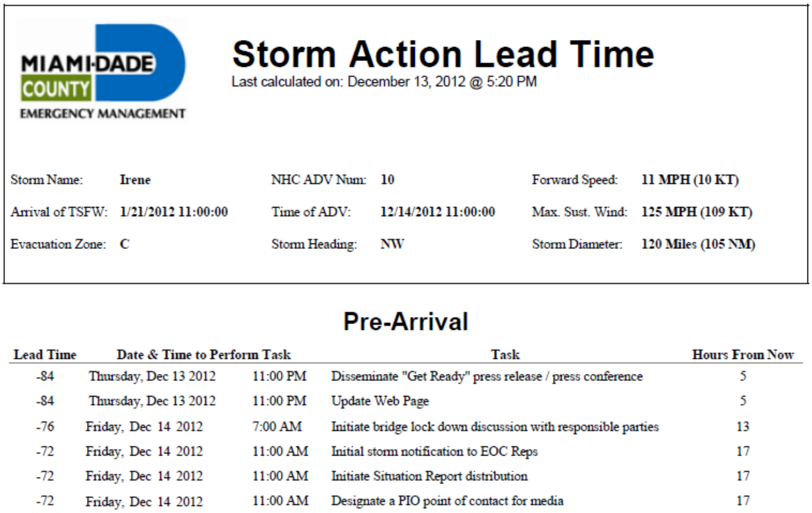
The EOC is responsible for preparing for, and responding to, emergency situations that can affect Miami-Dade County. The emergency situations do not necessarily have to be natural disasters as Miami has many factors that make it very unique from many other places. South Florida is a peninsula at the southern-most point of eastern United States. The Atlantic location provides the conditions to allow for the largest freight airport, the title of “cruise ship capital of the world” (MDC [8]), and the seventh most populous county in the United States, Census [9]. In order to provide power for so many people Miami-Dade County has the sixth largest power plant (nuclear), Turkey Point, USEI [10]. Although hurricanes are the highest threat in terms of likelihood, these conditions all present the potential for other non-natural disasters when assessing threats.

2.1 Logistics and planning

The EOC takes all the factors about Miami-Dade County into consideration in order to evaluate the total threat to the community. The result is a high priority for hurricanes, wildfires, flood, and a nuclear incident. Although the likelihood of a nuclear incident is found to be low, once omitting the federal governmental responsibility of outside threat mitigation, the magnitude of the potential impact makes it rank high. Unfortunately, there is not much warning of a nuclear incident and for severe radiation leaks there is not much that can be done for close-radius residents so most of the emphasis is placed on mitigation through safety policies, structure, training, and plant recertification procedures. For the population within range to still be affected by cross winds the procedure followed is very similar to that for hurricanes, but with shorter logistic timeframes.

The development of the comprehensive emergency management plan for the EOC has been an iterative process of experience and lessons learned throughout the years. The experience combined with technological advances in early warning systems, such as the Doppler radar systems, has allowed them to accurately generate a “laundry list” of tasks with timing. The system that allows them to do that is called SALT (storm action lead time). Providing parameters of an approaching tropical storm (such as evacuation zone, storm heading, forward speed, max sustained wind, diameter, etc.) allows the application to calculate all the pre-arrival logistics involved along with estimated lead times for each so that they are put in chronological order of execution (see Figure 1). Notice that the lead-time for “Irene” in order to begin the preparations is for 84 hours (which is 5 hours from the time of program execution).

Without proper planning and coordination, if the EOC were to be activated with representatives of every area and every department/organization in the county to respond to an emergency, it could get pretty haphazard and quickly drown out even the most vocal type person in the room. The EOC created Divisional Municipalities, which aggregates several areas into larger groups with one representative for each to create seven in total. This is a compromise between avoiding inefficiencies from having too many networking points yet being inclusive. To have resources and status updates from other areas (federal organizations, utilities, etc.) and divide the responsibility, the representatives from various areas are also included when the EOC activates (see Figure 2).


MIAMI-DADE COUNTY EMERGENCY MANAGEMENT

Storm Action Lead Time

Last calculated on: December 13, 2012 @ 5:20 PM

Storm Name:	Irene	NHC ADV Num:	10	Forward Speed:	11 MPH (10 KT)
Arrival of TSFW:	1/21/2012 11:00:00	Time of ADV:	12/14/2012 11:00:00	Max. Sust. Wind:	125 MPH (109 KT)
Evacuation Zone:	C	Storm Heading:	NW	Storm Diameter:	120 Miles (105 NM)

Pre-Arrival

Lead Time	Date & Time to Perform Task		Task	Hours From Now
-84	Thursday, Dec 13 2012	11:00 PM	Disseminate "Get Ready" press release / press conference	5
-84	Thursday, Dec 13 2012	11:00 PM	Update Web Page	5
-76	Friday, Dec 14 2012	7:00 AM	Initiate bridge lock down discussion with responsible parties	13
-72	Friday, Dec 14 2012	11:00 AM	Initial storm notification to EOC Reps	17
-72	Friday, Dec 14 2012	11:00 AM	Initiate Situation Report distribution	17
-72	Friday, Dec 14 2012	11:00 AM	Designate a PIO point of contact for media	17

Figure 1: SALT example (from Miami-Dade County).

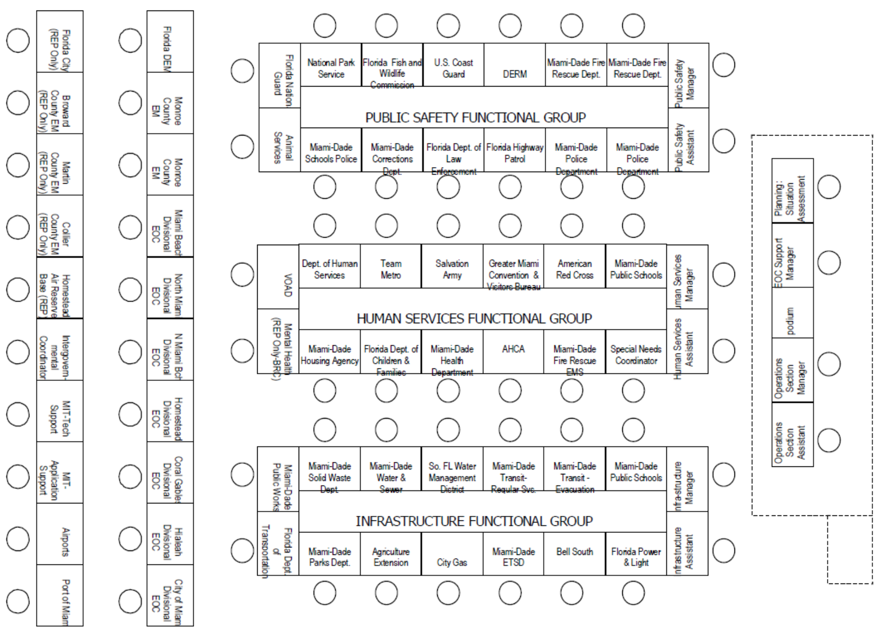


Figure 2: EOC floor-plan layout (from Becerra-Fernandez *et al.* [11]).

2.2 Static data

Data creates the solid foundation for basing decisions and developing a plan. It is important to have access to current information such as what resources are available, the demographics of an area, and status of shelters and other resources. Every type of information (shelters, mobile homes, gas stations, roads, addresses, hospitals, etc.) is a layer of GIS (Geographical Information System). There are hundreds of layers and ensuring that all the information is gathered and that all the layers are updated would be impossible for one department to handle. To address this, the EOC leveraged existing county departments and assigned areas of responsibility for what data is to be collected by each department. All operational data that is under the purview of the department is the responsibility of the department, but there are some grey areas, areas with no clear assignment of responsibility, that needed to be delegated. For example, the EOC is directly responsible for updating information related to the number of shelters, mobile homes in trailer park areas, Adjusted Living Facilities (ALF) and nursing homes. Furthermore, any public service facility that is obligated to apply for licensure from the state is required to submit an emergency management plan that is approved by the EOC, which allows them to add new facilities as they are created as well as ensure alignment with the county's plan. All these layers are added to the GIS base map to provide a decision maker with distribution and status of critical resources at-a-glance.

It is resource intensive to have the departments maintain operational capabilities and focus on continuous update to keep data relevant. For this reason a decision was made to have everyone update static data yearly immediately preceding the hurricane season, in July, to have it as accurate as possible for when it is needed.

It is possible to put every piece of static data onto a map and print it out but then it would be difficult to discern data and isolate data points of interest on the map. Users are able to decide what layers they want through GIS software. However, common emergency resource-related maps are always displayed throughout the EOC wall. These are maps with information of mobile home parks, gas stations with generators, grocery stores with generators, points of distribution, and hurricane evacuation centers, the nuclear power plant effect radius (see Figure 3 left to right: Gas Stations with Generators, Mobile Homes).

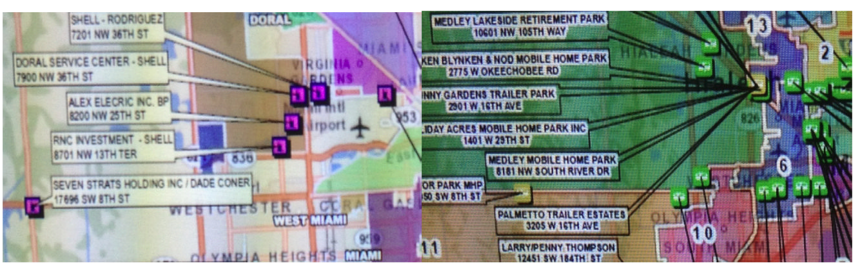


Figure 3: EOC static maps near Miami Intl. Airport.

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2.3 Real-time data

Although the delegation of responsibilities to each department has significantly reduced the burden of dedicating specific resources for continuously gathering and updating data, it did not provide a mechanism for acquisition of real-time data that they are not responsible for, such as that of the affected population, which will provide situational awareness during the crisis. To address this need the EOC developed a crowd-sourcing system at https://damage.miamidade.gov that is publically available for everyone to use. What this system achieves is giving a voice to the public to help the relief effort be more efficient. Unfortunately, there is a potential for misinformation so the EOC uses visualization to aid in assessing data quality and for prioritization. The EOC relies on a screening process to verify (to the best of their capabilities at the time) the data before it is used on any publicly accessible system. This also allows political filtering of data to prevent panic/pandemonium. The real-time data is scrolled in monitors at the center of the EOC to provide current information on road-closures and other critical information that may not be displayed on the GIS map (see Figure 4).

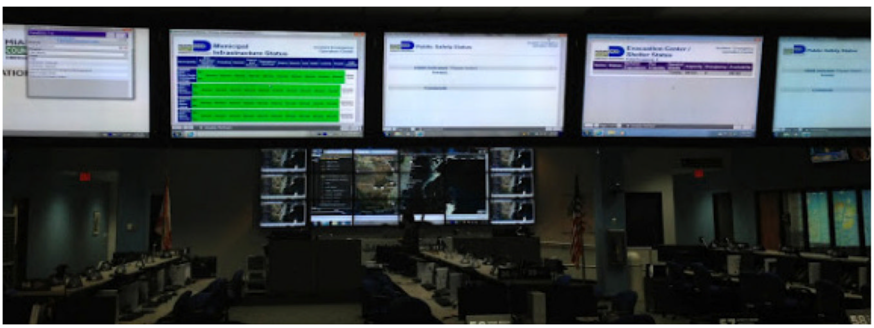

Figure 4: WebEOC real-time monitoring screens (from Miami-Dade County).

There are also visualization techniques that the EOC uses to verify information. By geocoding all the information and plotting it on a GIS map the result will be a cluster of dots, which can often show up as only one dot if they are highly concentrated. Due to the information potentially hidden by plotting points, the affected population data is instead visualized by using a heat map representation of the data. The heat map uses the color spectrum to provide concentration details, which ranges from green for areas of low concentration to red for areas of very high concentration. If someone is complaining that they are out of power, but that area of the map shows the area as green it is probably an isolated incident or can possibly be misinformation. This enabled the EOC to prioritize response efforts as well as perform rudimentary data quality assessments.

2.4 Graphical information system

The Information Technology Department (ITD), formerly the Enterprise Technology Services Department (ETSD), primarily maintains the GIS system, called ArcGIS, although the EOC has a point person that focuses only on their specific GIS needs. Creating a base layer is the most critical aspect of GIS because without having a solid foundation to add layers onto there will be issues with mismatching. If data availability was never an issue the application of GIS is as limitless as the imaginations of its users. Much of the data that is currently supporting the hundreds of layers for Miami-Dade County was developed through an iterative process based on the operational needs of the departments as well as the needs of decision makers. As explained by the Senior Systems Analyst in charge of GIS, "Every new layer added opens a can of worms because people start getting creative ideas about additional layers that can be used with the new layer to get something interesting out of the relationship. It ends up being a never ending cycle." As a result of the many years with GIS technology (Miami-Dade County was an early adopter), the ArcGIS system for the EOC has excess capability for supporting decisions that haven't been thought of yet.

Specific for the EOC is an application called Flipper (Florida Interoperable Picture Processing for Emergency Response), which is driven by the GIS infrastructure back-end. It provides a user-friendly interface for layering data and allows the capability of using streams of real-time data that come in from many sources, such as the National Hurricane Center, that can be added to the display if needed. Flipper is also able to visually represent attributes related to the objects, such as the status of a police station, as well as heat maps. This enhances GIS's ability to provide geospatial information into something that is better equipped to provide situational awareness for decision makers. Flipper is so central to knowledge dissemination and situational awareness that the front wall of the EOC is covered with 15 monitors, in a 3 high x 5 wide configuration, that is dedicated to displaying Flipper for the emergency response staff. The most common layers that are used are packaged as the "Critical Facilities Legend" which include: mobile home, nursing home, park-county, police station-county, police station-municipal, port, post office, public works facility, school-charter, school-private, school-public, adult care facility, adult living facility, ambulatory surgical center, bridge critical, canal structure, college (see Figures 5 and 6).

2.5 On-going monitoring

The data streams from the public (via http://damage.miamidade.gov) and from other internal web-based systems for each represented unit are all handled by a proprietary system called the WebEOC. In order to keep the constantly changing situational awareness central to the response staff the system is displayed in multiple screens at the center of the EOC facing in both directions. By complementing Flipper with this system the EOC is able to provide real-time situational awareness at-a-glance for the team members and decision makers. While Flipper is configured to show uni-dimensional geocoded data (such as overall color coded status of a resource plotted on a map), the WebEOC is

Figure 5: Flipper on main screen of EOC (from Miami-Dade County).

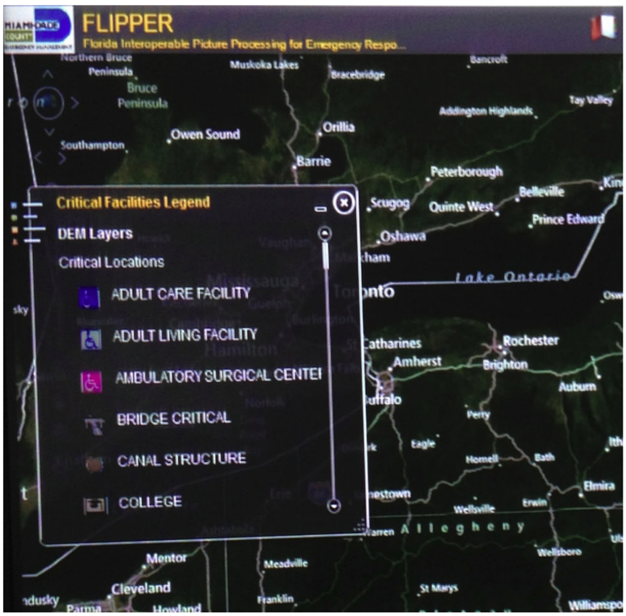

Figure 6: Flipper critical facilities layers (from Miami-Dade County).

intended to show multi-dimensional data about specific resources. For example, the central most screen has a WebEOC view that shows all the municipal infrastructure buildings as individual rows and their multidimensional status as columns (hazmat, flooding, roads, water, gas, electric, debris, emergency services, search and rescue, activation state) along with when the building's status was last updated. This allows one to see specific aspects of a resource beyond an overall color-coded status; although Flipper shows the over-all picture, the more granular details can be acquired from the WebEOC.

Due to the variety of resource types and areas of responsibility for the different members in the EOC it is important for the system to have views created with the resource information specific to each group's requirements. Apart from preventing flooding users with information it also allows for some level of quality control. The data requirements that most teams have in common are presented in the monitors at the center of the EOC. These screens include: Municipal Infrastructure Status (hazmat, flooding, roads, water, gas, electric, debris, emergency services, search and rescue, activation state), Public Safety Status (populated by Search and Rescue Teams), Evacuation Center/Shelter Status (name, status, general population, pet friendly, special needs, capacity, occupancy, availability), Road Closures (status, location, start date, end date, impact, address, detour, reason for closure), Disaster Assistance Centers (location, status, hours of operation), and Utilities Infrastructure Status (status along with percentages of customers impacted without electricity, water, etc.). For some of these views, such as road closures, the number of entries can quickly become more than what can be scrolled in a few seconds. These views are allocated additional monitors to minimize the time before an item of interest is scrolled for response staff. To achieve this the data is staggered so that one monitor starts at the first entry while the other starts at the twentieth entry, for example.

2.6 Current work

As GIS technology is now a very mature and integral component to Miami-Dade County it has become very easy for the EOC to find new useful layers. The challenge is that each layer that gets added needs to have an accompanying update plan that schedules updates every year prior to the commencement of the hurricane season. This puts a theoretical limitation on how many layers are possible due to limited resources. However, as more departments find a need for GIS software the processes used in updating this information becomes an integral part of the departments' operations and more resources are dedicated to that task for a double pay-off; it helps the departments collect GIS data that runs their operations, which the EOC can also use for emergency management purposes. Therefore, the EOC's biggest challenges come from the data related to the unpredictable public, which has become the target for more recent work.

In order to adequately model evacuation procedures it is necessary to understand just how many people plan to evacuate. This type of data is not easy to acquire, yet it is critical for planning. Knowing how many people plan to evacuate helps to appropriately stagger evacuations of areas depending on road capacity, have adequate Search and Rescue Teams and other resources, plan shelter capacity and locations, and minimize a lot of the guess work involved in capacity planning for emergencies. Slack resources are great to have in projects, but in emergency response situations it means that one area has too much at the expense of another area having too little. They are currently working on a research project to assess and quantify how many people would plan on evacuating, going to a shelter, or weathering the storm at home.

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Also, the demographic information contained in census data is updated every 10 years, which is useful for macro-level government planning but not very useful for the more detailed EOC requirements in one of the most dynamic counties of the country. It does not take into account the constant fluctuations of people present due to tourism, a large source of economic stimulus for Miami-Dade County, and the timing of those fluctuations. For this the county relies on inferences based on taxes, registrations, and travel data to have a better estimate of what the affected population is beyond the census data and allow them to plan better. This is constantly being done and improved upon as more data sources become available to base these inferences on.

3 Discussion and future research

Miami-Dade County's EOC illustrates how a carefully thought out knowledge management strategy can be extremely beneficial for an organization that is developing their emergency management plan. By consolidating areas of responsibility they were able to both significantly reduce the number of communication handshake points present at the EOC when it is activated for emergency response as well as substantially reduce the requirements for ensuring that data is updated on schedule with the hurricane season by assigning areas of responsibility. The championing of the EOC by the state also allows for ensuring that any new public service business conforms with their policies when applying for licensure.

Crowd-sourcing efforts have shown that there are benefits and drawbacks to empowering the public to provide affected population data. Although the website (http://damage.miamidade.gov) allows for leveraging the power of crowd-sourcing it can suffer from the data quality issues inherent in crowd-sourcing. The EOC was able to alleviate this by implementing an approval process with dedicated staff as well as incorporating heatmaps into their visualization tools to show concentrations of the affected population. The heatmaps help to differentiate between potentially erroneous individual incidents and incidents that can affect a large population.

Through an iterative learning process the EOC has also been able to model a logistical plan that has been incorporated into the SALT application, which is generated once the required parameters are input. Although this software may be unique to Miami-Dade County's characteristics for planning (which zones to evacuate first, how to stagger evacuation areas, etc.) this software would still serve as a starting point for helping others understand what is involved logistically in adequately responding to a hurricane well in advance of its arrival.

The EOC also shows how GIS-enabled visualization tools, such as Flipper and the WebEOC, allow for ubiquitous situational awareness of response staff as well as for immediate dissemination of state changes related to critical resources and the affected populations. The information that is common to all is being displayed on large screens for all to see, but there are also views created which are specific to groups and their delegated responsibilities that can be accessed at their respective stations. The critical facilities along with their color-coded status are presented in a large geographical map at the front of the room while the real-time data for roads, service centers, public service notices, and details of the critical facilities are scrolled in monitors at the center of the room.

The most common GIS resource layers, and operational data used by the various team members was presented in this paper, which should be similar to what most organizations will also find are common, however, we have not specifically gone into more granularity as those requirements are driven by each group's areas of responsibility. The more specific views are dependent on how the responsibilities were delegated, which will be different for any outside agency trying to mimic what the EOC has. For this reason a study that groups all the data requirements for each team into more general functional areas that can be delegated out would prove beneficial for the emergency management community.

Another future research direction could be in extrapolating out of all the resource requirements for the various types of disasters (natural and non-natural) the commonalities found regardless of the disaster type. No organization prepares entire teams specific to one type of emergency. With the exception of a few specialists with expertise and equipment for a specific type of threat, the rest of the response teams in general have much of their composition in common. This research would provide a rich source of information for organizations that wish to create mobilized emergency management groups to reallocate for areas in need. Although the United Nations and FEMA both have humanitarian response teams that are used in times of crisis neither has been able to provide seamless aid for any of the relief efforts (Crowley and Chan [12]). Analysing what the most experienced agencies at each category (California for earthquakes, Miami-Dade for hurricanes, etc.) utilize to help them overcome emergency management challenges could help other organizations advance in their relief efforts.

Acknowledgements

We would like to thank the amazing staff at Miami-Dade County Information Technology Department and Emergency Operations Center that volunteered their time to help us understand their complex emergency management process and tools, specifically Soheila Ajabshir and Karen Grassi. Finally, we would like to thank the FEMA trainer, Wayne Gurnee, for the guidance and vast experience shared with us in dealing with EM from a management perspective.

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Section 4
Critical information and communication technologies for disaster preparedness and response
(Special session organised by J. W. S. Liu)

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A linked-data based virtual repository for disaster management tools and applications

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Abstract

Nowadays, developed regions in the world, including Taiwan, have a wealth of data and information, which if made available in time for disaster preparedness and response purposes, can help save lives and minimize damage. With a few exceptions, however, state-of-the-art data management information systems (DMIS) available in most countries do not provide adequate support for search, discovery, access and use of data and information residing in independent sources across institutional boundaries. This paper describes architecture and design of a distributed middleware-level framework, called Virtual Repository (VR), together with functionalities and structures of its key components. By leveraging linked data and related technologies and tools, VR aims to eliminate this limitation. Two applications, Mobile Assistant for Disasters (MAD) and Automatic Disaster Alert System for Tourists (ADAST) are described to demonstrate the feasibility and effectiveness of VR

Keywords: linked data, disaster preparedness and response, information system.

1 Introduction

In recent years, news, historical records, published statistics and research studies on past disasters worldwide consistently tell us that data and information needed to support disaster preparedness and response decisions and operations are critical

www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/DMAN130171

to our abilities to cope with natural disasters, especially unforeseen catastrophic calamities. Such information, if made available in time, not only can help save lives and reduce damages for people affected by disasters, but also can make emergency response and rescue operations safer and more efficient. Statistics also show, however, that the positive impacts of information deteriorate rapidly with time following a disaster [1]. Therefore, making decision support information easily discoverable and accessible by Emergency Operation Center (EOC), emergency responders, victims and general public should be a primary design objective of all disaster management information systems (DMIS)

Today, this objective is met only partially by DMIS of numerous countries and regions in the world, including Taiwan and most of Asia. Typical state-of-the-art DMIS rely mainly on data and information in sources owned by government agencies responsible for disaster management. As a part of standard operating procedures (SOP) in preparation for a disaster, likely emergency scenarios are developed based on prior knowledge on similar disasters and experiences in dealing with them. When the disaster become imminent, the EOC determines the data and information needed to deal with the scenarios and has the data retrieved from available sources and cached on devices, computers and display systems and thus makes the data ready for use by decision makers and responders during the emergency. This practice and the DMIS used to support the SOP work sufficiently well for typhoons, downpours, earthquakes of usual severities, and other types of emergencies that occur frequently in the region.

The limitations of current DMIS have become evident time and again in unforeseen situations, however. In recent years, technologically advanced regions have a wealth of data beyond what are available in sources contained in the official DMIS. Some of these data (e.g., structures and surveillance data of damaged buildings in affected area, locations of people needed help to evacuate, real-time data on available private and public owned transports, and so on) can be invaluable when the levels of threat and devastations exceed the prediction. Yet, typical DMIS offer little or no support to enable timely discovery, access and use of such data, especially when the data are in sources outside of the official DMIS and across institutional boundaries.

This fact has motivated academics and industry, as well as governments of many countries, to exploit linked data and related technologies [2, 3] for disaster management. Adding semantics and relations to transform raw data into Linked Data (LD) not only eases the discovery and use of critically needed data during emergencies, but also enables the design and implementation of new and more effective disaster preparedness and response applications. Research projects on building emergency information system and management infrastructures on linked data and Linked Open Data (LOD) include the ones described in [4–6]. Tools provide by projects such as LOD2 [7] and SMILE [8] can help to reduce the effort and speed up the development of linked-data enabled DMIS and disaster management applications.

Building on this momentum, we proposed in a previous paper [9] architecture and design of a middleware-level framework called *virtual repository* (VR) for LD-based disaster preparedness and emergency response applications. Despite

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their commonly acknowledged advantages, adoption of LD and LOD within disaster management IT infrastructures has been slow. A reason is the enormous amounts of resources and efforts required to enhance existing DMIS with semantics and links [10] in anticipation of future needs. The virtual repository framework addresses this concern by offering applications with similar data requirements an extensible repository in which Universal Resource Identifiers (URIs) and links can be created from existing data sets on demand as needs for them arises. (When there is no possibility of ambiguity, we also call such a repository a VR.) In addition to supporting run-time access of linked data, each VR comes with tools using which the developers of the applications supported by the VR can easily create new linked data and maintain existing ones as the applications and data sources served by the repository evolve.

We describe in this paper the functionalities, structures and implementations of key components of a typical VR. Following this introduction, Section 2 further motivates the VR framework and its design rationales with the help of two applications, Mobile Assistant for Disasters (MAD) and Automatic Disaster Alert System for Tourists (ADAST). These applications share a VR. They were presented in [9] as case studies. Section 3 describes the VR architecture and implementation from application development perspective. Section 4 describes in detail VR components. Section 5 discusses our future work.

2 Motivation and rationales

Again, we use MAD and ADAST to help us explain the reasons for using LD, LOD and VR framework. We also use them to explain the functionalities required of the VR to support the development and use of these and similar applications.

2.1 To support development of work-anywhere applications

MAD is an application system designed to help the general public access and download to mobile devices information on where to go and what to do when a major disaster strikes so that they can carry the information with them during the emergency. Such information includes nearby buildings designated as public shelters, parks with portable water and food, emergency medical care centers, and so on. Many city and township governments in the world (including Taipei, San Francisco, and London [11–13]) have made this kind of information available on-line. So, it should be straightforward for applications such as MAD to retrieve the information using the open interfaces and API functions of the local web services and databases. Indeed, this is what the alpha version of MAD does.

Specifically, the proof-of-concept prototype MAD v0.5 serves only people in Taipei city. The application system has a client-server structure. As its name indicates, MAD clients are applications running on mobile devices commonly used by general public every day. One (or more) interface server (IS) retrieves from Taipei OpenData [12] disaster preparedness information for general public in the city, periodically during normal times and upon notification by alert authorities. The IS then partitions the data into location-specific subsets, each for a district of the city, and distributes the subsets pervasively to point-of-service (POS) servers running on computers and devices contributed by businesses (e.g., convenience stores and cafes) and organizations (e.g., schools and companies) within the districts. In this way, MAD makes the critically needed data highly available and downloadable to mobile clients via local connections when Internet and phone connections are disrupted.

MAD v0.5 allowed us to demonstrate the functionalities and usability of MAD but falls short on the maintainability and extensibility. A reason arises from the fact that information consumers targeted by sources such as Taipei OpenData are people, not programs. Often, inconsistencies in naming schemes and data schemas cross different domains have not been carefully eliminated. As an example, in Taipei OpenData, “property name” of a sports center and “organization name” of a hospital both refer to names of the respective facilities. Human can easily process this information despite the difference, but not programs. We solved this problem in MAD v0.5 by using brute-force, hand-coded mappings. As expected, MAD v0.5 is hard to maintain as these mappings must be updated when schemas of the data source(s) change.

We want future versions of MAD to be a work-anywhere service. In particular, the client component of MAD, once installed on a mobile device, can access and download local disaster preparedness information wherever such information and MAD service are available. Our current goal is to demonstrate that MAD 1.0 work in representative cities including Taipei, London and Tokyo. A way to accomplish this goal is to have MAD servers and clients work with a common data model and format regardless the data models, schemas and views of available local information sources. Resource Description Framework (RDF) [10] is a natural choice for this purpose: Translation tools such as the ones provided by LOD2 [7] can ease the effort of translating the structures and semantics of legacy data schemas into a RDF format. With data objects and resources named by their URIs, the problem due to multiple aliases for the same object or different objects with the same or similar names is eliminated.

An important advantage of the RDF model and associated formats over other choices of common data models, schemas and formats is that RDF enables us to link not only data sets retrieved by MAD from sources used by the system but also with data sets from external sources that support linked data. In places where local sources have linked open data (e.g., in numerous cities in the US and EU), MAD can easily discover and retrieve disaster preparedness data in a RDF format from the sources and directly forward the data to its mobile clients. At locations where the local sources do not have linked data (e.g., in Taipei) and may not even have open data (e.g., in many cities in Asia), MAD IS uses API functions, web crawlers and translation tools to retrieve the required disaster preparedness data, translate and store the data in RDF format. We advocate here that the linked data thus generated by MAD and similar applications be kept in a common triple store provided by a middleware so that the applications can share the data and the effort spent to create the links is amortized. In addition to space in the triple store, the middleware also provides supporting tools for the generation and use of linked data in the triple store, sources with linked data and legacy sources without linked data. This middleware is what we call a virtual repository (VR).

2.2 To enable discovery and effective use of data in independent sources

While the RDF model and format(s) are a design choice of internal data for applications such as MAD, they are essential for applications that must be able discover and access as soon as possible data from sources not contained in the official DMIS. ADAST is such an application: In response to an alert declared by a responsible authority (e.g., the Central Weather Bureau) warning of an imminent calamitous event (e.g., a severe storm and possible landslides), ADAST proactively notifies people in the affected areas specified by the alert. When the threatened areas include popular national parks, the application must reach not only local residents, but also tourists. The data required for this purpose are likely to be in sources maintained by multiple government agencies and companies. (For example, real-time data on numbers and locations of tourist groups are likely to be in databases maintained by Tourism Bureaus and tour companies.)

The VR serving this and similar applications should provide at least semantics on and links to data critical for the applications to meet their minimal requirements. In the case of ADAST, a minimal requirement is that the contact persons of all tour companies operating in the park(s) and park ranger stations are notified. Hence, a use scenario of the VR is that semantics and links to data on these entities are created and maintained in the storage of the VR during the design and development process of the application. For the same reason, applications designed to support rescue and evacuation operations need data on rescue equipment, hospital and emergency care facilities, and so on in the affected area. Providing the applications and their developers with tools to discover, link and cache such data is a function of the VR serving the applications.

In addition to the basic functions mentioned above, the VR also provides event-notification support. With a few exceptions, sources in and out of official DMIS are passive or interactive databases, sensor webs, web services, etc. Without help, a proactive application such as ADAST must poll their contents and pull from them data on recently posted disaster alerts and specifics about each alert. Having the VR do this work on behalf of all the applications served by it is a way to amortize the associate overhead and thus keep the overhead low. We are developing an Intelligent Active Storage Service (IASS) [14]: This component of the VR will provide applications requesting its service with the capability of monitoring events and conditions defined by the applications in terms of values of data in specified sources and the VR triple store and respond to the occurrences of a event/condition by pushing notifications to designated applications and end-users in ways specified by the applications. By doing so, IASS will turn existing pull-based data sources in part into push-based reactive/active sources.

The version of the VR described in subsequent sections has a simplified IASS, called *client subscribe and notification services*. To avail itself of the services, ADAST first register itself with the services and specifies in its request-for-service the types of disaster alerts (e.g., typhoon, earthquake, debris flows and downpour) about which it wants to be notified and the maximum allowable

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delay in notification for each type of alert. These services monitor the authorized information sources where the specified types of alerts and warnings are posted (or published) and notify ADAST when a specified alert is found (or received). Details on the structure, components and operations of ADAST are omitted since they are unimportant to our discussion here and can be found in [9].

3 Structure and design of virtual repository

Figure 1 illustrates the relation between a VR, its *client applications* (i.e., the applications served by the VR) and *client* (*data*) *sources* (i.e., data sources used by one or more client applications): The middle of the figure depicts the structure and components of a VR, which we will describe shortly. The dashed boxes on the top and bottom of the figure enclose its client applications (including MAD and ADAST as examples) and data sources, respectively. The vertical box in the right of the figure shows the generic interfaces such as HTTP GET/POST protocol that enable applications and sources to communicate with tools and components inside the VR.

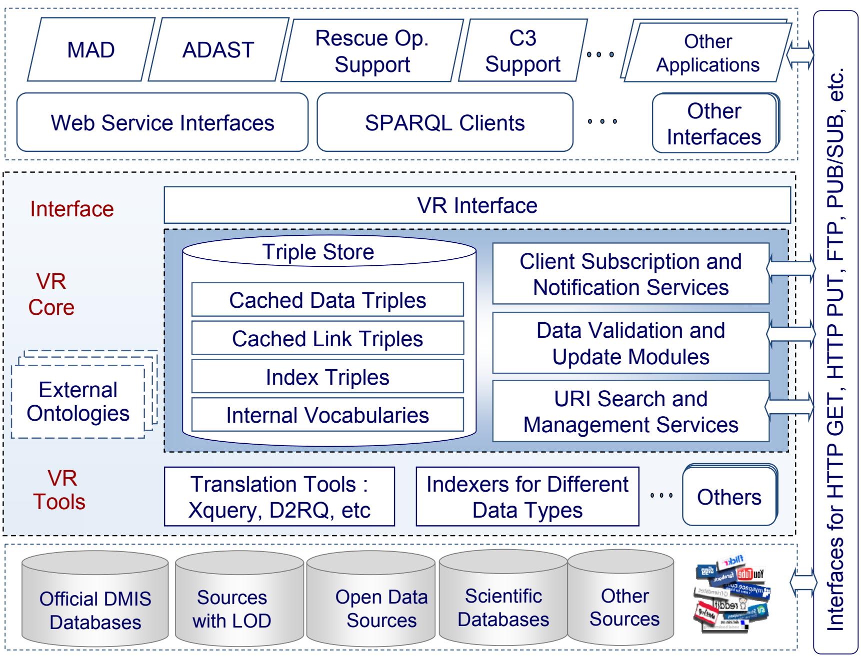

Figure 1: Structure of virtual repository.

In essence, a VR provides its client applications with a development and run-time support environment: By using the tools and processes provided by the VR, a user (i.e., a client application and/or its developer) can create and add as needed semantics and links for parts or all of the data in each source used by the application and selectively cache and publish the resultant links and LD to a shared common store and thus make them available to other applications.

3.1 Interface and tool layers

As we can see from Figure 1, VR has a layered structure: interface(s) on the top level, VR Core on the middle level and VR Tools on the bottom level. A VR-enabled client application can access data on links, linked data and tools provided by the VR, as well as data in client sources, via a variety of interfaces, including web service interfaces, SPARQL [15] endpoint, etc. The query language used internal to the VR is SPARQL, using which linked data can be queried in ways similar to querying a large database [16]. The VR Interface layer translates all user queries into SPARQL queries and sends the queries to retrieve the required information. In this way, each client application can query the VR with condition specified in SPARQL and set up the returned format or returned information displayed in its own way.

At the backend, the VR Tool layer makes available tools to translate raw data in common exchange formats (including XML, JSON and KML) and data record formats (including XLS and CSV) to linked data in the RDF N-triple format, refereed to simply as triples in Figure 1. Currently, translation tools offered by the VR Tool layer include XQuery [17] and D2RQ [18]. The former can be used to translate XML file to linked data, and the latter can be used to access a relational database as a RDF graph. The tool layer has a recommendation table. Using the table, developers can recommend other existing translation tools to be added the VR tool library or suggest missing tools to be designed and built in the future.

The contents of many files, including media files in formats such as JPEG, TIFF, AVI, MP3, etc. cannot be represented in a RDF format. The Indexers shown in Figure 1 are tools for building indexes for these files based on their metadata and/or user specified contents. The resultant indexes are in RDF N-triple format and stored as shown in the figure.

3.2 VR Core layer

VR Core is the essence of virtual repository: It provides the resources and functions needed to support the VR Interface to client applications and VR Tools for the underlying data sources. The layer is composed of storage components and functional components. The important ones are depicted within the darkened rectangle in the middle of Figure 1.

Before moving on to describe individual components, we note that as the name Virtual Repository implies, VR provides a storage system for information and data. This component is called *Triple Store*. Depending on the client applications, parts or all of the data links or linked data generated by the VR tools are stored and kept up to date in Triple Store. An application can treat Triple Store as a virtual storage, sending all of its requests and dealing with returned data as if all the data are in the component: The fact that some of data are stored only on the original data sources is hidden from such an application.

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Client applications can also choose to be unaware of the fact that Triple Store is physically distributed. The middleware places links and LD maintained within the VR core on multiple servers, some of which are physically outside of the areas threatened by the current calamity or in a highly available cloud, so that they remain available and accessible even when the data sources are damaged by the disaster. Some client applications (e.g., MAD) may store their LD pervasively on computers and devices chosen by them. This is a way to reduce the bandwidth and increase the availability of connections required to support end-user access to data. However, these data, unless duplicated in Triple Store, are not accessible by other client applications. Due to space limitation, we defer discussions on achievable availability, responsiveness and other quality of service attributes of alternative distributed configurations of the VR storage to a future paper.

4 Key VR Core components

Again, VR Core has two types of components: storage components and functional components. We now describe the ones shown in Figure 1.

4.1 Storage components

As Figure 1 shows, Triple Store contains at least four types of data: Cached Data Triples, Cached Link Triples, Index Triples and VR Internal Vocabularies. VR provides a space for optionally caching the linked data generated by the translation processes. So, when translating selected data from client sources into RDF triples, a user (i.e., an application or its developer) can choose to store the resultant triples in Triple Store. They are called Cached Data Triples, or simply data triples here. When a user searches data through the VR Interface, VR returns cached triples if they are in Triple Store, instead of assisting the user to find and access the raw data from client sources and translate the raw data to linked data again. Addition to saving the time and overheads of repeated translation, cached triples provide backup and enhance the availability of critical data.

In contrast to data triples, the user may choose to store only the link triples generated during translation. These triples provide the applications with connections to data triples within the VR and in external knowledge bases.

An index triple was generated by an indexer tool to mark a file based on the metadata of the file and/or data specified by the user. A file may have multiple index triples. As an example, let us consider a file containing a video of the terrain and landscape of a highly unstable mountain area shot by an unmanned aircraft before typhoon season as a part of disaster preparedness SOP. The metadata of this video include basic file information such as size and format of the file; geological information (including the location, coordinates, size and type of terrain of the area); weather and operation conditions (e.g., operator, purpose, goal, observed event, analysis report) and so on. These types of metadata are formatted into RDF triples. The resultant linked data on the file enable the file to be found more easily. Depending on the user's choice, the file itself may or may not be cached by the VR.

An important part of Triple Store is VR Internal Vocabularies, or Internal Ontology. Today, numerous ontologies, including DBpedia [19] and SUMO [20], are available. They define and provide representation of concepts and objects (entities) and relationship among them in diverse domains. Figure 1 calls them collectively external ontologies. VR makes use of them as much as possible. The VR Internal Ontology includes only the terms that are required by some client applications but cannot be found or are not defined appropriately in any of the commonly used external ontologies. As an example, when a user uses VR translation tools to translate information on shelters in a city to linked data, a URI is needed to represent the street name part of the address of a shelter. If the user cannot find an existing URI to represent the street, he/she creates an URI of the street and stores the new URI in Triple Store as a VR internal vocabulary with the help from the URI Management Service.

Some or all of the VR internal vocabularies may be valuable to web ontology communities or developers. For this reason, VR also provides a GUI and API functions using which ontology developers can access the vocabularies and evaluate them.

4.2 Functional components

The right part of the rectangle in the middle of Figure 1 encircles some of the functional components provided by the VR Core for both internal and external use. Earlier, we have already mentioned Client Subscription and Notification Services, hereafter, referred to as CSS and CNS, respectively. These services enable client applications and sources to publish and subscribe information to each other. VR provides a web UI and an API function, using which a user can register with CSS as a subscriber, providing the service with specifications of the required data, designated applications and end-users to notify and one or more trigger conditions. When CNS detects a condition in the trigger condition list is met, it retrieves the required data and sends the data as a notification to the subscriber and designated client applications or end-users. With CSS and CNS, client applications do not need to periodically check the data in VR to see whether the data have been updated. Instead, the applications can check the data once they receive notifications from CNS telling them that subscribed data is updated.

Data Validation and Update Modules (simply called DVM and DUM, respectively) are also key components of VR core. For data stored in Triple Store, DVM is responsible for validating the consistency of internal data with external data stored in the original sources. When a user decides to store the RDF data of the client application in Triple Store, the user specifies a valid (time) interval, or simply valid time, for each triple or set of related triples. A triple is considered expired and hence invalid when time elapses beyond its valid interval. As an example of where this is important, we note that a client application such as ADAST must examine the date or valid time interval of each alert. If the alert has already expired, it should not take any action as a response to the alert.

In addition to specifying a valid time interval for stored triples or sets of triples, a user may also provide parameters specifying when to update or not to update when the data is no longer valid. DUM updates the store data in VR based on the policy defined by such user-specified parameters and in the absence of parameters specifying otherwise, update the data by default.

The bottom box in the VR tool stack depicts URI Search and Management Services, called USS and UMS respectively. The former is provided to assist the users in their search for URIs, while the latter helps to manage (i.e., add, delete, and modify) internal URIs.

During a translation process, when a URI is needed to represent a term, the user (or a translator program) can use USS to search external ontologies for possible choices. USS provides the user with a UI and an API function for this purpose. Once USS receives a searched term via the UI or API function, the tool connects to existing ontologies in turn, queries each of them for URIs based on the search term and integrates URIs from the search into a list as the result of the search. In this way, USS enables the user to treat all external ontologies as a single source and thus avoid the need to search them individually manually.

After receiving a URI list from USS, a user can select a URI from the list to represent the term for which the search was performed. When none of the existing URIs in the list is inappropriate for a term, UMS assists the user to create and manage a new URI. UMS is part of the interface of VR Internal Vocabularies. Every term created by UMS is stored in the VR Internal Vocabularies. UMS allows both manual and automatic addition of new URIs. Specifically, the GUI of UMS lets ontology developers to manually classify and store new URIs offline. UMS also provides API functions using which a client application can request automatic addition of one or more URIs into VR Internal Vocabularies. Both USS and UMS work with VR Translation tools and Indexer.

5 Summary and future work

This paper describes the structure of a virtual repository (VR) designed to present to its client applications and users linked-data views of data contained in one or more sources that may or may not support linked data. Serving as a single data source, a VR enables its clients to be benefited from linked data despite their use of legacy databases and web services. The resources, tools and services made available by the VR aim to ease the tasks of transforming raw data from client data sources into linked data. In this way, the VR serves developers as a component of a development environment for the implementation of linked data enabled applications for disaster preparedness and response.

Specifically, previous sections described the three-level structure of VR. The top level is the VR Interface that enables applications or users to query for required information from the VR using commonly used interfaces. The middle level VR is composed of storage components and functional components. The storage components form a virtual repository of links and cached linked data. The functional components provide services including event notification, data management, URI management, etc. At the bottom level, VR tools assist the translation of raw data from client sources into linked data.

Much work remains to be done. Existing open sources tools and components gave the VR effort a running start. In the process of extending VR tool library and key components and completing a fully functional VR prototype, we will produce new tools and components and contribute them to the open source resource pool. Examples include the growing collection of URIs representing disaster preparedness and response concepts and objects in VR Internal Vocabularies, as well as functional components that support the VR services presented earlier.

In addition to MAD and ADAST, we plan to develop as case studies other representative disaster preparedness and early response applications that share a VR. They are needed, in addition to the VR prototype, for the purposes of demonstrating convincingly the merits and effectiveness of the VR approach to design and development of linked-data enabled applications and services.

We mentioned earlier that we will enhance CSS and CNS, redesigned them if needed, in order to turn them into an intelligent active storage service and a VR into an active/reactive information system. Until now, we have made ad hoc architectural choices for the distributed Triple Store. Now that the design and implementation of the prototype is well underway, we will begin to flesh out the alternative choices of distributing the contents of the Triple Store on available VR system resources and client data sources and evaluate their relative merits in terms of quality of services parameters such as data availability and responsiveness.

Acknowledgements

This work was supported by the Academia Sinica thematic project OpenISDM. The authors wish to thank Wen-Ray Su, I-Liang Shih, Shang-Yu Wu of Taiwan National Research Center for Disaster Reduction (NCDR) and many Co-PIs of project OpenISDM for their critiques and suggestions on this work.

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Physical-layer communication recovery for heterogeneous network

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Abstract

Natural and manmade disasters often cause failures in network components. Such failures induce communication service interruptions as well as packet and economic losses. To provide adequate communication recovery in disasters, we propose here a local fast failure recovery scheme, called Unaffected Alternate Selection (UAS), for avoiding traffic congestion and to achieve high survivability in the event of single link and router failures. Our simulation results show that the proposed scheme can successfully disperse affected traffic flows and recover failed physical-layer network communication in disasters.
Keywords: survivability, load balance, fast failure recovery.

1 Introduction

Unpredictable natural or manmade disasters often cause the outages of network communications. In traditional Internet routing protocols (such OSPF [1] or IS-IS [2]), a network component failure will trigger routers to reconstruct their own routing tables. The total recovery may take up to tens of seconds for the process to re-converge [3]. Such long recovery time may cause large data loss and devastating impacts on disaster response operations.

To address this and other challenges in providing effective disaster management information and communication supports, the three-year Open Information System for Disaster Management (OpenISDM) project is

WIT Transactions on The Built Environment, Vol 133,
www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/DMAN130181

developing an architectural framework and underlying technologies for building information and communication systems used to support disaster preparedness and response decisions and operations: A system built on the OpenISDM framework is open and sustainable. It can provide decision makers, responders, victims and general public with data and information from not only government sources but also from sources owned by non-government entities and individuals on a timely basis.

Clearly, this design goal can be met only when communication data and emergency information can be rapidly and timely broadcast throughout the Internet during and after disasters. This is why a major part of the OpenISDM project effort is devoted to developing the technology that is needed to provide robust heterogeneous and plug-n-play network communication for such systems. The local fast failure recovery scheme, termed the *Unaffected Alternate Selection* (*UAS*) scheme, presented in this paper is a part of this effort.

UAS addresses network survivability and load balance issues at the same time. It is designed to handle the most common network communication failures, including single link and node failures. UAS searches the unaffected router to be an alternate node for protecting single link or node failures. Once a link or node fails, the flows carried on the failed link or node are rerouted to the pre-determined unaffected router. The unaffected router guarantees successfully rerouting and ensures no routing loops during the fault recovery. Besides, the unaffected routers also help to balance the rerouted flows so as to avoid link congestion in the failure state. Simulation results indicate that UAS not only has high survivability but also balances network traffic flows in the slightly longer backup path hop count.

The remainder of this paper is organized as follows. Section 2 presents related work. We demonstrate the proposed Unaffected Alternate Selection (UAS) scheme and discuss the properties of UAS in Sections 3 and 4, respectively. In Section 5, the experimental results are shown and performance comparisons to other well-known schemes are conducted. Finally, concluding remarks are made in Section 6.

2 Related work

Existing robust network communications approaches include ECMP [4], LFA [5], and U-Turns [6]. The Equal-Cost Multi-Path (ECMP) [4] is a network communication recovery strategy in which when a network component fails, ECMP uses candidate shortest paths to recover the failed network areas. The Loop-Free Alternate (LFA) scheme [5] and U-Turns [6] are run on adjacent routers close to the failed network area to find an alternative route and redirect traffic such that the data and information can be successfully delivered throughout the Internet. Nevertheless, as described in [7], while these existing works contribute to protect Internet, the protection ability remains inadequate.

To improve protection ability, Tunnel-based schemes were presented [8–10]. In Tunnel-based schemes, when a router detects an adjacent failure, the router selects an intermediate router, encapsulates the packets carried on the failed link

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and reroutes them to the intermediate router to bypass the failed areas. Tunnels [8], Not-via address [9], and Protection Graphs Construction [10] adopt such design concept. However, to encapsulate information packets introduce extra burden on routers in the network. Some Backup Routing Table (BRT) based recovery schemes were introduced [11–19] to avoid encapsulating information packets. In BRT-based recovery schemes, each router pre-computes backup routing tables (or backup configurations) before any failure occurs. Once the primary forwarding network component fails, the protection switching is triggered on the routers adjacent to the failed component. However, the provision of only backup paths is not sufficient. In a failed network, the affected data traffic would be redirected to unaffected network areas. Such traffic data redirection may cause network congestion and thereby lead to more data or information losses.

Unlike existing approaches devoted to enhancing Internet protection ability, the proposed UAS scheme jointly considers network congestion and protection ability in disasters. Through UAS, the network communications affected by disasters are recovered and the network congestion is avoided in the duration of the failure recovery.

3 Proposed UAS scheme

We represent a network topology by a directed graph $G=(\boldsymbol{V},\boldsymbol{E})$, where $\boldsymbol{V}$ denotes the set of nodes and $\boldsymbol{E}$ denotes the set of links on the graph. The directed link is expressed as $e(i,j)\in\boldsymbol{E}$. In a link state routing protocol such as OSPF, each node forwards packets to other nodes based on the shortest path tree rooted at itself. We let $SPT(a)$ and $SP(a,v)$ denote the shortest path tree rooted at node a and shortest path from node a to node $v\in\boldsymbol{V}$, respectively; $\boldsymbol{E}_{SP(a,v)}$ denotes the set of links on $SP(a,v)$; and $\boldsymbol{V}_{SP(a,v)}$ denotes the set of nodes on $SP(a,v)$. Furthermore, we define a router i as an *unaffected router* if router i forwards a packet to destination d through the shortest path without traversing through the failed link or node, i.e., the failed link $e(i,j)\notin\boldsymbol{E}_{SP(i,d)}$ or the failed node $y\notin\boldsymbol{V}_{SP(i,d)}$.

When a link failure occurs, some connections are interrupted so that the destinations of these connections are unreachable. These unreachable destinations are termed the *unreachable nodes*. To further clarify the notation, we let $\boldsymbol{V}_{ne1(a)}$ and $\boldsymbol{V}_{ne2(a)}$ denote the set of one-hop and two-hop neighbors of node a. The goal of the UAS scheme is to find an *unaffected* alternative neighbor to reroute traffic affected by the link failure or the node failure for the unreachable nodes. Each router pre-builds a backup routing table with unaffected alternate neighbors before any single link or node failure occurs. Once a router detects a failure, it suppresses flooding of the failure information and uses the backup routing table to immediately reroute the affected traffic. The UAS adopts one-hop and two-hop searching procedures to find unaffected alternative neighbor

The pseudo-code of UAS is shown in Figure 1. The scheme uses the following two procedures:

Search One-hop Unaffected Alternative Neighbor**:** If link $e(a,b)$ fails, the upstream failure adjacent node a searches for an unaffected alternative neighbor from set $V_{ne1(a)}$ to reroute the packets destined for the unreachable nodes. Node *a* checks nodes in $V_{ne1(a)}$ to determine whether there is a node with the shortest path to the unreachable nodes which does not traverse through the failed link *e*(*a*,*b*).

```
Algorithm UAS for each node:
Step 1. Search one-hop unaffected alternative neighbor.
Step 2. If  one-hop unaffected alternative neighbor = null
            Search two-hop unaffected alternative neighbor.
        end If
Step 3. Build backup routing table through one-hop/two-hop
         unaffected alternative neighbors.
```

Figure 1: Pseudo code for UAS algorithm.

Search Two-hop Unaffected Alternative Neighbor**:** The two-hop searching procedure is triggered only if there is no unaffected alternative in the set of one-hop neighbors. The prodecures of two-hop searching are similar to one-hop searching. The difference between one-hop searching and two-hop searching is that the upstream failure adjacent node *a* searches for an unaffected alternative neighbor from set $V_{ne2(a)}$ rather than set $V_{ne1(a)}$.

We hope that the one-hop and two-hop searching methods presented above can be used to handle single link and node failures. Each node searches for unaffected routers via one-hop and two-hop searching procedures to protect neighboring links and nodes before one of them fails. The unaffected routers thus found are used to build backup routing table.

4 Packet forwarding and property of UAS

In this section, we describe the packet forwarding procedure and prove the loop-free property for UAS.

4.1 Packet forwarding procedure

Once each node builds its own backup routing table, the tables of all the nodes are is used to handle a network component failure as indicated by the packet forwarding flowchart (Figure 2).

When node *s* receives a packet with destination *d*, node *s* checks whether its primary next hop has failed. If so, node *s* uses the backup next hop to forward this packet; if the backup next hop doesn't exist, node *s* drops this packet. If this packet is rerouted by the backup next hop, node *s* inserts a 1-bit 'tag' into the header of the packet so that routers on the backup path know to use the backup next hop to forward this packet. On the other hand, if the primary next hop does not fail, node *s* checks whether the packet was marked 'tag'. If not, node *s* uses the primary next hop to forward this packet. If the packet was marked 'tag', node *s* uses the backup next hop to forward this packet if the backup next hop exists; node *s* uses the primary next hop to forward this packet if no backup next hop exists.

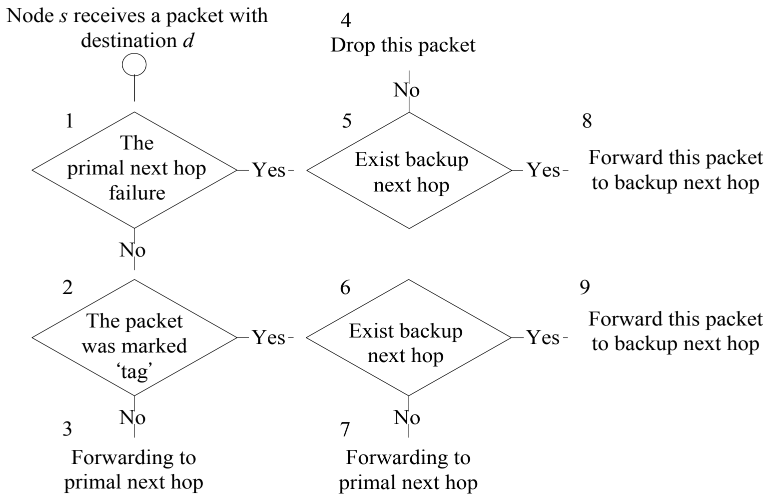

Figure 2: Packet forwarding flowchart.

4.2 Loop-Free property of UAS scheme

In the duration of failure recovery, the avoidance of routing loops is crucial. Hence, we prove that the proposed UAS guarantees loop-free packet forward during the fault recovery.

Theorem: The UAS scheme guarantees that the loop-free routing property holds during the entire fault recovery process.

Proof: In this proof, the loop-free routing property is proven for the case of a single link failure. The case of a single node failure can be easily proved using similar arguments and is therefore omitted.

We prove this loop-free property by contradiction. Assume that link $e(a,b)$ fails and node d consequently becomes an unreachable node. Suppose that $e(a,b) \in \boldsymbol{E}_{SP(a,d)}$ and node a reroutes the affected packet to destination d via an unaffected router, say x, whereby a routing loop is formed. In other words, the packets sent from a via x for d will finally return to node a. Since node x follows its primary routing table (because node x is an unaffected router) to forward packets for d, the only possible loop is that node $a \in \boldsymbol{V}_{sp(x,d)}$. Moreover, failed link $e(a,b) \in \boldsymbol{E}_{SP(a,d)}$. Hence, we can conclude that $\boldsymbol{E}_{SP(x,d)}$ will include the failed link $e(a,b)$. This contradicts the fact that node x is an unaffected router. Hence, using an unaffected router guarantees the loop-free property, which therefore stands proven.

The complexity of UAS is $O(|\boldsymbol{V}_{ne2}||N|^2) \approx O(|N|^2)$ since each node ($|N|$) needs to check all of its two-hop neighbors ($|\boldsymbol{V}_{ne2}|$) to protect all unreachable nodes ($|N|$) in the worst case scenario.

4.3 Traffic dispersion of UAS scheme

In UAS, each node searches one-hop and two-hop unaffected neighbors to reroute the affected traffic flows to reach the unreachable nodes. These affected traffic flows, in fact, are dispersed naturally. In the example shown in Figure 3, node *x* performs UAS scheme to protect those unreachable nodes, *a*, *y*, and *b* under link *l*(*x*,*y*) failure. The unaffected neighbor *e* is used to protect unreachable node *b*, while the unaffected neighbors *d* and *c* are used to protect unreachable nodes *a* and *y*, respectively.

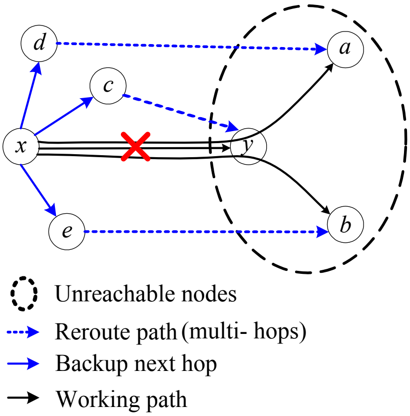

Figure 3: Traffic dispersion of UAS.

When link *l*(*x*,*y*) fails, the traffic carried on the failed link *l*(*x*,*y*) then is dispersed to the three rerouted paths leading to three respective unreachable destinations via UAS. In addition, we also select the most balanced unaffected neighbor to reroute the affected traffic for avoiding traffic congestion if there exit more than one unaffected neighbors to protect an unreachable node. The detailed performance analysis on load balance of UAS was shown in the next section.

5 Performance

In our simulation, we observed three key performance metrics, survivability, average backup path length, and the maximum link load. The UAS scheme was compared with conventional IP fast-reroute schemes including ECMP, LFA, and U-Turns under the five network benchmarks shown in Figure 4. We set the link weight to be an integer uniformly distributed between 1 and 65535. In particular, we set the link weight to be 1 for ECMP to improve the chance of finding multiple equal cost paths between node pairs. We assumed that two routers have a connection in each experimental network and that each connection follows IP shortest path routing. Cases of both single link and node failure were considered. The results were averaged over 100 trials, and the corresponding confidence intervals are plotted in each figure.

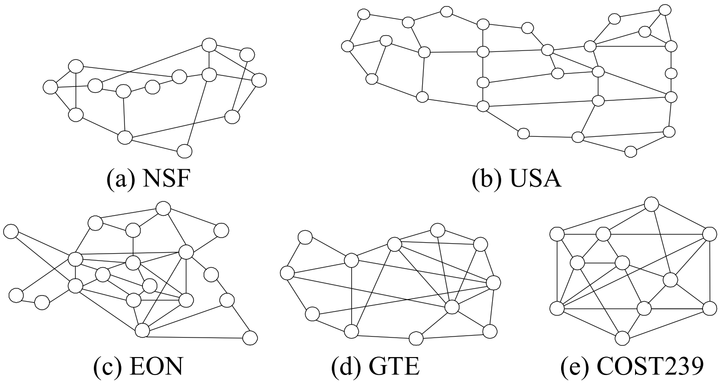

Figure 4: Benchmark networks for performance evaluation.

Figure 5 compares performance in regards to survivability. Survivability is defined as the ratio of the total number of connections that can be successfully

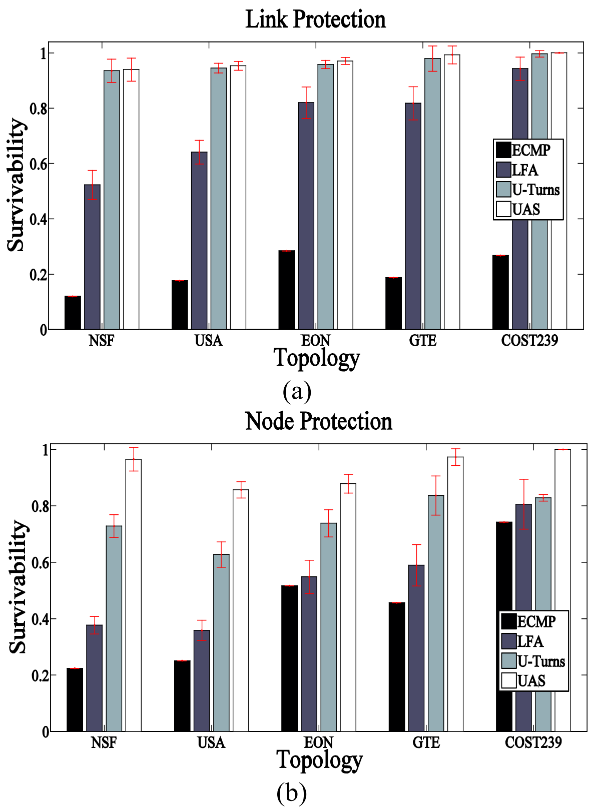

Figure 5: Average network survivability for (a) single link failures, (b) single node failures.

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rerouted to the total number of disrupted connections. Figure 5 shows that the UAS scheme outperforms other schemes and achieves a survivability ratio of up to 93.95%–100% and 85.68%–100% for single link and node failures, respectively. Particularly, in node failures case, UAS has outstanding performance.

Figure 6 shows the results for the backup path length. The average backup path length is defined as the ratio of the sum of hop counts of the backup path to the sum of hop counts of minimum hop count path. Since the link weight of ECMP is set as 1, the backup path length of ECMP maintains the lowest value. Since U-Turns allows rerouted packets to travel back one-hop upstream node, U-Turns has longer backup path length than LFA. In single link failures case, the backup path length of UAS is similar to U-Turns. For single node failures case, backup path length of UAS is 0.2 hops longer than U-Turns. The results indicate that the proposed UAS scheme would not incur a long backup path while achieving high survivability.

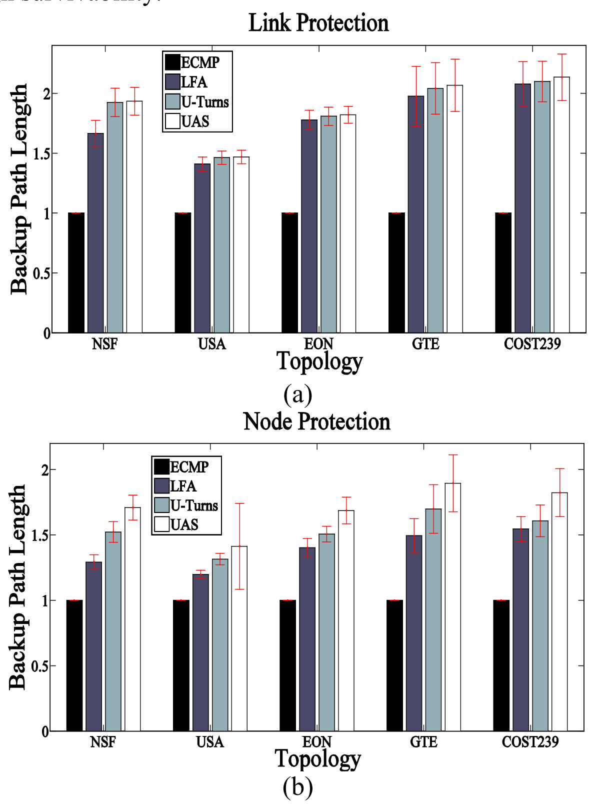

Figure 6: Average backup path length for (a) single link failures, (b) single node failures.

Finally, we perform UAS on COST239 network to observe the load on the most congested link in the failure state. The results are compared to OSPF recalculation and shown in Figure 7. In this experiment, we assumed the traffic demand between any two nodes to be 10Mb/s. The x axis represents the index of failed component and the y axis shows the load on the most congested link. Under different link or node failure, UAS has similar maximum link load to OSPF. This is because UAS uses the respective unaffected neighbor for the corresponding unreachable node. The flows carried on the failed link or node are then dispersed to each dedicated unaffected neighbor and reach their destination. The results indicate UAS can efficiently disperse the affected flows in the duration of fault recovery.

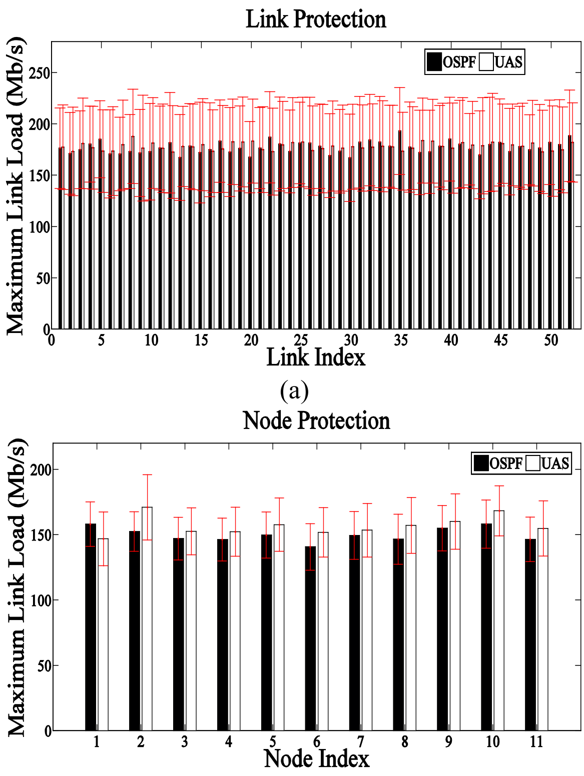

Figure 7: Maximum link load in COST239 network for (a) single link failures, (b) single node failures.

6 Conclusion

In this paper, we describe a high survivability IP protection scheme UAS to handle single link and node failures. The UAS scheme guarantees loop-free routing and avoids network congestion during the healing process. We have conducted simulations to evaluate the performance for survivability, backup path length, and link load distribution. The results show that UAS achieved the highest survivability, a slightly longer backup path length, and a balanced link load.

Acknowledgement

This work was partially supported by the Academia Sinica project OpenISDM.

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Landmark-based self-healing service recovery for distributed pub/sub services on disaster management and M2M systems

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Abstract

How to exchange information between parties in a disaster management system is one of the fundamental challenges to support timely and efficient disaster response and relief. Specifically, the timeliness, scalability, and availability are three desirable features for information exchange. We call the framework to support information exchange with the three features an Open Information Gateway (OIGY). In this paper, we present the challenges of information gateway and the design of the communication protocols and landmark-based service recovery mechanism to support the aforementioned features. The mechanism aims at recovering the real-time publish and subscription services within an affected region. The developed method allows a landmark service node to monitor pub/sub service within a region, rather than the entire pub/sub network. To evaluate the performance of the service-recover mechanism, we measured its transmission and recovery overhead under different number of message brokers in the network.
Keywords: middleware, message publish and subscription, service recovery.

1 Introduction

Timely disaster response requires the collaboration from many parties including telecommunication service providers, web service providers, general public, rescue agencies, and rescue coordinators. When disaster occurs, how to exchange

WIT Transactions on The Built Environment, Vol 133,
www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/DMAN130191

information among victims, rescuers, and decision makers is one of the most critical challenges. The goal of this work is to design and prototype a self-healing information gateway to enhance responsiveness and availability of information exchange for disaster response and machines-to-machines (M2M) communication.

In the last few decades, many attempts aimed at developing special communication devices and reserving specific communication channels for disaster rescue. Examples include satellite phones [1], IP-based 911 [2] and rescue radio [3]. However, the applicability of these new technologies was founded limited. Take satellite phones as an example. Satellite phones provide location-free communications no matter whether the users are located in mountainous area, metropolitan, or on the sea. It is extremely effective for rescuers in mountainous area and sailors on board. However, due to its high deployment cost, it is not possible to put a satellite phone in every emergency kit. During a typhoon, the sky could be blocked by thick cloud for several days. As a result, the rescue will be delayed until the sky is cleared [4].

The experience in last several disaster rescue efforts show that how to effectively make use of all available communication devices and services is the key to a successful rescue effort. During Haiti earthquake [5], the victims trapped in the damaged buildings sent text messages via their low-ended cell phones (or called feature phones) which allow the rescuers to locate them in the left-behind area and save more than 60 victims. During the 2009 Morakot flooding in Taiwan [4], the destroyed communication infrastructure prevented the victims from contacting their family members and rescue agencies. Fortunately, their family members posted messages on social network services such as plurk and twitter that the victims were not reachable, and marked their possible locations on online maps. The information was broadcast by phones and social network web services. Consequently, the rescue team was able to locate the victims, and provided food and water supply to the victims. This information exchange model was proved to be effective for disaster response. However, such a successful rescue requires both effective coordination and timely intelligent information, which were conducted by experienced rescuers and/or crowd sources.

We call an information exchange framework that are designing for collecting, fusing, and distributing information during disaster management the information system for disaster management, and refer to it as ISDM for short. An ISDM is capable of making diverse, multi-domain data and information generated by independently developed intelligent things and from people less fragmented and more trustworthy, delivering the information to independently developed disaster management applications and services with high availability and on a timely basis, and supporting different usages of the information for disaster preparedness, response and relief purposes and for research and planning in disaster reduction. The system can also adapt to needs, evolve and grow in capabilities with scientific and technological advances and can readily accommodate new information sources, applications and services as needed in response to unforeseen crisis situations.

An effective ISDM replies on many ICT (Information and Communication Technologies) components such as data repositories, fusion of symbiotic information, and information exchange. In this paper, we are interested on real-time information exchange in ISDM. In particular, we focus on how to recover the services when parts of the message delivery services are not available due to the damage to the communication network and computing services. During disaster response, it is very likely that the information is published by various sources. Pro-active data are collected from a collection of pre-installed or quickly-deployed sensor devices, monitoring stations, satellite images, as well as civilian witness reports. Each of the data sources has its individual characteristics of physical properties (e.g. proximity of observation location), temporal properties (e.g. how often data are reported), numerical properties (e.g. sensitivity capability), and even rational properties (e.g. observations under human emotional stress). Reactive data are collected by human including victims, rescue teams, volunteers, etc. An ISDM must be able to select and integrate multiple data sources into a coherent information service. Hence, how to discover and compose information service in an efficient manner is a major challenge for ISDM.

There are two major issues in existing communication systems for ISDM. One is that most, if not all, of the messaging exchange systems rely on static communication services. During the disaster, it could take from few days to few months to restore communication infrastructure. The second is that the communication experts are required to deploy temporary recovery communication services. Hence, in this work, we focus on designing a self-healing messaging exchange systems for disaster management and M2M systems. The remaining of this paper illustrates the design and performance evaluation of messaging services and service recovery mechanism of an ISDM. In Section 2, we illustrate the system architecture of message delivery services for disaster management and related works. Section 3 illustrates the landmark-based service recovery algorithm for real-time publication and subscription services. Section 4 presents the performance evaluation results to illustrate the overhead and service delay caused by the developed algorithm. We summarize the work and discuss the work to be completed in the near future in Section 5.

2 Background and system architecture

2.1 Publish/Subscribe model for message exchange

Publish/Subscribe is a messaging model to support asynchronous and persistent message-oriented communication. In this model, there are three major components. One is publisher, which is the information producer to provide information to the other. The second one is the subscriber, which is the information consumer to receive information from publisher. The third is the middleware, which is responsible for delivering information from publishers to subscribers. In comparison with traditional messaging model, the major characteristic of publish/subscribe is decoupling. The following are the decoupling properties in three dimensions [6].

• Space decoupling: the publisher does not need to know the address of the subscribers. It is the middleware that deliver the data to corresponding subscribers.

• Time decoupling: the subscriber does not need to be active when the publisher is sending data. If the subscriber is not active, the middleware temporarily stores the data until the subscriber is ready.

• Synchronization decoupling: The publisher and subscriber are not blocked when the message is being delivered. In other words, they are asynchronous. The publisher gives the messages to the middleware, and the middleware will be responsible for routing and buffering the messages.

These decoupling properties make publish/subscribe scalable and flexible. Hence, publish/subscribe is suitable for the disaster management system.

Advanced Message Queue Protocol (AMQP) [7] is an open standard for message oriented middleware (MOM) communication. AMQP grew out of the need for interaction between MOM systems both within, and between, corporate enterprises. Due to the proliferation of proprietary, closed-standard, messaging systems such integration is considered challenging. As such, the primary goal of AMQP is to enable better interoperability between MOM implementations. Since AMQPs inception, several, open-source, messaging software distributions have emerged. The Apache Qpid AMQP distribution is one of the widely used projects. It provides a Broker federation option that can de-centralize the architecture and share the workload among a group of Brokers linked with each other. Qpid also has built-in fault-tolerance features, in which the most critical one is High Availability Messaging Cluster. A cluster is a group of Qpid brokers with the same configurations for exchanges, queues, and other entities. The brokers in the cluster have to synchronize their event with each other. As a result, a cluster is a set of brokers in exactly the same state. With replicated states, the publish/subscribe service does not fail unless all the brokers in the cluster fail. Although cluster involves great amount of synchronization overhead, it is assumed to be sustainable. The reason is that Qpid is originally designed for message delivery in small area such like office building where the network connecting brokers is stable and fast enough. However, the assumption is not suitable for wide area network and disaster management. The other disadvantage is that cluster requires redundant computation resources which are usually not available in disaster management. Hence, we design a self-healing mechanism for Qpid which involves less overhead than cluster approach.

2.2 System architecture of OIGY

To support aforementioned desired features of information exchange services, we proposed to deploy an information exchange service framework, named Open Information Gateway (OIGY), to support distributed timely information exchange over heterogeneous networks. In this section, we present the methodology and advantages of each component in the system and how they interact with each other.

OIGY services will be executed on various types of devices in the network, including computationally weak devices such as cell phones and POS (Point-of-Services) in convenient stores, and computationally powerful devices such as weather forecast service on cloud servers and data repository server in data center. Figure 1 illustrates the system and software architecture of OIGY. As discussed earlier, numbers of individuals, news agencies, government agencies, and rescue agencies form the disaster management system. Each of them can be the providers and consumers of the information. For instance, data center in government agency can subscribe information from sensors in disaster area and publishes the fused/verified data to the subscribers including first responders, victims, news agencies, and general public. Victims in disaster area can also publish messages to the others and can subscribe information from their family members and government agencies. To achieve scalability, OIGY will be deployed as a middleware software component in the network. For victims, an OIGY widget can be installed on their cell phones; for weather forecast agency, an OIGY service can be installed on their powerful servers. In addition, OIGY can also be installed on Point-of-Service devices, which are located in supermarkets and convenient stores to publish and subscribe information.

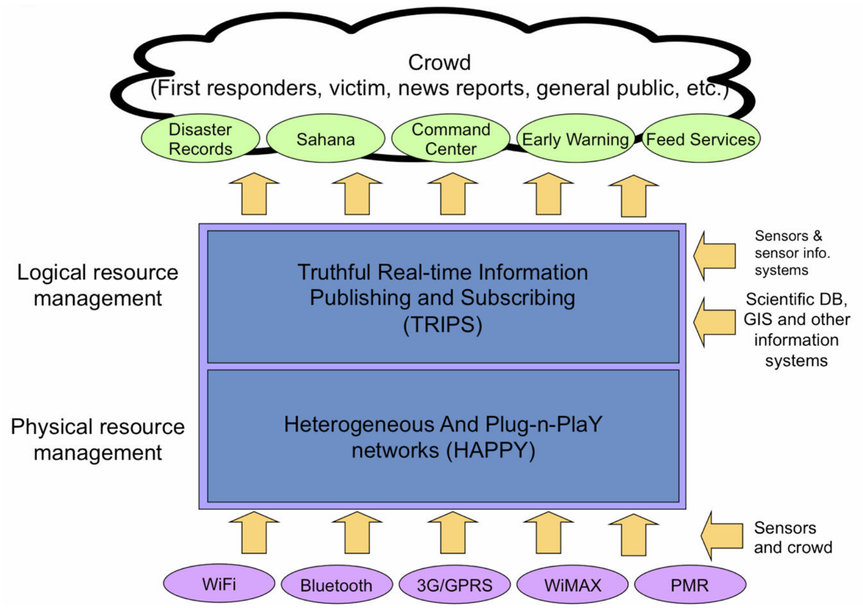

Figure 1: System architecture of Open Information Gateway (OIGY).

Open Information Gateway (OIGY) consists of two major components: one is the distributed Truthful Real-time Information Publishing and Subscribing (TRIPS), and the other one is Heterogeneous And Plug-n-PlaY networks (HAPPY). The objective of HAPPY is to interconnect all network-capable devices using all kinds of possible manners, which is comprised of heterogeneous network access technologies (e.g., WiFi, Bluetooth, Professional Mobile Radio (PMR), and 3G/GPRS) using different approaches (e.g., Infrastructure-based networks, wireless mesh networks, mobile ad hoc networks, and opportunistic networks). The objective of TRIPS is to support distributed real-time publish and subscription (P/S) services. Note that a device/service in the system is not limited to be either information publishers or subscribers. Usually, resource limited device/service act as information publishers only. The sensors to detect mud-slide, to measure rainfall and water level in river, and to monitor earthquake are examples. Most of the other services such as weather forecast services and GIS system will subscribe information from sensors, GIS databases, and other information sources and publish their information to the disaster management system and general public. While requesting for P/S service, the application specifies its Quality of Service or Class of Service of its P/S service including timeliness, description, resource requirements, etc. TRIPS will register and announce the P/S service. Hence, one capability of TRIPS is to manage the declarations, automatically establish connections between publishers and subscribers for matching topics and dynamically detect new status in the system. When the subscribed message arrives or is sent, TRIPS delivers the message to its subscribers.

Figure 2 illustrates the architecture of PubSub network over HAPPY network. In PubSub network, P/S brokers are responsible for storing and forwarding

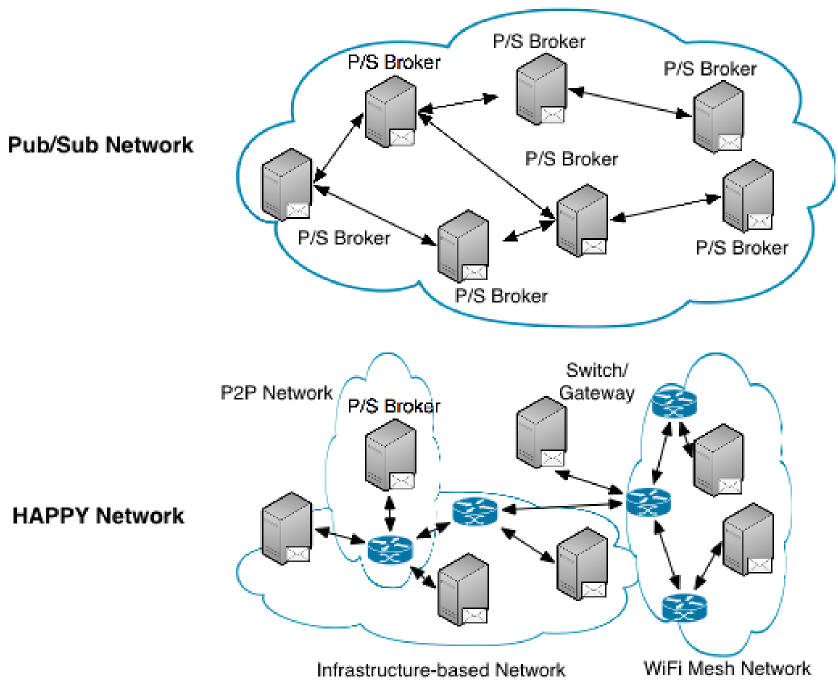

Figure 2: Pub/Sub Network over IP Network.

messages to the brokers and subscribers. The brokers are connected by the HAPPY networks and the messages are routed over the switches and gateways in HAPPY networks. In Qpid network, a link between two P/S brokers could be a route of multiple IP links and a shorter path on P/S networks do not necessarily be a route with shorter message transmission delay. Within HAPPY networks, HAPPY agents will be deployed on the nodes having multiple communication interfaces to bridge the communication between different physical communication networks.

3 Landmark-based service recovery

In the landmark-based service recovery framework, the PubSub network is divided into several disjointed subnets and each subset has a server to management the broker services. Figure 3 illustrates the architecture of the PubSub network within the subnet. Brokers are grouped into subnets according to their network identifications, for instance, combining IP address and port number can provide a unique identification within a subnet. Each subnet has one landmark monitor, at least one backbone node, and several brokers. Landmark monitor is a service process that is reachable from all the broker nodes in the subnet and is responsible for monitoring and recovering the service in case of node failure. The directed lines represent the links and data flow between broker nodes, backbone node, and landmark node. The dashed lines represent the flows of control messages; the solid lines represent the flows of pub/sub messages. Landmark monitor is usually deployed on a reliable node so that it has a very low failure rate or it can be recovered automatically or manually without disrupting its services. During runtime, the landmark listens to the messages sent

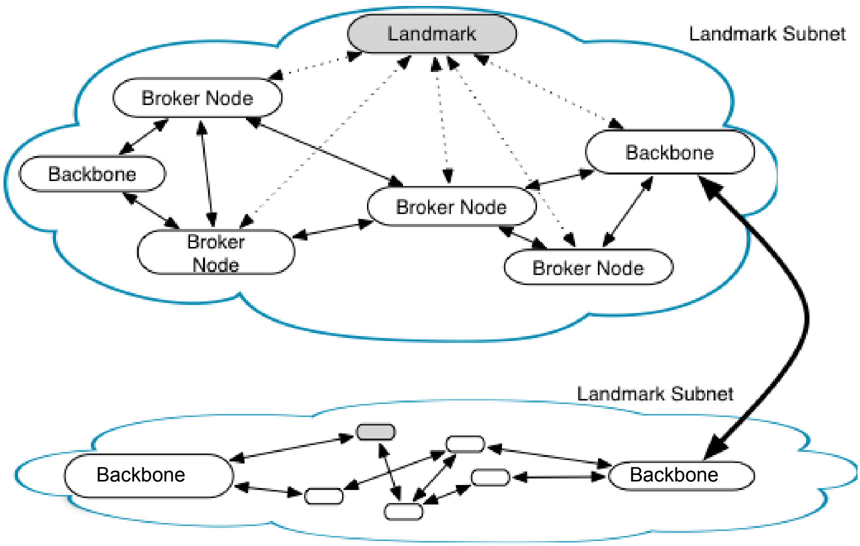

Figure 3: Pub/Sub networks with landmark and backbone nodes.

by each broker node, represented by dash lines in the figure, so as to learn the aliveness of each node. (The monitoring process between landmark monitors and broker nodes will be described later in the section.) In addition to service monitoring, the landmark monitor also duplicate the service objects on each broker node to its local repository. The duplication is conducted when the landmark monitor starts and a new broker service is detected. QPID/AMQP and several other Pub/Sub framework supports this functionality. Backbone node is a service node that is responsible for transmitting messages among subnets. In practice, we may deploy Landmark and Backbone nodes on single physical node for the sake of simplicity.

Landmark-based service recovery takes advantage of the reliability and reachability of landmark monitors to monitor and recover the service network. When a broker service is active and health, every messaging activity conducted by the broker service is transmitted over the PubSub network; change on queue configuration and queue state are forwarded to the landmark monitor by a QMF monitor on broker service. In addition, when a broker service learns that a link connected to or from itself is down, a control message is sent to the landmark monitor to report the failure broker service. Consequently, without actively probing the broker nodes, the landmark monitor can keep track of the activities of the broker services in the subnet and learns if a broker service fails.

When the landmark learns that a broker service is failed, it starts the recovery process. The first step of the recovery process is to update the distance vector table among broker services. The distance vector table keeps tracks of route length, which is represented by average transmission delay or average bandwidth between every pair of broker nodes in the subnet. To avoid injecting great amount of probing traffic, the table is updated when a service recovery process starts. Figure 4 illustrates the process to update distance vector table. To learn route length between nodes, each node executes ping daemon. To update the distance vector table, landmark monitor sends distance update request, i.e., Step 1 in Figure 4, to brokers. The daemon sends and reacts to ping requests from other broker nodes. When the daemon receives a distance update request from landmark monitor, it sends a ping message on application layer to the corresponding broker node, i.e., Step 2 in Figure 4. When the daemon on the corresponding broker node receives a ping request, it echoes a null message back to the sender, represented by Step 3 in Figure 4. After receiving the echo message, the sender calculates the distance based on the remained TTL in the packet header, represented by Step 4 in Figure 4. When the landmark has the remaining TTLs from a pair of broker nodes, it can calculate the number of hops between them and estimate the route length. Then, the landmark selects a node with shortest distance or shortest response time according to the distance vector table. Note that there is no need to update the distance vector table for all pairs of broker nodes in the subnet and only the distance of the routes connected to the neighbors of the failed node require updates. After the candidate node is selected, the second step is to re-create the service on the selected node, according to the local repository of landmark monitor. The landmark monitor also recreates the links to the neighbor nodes of the failed broker node.

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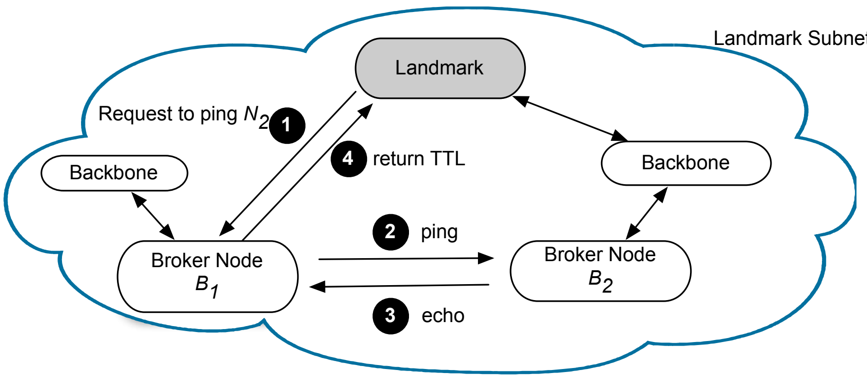

Figure 4: Procedure for ping daemon to collect route distance.

4 Performance evaluation

To evaluate the service recovery algorithms, we conduct extensive experiments to evaluate the network traffic overhead and recover latency for landmark-based service recovery mechanism.

The broker networks consist of 60 nodes, including broker nodes, gateway, and switch nodes, to simulate a broker network within a subnet. Client applications are ignored in this topology. Note that each broker node can support tens or hundreds publishers and subscribers. Hence, the network is designed to represent a network consisting of thousands of computing devices in the network. A subnet in this size represents a network to service the population in a metropolitan area. The simulated network consists of 60 computing devices. Among them, there is one landmark monitor, seven communication gateways, and the others are Qpid brokers.

In the experiments, we measure two metrics: (1) the amount of transmitted data for failure detection and failure recovery, and (2) time delay for failure detection and failure recovery. Figure 5 shows the network traffic on landmark monitor when the number of broker nodes (B_N) are 10, 20, 30, and 40. Note that the figure only shows the network traffic for changes on configuration and state. Pub/Sub messages are not sent to landmark monitor. When the landmark monitor starts at time 0, it queries reachable broker nodes in the subnet and receives great amount of network traffic. The length of initialization phase depends on the number of broker nodes in the subnet. When there are forty broker nodes, it takes less than 200 seconds to learn the configuration of broker nodes. After the initialization phase, the landmark monitor starts to listen to the control messages sent by broker nodes. Note that after the initialization phase, the control messages are sent only when the configuration or state of the broker node changes. When the number of broker nodes increase, the network traffic increase accordingly. The measurement shows that there are at most 400 bytes per second when there are forty broker nodes, which are negligible in bandwidth limited network.

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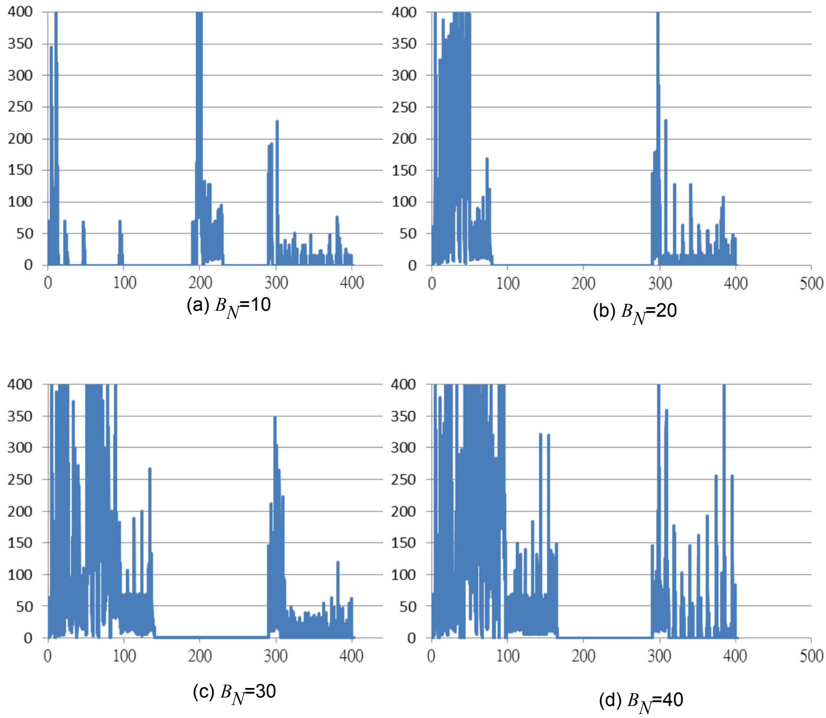

Figure 5: Traffic on landmark monitor.

Table 1 shows the average data rate on landmark monitor when a failure occurs and is detected. To recover a failure, the landmark monitor needs to transmit configuration data to a new node, reconfigure the broker networks, and fetch the messages from other brokers to the new broker node. Hence, the data rate during recovery is much greater than that during monitoring. The data rate increases as the number of brokers increase because the network traffic of updating distance vector table increases when the number of broker nodes increases. Table 2 shows the time overhead for recovering failed brokers. The results show that it takes 1.5 seconds in average to recover a failed service node. The time and network traffic overhead do not increase when the number of broker nodes increase. This is because recovery overhead mainly consists of

Table 1: Average data rate during fault detection and recovery.

Performance Metrics	B_N=10	B_N=20	B_N=30	B_N=40
Average Data Rate (KB/s)	23.97	42.86	68.92	89.49
Standard Deviation	1.67	2.97	3.27	6.68

Table 2: Recovery overhead of landmark-based service recovery.

Performance Metrics	B_N=10	B_N=20	B_N=30	B_N=40
Recovery Delay (s)	1.550	1.593	1.554	1.554
Recovery Traffic (KB)	200.54	321.26	249.07	246.96

transmitting configuration data and reconstructing the new broker service. Additional broker nodes in the subnet do not increase the recovery delay and recover traffic.

5 Summary

It has been shown that robust message exchange is the key to the success of disaster rescue. A self-healing service discovery mechanism can reduce human efforts during the disaster and shorten the blackout time of communication. Although landmark-based service recovery requires on a central server to collect service configuration and monitor the states of broker services, the proposed approach relies the QMF module on broker services to actively report the change on configuration and the monitor module on broker services to reactively report a failed service. As a result, the landmark node will not be overloaded by monitoring workload. The experiment results also confirm the aforementioned properties for a publish/subscribe network in a reasonable size. In the future, we will continue to develop a distributed service recovery mechanism to support large size publish/subscribe networks.

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An approach to assess suitable lands for disaster mitigation

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Abstract

This paper describes the goals, approaches, methods and results of the project ACDRS, Approaches and Criteria to Designate Relocation Sites for disaster prone areas. ACDRS was funded by the Urban and Rural Development Branch, Construction and Planning Agency of the Interior Ministry and is a part of the research program "Enhancing Innovation and Implementation of Disaster Reduction". ACDRS reviewed the relocation projects of the 921 Earthquake to identify key factors for successful relocations. Those factors were further developed as criteria and adopted the concept and advanced techniques in disaster risk management and GIS land suitability analysis to assess safety of lands for relocation and develop land-use strategies to meet disaster risk reduction and mitigation requirements. The results of the project include strategies and standard operating procedures for relocation development, in addition to assessments of safety of lands in disaster prone areas and their suitability of relocation purposes.
Keywords: disaster, uncertainty, vulnerability, risk analysis, suitability analysis.

1 Introduction

Experiences from the 921 Jiji Earthquake [1, 2] in Taiwan and devastating disasters worldwide give an important lesson that the time factor in disaster recovery and reconstruction management is critical. Rehabilitation, resettlement, relocation typically merge into a lengthy, complex process. Well-designed strategies and standard operating procedures (SOP) for relocation projects with commonly accepted, readily accessible relocation land assessments can significantly simplify and shortened the process. This is the underlying

WIT Transactions on The Built Environment, Vol 133,
www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/DMAN130201

motivation of the project ACDRS, which stands for Approaches and Criteria to Designate Relocation Sites for disaster prone area. ACDRS was a project within the research program called "Enhancing Innovation and Implementation of Disaster Reduction" funded by Taiwan government in year 2008–2011.

Project ACDRS adopted the concept and advanced techniques in disaster risk management and GIS land suitability analysis to assess land safety for relocation and develop land-use strategies to meet disaster risk reduction and mitigation requirements. The project started with an initial risk analysis framework for assessing the safety of lands in disaster-prone areas and their suitability of relocation purposes. The framework was then enhanced during the project with a broad range of databases, including databases on debris flows, landslide and flood disasters databases, as well as 2009 National Land-use Census data.

Debris flow, landslide and flood risk maps of disaster-prone areas in Taiwan were generated based on four vulnerability measurements made of the areas by the project. The risk maps, presented later in the paper, enable the identification of villages in Taiwan with high risk of debris flows, landslides and floods. A hundred of the high risk villages were surveyed to collect further detail information at community scale for safe relocation sites designation purposes. The results of the project are integrated into a Virtual Relocation Land Reserved System (VRLRS). The system of databases, containing official land assessments and administrative standard operating procedures to get information on relocation sites, can provide rapid responses to requests for rehabilitation, resettlement or relocation lands for displaced disasters' victims.

Following this introduction, the remainder of the paper is organized as follows. Section 2 discusses factors of relocations that must be considered. Data on disaster risks acquired during map making process contains uncertainties that can degrade the quality of the resultant risk map. Section 3 presents the types of uncertainty and approaches taken to reduce them. Sections 4 and 5 present the results of the project, including VRLRS, sample disaster risk maps, and so on. Section 6 summarises the paper.

2 Factors of relocation

The objectives of post-disaster relocation [3, 4] can range from merely the restoration of communities and livelihood of people in them to stimulation of drastic changes that can improve rather than merely to restore pre-disaster living standard and social conditions. Our land assessment and risk analysis methods take into account of the primary objective of each relocation project as well as the six factors that can affect the chance of success of the project. The factors are presented here in two groups. The first three factors are institutional legislation, location safety, and financial feasibility. The second three factors are surviving victims' social and culture connections, economic vitality and awareness and willingness.

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2.1 Factors affecting planning and implementation of relocation projects

Planning, implementation and administration of every post-disaster relocation project depend directly on regulations and institutional procedures of authorities involved in relocation affairs, as well as location safety and finance feasibility. In most parts of the world, relocation projects typically face numerous regulations governing land use and constructions. For example, in Taiwan, lands for relocation must be in the "Residence" category. To get approval for changing the zoning category of a chosen land from non-residence category to residence category, a relocation project must deal with rigid regulations and lengthy procedures. Similarly, the project would be required to submit environment impact statements or evaluations in order to get construction licenses, if the chosen relocation site were in hillsides or environment sensitivity area. By providing GIS information on ecological and culture landscapes, disaster sensitivity maps, etc., our VRLRS aims to support the identification of lands unsuitable for relocation for these reasons.

Location safety is another important consideration. Our land assessment and risk analysis methods start by identifying low disaster risk regions from maps of potential debris flows by Soil and Water Conservation Bureau, potential flooding depths by Water Conservation Agency and potential landslide areas by the Central Geological Survey [5–7]. We then confirm the safety of lands for relocation within the low risk regions by field surveys.

Relocation projects must be financial feasibility. Published statistics showed that more than 50% of relocation-project failures resulted from financial issues. For this reason, cost of lands for relocation must be taken into account. In Taiwan, this means placing high priority on land owned by governments or state-owned enterprises.

2.2 Factors affecting the well-being of surviving disaster victims

Social and culture connections are important for all surviving disaster victims. It is a particularly important factor for indigenous peoples. Taiwan's indigenous groups have long history living in Taiwan mountain area, which attributes to their identities and living styles. Past experiences show that it was difficult to preserve indigenous culture when the sites of relocation were far away from the original villages. Our relocation land assessment methods assume that the closer the relocation site is to the original village, the higher the chance for social and culture connections to be maintained or rebuilt. The methods also take into account the accessibility to original villages.

Disaster victims usually prefer reconstruction at the same place rather than relocation. It is more acceptable for them if the relocation sites are relatively advantageous in providing them with their former types of job and work. Our methods take into account this factor by giving higher weights to lands closer to agricultures and industries and to locations nearer to home lands of the victims.

Finally, land ownership, family and neighbour ties are among reasons for victims' desire to remain, even when their homelands are badly damaged and reconstruction is more costly than relocation. The information provided by our methods and VRLRS aims to support the challenging tasks of raising the awareness and willingness of victims to be relocated.

3 Data uncertainty

The risk maps based on land assessment may differ from the current situation because of uncertainty in the data used to generate the maps [8]. There are three kinds of uncertainty:

- Uncertainty in time and space: A disaster is dynamic. In contrast, the relevant GIS information on it (e.g., the hazard potential map published by Water Resources Agency, Soil and Water Conservation Bureau and The Central Geological Survey) is based on data taken at specific times. Differences between available GIS information and the current situation include disaster location, time, scope of influence and so on.
- Uncertainty in scale: For different types of disaster and the spatial extent of the planning process, the scale of existing map data are very different, including accuracy and unit size. Due to such limitation, a map may not provide the information of accuracy required in the development stage.
- Uncertainty in subjective and objective views: This uncertainty is the difference from analysis results and the local opinions. The relocation site suggested by risk assessment may not meet disaster victims' requirement.

In order to reduce uncertainties, we included field survey as an integral part of land assessment and risk analysis methods. Specifically, major elements of fieldwork are local interviews and field research as well as surveys of disaster types and current vulnerabilities of the locations and the current settlement status on record. This work in high risk villages is a part of the validation process.

Using data and information acquired first hand by researchers from interviews and meetings with people in each assessed area has proven to an effective means to reduce data uncertainty. Our current and future work on reduction of data uncertainty is supported by the Academia Sinica project OpenISDM [9].

4 VRLRS: virtual relocation land reserved system

As stated earlier, VRLRS provides relocation project planners and administrators and disaster victims with ready access to data and information on relocation land assessments and regulations governing urban and non-urban land development. It also provides SOPs for planners and administrators so that they can easily follow relocation development guidelines, regulations and best practices. In this way, VRLRS can help them launch relocation projects for victim villages of debris flow, landslide and flood disasters in the shortest time. The GIS databases, web services and tools were prepared during disaster-free period, and are continuously updated and maintained. Thus the databases can also contribute to disaster prevention or risk reduction for disaster-prone communities.

Specifically, in fieldwork, details on environment of each selected villages were observed and examined. Based on the accuracy of information thus collected, development guidelines and regulations in checklist forms were suggested. The forms also provides links to environment safety evaluation reports, environment impact statement/analysis, water and soil conservation plans, engineering geological surveys, that are needed to get the development permissions. Again, compared with disaster relocation/reconstruction projects are much more complicated, with much higher time pressure, than regular development projects. For this reason, it is important to establish a simplify administration procedure to coordinate the dialogs between various authorities in levels of community, local and central governments. This is another kind of support provided by VRLRS.

VRLRS is based on lessons learned from experiences gained from the 2009 Morakot Typhoon and the 921 Earthquake homeland redevelopment [10]. The process consists of the following four stages:

1. Identify and designate: In this stage, official GIS disaster information databases are used to generate disaster risk maps of Taiwan, which identify villages prone to debris flows, landslide and floods. The risk index of each village is then calculated. The results are risk distribution maps for these types of disasters in Taiwan. The next section will provide an example.
2. Pre-assessment: The goal of this stage is to seek suitable relocation land for a specified high disaster risk village based on available GIS map resources. The assessment of land location follows the principle of finding “the nearest suitable safe place”. Hence the priorities of relocation sites are within the village, the township, and then the nearest suitable lands, in decreasing priority order.
3. Vulnerability and safety field survey: The aim of the survey is to confirm the accuracy of pre-assessment and to designate the boundary of relocation sites, for each site, the results have location facts from field survey, not second-hand GIS data.
4. Guidelines and regulations for relocation development: based on the results of field survey on land safety and suitability assessments, guidelines and regulations of each relocation site alternative are developed according to the legislation entitled or required. Format and forms of zoning maps and legislation tables were designed accordingly.

5 Land assessments and risk maps

This section provides examples to our results and contents of VRLRS, mentioned in the previous sections.

5.1 Disaster risk map

The hazard and risk maps of debris flow, landslides and flood were derived using the disaster susceptible maps by Water and Soil Conservation Bureau, the

Central Geological Survey and Water Resources Agency respectively, overlaying with vulnerability map of population, land-use, public utilities and public facilities, including transportation network.

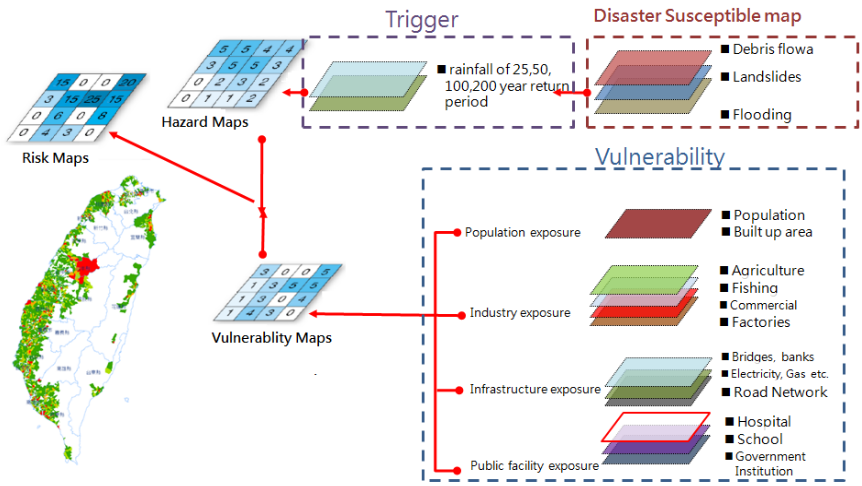

Figure 1: The debris flow risk map by villages.

The framework shown in Figure 1 explains how all the data come together in risk maps. The risk maps were further overlaid with village scheme map to obtain the complexity of disaster risks of each village and the worst risk value was selected to represent the disaster risk of the village. As an example, Figure 2 showed the spatial pattern of village debris-flow risk distribution, which indicates relative serious damage that local debris flows will cause to local villages.

5.2 Relocation land assessment

Based on the risk maps, top 100 high disaster risk villages were identified. Relocation land suitability analysis was applied to the 100 villages for the land assessment. The assessment, firstly, excluded the area under rigid developing controls of conservation or development-restricted zones by the 2nd overall review of Southern Regional Planning, considering the area is one of 19 environment sensitivity area. Secondly, settlement, industry, road network and public facility accessibilities were calculated spatially to illustrate the potential easiness of each land grid to access the village built environment. Figure 3 showed the map of the four accessibilities in the case of Xiaolin village. Figure 4 showed the process to present the accessibility map and the relocation site over Google Earth to examine topographic perspective of safety concerns, for example a table land is more resilient than valley land regarding to flood disasters.

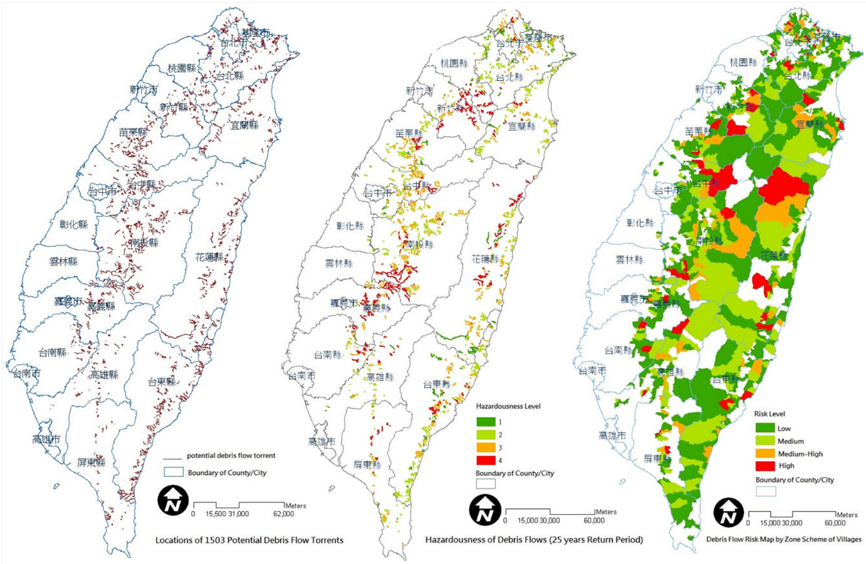

Figure 2: Series maps produces by debris-flow risk analysis.

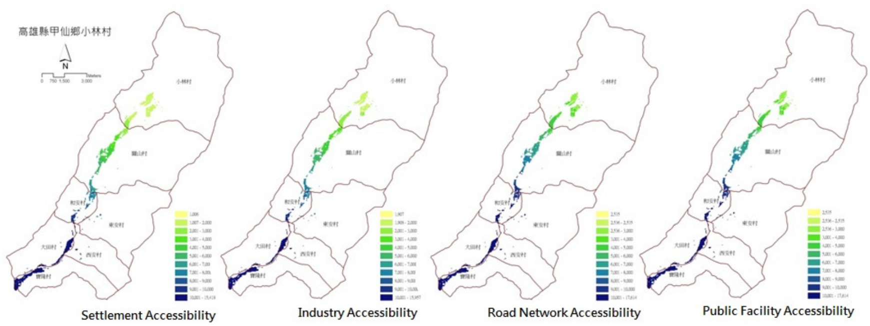

Figure 3: Accessibility map of relocation suitability assessment, Xiaolin village.

For the issue of data uncertainty and to confirm or to obtain the accuracy of the assessment at local community scale, a field survey on the type of disaster, the disaster affected area, the vulnerability of built environment and geological details was also designed [11, 12]. Figure 5 is an illustration of the geological map with the fact found during the field works.

Finally, profiles of relocation sites are produced. The comprehensive assessment lists contain the details of location in terms of X,Y coordinates, four accessibilities, land ownerships, land prices, land category, zoning regulation and land use are given.

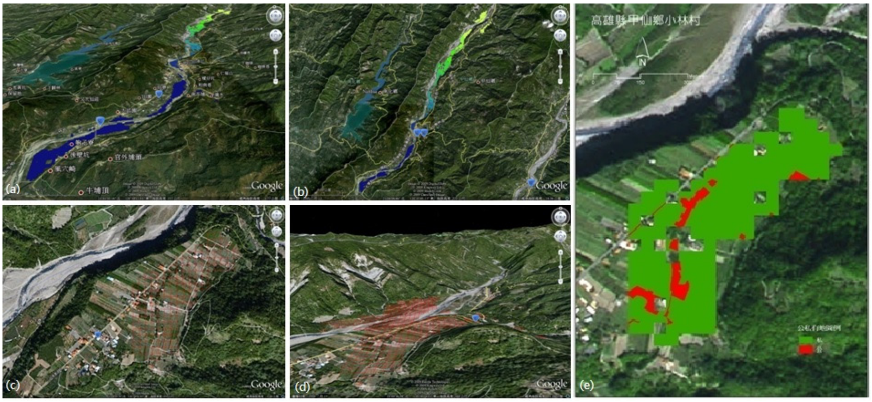

Figure 4: The accessibility map over Google Earth.

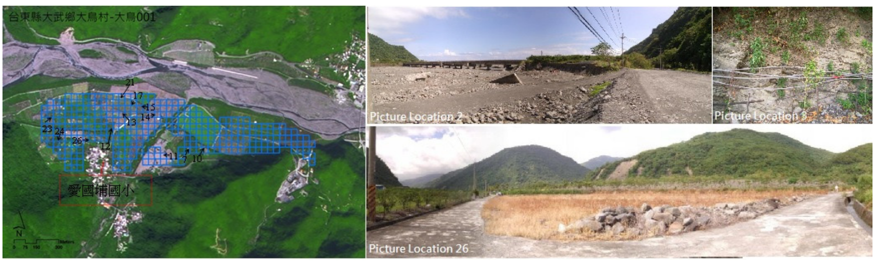

Figure 5: The geological map for field survey.

5.3 Web-GIS database

The presentation of the relocation land assessment information is also important [13, 14] in reducing the complexity of relocation projects for local authorities. Web-GIS technology is applied to meet the requirement that a platform to display the assessment data, information, pictures, imagines, documents etc. were established. Figure 6 is an illustration of the web-GIS platform. Figure 6(a) is the interface of the platform by Google Earth that provides as a geo-reference map engine to display disaster information as maps. Four types of maps can be queried, which are the map data used for assessing riskiness of villages, the hazardousness of villages, the riskiness of villages and the suggested relocation site for the top 100 riskiness villages. For the top 100 riskiness villages, the community level detail of environment dangerousness and suitability assessment for relocation by field investigation is also provided. Figure 6(b) is an example of Wulipu village's geological field investigation map, in which fragile geological spots are labelled with various illustrations. Besides, the profile of alternative relocation sites' information such as land ownership, land prices and land regulations etc. can also be queried.

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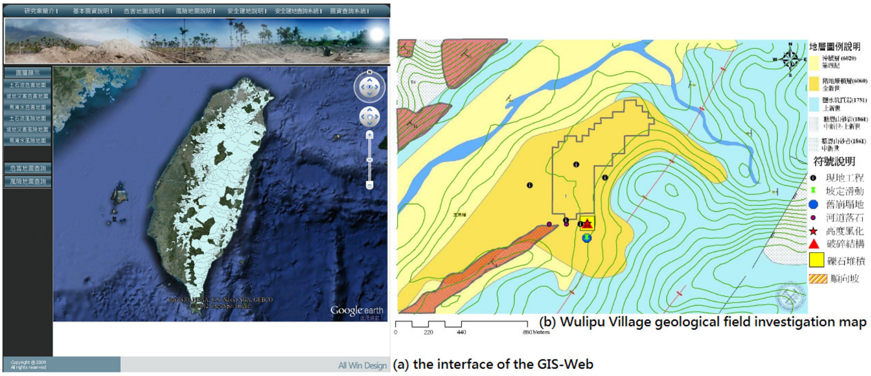

Figure 6: The Web-GIS platform.

6 Summary and future work

The virtual relocation land reserved system described in here is not just a land pre-assessment system; it is also a decision support system, as it provides relocation land assessments plus the SOP for relocation development projects. Such a SOP has four steps: (1) generate disaster risk maps and identify debris flow, landslides, flood prone villages in high risk area(s); (2) local land suitability analysis for relocation migration; (3) field survey to improve accuracy in safety and liveability assessments from village's perspectives; and (4) processes taken to conform to relocation guideline and regulation. The system allows relocation projects to follow the principle of "the nearest placement". In this way, it enables the projects to put the social and culture connectivity of affected disaster victims as one of the most important factors to consider in their choice of relocation site.

We note that from the viewpoint of disaster information uncertainty, disaster information in community level is particularly critical and vital for disaster prone communities. Official disaster decision support systems typically lack community level information. OpenISDM project is seeking IT solutions of issues of open disaster information resources, by which, the disaster information by private / individuals sectors can contribute to disaster prevention and mitigation. Our future study of using open data will focus on the uncertainty reduction, including the uncertainty characteristic of open data, measurement of the uncertainty, uncertainty reduction and efficiency assessment of the reduction processing.

Acknowledgements

This work was supported by Urban and Rural Development Branch, Construction and Planning Agency of the Interior Ministry and Taiwan Academia Sinica project OpenISDM (Open Information Systems for Disaster Management).

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www.witpress.com, ISSN 1743-3509 (on-line)

Participant selection for crowdsourcing disaster information

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Abstract

Experiences with past major disasters tell us that people with wireless devices and social network services can serve effectively as mobile human sensors. A disaster warning and response system can solicit eye-witness reports from selected participants and use information provided by them to supplement surveillance sensor coverage. This paper describes a natural formulation of the participant selection problem that the system needs to solve in order to select participants from available people given their qualities as human sensors and the costs of deploying them. For this, we developed a greedy algorithm, named PSP-G, that first calculates the benefit-to-cost (B2C) factor of each participant. It then dispatches participants to regions according to participants' B2C. We compared PSP-G with the two well-known optimization methods, BARON and BONMIN. The results show that PSP-G delivers a near optimal solution with a low time complexity. In particular, the time PSP-G needs can be merely one tenth of the execution time of the existing optimization methods, which makes PSP-G a practical solution for emergency needs in disaster areas.

Keywords: crowdsourcing, social network, disaster management.

1 Introduction

Despite advances in sensor technologies, disaster surveillance and response systems cannot always rely solely on sensors and sensor networks/systems for surveillance data to acquire situation awareness and support decisions.

www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/DMAN130211

Deployment costs may limit the coverage and density of sensors (e.g. [1, 2]). In-situ sensors in disaster affected areas may be damaged, and thick clouds, vegetation, buildings, etc. can render remote sensors (e.g. surveillance satellites and unmanned aerial vehicles) ineffective. Fragmented sensor coverage can leave decision makers and responders ill-informed of imminent dangers to hundreds of people. This was what happened during Typhoon Morakat in 2009 in Taiwan [3].

Using people armed with wireless devices and Web 2.0 services as mobile *human sensors* is a way for a system to enhance its surveillance capability. Eye-witness reports of conditions at selected locations can complement data from physical sensors to eliminate blind spots and mend fragmentation in sensor coverage. A disaster surveillance system designed to make use of human sensors triggers a *human sensor data collection* (HSDC) process under specified conditions. By selecting individuals from available human sensors to participate and directing the selected participants to explore the threatened area, the system aims to collect eye-witness reports needed for it to acquire situation awareness in the shortest time.

We call the problem of selecting individual human sensors to collect data in different regions of the threatened area in order to optimize some specified objective subject to constraints in the number and costs of human sensors the *participant selection problem* (PSP). Solutions to variants of the problem are bases of the participant selection strategy used by the system. This paper presents a natural formulation of the PSP and approximation and a heuristic algorithm for solving the problem.

Following this introduction, Section 2 presents models of the threatened area and human sensors available for selection. Section 3 presents formulations of the participant selection problem and variations of the problem. As it will become evident, PSP is an extension of a special case of the well-known maximum *generalized assignment problem* (GAP) [4, 5], which is known to be NP-hard and APX-hard to approximate it. Section 4 compares the problems and presents an overview of existing algorithms and solutions of *GAP* and its variants. Section 5 presents approximation and heuristic algorithms for solving variants of the PSP. Section 6 summarizes the paper and discusses future works.

2 Participant selection problem (PSP)

Specifically, the solution of a *participant selection problem* (PSP) is a selection of participants of a HSCD process and an assignment of the selected participants to regions to optimize some objective function, referred to as (total) *value*, subject to constraints in terms of the number, quality and costs of participants available for selection. Table 1 provides a summary. The formulations of PSP described in subsequent sections focus primarily on how to make best use of participants of types I and M.

Table 1: Model of participants.

Type	Property	Benefit	Cost
I	Professional responders	High	High
M	Registered Volunteers	Medium/Low	Medium/Low
U	Unregistered Volunteers	Low	Low

We use the notations defined below to denote the input parameters of the PSP:

- The area has ρ regions R_1, R_2, … R_ρ, and their values are v_1, v_2, … v_ρ, respectively.
- Among π participants P_1, P_2, … P_π , first π(I) participants are of type I ; the next π(M) participants are of type M; the remaining $\pi - \pi(\text{I}) - \pi(\text{M})$ participants are of type U.
- For $i = 1, 2, \ldots \pi$ and $k = 1, 2, \ldots \rho$
  - b_{ik} ($0 \leq b_{ik} \leq v_k$) is the *value* (*benefit*) achievable by P_i if he/she is assigned to explore region R_k and
  - c_{ik} ($0 \leq c_{ik}$) is the cost of P_i when assigned to explore region R_k.
- B (>0) is the total budget available to be spent on all selected participants.

We assume that values of regions, costs of participants and total budget are positive integers.

In terms of these notations, a variant of the PSP can be stated below:

Maximize $$V = \sum_{k=1}^{\rho} \sum_{i=1}^{\pi} b_{ik} x_{ik} \quad (1)$$

Subject to $$\sum_{i=1}^{\pi} b_{ik} x_{ik} \leq v_k \ , \ k = 1, 2, \ldots \pi \quad (2)$$

$$\sum_{k=1}^{\rho} x_{ik} \leq 1 \ , \ i = 1, 2, \ldots \rho \quad (3)$$

$$x_{ik} \in \{0, 1\}, \qquad i = 1, 2, \ldots \pi, \qquad k = 1, 2, \ldots \rho \quad (4)$$

$$\sum_{k=1}^{\rho} \sum_{i=1}^{\pi} c_{ik} x_{ik} \leq B \quad (5)$$

The variable $x_{ik} = 1$ means that participant P_i is selected and is assigned to region R_k; it is equal to 0 if otherwise. The set $\{x_{ik}\}$ for all $i = 1, 2, \ldots \pi$ and $k = 1, 2, \ldots \rho$ gives an assignment of a subset of participants to regions; the inequality (3) allows $\{x_{ik}\}$ to be a proper subset of the set of all participants. The term V given by Eq. (1) is the total value achievable by all the selected participants when they explore their assigned regions; V is equal to the sum of benefits contributed by all the participants. The inequality (5) says that the total cost incurred by them must not be greater than the budget B. The constraint (2) ensures that the solution $\{x_{ik}\}$ never assigns more participants to any region than needed to achieve the full value of the region. The variant of the PSP is called PSP-frugal, a solution of it will be presented in Section 4.

3 Related works

Problems on managing resources (e.g. devices/equipment, supplies, and human sensors) during disaster preparedness and response phases have been treated to a

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great extent in literature. As an example, Therese *et al.* [9] presented an Android-based disaster management system, which also handles participant selection and assignment. A major difference between their work and ours is in problem formulations and algorithms. Our work is among the first that apply GPS and knapsack algorithms to resource allocations by disaster surveillance and response applications. One of the most well-known crowdsourcing platforms is SAHANA [10]. Its primary function is to facilitate the collection, filtering, organizing and display social reports. Participant selection is not supported.

Human resource allocation problems have also been treated extensively for many other types of applications. As examples, Taesoo Kwon and Dong-Ho Cho [14], Bartoli *et al.* [15], and Chen Junjie *et al.* [16] proposed human resource allocation algorithms for various scenarios. Compared to the formulations presented in the previous section, their models and problem formulations are more ad hoc.

Returning to Section 2, we note that in the case of infinite budget (i.e. $B = \infty$), PSP-Frugal is a special case of the well-known maximum general assignment problem (GAP) [4, 5]. The GAP is a generalization of the assignment problem [7] that just celebrated its golden anniversary recently. The problem is often stated as that of seeking an optimal placement of objects in bins. For each bin, each object in it has a profit and a weight that are dependent on both the object and the bin. The objective is to find placements of objects in bins so that the total profit is maximized subject to the constraints that the total weight of all objects in every bin is no greater than the weight limit of the bin. The GAP is known to be NP-hard and APX-hard to approximate it. Some algorithms for solving the problem use algorithms for the 0-1 knapsack problem [7] as the basis. An example is the greedy (δ+1)-approximation algorithm in [4]: It finds a solution of the GAP iteratively using a δ-approximation algorithm for the knapsack problem to find a tentative solution of the single-bin sub-problem, one bin at a time.

Specifically, for $B = \infty$, the PSP-Frugal is the special case of the GAP where the weight and profit of every object put in every bin are equal. The special case of equal weight and profit knapsack problem is known as the subset sum problem [8]. The functional form of the subset sum problem can be stated as follows: Given a set of N non-negative integers, find a subset of integers with the maximum sum among all subsets with sums equal to or less than the given limit. This problem is known to be NP-hard in general, but can be solved exactly in a reasonable amount of time by exhaustive search when N is small (e.g. less than 20) or by dynamic programming when the precision of the problem is small. For the PSP-Frugal, N is the number π of candidate participants, which can be large. On the other hand, the number of distinct values of $b_{i,k}$ is usually small. In practice, it also makes sense to adjust the unit of $b_{i,k}$'s to reduce the precision of the problem.

4 PSP-G algorithms

The PSP-G (PSP-Greedy) algorithm shown in Table 2 is a greedy algorithm. After initializing related parameters (line 1), PSP-G calculates the benefit-to-cost

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(B2C) factor $Q_{i,k}$ (= b_{ik} / c_{ik}) of each participant P_i (line 2) and sorts all B2C factors by their values in non-increasing order (line 3). It then dispatches participants in turn to regions according to participants' B2C (line 4 to line 13). Each time, the participant with the highest B2C is selected first (line 5) and is dispatched to a region where he or she can increase the total value most if this assignment satisfies both the budget and the value constraints (line 6). The participant selection process stops until all participants are dispatched or total values cannot be further increased. Finally, another round of HDCS is issued to solicit more participants if the threatened areas are not fully explored (line14).

As one sees from Table 2, PSP-G first takes O($\rho\pi$) to calculate the B2C factors (line 2). It then takes O($\rho\pi$ log($\rho\pi$)) to sort them (line 3). The time complexity of the selection process (line 4 to 13) is bounded by O($\rho\pi$). Therefore, the time complexity of PSP-G is O($\rho\pi$ *ln* $\rho\pi$).

Table 2: Algorithm for PSP-G.

Algorithm for PSP-G
β_k: The current benefit region k gets from the selected participants
ψ: The remaining budget
Q: A ordering set to record all B2C factors $Q_{i,k}$ of participant i to region k.

1: Set $\psi = B$ and $\beta_k = 0,\ k = 1, 2, \ldots, \rho$;
2: Calculate all B2C factors (i.e., $Q_{i,k} = b_{ik} / c_{ik}$);
3: Sort $Q_{i,k}$ by their values in descending order;
4: **while (**Q is not empty**)**
5:   $H_{i,k}$ = the first element in Q;
6:   **if (**P_i is not selected and ($\beta_k + b_{ik} \le v_k$) and ($\psi - c_{ik} \ge 0$))
7:     β_k += b_{ik} ; ψ −= c_{ik} ;
8:     Dispatch P_i to R_k;
9:     Remove all P_i 's B2C factors from Q;
10:     Mark P_i as a selected participant;
11:   **end if**
12:   Remove $H_{i,k}$ from Q;
13: **end while**
14: If participants are not enough, broadcast participant collecting message on social network again.

Example:
To illustrate the PSP-G algorithm, we consider here a simple example. There are two regions R_1 and R_2 and three participants P_1, P_2, and P_3. The region value v_1 is 60 and v_2 is 50. The total budget is 100.

As Table 3 shows, the B2C factor list is 1.31, 1.29, 0.71, 0.69, 0.65, and 0.48. Hence, PSP-G first selects P_1 for examination. Because the total budget is not

Table 3: Profiles of participant.

Participant number	Cost in R_1	Cost in R_2	b_{i1}	b_{i2}	b_{i1} / c_{i1}	b_{i2} / c_{i2}
1	19	36	25	25	1.31	0.69
2	23	31	15	15	0.65	0.48
3	56	31	40	40	0.71	1.29

used up and the achieved value of region R_2 does not exceed the upper bound 50, P_1 is dispatched to region R_2. Then P_1's B2C factors 1.31 and 0.69 are removed from the B2C factor list. The achieved value V now becomes 25 and the available budget decreases to 81. PSP-G next selects P_2 for examination since its B2C factor 1.29 is now the largest in the list. Because both value and budget constraints can be satisfied, P2 is dispatched to R2. The total achieved value V becomes 65 and the available budget decreases to 50. Similarly, P_3 is dispatched to R_1 and the final V is 80, which is the optimal solution of this problem.

5 Experiment setup

We evaluated the PSP-G algorithm via simulation. Our simulation experiments were conducted on an Intel i7 processor with CPU speed 3.3GHz and the total RAM is 6Gb. The algorithm PSP-G was written in Java with Eclipse. We considered a big earthquake that seriously damaged Yunlin county, Taiwan. A HSDC process was triggered so as to collect data in different regions of the threatened area. The total budget B is 100. As Figure 1 shows, we have 9 regions: Mailiao, Lunbei, Erlun, Xiluo, Citomg, Taixi, Dongshi, Bauzhong and Tuku. Their values are set at 100, 100, 80, 60, 80, 60, 60, 60 and 60, respectively. Also, the total number of participants is 1000, and the number of each type participant is one-third of the total participants. Initially, all participants are uniformly distributed in each region. We determine the value of each b_{ik} by

$$b_{ik} = basic\ benenfit/distance,$$

where the basic benefit of a type-I participant is 10, of a type-M participant is 5 and of a type-U participant is 3. Our formulation indicates that the farther the participant P_i is away from the region R_k, the less R_k can be benefited by P_i. For a participant, the distance between any locations inside his/her original region is set at one. Whenever the participant moves across a region, the distance he moves increases one. In other words, the distance between any two nearby regions is set to one. For example, if we have a type-I participant P_1 in R_1 (Mailiao), then b_{11} is 10(=10/1), b_{12} is 5(=10/2), b_{16} is 5(=10/2) and b_{19} is 3.3(=10/3). Similarly, the value of each c_{ik} is determined by

$$c_{ik} = basic\ cost * distance,$$

where the basic distance of a type-I participant is 3, of a type-M participant is 2 and of a type-U participant is 1. The farther the participant P_i away from the region R_k, the higher the cost will be. For example, if we have a type-I participant P_1 in R_1 (Mailiao), then c_{11} is 10(=10*1), b_{12} is 20 (=10*2), b_{16} is 20 (=10*2) and b_{19} is 30(=10*3).

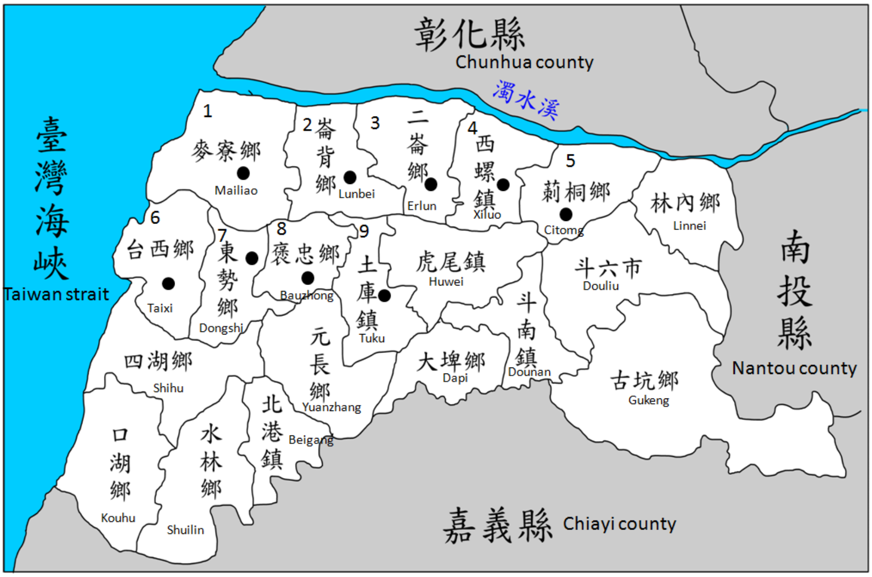

Figure 1: Map of Yunlin County, Taiwan.

We compare PSP-G with two commonly-used optimization methods. They are BARON [17] and BONMIN [18], which were executed by NEOS servers online [19]. BARON (Branch-And-Reduce Optimization Navigator) is a global optimization solver for convex optimization problems. It solves both linear programming and nonlinear programming problem by using branch and bound strategies. BONMIN (Basic Open-source Nonlinear Mixed Integer programming), also a global optimizer, adopts six different strategies (i.e., B-BB, B-OA, B-QG, B-Hyb, B-ECP and B-iFP) to have better performance in optimization. These two optimization solvers well represent the state of the art in optimization software. In our experiments, we first evaluated the performance of PSP-G in maximizing the total benefits contributed by all participants. We then compared the execution time of PSP-G with that of BARON and BONMIN respectively.

6 Performance measures and simulation results

The performance data obtained from our experiments is summarized by Figure 2. Let V_g represent the total benefits achieved by PSP-G, V_{br} represent that by BRARON, V_{bo} represent that by BONMIN. Performance ratio refers to the ratio of the total benefits achieved by two different methods. In Figure 2 the x-axis is the number of threatened regions and y-axis is the performance ratio. Although BARON and BONMIN are global optimizers, V_{bo} and V_{br} are not the same. This is because each of them has a different converging speed of searching the optimal solution and different stop conditions. In all test cases, both performance ratios V_g/V_{br} and V_g/V_{bo} are closed to 1. It particular, PSP-G delivers almost the same result as BARON and BONMIN when the number of region is nine. Our numerical results indicate that PSP-G, a polynomial time algorithm, can deliver a near optimal solution with less time complexity.

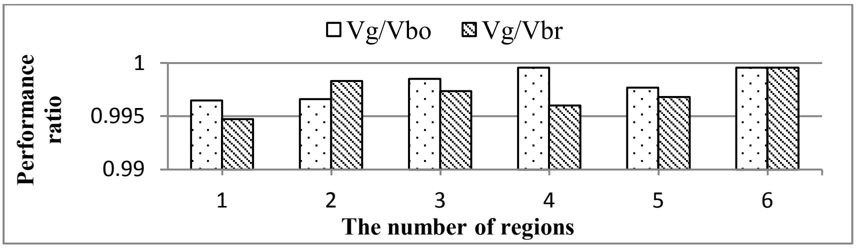

Figure 2: The performance ratio.

We further measured the execution times of PSP-G, BAROM and BONMIN respectively. We set the number of regions at nine and varied the number of participants from 1,000 to 8,000. As Figure 3 shows, compared to BAROM and BONMIN, the execution time of PSP-G increases slightly when the number of participants increases. Most of the experiment configurations can be finished by PSP-G in a few seconds. In contrast, the execution time of BONMIN and BONMIN increases significantly when the number of participants becomes large. In particular, when the number of participants comes to 8,000, the execution time BARON takes is almost 10 times longer than PSP-G. According to our experiment results, we argue that PSP-G is a practical solution for dispatching participants, especially for emergency cases which cannot be postponed until the threatened areas are fully explored.

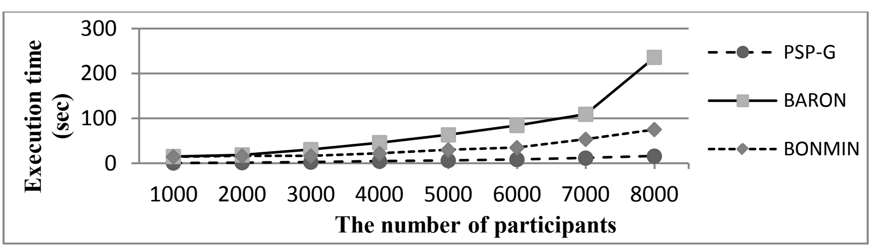

Figure 3: The execution time.

7 Summary and future work

In this paper, we presented a formulation of participant selection, in which the total benefits contributed by all participants should be maximized. We developed PSP-G, a greedy algorithm that first calculates the B2C factor of each participant. It then dispatches participants to regions according to participants' B2C. Each time the algorithm tries to maximize the total budget of the partial assignment. According to our experimental results, PSP-G delivers a near optimal solution with less time complexity. In particular, its execution time can be reduced to only one tenth of that of existing optimization methods. The experiment results show that PSP-G is a practical solution for emergency needs in disaster areas. In the future, we plan to integrate PSP-G with an existing open source disaster management system so as to further demonstrate the applicability of PSP-G.

Acknowledgements

This work was partially support by The Academic Sinica Project Open ISDN (Open Information System for Disaster Management) and by the Taiwan National Science Council Grants NSC 100-2219-E-224-001.

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Trustworthy emergency information brokerage service (TIBS)

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Abstract

Availability and timeliness of relevant information is of paramount importance during disaster response. Structural and situational information should be made available lavishly to decision makers, field workers, victims, even the general public provided that it would be possible to track down potential abuses. The trustworthy emergency information brokerage service (TIBS) described in this paper was developed based on such a conviction. This pervasive information flow control system offers information desensitization, flow traceability and use accountability services in two separate phases of disaster management: (1) in the preparatory phase, a prospective P-TIBS subsystem will provide information filtering and fusion tools that can help resource owners to desensitize organizational/structural information and store them in a virtual repository deployed pervasively on many points of service (POS); (2) during the disaster responsive phase, a retrospective R-TIBS subsystem will lease the desensitized information and offer information flow traceability as well as use accountability services according to pre-specified information release and accountability policies. This accountability approach will be more scalable and responsive than the "break-the-glass" access control overriding mechanism available in many hospital information systems as it alleviates the need to authenticate individual users and authorize their emergency information access. This paper provides an overview of the TIBS system architecture and the enabling technology it employs.

Keywords: disaster response, information accountability, authorization override.

WIT Transactions on The Built Environment, Vol 133,
www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/DMAN130221

1 Introduction

Recent epics of disaster reminded us that when a disaster strikes, accurate structural information and timely situational information can be vital for carrying out efficient evacuation/rescue operations and performing effective damage control provided that such information can be made widely available to decision makers, field workers, victims, even the general public while the physical and social infrastructures are in turmoil. Two major obstacles currently hinder effective information dissemination during disasters. First, the owners of vital information often set up security and privacy protection to prevent illegal access. For examples, owners of private buildings often safeguard their structural details; mobile service providers refuse to disclose the locations and use patterns of their customers; even government agencies may conceal the extent of a flood due to their concerns about public perception. Then, ironically, in this "information age", we still lack a pervasive robust information/communication infrastructure that can withstand disasters and offer highly available services. This paper tries to address the first issue while leaving the second issue to a companion paper on Open Information Gateways [1].

The obstacle introduced by security and privacy protection may be circumvented in part by adding the emergent "break-the-glass" (BTG) extensions to standard role based access control model [2, 3]. Using these extensions, one can specify a hierarchy of emergency access control policies based on the security overriding requirements at different levels of emergency. Usually, BTG polices for more severe emergency cases allow more flexibility in overriding nominal access control decisions while imposing more extensive auditing requirements. These BTG extensions are quite capable of handling the emergency access control cases arise among electronic health record systems, which usually require permissions to be granted to healthcare professionals so that they can access unconscious patients' medical records without their consent [4]. In those cases, the group of subjects, e.g. healthcare professionals in a hospital, is usually small and can be authenticated by a functioning hospital information system. When a disaster strikes, however, thousands of victims and ad-hoc rescue workers may need to find their ways through collapsed buildings and flooded streets. With servers down and cell phones barely connected to one another via Bluetooth or Wi-Fi, it would be impossible to authenticate any of the subjects; yet, accurate and timely information must be given to them in these life-or-death situations. Furthermore, useful information may have to be gathered from different organizations residing within separate security or network domains. Existing BTG access control override simply do not work in these cases.

This paper presents a pervasive information flow control system, named the Trustworthy Information Brokerage Service (or TIBS for short), as a more scalable and responsive alternative. Unlike conventional access control system, TIBS offers *information desensitization*, *flow traceability* and *use accountability* services in two separate phases of disaster management. First, in the preparedness phase, a prospective or P-TIBS subsystem will provide information filtering/fusion services to help resource owners to desensitize organizational or structural information and store them in a *virtual repository* distributed on points of service (POS) that are deployed pervasively for the sake of availability and responsiveness. Then, in the response phase, a retrospective or R-TIBS subsystem will offer information flow traceability and use accountability services based on pre-specified *information release* and *accountability policy clauses* while largely eliminate user authentication requirements. Among them, the information release clauses specify the *conditions* under which information may be released to the public while the use accountability clauses state the *obligations* such as providing mobile phone numbers and generating attestation meta-data tags that the recipients must fulfil. Just as the BTG conditions can be derived from information requirements in emergency cases, so are the release and accountability conditions of each piece of information correspond to different levels of emergencies.

The rest of this paper provides a stream-lined presentation of TIBS. An overview of its structural and functional architectures is included in Section 2. The technologies developed for or employed in the P-TIBS and R-TIBS subsystems are described in Sections 3 and 4 respectively. As a conclusion, Section 5 summarizes the completed tasks and outlines a future plan.

2 System overview

First of all, TIBS does not work alone. It functions as the frontend as well as the backend of an emergency information management framework, known as the Virtual Repository (VR) [5]. By itself, VR is a distributed survivable Linked Data framework that provides services and tools for publishing information relevant to disaster mitigation and response. It adopts Resource Description Framework (RDF) as its data model, Universal Resource Identifiers (URI) as its resource identifiers and semantic web ontology as its vocabularies [6].

On the next page, Figure 1 shows the functional architecture of VR and its relationship with the applications and the information sources it serves. Following are the components crucial to the interoperation between TIBS and VR.

- Information Virtualization Layer or VR Tools: they are assorted information filtering, access and translation tools that convert gathered information from multiple sources to suite different applications and services.
- Intelligent Active Storage Service (IASS) or VR Core: this is a distributed middleware layer that performs event-triggered, push-based information delivery according to Event-Condition-Action and QoS (ECA+Q) rules.
- Points of Service (POS) Servers: these are lightweight servers deployed in various public places equipped with computing, data storage and communication resources. The best examples are the public Wi-Fi stations installed in many café or convenience stores.
- Mobile Assistants for Disasters (MAD) [7] or similar VR client applications: these applications may search and retrieve disaster mitigation and response information under the control of TIBS information flow traceability and use accountability services.

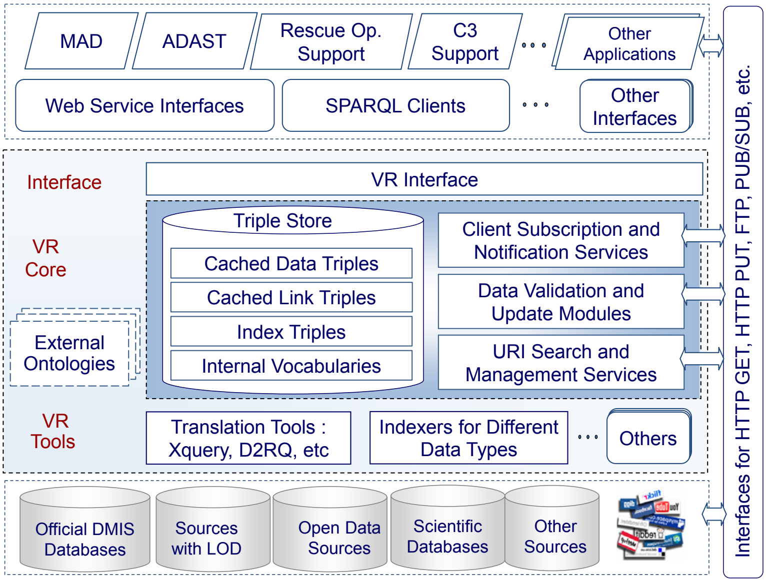

Figure 1: Functional architecture of virtual repository (VR).

As mentioned, TIBS can be divided into a prospective P-TIBS subsystem that helps resource owners to desensitize information for public release and a retrospective R-TIBS subsystem that offer information flow traceability and use accountability services based on information release and accountability policies. Their interactions with resource owners and VR are illustrated in Figure 2.

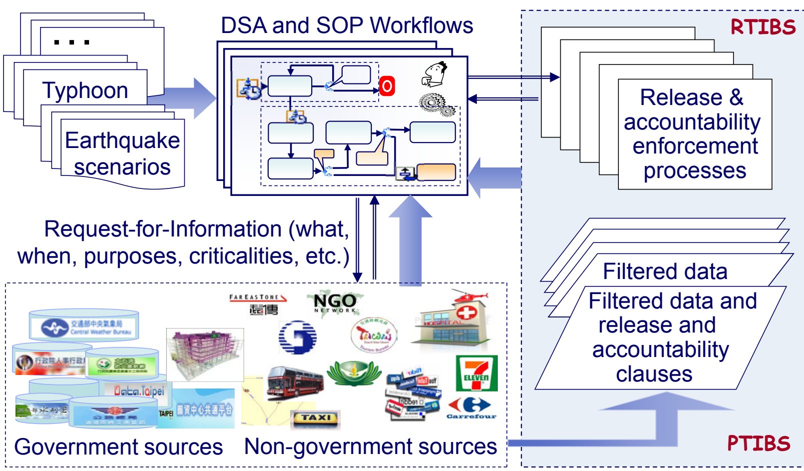

Figure 2: Interactions between TIBS, resource owners and Virtual Repository.

Specifically, P-TIBS serves as the backend gatekeeper for VR. It enforces multi-domain attribute/role-based access control between various resource owners and the VR-IASS core. In addition, P-TIBS enables resource owners to use the filtering and fusion tools available in the VR Information Visualization Layer to desensitize the information to be released and place them into the VR Triple Store. Since these transactions will be carried out in normal circumstances during the disaster preparedness phase, they resemble the data transfers among private hospital information systems and a government-run electronic health record repository. In both cases, a multi-domain access control system must be in place to manage the transactions according to the access control policies established with each resource owner. Section 3 provides an overview of the technologies employed by P-TIBS.

R-TIBS, on the other hand, serves as the frontend gatekeeper for VR. It implements a distributed infrastructure among VR POS servers and its client application similar to Weitzner's Information Accountability Framework [8]. Following are the essential components.

- Accountability Appliances: these are trustworthy devices and programs that mediate information accesses, maintain data transfer logs and provenance records. POS servers and MAD are typical examples.
- Provenance Controllers: these are trusted servers that enforce information release/accountability policies and also operate as the trusted third party for the user intention and usage restriction handshake [9, 10] in the HTTPa protocol, which we employed to conduct information assurance with accountability assurance. POS servers play this crucial role.
- Distributed Transaction Logs: Accountability Appliances must all take up the responsibility of recording all information transfer and use instances so that information usage can be monitored and users can be held accountable in case they abuse the information. POS and MAD will all keep transaction logs in Accountability-in-RDF (AIR) format [11] and upload these logs opportunistically onto the VR Triple Store.

3 Prospective TIB technology

According to XACML architecture [12], a role/attribute-based access control (A/RBAC) system consists of Policy Administration Points (PAP) that manage the access control policies, Policy Decision Points (PDP) that make the authorization decisions, Policy Enforcement Points (PEP) that carry out the decisions and Policy Information Point (PIP) that supply attribute values of subjects, resources, actions and action environments. In multi-domain systems, these components may be installed in distributed servers and make access control decisions based on policies and role/attribute assignments associated with individual domain. For P-TIBS, we employed PERMIS, a mature open-source authorization engine as its PDP. We also developed a generic object-based A/RBAC policy specification and proposed two extensions to the OAuth 2.0 protocol standard. All these are discussed in the following paragraphs.

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3.1 PERMIS Access control authorization engine

PERMIS (PrivilEge and Role Management Infrastructure Standards) [13, 14] is an access control authorization system that provides the necessary facilities for users to manage authorization policies and for applications to make authorization decisions. PERMIS supports distributed assignments of roles and attributes to users via multiple attribute authorities and uses X.509 attribute certificates to maintain these attributes. PERMIS can be integrated with virtually any application and any authentication mechanisms including usernames/passwords, Kerberos, Shibboleth, public key infrastructures and OpenID. In addition to mundane policy and credential management, PERMIS provides two essential services: (1) the *credential validation service* that validates users' roles according to *user-role assignment rules* and (2) the *authorization decision engine*, which embodies a Policy Decision Point (PDP), evaluates users' access requests according to *role-permission assignment rules*.

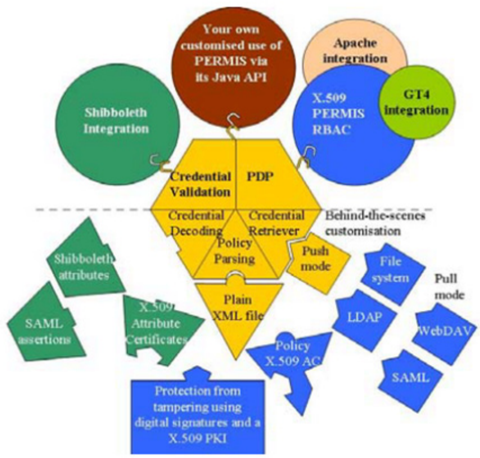

Figure 3: Functional architecture of PERMIS [13].

3.2 Generic object based A/RBAC policy specification

Mimicking the generic object-oriented programming paradigm, we devised a generic A/RBAC policy specification as a modular, expressive and reusable way to specify attribute/role-based access control policies in multi-domain environments. Beside of developing a *polymorphic typing scheme* to articulate the role hierarchies, we also implemented a *policy translator* and a *static policy checker*, which can convert Java-like generic policy specification into standard XACML policies. The entire system can run in the Eclipse integrated programming environment and used as a policy pre-processor of PERMIS authorization decision engine. This schema was devised originally for specifying access control policies of electronic health records. It was adopted into P-TIBS to express multi-domain access control policies that are enforced among different information owners and providers.

The generic A/RBAC policy specification was built upon three polymorphic typing principles: First, for the sake of mutual independence and symmetry, Object Roles were added as a first-class component alongside with Subject Roles and Actions. Figure 1 shows the symmetric bindings exist among all the first-class components. Note that there are two kinds of entity-role-action bindings: the Subject Sessions that assign specific Subjects to each Subject Role as well as the Object Sessions that bind different Objects to the Object Roles. These sessions can be established and dismantled asynchronously and hence greatly enhance the dynamics of subject/object permission bindings while maintaining the static nature of the A/RBAC policies.

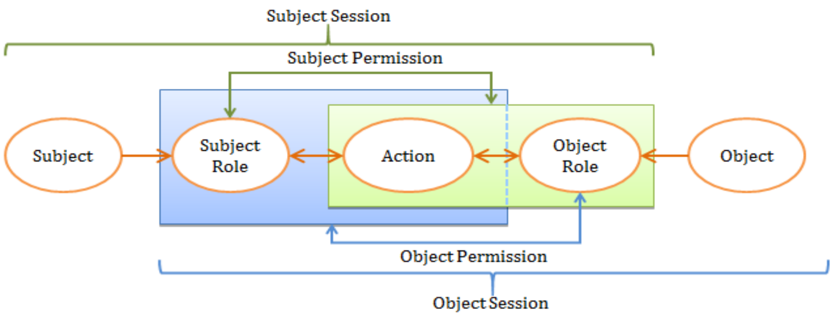

Figure 4: Components of generic A-RBAC policy specification.

Second, *type parameters* were introduced to cast Subject and Object Roles as *bounded polymorphic types*. In the following example, `Dept`, `Rank` and `Status` are all type parameters of the polymorphic type, **`Nurse`**.

```
Nurse <Dept, Rank, Status>
Patient <Dept>
Dept   ∈    {Oncology, Cardiology, Urology, GI, … }
Rank   ∈    {Graduate, Registered, Practitioner}
Status ∈    {Observer, OnDuty, InCharge}
```

The polymorphic nature of Subject and Object Roles enables policy administrators to articulate role inheritance hierarchies in terms of subtype relations. Most importantly, this polymorphic typing system allows the subtype relations among Roles to be specified in terms of parallel subtype relations existing among their type parameters. For example, the following policy, which is applicable to *any* nurse on duty:

```
Nurse <ANY, ANY, OnDuty>}{
permission(GUIDE, Patient<ANY:Dept>);
}
```

It will be inherited by a registered nurse of a specific department *d*,

```
Nurse <d, Registered, OnDuty>{
  permission(INJECT, Patient<d>);
  permission(GUIDE, Patient<ANY>);
}
```

These *type inference rules* not only greatly reduce the number of explicit role specifications — which has always been a major issue in RBAC policy model — they also simply the expressions of policy specification.

Finally, static type checking was employed to verify the consistency among policy specifications. To aid this process, the ranges of action binding with both Subject and Object Roles were specified explicitly as follows:

```
action endoscopy (Doctor<GI, Proctologist, OnDuty>,
Patient<GI, colon-cancer, ANY>)
```

These *action range specifications* were prescribed as an integral part of the policy template for an application. They enable us to build the *policy translator* and the *static checker* for generic A/RBAC policies.

3.3 OAuth subject role and target scope extensions

In multi-domain access control, information providers do not have the right to know the identity of information users. However, the providers should have the prerogative to limit the scope of information accessible to the users. To enforce these principles of least privilege, we also proposed two extensions to the standard OAuth 2.0 authorization protocol [15]. These extensions have been added to the open OAuth reference implementation and will be submitted as an Internet Draft to the IETF OAuth working group.

4 Retrospective TIBS technology

Enforcing information accountability during disaster response is both a massive and a relatively straightforward task. It is *massive* because the operation often involves unforeseeable number of people devouring large amount of highly dynamic situational information. It is nonetheless *relatively straightforward* because the disclosed information should be consumed within a limited space and time span. Users who want to obtain similar information outside of the emergency situations should do so via regular venues. Consequently, among the four components of Weitzner's Information Accountability Framework [7], *policy specification* and *policy reasoning tools* shall be rather straightforward to implement: the policy specification should prescribe the space/time limits for legitimate use of disseminated information while the policy reasoning tools should prevent the spread of information beyond those limits. The challenges lie with the detection of off-limit information use and the backtracking of information flow by means of *transaction logs* in order to hold the culprits accountable for their acts. Following are the brief discussions of these issues. Although most of the development work is still on the drawing board, we are trying to employ existing technologies in our design.

4.1 Information flow and transaction logs

As Sloan and Warner pointed out in [16], in order to assure accountable information usage, one may require to log "every transaction everyone makes everywhere". These logs must be kept by every endpoint in the distributed computing framework. To make this task a bit more manageable for TIBS, we intend to log *every information transfer* across the boundaries of *every information domain*. Each domain is defined as a group of users and their computing devices that possess a piece of information. For example, if the layout of a damaged building was given to a rescue team, sharing that layout among the computing equipment owned by the team members is regarded as *intra-domain transfers* and not to be logged; however, sharing it with a member of another team will be regarded as an *inter-domain transfer* and hence must be logged. Since information may be shared through peer-to-peer communication, *every* VR client application as well as *every* POS server must play the role of an Accountable Appliance and perform the transaction logging function faithfully.

Each transaction log must record the source and destination, the date and time as well as the provenance record of the information transfer. Since strong authentication may not be enforced in emergency situations, information source and destination may be tentatively tied to users' mobile phone numbers or personal identities. Once the Host Identity Protocol (HIP) [17] is widely deployed, host identities with implicit certification capability will be used as the official source and destination identities.

In order to maintain syntactic compatibility with the other data kept in the VR Triple Store, we adopted the Accountability in RDF (AIR) policy language [18] developed by Weitzner's Decentralized Information Group (DIG) at MIT. AIR uses the Terse RDF Triple (Turtle) language [19] and the Notation 3 logic framework [20] to support AMORD-like deductive reasoning on dependency. The transaction logs in AIR can be used to support dependency tracking and help to trace an information abuse back to the plausible culprits.

Finally, R-TIBS must enable POS servers and VR client applications to conduct information exchanges freely with accountability assurance support during emergency situations. For that purpose, we employed the HTTPa protocol [9] also developed by MIT DIG to provide blanket protection to these transactions because all web-based client-server exchanges are conducted via HTTP. The crucial role of the Provenance Controllers of released information shall be played by the POS servers that constitute the VR storage core.

4.2 Accountability policy specification and reasoning tools

R-TIBS policy specification consists of two parts: the *information release clauses*, which specify the conditions under which information may be released to the public and the *information use accountability clauses*, which state the obligations that the recipients of information must fulfil.

The information release clauses extend the event-condition-action (ECA) rules used in the active database systems with an addition of quality-of-service (QoS) requirements. Together, they prescribe the events that trigger the release of information stored in the POS servers, the transformations that convert the information into releasable and useful forms and the QoS requirements that the data dissemination processes are expected to satisfy. The actions of information release and transformation will be carried out by the VR Interfaces while the

QoS requirements will be passed to the Open Information Gateways and enforced by the overlay network.

The information use accountability clauses state the space and time spans as the conditions under which the information dissemination processes are allowed to proceed and the specifics of the transaction logs as the obligations that the dissemination processes are expected to fulfil. Both the release and the accountability clauses will be expressed as XACML v.3 policies and parsed by the Policy Enforcement Points (PEP) embedded in the Accountable Appliances.

5 Summary and future work

The entire OpenISDM project has just finished its first year. In the past year, the TIBS subproject has been focused on the development of P-TIBS subsystem, especially the construction of a distributed multi-domain A/RBAC authorization platform to aid the release of organizational and structural information crucial to disaster preparation, mitigation and response. A PERMIS based proof-of-concept prototype (Figure 5) has been built and tested. In addition, a development plan for R-TIBS subsystem has been laid out and the key technologies chosen. In this and the next year, an information accountability infrastructure for disaster response will gradually be put in place. Innovative techniques will be spawned off naturally during this process.

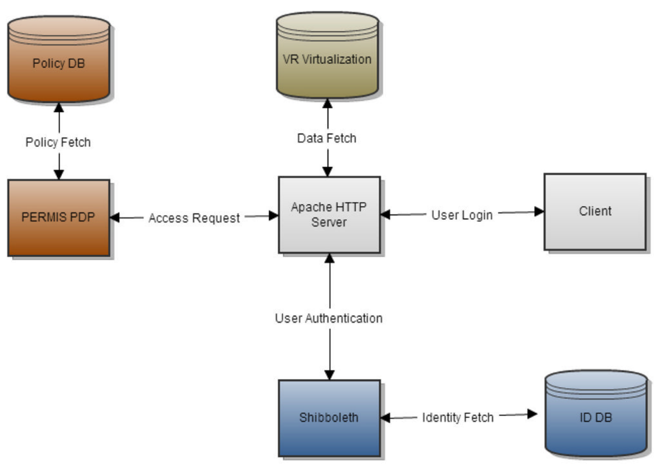

Figure 5: Functional modules of P-TIBS proof-of-concept prototype.

Acknowledgement

This work is supported by the Academia Sinica OpenISDM (Open Information System for Disaster Management) project.

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Section 5
Risk mitigation

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Landslide risk management in Malaysia

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Abstract

Malaysia is located in a tropical region where rainfall is abundant. Due to this condition, Malaysia experiences frequent flooding and landslides. The Slope Engineering Branch of the Public Works Department of Malaysia is given the task by the Malaysian Government to monitor and enhance slope safety. Losses due to landslides in Malaysia are estimated to be more than USD 1 billion since 1973. One of the first thing carried out by the Slope Engineering Branch after its establishment in 2004 is the drafting of a National Slope Master Plan (NSMP) to pave the way for enhancement of slope management. The goal of the NSMP is to reduce risks and losses due to landslides. There are ten components in the NSMP. The NSMP laid out strategies and action plans required to better manage the slopes in Malaysia. Some of the action plans that have been translated to practice include but not limited to the following activities: inventorizing slopes; producing hazard and risk maps; carrying out public awareness and education programs; and forming committees among agencies to formulate effective slope mitigation policies and cooperation. The paper describes the actions taken by the Public Works Department to mitigate landslides in Malaysia.
Keywords: slope master plan, risks, losses, action plans, landslide, mitigation.

1 Introduction

Malaysia has been experiencing rapid economic development since the early 1990s. As a result, more hilly terrain areas have opened up for development. From 1973 to 2011, there have been a number of major landslides in Malaysia with a total loss of lives amounting to more than 600. Figure 1 shows the number of landslide events and fatalities from 1973 to 2011. It is estimated that economic losses due to landslides since 1973 is more than USD 1 billion. Faced with landslides that seemed to increase annually, the Malaysian Government took steps to come up with mitigation measures. In 2004, the Slope Engineering

WIT Transactions on The Built Environment, Vol 133,
www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/DMAN130231

Branch was established within the Public Works Department Malaysia (PWD). In the same year the Malaysian Government instructed the PWD to prepare a National Slope Master Plan (NSMP) to reduce risks and losses due to landslides. The NSMP was completed and approved by the Government in 2009. There are ten components of the NSMP (PWD [1]). They are: 1) Policies and institutional framework; 2) Hazard mapping and assessments; 3) Early warning and real-time monitoring system; 4) Loss assessment; 5) Information collection, interpretation, dissemination, and archiving; 6) Training; 7) Public awareness and education; 8) Loss reduction measures; 9) Emergency preparedness, response and recovery; and 10) Research and development.

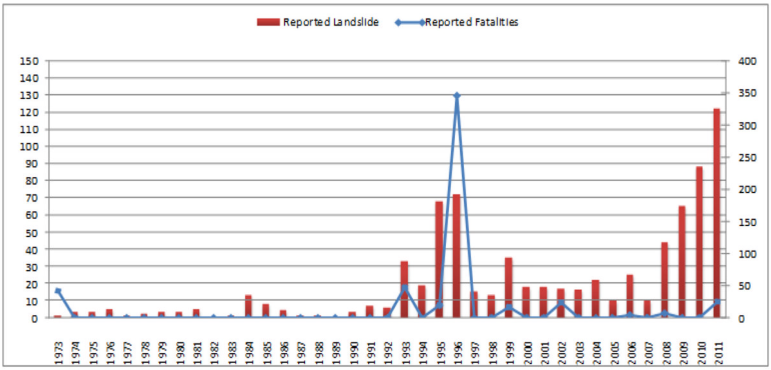

Figure 1: Annual landslides and fatalities in Malaysia.

The NSMP was planned to be implemented in three stages beginning from 2009 up to 2023. Some of the actions taken to manage landslide risks in Malaysia are presented.

2 Data collection, landslide hazard and risk mapping

Lack of a data base on slopes and landslides in Malaysia is one of the reasons why effective decision making on land use planning, maintenance, and quantitative assessment of risks has been difficult. Therefore, one of the first actions taken by the Slope Engineering Branch is to collect data by cataloguing slopes for effective slope management. Inadequate information may result in wastage of funding, difficulty in justifying budget allocation, wrong type of treatment for a slope, and difficulty in the preparation of yearly budgets. Even when money is spent on slopes, the safety of most of these slopes may not be assured if information on the slope is inadequate. A hazard rating based on a ranking system known as Slope Management and Risk Tracking or SMART has been developed. The SMART system has been applied elsewhere within Malaysia and is found to be valid for linear application, i.e., road slopes. To date, more than 25,000 man-made slopes along federal roads have been catalogued. Hazard mapping based on the SMART system and risk mapping of the slopes are in progress.

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PWD was also given the task to catalogue slopes and produce hazard and risk maps in high-risk areas, especially cities and towns where sometimes development was carried out without proper planning, design and construction. To date, more than 400 km^2 of hilly areas around Kuala Lumpur, the capital of Malaysia, and Penang Island have been catalogued and mapped for hazards and risks. The information obtained from the studies has then been given to the relevant local authorities for development planning, inspection, maintenance, monitoring and other purposes. Several local authorities have used the data to successfully reduce the number of major landslides in their areas. However, not all authorities is proactively using the data given to them to carry out appropriate measures to mitigate landslides. Some of the reasons are due to lack of funds and technical personnel to tackle technical issues.

A budget for more hazard and risk mapping for landslide-prone areas with an approximately area of 1,700 km^2 has been approved. The new project should cover more than 95% of the landslide-prone areas in high-risk areas in Malaysia, as shown in Figure 2.

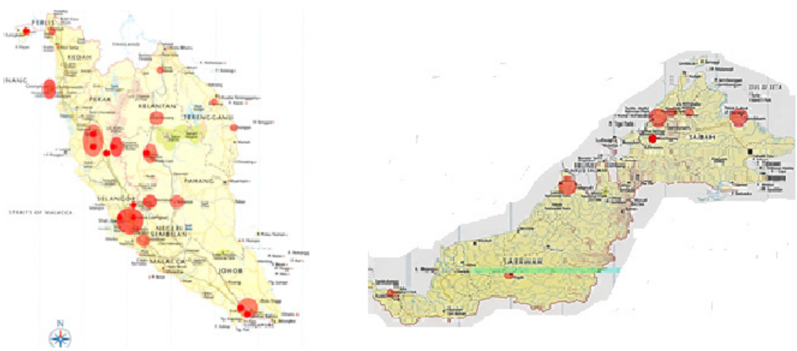

Figure 2: Landslide prone areas in Malaysia are shaded.

The spatial study is divided into two phases, i.e. (i) geomorphological mapping works and (ii) production of hazard map and documentation. In the geomorphological mapping works, LiDAR (Light Detection And Ranging) technology was used in the development of digital terrain models (DTM). Based on this DTM, a ground survey team will carry out field mapping and drainage investigation works. At this stage, qualitative risk analysis was carried out to obtain risk rating for the slope. In the near future, with more data quantitative analysis and risk rating will be given to these slopes.

3 Landslide monitoring and warning system

Landslide warning systems are intended to prompt the public to take precautionary measures to reduce their exposure to risk posed by landslips, and to assist engineers, contractors and others who are likely to suffer losses from landslips. The warning also alerts the relevant government departments and organizations to take appropriate actions, such as the opening of temporary shelters, search and rescue operations, closure of schools and relief work (Hong Kong Observatory, [2]). The Landslide Warning (LW) model can be divided into two functions: 1) for monitoring of regions susceptible to landslides; and 2) for critical locations where active landslides are present. For regions susceptible to landslides, a network of rain gauges will be used. It is based on rainfall as a triggering mechanism of landslides. An early warning system based on rainfall pattern and forecasting can be used in an area where studies have been conducted to correlate rainfall with landslides.

For locations where an active landslide is present, instruments such as automatic survey station, piezometer, inclinometer and other sensors can be installed in addition to rain gauges to monitor groundwater level fluctuation and any movement of the unstable slope mass. LW can be issued based on data collected via sensors or instrumentations, warning criteria based on threshold values, communication and information equipment as sensors and human interfaces as tools for dissemination of warning.

For a combination of related matters mentioned above, expertise in various fields is needed in the development of LW. They are listed below:

a. Instrumentation technologies related to landslides;
b. Landslide-related knowledge (process, behaviours, triggering mechanisms);
c. Communication technologies for remote data transmission, and
d. Information technologies for analysis and dissemination of warning.

The output of the LW consists of various levels of warning that can be used by the relevant authorities to execute appropriate measures (such as closing the road or issues evacuation order) and to minimize the effect of the landslides risks if it happens. PWD is discussing with various stakeholders headed by the National Security Council in the Prime Minister's Department to establish a networking system for Landslide Warning System (LWS).

To date, the Slope Engineering Branch, PWD Malaysia has installed more than 30 rain gauges along federal roads. This rain gauge network is necessary infrastructure for LW. The Meteorological Department has also recently installed Doppler radars that have coverage over the whole of Malaysia; however, the radars have yet to be calibrated.

There is an ongoing study carried out by the Slope Engineering Branch for the development of a relationship between rainfall and landslides occurrences to determine the thresholds to be used in the LWS. With an abundance of data on past landslides occurrences over the country and rainfall data obtained from the Department of Irrigation and Drainage and the Meteorological Department, the relationship and thresholds can be determined. A pilot study has started along the Tapah to Cameron Highlands road in Perak. Perak is a state located north of the capital city of Kuala Lumpur.

A slope movement monitoring activity is being carried out at km 44 and 46 along a federal road from Simpang Pulai to Lojing, another road in the state of Perak. The geology around Mount Pass consists of a sequence of meta-sedimentary rocks that are confined within a 4 km-wide area surrounding the mountain complex. The rocks are highly deformed and adulated, and have undergone low to medium-grade dynamic metamorphism (Andrew Malone Ltd., [3]). The original sedimentary rocks are thought to have been deposited during the Ordovician period (Geological Survey of Malaysia, [4]). During the late Palaeozoic period it was deformed and metamorphosed. The meta-sedimentary rocks have been intruded by granite plutons that are predominantly Permian to Jurassic in age (Gobbet & Hutchinson, [5]). The exposed rock cut slope within the site includes quartz mica schist, graphitic schist, quartzite and phyllite with weathering grades varying from Grade II (slightly weathered) to Grade VI (residual soils). The residual soils are confined to the 3 to 6 m top section of the slopes. According to a study by Andrew Malone Ltd [3], the rock sequence is cut by a series of faults that are grouped into 3 categories. The first is the most prevalent within the graphitic schist unit, consisting of low to moderately dipping faults that are associated with quartz veining. The second consists of steep faults that cut sharply across the foliation.

At km 44, a cut slope has translated downward and outward by more than 30 m. Even during construction, this slope had already started to fail. It was initially designed for a cut of no more than 40 m high, which is quite common in Malaysia when tunnels and viaducts are deemed too expensive compared with cut and fill. PWD has drafted the Slope Design Guidelines (Slope Engineering Branch, [6]) to limit the height of cut and fill slopes to less than 40 m to facilitate maintenance of the slope and reduce environmental impact of the construction. At the same time the guidelines encourage the construction of tunnels and viaducts, which is more environmental friendly. This case clearly illustrates that the present method of cut and fill may not necessarily be more cost effective compared with tunnels and viaducts in the long run. Monitoring of the slope movement is carried out in real-time using surface monitoring device to measure the movements of the slope surface. In this case, two automatic total stations

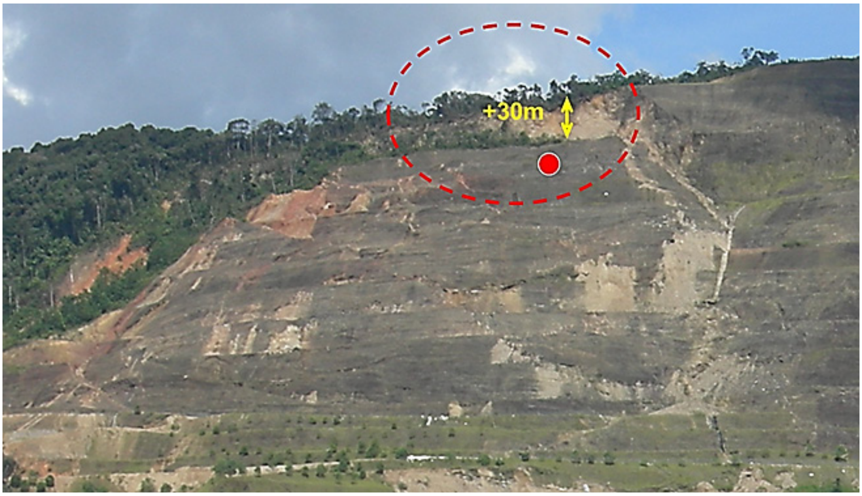

Figure 3: Landslip at Gunung Pass and location of one of the prism markers.

with prisms as markers are used to monitor the movements of the slope. Some of the actions taken include conducting round-the-clock inspections, monitoring and minor realignment of the road. Figure 3 shows the head scarp at the top of the mountain and the location of the markers on the slope surface.

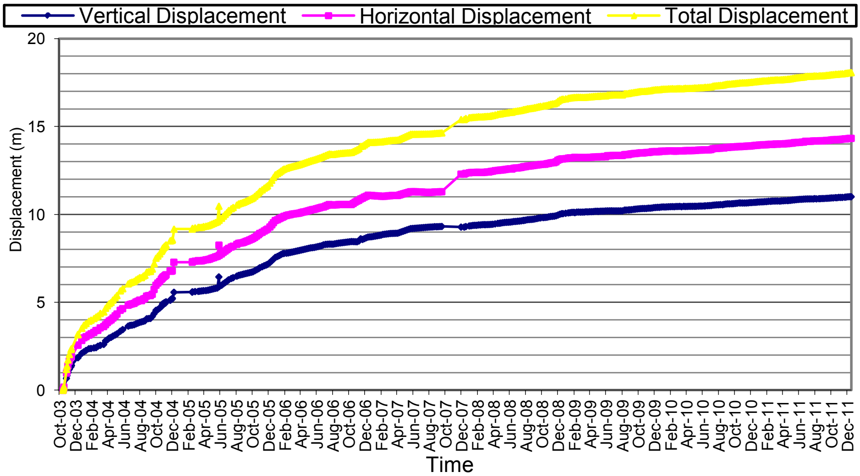

Figure 4: Largest movements at prism marker indicated in Figure 3.

Movements of the slope surface have been monitored since 2003. Initially, the monitoring was done manually until 2007 when two automatic total stations were installed and data was acquired at three-hour interval as opposed to once a day when measurements were taken manually. Figure 4 presents the movements of the most active marker near the head scarp. The slope face is still moving at a rate of 0.4m per year.

4 Slope inspection program

Slope inspection for all federal roads is carried out in preparation for the rainy monsoon seasons by the PWD technical staff with the help of the district engineer's staff. A few local authorities are also carrying out regular inspections on the slope under their authority. Efforts have been to create awareness amongst the local authorities so that regular inspection and maintenance are carried out to reduce the risk of landslides.

Emphasis during the slope inspection is placed on ensuring that the drainage system is well maintained, i.e., free of debris and any damage has to be reported and repaired. Another aspect of slope inspection is to detect signs that may indicate or cause instability such as tension cracks and seepage within the slopes. This program has just been initiated and guidelines for maintenance have been introduced. At the outset the process seemed quite simple. However, ensuring the effectiveness of the program requires a lot of groundwork, such as training

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for the inspectors – usually technicians and engineer's assistants, proper equipment, and of course enough personnel to carry out the inspections. Other impediments to the slope inspection program include inadequate facilities for inspection purposes. Usually cut slopes in Malaysia are constructed at more than 35° and some rock slopes are constructed at more than 75°, which means that a special ladder or stairs have to be provided for scaling the slopes. In actual fact, such facilities are generally ignored during the design. On top of this problem, the slopes are generally heavily vegetated. PWD is trying to remedy the situation by constructing facilities to facilitate inspection of the slopes.

Previously, there was no limit to the height of the cut slope, so the highest road cut slope is approximately 260m. Many slopes are more than 40m high which means only very physically fit personnel would be able to scale the slopes. Coupled with the inadequate facilities as mentioned above, the task of proper inspection is difficult. Apart from manual inspection, PWD are looking at ways to carry out remote inspection. One of the ways is to inspect using unmanned model helicopter or plane with viewing device attached; however, this is still undergoing trials and experiments.

Once the inspection process is completed, the next step would be to perform proper maintenance and repair. Apart from the physical impediments mentioned above that makes maintenance and repair difficult and costly, adequate funding is always an issue. For routine maintenance and minor repairs of road slopes, PWD is provided with approximately USD 33 million annually.

5 Guidelines

Manuals and guidelines facilitate routine works and procedures that need to be done quickly and efficiently. Several guidelines have been produced to help engineers, especially those in PWD to carry out their works. Guidelines are sometimes adopted with some modification from other established organizations that have already come up with a proper procedure.

Some of the guidelines that have been produced are slope design and maintenance guidelines. In the slope design guidelines, some cut slope and embankment dimensions are clearly spelled out, for example the maximum number of benches are now limited to 6 and the height between each bench shall not exceed 6 m. The minimum bench width of the slope is also specified. The factor of safety cut slope and treated slopes are specified.

Malaysia's slope maintenance guidelines have been adopted with some modification from the Hong Kong slope maintenance guidelines. In the guidelines, inspection program for slopes is presented including the personnel and the frequency of inspection. The guidelines also include what needs to be maintained and how it should be carried out. As in any other maintenance guidelines, special attention is paid to the condition of drains on the slopes. Any signs of instability have to be attended speedily before the condition becomes worse. Examples of well and poorly maintained slopes were shown by way of pictures and illustrations. The maintenance manual can be downloaded for free from PWD's website and the maintenance guidelines have been distributed to local authorities for maintenance of their slopes, which usually include slopes along municipal roads and around residential areas.

The Town and Country Planning Department, a federal agency, has also drafted development on hilly terrain and highlands guidelines in 2009 to ensure man-made slopes are well planned, suitably designed, well-constructed, and properly maintained. The guidelines are mandatory for developers if the local authorities choose to enforce them. Some states have since drafted more stringent guidelines to reduce the risks of landslides. Public pressure has resulted in the federal and state government to take more proactive actions to reduce major landslide disasters.

Works on regional rainfall-induced landslide warning system has started with some research being carried out along the road between Tapah to Cameron Highlands, a road that traverse through a hilly terrain area.

6 Training

In this component two strategies were proposed to increase knowledge and awareness among students, practicing engineers, stakeholders such as developers, local government officers, contractors, planners and geologists. In the case of students, one of the recommendations was to introduce curriculum and course templates for undergraduates and post graduates courses. Discussions with the academia from various local universities during the drafting of the NSMP did not yield a favourable response from them simply because there is no space for a new course to be taught within the already congested course schedule. It was suggested that special talks be given by practising engineers on relevant topics on slope engineering to under and post graduates students. The programme has already started with a few universities and will be expanded to other institutes that teach civil engineering and soil sciences (Abdullah [7]).

Currently more efforts are spent on training engineers and technical personnel from the local authorities so that they can response to the demand from the public to provide technical advice, carry out inspection on slopes and recognising signs of landslides so that they can take preventive actions should the need arises.

Other stakeholders include practicing engineers, planners, developers, contractors and geologists who would require training and awareness programmes. Developers and contractors in particular would require such training so that their works have better quality. PWD plans to work with the Malaysian Construction Industry Development Board to carry out a systematic courses and seminars for the construction industry players on good practices on slopes.

7 Public awareness and education

One of the first programmes to be rolled out upon the completion of the NSMP was public awareness and education. The programme was about creating awareness of slope safety by minimising the effects of landslides through

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proactive actions and measures that can be taken by community members as well as by government and private owners of slopes.

Generally, people tend to focus on safety only after a disaster happens, so the programme aimed at getting them thinking about averting disasters before they occur (Motoyama and Abdullah [8]).

Although the main target groups of the programmes were the communities-at-risk and the general public, there were other target groups consisting of the state and local governments, private slope owners, media, universities and schools.

The objective of the awareness programmes was to convey two key messages to the public. The first was to let the public know that there is a body of useful information that is available to the public on the phenomenon of landslides and tips on monitoring and maintenance. The second is that there is a government agency dedicated to safeguarding the interest of public safety.

Figure 5: Children lining up to receive prizes in a colouring contest in one of the public awareness programmes.

These messages were encapsulated in the campaign theme of “Learn, Maintain, Monitor and Report” and all activities of the awareness programmes were centered around this theme. The motif that tied all these activities together was the slogan “Safe Slopes Save Lives”, courtesy of the Geotechnical Engineering Office in Hong Kong.

One of the most important groups is the communities in at-risk areas because of the obvious risk to life and property. The assumption at the outset of the programme was that public awareness to this group would yield the best results among all the target groups because of the immediate safety concern to themselves.

Next to communities-at-risk, the most important target group was the local authorities. The authorities are the only government body with the charter to enforce safety guidelines and by-laws and engage in maintenance measures. Because they are the first line of contact with the residents, it is crucial that the engineering departments of the authorities are well-trained and well-equipped.

The outcomes resulting from this programme are significant in that they reflect institutional and long-term changes that affect the way hillside developments will be carried out in the future. They are as follows:

1. Awareness among local authorities in hilly areas for a proper slope management mechanism within their scope of work and the subsequent establishment of Slope unit within 3 local authorities in the high-risk states in the country
2. Establishment of state-level independent slope oversight committees for checking and approving all new development orders involving hills.
3. Reporters of newspapers providing regular coverage of slope issues in the local beat, and coverage now includes educational material in addition to problem cases.
4. Formation of SlopeWatch, a community-based organization that has grown into an non-governmental organization due to demand by residents for more information and advice on averting slope problems and pushing the authorities for stricter supervision of developers.
5. Residents associations in urban areas establishing sub-committees on slope monitoring so that residents can do their own monitoring and report to the authorities on any signs (Motoyama and Abdullah [8])

These are some of the changes that the programme has affected.

8 Setting up of Inter-governmental Committee on Slope Management (ICSM)

One of the action plans in the National Slope Master Plan is the setting up of the ICSM (PWD, [9]) at federal and state levels. Federal-level ICSM was set up in 2010. The primary purpose is to provide a mechanism for the active participation of all stakeholders, including technical experts and communities, in slope management planning and operations, where relevant role players consult one another and coordinate their activities on slope management issues.

The ICSM members include but not limited to the following organisations: Slope Engineering Branch; National Security Council; Town and Country Planning Department; Department of Environment; Department of Mineral and Geoscience; Malaysian Meteorological Department; Malaysian Centre for Remote Sensing; PWD Malaysia; Malaysian Highway Authority; Department of Survey and Mapping; Royal Malaysian Police Force; Malaysian Fire and Rescue Department; Social Welfare Department; the Red Crescent; highway concessionaires and other relevant governmental and non-governmental organisations.

The ICSM must advise and make recommendations on issues relating to slope management and the establishment of the landslide disaster management framework. The committee has recently agreed to form sub-committees headed by National Security Council to review the efficiency of the rescue operation for landslides and to facilitate information exchange among various agencies not only on landslide matters but also other information that any of the agencies have acquired.

9 Conclusion

Some of the slope management issues and actions taken by the Slope Engineering Branch of PWD Malaysia and other agencies are presented. PWD is at the forefront of managing landslide risks in Malaysia. The process commenced as soon as the Slope Engineering Branch was established within PWD and the drafting of the NSMP. The Malaysian Government has started to pay more attention to the landslide issues as public outcries grew louder. Some local authorities that are at the front line of public anger whenever major landslides occurred have yet to provide better services while others have used guidelines and relevant acts to act against errant developers and land owners. Landslide risk management requires the cooperation from all sectors of the society, from the federal and state government, local authorities, non-governmental organisations and the public for its success.

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Individualised risk communication of sediment-disaster evaluated using a psychological process model

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Abstract

This study developed a non-emergency risk-communication program focusing on sediment disasters. The program, which targeted local residents, included a motivational leaflet, easily understandable information, and a questionnaire requesting to make a behavioural plan. To verify the effectiveness of the program, it was tested in the town of Tosa in Kochi Prefecture, Japan. Participants in Tosa were randomly divided into two groups, with one group serving as the control and the other as the experimental group. The results showed that understanding of sediment disaster risk was significantly higher in the experimental group than in the control group. However, the program had only a limited effect on participants who did not trust the local government, indicating the importance of the credibility of local government agencies responsible for disaster prevention. The risk-communication program also had a positive effect on inducing evacuation behaviour.
Keywords: risk communication, evacuation behaviour, psychological process model, sediment disaster.

www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/DMAN130241

1 Introduction

In Japan, warnings regarding sediment hazards have been broadcast on TV and radio since 2007. However, it has been found that many people do not fully understand the meanings and roles of these warning notices and how they differ from other evacuation alarms or weather advisories. Furthermore, these notices do not necessarily induce evacuation behaviour [1]. An effective risk-communication program that can induce evacuation when necessary is needed across Japan, and research on effective programs is underway. A risk-communication program should include not only information on the risk but also tips designed to induce people to consider how they will behave in a risk situation.

One type of communicative program that has been shown to induce voluntary behavioural changes is mobility management, a "soft" transportation measure that has been adopted throughout the world [2]. Mobility management incorporates findings of psychology in a practical yet sophisticated method that can have significant effects on travel behaviour. In this study, we examined whether this practical approach from the transportation field can be applied to risk communication to induce disaster evacuation behaviour.

We developed a program to communicate sediment-disaster risk and induce evacuation behaviour. The program material included a simple motivational leaflet with information on concrete actions to take during an evacuation and a questionnaire that induced participants to consider their behavioural plan. Using control and experimental groups, we tested the program among residents of Tosa Town, Kochi Prefecture, Japan, and verified its effectiveness as a psychological process model for behavioural change.

Basically, the goal of such a communication program is to induce evacuation 'behaviour'. However, in the real world, it may be difficult to test the effectiveness of a program empirically by actual evacuation behaviour. Therefore, we tested the effectiveness of the program by measuring and analysing psychological factors that were considered to have significant relationships with behaviour.

2 Literature review

2.1 Process model of risk-coping behaviour and trust

Rowan [3] proposed the CAUSE model to describe a process of risk-coping behaviour. The model includes five phases as goals of risk communication: 'credibility', 'awareness', 'understanding', 'solution', and 'enactment'. Using this model, Fujii [4] suggested a process model to induce risk-coping behaviour.

An advantage of this model is that it is possible to determine participants' current phase of the process model and to then communicate appropriately for the phase. Moreover, this model assumes that 'credibility' is the deepest factor, reflecting many psychological research findings that 'trust' is fundamentally important in risk communication (e.g. Nakayachi and Cvetkovich [5] and

Nakayachi and Watabe [6]). Yamagishi [7] proposed that general trust in other people or organization is determined by both trust in competency and trust in intention, and this idea has been widely accepted.

2.2 Process model of attitude and behavioural change

Taniguchi and Fujii [8] suggested an integrated model of voluntary change in travel behaviour. The model was based on the assumption that the behaviour of reducing car use is influenced by the behavioural intention to reduce automobile use. That behavioural intention is, in turn, influenced by psychological factors, including attitude and perceived behavioural control. These factors are considered in the theory of planned behaviour, one of the most widely used behavioural theories [9].

Behavioural intention is necessary for sustained behavioural change, but it is not sufficient. In the real world, behaviour is not always modified, even if one has an intention to do so. In an attempt to determine how intentions are implemented in behaviour, Heckhausen and Gollwitzer [10] and Gollwitzer [11, 12] distinguished between 'goal intention' and 'implementation intention'. Goal intention can be regarded as a behavioural intention [13, 14], whereas implementation intention entails a plan for when, where, and how the target behaviour is to be implemented. Gärling and Fujii [13] hypothesised that the effect of behavioural intention on behaviour is mediated by implementation intention. They used data on causal relationships among behavioural intention, implementation intention or planning, and actual behaviour to support this assumption.

2.3 Practical measures to induce voluntary behavioural change

Even when people have a behavioural intention, such as 'I am going to evacuate when strong rainfall occurs', they often fail to implement the actual behaviour because they lack an implementation intention. An example of an implementation intention is, 'I am going to evacuate on a specific occasion to a specific location (such as a shelter)'.

To reduce the gap between intention and behaviour and activate implementation intention, Fujii and Taniguchi [15] and Taniguchi and Fujii [16] suggested a practical technique called a 'behavioural plan' for travel-behaviour change. In their travel-behaviour plan, participants were asked to complete a questionnaire regarding a specific occasion for which they would indicate when and from where they would telephone to reserve an on-demand bus service. Their results showed that requesting participants' behavioural plans was effective in inducing voluntary change in their travel behaviour. We thought that this technique could also be applied to induce other behaviours, such as evacuation behaviour in a risk situation.

3 Method

3.1 Overview of the target area, Tosa town

Tosa Town is located in a central, mountainous part of Shikoku Island, Japan, and receives an average of 2,500 mm annual rainfall. The population at the time of our study was approximately 4,500 (1,860 households). The main industries were agriculture and forestry. The population included a large percentage of people 65 years old and over, who made up 39.8% of the total population (in 2008), and in some areas, 70–80%. Local government officials in Tosa Town were interested in implementing our experimental program and had previously cooperated in other experiments designed by national ministries and Kochi Prefecture agencies. In addition, because Tosa Town have risks of debris flow and slope failure, we used the term "sediment disaster" as a general word to express the disaster in our program.

Before implementing the program, we interviewed a town official to better understand local circumstances. The interview revealed that Tosa residents already knew of evacuation areas. However, deciding which area would be safe under specific circumstances was a problem because Tosa Town is surrounded by mountains where sediment disasters could occur. The town official hoped that residents would think about which areas would be safe and use such judgements when evacuating.

In view of these circumstances, the program had to be senior friendly, and the goal was to induce voluntary evacuation in risk situations.

3.2 Individualised risk-communication program for a sediment disaster

We developed a risk-communication program that included a questionnaire aimed at inducing respondents to consider their behavioural plans. Tosa Town had 46 neighbourhood associations. We excluded some, such as those that had only a single household or that did not have high potential of sediment disaster, such as areas near the river. We then chose 21 neighbourhood associations and randomly assigned them to the target group (10 associations, 819 households) and control group (11 associations, 622 households).

Figure 1 shows the experiment schedule and the surveys used to investigate the program's effectiveness. As shown in the figure, the program kit consisted of

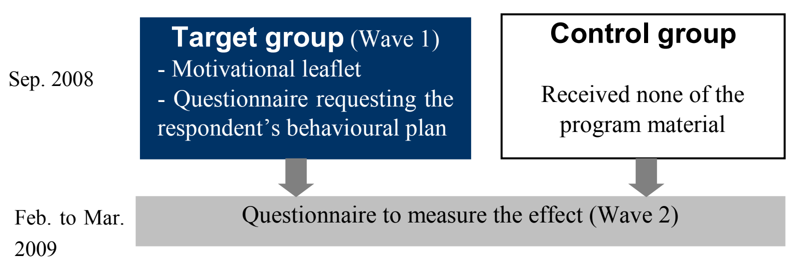

Figure 1: Flow diagram of the program.

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the questionnaire requesting a behavioural plan, a motivational leaflet, a sediment hazard map, and a magnet bar with which to display the behavioural plan. Kits were distributed in September 2004 to the target group through the neighbourhood associations.

All of the program kit material was designed to accommodate senior participants, such as by using large characters and having simple explanations. The program kit is described in detail below.

- The questionnaire with a behavioural plan

The one-and-a-half page questionnaire requested that participants read the motivational leaflet and refer to the hazard map for their residential area. Then, they were asked to answer questions such as the following: ‘Could you mark your home on the hazard map?’; ‘Is your home located within a red zone for sediment disaster?’; ‘Where will you evacuate to in the case of a sediment disaster?’; ‘Do you have a friend or acquaintance living within the red zone?’; ‘Do you know their contact information?’

Next, respondents were asked to fill in the behavioural plan sheet. Items included ‘In case of heavy rain, I will seek refuge in [location] _____ ’; ‘The telephone number of the refuge area is [tel. number] _____’; and ‘In such cases, I will tell [person’s name] _____ to seek refuge; their telephone number is _____’. Lastly, participants were asked where they would hang the behavioural plan, such as on their refrigerator, wall, or the back of a door, and they were asked to use the magnet bar that was distributed in the program kit to do this.

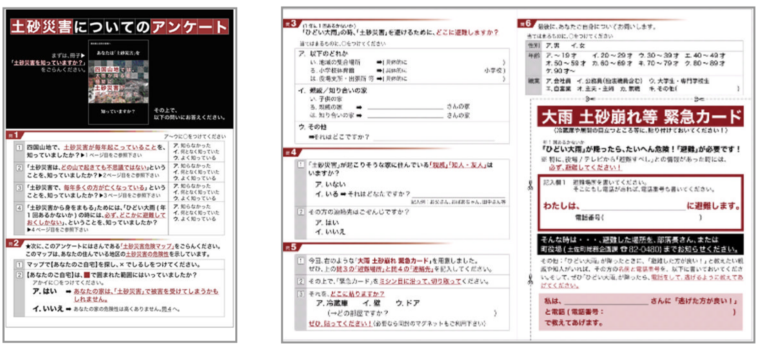

Figure 2: The questionnaire with behavioural plan (partial).

These questions and requests were designed to stimulate participants to consider how they would behave in the case of a sediment disaster.

- The motivational leaflet

To explain the risks of sediment disasters and how to behave appropriately, we made an A5-sized motivational leaflet. We tried to make the information as simple and easy to understand as possible. The contents of the leaflet were organised as short lists, photographs, and a graph of sediment disasters in Shikoku. The importance of evacuating to prevent human harm was emphasised.

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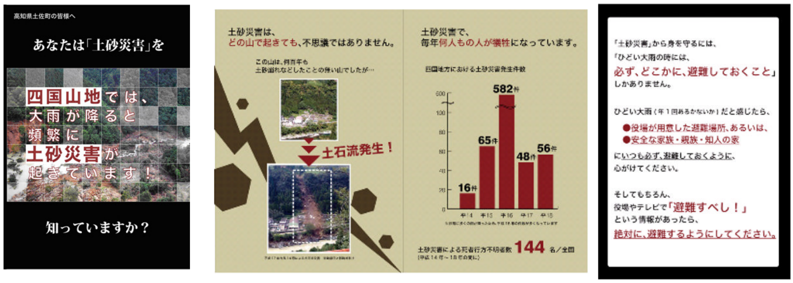

Figure 3: Motivational leaflet.

- *The sediment hazard map*

Using hazard data provided by Kochi Prefecture, we made four hazard maps in which sediment hazard zones were clearly indicated in red for each part of Tosa Town. The map was folded inside the questionnaire when the kit was distributed.

- *The magnet bar*

To remind people of sediment disaster risk and how to behave during a sediment disaster, we requested that participants place or hang the behavioural plan on their refrigerator, wall, or a door. The magnet bar was distributed to aid in displaying the plan.

About 6 months after the intervention, during February to March 2009, we distributed a questionnaire to all the households to measure the effects of the program (Wave 2).

3.3 Framework of analysis

As described in section 2, we used a psychological process model (Figure 3) to measure the effects of the risk-communication program described in subsection 3.2. This model was based on the CAUSE model, the model of trust, and the theory of planned behaviour.

The measures for each factor are shown in Table 1.

4 Results and discussions

We distributed the Wave 2 survey questionnaire to 1,441 households (819 target group, and 622 control group) and collected 374 (217 from the target group, 157 from the control group). We used these data to analyse the effects of the program.

4.1 Mean, standard deviation, and *t*-test

Table 2 shows the means and standard deviations for the target and control groups and the results of the one-tailed *t*-test assessing differences between them. Scores on all factors were higher in the target group than in the control group. A

Table 1: Questions used to measure factors in the Wave 2 questionnaire and the possible responses to the measures.

Index	Question	Ends of the scale/alternatives
Credibility (general trust)	Do you trust the local government's disaster-prevention office?	No/Yes Five-point scale
Trust in competency	Do you think that the local government's disaster-prevention office is competent to prevent sediment disaster?	No/Yes Five-point scale
Trust in intention	Do you think that the local government's disaster-prevention office intends to prevent sediment disaster?	No/Yes Five-point scale
Awareness	Do you think that there is a risk of sediment disaster in Tosa Town?	No/Yes Five-point scale
Understanding	Do you know that many cases of sediment disaster are caused by heavy rain?	No/Yes Five-point scale
Solution	Do you think that "just evacuating" is important to prevent human harm during a sediment disaster?	No/Yes Five-point scale
Behavioural intention	Do you think that you will evacuate during a heavy rain that is likely to cause a sediment disaster?	No/Yes Five-point scale
Implementation intention	Can you imagine with whom, to where, and how you will evacuate in the case of heavy rain that is likely to cause a sediment disaster?	No/Yes Five-point scale
† Memory of the program	Do you remember the program held in September 2008?	Remember/Remember somewhat/Do not remember
Below are dummy variables for the experimental group only based on the 'Memory of the program' question. These are the dummy variables relative to the control group.		
No memory dummy	The dummy variable was set to 1 if the participant answered 'Do not remember'; otherwise, the value was set to 0.	
Some memory dummy	The dummy variable was set to 1 if the participant answered 'Remember somewhat'; otherwise the value was set to 0.	
Memory dummy	The dummy variable was set to 1 if the participant answered 'Remember'; otherwise, the value was set to 0.	

†: This question was not included in the questionnaire for the control group.

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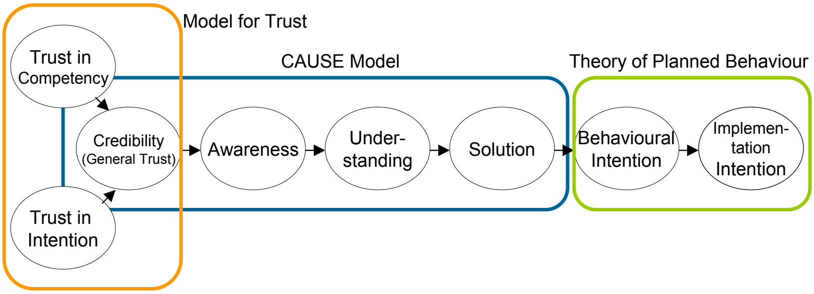

Figure 4: Framework of analysis based on three theories.

significant difference was found in the factor of 'understanding'. These results indicate that the risk-communication program developed in this study was effective in activating psychological factors for inducing evacuation behaviour to avoid sediment disasters.

For further analysis, the target group was divided into three groups according to answers regarding 'memory of the program'. Table 3 presents mean and standard deviations for the three groups. As shown in Table 3, more

Table 2: Comparison of the target and control groups and results of the one-tailed *t*-test.

	Control group			Target group			*t*-test Control vs. target		
	n	M	SD	n	M	SD	t	df	p
Credibility (general trust)	154	3.36	0.99	215	3.43	1.01	-0.74	367	0.23
Trust in competency	154	3.16	1.00	215	3.19	1.06	-0.22	367	0.41
Trust in intention	153	3.61	0.95	214	3.63	1.83	-0.09	365	0.47
Awareness	153	4.36	0.76	212	4.40	0.86	-0.46	363	0.32
Understanding	153	4.75	0.64	212	4.87	0.50	-2.02	363	0.02
Solution	154	4.64	0.64	216	4.70	0.64	-0.90	368	0.18
Behavioral intention	153	4.08	1.00	214	4.17	0.98	-0.93	365	0.18
Implementation intention	151	3.39	1.32	213	3.55	1.24	-1.21	362	0.11

n : number in sample; M: mean; SD: standard deviation
t : *t*-value; df: degrees of freedom; *p* : significance (one-tailed)

Table 3: Mean and standard deviation of the target group categorised by memory of the program.

	Target group, no memory			Target group, some memory			Target group, memory		
	n	M	SD	n	M	SD	n	M	SD
Credibility (general trust)	43	2.98	0.89	67	3.39	0.98	86	3.61	1.00
Trust in competency	43	2.72	1.05	67	3.27	1.01	86	3.34	0.99
Trust in intention	42	2.95	1.19	67	3.88	2.79	86	3.66	1.09
Awareness	43	4.16	1.19	68	4.34	0.78	83	4.53	0.68
Understanding	41	4.68	0.91	66	4.86	0.46	86	4.98	0.15
Solution	43	4.56	0.85	68	4.60	0.65	86	4.86	0.44
Behavioral intention	43	3.74	1.29	68	4.24	0.88	84	4.32	0.87
Implementation intention	43	3.19	1.28	67	3.45	1.27	86	3.79	1.18

n : number in sample; M: mean; SD: standard deviation psychological factors were activated in participants who had greater memory than in those with less memory of the program. The scores in the 'no memory' group were lower than those in the control group. In the next section, we will examine the factors that led to this result.

4.2 Psychological process model for evacuation behaviour and effects of participants' memory of the program

To verify that the psychological process model induced evacuation behaviour and to identify which factors differed among the three groups, we used the model shown in Figure 4. In this model, the relationships between the three dummy variables (shown at the bottom of Table 1) indicating memory of the program and the psychological process model for evacuation behaviour were examined. We tested this model by using hierarchical multiple regression analysis, setting the factors on the right side as dependent variables and those on the left side as independent variables. For example, for the dependent variable 'understanding', the independent variables are 'awareness', 'credibility', 'trust in competency', 'trust in intention', and the three dummy variables.

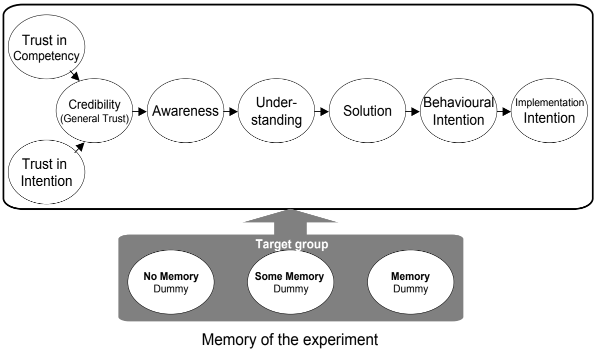

Figure 5: Proposed psychological process model for evacuation behaviour.

Table 4 and Figure 5 show the results of hierarchical multiple regression analysis.

First, trust in the local government's competency and trust in the local government's intention had significant effects on credibility, which replicated former research findings. Only trust in intention had a significant effect on awareness, and there was no significant effect of credibility or trust on competency. Awareness had a significant effect on understanding, and understanding and awareness had significant effects on solution. Credibility, trust in competency, and solution had significant effects on behavioural intention, and awareness had a marginally significant effect on behavioural intention. Furthermore, credibility, understanding, and behavioural intention had significant effects on implementation intention. These results indicated that the psychological process model was appropriate to describe a process of evacuation behaviour.

Additionally, trust in intention had a marginally significant negative effect on implementation intention. Although the coefficient of this pass was

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comparatively small (= -0.08), further research is needed to clarify the reason for this result.

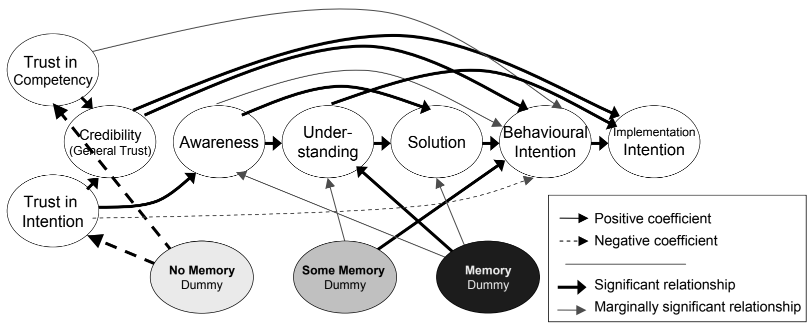

Figure 6: Results of hierarchical multiple regression analysis.

Second, concerning the dummy for memory of the program, the results shown in Figure 5 and Table 4 do not mean that there were causal relationships between the dummy variables and other psychological factors. These analyses were done to verify an existence of correlation between dummy and psychological factors and also to identify differences among the three dummy groups in comparison with the control group.

Table 4: Results of the multiple regression analyses of relationships between factors.

Dependent variable	Independent variable	β	t	p
Implementation Intention	(constant)	–	-2.15	0.02
	Credibility (general trust)	0.15	2.30	0.01
	Trust in competency	0.05	0.76	0.22
	Trust in intention	0.02	0.32	0.38
	Awareness	-0.03	-0.53	0.30
	Understanding	0.16	3.01	0.00
	Solution	0.03	0.51	0.31
	Behavioral Intention	0.38	7.08	0.00
	D_No memory	0.02	0.47	0.32
	D_Some memory	-0.05	-0.92	0.18
	D_Memory	0.04	0.80	0.21
Behavioral Intention	(constant)	–	-0.04	0.48
	Credibility (general trust)	0.13	1.85	0.03
	Trust in competency	0.10	1.51	0.07
	Trust in intention	-0.08	-1.62	0.05
	Awareness	0.08	1.53	0.06
	Understanding	0.02	0.34	0.37
	Solution	0.43	8.29	0.00
	D_No memory	-0.05	-0.97	0.17
	D_Some memory	0.09	1.75	0.04
	D_Memory	0.01	0.25	0.40
Solution	(constant)	–	7.11	0.00
	Credibility (general trust)	0.07	0.95	0.17
	Trust in competency	-0.01	-0.18	0.43
	Trust in intention	0.03	0.54	0.29
	Awareness	0.11	2.13	0.02
	Understanding	0.38	7.27	0.00
	D_No memory	-0.02	-0.31	0.38
	D_Some memory	-0.05	-0.91	0.18
	D_Memory	0.07	1.35	0.09

Dependent variable	Independent variable	β	t	p
Understanding	(constant)	–	20.19	0.00
	Credibility (general trust)	0.02	0.31	0.38
	Trust in competency	-0.04	-0.56	0.29
	Trust in intention	0.04	0.67	0.25
	Awareness	0.37	7.51	0.00
	D_No memory	-0.02	-0.32	0.37
	D_Some memory	0.08	1.46	0.07
	D_Memory	0.13	2.47	0.01
Awareness	(constant)	–	23.52	0.00
	Credibility (general trust)	0.09	1.12	0.13
	Trust in competency	-0.07	-0.94	0.17
	Trust in intention	0.16	2.83	0.00
	D_No memory	-0.05	-0.88	0.19
	D_Some memory	-0.03	-0.55	0.29
	D_Memory	0.08	1.35	0.09
Credibility (general trust)	(constant)	–	8.46	0.00
	Credibility (general trust)	0.69	17.51	0.00
	Trust in competency	0.08	2.13	0.02
	D_No memory	-0.03	-0.86	0.20
	D_Some memory	-0.04	-1.03	0.15
	D_Memory	0.04	0.98	0.16
Trust in competency	(constant)	–	40.73	0.00
	D_No memory	-0.14	-2.59	0.00
	D_Some memory	0.04	0.65	0.26
	D_Memory	0.07	1.21	0.11
Trust in intention	(constant)	–	31.83	0.00
	D_No memory	-0.15	-2.75	0.00
	D_Some memory	0.05	0.97	0.17
	D_Memory	0.00	-0.06	0.48

β: Standardized coefficient; *p* : significance (one-tailed)

As shown in Figure 5 and Table 4, the 'no memory' dummy had a significant negative relationship with trust in competency and trust in intention. The reason for this result is uncertain, but a possible explanation may be that people who did not trust local government did not put serious effort into the program and thus did not remember the program. The 'some memory' dummy was significantly associated with behavioural intention and had a marginally significant relationship with understanding. The 'memory' dummy showed a significant association with understanding and a marginally significant association with awareness and solution. There results suggest that the more people were aware of the risk of sediment disaster, the more memory they had of the program.

Overall, our results indicate that our psychological process model was appropriate for describing the process of evacuation behaviour. Furthermore, trust in local government was found to be a fundamental factor in inducing voluntary evacuation behaviour. If people did not trust in local government for disaster prevention, they tended not to remember the risk-communication program provided by the local government.

5 Conclusion

We developed an individualised risk-communication program to induce voluntary evacuation behaviour as a governmental measure and tested the program in Tosa Town in Kochi Prefecture, Japan. We then examined the psychological variables that were directly associated with evacuation behaviour and created a psychological process model based on existing theories.

Our results showed that scores on psychological factors supporting an evacuation plan were significantly higher for the target group than the control group. The psychological process model that we suggested was also found to be appropriate for describing a process of evacuation behaviour. Furthermore, trust in local government was of fundamental importance in inducing voluntary evacuation behaviour.

In this program, psychological factors such as understanding and behavioural intention were activated in at least 70% of the target group (the total of the memory and some memory groups). Additionally, nearly 30% of the target group reported that they displayed their behavioural plan in their home (e.g., on a wall, the refrigerator, or a door). These results suggest that the program was effective and practical. Future research should examine the applicability of this program to government measures in other areas.

Acknowledgements

The English in this document has been checked by at least two professional editors, both native speakers of English. For a certificate, please see: http://www.textcheck.com/certificate/fRIfY1.

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Section 6
Multihazard risk assessment
(Special session organised by D. A. Novelo-Casanova)

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Integrated risk assessment to natural hazards: case study – Motozintla, Chiapas, Mexico

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Abstract

In this work we assess the risk to natural hazards in the community of Motozintla located in southern Mexico in the state of Chiapas (15.37ºN, 92.25ºW) with a population of more than 20,000 people. Due to its geographical and geological location, this community is continuously exposed to the impact of many different natural hazards (earthquakes, landslides, volcanic eruptions, and floods). To determine the level of risk to natural hazards in the community, we developed integrated analysis of seismic microzonation, landslide and flood susceptibility as well as volcanic impact using standard methodologies. Vulnerability was quantified from interviews of local families considering structural and socio-economic variables. The families surveyed were randomly selected considering a sample statistically significant. All results were spatially analyzed using a Geographical Information System (GIS). Our results indicate that the community of Motozintla is highly exposed to floods, landslides and earthquakes and to a lesser extent to the impact of volcanic eruptions. The locality has a high level of structural and socio-economic vulnerability to the main identified hazards (floods and landslides). Another major observation is that the community organization for disaster prevention is practically nonexistent. These natural and social conditions indicate that the community of Motozintla has a very high level

WIT Transactions on The Built Environment, Vol 133,
www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/DMAN130251

of risk to natural hazards. This research will support local decision makers in the development of an integrated comprehensive natural hazards mitigation and prevention program.

Keywords: risk assessment, natural hazards, social vulnerability, Chiapas, Mexico.

1 Introduction

An integrated risk assessment includes the analysis of all components of individual constituents of risk such as baseline study, hazard identification and categorization, hazard exposure, and vulnerability. Risk is the probability of a loss, and this loss depends on two elements: hazard, and vulnerability [1]. Vulnerability is a pre-existing condition that affects a society's ability to prepare for and recover from a disruptive event. Thus, risk is the estimated impact that a hazard event would have on people, services, facilities, structures and assets in a determined community.

Disasters arising from hazards of natural origin are only partially determined by the physical event itself. Reducing disaster risk requires the assessment of the level of the hazard and the various types of vulnerabilities (economical, social, environmental, etc.) of the affected society. Hazards are often grouped into three main categories, according to their causes: natural (earthquakes, hurricanes, etc.), technological (explosions, release of toxic material, etc.) and anthropogenic (terrorist activity, crowd-related, etc.) [2]. However, hazards may have interrelated causes and the allocation of a hazard to one class is often difficult.

Vulnerability is a function of the level of sensitivity or susceptibility of a system (community, household, building, infrastructure, nation, etc.) to be damaged. Rashed and Weeks [3] pointed out that vulnerability is independent from any particular magnitude of a specific natural event and depends only on the social context in which it occurs. Thus, vulnerability cannot be assessed in absolute terms. The performance of a determined community should be assessed with reference to specific spatial and temporal scales.

In this work, we assess the risk to natural hazards (earthquakes, landslides, volcanic eruptions and floods) considering the social and economic vulnerability of the community of Motozintla located in Chiapas, southern Mexico (15.37ºN, 92.25ºW) (Fig. 1).

2 Natural hazards in Motozintla

Motozintla is frequently impacted by natural events. Recently, this community faced two disasters due to flooding and landslides. The first of these disasters occurred during hurricane Earl in 1998. The population was impacted by the occurrence of heavy rains up to 350 mm in 48 hours. This phenomenon caused 200 deaths and about 8,000 people were directly affected [4]. The second disaster took place during hurricane Stan in October 2005, affecting about 66% of the municipality and generating damages to the state of Chiapas by approximately 640 million dollars [5]. In addition, other hydro-meteorological events in 1985, 1988, 1997, 2000, and 2006 also caused damage to the agriculture sector as well as the local rural infrastructure.

The estate of Chiapas is one of those with great seismicity in Mexico. At the beginning of last century, three large earthquakes of magnitude greater than 7 occurred in this region (1902, 1903) causing great damage to the local community. Recent earthquakes took place in 1970 (M=7.3), and 1993 (M=7.2) with epicenters in southern Chiapas [6]. Landslides occur regularly in Motozintla. During the 1998 hurricane event, more than 300 people died in the communities of Motozintla, Jaltenango de la Paz, and Valdivia in the state of Chiapas as a consequence of this phenomenon. In 2005, hurricane Stan generated several landslides killing 10 people in Motozintla [5].

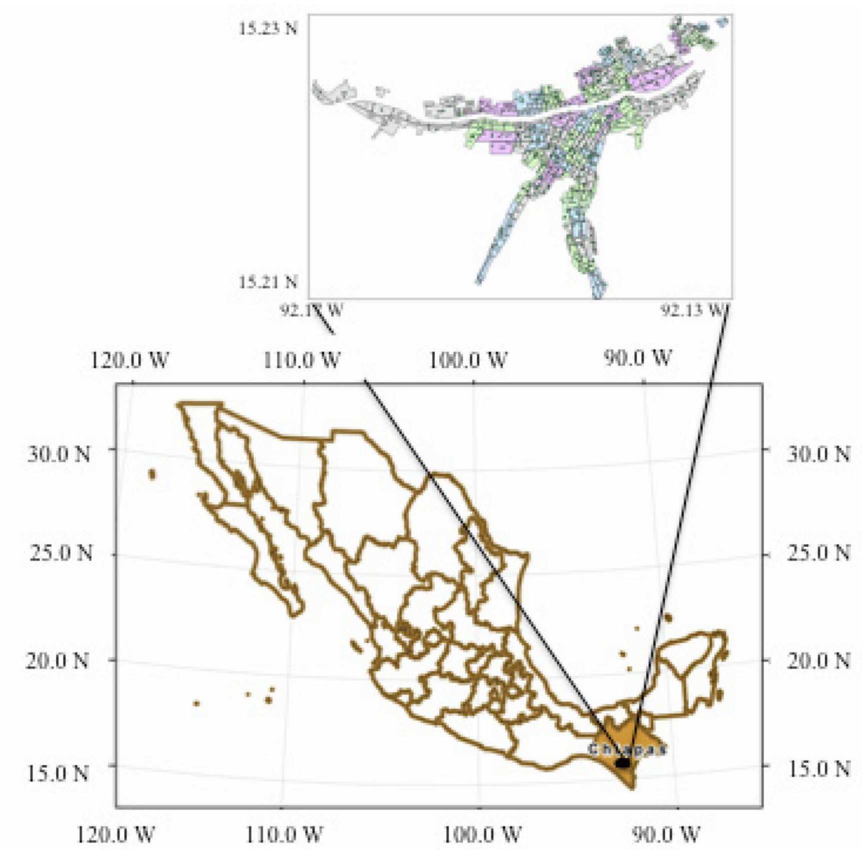

Figure 1: Location of the area of study.

Although the city of Motozintla is potentially exposed to the effect of eruptions of Chichon and Tacana volcanoes, the historic geology of this region indicates that large volcanic eruptions have impacted in the past to pre-hispanic human settlements around Motozintla by only small amounts of ash-fall [7].

Under these conditions, we consider that volcanic hazard is practically non-existent and that no further evaluation is needed in this respect.

3 Methodology

To determine the level of risk of the community of Motozintla to natural hazards, we developed integrated studies and analysis of seismic microzonation, landslide and flood susceptibility using standard methodologies. We estimated the structural and socio-economic vulnerabilities using the variables indicated in Table 1. Five levels of vulnerability were considered: very high, high, moderate, low and very low. To have a 95% confidence level in our survey, we considered a sample size of the community statistically significant. Once the number of families living in Motozintla was determined, we selected the families to be interviewed using the simple random sampling technique with replacement. With these procedures, each family was chosen randomly and entirely by chance with the same probability of being chosen at any stage during the sampling process. Considering that the number of households in Motozintla is 5,000 the minimum survey sample size is 386. However, we surveyed a total of 444 families. The interviewed persons were residents aged 15 years and over that have responsibilities in household maintenance.

Three field works were carried out (October and November 2009; October 2010) to collect data for vulnerability analysis. The different estimated levels of vulnerability were spatially located using a Geographical Information System and the Inverse Distance Weighted (IDW) process.

4 Results

To facilitate our analysis, our results are presented in spatial maps showing the areas of different levels of exposure and/or risk to the analyzed hazards. These maps are intended to be useful tools for emergency managers and policy developers and to increase the overall awareness of decision makers for the implementation of disaster prevention and mitigation plans in Motozintla. It is important to underline that this study presents a first evaluation of the main natural hazards that may affect Motozintla. A full hazard analysis of this community should include a complete and quantitative hazards assessment modeling. However, our results constitute the basis of future mitigation risk projects in this town.

4.1 Earthquake hazards

Using the method of Nakamura [8], we identified three different spatial seismic zones in Motozintla: Zone I, Zone II and Zone III with low, high and very high seismic amplification areas, respectively (Fig. 2). This site conditions indicate that Motozintla can be highly impacted by a large earthquake in the future. The soil response to seismic waves is very high near to the main river bed where most of the houses were identified with high structural vulnerability (see below).

Table 1: Variables and levels of vulnerability.

Vulnerability	Variables	Level of Vulnerability (number of variables that increase vulnerability)
Structural	<u>House with</u>:	
	1. Laminated roof	*Low*: One
	2. Block walls	*Moderate*: Two
	3. One floor	*High*: Three
	4. With a maximum of two rooms	*Very high*: Four
Socio-economic	<u>*Household living conditions:*</u>	
	1. More than five family members living in the house	*Very low*: One *Low*: Two-Three
	2. Family member over 70 or/and under 5 years old	*Moderate*: Four-Five *High*: Six-Seven
	3. Family member with disability	*Very High*: Eight-Nine
	4. Existing illiterate member	
	5. Lack of institutional medical service	
	6. No television and/or radio	
	7. No telephone or mobile phone	
	8. Income less than the minimum government wage	
	9. Lack of capacity for savings	
	<u>*Lack of basic services*</u>	
	1. Water	*Low*: One
	2. Drainage	*Moderate*: Two
	3. Electricity	*High*: Three
	<u>*Lack of response plans*</u>	
	1. Governmental	*Moderate*: One
	2. Neighborhood	*High*: Two
Global	*Any structural and/or socio-economic variable*	*Very low*: One-Four *Low*: Five-Eight *Moderate*: Nine-Twelve *High*: Thirteen-Sixteen *Very high*: Seventeen-Eighteen

Motozintla is affected by earthquakes from two seismic sources: the Polochic-Motagua Fault and the Mexican Seismic Trench [9]. Although with the present knowledge, the return period of these seismic sources cannot be determined, the occurrence of a large earthquake along the Polochic-Motagua fault may cause a major impact to the community. The Motagua-Polochic fault system is particularly active as evidenced by the great 1976 earthquake (Ms=7.5) [10]. This fault also ruptured in previous large earthquakes during last century: 1945 (Ms=5.7); 1980 (Ms=6.4) [11]. Thus, we consider that earthquakes are one of the main hazards to which Motozintla is in high risk. However, our study demonstrates that some variations of an earthquake impact may exist due to the different soil conditions (Fig. 2).

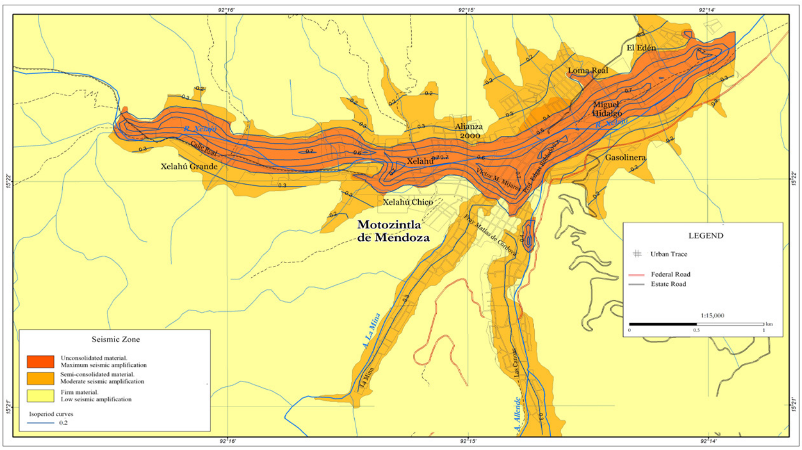

Figure 2: Seismic amplification areas in Motozintla. Zone 1: Low amplification zone; Zone II. High seismic amplification area (four times larger than in Zone I); Zone III. Very high seismic amplification area (five times larger than in Zone I).

4.2 Mass movements hazards

We identified 88 zones that were subject to large mass movement processes during the past 25 ky represented by debris avalanches, rock falls, slides and debris flows (Fig. 3). These 88 areas are a natural potential hazard for the Motozintla basin. Although landslides and debris flows are dangerous phenomena that may directly impact the city of Motozintla, those events related to road construction and opencast activities may also have a high social impact in the area. Future mass movement processes may happen mainly in the NW part of the basin where highly altered rocks of the Chiapas massif and Todos Santos Formation are exposed. The 1998 and 2005 hydro-meteorological events provoked hundreds of landslides in the Motozintla basin from the upper parts of the basin, transporting loose debris downhill loading the rivers and eventually flooding the town of Motozintla and other small communities.

We consider Motozintla with a high risk to mass movement hazards (Fig. 3) because of the following identified reasons: 1) The geo-morphological characteristics of the local topography; 2) The local high exposure to hydro-meteorological events such as hurricanes and heavy precipitations that cause frequent mass movements; and 3) Their large direct social impact.

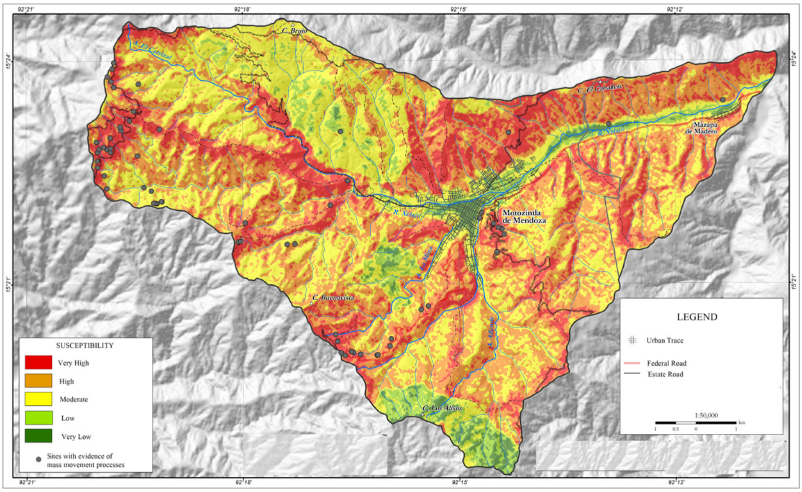

Figure 3: Mass movements susceptibility.

4.3 Flood hazards

In September 1998, the rainfall of the tropical storm “Earl” totaled 175 and 130 mm on September 8 and 9, respectively, duplicating in two days the average monthly precipitation in the region. Most sections of Motozintla city were inundated during these hydro-meteorological events. Communication of Motozintla with the rest of the Chiapas state was interrupted for about a month as well as the supply of potable water, food, electricity, and fuel [12]. Flooding in Motozintla has been the cause of death and of much property damage. The Xelaju River has been the pathway of large floods during the last 6000 years. At least two historic floods have occurred during the last 100 years [12].

Frequency analysis of the historical record of daily rainfall in the Motozintla area suggests that events like that of September, 1998, have a recurrence interval of about 25 years [12]. In this work three possible flood scenarios were considered with period of recurrence of 5, 10 and 20 years for precipitations of 30, 99, and 528 mm/hr, respectively (Fig. 4). The areas identified with greater exposure to flood hazard are those near the Xelaju river. Clearly, property location and conditions is critical during floods.

Based on our discussion above and because of the frequent high rates of average and daily rainfall, we consider flooding from rainfall as the most important hazard in Motozintla.

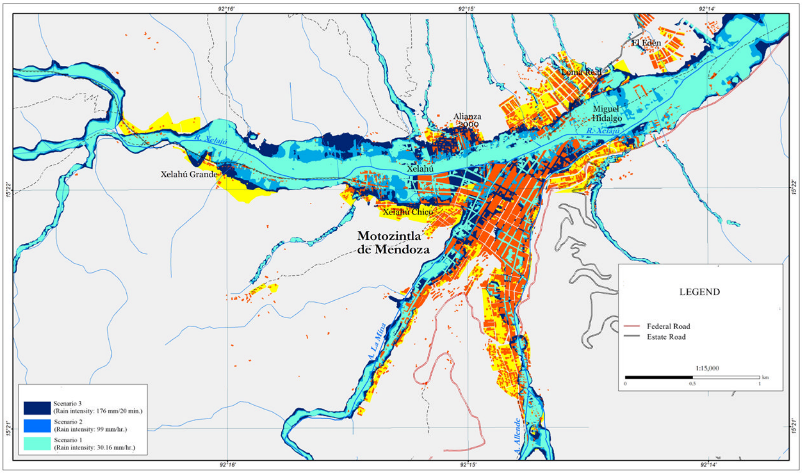

Figure 4: Flood hazard scenarios for the studied region.

4.4 Global vulnerability and flood risk

The measured structural vulnerability varies from medium to low, especially in the central part of Motozintla. Towards the northern side of the town, the structural vulnerability conditions are high because about 60% of the houses are built with low cost materials (adobe) (map not shown here).

The socio-economic vulnerability of the city of Motozintla was measured between moderate and high. Approximately 72% of the local families have a daily expense that varies from 3 to 11 USA dollars. About 36% of the population does not have any type of social security services and from this group, only 7% are entitled to complete services that include hospitalization and surgical procedures. Approximately 66% of the population of Motozintla stated that they de not know any government or municipal emergency plan to respond in case of emergencies. Also, they indicated the lack of a neighborhood action plan to attend disaster situations.

We call “global vulnerability” to the result of combining structural and socio-economic vulnerabilities. Global vulnerability is considered as those elements that make the population susceptible to suffer damages in their physical integrity, belongings and environment due to the occurrence of a disastrous event. A high percentage (60%) of the territory of Motozintla was identified with high global vulnerability while a 30% have moderate vulnerability and 10% of the territory has very high vulnerability (maps not shown here).

Due to the fact that floods are one of the major natural hazards in Motozintla, Fig. 5 displays the risk of the population of Motozintla considering the level of the identified flood hazards and the estimated global vulnerability. Our results indicate that most of the Motozintla community (about 95%) has a high level of global vulnerability to flood hazards. As a consequence, Motozintla is in high risk to floods. This result is mainly associated to the local social conditions and the poor structural housing constructions.

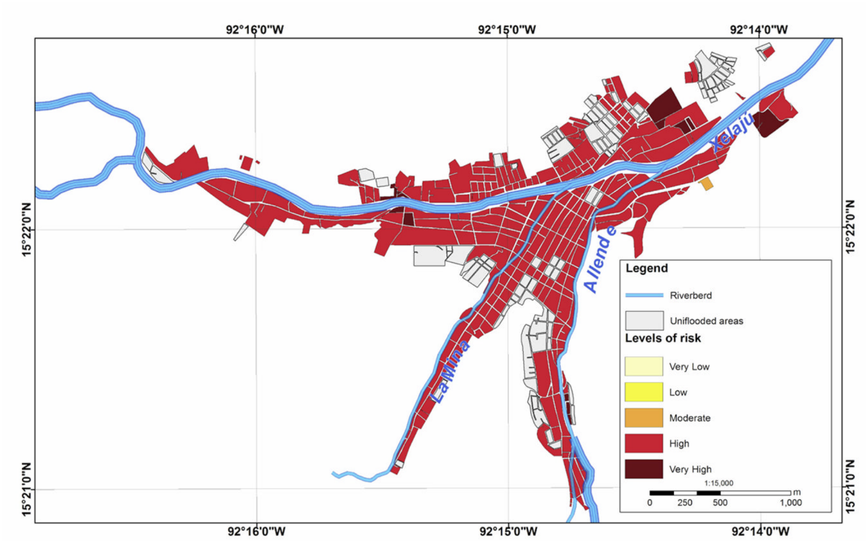

Figure 5: Spatial distribution of global vulnerability and flood hazard.

5 Discussion

Our results indicate that the community of Motozintla is highly exposed to floods, landslides and earthquakes and to a lesser extent to the impact of volcanic eruptions. The local impact of an earthquake will vary due to the different soil conditions. Mass movements are one of the main hazards in the region due to the geo-morphological and topographical characteristics as well as the high rate of hydro-meteorological events. Because of the high rates of annual rainfall, flooding is the most important hazard in Motozintla. The risk to all these natural hazards is increased by the high levels of the global vulnerability measured.

The structural vulnerability is greater towards the north and northeastern zones of Motozintla. In general, the structural vulnerability varies from moderate to low, especially in the central part of Motozintla. We determined that the local structural vulnerability has higher influence in the increase of risk than the lack of public basic services, which although unfavorable for the population, it is not a factor for preserving life or housing. Another interesting result is that the lack of preparation of the community to face a disaster generates a higher risk level than the other analyzed socio-economic conditions.

Global vulnerability indicates that the area with the highest flood risk is located in the margins of the Xelajú River. This area is where the rivers Xelajú, Allende and La Mina meet and the river flow increases (Fig. 5). Another social factor that increases vulnerability is the fact that approximately 66% of the population reported that does not know any existing Civil Protection Plan.

It is important to understand that disasters arising from hazards of natural origin are only partially determined by the physical event itself. Thus, reducing disaster risk requires the assessment of the level of the hazard and the various types of vulnerabilities (economical, social, environmental, etc.) of the affected society. In this work, we determined the levels of the natural hazards that the city of Motozintla is exposed as well as its structural, socio-economic and global vulnerabilities and our integrated analysis represent an important step for the development a of an integrated comprehensive natural hazards mitigation and prevention program.

6 Conclusions

The community of Motozintla is highly exposed to floods, landslides and earthquakes. The locality also has a high level of global vulnerability. These natural and social conditions indicate that the community of Motozintla has a very high level of risk to natural hazards (mainly floods, landslides and earthquakes). This research will support the overall awareness of decision makers in Mexico, and particularly from the state of Chiapas, for the development of an integrated comprehensive natural hazards mitigation and prevention program in this region.

Acknowledgements

The authors are grateful to an anonymous reviewer for his thoughtful review of this work and providing helpful comments. Our appreciation to the local authorities of the government of Motozintla that made this study possible and who kindly provided their expertise, time and data. This research was supported from grants of the Mexican National Council of Science and Technology (CONACYT; Project No. 56624) and the Program to Support Research Projects and Technology Innovation of the National Autonomous University of Mexico (UNAM; PAPIIT Project No. IN116208).

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Bridging research, policy, and practice: development of an integrated research programme

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Abstract

Integrated Research on Disaster Risk (IRDR), a decade-long programme co-sponsored by the International Council for Science (ICSU), the International Social Science Council (ISSC), and the United Nations International Strategy for Disaster Reduction (UNISDR), has been developed to address research gaps, siloed approaches to research, and research to policy voids in a trans-disciplinary, global approach. This is being implemented through four initiatives – Assessment of Integrated Research on Disaster Risk (AIRDR), Disaster Loss Data (DATA), Forensic Investigations of Disasters (FORIN) and Risk Interpretation and Action (RIA) – each developed to address different aspects of disaster risk research.
Keywords: hazard, disaster, risk reduction, science, integration, policy, trans-disciplinary, decision making, case studies, data management.

1 Introduction

There is a story of about six blind men being asked to describe an elephant. They said it has skin like a wall; tail like a rope; ears like fans; tusks like a spear; legs like a tree; and a trunk like a snake. This is what happens when you try to bring together natural and social scientists with policy makers. Each sees the hazard risk through their own lens and vision. Natural scientists talk about wind speeds, ground motion, wave heights, and the like. Social scientists speak about age, gender, ethnicity, and other such variables. Policy makers look at planning, policy and funding. The reality is we need to be talking about risk reduction, lowering people's vulnerability to the hazards, and sustainability. What they fail to see and discuss is the complete picture. Disasters are about people; most

www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/DMAN130261

people do not care if a hazard occurs where there is no development. However, when we speak of reducing a community's or people's risk and vulnerability, we have to look at it in a manner that not only takes into consideration the community's social composition but also the size, location, and intensity of the hazard itself. We can no longer look at hazards and disasters as simply geological, meteorological or hydrological events. They are complex science problems that must be addressed in a comprehensive, multidisciplinary and culturally appropriate manner.

In order to address this need and to answer why, despite advances in the natural and social science of hazards and disasters, do losses continue to increase? And how do we address the lack of sustainability in current disaster practices? The International Council for Science (ICSU), International Social Science Council (ISSC) and United Nations International Strategy for Disaster Reduction (UNISDR) created the Integrated Research on Disaster Risk (IRDR) programme.

2 IRDR programme

The IRDR programme seeks to address the challenges posed by natural and human-induced environmental hazards. It is designed to fully integrate research expertise from the social, natural, engineering, health and technology spheres to address these issues. This, coupled with socio-economic analysis, the role of decision-making, and a policy and practitioner interface, distinguishes the IRDR programme from previous endeavours. The programme is guided by "A Science Plan for Integrated Research on Disaster Risk: Addressing the challenge of natural and human-induced environmental hazards" as developed by ICSU [1]. This document describes the vision for the 10 year initiative.

2.1 Objectives

The IRDR Science Plan [1] outlines three main research objectives:

- Characterization of hazards, vulnerability, and risk
- Understanding decision-making in complex and changing risk contexts
- Reducing risk and curbing losses through knowledge-based actions

In pursuit of these objectives the IRDR programme will create successful projects that lead to a better understanding of hazards, vulnerability and risk, and an enhanced capacity to model and forecast the risk; a better understanding of the decision-making choices that lead to risk and how they may be influenced; and how this knowledge can be better used towards disaster risk reduction. Three cross-cutting themes support these objectives:

- Capacity building, including mapping capacity for disaster reduction and building self-sustaining capacity at various levels for different hazards;
- Development and compilation case studies and demonstration projects;

and

- Assessment, data management, and monitoring of hazards, risks, and disasters.

IRDR focuses on all hazards related to hydro-meteorological and geophysical trigger events, e.g., earthquakes, volcanoes, flooding, storms (hurricanes, typhoons, etc.), heat waves, droughts, fires, tsunamis, coastal erosion, landslides, aspects of climate change (increases in occurrence of extreme events), and space weather, as well as impacts by near-Earth objects including the effects of human activities on creating or enhancing these hazards.

2.2 IRDR working groups

The IRDR programme is governed by a Science Committee comprising 15 experts from around the world and multiple disciplines. They have identified several key areas, organised into four working groups, which will help to address the proposed questions and fulfil the research objectives: Assessment of Integrated Research on Disaster Risk (AIRDR), Disaster Loss Data (DATA), Forensic Investigations of Disasters (FORIN) and Risk Interpretation and Action (RIA). These working groups are keys to the success of the programme, but are not the only method in which the IRDR is moving forward. These groups create a global IRDR community made up of scientists of all disciplines, as well as practitioners and policy-makers in disaster risk reduction and management.

2.2.1 Assessment of Integrated Research on Disaster Risk (AIRDR)

Its purpose is to undertake the first systematic and critical global assessment of research on disaster risk [2]. This will generate new knowledge about risk as well as create a baseline for future research and policy. The goals of AIRDR are to provide a baseline of current state-of-the-science in integrated research on disaster risk to measure the effectiveness of multiple research programmes; identify and support a long-term science agenda for the research community and funding entities; and provide scientific evidentiary basis in support of policy and practice. The outcomes will be the documentation and critical assessment of the literature on disaster risk. This project primarily will utilise documentation and critical assessment of extant literature on disaster risk to understand what kinds of research qualify as ‘integrated” and how it is being constituted and organized. Additionally, the identification of the strengths, weaknesses, gaps and opportunities for new knowledge and investments will be used to further build the assessment. Essentially, what is known well and empirically supported, what is less well known, what gaps exist in our research knowledge base, and what opportunities exist for new research in the co-production of knowledge.

The review will include literature from 1993–2013, primarily from peer-reviewed, published literature; however, widely available grey literature that has already undergone some type of peer or official review (such as government reports) will be included where appropriate. This research will be conducted regionally – Latin America and the Caribbean, Africa, Asia, Middle

East-North Africa, North America, Europe, and Oceania – including authors from all regions based on a nomination process and vetting. This will include young and senior scholars from multiple disciplines and approaches, who possess an openness to other perspectives.

2.2.2 Forensic investigations of disasters (FORIN)

As prescribed in the IRDR Science Plan [1] Forensic Investigations of Disasters (FORIN) is a keystone of the IRDR programme. FORIN case studies are to be carried out in the form of forensic investigations, where the term 'forensic' is used to suggest the qualities of serious, all-encompassing, arms-length, careful and detailed analysis of past disaster events [3]. These studies will establish a basis for analysis based on actual evidence and applied scientific methodologies/principles as well as delve more deeply into the causes of disasters in an integrated, comprehensive, transparent and investigative nature. The main objectives of FORIN address areas related to policy, management, scientific research, development, and disaster risk reduction. These are based on the common hypothesis that past and current programmes and activities are not being guided or supported by sufficiently strong and grounded knowledge of hazards and disasters, particularly a true understanding of their root causes.

FORIN will not only be interested in disaster 'failures', or cases where mistakes were made; it is also conducting forensic investigations of success stories to help accumulate evidence of best practices. The risk reduction community needs to begin to systematically document what works in reducing risk, not just the failures. These studies are not limited to any given hazard, location or social construct. The more types of events studied in varying environments will only help the community to better understand the risk, vulnerability and possible solutions. This will also help to identify any research gaps and factors that need further study. Several of these FORIN studies have been conduct in Japan with others currently underway in Algeria, China, and New Zealand.

2.2.3 Disaster loss data (DATA)

One of IRDR's fundamental goals is to both generate new information and data and to leave a legacy of coordinated and integrated global data and information sets across hazards and disciplines, with an unprecedented degree of access. One of the main contributions of the programme will be to serve as a framework for the development of a range of modern information systems devoted to disaster risk reduction.

The community that address disaster loss date is growing rapidly and the disaster data landscape itself is changing rapidly. Multiple organizations collect and store data related to the monetary, environmental and human losses related to a disaster. However, the accuracy, consistency and thoroughness of this data vary greatly. This results in inconsistent overlaps, gaps in data and biases that impact the quality of the policies developed and research conducted in relation to disasters.

The IRDR-DATA project is designed to bring together stakeholders from all levels of government, private sector, research and academia as well as multiple disciplines to reconcile these issues and develop synergies on the collaboration in the production and utilization of the data. The key objectives are to bring together loss data stakeholders and develop synergies and capitalize on them; identify the quality of existing data and what data are needed to improve disaster risk management; develop recognized standards or protocols to reduce uncertainty in the data; define “losses” and create transparent methodologies for assessing them; advocate an increased downscaling of loss data to sub-national geographical levels for policy makers; and educate users regarding data interpretation and data biases.

This will allow for the establishment of an overall framework with appropriate nodes and networks for databases and, ultimately, conducting sensitivity testing among databases to ensure comparability. Making data more usable and reliable for all to utilize in an effort to reduce risk and vulnerability to hazards is an essential outcome of IRDR.

2.2.4 Risk Interpretation and Action (RIA)

The Risk Interpretation and Action (RIA) group focuses on the question of how people - both decision-makers and ordinary citizens - make decisions, individually and collectively, in the face of risk. In order to reduce disaster risk, there needs to be integrated risk analysis, including consideration of relevant human behaviour, its motivations, constraints and consequences, and decision-making processes in the face of risk. It is the goal to better understand decision-making in complex and changing risk contexts, risk governance and institutional development. Understanding how people interpret risks and choose actions based on their interpretations is vital to any strategy for disaster reduction.

The key objective of RIA is to build a community of practice that addresses these issues. This is in response to the demands of the policy and science communities. The RIA community will be interdisciplinary, international and integrative. It builds on an existing core network of internationally recognised scientists and practitioners active across the disciplines identified above, but the community will be open to all disciplinary traditions, natural, social, behavioural and from the humanities with interests in risk communication. The goal is to further develop this core group, expand into a self-organised community and promote the co-ordinated development of new approaches, methods and experiences in communicating risk and development between natural, engineering, and social science practitioners and those at risk.

Key outputs of RIA include the origination and recording of data collection tools for resilience, which can feed into the IRDR DATA project, and also of templates for the analysis of risk communication and perception in the production of disaster risk and loss, which will contribute to the framing of FORIN studies.

It is import to remember that not only does IRDR demand integration in research but also practices integration across its projects and activities. The four IRDR working groups are individually integrated across disciplines but are also integrated across the working groups. FORIN, RIA and AIRDR will all feed into DATA and practice the guidelines given by the DATA working group. RIA and FORIN will often overlap to help create a more complete picture of the problem and identify possible solutions. These key activities will help to fulfil the vision of the IRDR co-sponsors; but, more importantly, help the communities, researchers and policy-makers that are living with and addressing hazards.

3 Network building

In addition to new research IRDR is working to build on and complement existing research. IRDR is working to establish networks of organizations, research and others to build a stronger community to address the issues around disaster risk. This is being implemented through partnerships with various hazard related organizations. One example is the Inter-Asia Partnership (UNISDR). IRDR is working to establish a network of researchers, academicians, policy-makers, and civil society groups to implement and develop more science-based hazard and disaster risk reduction programmes and activities. It is also used to avoid duplication of work to ensure maximum benefit from programme funds. This supports the Yogyakarta Declaration on Disaster Risk Reduction in Asia and the Pacific 2012 and, more specifically, Annex 10 [4].

3.1 National and regional IRDR committees

IRDR National and Regional Committees are designed to encourage the development of crucial links between national and regional disaster risk reduction programmes and activities within the IRDR international framework. These committees will help foster the much-needed interdisciplinary approach to disaster risk reduction within national and regional scientific and policy-making communities, and serve as important national or regional focal points between disciplinary scientific associations. National Committees are designed to support national researcher to look at national issues through the integrated model.

3.2 International Centres of Excellence (ICoE)

IRDR has also begun to establish IRDR International Centres of Excellence (ICoE). Each ICoE research programme embodies an integrated approach to disaster risk reduction that directly contributes to the IRDR Science Plan and its objectives. ICoE and IRDR projects will collaborate to provide global contributions towards achieving the IRDR legacy – an enhanced global capacity to address hazards and make informed decisions to reduce their impacts. The ICoEs will, in particular, enable regional scientific activities through geographically-focused contributions based on more localized inputs and by being visible centres of research excellence to motivate participation in the IRDR programme, especially among young researchers. Each ICoE will have its own sources of funding from host agencies and organizations.

The ICoEs will have both local and international components. The local component will consist of a strong cadre of disaster risk reduction academics and researchers from universities, academies of science, institutes, and centres within the host country (or countries). The international component will consist of short- and longer-term visiting scientists from developed and developing countries, in addition to supporting workshops, colloquia, and scientific meetings that, for example, bring together scientists to work on case studies or forensic investigations. These could then be extended to other countries in longer-term cooperative studies.

4 Overall legacy

The Hyogo Framework for Action (HFA) [5] states: "The starting point for reducing disaster risk and for promoting a culture of disaster resilience lies in the knowledge of the hazards and the physical, social, economic and environmental vulnerabilities to disasters that most societies face, and of the ways in which hazards and vulnerabilities are changing in the short and long term,…" Many examples exist that demonstrate the importance of science and technology towards disaster risk reduction. The resulting legacy of the IRDR programme will be the enhanced capacity around the world to address hazards and make informed decisions on actions to reduce their impacts. IRDR has a commitment towards the development of science and development of broadly-based capacity. IRDR will work with partners to have in place quality-controlled, comprehensive data and information, so another legacy will be a firm basis for the determination of trends and demonstrations of success, for which we all strive.

IRDR's main legacy will be an enhanced capacity around the world to address hazards and make informed decisions on actions to reduce their impacts. This will include a shift in focus from response–recovery towards prevention–mitigation strategies, and the building of resilience and reduction of risk through learning and sharing from past experiences and avoidance of past mistakes. By way of this enhanced capacity and a shift in strategic approaches there will be a reduction in loss of life, fewer people adversely impacted, and wiser investments and choices made by civil society when comparable events occur in the future.

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Section 7
Learning from disasters

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Public opinion guidance and science and technology dissemination for public health emergencies

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Abstract

Public opinion guidance plays a positive role in public health emergencies response and handling. This paper firstly discusses the guidance of science and technology dissemination on public opinion during health emergencies, and then analyzes the media agenda setting, public reaction change and government policies for the 2009 pandemic influenza A H1N1 with agenda-setting theory and case study method. On the basis of that, this paper makes further discussion on science and technology dissemination strategies for public health emergencies and reaches a conclusion that the content of dissemination should be directly related to security and health; should be information about incident development and government response which helps to compose an overall information stream during crisis communication; and should focus on problems arising after incident outbreak and subjects the public is interested in or concerned with; and also science and technology dissemination should be done at different developing stages of the incident with corresponding focuses.
Keywords: public health emergencies, public opinion guidance, media reports, science and technology dissemination strategies for emergencies.

1 Introduction

Public opinion guidance plays a positive role in public emergencies response and handling. Traditional "judge as it stands" method often cause inefficiency because of the complexity and urgency of the incident. In recent years, scientific reports made by the media about public emergencies have been highly praised by authorities and scholars for their uniquely active role on public opinion guidance during emergencies dealing. However, it is still a tough question to conduct

WIT Transactions on The Built Environment, Vol 133,
www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/DMAN130271

sci-tech information dissemination systematically and orderly for public opinion guidance when public health emergencies happen. By far, most of the research in this field focuses on conception-introduction, lacking systematic theory.

This paper firstly discusses the guidance of science and technology dissemination on public opinion during health emergencies, and then analyzes media agenda setting, public agenda setting and policy agenda setting for 2009 pandemic influenza A H1N1 with agenda-setting theory and case study method. On the basis of that, this paper makes further discussion on science and technology dissemination strategies for public health emergencies.

2 Public opinion guidance and science and technology dissemination for public health emergencies

Public health emergencies refer to the outbreak of public incidents that have happened or may happen. They can be infectious diseases, uncertain group epidemics, serious food poisoning or occupational poisoning, and other public emergencies which may do harm to public health. Most public health emergencies are of the nature of crisis. The abruptness, uncertainty and perniciousness of such emergencies usually make people unprepared and bring forth different public opinions that are of 'fission' diffusion, abnormal development and rapid spreading.

Science acts as the terminator of rumors and sci-tech information dissemination can effectively surpass the abnormal fission diffusion of public opinions. Science and technology dissemination can assimilate the public and transform their standpoints and views on public emergencies scientifically, thus guiding public opinions actively.

3 Case analysis of public opinion guidance of science and technology dissemination through the media during the infection of influenza A H1N1

3.1 Media Scientific reports on influenza A H1N1

This paper chooses People's Daily and Sina.com as representatives of the media who disseminated science and technology related to influenza A H1N1 effectively.

3.1.1 Scientific reports on influenza A H1N1 in people's daily

According to our study, among the reports about influenza A H1N1 made by People's Daily from May 1^{st} 2009 to December 31^{st} 2009, 64 out of 110 take influenza A H1N1 as the sole topic, taking up 58.18% of the whole [1]

The 64 reports focusing on influenza A H1N1 can be classified into five parts, i.e. infection situation introduction, prevention and handling measures, typical people, international situation and others. Among these 64 reports, 8 on infection situation introduction and 29 on prevention and handling measures are the large

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parts, taking up 45% of the whole. The 11 special reports about national leaders and influenza A victims playing an important role in media science and technology dissemination. The rest are 11 reports about international situation and 5 others [1].

Besides, 53 out of the 64 reports are science and technology news, taking up 82.8% of the whole. At the incubation period of Influenza A, reports stressed authorized information, including overseas epidemic situation and response mechanism. When the epidemic was getting close to the evolution period, science reports focused on two aspects. One is about prevention measures taken by different countries, districts, organizations and departments, like the reports in People Daily titled Move Forth Scientific Cure and Prevention to Control Influenza Orderly and Effectively on May 30th, Enhance Prevention and Control Measures and Continue Related Efforts Orderly on June 13th and Orderly and Forcefully Move Forward Influenza A Prevention and Control in Autumn and Winter on September 11th. The other is about development of detection reagents and influenza vaccines done by scientific research institutes home and abroad, like reports in People's Daily titled American Companies Produce First Batch of Influenza A Vaccines on June 25th and Traditional Chinese Medicine Community Develop New Medicine for Influenza A on December 18th.

3.1.2 Scientific reports on influenza A H1N1 in sina.com

From April 24th, Sinn.com began to provide real-time report on the influenza with a special column of Influenza A H1N1. Content for the column are set into more than ten sections, such as the latest epidemic situation broadcast, epidemic situation in China, global epidemic situation, epidemic situation guidance, response measures, experts interpretation, media reviews and related video coverage. From April 27th to May 16th , Sina.com offered 136 different reviews made by more than 40 internal and external media units like People's Daily, the Beijing News, Nanfang Daily, Southern Metropolis Daily and Xinhua News Agency. Generally speaking, these reviews are mainly about influenza knowledge introduction, outbreak causes, countermeasures, experience summary and influenza impact. Agenda setting emphasizes how to fight against the influenza and appealing the joint efforts from all the society, with reviews on the two topics taking up 35.3% of the whole. Meanwhile, there are 26 reviews on the warning about weak links in epidemic prevention and the clues of improper response, taking up 19.1% of the whole. With the spreading of influenza, the hey points of media reviews moved from related knowledge and outbreak reasons to how to react and joint efforts appeal and then to continuous fighting so as to meet information need and psychological expect of the public [2].

3.2 Cognition and behavior change of the public to influenza A H1N1

In September 2009, Suzhou Municipal Center for Disease Control and Prevention conducted a questionnaire survey on people's understanding of influenza A H1N1 and related information sources. The result suggests that citizen understanding rate on influenza A H1N1 was 85.8% and most respondents had gained basic knowledge about the prevention and cure of influenza A H1N1, which demonstrates public confidence in fighting against the disease [3].

From November 2009 to March 2010, Chinese Center for Disease Control and Prevention made six telephone surveys on the KAP (knowledge, attitude and practice) at different development stages of the influenza A (H1N1) and found there was drastic change in public related knowledge. In fact, with the penetration of propaganda and education, understanding of influenza A H1N1 among the public increased gradually. For example, people got to know "air on the condition of ventilation", "hand-shake and hug during the epidemic period", "free inoculation policy against influenza A H1N1" and "priority inoculation policy against influenza A H1N1". It was shown that the basic sanitary knowledge about coughing, sneezing and face-to-face talking are highly recognized during the surveys. It was also found that sanitary protective behaviors like "covering mouths and noses when coughing or sneezing", "wash hands when arriving home" were generally on the rise. The behavior of "washing hands with soaps and sanitizer" was always stressed, with 97.9% of the respondents recognized. People who "have been inoculated with ordinary influenza vaccine" and "are inoculated with influenza A H1N1 vaccine" were generally on the rise. The rates of being inoculated with influenza A H1N1 during the first and fourth surveys respectively dropped a little, but began to rise during the last two [4].

According to the survey results, the media propaganda and education in China has played an important role in enriching related knowledge among the public.

3.3 Government policies against influenza A H1N1

Approved by the State Council, Ministry of Health of the PRC announced on April 30th that influenza A H1N1 would be included into category B infectious disease stipulated by the Law of the People's Republic of China on the Prevention and Treatment of Infectious Diseases and should be prevented and controlled as category A infectious disease.

In order to prevent the import and spreading of the influenza, influenza A H1N1 is also included into the quarantinable disease stipulated by the Law of the Frontier Health and Quarantine Law of the People's Republic of China. Ministry of Health also declared to release the prevention and control progress of influenza A H1N1 on its official website regularly. For example, it informed the public on July 11th 2009 of the fact that there are 79 new confirmed cases of influenza A H1N1 from 6 pm on July 9th to 6 pm on July 11th in China, among which 64 cases are overseas imported and 15 are infectious within the country. The timely release of related data effectively cleared panic among the public.

On May 29th 2009, Chinese Center for Disease Prevention and Control published the Technical Guide on the Epidemiological Investigation and Epidemic Situation Handling for Influenza A H1N1. The document applies to the imported cases of influenza A H1N1, infection among humans and even the disease outbreak at community level. It offered scientific guidance to the epidemic situation investigation of influenza A H1N1 for disease prevention and control institutions at different levels.

Meanwhile, Chinese Center for Disease Prevention and Control opened a health column of Influenza A H1N1 on its official website. The column provides information on epidemic situation variation diagram, epidemic situation, working trends, consulting phone numbers, countermeasures, technical guide, risk communication, science documents and video materials.

What's more, Gov.cn established a special website for preventing human-infected influenza A H1N1. The public can search different media materials like pictures about influenza A H1N1 prevention, general epidemic situation of different countries (the confirmed cases in a country or a district), epidemic situation express, symptoms of the disease, latest related news, newest videos and thematic reviews.

4 Science and technology dissemination Strategies for public opinion guidance during public health emergencies

From the above case analysis, it can be concluded that science and technology dissemination during public emergencies should be conducted in the following ways so as to guide public opinion effectively.

4.1 Disseminating sci-tech information on public health emergencies development and government response to compose an overall information stream on crisis communication

A complete government news release chain should include three parts, i.e. dynamic news about the incident, government response (expressing attitude is also a response) and scientific knowledge information. The first refers to current situation and future development trend of an emergency. The second usually includes the standpoints and attitudes of the government towards the emergency as well as specific measures they plan to take. And the last is the explanation of causes and development of the incident, scientific analysis of the developing trend, and scientific decisions and action of the government. During information release of a public health emergency, it is far from enough to simply emphasize the disclosure of government administrative information. Scientific information dissemination should also be stressed to dispel doubts, meet public demand for scientific knowledge and guide public opinions. Any single information cannot compose an overall information stream, only when the three integrate with one another.

4.2 Disseminating information about problems arising after public health incident and the subjects the public tend to be interested in or concerned with

(1) Sci-tech information dissemination should focus on issues that people are interested in and concerned with. Generally, there are always some rumors after a public health incident because of dissemination deviation or knowledge insufficiency. Since the public desire to testify the rumor with the truth, sci-tech

information dissemination at this time would play an important role in supervising public opinions and stabilizing society.

(2) Content of sci-tech information dissemination contains main problems, causes and influence of the emergencies. That is to say, such dissemination should first pose main problems that can arouse people's interest directly, analyze them to dispel the doubts and finally provide the views and research results of some expert or all the scientists to enhance the effect of the effort.

4.3 Sci-tech information dissemination should be done at different developing stages of a public health incident with corresponding focuses

According to the four-stage model presented by Steven Fink, crisis communication can be divided into four stages: potential, out-bursting, spreading and being solved. Disseminators should not only inform the media and the public of present state of the indent and so-far measures taken by the government, but also try to gain support from the public by helping them understand the coming danger correctly, providing for them with more pertinent background information and analyzing the situation with scientific knowledge, facts and data.

At the first stage, disseminators should make a series of preparation, such as making preplans, understanding the potential risks, collecting scientific materials about the coming crisis, contacting with the media and related government departments frequently and improving scientific quality.

The second stage of incident outbreak is always coupled with confusing and complex situation. Due to the difficulty to know the exact situation and true causes, the public need eagerly information about government attitudes and scientific countermeasures. At this stage, disseminators should provide for the public with authorized and verified information about the incident development, government and standpoints and attitudes and also sufficient scientific knowledge to determine the incident nature initially, clear rumors and react scientifically.

At the stage of spreading, scientific analysis of the incident and its development trend is the great concern for the public. So disseminators should help the public understand the danger they face accurately, accept feedbacks, define the incident nature formally and interpret government decisions.

At the last stage of solving the crisis, people are concerned with how to prevent new crisis, how to evaluate an emergency in a scientific way and how the responsibility is defined. Disseminators should digest feedbacks and raise people's sense of protection to avoid new crisis.

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Study of the liquefaction phenomenon due to an earthquake: case study of Urayasu city

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Abstract

Soil liquefaction describes a phenomenon whereby a saturated soil substantially loses strength and stiffness in response to an applied stress, usually earthquake shaking or another sudden change in stress condition, causing it to behave like a liquid. The liquefaction phenomenon due to the Great East Japan Earthquake 2011 occurred to the reclaimed land around the Tokyo Bay area. Urayasu city was caused extensive damage by liquefaction due to the earthquake, and recovery from the disaster is still going on.

This paper describes some remarkable damage against the structures due to the liquefaction by the earthquake, and indicates the possibility of liquefaction by current determination methods using published soil profile and N value of SPT (Standard Penetration Test). The authors also carried out a series of laboratory liquefaction tests (the cyclic undrained triaxial test) in order to make clear the characteristics of liquefaction, using Urayasu sand taken from the liquefied site in Urayasu city.
Keywords: earthquake, liquefaction, Urayasu city, damage types, liquefaction strength.

1 Overview of the great East Japan earthquake

The Great East Japan Earthquake (Mw=9.0) occurred on Mar 11, 2011 with an epicentre about 130 km away from the coast of Tohoku. Figure 1 indicates the seismic intensity observed in various parts of Japan, and it shows that the earthquake was observed in a wide area of Japan. Extensive damage was caused by the huge tsunami that exceeded 10m by the earthquake that occurred in the

WIT Transactions on The Built Environment, Vol 133,
www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/DMAN130281

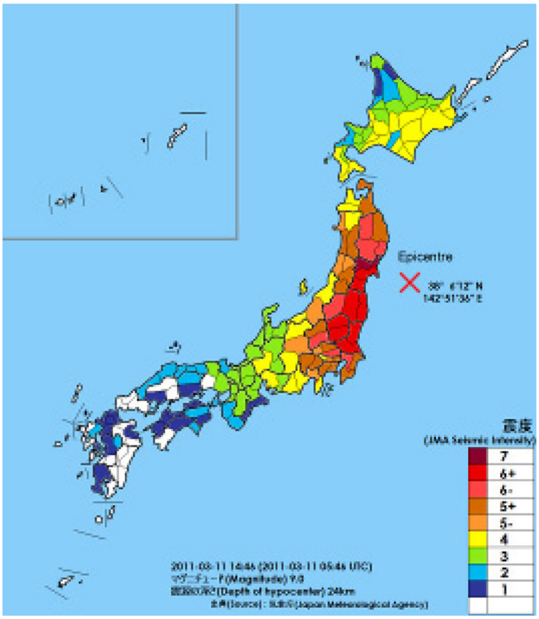

Figure 1: Epicentre and seismic intensity [1].

north-eastern coastal areas near the epicentre. The number of dead or missing to date (March 2013) has been more than 18,500 people.

Conversely, in the region of the coast of Tokyo Bay in the Kanto area, more than 400 km away from the epicentre, which has rarely seen damage caused by a tsunami, liquefaction of the ground, settlement and tilting of buildings/ground has frequently occurred.

From Figures 2 and 3, it can be seen that the liquefaction damage in the Kanto area is not only around the Tokyo Bay coast, but also the coastal areas with reclaimed soft ground in Tone River, Arakawa River and Kasumigaura which used to be a river, pond or sea. The highest amount of liquefaction damage occurred in Urayasu city where about 8,700 houses were damaged.

Figure 4(a) shows the acceleration-time history of the Great East Japan Earthquake observed in Urayasu city near the city office. The seismic wave was about 150 gal at maximum acceleration and not so large, but the duration of seismic waves was more than 70 seconds and long compared to previous earthquakes. Urayasu city is located facing Tokyo Bay, and about 75% of the land of the city was reclaimed after the 1960s, and the reclaimed area was devastated largely by the earthquake. For the comparison, Figure 4(b) shows an acceleration-time history observed at the time of the Great Hanshin-Awaji earthquake in Kobe city in 1995. The seismic wave's characteristic of the Great Hanshin-Awaji earthquake is that acceleration exceeding 400gal for about 20 seconds, and it is relatively short. Liquefaction at the Great Hanshin-Awaji earthquake was limited in the area with more than seismic intensity 6, but in Urayasu city during the Great East Japan earthquake there was a seismic

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intensity of 5+. Therefore, long seismic wave duration is considered to be contributing to the occurrence of liquefaction. In addition, the three aftershocks (Mw=7.0, 7.4, 7.2) after the main earthquake occurred without much time difference (approximately 20 to 35 minutes) and it might also have contributed to the liquefaction.

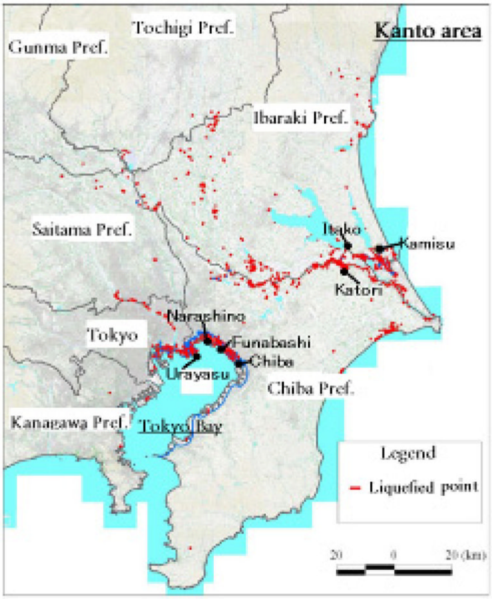

Figure 2: Liquefied point in the Kanto area [2].

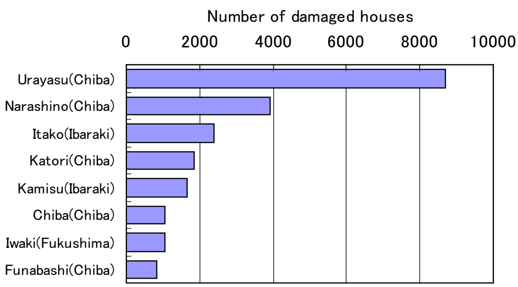

Figure 3: Number of damaged houses caused by liquefaction [2].

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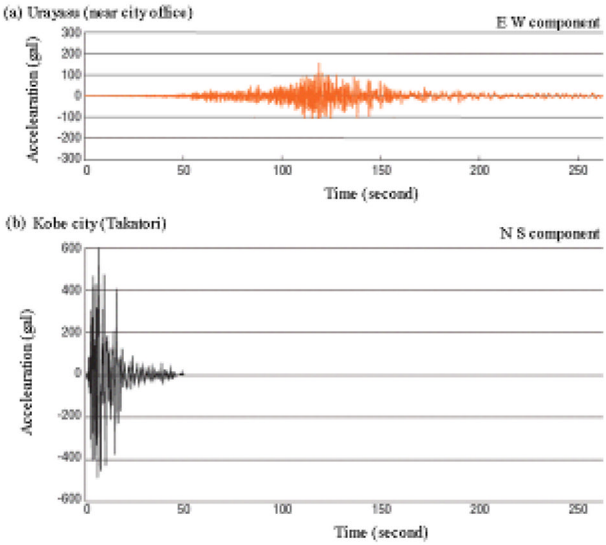

Figure 4: Observed acceleration time histories [3]: (a) The Great East Japan earthquake (2011); (b) The Great Hanshin-Awaji earthquake (1995).

2 Characteristics of liquefaction damage in Urayasu city

Liquefaction damage that occurred in Urayasu city occurred throughout nearly all the Nakamachi area reclaimed after 1964 and all the Shinmachi area reclaimed after 1972. A summary of the most notable damage is as follows.

(1) Damage to small residences
The ground which lost its bearing capacity by liquefaction could not support structures, and caused settlement and tilting of small residences based on spread foundation. Also, by boiling effect, sand eruptions were found in many places (Figures 5(a) and (b)).

(a) (b)

Figure 5: (a) Tilting of a small residence. (b) Tilting of a police station.

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(2) Damage to medium and large-scale buildings
Collective housing and large-scale buildings adopted a pile foundation around this area, so the damage was, relatively, not seen. However, at the contact point of the foundations and ground, there was frequent damage relating to lifelines such as drain pipes shutting off (Figure 6(a) and (b))/

(a)

(b)

Figure 6: (a) Contact point of foundation and ground. (b) Contact point of footing and ground.

(3) Damage to other infrastructures (road and lifeline)
In the road, a sand boiling effect was seen all over from cracks in the pavement. In addition, a manhole, once lying underground was lifted by buoyancy and caused damage (Figure 7(a) and (b)).

(a)

(b)

Figure 7: (a) Boiled sand on the road. (b) Lifted manhole.

3 Overview of the terrain in Urayasu city (from past to current)

Urayasu city, in the Chiba prefecture, faces Tokyo Bay; Edogawa River flows on the west side of the city; it also connects with the Edogawa Ward of Tokyo. It is also on the Edogawa River Delta, and was a former fishing village (see Figure 8).

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Figure 8: Former fishing village Urayasu in 1960s [4].

After 1964, for the purpose of creating housing, an amusement park and a distribution base for the steel industry, landfill started. At the end of 1980, with completion of the landfill, the city area had expanded 4 times more than before.

Figures 9–12 [4] are aerial photographs that show the status of the landfill in Urayasu from 1948 to the current time. As a result of reclamation, these photographs show how the city area has expanded to four times its original size.

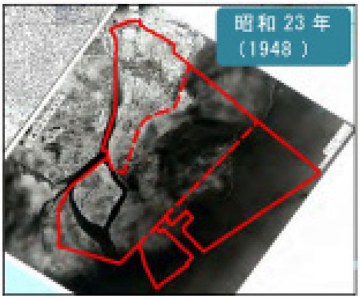

Figure 9: Urayasu in 1948.

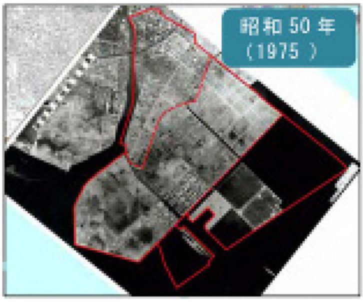

Figure 10: Urayasu in 1975.

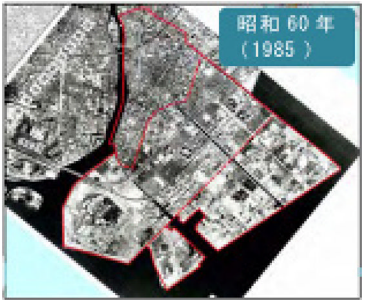

Figure 11: Urayasu in 1985.

Figure 12: Urayasu in 2003.

The land in Urayasu city can be divided into 3 parts; Motomachi, Nakamachi and Shinmachi which means, respectively, Old Town, Middle Town and New Town in Japanese. Motomachi is inside the blue line in Figure 13, and is the

Edogawa River Delta made by river deposit; it is an old town which previously flourished as a fishing village. Nakamachi is inside the yellow line in Figure 13, and reclamation started from 1964. Newest Shinmachi is inside the red line, and its reclamation took place between 1972 and 1980; this is the newest land.

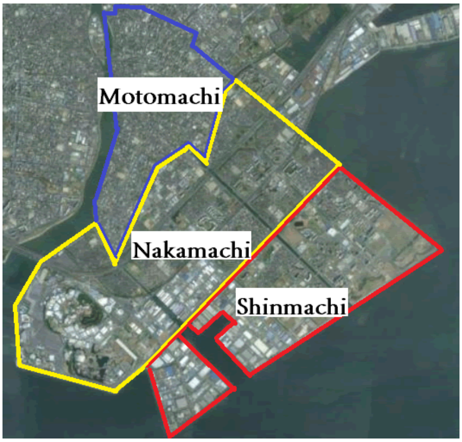

Figure 13: Three part sof Urayasu city (blue, yellow and red).

4 Liquefaction determination method

There are several liquefaction determination methods in Japan; in this paper the FL method and PL method are considered.

(1) FL method
Foundation design in Japan, the liquefaction was evaluated using a factor of liquefaction resistance (FL value), shown in Eq. (1) by the Japan Road Association [5]. The FL method calculates the FL value by each 1m, and evaluates the possibility of liquefaction quantitatively. If the FL values obtained by each depth are lower than 1.0, its land is evaluated as due to become liquefaction

$$FL = R / L \tag{1}$$

where

FL: Liquefaction resistance factor
R: Dynamic shear ratio, $R = c_w R_L$
L: Seismic shear stress ratio
R_L: Cyclic triaxial shear stress ratio (20 cycles)
c_W: Modification factor for earthquake ground motion

(2) PL method
As an index for the assessment of liquefaction potential, the liquefaction index (PL value) is adopted in earthquake damage assessment of many local governments in Japan by making a hazard map for liquefaction, etc. The PL

method [6] is an evaluation method using the previous FL method with a depth of possible liquefaction and non-liquefaction layers' thickness, etc. The PL value can be obtained by following Eq. (2). Also, by using the PL value, determination of liquefaction possibility is shown in Table 1.

$$PL = \int_0^{20} F * w(z) dz \tag{2}$$

where $F = 1 - FL$ for $FL \leq 1.0$, and $F = 0$ for $FL > 1.0$ $w(z)$: a weight function to the depth, given by $w(z) = 10 - 0.5 * z$.

Table 1: PL value and possibility of liquefaction.

PL value	Liquefaction Possibility
0	quite low
0-5	low
5-15	high
15-	very high

5 Determination of soil liquefaction in Urayasu city

Figures 14–16 show the calculated FL value of three sites (Shinmachi, Nakamachi and Motomachi) in Urayasu city by using published boring data [7]. These figures show the data at Hinode in the Shinmachi area, at Mihama in the Nakamachi area and at Kitasakae in the Motomachi area, respectively. The PL values of these sites are shown in Table 2 by Eq. (2). From these figures and table, the calculated FL values are lower than 1.0 at any depth in the Hinode and Mihama areas which are the new reclamation lands of Shinmachi and Nakamachi. At the former fishing village of Kitasakae in Motomachi, some FL values are higher than 1.0, or the ground consists of silt deposit so that analysis of the liquefaction is not necessary. While the possibilities of liquefaction at Hinode and Mihama are "very high" because the PL values are higher than 15, at Kitasakae in Motomachi, the PL value is lower than 15, and the liquefaction possibility is "high" by Table 2.

Table 2: Calculated PL value.

Site	PL value
Hinode (Shinmachi)	31.3
Mihama (Nakamachi)	31.3
Kitaei (Motomachi)	12.4

Figure 17 shows the liquefaction hazard map published by Chiba Prefecture [6]. Accuracy of this hazard map is not very high, but it indicates that the possibility of liquefaction is high in almost all areas of Urayasu city. As a subject

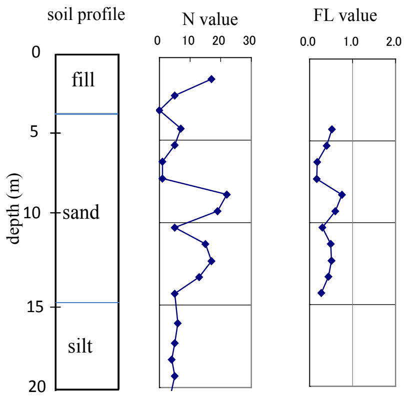

Figure 14: Calculated FL value – Hinode (Shinmachi).

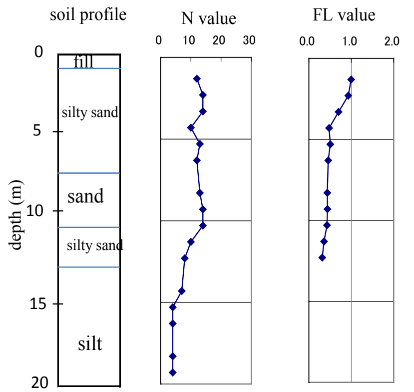

Figure 15: Calculated FL value – Mihama (Nakamachi).

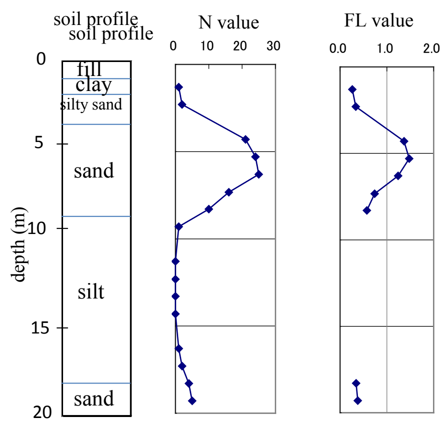

Figure 16: Calculated FL value – Kitasakae (Motomachi).

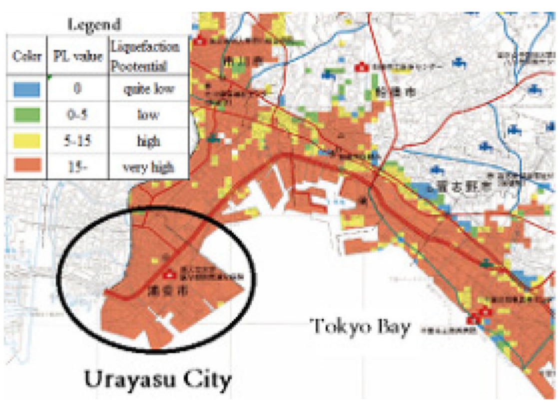

Figure 17: Liquefaction hazard map around the Tokyo Bay area [6].

for future discussion in liquefaction determination, it is considered to be necessary to make a highly accurate hazard map. Hazard map creation is desired by collecting existing boring data and by conducting a lot of new borings with high accuracy.

6 Liquefaction strength of Urayasu city's sand

By using sand samples taken from Urayasu city where the liquefaction was high in the Great East Japan earthquake, a series of cyclic undrained triaxial tests were carried out. Also, the test was taken for Toyoura standard sand for comparison purposes.

Soil profiles and test conditions are shown in Tables 3 and 4 and Figure 18, respectively. The difference between Urayasu sand and Toyoura sand is that Urayasu sand has finer grains, and the value of fine grain content is higher than Toyoura sand. Therefore, Urayasu sand's maximum density and minimum density are smaller compared to Toyoura sand.

Table 3: Soil properties of used sand.

soil properties			Urayasu	Toyoura
density of soil particle	ρ_s	g/cm^3	2.695	2.641
maximum density	ρ_{dmax}	g/cm^3	1.337	1.672
minimum density	ρ_{dmin}	g/cm^3	0.978	1.374
mean particle size	D_{50}	mm	0.148	0.161
fine fraction content	F_C	%	15.5	0.2

Table 4: Test conditions.

Sample	Dr (%)	σ_c' (kPa)	f (Hz)	R $\sigma_d/(2\sigma_c')$
Toyoua	40	100	0.2	0.12、0.14、0.16
	60			0.17、0.19、0.21
	80			0.21、0.24、0.29
Urayasu	60			0.17、0.19、0.21
	80			0.21、0.24、0.29

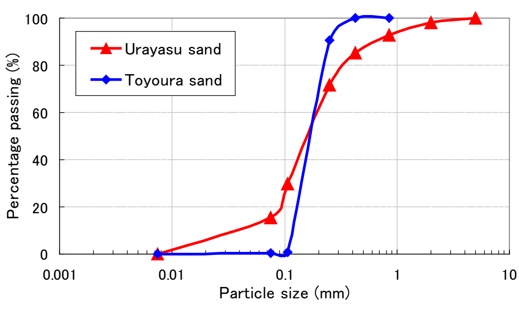

Figure 18: Particle size of sand.

Figures 19 and 20 show the relationships between cyclic shear stress ration and repeated numbers for both sands. In Toyoura sand, the difference of liquefaction intensity in each relative density is seen clearly. On the other hand, liquefaction strength in Urayasu sand is not affected by relative density so much. This result is consistent with the varying fine fraction content's test result by Yokoyama [8].

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Figure 21 plots the relation of liquefaction strength and relative density of Urayasu sand and Toyoura sand. For a medium sample (Dr=60%), there is no difference, but in a dense sample (Dr=80%), Urayasu sand has a tendency for smaller liquefaction strength. This tendency can be understood due to the above fine fraction content.

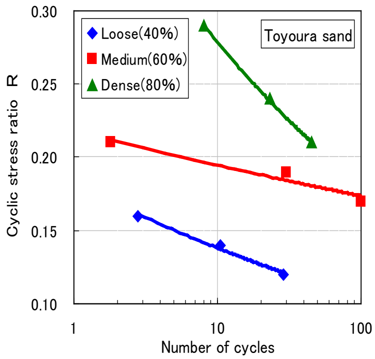

Figure 19: Relationship between cyclic stress ratio and number of cycles (Toyoura sand).

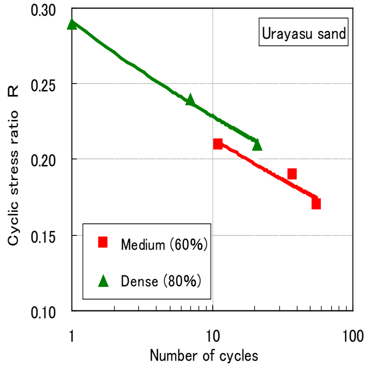

Figure 20: Relationship between cyclic stress ratio and number of cycles (Urayasu sand).

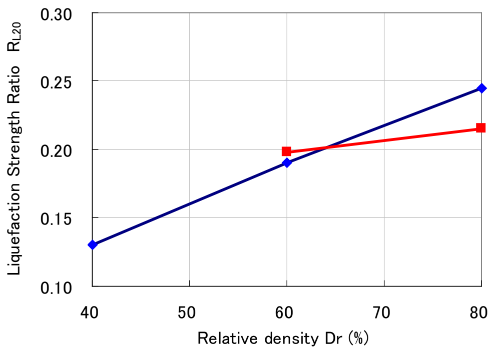

Figure 21: Relationship between liquefaction strength and relative density.

7 Measures for liquefaction in Urayasu city

The occurrence of liquefaction needs three conditions.
1) Loose sand deposit,
2) Groundwater, and
3) Earthquake movement.

Therefore, a measure for preventing liquefaction needs to eliminate all three conditions.

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Currently, the principles of liquefaction measures taken in Urayasu is as follows.

・Increase the soil density
・Solidify sand particles
・Lowering the ground water table
・Disperse the pore water pressure
・Control the shear deformation
・Improve the structure

For the selection of construction method with principle improvement, it is influenced largely by size and area requiring improvement. Countermeasures to prevent liquefaction in Urayasu need to apply to many numbers of residential houses, and it is a big characteristic. In other words, the most economical construction method for small size improvement needs to be chosen.

8 Conclusion

1) In the Tohoku earthquake, even the Tokyo Bay coast – so far away from the epicentre – suffered a devastating damage caused by soil liquefaction.
2) More than 70% of the land in Urayasu City, which suffered the largest damage from soil liquefaction, was of landfill sites reclaimed after the 1960s.
3) Calculated FL and PL values by current estimation method indicates a high possibility of liquefaction occurring.
4) The liquefaction resistance test on Urayasu sand revealed that it has smaller resistance to liquefaction despite the fact that it contains fine-grained fractions.
5) Liquefaction resistant structures are mainly used for residential houses, and therefore, choosing an economical and inexpensive resistant structure is of great importance.

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Section 8
Socio-economic issues

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Disaster management policy and conflict resolution: a case study of South Korea's dam construction

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Abstract

The aim of this article is to extract the factors for successful conflict resolution by analyzing the multi-stakeholders' conflict framing and the course of conflicts in the context of dam construction as one of the measures of disaster mitigation. The author examined the stakeholders, perceptual framing and conflict resolution mechanism of the conflict in the process of constructing Hantan River dam of South Korea. The results suggest that the personnel in charge 1) establish joint fact-finding procedures, 2) expand citizen participation in policy making by sharing information, 3) coordinate inter-agency, 4) enact related Acts to develop long-term measures for the residents and 5) create a standard manual of conflict in the context of disaster for a successful completion of the relevant projects in the future.
Keywords: disaster management policy, conflict resolution, ADR, dam, Hantan River, Dong River.

1 Introduction

Concern about occurrence of various catastrophes result from climate change has surfaced as a serious issue in the world. Since 1990s, Korea has experienced a variety of conflicts emerged as a consequence of great disasters or in the process of decision making and implementing disaster policies (e.g. dam construction as one of the measures of disaster mitigation). However the fundamental importance of the systematic approach like understanding people's perception to build consensus that integrates the different views among the affected groups of interest has largely been ignored. Given my desire to know what conflict partners are perceiving and thinking about the interaction and how these differences in

WIT Transactions on The Built Environment, Vol 133,
www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/DMAN130291

perception and definition affect conflict management (Sillars *et al.* [13]), it is appropriate to investigate the ways in which people articulate their conceptualizations of interpersonal conflicts.

As such, this article employed the conflict framing to examine the stakeholder, perceptual framing and conflict resolution mechanism of the conflict in the process of constructing Hantan River dam of South Korea. The used research method involves a review and analysis of documents such as daily newspapers between 2001 and 2009, official documents, and so on. Face to face interviews with interested parties were also conducted. The author asked them to reflect upon their experiences of working and activities and what they felt were its benefits and negative aspects.

2 Theoretical framework

2.1 Conflict and framing

Scholars of communication and conflict are in general agreement that conflict can be conceptualized as an expressed struggle between two or more interdependent parties who perceive goal incompatibility, scarce resources, and interference from the other party in their individual goal achievement [2, 5]. Scholars tend to be in further agreement that perception is the most central variable in both the creation and management of conflict interaction Randall [12].

Broadly speaking, framing is the process by which people individually define and assign meaning to a class of objects, persons, and events (Randall [12]). In recent years, framing has become a popular concept among scholars of conflict and negotiation [7, 11].

2.2 Approaches to Research on Framing

Putnam and Holmer [11] identify three separate orientations to framing research: the cognitive heuristic approach, the frame categories approach, and the issue development orientation. To begin, the cognitive heuristics orientation focuses on how individuals make decisions about management strategies according to the perceived benefits and losses associated with particular options (Blount and Larrick [1]). This line of inquiry has generally explored the static individual biases and decision-making structures that influence negotiation behavior.
According to the frame categories line of research, frames are internal expectancy sets that individuals employ to make sense of an existing interaction. Researchers working in this realm have principally investigated the types of frames individuals use to define their conflicts and the relationship of frames to outcome goals and expected satisfaction (Pinkley [10]). They initially posit six types of categories: (1) substantive frames define what the conflict is about, (2) loss-gain frames provide interpretations associated with the risk or benefits of various outcomes, (3) characterization frames are expectations and evaluations of the other disputants' behaviors and attitudes, (4) process frames are expectations

about how the negotiation will or should proceed, (5) aspiration frames express the disputants' underlying interests and needs, (6) outcome frames are the disputants' preferred positions or solutions (Gray *et al.* [6]).

The third orientation is the issue development approach (Drake and Donohue [3]). Similar to the frames as categories perspective, the issue development orientation focuses on communicators' discourse to glean insight into how parties use frames to define a conflict event. Yet unlike the frames as categories orientation, issue development researchers focus on how frames are developed, negotiated, and transformed during the course of interaction. Research from this perspective has explored the ways in which disputants individually define the topic of the conflict and how those definitions are negotiated with the other party (Drake and Donohue [3]). Of particular interest to this investigation are the frame categories and issue development areas of research.

3 Research Framework

The conflict framing can be conceptualized according to Figure 1. Drawing on frame categories, this study employed loss-gain frames, characterization frames, process frames and fact-relevance frames to analyze the characteristics of the course of conflicts and their settlements in the cases of Hantan River dam in Korea. Fact-relevance frames are new ones the author added through a review of documents. They express the disputants' different points of view in phenomena due to scientific uncertainties. Dam construction involves various interested groups(government, NGOs, citizens, etc.) with divergent interests and experiences that make the implementation process complicated: (1) the Ministry of Construction and Transportation ("MoCT"); (2) the Korea Water Resource Corporation ("KWRC") which together with the Ministry was in charge of dam construction; (3) people living in the Dam site and downstream ("PD"); (4) people living in the upper stream area of the Hantan River Dam site ("PU"); (5) NGOs for environmental movements;(6) local government ("LG"); (7) people living in submerged districts("PSD"); (8) the Ministry of Environment("ME"). In general, the MoCT, KWRC, and PD were in favor of dam construction, while the PU, NGOs and ME were opposed. The LG and PSD took both positions.

4 A case study of Hantan River dam conflict

4.1 Background

The Hantan River is a main tributary of the Imjin River, which is 253.6km long and drains 21 major watersheds in the trans-boundary area between South and North Korea. The Han River originates from Pyonggang county in North Korea and flows into the Imjin River at Yeoncheon county in South Korea near the DMZ running through Chulwon and Pocheon. The Hantan River is 144km long (86 km in South Korea, 55 km in North Korea) and accounts for 30 percent of the Imjin River's basin area.

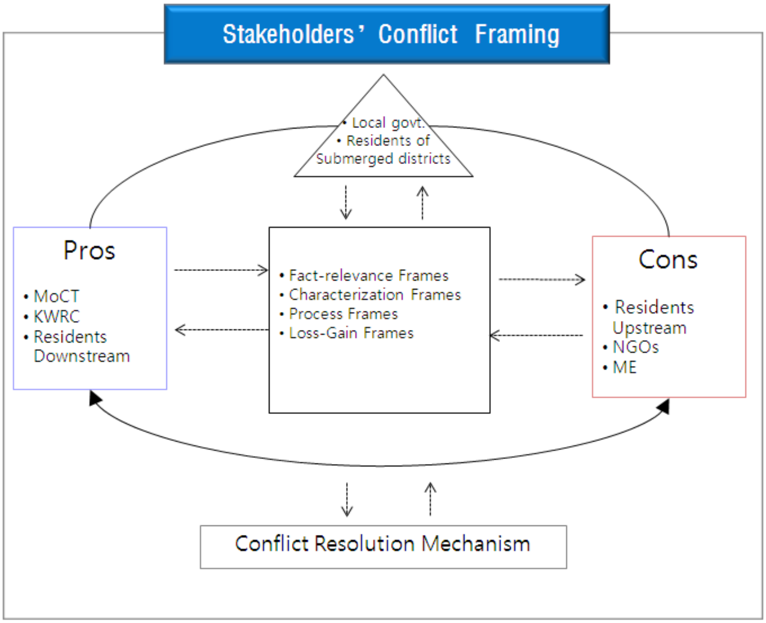

Figure 1: Conflict framing.

The Hantan River dam was planned in 1999 as a flood prevention measure after large-scale floods in the late 1990s. In 1996, a concentrated rainfall measuring over 600mm in the Hantan river basin overwhelmed the Yeoncheon dam's flood control volume and flooded the downstream region. Shortly thereafter, the dam collapsed. In August 1998, a surprising record rainfall fell across Korea, which affected 14,776 people and caused 310 billion won of property damage along the Imjin River. In 1999, in the Imjin river basin, a rainfall of over 700mm destroyed Yeoncheon dam once again, and caused severe flood damage in Moonsan and Yeoncheon. The three floods together killed 128, affected 31,439 others, and caused 900billion won in property damage along the Imjin River PCSD [9].

A plan was to build a dam between Yeoncheon and Pocheon to a height of 85 meters and length of 705 meters in order to control 3.05 million tons of flood volume with 3.11 million tons of water storage capacity. The Ministry of Construction and Transportation (MoCT) officially announced the plan in 2001 as part of the long-term plan of constructing 12 dams nationwide. However, local resistance disrupted the public consultation process. A grassroots networking organization, Hantannet, was established in 2000. It mobilized the anti-dam movement of local communities and a nationwide network organization, People's Action for No Dam (PAND), arose. Experts' assistance regarding technical and scientific issues enabled local people to reveal the contradictions of the plan, which escalated the animosity between the government and communities.

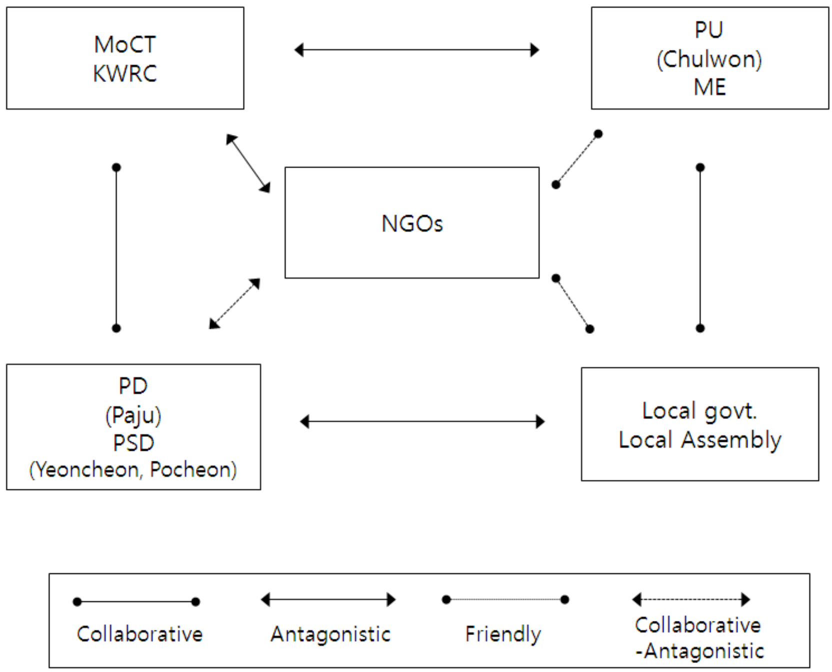

Figure 2: A relation chart among interested parties.

4.2 Conflict framing

4.2.1 Fact-relevance frames

The conflict was seemingly caused by the Hantan River dam plan, but in substance, the challenge against the dam-centered water supply policy underlies it. Transparency of information and analysis is essential to building and maintaining the trust needed to identify mutual interests. Advocacy science is common in environmental disputes involving complexity and uncertainty (Randall [12]). Public debates had developed for several years partly due to scientific uncertainties, but mostly to the veiled process of data collection and analysis.

The limited public access to information such as the total flood volume and the flood control volume of the dam generated the iterative disagreement about facts and assumptions and further diminished trust between stakeholders and governmental agencies. Above all, the effectiveness of the dam to control flooding of the downstream Imjin River was called into question because the Hantan River occupies only 16.6% of the Imjin River basin, which means its maximum flood control volume is less than 13.6% of the total. Moreover, the dam's location, planned to be above the spot at which the Hantan River joins its main tributary, the Youngpyungcheon, indicated that the dam would be too small to control flooding of the bigger river.

The Korea Water Resources Corporation's (KWRC) frequent changes in basic flood data also escalated mistrust. For example, the flood control volume of the dam upstream was originally 2,560cms, and downstream (Moonsan) was 2,700 cms. However, the basin area downstream is six times larger than that upstream. Therefore, the discharge volume downstream should be smaller than that upstream. KWRC adjusted the upstream rainfall from 471 mm/year to 520 mm/year in 2000, and again to 568 mm/year in 2002 to prove the dam's flood control volume to be 2,700cms. Furthermore, the dam's flood control volume was calculated based on very limited hydraulic and watergate data. Political interests and culture, popular attitudes, and laws can trigger environmental conflicts.

4.2.2 Characterization frames

Hantan River dam conflict represents the difference in values and collective identity among the bureaucracy, PU or NGOs. Threats to their identity cause severe conflicts and hostility (Randall [12]). Two parties had negative thoughts mutually with respect to characterization frames.

Anti-dam residents asked the government to address procedural and environmental issues of the plan, which in part coincided with the interests of the NGOs. The NGOs refuted the feasibility of the plan based on scientific analysis and procedural legitimacy. The government, however, stuck to the planned dam construction and its procedural rationality as the best option for flood control in the Imjin River basin. While the government considered anti-dam residents as only seeking for compensation, residents and NGOs insisted that the MoCT and KWRC carried forward the dam construction to maintain their organization.

4.2.3 Process frames

Historically, the vicious cycle of top-down decision-making and successive failed resolution attempts exacerbated the relationships between communities and the government. Poor participation methods, such as public hearings or consultation, also contributed to the escalating mistrust that hindered appropriate communication. The structural conflict is mainly related to the problem of legitimizing a decision-making process. The top-down policy making prevented deliberation on the alternatives and on the timeline for dam construction. The government preferred a fast track of policy making, hoping thereby to minimize the potential flood damage and the extra costs generated by the project's delay, while residents asked for extended research and resource investment to find the optimal solution.3 The unequal distribution of resources, such as experts, information, and money, also restricted communication between the government and local residents, and hindered their ability to seek common ground. Lastly, the perceived distribution of benefits and costs generated by the dam's construction divided communities.

The public review process of the Environmental Impact Assessment failed to mollify the local population. Public consultation was sought on the plan's first draft in 2001. The Ministry of the Environment completed the review process of the EIA on the third re-submitted plan in December 2003 and recommended two amendments: the water gate was to be open for 350 days of every year so as to preserve the ecosystem, and the design of the dam was to be switched from multi-purpose to flood control. The frequent changes made by MoCT over technical issues strained the credibility of the plan, which fueled the anti-dam movement. Local authorities and councils also opposed the dam project and the Gangwon provincial governor officially announced his position against the dam in August 2003, a position prompted by an October 2002 mass rally in Cheolwon.

4.2.4 Loss-gain frames

The people in downstream areas who had suffered from repeated flood damage mainly approved of the plan as they anticipated the benefits of flood control, such as an increase in property value and regional economic development. In contrast, the upstream area was largely against the project, because of fear of the economic, environmental, and social costs of dam construction and the introduction of new regulation.

Anti-dam residents also asked the government to address the technological and procedural issues of the plan, which in part coincided with the interests of the NGOs. The NGOs refuted the feasibility of the plan based on scientific analysis, hoping the case would generate momentum to reorient the existing water supply policy. The government, however, stuck to the planned dam construction and its procedural rationality as the best option for flood control in the Imjin River basin.

4.3 Conflict resolution mechanism

The ongoing rallies and protests led the National Assembly in 2003 to disapprove the dam construction budget for the next year, but MoCT continued its controversial plan. The conflict reached a turning point on 19 December 2003 when President Roh promised during a dialogue with Gangwon Province residents to reconsider the Hantan River dam project. He ordered the Presidential Committee on Sustainable Development (PCSD) to take charge of the case and to initiate a consensus-building process for conflict resolution. It was expected that its final decision would be accepted by both proponents and opponents if they agreed with the process and the outcome.

As such, PCSD established the action plan, which encompassed organization of a preparation team, process design, organization of a conflict mediation sub-committee, and the mediation process among stakeholders.

However, there were four serious obstacles to mediation. First, there was not enough data on the amount of flooding in the Imjin River, and no way to measure it, because the great majority of the river was in North Korea. Second, local elections of the PU made mediation difficult because political candidates locked themselves into positions opposing the dam. Third, there were communication problems and intransigence. For example, a common communication problem involved a first party raising an issue and a second party providing a solution, but the first party refused to accept the solution due to stubbornness. In effect, the first party lacked confidence and trust in the second party, and maintained an unmoving stance on all issues. Fourth, PU representatives had different interests in participating in the mediation process. Some wanted to build their political reputation, while others made efforts to get more benefits for their communities.

As a consequence, the Hantan River dam conflict remained unresolved and went to the Supreme Court in 2007. In 2009, the Supreme Court decided against the plaintiff, namely PU.

5 Discussion and conclusion

This case study has examined the multi-stakeholders' conflict framing and the course of conflicts in the context of dam construction as one of the measures of disaster mitigation to extract successful conflict resolution factors. The Hantan River dam conflict is the first case to which a well-designed conflict management process has been applied with political support in Korea. The experiment was not successful, despite certain achievements.

This article has five main findings. One possible starting point for this discussion is to establish joint fact-finding procedures. Joint fact-finding offers an alternative to the process of adversary science when important technical or science-intensive issues are at stake (Ehrmann and Stinson [4]). Scientific information, knowledge and expertise are important sources of power in decision making because they are used to identify a problem and its solutions, and to persuade decision makers to support and choose among the alternatives Ozawa [8]. Joint fact-finding is a central part of the consensus building process for environmental issues involving uncertainty and risks.

Second, the government needs to observe the correct procedures by sharing information and expand citizen participation in policy making to dam construction. Substantive 'Environmental Effects Evaluation' and effective public hearings can be good examples to attain the goal.

Third, closer interagency coordination is required. The MoCT and KWRC consult with the Ministry of Environment and the Ministry of Strategy and Finance to perform 'Environmental Effects Evaluation and to secure funding when decision making. When it comes to disaster management, the Ministry of Safety and Public Affairs and the National Emergency Management Agency participate in the dam construction policy processes.

Fourth, likewise we experienced the yearlong disputes over compensation for the residents in the submerged area in Hantan River dam conflict. It is necessary to enact related Acts to develop long-term measures for them. Lastly, it is also providing support to develop standard manual for conflicts for disaster respondents.

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Development and validation of a stochastic disaster impact model

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Abstract

Natural disasters result in economic losses as capital and industry are destroyed, as transportation and communication lines are severed, and as customers temporarily flee a region. In many cases, production and sales levels remain depressed as the region rebuilds. Furthermore, these direct losses account for only a portion of the total economic loss experienced.

This paper presents a disaster impact model (DIM) to quantify the economic impact of natural disasters on regional output, GDP contribution, labor income, tax income, and employment, as well as the time to recovery. The model is developed to measure the impact of Hurricane Ike on eight Texas Gulf Coast counties and is then extended to a wildfire in central Texas. Actual county sales data are modeled for a period of years before the event, accounting for trends over time and between fiscal quarters, and are used to predict quarterly and annual sales by industry and agricultural commodity in post-event quarters. IMPLAN input-output multipliers are applied to the predicted sales, and stochastic estimates of total impacts are generated using Simetar. Actual post-event impacts are then compared to predicted impacts to estimate the quarterly and annual total economic losses attributable to each industry. Losses are reported at the county and state levels for individual industries as well as across the regional economy. Results show that Hurricane Ike (and a global recession) impacted the coastal economy negatively for at least three years after the event, and industries and locations exhibited different initial responses and recovery paths. Wildfire losses were more sector-specific and shorter in duration.
Keywords: disaster impact model, disaster economic impact, resilience, stochastic model.

www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/DMAN130301

1 Introduction

Natural disasters cause widespread damage to structures, machinery, and inventories within a region. The need to replace capital and inventories is complicated by decimated transportation and communication networks and by residents (labor force and consumers) and visitors (consumers) fleeing the area. Thus, it can take months or years before a region's economy is able to rebuild.

Local and state officials, business leaders, and residents want to restore the regional economy quickly. Understanding the recovery patterns of various businesses can help leaders to identify opportunities to improve resilience. This paper discusses the development of a disaster impact model (DIM), using data from an eight-county study area in coastal Texas prior to and immediately following Hurricane Ike. Ideally, a DIM will be generalizable across various types of disasters. Therefore, the model is adapted for a wildfire in central Texas.

The economy of the Texas Gulf coast in the U.S. was severely impacted by Hurricane Ike in September 2008. The storm began as a Cape Verde-type storm off the coast of Africa in late August. The storm surge topped the Galveston, Texas, seawall on September 12, and the storm made final landfall in Galveston County on September 13 as a category 2 hurricane with sustained winds of 175 km/h and a 6.8 m storm surge. The storm continued inland, breaking windows and leading to flooding in many coastal areas and to power outages lasting several weeks in Houston.

Ike was the third costliest storm in U.S. history and the most costly storm in Texas history with more than $27.0 billion (2008 U.S. dollars) in damages (Lott *et al.* [1]). This direct loss accounts for only a portion of the total economic loss attributable to Ike. Reduced spending due to production constraints and reduced consumer spending triggers wider losses as businesses buy fewer inputs from suppliers and/or lay off employees. In turn, supply businesses and former employees reduce expenditures as well. Different regions and industries may react differently based upon the structure of the regional economy and its internal linkages.

The economic reaction and recovery may also be affected by the type of disaster. Hurricanes have a massive effect on a relatively large region, and coastal areas tend to be heavily populated with a high concentration of economic activity. Hurricanes occur over a short period of time but require a long recovery period. These features make them ideal disasters for economic modeling. Wildfires may consume vast tracts of land but often occur in more rural settings with abundant fuel (e.g., dry grasses, brush, or trees). More populated places are generally better protected so population and economic activity are less dense in fire-devastated areas. Furthermore, the timing of a fire affects the extent to which farm commodities are destroyed, which can be a major factor in the economic consequences of the fire. Wildfires often build upon drought conditions, which can make fire-specific losses more difficult to identify.

Cross Plains, Texas, was engulfed by a wildfire December 27, 2005. The fire in Cross Plains, considered an urban wildland interface fire, was one fire within a 515-day Texas fire season caused by drought conditions and high winds (Gray

[2]). The fire season in the state included the loss of 734 homes and 1,320 other structure. The Cross Plains fire accounted for 110 homes, 6 hotel units, and a church. These losses were significant in a city with 1,068 people and 554 housing units in 2000 (Census [3]). Most economic damage occurred outside urbanized areas in Callahan and Eastland counties as livestock, crops, and rangeland were destroyed. In Callahan County, 2,765 acres were destroyed, and 14,285 acres were destroyed in neighboring Eastland County.

The winter timing of the fire meant that fall crops had been harvested, spring crops were not yet planted, and fields of fall-planted spring crops (e.g., wheat) could be replanted with another crop. Rangeland used for livestock would begin to recover with spring rains, although it would initially be able to support fewer animals per acre. Both crops and livestock lost in the fire were eligible for agricultural insurance payments, which mitigated the loss for farmers and ranchers.

The paper proceeds as follows: Section 2 provides a brief review of the literature discussing the economic impacts of disasters, Section 3 describes the data, Section 4 introduces the methods, Section 5 discusses results, and Section 6 concludes.

2 Review of the disaster impact literature

Okuyama [4] provides a thorough but succinct discussion of the history of disaster impact analysis. Input-output analysis is a common method of impact analysis dating back to the 1940s. Input-output studies are popular because they reflect linkages between industries; even if an industry is not directly affected by the storm, it may be affected by changes in the spending patterns of other businesses and their consumers. Several studies use input-output and related methods to quantify the impact of storms on regional economies (Rose and Liao [5], Donaghy *et al*. [6], Okuyama *et al*. [7], and Xiao [8]).

West and Lenze [9], analyzing the impact of Hurricane Andres, note several challenges to calculating the regional impacts of disasters: the size of the event is not well known, the wide range of industries affected sets the stage for double-counting, the event is neither exclusively supply- nor demand-driven, and the reactions of households are not well-understood. The expected effects of wealth change may not be applicable given loss of physical possessions, disrupted the links between income and spending, altered investment links, housing supply and demand shifts, and possible work-force and migration changes. Furthermore, sector demand may be atypical following a storm (e.g., an increase in construction), and jobs created may be temporary and attract migrant workers. Impact models do not generally account for these scenarios.

Swenson [10] notes that it is difficult to identify whether economic changes over time are attributable to a specific event, such as a natural disaster, rather than overall economic changes or a combination of events. Never-the-less, Mantell [11] points out that disasters require immediate attention and that models providing immediate results are needed. More complicated models may provide refined results at a later point. This study aims to provide a rapid-response model that is flexible enough to accommodate different types of disasters and economic structures and that can be refined as more data becomes available.

3 Data

The goal of the study was to model the recovery paths of industries within a disaster-impacted region with the county as the unit of analysis. In Texas, the Comptroller of Public Accounts (Combs [12]) publishes quarterly sales data for 20 industries defined at the two-digit NAICS level (Census Bureau [13]). The dataset includes all sales and taxable sales within each county and city going back to 2002, which is almost four years before the fire and six years before the hurricane. The comptroller's data site was used because it provides sub-annual data at the local level and because other states have comparable data, allowing the model to be expanded to other states.

Agricultural data is available only on an annual basis because most plant and animal commodities produce one crop per year. The variable of interest for the impact model is annual sales for each commodity. However, annual sales are estimated as a function of prices, production, acreage planted, and livestock counts. These data for 1998 through 2009 were obtained from the National Agricultural Statistics Service (U.S. Department of Agriculture [14]). Agricultural statistics dating back to 1968 are available at the county level for all states. Price and production data were obtained for corn, cotton, grain sorghum, rice, soybeans, wheat, beef cattle, goats, and sheep.

Data on national and state-level recessions were collected from the National Bureau of Economic Research [15]. However, no quarters in this study were considered recessionary. The 2001 recession ended before the sales tax data set began, and Texas remained insulated from the recession that began in December 2007 until 2009, after Hurricane Ike. Without past recessionary quarters in the dataset, no coefficient is estimated for future recessionary quarters.

It was important that data be general in nature so the model could be adapted to disasters in other regions and in future periods. Disasters often affect multiple states so similar data was required across states. The model predicted a stochastic growth path using data that could be readily available for future quarters. In the case of industry and services, the year and quarters occur regardless of whether an area is affected by a disaster. Recession data, if incorporated later, allow for normal or adverse-case recovery paths to be analysed. For agricultural commodities, previous year prices as well as planted acres and livestock counts are readily available and inform expectations about future sales.

4 Methods

The model uses three steps to determine the economic impact of a natural disaster on a regional economy. First, the sales path for each industry within each county is estimated using regression analysis with stochastic predictions for sales in future years. Second, weighted input-output multipliers are applied to industry sales estimates and observed sales data to capture economy-wide impacts.

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Finally, the total impacts for each industry are simulated stochastically to produce a range of loss estimates, and differences between stochastic predicted impacts and actual impacts are measured as the extent of the disaster.

4.1 Stochastic modelling of expected sales paths

Disasters cause a deviation in sales trends for most industries. Measuring the impact of a disaster requires predicting sales in a given industry had the disaster not occurred. For industries other than production agriculture, 2002-2011 sales (IndSales) for each industry i and county r were modeled as a function of time (Year) and calendar year quarter dummy variables (Qtr), eqn (1). The third quarter including July through September was omitted. The year and quarter variables accounted for trends over time and between quarters. The need to account for overarching economic events, such as the Great Recession, was recognized. However, no quarters were identified as recessionary during the study period so that variable was not used in the model estimation, although space for a Recession variable was retained in the Excel spreadsheet containing the model.

$$IndSales_{i,r} = \alpha + \beta_1 Year + \beta_2 Qtr1 + \beta_3 Qtr2 + \beta_4\ Qtr4 + \beta_5 Recession + \varepsilon \qquad (1)$$

Agricultural commodity sales (AgSales) were modeled based on the number of years from the 1999 base (BaseYr), the squared years from base (BaseYrSq), the previous year's commodity price (PrevYrP) and a dummy variable for disaster years (Disaster), eqn (2). The year variables accounted for production trends over time while previous year's price is associated with current year planting decisions and thus current year sales. Products that had only been grown a few times or that had not been grown in the last two years were not modeled. Data from 1999 to 2008 were used to estimate coefficients for each commodity.

$$AgSales_{i,r,} = \alpha + \beta_1 BaseYr + \beta_2 BaseYrSq + \beta_3 PrevYrP + \beta_4 Disaster + \varepsilon \qquad (2)$$

Each industry-county combination was modeled using ordinary least squares (OLS) regression with Simetar® (Richardson *et al*. [16]). Based on the trend regressions, Simetar also generated stochastic forecasts for an additional eight quarters (later sixteen quarters) and two agricultural production years after Hurricane Ike (Q3 2008) to reflect production and price risk and the variability of production across years. The same methods were used to analyse the effects of the Cross Plains fire (Q4 2005) for eight quarters and two agricultural production years.

Simetar is a simulation language that allows researchers to simulate random variables, conduct parameter estimation and statistical analyses, manipulate and analyse data, and conduct regression and probabilistic forecasting. The Simetar functions are dynamic so most parameters, hypothesis tests, and regression models are automatically updated when new data is entered. Thus, in preparation for an impending disaster or in the immediate wake of a disaster, historical data from the affected region can be imported into the spreadsheet, and the OLS regressions and stochastic calculations will automatically update to reflect local economic relationships.

4.2 Input-Output analysis of expected and actual sales

The stochastic estimates for post-Ike quarters were combined with IMPLAN (Minnesota IMPLAN Group [17]) multipliers to estimate total economic losses following Hurricane Ike and the Cross Plains fire. IMPLAN is an input-output modelling tool originally developed by the USDA Forest Service and later privatized. IMPLAN provides the software tools and region-specific data to create and manipulate social accounting matrices for a user-defined region. These matrices are used to calculate multipliers to estimate impacts on 440 sectors of the regional economy. The change in final demand sales within a regional industry is the direct impact. The direct impact leads to indirect impacts as directly affected businesses purchase inputs from regional suppliers and induced impacts as employees of directly and indirectly affected businesses spend their incomes. The direct, indirect, and induced effects are collectively the total impact across the regional economy.

Comptroller data was available only at the two-digit sector level. However, IMPLAN uses more precise sector breakdowns in calculating industry multipliers. Therefore, the multipliers were weighted according to sales volume of each IMPLAN sector within a given two-digit NAICS sector. Agricultural commodities used the multipliers for their respective IMPLAN-assigned industry.

The weighted multipliers were applied to the stochastic sales predictions for each county's goods-producing and services industries to estimate actual and predicted total economic impacts quarterly. The initial analysis of Hurricane Ike included eight post-Ike quarters. The simulation was expanded to 16 quarters because many sectors had not recovered within two years, although only 11 quarters of sales data were available. Additional data can be added as it is posted to the Comptroller's website. Multipliers on agricultural commodities were used to estimate economy-wide impacts for two years post-disaster for crops and livestock. The fire in Callahan and Eastland counties was evaluated for two years (eight quarters).

4.3 Simulation of sales impacts and calculation of economic losses by industry

The total economic impact predictions for each industry/commodity and quarter/year were simulated using Simetar. The minimum, maximum, and mean total economic effect forecasts from the simulations were recorded as the average and bounds of the predicted industry sales. Stochastic effects were assigned a lower bound of zero as negative sales are precluded. The summary statistics were used to facilitate conversion to a web-based delivery format and to aid comprehension by community leaders and the general public.

The weighted multipliers from IMPLAN were applied to the actual sales for each industry. The total impacts resulting from actual sales then were subtracted from minimum, maximum and mean predicted impacts for each industry to determine the average and bounds of economic losses within each county. Because the IMPLAN model is linear, subtracting actual impacts from predicted impacts is equivalent to applying the IMPLAN multipliers to the differences between actual from predicted direct sales. The method used here allows the full impact of the actual and predicted sales paths to be shown graphically. The economic losses for each industry were summed to calculate the economy-wide loss across all industries in a county.

5 Results

The model produces 20 industry-specific graphs for each county and up to nine graphs for agricultural commodities, depending upon the number of commodities produced in the county. An additional four graphs summarize the economic impacts on the goods-producing, service, and agricultural sectors and the entire economy for each county. Consequently, it is impractical to present all result data and graphs in this section. Furthermore, the aim of this paper is to present the methods used in developing the model; the case studies of Hurricane Ike and the Cross Plains fire serve to demonstrate and validate the model. Results presented in this section are intended to show the outputs of the model. Results from Galveston County are used to demonstrate the hurricane application of the model, and results from Eastland County demonstrate the adaptability of the model to a fire application. Full results from the first year following Hurricane Ike are available under the Learn tab at The Storm Resource website (http://thestormresource.com/learn.aspx, Texas Engineering Extension Service [18]).

5.1 Hurricane Ike Results – Galveston County

Hurricane Ike made landfall in coastal Galveston County with devastating results for homeowners and businesses. The county economy still had not recovered three years later (Fig. 1). The goods-producing sector, which comprised 96% of the county's economy in 2008 and 91% in 2010, was most damaged, both initially and throughout the prolonged recession. The recovery graph for the goods-producing sector is almost identical to that of the overall economy. The service sector was relatively more stable and rebounded after the completion of a massive new health services facility at the end of the study period. Agriculture is only a very small component of the county's economy.

Effects of the storm varied by industry. Some industries were extremely vulnerable and others more resilient. For example, transportation was effected only in the first quarter post-hurricane (Fig. 2, panel a). Manufacturing (panel b) declined in the first quarters after the hurricane and continued to perform poorly throughout the recession. The mining, oil, and gas sector was hurt by the

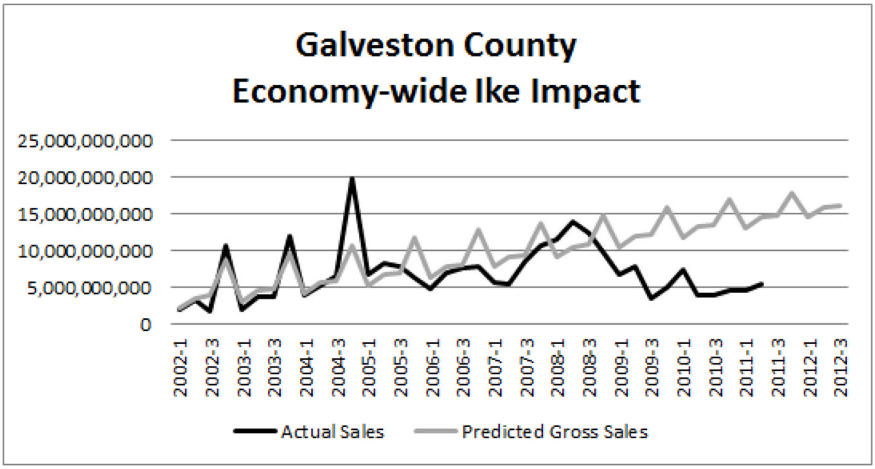

Figure 1: Predicted versus actual sales, full economy, Galveston County.

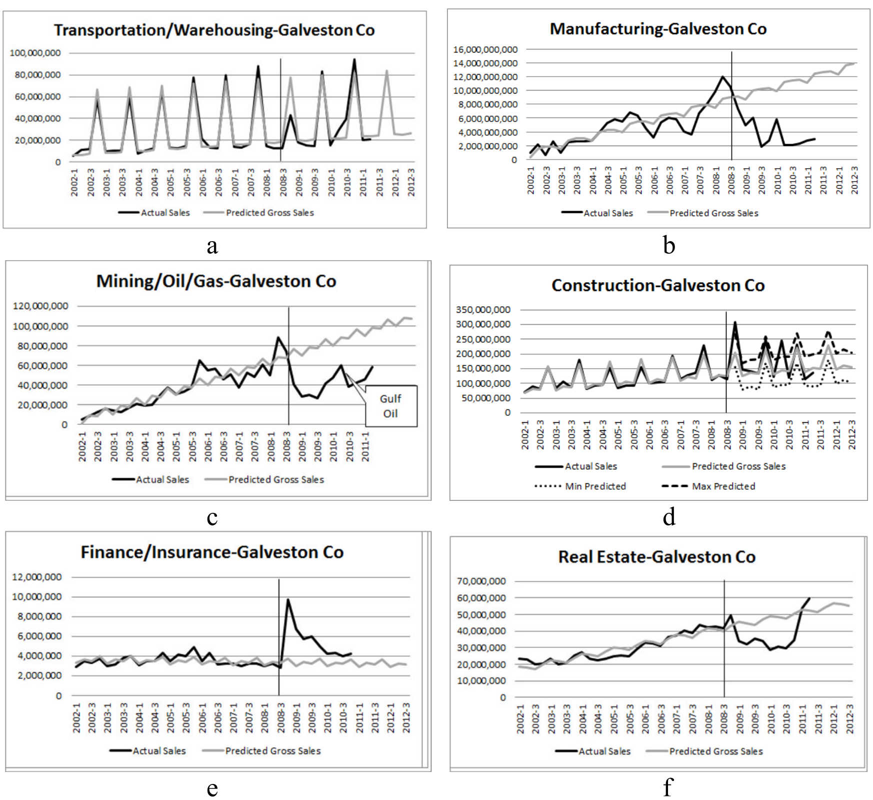

Figure 2: Predicted versus actual sales, selected industries, Galveston County.

hurricane and received another setback in the form of the 2010 Deepwater Horizon oil spill (panel c). The construction sector outperformed expectations in the immediate aftermath of the hurricane and continued to perform well as residents and businesses rebuilt over time (panel d). Panel d also shows the minimum and maximum sales expectations for the construction sector. These lines were excluded from most published graphs because they were deemed confusing to the lay audience.

Within the service sector, the finance and insurance industry was notable for the immediate spike in activity following Hurricane Ike (Fig. 2, panel e). This activity slowly returned to predicted volumes. Real estate sales rose slightly immediately following the hurricane, perhaps as a result of small-firm reporting in the fourth quarter, but remained depressed until the first quarter of 2011 (panel f). Most service industry sales remained fairly similar to predicted values during the hurricane recovery period.

These results indicate that it is useful to examine individual industries as well as the overall economy. It is also important to note that a single industry may perform differently in counties with different economic structures and different levels of damage. For example, the hotel and restaurant industry experienced lower sales immediately in Galveston County but rose slightly in neighbouring Brazoria County, probably as a result of relief workers' accommodations.

5.2 Wildfire results – Eastland County

The impacts of the wildfires in Eastland and Callahan Counties were markedly different than those of Hurricane Ike. While many homes were destroyed by the December 2005 fire, much of the damage was to agricultural facilities and livestock. Both the construction and agriculture support industries experienced an increase in sales volume post-fire as residents replaced housing, agricultural structures, and fences (Fig. 3, panels a and b). Considering that most losses (both personal and agricultural) were insured, it is not surprising that retail trade remained fairly constant following the fire (panel c). Within the important agriculture sector in that county, only the beef cattle industry experienced significant losses (panel d). The fire occurred in winter after crops had been harvested, and farmers could plant fields with burned fall-planted crop (e.g., winter wheat) with a spring crop (e.g., corn). Cattle are the predominant livestock species in the region. Some cattle were destroyed by fire while others were sold due to a lack of forage for grazing following the fire and preceding drought. Thus, future herd sizes and sales declined.

6 Conclusion

The disaster impact model estimated economic losses to industries and counties within two study areas: eight counties directly affected by Hurricane Ike and two counties impacted by wildfire. Results provided by the DIM were larger than previous loss estimates that did not account for economic impacts, especially in the case of Hurricane Ike. Almost all sectors were negatively impacted by

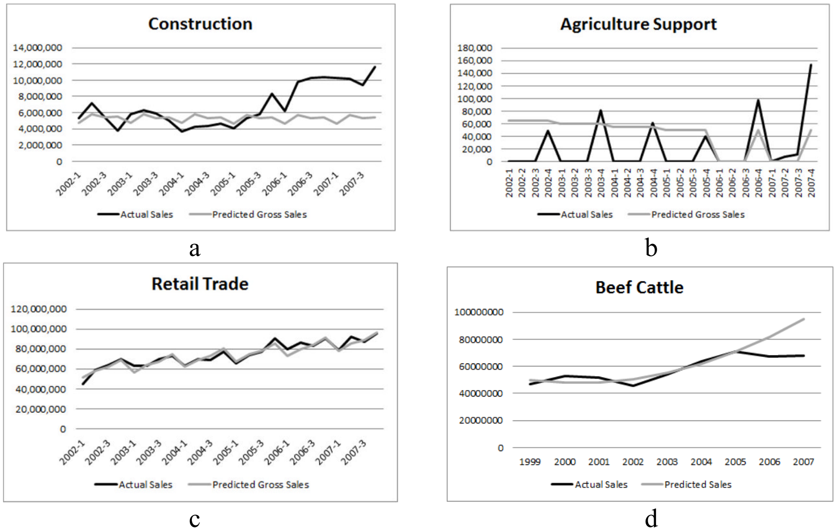

Figure 3: Predicted versus actual sales, selected industries, Eastland County.

Hurricane Ike, while only agricultural and construction industries were significantly affected by the central Texas wildfire, and even agricultural impacts from the winter fire were limited. The differing results between the two disasters helped to validate the model's sensitivity to the scope and type of disaster. The model also identified industries with a high degree of vulnerability as well as recovery paths for each industry. The model proved easy to update when new data was available and to adapt between disaster types (i.e., hurricane and wildfire).

A region's initial reaction and its resilience seem to be affected by the structure of the regional economy, which implies economic development strategies should include a disaster-preparedness component. Specifically, officials may be able to work with businesses in vulnerable industries to mitigate damage. This may include encouraging coordinated disaster planning across all sectors as well as working with key suppliers, such as utilities, to identify priority service restorations.

This information is useful to community leaders and planners with disaster-preparedness responsibilities. In fact, results from the first eight quarters following Hurricane Ike were interpreted in a web-based delivery system accessible by the general public. The model has the advantage that additional counties can be incorporated into the model quickly when disasters are impending. The model is also easy to update as new sales become available.

Local and state officials may be able to request and target disaster assistance based on modeled predictions. However, additional validation of the model is required to confidently predict losses ex-ante. Only eight counties experiencing a single hurricane prior to an international recession and only two counties experiencing a wildfire were modeled. Additional hurricanes and fires must be

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analyzed, preferably in other counties, to create a more robust data set and validate that losses and recovery paths are similar given the disaster type and timing and the regional economic structure. This is an area of ongoing research. Another avenue of further research is the incorporation of the DIM into a broader resilience analysis process that includes facility risk, service delivery and control systems, and system interdependences. Opportunities to broaden the resilience model as part of such a resilience tool are being explored.

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The impact of flood on the socio-economic status of residents of Wadata and Gado-villa communities in the Makurdi metropolitan area of Benue State, Nigeria

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Abstract

The study examined the effect of flood on the socio-economic status of residents of Wadata and Gado-villa communities in the Makurdi metropolitan area of Benue State, Nigeria. A sample of five hundred and two (502) displaced residents consisting of males and females camped at St. Theresa Catholic and St. Catherine primary school, Makurdi participated in the study. A questionnaire consisting of six sections measuring demographic variables and impacts of flood on socio-economic status such as agriculture, education, health, housing, water and sanitation was used to collect data. The study established that flood impacted negatively on the socio-economic well-being of residents in the two communities. It is recommended that the government should provide a low-cost housing estate for the flood victims as they have expressed willingness to relocate from the flood prone area so that their children can go back to school as soon as possible. Further allocation of land for residential building in the flood prone areas should be stopped by the government and private land owners. The river banks should be converted to recreation centres and green areas.
Keywords: flood, socio-economic status, residents, Makurdi, Nigeria.

www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/DMAN130311

1 Introduction

Flood is one of the natural disasters that many at times resulted in direct loss of social and economic properties, physical injuries, to the extent of psychological injuries. Natural disasters threaten lives thus causing a lot of anxieties and fear in an individual. As observed by Nasir *et al.* [1], socio-economic impact of flood included the loss of and destruction of properties and life, which may eventually last for a short or long term. Serious floods in Nigeria are rare events and relatively “tame” when compared with those in other parts of the world. Their psychological impacts on health vary from between population for reasons relating to population vulnerability and type of flood events (Ahern *et al.* [2]). In August 2012, water released from Lagdo Dam located in the northern province of Cameroon which is up-stream of River Benue lead to increase in volume of River Benue and flooded several towns and villages along its course. These include Adamawa, Anambra, Edo, Taraba, Benue, Kogi, Bayelsa and Delta. The flooding resulted in over 10 deaths and loss of properties worth several millions of naira and displaced about 131,011 people (The Nation [3]). This is not the first time of such an occurrence, but the government of Nigeria is still yet to find a solution. Governments as well as the affected communities were taken completely by surprise at the severity of the event considering the fact that flood warnings were issued by the Nigeria Metrological Agency (NMET), National Emergency Management Agency (NEMA) and Federal Ministry of Environment to local residents but no action was taken. Areas that were never thought could be flooded were completely submerged in water for days.

The socio-economic impacts refers to all changes in the way people live, work, relate, organise and how these interactions have direct influence on means of livelihood, the purchasing and production power, mass migration and agriculture. More specifically, social impacts concern poverty, loss of life, health effects, loss of community cohesion, loss of time, changing attitudes, impoverish neighbourhood etc, which are difficult to quantify in monetary terms (Messner and Green [4]). On the other hand, the economic impacts include disruptions of clean water and electricity supply, transport, communication, education, health care services, reduction in purchasing power and loss of land value in the flood plains which can lead to increased vulnerabilities of communities in the living area. The additional cost of rehabilitation, relocation of flood victims and removal of property from flood-affected areas can divert the capital required for maintaining production.

Many people experienced a number of associated problems which contributed to the levels of stress suffered, such as problems with personal relationships (at home and at work), problems with employment as well as lack of understanding and sympathy from authorities and society in general. People in employment found it particularly difficult to cope with all the arrangements that had to be made for getting the house back in order (Awopetu [5]).

Studies have shown that socio-economic impacts of floods like the wide impact-survey in Scotland (Werrity *et al.* [6]) and the survey on flood experience in Belgium (Grinwis and Duyck [7]) flood victims experience intangible impacts

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as being even more severe than tangible impacts. This confirms the high cost of relief and recovery which may adversely impact investment in infrastructure and other development activities in the area and in certain cases may cripple the frail economy of the communities. Recurrent flooding in a region or state/nation may discourage long- term investments by the government and private sector alike. Lack of livelihoods, combined with migration of skilled labour and inflation may have a negative impact on a nation's economic growth. Loss of resources can as well lead to high costs of goods and services, delaying its development programmes.

The social economic impacts are experienced by different people in different ways. Against this background, therefore, this paper aims at assessing the impact of flood on socio-economic status of residents in two communities affected by the 2012 Makurdi flood, in Benue State, Nigeria.

2 The study area

Makurdi Metropolitan area is the capital city of Benue State and is located in the middle belt region (north-central) of Nigeria (6°45′–8°15′E, 7°30′–9°45′N). It has a population of 297,398 spread out over an area of 41,035 km^2 making it the most densely populated local government area in Benue State, with a mean of 257 people per km^2. It has a diverse cultural make-up, among which the following ethnic groups are prominent: Tivs, Idomas, Igedes, Hausas, Yorubas and Ibos (National Population Census [8]).

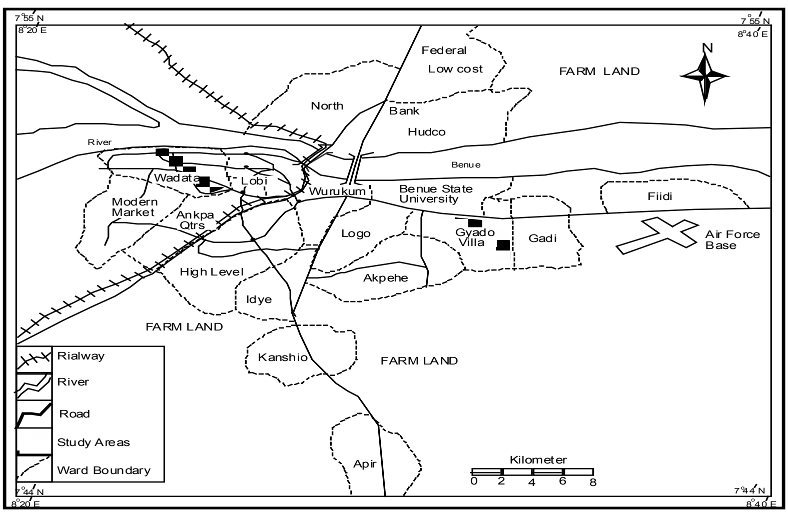

Figure 1: Map of the study area.

3 Method

The study which employed quantitative approach used sample consisted of victims of 2012 Makurdi flood. The victims were camped at St. Catherine and St. Theresa primary schools. A sample size of five hundred and two (502) victims participated in the assessment survey. A purposive sampling was adopted, this is because, according to Strydom *et al.* [9], purposive sampling is entirely based on the judgment of the researcher, in that a sample is composed of elements that contain the most characteristics, representative or typical attributes of the population.

3.1 Instruments

The instrument for the study was a household questionnaire. The questionnaire consisted of six sections measuring demographic variables and impacts of flood on socio-economic status such as agriculture, education, health, housing, water and sanitation is used to collect data. Section A measures demographic variables, section B measures flood impact on agriculture, section C measures flood impact on education, section D measures flood impact on health, section E measures flood impact on housing and section F measures flood impact on water and sanitation.

3.2 Procedure

A copy of each questionnaire was given to the respondents at the relief camps. Five hundred and fifty questionnaires were administered to the respondents, by the time of retrieval; only five hundred and two were retrieved due to inappropriate fillings of some of the questionnaires.

3.3 Data analysis

Simple percentages and frequency were used in analysing the data.

4 Results and discussion

Often mostly affected by natural disaster such as flood are women and children. More than half of the respondents interviewed (52.2%) were female and more than 8 out of every 10 respondents interviewed are married (Table 1). Health and sanitation was a big issue. The two camps set up in a government own schools had no bathing facility. Whereas the men and young children can take baths outside on the school lawn, women do not have that option. Many people did not have a chance to pick up their belongings when the floods hit their houses so they have no change of clothes. Many are wearing what they left home in and without being able to wash and women’s hygiene in particular has deteriorated. The situation is even worse for menstruating and pregnant women.

Also from table 1, it can be seen that respondents age were categorized into five different age groups and the greater proportion of respondent falls between

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the age group 26–30 (30.3%) followed by age group 41 and above with 24.7%, age group 31–35 accounted for 18.9% of the respondents, age group 18–25 accounted for 13.1% of the respondents and age group 36–40 is the closest age group to the least age group with the total of 12.9%. From the data above, it is crystal clear that adults in their productive age (26–40 years), which form 62.1% of the respondents, are affected by the flood. This will impact negatively on the economy of the study area most especially when a large percentage of the respondents are self employed (figure 2).

Table 1: Percentage distribution of respondent's socio-demographic characteristics.

Variables	Frequency	Percentage
Respondent's marital status		
Married	404	80.5
Single	66	13.1
Divorced	32	6.4
Total	502	100.0
Respondent's sex		
Male	240	47.8
Female	262	52.2
Total	502	100.0
Respondent's age group		
18–25	66	13.1
26–30	152	30.3
31–35	95	18.9
36–40	65	12.9
41 and above	124	24.7
Total	502	100.0

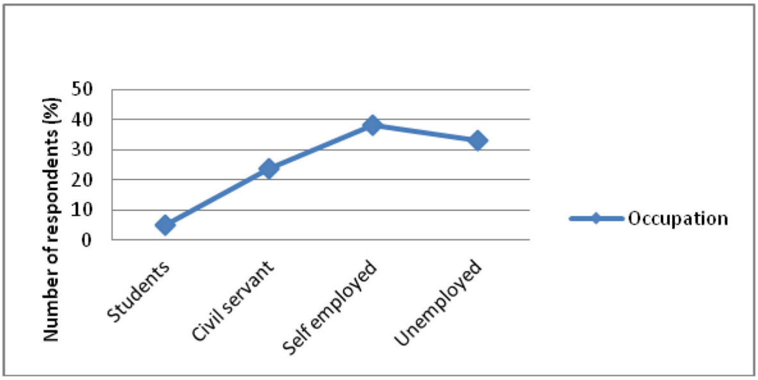

Figure 2: Occupational status of the respondents.

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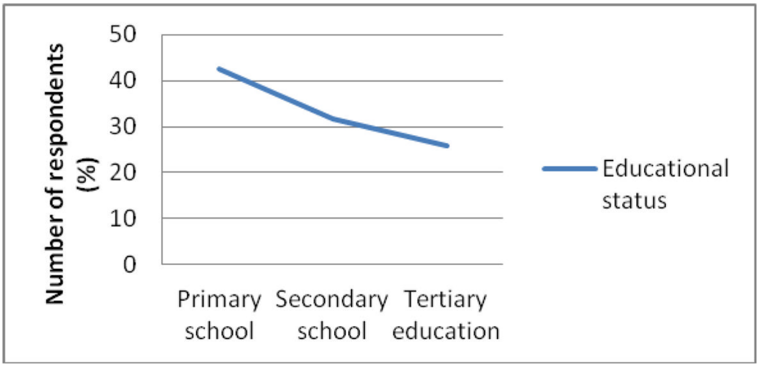

Figure 3: Educational status of the respondents.

Furthermore, the figure 3 shows that slightly above 4 in every 10 respondents are reported to have primary education (42.4%) which implies that the majority of the respondents interviewed have primary education, followed by the respondent who reported to have secondary education (31.7%), while the respondents with tertiary education has the least percentage (25.9%). The educational statuses of the respondents are low but it cannot be generalised that the educational status of the people that are affected by the flood are generally low. This is because, flood affected people with high educational status are either gainfully employed and therefore can afford to pay for temporary accommodation or relocate to live with friend temporarily.

The 2012 flood has inflicted severe direct and indirect damages on social; infrastructure and economic sectors of Makurdi metropolis. Close to half of the respondents (48.0%) reported that their houses were collapsed. About 12,000 people were displaced from their dwelling. A high number of deaths was not

Table 2: Percentage distribution of respondent's response on the impact of flood on agriculture.

variables`	frequency	Percentage
Household experienced crop damage as a result of flood		
Yes	342	68.1
No	160	31.9
Total	502	100.0
The main staple crop damaged as a result of flood		
Yes	360	71.7
No	142	28.3
Total	502	100.0
Household experienced loss of food stock as a result of flood		
Yes	481	95.8
No	21	4.2
Total	502	100.0

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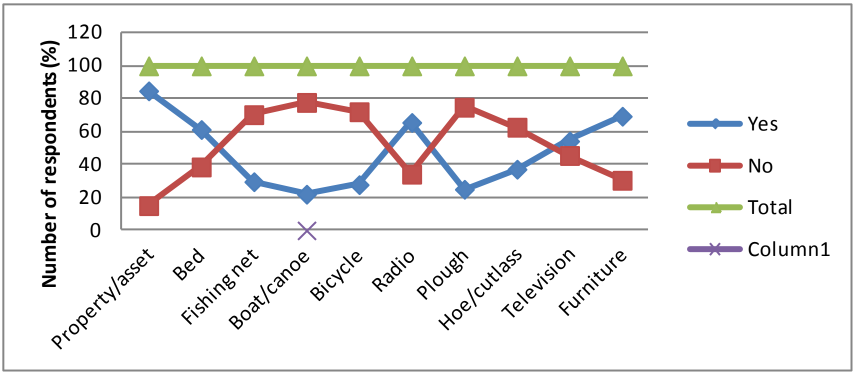

Figure 4: Percentage distribution of respondent's response on the impact of flood on housing/property/assets.

recorded because the flood gradually hit the town while people were opportune to remove some of their movable belongings. In spite of this, many people lost their fishing nets, canoes, furniture, electronics and plough (figure 4). It was also revealed from table 2 that close to 7 in every 10 respondents (68.1%) reported that their household experienced crop damage as a result of flood. More than 7 in every 10 respondents (71.7%) reported that their main staple crop was damaged as a result of flood. Similarly, majority of the respondents (95.8%) reported that their household experienced loss of food stock as a result of flood.

It can be seen from figure 5 that the educational facilities such as school buildings, learning material such as books and furniture were also affected. Worse still, majority of the respondents (73.1%) revealed that school going children in their household experience disruption in learning activities as well as school attendance for about three months due to the flood. More so, the table revealed that more than half of the respondents (53.6%) reported that road being impassable is the main reason why children in their household experience disruption in an attendance Also, revealed in figure 5 is that 44.6% of the respondents reported that bridge culvert washed away or submerged is the main reason why children in their household experience disruption in an attendance while 60.8% of the respondents reported that school submerged/surrounded by water is the main reason why children in their household experience disruption in an attendance.

*	Educational facilities is available in your area
**	School infrastructures were damaged due to flood
***	School going children in your household experience any disruption in an attendance due to the flood
****	Road impassable is the main reason why children in your household experience any disruption in an attendance

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***** Bridge culvert washed away or submerged is the main reason why children in your household experience any disruption in an attendance

****** School submerged/surrounded by water is the main reason why children in your household experience any disruption in an attendance

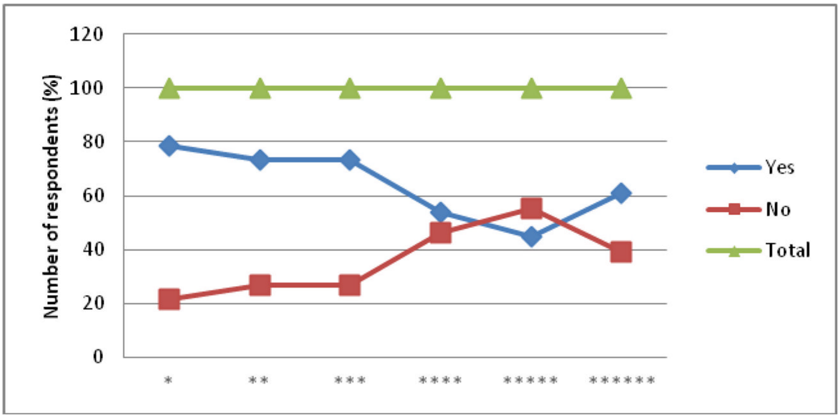

Figure 5: Percentage distribution of respondent's response on the impact of flood on education.

Health care facilities were not left out in the flood disaster. From figure 6, it can be seen that 61.2% of the respondents reported that health facilities available in their area where damaged due to flood. More than 6 in every 10 respondents (63.1%) reported that there is disruption in access to health service as a result of the flood. Furthermore, the figure 6 revealed that more than 8 in every 10 respondents (81.5%) reported that their household members get sick during the flood while 9.4% of the respondent specifically reported that diarrhea were experienced by their household member who got sick.

It can be seen from Table 3 that the majority of the respondents (25.5%) reported that river water is the common source of their drinking water, 21.1% of the respondents reported that protected well is their common source of drinking water while 18.3% and 16.5% of the respondents reported that borehole and unprotected respectively well are their common source of their drinking water. Close to 9 in every 10 respondents revealed that their source of water are affected by the flood while 13.1% of the respondents disagreed with the fact that source of water are affected by the flood.

Also, the majority of the respondents (69.5%) reported that traditional pit latrine is the type of sanitary facilities available in their area, 18.9% of the respondents reported that reticulated sewerage is the type of sanitary facilities available in their area while 10.0% and 1.6% of the respondents reported that VIP and others respectively are the type of sanitary facilities available in their area. More than 9 in every 10 respondents revealed that their sanitary facilities affected by the flood water while 4.8% of the respondents disagreed with the fact that sanitary facilities affected by the flood water in their area.

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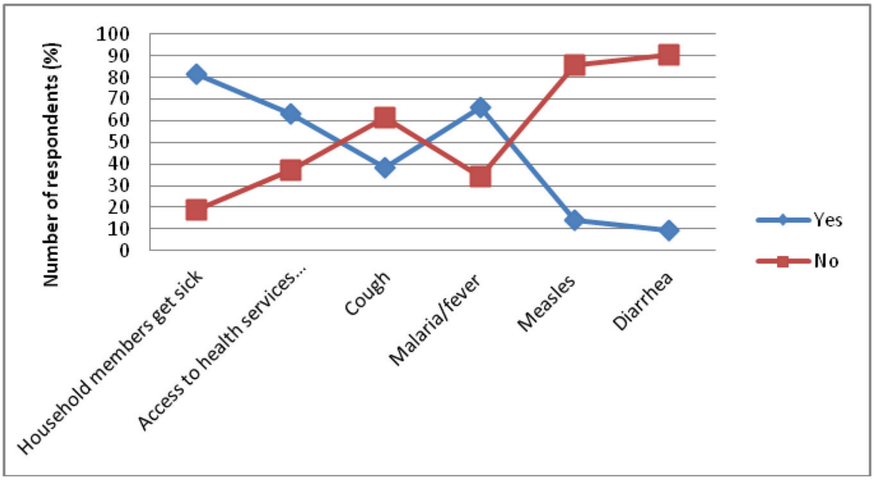

Figure 6: Percentage distribution of respondent's response on the impact of flood on health.

Table 3: Percentage distribution of respondent's response on the impact of flood on water and sanitation.

Variables	Frequency	Percentage
Common source of drinking water		
Borehole	92	18.3
Protected well	106	21.1
Unprotected well	83	16.5
River	128	25.5
Spring	21	4.2
Sachet/bottled water	72	14.3
Total	502	100.0
Source of water affected by the flood		
Yes	436	86.9
No	66	13.1
Total	502	100.0
Types of sanitary facilities available		
Vip	50	10.0
Traditional pit latrine	349	69.5
Reticulated sewerage	95	18.9
Others	8	1.6
Total	502	100.0
Our sanitary facilities affected by the flood water		
Yes	478	95.2
No	24	4.8
Total	502	100.0

5 Conclusions and recommendations

Flood waters carry nutrients and sediments, which are deposited on flood plains, enriching the soil reducing or obviating the need for nourishment through artificial fertilizers. Inundated areas retain soil moisture that helps raise crops without irrigation. Rice paddies are sometimes flooded deliberately to take advantage of this natural fertilization process. A river basin is an ecological unit interconnecting spawning habitats with rearing habitats for a variety of species and other aquatic systems. Seasonal habitats on the flood plain, created by variable flow regimes, are essential for various stages of the life cycle of species. Floods provide an ecological trigger for both the spawning and migration of certain species.

The river ecosystem is a critical habitat for the biota: fish, wildlife and waterfowl. Seasonal variability and variable sediment and flow regimes help maintain comparably high levels of biodiversity in rivers and flood plains. Wetlands or swamps located in flood plains serve as natural buffer zones for excessive flood flows and play host to many birds, fish and plants. Those areas can provide a number of ecosystem services and products such as water purification, food and fibre supplies and under certain circumstances (or antecedent conditions) flood mitigation benefits. Supplementary livelihoods in the form of recreational and eco-tourism activities can be made possible by the presence of the rich river ecosystem, bestowed with abundant flora and fauna. Surface runoff and flooding can help wash down pollutants and contaminants deposited on land caused by the intensive use of pesticides and fertilizers. They also flush out accumulated organic substances brought by untreated drainage water from farmlands, stockyards, factories and domestic use and restore the ecological health of stagnant river reaches and streams by diluting them and providing clean water.

However, immediate impacts of flooding include loss of human life, damage to property, destruction of crops, loss of livestock, non-functioning of infrastructure facilities and deterioration of health condition owing to waterborne diseases. Flash floods, with little or no warning time, cause more deaths than slow-rising riverine floods. In monetary terms, the extent of damages caused by floods is on the one hand dependent on the extent, depth and duration of flooding, and the velocities of flows in the flooded areas. On the other hand it is dependent on the vulnerabilities of economic activities and communities. The huge psycho-social effects on flood victims and their families can traumatize them for long periods of time. The loss of loved ones can generate deep impacts, especially on children. Displacement from one's home, loss of property, loss of memorabilia and livelihoods, decreased levels of security in the aftermath of floods and in temporary shelters, and disruption to business and social affairs can cause stress. The stress of overcoming these losses can be overwhelming and produce lasting psychological impacts.

The main conclusion is that most of the flood victims, having gone through serious hardship at their relief camps, felt that life had to continue. They were able to get back to their various houses and start life. While some were able to

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get back to work quickly, some are still finding it difficult to embark into normal life. It is therefore recommended that further study(s) should be conducted on the post flood assessment on the victims and traumatic experiences. Efforts should be made by government to create awareness on early warnings made by metrological departments.

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Community resilience factors to disaster in Saudi Arabia: the case of Makkah Province

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Abstract

Purpose: Saudi Arabia has recently experienced a number of natural disasters, including floods, epidemics and dust storms. Preparing a community to overcome disasters enhances its capacity to recover from potentially induced negative impacts. Therefore, building community resilience to disaster is a fundamental necessity for disaster management. The objective of this study is to identify the factors that can be used to improve readiness in Saudi Arabia in relation to disasters.

Methodology: This study is based on a questionnaire survey across 13 regions in Saudi Arabia and focuses on Jeddah city in Makkah Province as a case study given its experience with flooding, in particular ones that occurred in 2009 and 2010. The questionnaire was conducted in March for two months in 2012 and resulted in 267 responses.

Findings: The results show that a number of factors such as willingness and faith are essential to building community resilience to disaster. However, some factors which would assist in building community resilience, such as personal experience of disasters, are overlooked.

Research limitations: This research was conducted amongst people who have access to email, consequently not allowing access to those who do not.
Keywords: disasters, community resilience, Makkah Province, Saudi Arabia.

1 Introduction

Disasters are on the increase worldwide (Becken and Ren [1], Gaillard and Texier [2]). During the past 20 years, various part of the world have been affected by natural or man-made disasters which have a far-reaching impact on the lives of the people and can also result in considerable economic losses (Jafari

www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/DMAN130321

et al. [3], Becken and Ren [1]). Recovery from disaster can be impacted by a lack of community resilience, not just a poor or non-existent infrastructure (Barker [4]). Hence, greater importance is now given to developing the capacity of disaster-affected communities to recover from the aftermaths of disasters, with or without overseas aid (Bosher and Dainty [5]). Therefore, a change has been required in the disaster risk reduction culture, with a stronger emphasis being placed upon resilience rather than on vulnerability (Manyena [6]).

The importance of the concept of 'resilience' in disaster discourse was confirmed by the 2005 World Conference on Disaster Reduction (WCDR), and gave birth to a new culture of disaster response (Cimellaro *et al.* [7]). Thus, concepts relevant to resilience, such as 'sustainable and resilient communities', 'building community resilience' (Manyena [6]), 'disaster resilience' and 'community resilience' have become commonplace in academic articles (Castleden [8]).

A disaster resilient community is a community that can resist disaster and is able to take mitigation actions consistent with achieving the required level of protection (Cimellaro *et al.* [7]). Research identifies eight levers of community resilience: wellness, access, education, engagement, self-sufficiency, partnership, quality, and efficiency (Chandra [9]). Developing strategies and policies that develop these levers has been revealed as fundamental to the management of disaster by assisting communities to improve their ability to withstand and recover from disasters through undertaking activities (Godschalk [10], Tidball and Krasny [11], Chandra [9]).

Saudi Arabia is not widely known for natural or man-made disasters, despite the presence of volcanic and seismic areas (Al-Saud [12]); but since 2000, the rate of their occurrence has increased (Al-Saud [12], EM-DAT [13]). In recent years, floods have been the most commonly occurring natural hazard in the Kingdom (Al-Saud [12], Alshehri *et al.* [14]). One region prone to disasters is the highly populated Makkah Province (CDSI [15]). The latter forms the focus area of the research. It lies in the west of Saudi Arabia and has a population of more than 5 million (according to the 2004 census) distributed over an area of 164,000 km² (CDSI [15]). The biggest city is Jeddah which is also the main port of the region, while the holy city of Makkah is the capital (CDSI [15]). Several instances of the natural disasters have been experienced in this region including earthquakes, floods and dust storms (Al-Saud [12], Alshehri *et al.* [14]).

Additional hazards occur during the *hajj* (Islamic pilgrimage) or in the month of Ramadan when more than three million pilgrims visit the holy places in Makkah and Medina (WikiIslam [16]). This number of visitors in a confined area poses a significant challenge for the local authorities (Memish [17]). However, Alshehri *et al.* [14] mentioned that there have been a number of tragic accidents at the hajj which have led to considerable loss of lifes over the years. For instance, more than1,000 people were trampled in an overcrowded pedestrian tunnel leading to Makkah in 1990 (WikiIslam [16]) and 346 people died due to crowding at Jamarat Bridge in Mina in 2006 (WikiIslam [16]).

Although the government has a master plan in place to cope with disasters, this paper highlights factors that can be used to build a community resilience framework to disaster in Saudi Arabia.

2 Methodology

The main objective of this paper is to identify the factors which enhance community readiness in Saudi Arabia in order to reduce the negative impacts of disasters. Furthermore, to build community readiness, it is necessary to understand public perceptions about disasters in Saudi Arabia in order to start building community resilience to support disaster management in the country. Therefore, a questionnaire was designed which included classification questions, knowledge questions and responsibility questions. The design of the questionnaire was informed by a number of related surveys (Bird [18], PRRI [19], Spence *et al.* [20]). The questionnaire was hosted online using "SurveyMonkey" (www.surveymonkey.com) in both Arabic and English. Due to the geographic size of Saudi Arabia it is difficult to in cover the entire country; consequently, e-mail was used as the delivery method from March 2012 to the end of May (see (Alshehri *et al.* [14]).

3 Results and discussion

There were 379 questionnaires opened and 267 questionnaires completed. Among the respondents, the proportion of males was higher than that of the females. This is probably due to customs and traditions in Saudi Arabia which makes recruiting female respondents difficult (Zabin [21]). About 64% of respondents were married, of which 70% reported having children.

The assessment of community resilience has become a difficult process due to the dynamic interactions of people with their communities, the environment and their societies (Manyena [6]). Consequently, various conceptual frameworks have been proposed and developed in order to assess the resilience of community (Cutter *et al.* [22]). For example, a conceptual framework has four dimensions include: technical, organisational, social, and economic, and are used to assess resilience (Chang and Shinozuka [23]). However, another conceptual framework has been proposed for the development of community resilience that uses five capital dimensions. These are:

1. Social capital, such as social structure, trust, norms, and social networks.
2. Economic capital (financial resources that people use to achieve and maintain their livelihoods), including savings, income, investments, and credit.
3. Physical capital, which refers to the built environment, such as public buildings, business/industry, dams and levees, and shelters.
4. Human capital, such as education, health, skills and knowledge.
5. Natural capital, such as resources, stocks, land and water, and the ecosystem (Manyena [6]).

Paton [24] highlights several elements that can be measured to assess the resilience of a community at an individual (e.g. information and advice, personal and community support) and community levels (e.g. knowledge of hazards, shared community values), on the basis of how best to manage them. While, there are indicators have been proposed by The Disaster Resilience of a Place Model (DROP) such as Demographics (age, race, class, gender, and occupation), Social networks and Community values-cohesion, Faith-based organisations, Employment (Cutter *et al.* [22]).

The current study demonstrates that there are a number of factors which indicate a certain ability of the population to be resilient to disasters. For example:

Age: This is a positive factor in building community resilience. Several studies suggest that communities in which elderly people are a smaller proportion of the population are more resilient to disaster. This can be attributed to several reasons, including the ability of a younger population to learn and access relevant information, as well as having greater income resources to cope with disaster (Manyena [6], Cutter *et al.* [25]). This research confirmed that most of respondents are within the working age supporting the positive age factor in the process of disaster management. This result compatible with static figures of population in Saudi Arabia (CDSI [15]).

Education: Education levels are an important factor in improving community resilience for a number of reasons. First, the higher the education level the greater the ability is to access information. Second, it has been emphasised that educated people are more resilient to disasters and can also help in improving the community planning (Jafari *et al.* [3]). Third, the level of education is related to the ability to understand warning information. In this paper about 63% of participants had a university degree. However the results reveal significant clear differences in the level of awareness of generators of disaster (see Table 1).

Table 1: Respondent's knowledge of generators of disasters.

Generator of disaster	Response
Conflicts	75%
Earthquake	67%
Flood	68%
Epidemic	54%
Tsunami	46%
Tornado	40%
Volcanic eruption	38%
Landslide	31%

Economic: Economic development is an important contributing issue to building community resilience. It may be measured by many factors such as income, property value, and employment (Cutter *et al.* [25], Manyena [26]) Joerin *et al.* [27]). For example, wealth can be used directly to raise resilience through increasing the ability and capacity of individuals and communities to overcome the negative impacts of disasters. In terms of the survey, the income of most the participants is beneficial in the sense that there is no poverty. About 66% reported being currently employed and approximately 73% stated that their income was 6,000 Saudi Riyal (≈ 1.200$) per month or greater.

Risk perception: Several studies have proved that there is a direct relationship between risk perception and the disaster preparedness (Ainuddin [28]). Risk perception can determine the response of individuals or communities to disasters (Howe [29]). For instance, a community with low perceptions of risk are likely to cope poorly with disasters, while a community which has high risk perceptions tends to behave in a positive anticipatory way to build more disaster-resilient communities (Gaillard and Texier [2]).

In this research, participants were asked to indicate the extent to which they agree that people in Saudi Arabia are at risk from disasters and whether or not they are concerned about disasters. Almost two-thirds (61%) of respondents were concerned about disasters, indicating that they are 'fairly' or 'very' concerned, while 71% either agreed or completely agreed that there are risks to people in Saudi Arabia from disasters. Slightly more than 70% of respondents think that their region could be affected by disaster; however, the vast majority (80%) have never experienced a disaster.

The survey also assessed public perception of the causes of disasters and reality. 63% of respondents believe that disasters are caused by a combination of human activity and natural processes. Furthermore, the study shows the extent of respondents' knowledge of communicable diseases that can occur after a disaster. For instance, 82% of respondents believe that a new communicable disease can threaten their community, which is consistent with several studies (Leung *et al.* [30], Kamate *et al.* [31]). In addition, about 59% of participants think that people can take action to prevent the outbreak of a new disease in Saudi Arabia.

In spite of the lack of personal experience with disaster, the study proved that there is a high degree of disaster risk perception. This is a positive indicator for building community resilience to disaster.

Willingness: Community resilience is dependent on individuals and families within the community (Van Breda [32], Zauszniewski *et al.* [33]). When there is a great level of familial responsibility, the community is better placed to respond quickly and effectively to disasters (Kulig *et al.* [34]).

The study reveals that respondents are willing to learn more about disasters, thereby positively affecting their attitudes toward preparedness. For example, they believe that they have a responsibility to help their families during a disaster event. Moreover, they have a desire to contribute to reducing the risk of disasters, and have indicated a willingness to comply with the evacuation procedures under any circumstances (Figure 1).

Furthermore, all participants were asked to rank by importance resilience factors which increase the community's ability to cope with disasters. As Figure 2 illustrates that *Raising risk awareness* was chosen as the most important factor followed in order by *Early warning system, Disaster management, Evacuation plan,* and *Prosocial behaviour during disasters.*

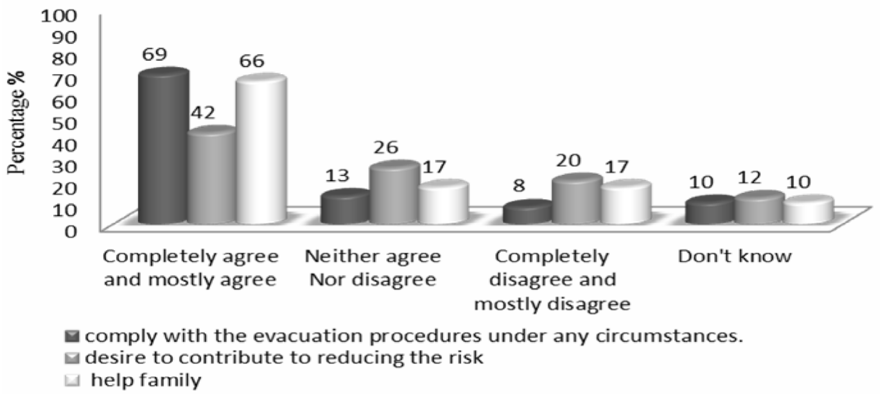

Figure 1: Responsibility towards disasters.

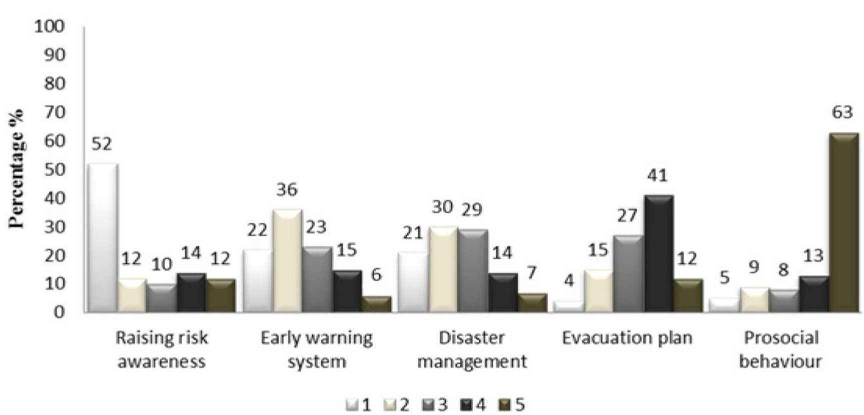

Figure 2: Ranking of resilience factors.

However, a number of respondents noted that all the options "have the same priority because they believe that people are not aware of these. Also, it is a combination of community, government and individual responsibilities". Thus, numerous respondents were either unaware of emergency procedures or do not know what to do in the occurrence of a disaster, as a result of lack of awareness and training.

Importantly, one of the most significant resilience factors is religious faith (Paradise [35]). This factor is high in this study for several reasons. First, Saudi Arabia is a Muslim society, with the Holy Qur'an forming the basis for its constitution (Madani *et al.* [36], CDSI [15]). Furthermore, religious subjects are taught at all levels up to and including university level (Prokop [37]).

The majority of the respondents believe that God controls the world and such disasters are a punishment from God. This result broadly aligns with other studies (Alam and Collins [38], Bhargava [39], Gaillard and Texier [2], Paradise

[35]), and is drawn from the Qur'an where it is stated "So We sent on them: the flood, the locusts, the lice, the frogs, and the blood (as a succession of) manifest signs, yet they remained arrogant, and they were of those people who were Mujrimûn (criminals)" (Qur'an [40]). However, unlike the other studies (Paradise [34]), this survey determined that the respondents in general display a willingness to cope with disasters (Alshehri *et al.* [14]).

Access to sources (information and knowledge): Knowledge includes the ability to search for information, which can be collected from various formal and informal sources such as news media, experts, government officials, friends and families (Howe [29]). Through an analysis of the results of this study, it is clear that a high percentage of the participants have the ability to access sources of information and knowledge using different methods. For example, the study proves that nearly 82% of participants using the internet, while 80% of respondents receive information from the TV. Moreover, 63% prefer to use cell phones as a source of receiving information and warnings about disasters. These findings are consistent with previous studies (Spence *et al.* [41]).

However, despite the high internet use, a high percentage of participants do not use official websites provided by government including Civil Defence and, the Ministry of Health. This may be due to the shortage of previous disasters in Saudi Arabia or the participants' lack of awareness of the sites (Alshehri *et al.* [14]).

The results clearly indicate that the respondents have the ability and willingness to participate in actions directed towards building community resilience.

4 Conclusion

The resilience concept has been considered in several frameworks as mentioned in the above discussion section based on factors that contribute towards raising community resilience to disasters.

This paper has attempted to identify community resilience factors in relation to explicit indicators at the local level in the context of disasters in Saudi Arabia. The public's perception to disasters was surveyed to asses if factors deemed necessary to building to community resilience were present in Saudi Arabia. These factors included *Age*, *Education level*, *Economic, Risk Perception, Access to sources and Willingness and Responsibility*. However, other important factors, such as lack of: raising awareness, training, and knowledge regarding information access to official websites, can decrease community resilience are also evident from the survey.

The results indicate that the willingness and responsibility of most respondents should present significant opportunities to engage community members with the preparation of responses to disasters and to encourage informed action.

This paper reveals that enhanced efforts are needed to build a community resilience framework to disaster in Saudi Arabia. This framework requires further research work using the Delphi Technique in order to gather data from respondents within their field of expertise so that community resilience towards disasters in Saudi Arabia is built.

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Housing policy in Mexico and its impacts

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Abstract

This paper attempts to demonstrate that while housing policy in Mexico is aimed at satisfying the needs of the construction sector and the demand for housing, it does not consider climatic effects, soil quality or consequences for the existing housing inventory. Therefore, the residential complexes built during the last 15–20 years are exposed to a number of threats including flooding, subsidence and crack, as well as hurricanes in the case of housing built along coastlines. There is an inconsistency between housing policy and the housing demand for low-income families, most of whom are unable to access public housing programs. The result is that, first of all, low-income families acquire land not suitable for construction, and are thus highly vulnerable to hydrometeorological and edaphological effects, and secondly, some housing developers acquire territorial reserves at a low cost, in order to increase their own benefits, but the land is not always suitable for housing construction. One case is presented in the current study in the Iztapalapa city district of Mexico City (Federal District), where residential complexes have been authorized without considering environmental impacts or existing hazards.
Keywords: housing policy, hazards, vulnerability, territorial reserves, Mexico.

1 Introduction

The guidelines for housing policy in Mexico have been established within the framework of plans and programs such as the 2007–2012 National Development Plan and the 2009–2012 National Urban Development Plan. One of the objectives defined by the latter is "to establish preventative actions and timely responses to natural hazards" and "to build dense, compact cities with a combination of compatible land uses." These objectives orient urban and housing policy.

www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/DMAN130331

The public strategy for supporting the construction of new residential complexes is manifested through bridge credit lines and through the challenge of building residential complexes that incorporate sustainability characteristics on a massive scale. To this end the public sector has created a program known as *Esta en tu casa* (This is your home), and since March 1, 2009, it has incorporated the condition that new housing units have a basic package of measures for minimizing the use of water, electricity and gas, with the aim of mitigating the effects of climate change and its negative consequences for the environment.
The response since 2001 from construction companies such as GEO, ARA, HOMEX, URBI, SARE, and the HOGAR consortium has been significant. In the state of Mexico alone, we find that from 1999 to 2009, a total of 555,722 housing units have been built, benefitting 2.5 million families.

However, not all of the residential complexes have been constructed in safe zones, and the housing built in coastal areas is vulnerable to hurricanes. In addition many housing developments have been built on land where all types of fissures have occurred, in areas where the land is sinking, and in areas characterized by flooding. The entities that issue building permits do not necessarily review hazard maps, when such exist, and many municipalities do not yet have this type of map.

National housing policy is oriented toward producing housing that will mitigate the effects of climate change, but there are no specifications or particular standards in building regulations. No specific consideration is given to anthropogenic or natural hazards in the process of constructing new housing developments.

In addition housing policy neglects approximately 60% of the population that does not have access to public programs (INFONAVIT and FOVISSSTE, SHF and FONHAPO), plus "environmental deterioration displaces poor people who end up living in hazardous zones" (WSF [1]). This population in need of housing has no other option but to occupy (through purchasing or invading) land that is unsuitable for construction. Consequently, every year approximately 90,000 households settle in hazardous areas with precarious modalities and located far from workplaces.

2 Housing policy in Mexico

The production of housing and especially public housing has increased notably since 2001. From January 2001 to December 2005, 3,394,973 loans and subsidies were granted in different program modalities. Of this number, 2,321,331 were granted for the purpose of acquiring housing, and 1,073,642 for housing improvement and other types of loans (CIDOC [2]). In terms of the private sector, mortgage loans granted by SOFOLES increased from 45,556 to 102,377 (+224%) from 2000 to 2005, and to 110,995 in 2007, and then dropped to 99,487 in 2008. Development Banks went from granting almost no loans at all to 55,537 loans in 2005; 54,119 in 2007; and 88,671 in 2008. As for INFONAVIT and FOVISSSTE, the number of loans granted increased from 458,701 in 2007 to 494,073 in 2008 [2], and from 70,528 in 2007 to 90,140 in

2008, respectively. In other words, a significant increase in the number of loans granted by all public and private credit institutions can be observed over a period of eight to nine years.

The housing market in Mexico is of a significant size, but in constant fluctuation. Following a major decline in 2009, housing construction (of individual houses, housing complexes and departments) began to increase again, beginning in 2010. The annual percentages of the GDP corresponding to housing from 2006 to 2011 were as follows [2]:

Table 1: Housing GDP for 2006–2011, annual percentage variation (Source: CIDOC; 2011).

Years	2006	2007	2008	2009	2010	2011
Annual % of GDP	17.6	7.8	9.6	-15.4	-1.9	5.6

There are approximately 4,370 housing construction and development companies in Mexico in 2011 [2]. Six of the eleven largest companies are listed on the Mexican Stock Exchange: GEO Corporation, ARA Consortium, HOMEX Developers, SARE Holding, URBI, and HOGAR Consortium. The volume handled by these six companies represents 1.4% of the GDP corresponding to housing construction for the second quarter of 2011. All of these are vertically integrated companies; they buy land, install services, build houses, and sell the houses with services, ready for applying for loans from credit entities. They have a long-term vision, with a policy of purchasing territorial reserves. Between 2005 and 2007, the value of GEO stocks increased from 27.35 to 64.25 (see Figure 1).

Figure 1: Value of GEO stock between 2005 and 2007 (source: GEO).

In the second half of 2011, GEO was the company with the most housing units with deeds, at 14,724, followed by Homex with 12,576 housing units, and URBI, which obtained deeds for nearly 9,000 housing units. The company with the most territorial reserves is Homex, with 8,020 hectares, followed by GEO and URBI, as indicated in the following table:

Table 2: Housing units and territorial reserves (2011).

Developer	Housing units with deeds (Number)	Territorial reserves (Hectares)
Geo	14,742	7,167
Homex	12,576	8,020
Urbi	8,932	5,690
Ara	4,387	4,450
Sare	837	862
Hogar	477	726
Total	41,951	26,915

(Source: CIDOC, 2011, with information from SHF and the Mexican Stock Exchange).

CIDOC [2] estimates that six of the 18 worst public housing complexes evaluated were built by GEO, according to information from a survey on housing satisfaction conducted in all Mexican states. The results of the survey are based on a "satisfaction with housing" index, which is the average weighed from the scores given to physical characteristics associated with construction, space and functionality, plus adaptations, transformations and environmental characteristics. The only scores that dropped from 2009 and 2010 were associated with environmental characteristics. This means that public housing is poorly adapted or adaptable to climate and the environment.

According to the CIDOC study [2], the number of housing units will increase by a factor of 1.5 from 2010 to 2040, from 28.6 million to 43.2 million, equivalent to 486,000 housing units every year. If we consider that 251 square meters of land are needed for each housing unit, there will be a demand for over 351,000 hectares of land suitable for construction. In reality this suitable land does not exist in cities or their peripheries. Government Housing Entities (*Organismos Estatales de Vivienda* – OREVIS) and developers alone have only 15% (52,650 hectares) of the total land needed, and it is supposedly suitable for building. Beginning in the 2040s, there will be excessive regularization of land to resolve the insufficient availability of land, and housing will be built on land vulnerable to flooding or exposed to threats such as land fissures and sinking, and hurricanes – even more than today. There will be a rise in the value of urban land suitable for construction (due to its limited availability), and developers will opt to use land unsuitable for building.

In the Strategic Guidelines for Housing in the 2007–2012 National Development Program, assistance for the segment of the population with housing needs is only planned in the case of natural disasters and in high-risk areas. A prevention-oriented phase of generating access for low-income families to land suitable for building is not considered.

There is currently intense pressure on land use from the increased housing demand caused by the growing young-adult population that has multiplied the number of households. According to the report entitled "Current housing situation in Mexico 2009," approximately 45,071 hectares of land will be needed by 2012 for the segments of the population earning less than three minimum wages. This represents 54.4% of total land requirements primarily in urban localities. And this means that 3.988 million dwellings will be needed over the next five years (see Figure 2).

Figure 2: ARA Complex in Puebla (source: ARA).

Water-related conflicts in the state of Mexico demonstrate that urban planning has a determining role in social risk construction, with the latter understood as a process of decision-making based on knowledge derived from the connection between natural and social sciences. Deficiencies in this connection, the absence of its transformation into coherent territorial ordering and public policies, and inconsistency in its implementation are all determining factors in increased urban vulnerability, and thus, risks from natural and human-caused disasters. Housing policy in Mexico plays a part in this inconsistency, and thus contributes to social risk construction.

3 Hydrometeorological hazards for the existing housing (formal and informal) inventory

Socially produced housing, as well as dwellings financed by public housing entities, are more vulnerable to geological hazards (land fissures, land sinking), because they are built on land acquired at lower cost. They are also highly vulnerable to hydrometeorological phenomena such as hurricanes and flooding because they are not sufficiently adaptable to climate variability. Few processes of adaptation to climatic phenomena and threats have been integrated into social housing production thus far. Housing designs are very similar in all types of settings. The satisfaction survey cited earlier in this document indicates a deficiency in the designing of public housing with respect to environmental adaptation.

Vernacular dwellings in Mexico are more adaptable to these phenomena. For example, the Mayan dwellings used in the Yucatan have roofs adapted to the strong winds from hurricanes. Also, some Chontal homes in flood-prone areas of Tabasco are permanently built on piles. Another problem encountered is that hazard zoning maps – when they exist – are not always issued by those responsible for urbanization, and the latter tend to view them as more of an obstacle than an important tool.

According to Hernández Cerda *et al*. [3], the main areas considered to be the most vulnerable to hurricanes are the following:

- Peripheries of urban areas, since there are few buildings to reduce wind velocity. Generally, peripheral areas are those where precarious dwellings are found and are the first to suffer damages.
- Zones in which a localized increase in wind is expected due to topographic characteristics, such as areas located on rising slopes.
- Tall or high-altitude buildings may receive gusts of wind up to 250 kilometers per hour.
- Areas where strong wind currents develop, as in canyons and narrow streets.
- Areas with ocean exposure, such as tourist areas and hotels, are the most vulnerable. It is worth mentioning here that Mayan dwellings in the Mexican Caribbean region are not traditionally built in exposed areas along coastal areas.

Precipitation produced by hurricanes in the Caribbean region are sometimes extreme (accumulations above 400 mm in a single day) and produce flooding, especially when there are limited areas where seepage may occur. The main threat from intense rainfall in rural areas is the possibility of landslides and mudflows, as in the case of Hurricane Stan in 2005 in Chiapas, particularly in Motozintla. In addition, housing located along the Cancún coastline are particularly exposed to ocean swells, wind and flooding.

The Mexican Institute of Water Technology (*Instituto Mexicano de Tecnología del Agua* – IMTA), in its analysis entitled "*Análisis de posibles impactos del cambio climático* (Analysis of possible impacts of climate change) [4], recommends implementing regulations for appropriate construction in the Caribbean region near Cancún:

- Non-structural elements (finishing details) are very fragile when exposed to strong winds. The use of *cortinas* designed to provide protection from extreme winds is recommended.
- Hotels and buildings located near the Caribbean Sea should be designed or redesigned to consider the possibility of the combined effects of storm tides and surges from extreme hurricane conditions (with wave heights up to 14 meters).

According to Magaña and Gay García [5], there are approximately 18 million inhabitants at this time living in areas at high risk of flooding. This means that one-fifth of the country's population has one of the highest degrees of vulnerability to climatic variations caused by *El Niño*/*La Niña* events or tendencies toward increased extreme hydrometeorological events caused by the earth's warming, such as more severe hurricanes, for example. The main causes of flooding are the overflowing of rivers, intense tropical rains and hurricanes accompanied by torrential rainfall. In Mexico, three states are particularly affected by intense rainfall. Specifically, Chiapas, Tabasco and Veracruz already receive between 1,500 and 2,500 mm of annual average precipitation, and these levels will increase further with climate changes. The case of Tabasco in October 2007 (with 80% of the state flooded) is a perfect example that illustrates the effects of socially and politically constructed vulnerability and points to the significance of climate change.

The main effects from flooding on habitats are generally irreversible in the case of precarious and traditional dwellings (made from wood, corrugated cardboard or materials such as adobe and *bajareque*). Adobe constructions cannot resist flooding for very long, because clay has a very high absorption coefficient and it turns into mud. Dwellings along riverbanks are the most seriously exposed (especially if located on a former riverbed). The risks increase with the growth of human settlements in flood-prone areas, and due to modifications in land surfaces, such as destruction of vegetation and soil erosion (Lugo Hubp and Inbar [6]). Cities and urban areas in general are prone to flooding because natural surfaces that allow for water seepage are very limited (only parks and gardens, etc.).

4 The case of housing in Iztapalapa

The case of the Iztapalapa district of Mexico City is interesting because it is the city district with the greatest population and the most hazards, including flooding, standing water, subsidence and crack Overpopulation in this city district has spread extensively throughout its territory, including areas characterized by more serious hazards, such as areas with uneven terrain and geological faults, making them unsuitable for urban development (PDDU [7]). The population is therefore highly vulnerable. Iztapalapa is perhaps the city district in which the most residential buildings have been established, and on extremely unstable soil. Building permits for residential complexes have been issued since the 1960s without requiring developers to conduct technical soil testing. Consequently, 716 residential complexes have been built, and are distributed throughout the district: 12 in Santa Catarina; 135 in Paraje San Juan; 47 in Ermita Zaragoza; 72 in Cabeza de Juárez; 83 in the Centro; 128 in Aculco; and 239 in San Lorenzo. The 2005 Census calculated a population of 1,820,888 inhabitants residing in 441,334 housing units in this city district. According to INEGI, most of the housing in this district consists of *vivienda en conjunto* (housing complexes) and *casa independiente* (single houses) (69.48% and

18.48%, respectively), with the rest distributed among what may be considered to be inadequate types of housing.

The problem of housing with the potential for hazards is found in neighborhoods located in mined areas, with geological faults running through, or on unstable soil of lacustrian origin. In neighborhoods such as Santa Cruz Meyehualco, Ejército de Oriente zona Peñón, José María Morelos y Pavón, Vicente Guerrero, and Ermita Zaragoza, the main hazards are derived from geological elements, from the readjusting of tectonic layers or fissures in the subsoil (PPDU [7]). It is estimated that 50% of the land surface in the city district is located in a lacustrian zone (Lagos de Chalco-Xochimilco and Texcoco). This means the land is of poor quality for constructing buildings, and thus housing built by owners may be at risk (PDPC [8]). This also signifies that a large number of residential complexes that complied with the provisions in building regulations at the time of construction do not comply with current provisions with respect to the resistance and deformability that must be maintained in order to tolerate the effects from high-magnitude earthquakes.

Approximately 40% of the territory in the Iztapalapa district is affected by problems associated with the risk of land fissures, subsidence or giving way, mining cavities and unstable slopes, affecting 1,746 constructions, primarily residential buildings, and representing an element to be considered in future constructions. Due to differential sinking in the district's territory and deficiencies in the sewage systems, areas at risk due to flooding and standing water have been detected, affecting the population's health, assets and traffic (Atlas de riesgo, Delegación Iztapalapa [9]).

In 2005 a total of 1,746 housing units with detectable cracks in seven neighborhoods were identified. Most of the housing units affected are in residential complexes, as mentioned in Table 5. In 2012 property taxes were cancelled in 22 neighborhoods and residential complexes in Iztapalapa due to structural damage. Specifically: "The Mexico City government will cancel property taxes for those owning or possessing property with structural damages caused by land fissures or sinking" (*El Universal*, October 2012).

The problem is so severe that not a great deal can be done technically except to demolish the damaged homes or buildings. In some cases buildings have been temporarily vacated, as in the case of Unidad Habitacional Juárez 34. Specifically, after structural damage was verified in buildings "H" and "J" in a technical report prepared by the Center for Monitoring Fissures in Subsoil, Iztapalapa's Civil Protection Unit initiated efforts to evacuate the buildings, each of which contained 20 apartments. With assistance from the Iztapalapa local government, inhabitants began to evacuate their apartments. Each apartment owner received an economic subsidy of approximately 3,000 pesos a month from the Natural Disaster Fund (*Fondo de Desastres Naturales* – FONDEN), in exchange for leaving the building and renting other housing during the process of leveling the buildings. For a period of six months, apartment owners received this economic assistance on a regular basis. After that, delays in the bank deposits began, and then the necessary budget for granting this subsidy was no longer available. Consequently, some inhabitants decided to return to their apartments (12 apartments in all) and reside there once again, despite the recommendations made by the Center for Monitoring Fissures in Subsoil (Sánchez Chávez [10]).

The housing situation in Iztapalapa is, to some degree, the consequence of a housing policy that has permitted the construction of residential complexes since the 1960s (by INDECO) without the necessary soil analysis. Furthermore, due to the ongoing extraction of underground water, the problem has intensified and caused more sinking of land and more fissures, and thus more damage to buildings.

5 Discussion and conclusions

Although elements of climate change have been taken into consideration in housing policy since 2009, through the program known as *Esta es tu casa*, with a basic package of measures for minimizing use of water, electricity and gas, there is inconsistency between urban planning (urban development plans) and housing policy, which is designed for major construction companies, to enable them to make huge profits with support from public housing programs (INFONAVIT, FOVISSSTE, etc.). Government financial assistance, with the goal of reaching 40% of the population, was achieved as a result of the Program for Financing Schemes and Federal Subsidies for Housing (*Programa de Esquemas de Financiamiento y Subsidio Federal para Vivienda*) (2007). The objective was to facilitate housing for families earning four minimum wages (6,000 Mexican pesos a month) or less, representing 40% of the population.

The real estate business operates in such a way that in its initial stage, large land plots are purchased without utilities and located on the periphery of cities, without any real concern for the possibility of natural threats or hazards. Then, the land is urbanized and numerous residential complexes are established, typically with a model for a standard of living in accordance with low and middle-income housing. In terms of land use, the major developers involved have a long-term vision with a business perspective, and have specialized departments for acquiring and administering land, consistently looking for profitable purchase opportunities.

Both the disappearance of direct subsidies for acquiring land and housing, and reforms made to the public entities responsible for low-cost housing (basically FONHAPO and INFONAVIT) – with the objective of enhancing their financial and operational efficiency – have led to restrictions on access to financing for acquiring housing, affecting workers with minimum income levels and those who are underemployed, and have led to practically the complete disappearance of public assistance for acquiring low-cost housing and for helping individuals build their own housing.

For nearly a decade now, the incorporation of land in urban development – in the terms anticipated by urban development plans in population centers and particularly dedicated to low-cost housing – has been regulated almost exclusively by criteria dictated by the real estate market. For the population with the greatest housing needs, the fewest economic resources, and the aspiration to

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obtain financing for their housing, this has signified being abandoned outside the market's formal channels.

Given the minimal participation by programs for progressive housing and improvement, and considering that nearly two-thirds of the housing inventory in Mexico and over half of new housing constructed corresponds to housing built by the individuals who own it, it is clear that a significant sector of the population is not receiving the attention it requires through the current financing schemes. If we also consider the fact that 75% of the housing in the entire country is in need of some level of repair, including 14% that most likely needs to be completely replaced, the problem is indeed serious and we may conclude that existing housing is characterized by a high level of vulnerability to hydrometeorological and edaphological phenomena.

By orienting housing policy to a limited sector of the population (new housing for middle-class families), for the benefit of major developers, the housing units requiring improvements or replacement have been neglected during the last two six-year presidential terms, and therefore 75% of housing in Mexico is vulnerable to hydrometeorological events and earthquakes.

The goal of this paper has been to demonstrate the way in which risks may be socially constructed through policies. The case of housing policy and hydrometeorological and edaphological risks (in the case of Iztapalapa) has been presented here. However, the same exercise could be conducted with other policies, such as hazard management policy, which is focused more on emergency situations than on prevention, and in this way contributes to social risk construction.

Acknowledgements

The author expresses his appreciation to the institution that made this research possible: the SIP at IPN (SIP No. 20121231).

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Volunteers in emergency management: an investment in the future?

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Abstract

There are currently two interconnected and conflicting challenges in many countries in the world: emergency and disaster preparedness and the public finance crisis. Volunteers are a valuable and necessary resource for emergency and disaster management. This paper deals with various experiences and emergencies in the Czech Republic in which the nonprofit sector is significantly involved. The aim of the paper is to identify the scope of Czech emergency volunteering and its role in the national Integrated Rescue System (IRS). The Czech IRS is a well-established system based partly on volunteers. The volunteer-to-professional ratio is nearly 12 to 1 for firefighters and about 3.6 to 1 for the mountain rescue service; the water rescue service consists exclusively of volunteers. Moreover, hundreds or thousands of people volunteer during large floods. The scope of volunteer engagement during emergency situations can also be illustrated through estimates of its economic value. The Czech Republic saves public finances for operational expenditures of parties of the IRS, because these costs could be lowered with volunteer participation. It is possible to consider past investments in emergency volunteering as investments in the high-functioning IRS. Analogically, current investments in emergency volunteering can and should be considered as investments in sustaining the current activities of the IRS. The Czech model should be explored more thoroughly; it could be interesting for other countries with problems in emergency and disaster response, especially countries that need to reduce public expenditures.
Keywords: volunteers, emergency management, investments, the Czech Republic, rescue system, economic value of volunteering.

www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/DMAN130341

1 Introduction

An overwhelming majority of countries throughout the world are coping with two problems: emergencies or even disasters and the financial crisis. Countries spend public funds to resolve the consequences of emergencies and disasters; however, the financial crisis creates pressure to decrease public expenditures. In this situation, another, non-monetary source comes into consideration to address emergencies and disasters, which is volunteering.

Currently, emergency volunteering is most commonly done through volunteer organizations (non-governmental, non-profit organizations – NGOs). The existence of these organizations is influenced by national policies. Communism was installed in a considerable part of the world in the past century. Palubinskas [1] wrote that the implementation of communism in Central and Eastern Europe resulted in the virtual elimination of NGOs. The NGOs that were not dissolved by communist regimes gradually came under their control. Although some NGOs continued operating, for example the Czech Red Cross and Caritas, they were not truly NGOs because they were not independent of the state. After the fall of communist regimes, these organizations had to learn to function as NGOs again, which means, among other things, that they had to acquire a private character and be independent of the state.

The Czech Republic is a former Eastern bloc country where the communist regime collapsed in November 1989. Czech NGOs, including humanitarian ones, were in a kind of stasis then. Large-scale flooding requiring massive humanitarian aid had not occurred in (then) Czechoslovakia for decades, and humanitarian aid in the country had been fully under the baton of the state during the communist regime (Rektořík *et al*. [2]).

Volunteer firefighting continued in the Czech Republic under the communist regime and this tradition has continued to a considerable extent to the present day, and volunteer firefighters form an integral part of the firefighting service in the Czech Republic (Kavan *et al*. [3])

Apart from ordinary emergencies such as fires and traffic accidents, the Czech Republic also has to cope with accidents occurring in its mountains and on its watercourses (rivers, lakes, dams, etc.). These are areas where volunteers play an irreplaceable role performing rescue work.

The most devastating natural disasters in the Czech Republic are floods. The Czech Republic was hit by eight large floods between 1997 and 2010, with 116 casualties and damages costing close to CZK 172 billion (about EUR 6.65 billion) (Rektořík *et al*. [2])

NGOs and their volunteers have become an integral part of the Integrated Rescue System. Their activities require funding, or they cannot in some matters further develop their operations. The costs for volunteers include insurance, training, etc. For specialized volunteers, such as volunteer firefighters and rescue workers, the costs additionally include equipment. These costs are partially covered by donations and partially from public sources.

Enormous progress has been recently made in methods for measuring the economic value of volunteering. For example, Stiglitz *et al*. [4], Waring [5], and

Soupourmas and Ironmonger [6] concluded that traditional indicators such as GDP are insufficient measures of contemporary economic performance. These traditional indicators do not include values other than market production, such as volunteering, which has its own specific value, as noted by Sues and Wilson [7], Emanuele [8], Steinberg [9], Femida and Narasimhan [10], Brown [11], Ross [12] and Montmarquette and Monty [13]. According to Salamon *et al*. [14], Colman [15], Soupourmas and Ironmonger [6] and Novák [16], the value of volunteerism is measurable and it is advisable to measure it. For this reason, the economic value of volunteering will be estimated in selected cases in this article.

The objective of this article is to identify the scope of volunteer engagement during emergencies in the Czech Republic and the role of volunteerism in the country's Integrated Rescue System (IRS).

2 Materials and methods

The role of NGOs in the IRS will be identified through the links between NGOs and their volunteers within the IRS, in terms of both the legal (theoretical) and factual (practical) aspects. The scope of volunteering in emergencies will be determined by comparing the number of volunteers to the number of paid staff in a specific area and by estimating the economic value of selected types of volunteering.

The work methodology is based on bibliographic research and research of available internet resources and on estimations of the economic value of voluntary work during emergencies.

The estimations were made using the methodology of the Czech Statistical Office, which is in compliance with the International Labour Organization (ILO) methodology [17]. The approach measures inputs in the form of volunteer work by means of replacement costs, when the selected type of replacement cost is the generalist wage. This approach was selected for its analytical simplicity. Basically, this evaluates the time invested by volunteers as the main input of their work. The replacement wage is the median hourly wage in the non-profit sector. Two basic types of data are required for calculation: the number of volunteer hours and the replacement median hourly wage in the particular economy or, more specifically, in its non-profit sector. In the Czech Republic, this data is available in the Average Earnings Information System kept by the Ministry of Labour and Social Affairs.

The calculation involves multiplying the number of volunteer hours by the replacement hourly wage.

$$V = t * w \tag{1}$$

V The economic value of volunteering;
t The number of volunteer hours;
w The replacement median hourly wage in the given economy.

This method may be used to estimate the values of volunteer work performed both by volunteers of individual organizations and the whole volunteer sector during emergencies when we have necessary data available. However, a substantial lack of data on volunteer hours is a problem in many countries, including the Czech Republic. The examples mentioned in this paper are exceptional. Although figures concerning total volunteer hours are not available in some cases, they may be count on the basis of the figure about the total number of volunteers and the number of volunteer hours which the volunteers were working per day.

The paper uses the definition of volunteering by Salamon *et al*. [14] and the ILO [17], according to which volunteering is "unpaid non-compulsory work; that is time individuals give without pay to activities performed either through an organization or directly for others outside their own household."

3 Results

Emergency volunteering is practically a phenomenon in the Czech Republic. Thousands of volunteers are involved during any large-scale flooding, and tens of thousands more annually serve as volunteer firefighters and rescue workers. We present the role of volunteers during emergencies in the Integrated Rescue System (IRS) of the Czech Republic and the scope of the volunteering.

3.1 The role of volunteers in IRS

The Integrated Rescue System of the Czech Republic is not an institution, state agency, association, or legal entity. It is a system of connections and rules for cooperation and coordination of rescue and safety forces, public administration bodies, natural persons, and legal entities in jointly performed rescue and clean-up operations and emergency preparation. It is governed by Act 239/2000 Coll., on the Integrated Rescue System (IRS) [18].

The Act provides for the main and subsidiary components of IRS, classifying non-governmental non-profit organizations (NGOs) among the subsidiary components that may be used for rescue and clean-up operations. The NGOs use volunteers for these activities. Results from previous research (Dostál [19]) indicate that the engagement of NGOs and volunteers in the IRS is both theoretically possible and implemented in practice. Volunteer firefighters and paramedics are usually directly involved in rescue operations, and the "standard" volunteers are involved in flood clean up or in providing humanitarian aid, with the NGOs mediating their assistance often involved in regional or municipal emergency plans. Through their representatives, volunteer NGOs participate in meetings of respective task forces and the Panel, a coordination platform where representatives of NGOs and the public administration meet to coordinate the assistance provided by NGOs, including volunteer aid.

3.2 The scope of volunteering during emergencies in the Czech Republic

The scope of volunteering during emergencies in the Czech Republic will be shown by numbers of volunteers and by measuring the economic value of their work. The economic value will be based on the methodology of the Czech Statistical Office which complies with the methodology of the ILO [17].

3.2.1 "Standard" volunteering during floods

These volunteers perform activities that are mostly unqualified in terms of knowledge and skills, such as waste matter removal, cleaning operations, monitoring of the situation, assistance in distributing in-kind aid, assistance in organizing in a specific municipality, or supporting (listening to) people affected by flooding (Koláček and Diatková [20]). Thousands of volunteers participate under various NGOs during any large-scale flooding. Two examples of such engagement with the necessary data available are People in Need, a non-governmental organization, during the floods in 2002, and ADRA in 2010.

3.2.1.1 Volunteers of the people in need during the floods in 2002 More than 3,000 volunteers, working a total of about 150,000 volunteer hours, were engaged through the People in Need during the floods. [21] We use the equation in the Materials and Methods section to measure the economic value of those volunteers. The total number of hours was 150,000, and the replacement median hourly wage for 2002 was CZK 90.15 [22].

$$\mathrm{TV} = 150{,}000 * 90{,}15 \tag{2}$$
$$TV = 13{,}522{,}500 \tag{3}$$

The estimated economic value of volunteers of the People in Need during the floods in 2002 is CZK 13,522,500 (about EUR 523,013).

3.2.1.2 ADRA volunteers during the floods in August 2010 The exact number of volunteer hours for ADRA during the 2010 floods is not known, but it can be calculated. Chodurová [23] states that ADRA sent out more than 1,200 volunteers during these floods, hence we will proceed from the presumption that there were 1,200 volunteers of ADRA. The volunteers operated in the Liberec region from August 7 to September 11, 2010, with a median number of four 8-hour days per volunteer [23].

Tt	The total number of ADRA volunteer hours during the floods;
1,200	The total number of ADRA volunteers during the floods;
4	The median number of ADRA volunteer days during the floods;
8	The average number of ADRA volunteer hours during the floods.

$$\mathrm{Tt} = 1{,}200 * 4 * 8 \tag{4}$$
$$\mathrm{Tt} = 38{,}400 \tag{5}$$

The estimated number of volunteer hours worked by ADRA volunteers is 38,400. The replacement median hourly wage for 2010 was CZK 137.34 [24]. We use those figures to estimate the economic value of ADRA volunteers during the floods in August 2010.

$$\mathrm{TV} = 38{,}400 * \ 137.34 \tag{6}$$
$$\mathrm{TV} = \ 5{,}273{,}856 \tag{7}$$

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The estimated economic value of the volunteers in 2010 is CZK 5,273,856 (about EUR 203,978).

These two examples serve to illustrate that even volunteering in the form of unqualified activities implies a considerable economic value.

3.2.2 Volunteer rescue workers

There are a number of volunteer rescue workers in the Czech Republic. The two main types, mountain rescue service and water rescue service, are described in detail below. Rescue workers providing specialized services in various situations, such as disasters and cave accidents (speleological rescue service), emergencies requiring dog experts (rescue brigades of cynologists), etc. also operate in the Czech Republic.

3.2.2.1 Mountain Rescue Service The Mountain Rescue Service of the Czech Republic has about 110 professional and approximately 400 volunteer members [25]. This means that there are about 3.6 volunteer rescue workers per one professional. Their work is highly specialized; the mountain rescue service members include various specialists.

To estimate the economic value of volunteers for the mountain rescue service, we need to know the total number of hours they worked. The figure is not available, but it may be estimated.

Approximately 400 volunteers operated in the mountain rescue service in 2011 [25], although there are no available data on the number of hours they worked or estimates of the economic value of their work. Volunteers of the mountain rescue service work 20 to 25 days a year on average; we will use the average of those numbers: 22.5 days a year. The working day of a volunteer usually lasts 8 hours [26]. We multiply the estimated total number of volunteer hours (Tt) with the replacement hourly wage, which was CZK 140.75 for 2011 [27].

$$\mathrm{TV} = 72{,}000 * 140.75 \tag{8}$$

$$\mathrm{TV} = 10{,}134{,}000 \tag{9}$$

The estimated economic value of volunteer work performed by volunteers of the mountain rescue service in 2011 is CZK 10,134,000 (approximately EUR 391,955).

3.2.2.2 Water Rescue Service This is another area where volunteer rescue workers are significantly engaged. With 1,450 members, the Water Rescue Service of the Czech Red Cross (WRS CRC) is the main player in this field [3]. There are no professional water rescue workers in the Czech Republic; therefore the water rescue service in the country is performed exclusively by volunteers. Data about the number of adult volunteers of the Water Rescue Service and the hours they worked are available for 2004.

In 2004, 770 adult volunteers worked 72,907 hours for the Water Rescue Service and according the estimate of WRS CRC, the property valued at several millions of CZK was rescued [28]. Let us however have a look now at the estimate by means of the methodology of the Czech Statistical Office. The replacement median hourly wage was CZK 106.73 for 2004 [29].

$$\mathrm{TV} = 72{,}907 * 106.73 \quad (10)$$

$$\mathrm{TV} = 7{,}781{,}364.11 \quad (11)$$

The estimate of the economic value of volunteers of the Water Rescue Service of the Czech Red Cross for 2004 is CZK 7,781,364.11 (approximately EUR 300,961).

3.2.2.3 Volunteer firefighters Currently, there are about 75,000 volunteer firefighters in the Czech Republic plus more than 300,000 other members of the volunteer firefighters association. There are about 9,000 professional firefighters in the Czech Republic, out of whom approximately 6,400 are those who are going to intervene to in case of emergency (Dostál and Hrůza [30]). Significance of volunteer firefighting will be explicated using the example of the district of Mělník, comprising nearly one hundredth of the territory of the Czech Republic. The following table provides detailed information about the district.

Table 1: Volunteer firefighters in the district of Mělník within the context of the Czech Republic.

	District of Mělník	CR	Ratio
Area	701.08 km^2	78,867 km^2	1/112
Inhabitants	104,169 km^2	10,505,445 km^2	1/101
Number of volunteer firefighters	3,768	75,000	1/20
Number of hours worked	26,448	N/A	N/A
Number of volunteer firefighters units	31	N/A	N/A
Number of interventions by volunteer firefighters	548	N/A	N/A
Volunteer work value (CZK)	CZK 3,598,779 (EUR 139,190)	N/A	N/A

Source: drawn up by the authors on the basis of [31].

This component of volunteer firefighting in the Czech Republic was selected due to the availability of aggregate data at least for one whole district. Usually, data about the number of volunteer hours are inconsistently available and only for individual units.

We know the number of volunteer hours, and the replacement median hourly wage was CZK 136.07 for 2012 (the 1st term) [32].

$$\mathrm{TV} = 26{,}448 * 136.07 \quad (12)$$

$$\mathrm{TV} = 3{,}598{,}779.36 \quad (13)$$

The economic value of firefighters in a single district of the Czech Republic was CZK 3,598,779.36 (approximately EUR 139,190). However, there are about 20 times more volunteer firefighters in the Czech Republic. Hence, the economic value of volunteer firefighting in the whole Czech Republic is certainly higher. If all volunteer firefighters in the Czech Republic worked on average the same number of hours, the economic value of all volunteer firefighters in the Czech Republic would be CZK 71,975,587.2 (about EUR 2,783,816).

4 Conclusion

Volunteers in emergencies save significant public expenses. . Table 2 summarizes data about selected examples of volunteering, specifically the number of volunteer hours, the estimated economic value of individual examples of volunteering, and the ratio of volunteers to professionals.

Table 2: Scale of emergency volunteering in the Czech Republic.

NGO	Year	Number of volunteer hours	Economic value (EUR)	Volunteer to professional ratio
People in Need during floods	2002	150,000 during the flood	523,013	N/A
Water Rescue Service	2004	72,907 for the year	300,961	Exclusively volunteers
ADRA during floods	2010	38,400 during the flood	203, 978	N/A
Mountain Rescue Service	2011	72,000 for the year	391,955	3.64 to 1
Volunteer firefighters in the District of Mělník (1/112 the territory of CR)	2012	26,448 for the year	139,190	11.72 to 1

Source: calculations by the authors.

Failure to provide volunteer aid in emergencies would probably have fatal impacts on the Integrated Rescue System of the Czech Republic, especially on the provision of water rescue services, mountain rescue services, and fire protection. The decrease in human resources to cope with consequences of flooding would also be considerable.

The paper estimates the economic value of selected types of volunteering in emergencies. The initial estimates show a considerable economic value, running to hundreds of thousands of euro for individual types of volunteering. The gross estimates for the total volunteer firefighting in the Czech Republic amount to millions of euro annually.

Although volunteers perform their activities free of charge, certain financial means are required to fund them. Volunteers during floods must get to the site where they will provide assistance; ideally they are also insured and trained. Volunteer firefighters and rescue workers need equipment and qualification requirements lead to a considerably higher need for training which also requires some funding. Because volunteers in these cases perform functions that the state is responsible for, the logical funding for these costs are public budgets.

Public expenditures cover part of the costs of the volunteering. However, the financial support may not be considered only to be support volunteering as a free-time activity which is helping the volunteers, but also as investments to the Integrated Rescue Service of the Czech Republic. It is very likely that without the past investments in volunteering in emergencies, this part of the non-profit sector in the Czech Republic would be nowhere near as developed as it is. There is another point of view. If the state stopped supporting volunteering in emergencies and the volunteer activities were limited considerably, the Integrated Rescue System would be endangered by at least partial collapse. This connection is most marked for volunteer firefighters, whose activities require investments in equipment and vehicles, etc. To transfer the Czech model to other countries would require further analysis, but it can now be stated that the Czech model is, at least, an interesting example for any country that regularly suffers from emergencies and disasters, especially for those that feel pressure from decreasing public expenditures.

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