DISASTER MANAGEMENT AND COMMUNITY WARNING (CW) SYSTEMS: INTER-ORGANISATIONAL COLLABORATION AND ICT INNOVATION.

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Abstract

Emergency Services Agencies (ESA) are required to co-operate and collaborate on a regular basis to provide their communities with warning information about disasters and incidents. Community Warning (CW) systems are a vital component of ESA operations as there are many different types of disasters and emergency scenarios of varying complexity and uncertainty, which in turn directly influence the type of CW systems that should be employed by an ESA for any particular incident.

This paper outlines research conducted into CW systems in New South Wales (NSW) state government ESA. This research highlights a unified collaborative approach to the assessment, development, deployment and use of CW systems that is based on crisis management theory. This approach could be utilised by governments at federal, state and local levels for cross border and jurisdictional management of ESA informational, ICT and process resources. Such an approach would assist government in better targeting expenditure on CW systems and using ICT in an innovative manner.

Results also highlight that when developing and deploying CW systems, there should be careful consideration of a number of background contextual issues such as: stakeholder involvement, incident complexity; utilisation of multi-ICT delivery platforms for economies of scale; integration of multi-ESA operational, community, communication and ICT requirements for shared direction; and development of an ICT architecture for building learning capabilities and skills of stakeholders.

1. Introduction

The efficacy of community warning (CW) systems and emergency incident response (EIR) activities is now a critical issue to be resolved by global government, especially in relation to disasters caused by extreme climate events such as hailstorms, fires, floods, cyclones and other events such as biohazards, pandemics, refugee movements, terrorism and the like. In Australia, most recently, we have witnessed the impact of the Sydney Hailstorm – April, 1999, NSW Bushfires – 2002, 2005, Canberra Bushfires – January 2003, Queensland Tropical Cyclone “Larry” - March 2006, Hunter Floods – June 2007, Equine Flu – 2007-2008, Victorian Bushfires - February 2009 and Queensland Floods – February and May 2009. New South Wales (NSW) is an Australian state with a population of approximately 6,889,100 people nearly all of whom live on or near the coast or in the capital of Sydney which houses 4,284,379 of the total NSW population (ABS 2008). The damage caused by natural disasters in NSW has been estimated at $992 million per annum. Risk Frontiers Quarterly suggests that NSW suffers more of each type of emergency (apart from Cyclones) than any other jurisdiction (Anonymous 2006).

Traditionally, approaches to CW and EIR by Emergency Services Agencies (ESA) have focussed around invoking command and control systems and structures around CM and EIR activities (Kost & Moyer 2003, COE 2005, OESC 2006, ACT AGO 2007). The immediacy of a threat, the impact on the community and the downstream management of the threat and impact, generally means that government and their ESA have to mobilise quickly and efficiently to deal with differing and emergent scenarios. In dealing with a crisis, government rarely has the luxury of completely understanding, harnessing and managing collaborative and inter-organisational information management and processes to optimise outcomes in an emergency incident or disaster. Stakeholder characteristics are generally highly complex and difficult to manage in these scenarios as well, with different levels and location of government and their ESA, various community groups, businesses and individuals, as well as their information and communications technology (ICT) service and product providers, all requiring co-ordination and attention to their individual requirements and needs at any given time. This complexity is also magnified as each organisation or group has their own individual culture, structure and way of doing things, which must also be accommodated. In most cases, effective community warning can mean the difference between inconvenience and disaster for those who are affected (Blanchard-Boehm 1998, Betts 2003, Kost & Moyer 2003, Sikich 2005, Tarrant 2005). Incidents such as the WTC (2001), Bali (2002) and London (2005) bombings, the South East Asian tsunami (2004) as well as Hurricane Katrina in the US in 2005 give us prime examples of the complexity of information use for community warning purposes in these situations (OESC 2006).

This often leads to critical problems and miscommunications between CW and EIR stakeholders in times of crisis. Information processing delays, replication and double handling; duplicate and inconsistent recording and storage of data; and system errors resulting in unnecessary costs, resource wastage and ineffective response are all problems which routinely present themselves in these situations. Providing better integrated and more collaborative management information and processes around the organisations, people, systems and ICT infrastructure that support CW and EIR is a paradigmatic shift in the way that we think about government, ESAs and their interaction with the community.

CW systems are defined by the NSW Office of Emergency Services (OES) as systems responsible for the "effective delivery of a message to influence behaviour". The elements of CW systems are therefore:

- ***Effective delivery*** - a range of methods and media;
- ***Of a message*** - clear, consistent and from a trusted source; and
- ***To influence behaviour*** - people do something that reduces risk to them or their property.

CW systems are also highly reliant on the effective evaluation and deployment of ICT innovations and in many instances the full potential of these innovations is not realised, due to the different approaches to community warning taken by ESA as well as their dispersed geographical locations.

2. Background Theories

Many of the theories that underpin CW and EIR have been developed in the crisis management literature. Crisis management has long been a focal point for management theorists as organisations prepare to cope with natural and man-made crisis events (Pearson and Mitroff 1993, Pauchant et al. 1992, Pearson and Clair 1998). Pearson and Mitroff (1993) argue that there are 4 types of crisis variable: types; phases; systems; and stakeholders. *Types of crisis* influence: organisational preparation; scope of crisis plans; crises that can be safely ignored; and rationale for inclusion/exclusion of a crisis. *Phases* of a crisis affect: timing; detailed activities; phase management; and reactivity versus pro-activity. *Systems:* can cause or prevent crises; may not be well understood; are comprised of complex components (technology, people, process, organisations, emotions) and their interaction. *Stakeholders:* can affect and be affected by crisis management approaches; and need to be systematically analysed and anticipated in a crisis.

Pauchant et al. (1992) advocate the need in crisis management "for going beyond operational matters - pg 70" in the development of strategic plans and processes. These must focus on: relations a firm has with the environment; how it deals with its stakeholders; involvement of top management; survival and development of the organisation as a whole; consistent patterns of actions; and development of crisis management as an emergent process. Pearson and Clair (1998) build an integrated model of crisis management which points to: the need for collaboration and collective intra and inter-organisational action for effective crisis management with attention to be paid to; organisational culture; risk perceptions; crisis preparations; individual and shared assumptions; establishment of crisis management teams; and building of alliances and co-ordination of crisis management plans through candid information sharing with critical external stakeholders.

The next section of the paper deals with defining inter-organisational ESA collaboration through the use of *negotiated arrangements theory* as it is applied to crisis management and CW issues. We then detail our research questions, objective and methods, data collection and analysis and then finally define our contribution to research and practice regarding CW systems and areas for further research.

3. Inter-Organisational (ESA) Collaboration and Negotiated Arrangements Theory

As a result of the focus within crisis management theory, this study has utilised negotiated arrangements theory to explain phenomena in ESA collaboration for the support and utilisation of CW systems and innovations (see Figure 1). Negotiation is an important part of organisational collaboration so when organisations agree on an issue, negotiation is used to find the best way or the best solution to address a task. On the other hand, when organisations 'agree to disagree' on a particular issue, negotiation is about an organisation's willingness to compromise in order to find common ground. When organisations (or emergency services agencies in the case of this study) collaborate, they have to come to terms with having a common strategy, common business processes and ICT architectural design.

Negotiated order theory has been used to study the social process of collaboration by which order is negotiated (Gray 1985). "Negotiated order theory thus focuses on the symbolic and perceptual aspects of interorganisational relationships, particularly on the evolution of shared understandings among stakeholders of the domain's structures and processes, limits and possibilities" (Gray and Wood 1991, p. 10). The approach taken by this theory is to examine the interactions between different stakeholders (i.e. different government agencies) to address a shared problem or cause (Nathan and Mitroff 1991).

Organisations involved in the negotiation will have to agree on terms and conditions when interacting as part of a collaboration group (Nathan and Mitroff 1991), however, negotiated order is subject to change when conditions change. Collaborative negotiation allows government agencies with different perspectives to express their interests and needs, and to negotiate their differences and any changes required to make the collaboration successful. Incremental collaborative negotiation helps to build commitment from government agencies with different perspectives (Westley and Vredenburg 1991). Furthermore, the outcomes from negotiations have to be 'sold' to other departments within the agency.

The 'degree of interpenetration' is the extent of collaborative negotiation that an organisation is willing to commit to (Westley and Vredenburg 1991). There are four common organisational "patterns" of collaborative negotiation and commitment-building identified by Westley and Vredenburg (1991): multiparty roundtables, joint ventures, strategic bridging and mediation which are shown in Figure 1. We suggest that each of these patterns are evident in ESA collaboration to achieve community warning outcomes.

McCann (1983) outlines that *negotiated arrangements* (processes) are also needed by organisations in a shared problem domain. If organisations do not have the ability to negotiate, then they may not achieve and realise their objectives and goals in a shared problem domain. The five negotiated arrangements outlined by McCann (1983, p. 181) are as follows:

(a) Assure that benefits accruing to stakeholders as a result of their involvement are favourably balanced against their contributions over the long run;

(b) Manage uncertainty and complexity within the domain by developing coordination and control mechanisms for implementing policies and programs;

(c) Generate economies of scale or otherwise facilitate the efficient procurement and allocation of resources among stakeholders;

(d) Help maintain the sense of shared direction and legitimacy of that direction by creating and building a visible identity for those involved – e.g., a legally formed association or cooperation; and

(e) Provide an orderly process for adapting to change by building the learning capacities and skills of stakeholders.

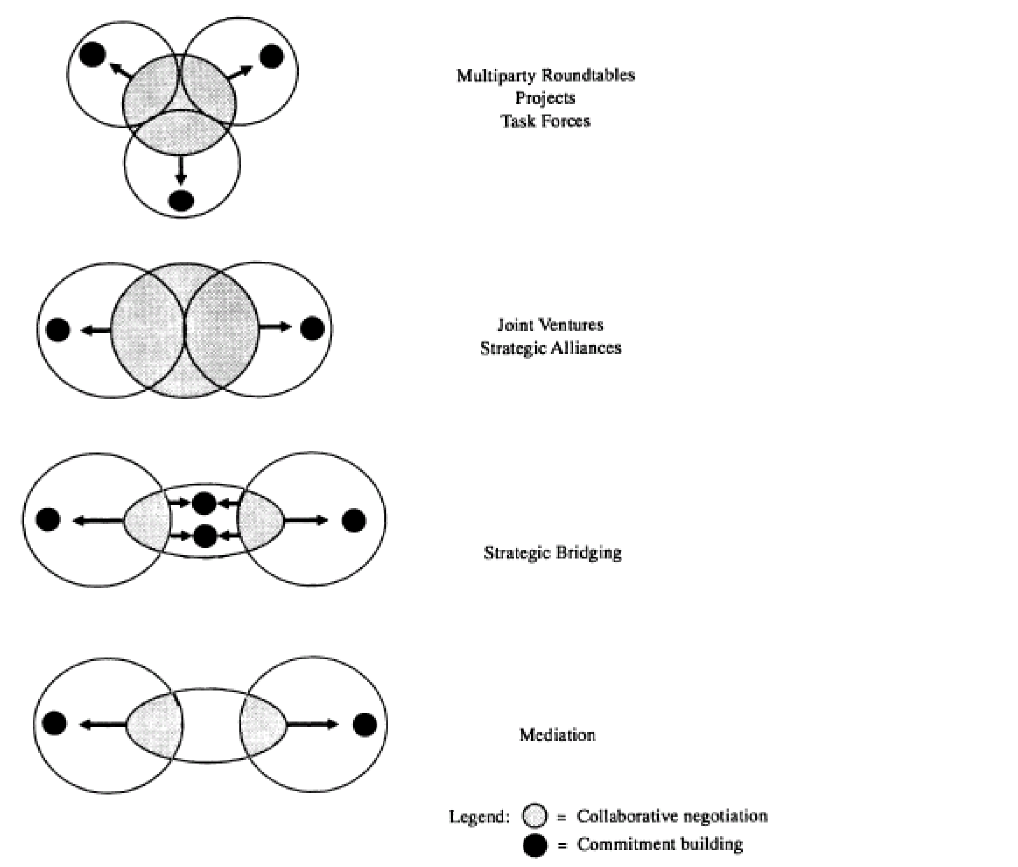

Figure 1 (source: Westley and Vredenburg 1991, p. 69)

4. Research Objectives and Questions

This research seeks to identify opportunities to improve CW and thus EIR collaboration processes, by studying NSW government ESA practices as an example.

These complex collaborative interactions are analysed and examined by applying McCann's (1983) collaborative negotiated arrangements theory (previously discussed) as a means of supplementing crisis management theory, in order to answer the following research questions:

- How do ESA collaborate to support and utilise CW systems in times of crisis through **(a)** stakeholder involvement; **(b)** dealing with uncertainty and complexity; **(c)** developing economies of scale; **(d)** developing a sense of shared direction?
- How do ESA know if they employ the most effective and innovative CW systems to detect disasters, threats, incidents and hazards and then generate appropriate responses through **(e)** an orderly process for adapting to change (ICT architecture)?

5. Research Method

This paper documents the outcome of the first phase - *diagnosing* - of an action research study in the NSW government ESA. The use of action research is critical to the effectiveness of the data collection and analysis due to the nature of the multi-stakeholder environment of government ESA and their differing contextual modes of operation. That is to say, more quantitative methods of data collection such as experiments, surveys and field studies would not gather the most appropriate data for interpretation, to detect the subtleties and differences between agencies, as deeply and effectively as an action research approach. This approach has been applied to other industry sectors for the study of collaborative processes and ICT innovation (Bunker et al. 2007, Pang and Bunker 2005, Smith et al. 2006).

The key component of action research of particular relevance to this paper is: the *diagnostic* component, involving researchers and other subjects in developing shared interpretation of community warning objectives, assumptions, information, process and ICT support practices; diagnosis also involves problems related to implementation of a particular design and achievements of the objectives. Other phases that will form later parts of this research project will be the *intervention* component (also called therapeutic), involving the design and re-design of community warning information, processes and ICT support based on diagnosis; and the *learning* component, involving distinct, ongoing processes of collaborative reflection on consultative practices underway and learning from observations of changes in these practices resulting from changes in the design of community warning systems. While there are several different models and forms of action research, the most appropriate for this study is the canonical form as it implies cyclic, reflective, linear and rigorous process (Baskerville and Wood-Harper 1998). Each cycle in this process involves phases of diagnosing, action planning, action taking, evaluating and specifying learning (Figure 2).

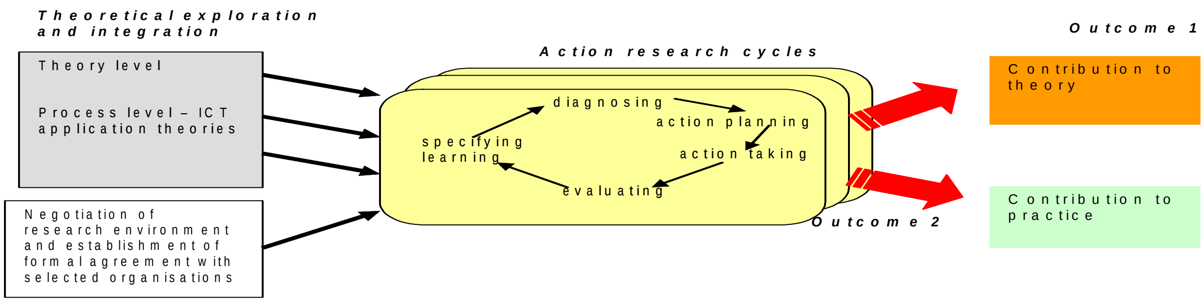

Figure 2 – The Action Research Cycle

Data was collected throughout the *diagnosing phase* using methods including: collection of ESA documentation on current CW systems plans and systems; interviews with key stakeholders; attendance and note taking at relevant meetings and thematic, pattern, grounded theory and hermeneutic analysis of documents, interviews and meeting notes to determine current ESA operations and CW systems issues.

6. Data Collection and Analysis

The **NSW State Emergency Management Committee (SEMC)** commissioned this research project and is responsible for emergency planning for the State government. Among the numerous functions discharged by this committee is that of "arranging for graduated warnings to public". The SEMC has adopted a Prevent, Prepare, Respond and Recover (PPRR) protocol which provides a common government strategy for the community warning activities of all ESA.

The SEMC performs a high level co-ordination and response function for all ESA and subsequently has an overview of the further collaborative possibilities for ESA. This study represents findings from data collected in the *diagnosing phase* of the action research cycle from May 2007 to August 2007 conducted with a representative group of ESA participants from across the NSW Government (see Table 1).

Table 1 – Study Participants

Emergency Services Agency	Agency Role	Agency Participant Title
State Emergency Services (SES)	Emergency services management in times of natural disasters	Senior Management Team
Rural Fire Service (FRS)	Fire fighting and population control in non-urban areas	Communications Management
NSW Ambulance Service (NSWAS)	Transportation and evacuation of sick and disabled.	Director Management Co-ordination
NSW Police	Policing and Civil Order	Deputy Commissioner
State Emergency Management Committee – Office of Emergency Services (SEMC - OES)	Emergency Planning	Chair

The analysis of the data from this stage of the action research cycle follows McCann's (1983) collaborative negotiated arrangements theory for organisations and highlights the following areas of: (a) stakeholder involvement, (b) uncertainty and complexity, (c) ecomomies of scale in the use of ICT innovations (d) shared direction and legitimacy; and (e) an orderly process for adapting to change (ICT architecture). Evidence is also presented within this paper from notes and documents from a debriefing of multiple agencies ("Hunter Storms" 2007) and where there is a high degree of concurrence of opinion between ESA from individual interview data.

Research Question 1 - How do ESA collaborate to support and utilise CW systems in times of crisis through **(a)** stakeholder involvement; **(b)** dealing with uncertainty and complexity; **(c)** developing economies of scale; **(d)** developing a sense of shared direction?

(a) ESA Stakeholder Involvement

There are many ESA (as well as the communities they serve) who are direct stakeholders in community warning activities. Each ESA has its primary responsibility and area of focus in the sphere of community warning. For example in the recent NSW "Hunter Storms" in 2007 ESA primary responsibilities were reflected in the activities assumed, and reported on, by each agency. Table 2 highlights these.

Table 2 - Stakeholder Primary Activities NSW "Hunter Storms" 2007

ESA Stakeholder	Activities
State Emergency Services	Co-ordination of agencies and resources.
Rural Fire Service	Effective use of resources to assist in "troubleshooting".
NSW Ambulance Service	Evacuation in wet weather (specialist knowledge).
NSW Police	Preservation of life, control of public reaction, search and rescue.
NSW Department of Commerce (Communications)	Management of hierarchy of communications technologies and activities.
NSW Fire Brigades	Emergency response, hazard reduction.
Department of Primary Industry	Animal welfare, inclusive response.
Bureau of Meteorology	Weather prediction model and public message management.
Department of Community Services	Human welfare.

Major incident response in this case highlights the high level of collaboration and co-operation already in place within and between ESA and there is an ability to further build on this by developing a more comprehensive understanding of intra and inter-ESA community warning activities and processes and the technologies underpinning them. This has been facilitated though the PPRR protocol that was adopted by the SEMC. As we can see by Table 2 stakeholders can have quite different (but aligned) objectives which may require many ways of understanding the characteristics of the emergency incident and the community warning response to it.

(b) Managing Uncertainty and Complexity - Emergency Incident Scenarios & CW Systems

There are many emergency incident scenarios that require a community warning response from one or many ESA. An emergency incident takes many forms and can move through many media (fire, earth, air, water, structures). They have agency (explosive, natural activity, chemical, biological, electrical etc) and an elapsed time to full effect as well as a lead time for warning. Incidents have dimensions of amplitude, magnitude, area and containment potential. They can impact the community on a local or social level and can be planned for or entirely random. Agencies stressed that CW systems and processes were highly dependent on the characteristics of each scenario and the agency responsible for co-ordinating the response. They also stressed that individual ESA operational systems and infrastructure were also key components of any EIR. ***(c) Economies of Scale - ICT Innovations and Their Use in Community Warning Systems*** Study respondents agreed that CW systems must reflect and cope with incident scenario complexity in order to enhance and support the collective ESA response to any given emergency incident. CW systems must not rely solely on any one information and communications technology (ICT) platform or delivery system (or indeed on ICT alone) to support ESA response and they need to integrate operational, community, communication and ICT requirements in order provide effective support for ESA activities.

Table 3 – Warning Technologies and their Communication Uses

MESSAGE TYPE	ALERT							NOTIFY						
WARNING TECHNOLOGY	FREE TO AIR TV AND RADIO	CALL CENTRE (DIAL IN)	RURAL WARDENS	FIXED PA	PERSONAL NOTIFICATION	DIAL OUT	TONE ALERT RADIO	FREE TO AIR TV AND RADIO	CALL CENTRE (DIAL IN)	RURAL WARDENS	FIXED PA	PERSONAL NOTIFICATION	DIAL OUT	TONE ALERT RADIO
COMMUNICATION BARRIER														
INDOORS	N	N	Y	Y	Y	Y	Y	Y	Y	Y	?	Y	Y	Y
ASLEEP	N	N	Y	Y	Y	Y	Y	N	N	Y	N	Y	Y	Y
OUTSIDE FLOOD ZONE	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N
NO POWER	N	N	Y	Y	Y	?	?	N	?	Y	Y	Y	Y	?
NO TELEPHONE	N	N	?	Y	Y	N	Y	Y	N	?	Y	Y	N	Y
NO ROAD ACCESS	N	N	?	Y	N	Y	Y	Y	Y	?	Y	N	Y	Y
NO RADIO RECEPTION	N	N	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	N
LANGUAGE OTHER THAN ENGLISH	N	N	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N
HEARING IMPAIRED	N	N	?	N	?	N	N	Y	Y	N	N	N	N	N

Table 3 uses respondent data to structure a way of considering how each technology overcomes communication barriers and how they might be integrated with CWS in the most effective way. The first row of the table considers the type of warning message, which needs to be communicated. There are two types: alert and warning. The alert message simply tells people that there is impending danger; the notification provides more detail about the type of danger and the appropriate response. The level of detail in the notification message will be determined by the limitations of the technology and the broader content issues of the overall community preparedness strategy. Fixed PA is the best performing technology overall but it has its limitations and there are a number of criteria against which other approaches are better performers. Respondents highlighted that a risk management approach is the most appropriate way to design an integrated warning system for all types of emergency incidents.

Put simply, the warning system needs to get a message across to as many people as possible. There are a number of communication barriers, which it will need to overcome, and there may be some individuals who will not receive the warning message because it is not possible, practical or affordable to commit all the resources necessary to overcome all of the barriers to communicating the warning message to them.

(d) Sense of Shared Direction/ Legitimacy – State Emergency Services (SES) and Flood Scenarios

SES respondents highlighted that various types of warning technologies already in use should be integrated into a total warning system for the complex scenario of flood hazards (see Table 3). Respondents also highlighted that those warning technologies, which are already in place, would be part of an integrated warning system for the Hawkesbury Nepean area of NSW. Respondents indicated that other technologies, if adopted, would integrate with the core elements of this warning system.

SES utilizes a cross-section of information delivery technologies: radio; SMS; telephone; warden systems and are currently looking at the Common Alerting Protocol (CAP) as another mechanism that may be utilised. Emergency Management Australia (EMA) are, on behalf of the National Forum on Emergency Warnings to the Community, undertaking to progress consideration of CAP as the protocol in Australia to be adopted for the electronic distribution of all emergency warnings. Respondents also believe, however, that technology needs to be as broadly defined as possible within the project in order to understand that the technologies applied to this problem may not necessarily be computer based.

The characteristics of the "message" were also important to the type of CW systems in use. The volumes and frequency of information and how it is used; inter generational characteristics of information use; channel dependency of information; issues for non-English speakers; examples of "best practice" are all critical for effective CW systems. For SES face-to-face communications have proven to be the most useful in "imprecise" community warning. This includes door-knocking which is also used by NSW Fire Brigades. These respondents also stressed that technological reliant/intensive systems are more appropriate for high level messages and information provision.

Social issues (and their effect on community warning systems) were also highlighted by these respondents and they felt that they have not been studied widely enough even though these have the greatest effect on outcomes. For example public expectation of community warning systems must be carefully managed to give a "realistic" view of what can actually be achieved by government. There are many different attitudes towards information warning and problem/hazard understanding. Education and community awareness (managing the message) is also an important part of any CW systems project e.g. how various media can be utilized more effectively to get the message to the community.

(d) Sense of Shared Direction & Legitimacy - All Emergency Services Agencies

A sense of shared direction and legitimacy was highlighted through the Prevent, Prepare, Respond and Recover (PPRR) protocol (as adopted by the SEMC) to CW systems in their various forms, showing the heavy use of publishing and broadcast technologies for the *prevent* and *prepare* stages with a move to 1:1 communications technologies such as phones and SMS for *response* purposes. Publishing and broadcasting is then reverted to in the *recovery* stage. In order to effectively follow the PPRR protocol, ESA and their CW systems need to use current proven technology with ability for continued scalability and enhancement to ensure best value for money. Alert messages must be delivered via a multitude of channels including telephone, mobile phone, SMS, facsimile, email, web pages.

Respondents endorsed the use of an architectural approach to the assessment, development, deployment and use of CW systems which could be utilised by governments at all levels, to more effectively and efficiently utilise government and ESA human, ICT, information and process resources. It was stated that such an approach would assist government in better targeting expenditure on CW systems.

Respondents feel that a number of strategies and standards can be employed to assist ESA to more effectively co-operate and collaborate in community warning scenarios and develop a more architectural view of their CW systems. These include the initial implementation of: Common Alerting Protocol (CAP) Oasis V1.1 for emergency messaging interoperability; full state coverage with mapping and Integrated Public Number Database (IPND); and the use spatial data for mapping incidents where appropriate.

There are also a number of other systems issues to be considered when developing an architectural approach to CW systems and these include consideration and evaluation of systems: redundancy; robustness; security; false alerts; administration/management; and levels of messaging - ESA and public.

Research Question 2 - How do ESA know if they employ the most effective and innovative CW systems to detect disasters, threats, incidents and hazards and then generate appropriate responses through **(e)** an orderly process for adapting to change (ICT architecture)?

(e) An Orderly Process for Adapting Change – An ICT Architecture

In the previous analysis we have seen that the theme of an architectural approach to the assessment, development, deployment and use of CW systems is emerging from the data. Respondents felt that such an approach would assist governments in better targeting expenditure on CW systems. Having highlighted a CW systems architectural approach, it was then indicated by respondents that evaluation and deployment metrics for CW systems, were required, to accurately capture and measure all ESA operational and performance criteria.

i) Designing a Warning System – Risk Management

Respondents feel that no single technology or system performs well against all the identified community warning criteria and many of the technologies investigated have not been tested in real emergencies. For these reasons any decision to invest in a technology or implement a particular warning system needs to recognise the uncertainties involved. Respondents stated that an appropriate response to this situation is likely to be a 'layered' strategy that seeks to implement complementary approaches using a risk management philosophy. Which particular technologies are combined, may vary according to the characteristics of the incident as well as the characteristics of the technological innovation on offer.

ii) Integrating Technologies and Warning Message Content

It must be recognised that designing CW systems is not simply selecting the technology or mix of technologies, which will be used to disseminate a warning. It also involves carefully designing the warning message content which may vary between the dissemination technologies. Furthermore, it must be integrated with a whole awareness and preparedness strategy for the affected communities so that when a warning is issued appropriate responses can be made. It was beyond the scope of this study to explore all of the community preparedness and message content issues but reference was made to these in discussing the relative merits of technologies and the design of an overall warning system.

iii) Evaluation Criteria

A set of evaluation and deployment metrics to effectively select, implement and operate CW systems, should be developed, in order to accurately capture and measure all ESA operational and performance criteria. These metrics also lend support to an architectural view of CW systems and give all ESA the means to benchmark and evaluate these systems under their own operational and process conditions. Respondents indicated that there are many different criteria to consider when evaluating CW systems covering such issues as: whether the system would alert, notify or do both; effectiveness of community warning messaging; cost of all aspects of the system (not just technology components); speed of the system in delivering warning information; reliance on the infrastructure of other organisations and ESA; community resistance to use of the system; and longevity of the technology components.

The evaluation of the performance of each system against the evaluation criteria can be undertaken by: identifying information requirements for each system to facilitate the assessment of its performance against each criterion; contacting suppliers of the technology in Australia where possible and overseas in other instances, seeking assistance with information requirements; reaching a consensus with ESA and suppliers on assumptions needed to estimate performance; estimating performance with respect to the agreed assumptions; and cross checking results to ensure consistency.

Sensitivity analyses can also be incorporated into metrics by estimating optimistic and pessimistic performance scores for each option against each criterion in addition to the best estimate performances. In addition, weightings can be given to each criterion (expressed by individual ESA) as to the importance of that criterion in choosing between technologies. Applying these principles could lead to the adoption of different technologies in different locations depending on the particular features of an area; and/or the use of multiple technologies in some areas to ensure that the limitations of one technology do not prevent the warning being delivered to most of the population.

iv) Delivering an Effective CW System

It is considered prudent by ESA respondents to trial the higher capital cost technologies in a small area first before committing to installing them and relying upon them across large areas of NSW. There is also a need to consult with the community and local government (councils) in the areas for such trials to ensure that they understand and support the need for pilot programs (the SES has evaluated technologies in this way). Consultation will also provide an opportunity to gauge community attitudes towards the suite of warning technologies being actively considered.

Metrics are a useful tool to ensure that: diverse options are effectively compared against a wide range of criteria; traditional lower technology options such as door knocking and public media broadcasts are properly evaluated against heavily technology dependent options; no single technology is relied upon to alert and notify the community; a layered approach with more than one technology will maximise the reach of the warning and provide backup communication in the event of contingencies; any developing system incorporates community expectation and needs, emergency service capacity and decisions about public communications, and established community awareness and preparedness campaigns and reliable and compatible secondary information sources; and public warning systems integrate operational, community, communications and technology factors – a huge challenge

It was stressed by ESA that to develop and deploy effective CW systems is a long process of informing, educating, reinforcing and re-education of the public for sustainable systems and a prepared community. No ESA accepted that CW systems could be effective in a one-hit emergency call or any single information channel.

7. Conclusion - Contributions to Practice

Analysis of the data collected in the diagnosing phase of this study highlights that CW systems are not only a technical problem but also one of management of information, the message and trust in the community. This is best highlighted by ESA where a high percentage of staff who participate in community warning and incident response are volunteers. ESA such as SES and RFS have critical interaction and collaboration with their local communities and it is though these interactions that they are able to provide such effective community warning strategies and responses.

It is important to consider the many different contextual issues outlined by ESA when developing and deploying CW systems. In doing so, the effective use of these systems by ESA and the community are supported by, and entrenched within these systems. ESA respondents highlighted that CW systems: **1)** have different (but aligned) ESA stakeholder objectives which also add a layer of complexity to their specification; **2)** encompass different types of emergency incidents of varying complexity and so must reflect and cope with incident complexity; **3)** must not rely solely on any one information and communications technology (ICT) platform or delivery system for their economies of scale; **4)** need to integrate ESA operational, community, communication and ICT requirements to legitimise and give them a sense of direction; **5)** collaborative processes require further and more detailed studies into the psychology, content and action resulting from messaging and **6)** need to be developed and deployed with a view to adaptation and change.

ESA currently use multiple CW systems to inform or advise the community rather than just one type. This tactic minimises the risk of a message NOT being received. In an emergency it is always better to receive a repeat of the message multiple times rather than using a single approach, which may miss, contacting members of the public. The reverse also applies when members of the public provide intelligence and information to ESA. ESA also use a range of (non technology based) public information seminars, training sessions, accredited courses and demonstrations to inform the public on the recommended actions to be undertaken in an emergency. Printed material and facts sheets are also used by some ESA for public information provision and awareness raising. Significant issues still remain outstanding, however, with the intended meaning of a message and the re/action of the public.

While much is being done to assess CW systems a significant amount of investigation also needs to be undertaken into the psychology of messaging, content and action resulting form messages in this field.

8. Conclusion - Contribution to Theory

Data collected in the diagnosing phase of this study has also highlighted a number of issues that contribute to the body of theory in this area. Collaboration theory in information systems is not very "deep" and relates mostly to supply/service chain management. We have been able to supplement this theory and body of knowledge (BoK) by focussing on and extending crisis management theory as it applies to collaboration for CW systems. Initial findings highlight that: **1)** collaboration theories should be used to better articulate the CW approaches for government institutions (like ESA); **2)** CW systems are multi-layered constructions (complex systems) i.e. no one system or medium will be able to do the job (different use and format of messages/information, applications, processes, technology & media) for various ESA; **3)** command and control structures are important for effective CW systems use and ESA operations and need to be considered in a more strategic fashion when developing a CW systems architecture; **4)** any CW system needs to function for an individual ESA as well as be made accessible (where appropriate) to all ESA (hierarchy of command and control); **5)** public and media expectations of CW systems must be managed in a more cohesive and unified fashion; **6)** education plays an important role in public impact and use of CW systems (public liaison); **7)** global/local knowledge plays an important role in CW systems use and ESA operations; and **8)** networking with communities and understanding societal/psychological effects of CW systems messaging is important.

If collaborative benefits are realised across government in a more integrated way through the understanding and effective facilitation of complex inter-ESA collaborations between stakeholders, these will flow directly into more effective early warning and incident response for the general public. ICT resources will also be more critically evaluated giving government better budget outcomes, saving money from the public purse, as well as ensuring the loss of life, property and livelihoods are minimized to the community. We have shown that the crisis variables (Pearson and Mitroff 1993) of: types; phases; systems; and stakeholders, can be supplemented by a collaborative theory such as McCann's (1983) *negotiated arrangements* theory to make sense of collaborative processes for CW systems.

The complexities of such processes, the ICT innovations that support them and the circumstances to which they relate often lead, as we have seen, to significant problems. Providing better integrated and more collaborative information and process management, structures and activities around the ICT innovations that support early warning and incident response, will increase the effectiveness of all ESA and the utilisation of their ICT innovations in the long term.

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