Original paper

Improving the Governance Context and Framework Conditions of Natural Hazard Early Warning Systems

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Abstract Early Warning Systems (EWSs) are a major element of disaster reduction. They provide resilience to natural hazards, protect economic assets and development gains. Until now, most EWS have focused mainly on hazard detection and the immediate warning and evacuation processes with an effort of saving lives in the context of an extreme event. However, the incidence of global societal calamities and losses continue to grow. Risks, crises and disasters are becoming more and more intricate, complex and multi-faceted. Some of the key challenges of EWSs include lack of an end to end and people-centred approach, and major weakness in terms of governance and institutional arrangements as the cross-cutting issues of EWSs. In this context, the governance aspect and framework conditions of EWSs need to be revisited. The paper reviews and analyses various concepts and frameworks related to EWSs in order to present ideas about how to systematise characteristics and dimensions of governance for an improved conceptual governance framework for EWSs. In this regard, the framework conditions and the governance context of EWSs are outlined in order to improve EWSs.

The review process shows that EWSs framework to this point has evolved from the traditional three phase linear chain typology to a more complex and integrated cyclic model framework incorporating risk knowledge and appropriate response elements. Additional aspects include participation, feedbacks from different actors and the community and the required driving incentive structures for sustainability. A number of governance related weaknesses are identified in the existing concepts and frameworks. In addition, EWS do not systematically or methodologically take into account hazard-social ecological conditions. The governance aspects and framework conditions proposed in this paper include the four core EWS elements (risk knowledge, monitoring & warning, dissemination & communication, and response). Communication should be a central element operating at all times, levels and scales of the process. Additional aspects include: (1) the social-ecological system governance perspective (2) the governance perspectives directly related with the EWS in terms of architectures, the actors and the community, and (3) the broader systems of governance (i.e. political, economic, social and technological); to emphasis the driving incentive structures required for implementing and supporting an effective and sustainable EWS.

Key words: Early Warning Systems; Natural Hazards; Governance; Institutions; Framework

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1. Introduction

The incidence of global societal calamities is growing and escalating in losses (ProventionConsortium 2004: 3, MunichRe, UN-ISDR 2011). The cost of disaster recovery far exceeds the cost of effective and sustainable hazard management. Disaster impacts are generally increasing as a result of the combination of increasing populations, greater concentrations of people and assets in vulnerable areas, and the modification and degradation of natural environments, such as floodplain settlement, coastal exploitation, wetland destruction, river channeling, deforestation, soil erosion and fertility decline. Vulnerability to hazards is exacerbated by poverty, disease, conflicts and population displacement (Basher 2006). Overall, risks, crises and disasters are becoming more and more intricate, complex and multi-faceted; particularly in the light of climate change.

EWSs are a major element of disaster reduction. They should empower societies and communities to prepare for and confront the power and the uncertainties of both natural and climate change-driven hazards. EWS provides resilience to natural hazards, and protects economic assets and development gains (IEWP 2006). Early warning systems exist for natural hydro-meteorological-geophysical hazards, biological hazards, socio-political emergencies, industrial hazards, personal health risks and many other related risks (Chang Seng&Birkmann 2011).

On the other hand, the escalating losses associated with these extreme natural hazards indicate that most governments have yet to find affective ways of reducing and managing risks they pose (UN-ISDR 2011). The absence or lack of an effective EWS also explains why disaster impacts are increasing such as in the case of the December 2004 Indian Ocean tsunami and Hurricane Katrina in the United States in 2005. Globally, many countries and millions of people are not protected by effective early warning systems (EWSs) (IEWP 2006). Some of the key challenges of EWSs include lack of an end to end and people-centred approach and major weakness in terms of governance and institutional arrangements as the cross-cutting issues of EWSs (United Nations, 2006). In addition, a United Nations Development Program (UNDP 2004) report entitled: “Reducing Disaster Risk: a challenge for development” highlighted that the critical cross-cutting issue of governance remains a key unresolved challenging problem and there is the need to further strengthen institutional and legislative systems for disaster risk management. In addition, the UN Survey requested by Annan (2005) on a global EWS for all natural hazards confirmed that there is inadequate institutional and governance commitment. In this context, the governance aspects and framework conditions of EWSs deserves a closer attention of analysis.

Therefore, the aim of this paper is to review and analyse various concepts, characteristics and frameworks related to EWSs. Secondly, it presents the governance context and framework conditions for improving EWSs. The current work will contribute towards the better framing, understanding, assessment, design and governance of EWSs.

The key research questions are as follows:

1. What are the existing typology, concept, design, and framework of natural hazard EWSs?
2. What is an effective and sustainable EWS?
3. What are the current governance related gaps, and weaknesses in the framework conditions of EWSs?
4. What additional governance aspects and framework conditions are required to improve EWSs, and how are EWSs factored in the Integrated Disaster Risk Management Spectrum?

2. General Typology, Concepts, Designs and Frameworks of Natural Hazard EWSs

It is underscored that Lassa (2008) reported on five existing typology of EWS models. The EWS chain model (Figure 1 a) focuses on flows of sources/resources or ‘materials/objects through a sequence of steps which emphasize movement and transformation through a series of stages that are often ordered and linear simple steps’ (Sobal et al. 1998:855). Moreover, it includes a chain of decision and actions that follow ‘input through output’ sequences. The cycle model (Figure 1 b) for single hazard is similar to the chain model. It addresses a specific hazard along a time continuum, but it flows in a clockwise direction. In contrast to the single-cycle model, a multiple-cycle model (Figure 1 c) is used to illustrate the coexistence of different units of EWS addressing different types of hazards. On the other hand, the network model (Figure 1 d) can be considered as an architecture and social network, characterized with human nodes connected by ties, which are values, visions, mandates, technological instruments, governance etc. Isolated EWS models (Figure 1 e) has its own mechanism of knowledge transfer, particularly through cultural and traditional experiences as a result of repeated events, and is embedded in a society and can exist only in a specific social-ecological context.

Figure 1: Typology of EWS Model (source: Lassa 2008)

2.1. The Traditional Three Phase Early Warning System Framework

The traditional framework of EWSs is composed of three phases (see Figure 2): monitoring of precursors, forecasting of a probable event, and the notification of a warning or an alert should an event of catastrophic proportions take place (Villagran 2006). It is essentially a linear top down warning chain typology model (See Figure 1 a), that is expert-driven and hazard-focused from observation through warning generation and transmission to users (Basher 2006).

Figure 2: Three Phases of Early Warning Systems -Linear Chain Model (Source: Adapted from Villagran 2006)

2.2. Four Phase People-Centred Early Warning System Framework

Currently, one of the most widely known EWS framework is the four phase EWS (Figure 3), promoted by the International Strategy for Disaster Risk Reduction (ISDR) and partners. It is promoted to enhance the effectiveness and efficiency of EWSs. ISDR underlines that for an EWS to be effective, it must be people-centred and should integrate and span four elements as defined by the ISDR model: (i) a knowledge of the risks faced; (ii) a technical monitoring and warning service; (iii) the dissemination of meaningful warnings to those at risk; and (iv) responses which depend on public awareness and preparedness (refer to IEWP 2006 for further details regarding the specific elements). In relation to the people-centred approach, a key outcome of the World Conference on Disaster Reduction, in January 2005, in Kobe Japan, describes the core components of people-centered EWSs as follows: a combination of ‘bottom-up’ and ‘top-down’ elements, involvement of local communities in the Early Warning process, building awareness into the structure of communities. The four phases people-centred EWS follows a single ‘clockwise’ oriented cyclic model (see Figure 1 b). This implies that risk knowledge component feeds into the monitoring and warning component, which in turn feeds into the dissemination and communication which then triggers or activates the response component. While this set of four elements appears to have a logical sequence as described above, in fact each element has a direct two-way linkage and interaction with each of the other elements as indicated with the double arrows.

Figure 3: The Four Elements for an Effective People Centred EWS Framework (Source: International Early Warning Programme 2006)

2.3. An Integrated System Model for EWS

Another interesting view of EWS was proposed by Basher (2006). According to Basher, the integrated model proposed (see Figure 4), includes the core warning system elements, but in addition contains two new key features. The first is the inclusion of actors that often are not recognised as part of the warning system, most notably the political-administrative supporting entities, the district and community actors, and the research community. The second feature is the explicit inclusion of multiple linkages and feedback paths, particularly from affected populations through their organisations to the political and technical actors. The model could be elaborated further for the particular circumstances of countries, for example, to better specify the district-level and community-level elements or the collaborative roles of different discipline-based technical institutions (e.g. such as seismological, oceanographic and meteorological organisations in a tsunami early warning system). In this context, the model does not seem to follow any specific typology as described in Figure 1, but the integrated model for EWS is viewed as a very important step towards improving the concept of EWS.

Figure 4: Integrated Early Warning System (Source: Basher 2006)

2.4. Framework for Sustainability Assessment for EWS

Another interesting version of EWS framework was proposed by Lassa in 2008 (see Figure 5). He suggested the quantitative measurements for incentive structures for a sustainable EWS such as governance and institutional indicators, knowledge society indicators, economic and human development indicators extracted from World Bank's (2007) KAM database. It also proposes qualitative measures for assessing micro level EWSs using composite concepts of efficiency, effectiveness, equity and legitimacy (i.e. EEEL principles).

Figure 5: Framework for sustainability assessment for EWS (Source: Lassa 2008)

2.5. Current Weaknesses and Gaps: Governance Context and Framework Conditions

Basher (2006) underlines that the main shortcoming of the linear paradigm EWS (Figure 2) is the high focus on the hazard, with less emphasis on the vulnerabilities, risks and response capacities. In addition, the different hazards are managed by separate independent technical institutions, with little corporation and collaboration in terms of research and knowledge exchange. This is not to suggest that separate hazard EWS is not favourable, but rather there should be a certain level of communication, corporation and collaboration between actors and respective institutions operating different natural hazard EWSs. In addition, the dominance of the technical expert does not engage and empower the people at risks to consolidate the political and budgetary support for the warning system.

The IEWP model (Figure 3), for effective EWS lacks the differentiation of the communication process between actors during the time when there are no threatening hazard events and during impending disaster events. Apparently, the model shows communication as active only between the monitoring, warning and response processes. Therefore, it is necessary to differentiate between the two communication processes and to show that communication is a central element across all the components of an EWS. In addition, although institutional and governance aspects are acknowledged as important cross-cutting issues for an effective EWS, they are not always illustrated and elaborated methodologically in the model framework.

The key weakness of the integrated model for EWS (Figure 4), is that participation is not structured under a main theme or dimension such as governance. Participation is only one attribute of governance. In addition, the integrated model only shows hazard knowledge rather than risk knowledge as a key element of EWS.

On the other hand, in regards to the sustainability framework for EWS, Lassa (2008) recognises that the model has not been tested to this point while EEEL principles demand feedback and ensure accountability in the system. The framework does not show the dynamic interactions between the core elements of the EWS. Secondly, the framework focuses on sustainability assessment rather than effectiveness of EWSs. The effectiveness of EWS is a critical factor in determining its sustainability. For example, if the public views the EWS as ineffective, they would most likely have little incentive to engage and consolidate the political and budgetary support for the EWS. Thirdly, the sustainability framework centres around indicators and pays little attention to the underlying processes such as contrasting between formal and informal institutions that constrain the actors behaviour and actions. In addition, the framework is not consistent in defining the indicators for measuring sustainability of EWSs. For example the indicators to measure effectiveness, efficiency, equity and legitimacy are not represented and elaborated in the framework.

Overall, all the frameworks presented here in this paper fails to link EWS with social-ecological aspects of governance. Critical thresholds, uncertainty, scale, fit, potential tipping points in social-ecological systems are critical elements to factor as part of governance context and framework conditions of EWSs.

2.6. What is an Effective and Sustainable EWS?

There is a lack of literature which specifically defines what is an effective and sustainable EWS. On the other hand, the current body of literature suggest how to improve EWSs (see table 1). UN-ISDR defines an effective early warning as ‘the provision of timely and effective information, through identified institutions, that allows individuals exposed to a hazard to take action to avoid or reduce their risk and prepare for effective response’ (UN-ISDR 2004). Lassa (2008) defines an effective and useful early warning in terms of not only if warnings are issued per se but rather on whether the warning facilitates appropriate and timely decision-making by those at risk.

2.7. General Understanding of How to Improve EWS

Basher (2006) suggested that an effective and sustainable EWS needs to have not only a strong scientific and technical basis, but also a strong focus on the people exposed to risk, with a systems approach that incorporates all of the relevant factors in that risk, whether arising from the natural hazards or social vulnerabilities or from short-term or long-term processes. This requires an integrated approach characterised with linkages and interactions, feedback from the population at risk through their organisations, the actors, i.e. political administrators, the district and community actors, and the research community, and links to international communities (See Figure 4). The risk manager and citizens are most concerned with the integrated risks faced and how to mitigate and prepare for them. This implies that an approach that addresses all relevant hazards in an integrated fashion and tailor made, and not as separate unconnected systems, is more appropriate to the management of natural risks. It must be tailored for each hazard, and the issue is how to create a coordinated “system of systems”.

The architecture or design of EWS should start by analysing situations in the ways that they are meaningful to the people involved (Agre 2000). In that sense, the effectiveness of an institutionalized EWS can only be achieved by close cooperation between agencies running the system and the vulnerable people. EWS need to be adapted to different conditions. The complex structure of large cities, for example, requires different arrangements than a rural environment. In order to reach the last mile, an integrated approach to early warning has to be based on the needs, priorities, capacities, and cultures of those people at risk. People at risk must be partners in the system, not controlled by it. People-centred early warning brings the people into the system where they play an active role, but it should not bring the people to the segment where they are not needed or where they cannot contribute effectively.

Experience has shown that an effective EWS must be both technically systematic and people-centred (UN-ISDR 2006). Being people-centred means including actors and the risk community, identifying the risks through social interactions, exploring mapping, planning and responses, generating public information, and using the media, perception surveys, monuments, publications, organising annual events, exercise, drills and simulations. Such activities require the coordinated participation of different organisations. They should be based on community engagement, empowerment and the sense of ownership. In this respect local governance should lead these outcomes. In this context, it is important to understand intrinsic human interactions and persistence in the existing institutional order. These issues influence the individual, community members’ motivation to cooperate, participate, and communicate with each other, obey rules, use and manage local affairs in a ‘positive’ way. Such initiatives are the conditions for a sustainable, scaled up and most importantly, adaptable and resilient system. To have a sustainable early warning system requires annual and long term strategies. The other important issue to consider when designing and operating an EWS is the need to keep in mind for different risk knowledge and management strategies. These specifically include knowledge and management strategies of how to deal with routine, mundane risks, complex and sophisticated risks, highly uncertain risks, highly

ambiguous risks and imminent dangers and crises. The IRGC (2005) proposes that for highly complex risks, there is a need for risk-informed and plural knowledge strategies with stakeholder participation through mainly epistemological or theory of knowledge discourse. On the other hand, highly uncertain risks require a precautionary and resilience building approach including making compromises between too much and too little precaution with a reflective discourse approach. Ambiguous risks require plural value input social groups in terms of reflective discourse. In addition, EWSs not only need to continue to innovate and adapt in the context of technologies, but must also continuously review their aims during performance and renegotiate the multiple organisational and community relationships of the system. A prerequisite for an effective EWS is the recognition of its benefits by the general public, policy makers, and the private sector. A cost benefit analysis for example will help to foster the necessary political engagement and the will to promote the objectives. Table 1 summarises the key characteristics, criteria for an effective EWS. In this regard, the next section aims to systematise the governance related aspects, and the framework conditions of EWSs.

Table1: Key criteria/indicators for improving EWS

Effective and Sustainable EWS		
Traditional Issues	Cross-Cutting Issues	
<ul style="list-style-type: none"> - Timely - Meaningful - Lives saved - Reduction of damage and losses - Systematic collection of data - Scientific and technical basis - Integrated risks - Risk assessment maps - Risk management strategies - Multi-mode systems - Feedback - Coordinated “system of systems” - Training - Scenario practises - Drills 	<ul style="list-style-type: none"> - Optimality - Sacrifices and gains - Added value - Reducing cost - Cost i.e. benefit analysis - Integrated approach - Multi-Hazard Approach - Tailor made - Plurality in knowledge - Human justice - Inequality - Coordinated participation - Social interactions - Inclusiveness 	<ul style="list-style-type: none"> - People-Centred Approach - Cooperation - Rightfulness of decision - Engagement - Empowerment - Ownership - Autonomy - Renegotiate - Existing institutional order - Formal & Informal - Human behaviours - Partners - Multi-Level and scale - Review aims - Long term strategies - Livelihood protection

3. Proposed Governance Context and Framework Conditions for EWS

Overall, considering the different concepts, frameworks and discussions outlined in section 2.0, the governance context and framework conditions of EWSs is proposed (see Figure 6). The framework conditions are centred on the EWS core components (IEWP 2006). In addition, communication as an extra element should function at all times, levels, and across all scales, and not only during impending disasters. Secondly, it includes the issues of social-ecological system governance perspective. Thirdly, the framework conditions focuses on the governance aspects closely related to the EWS architectures, the

actors and the community. Fourthly, it links with the broader system of governance (i.e. political, economic and social and technological), to emphasis on the main pillars and driving incentives required for implementing and supporting an effective, and sustainable EWS. The framework is scalable depending on availability of data and specific use. This implies new dimensions; elements or indicators can be added or equally reduced depending on the local context of application. In the following section, the governance aspects of the framework conditions are further discussed.

3.1. Risk Communication Perspective of Governance

The IEWP model for effective EWS has one major weakness-It lacks the differentiation of the communication process between actors during both the time when there are no hazards threat or events and during impending disaster events. Apparently, the model shows communication as active only between the monitoring; warning and response processes (see Figure 3). Therefore, it is necessary to differentiate between the two communication processes and to show that communication is a central element across all the components of an EWS. In other words, communication between actors is viewed as a central and important mechanism which should remain active at all times throughout the process to improve learning, information exchange and coordination (Thompson 1967, Galbraith 1977, IRG 2005). This should be promoted through governance aspects. It is pointed out that it is important to differentiate between the different modes of communication. This implies that one will not necessarily use the same medium and mechanisms of communication for each respective communication phases.

3.2. Social-Ecological System Perspective of Governance

A key perspective of governance which needs to be considered particularly when designing EWSs is the socio-ecological system context of governance. A social –ecological system of governance can be understood as an interaction between certain attributes of governance (e.g. participatory, accountability etc) in society to enhance the capacity to manage resilience. A society's ability to manage resilience resides in actors, social networks, and institutions (see Lebel et al., 2006). The condition and properties of the ecosystems that people use can make management an easy or a hard task. In this context, Lebel et al (2006) suggested that it would be helpful as a first step, to break down this ability into capacities (e.g. Self-organization, adaptation, and learning, threshold, scale, fit, tipping points surprise, knowledge and diversity etc). These are further explained below.

3.2.1. Self-organisation

A system can maintain and renovate its identity if it has the capacity for self organisation. Although most systems are linked to, and impacted by other systems, self-organizing systems are able to buffer the impacts of other systems and do not need to be continually invested in, subsidized, or replenished from outside to persist (Ostrom 1999, Carpenter et al. 2001, Holling 2001). Management systems can get better over time with an increased ability to learn and adapt (Adger et al. 2005, Brooks et al. 2005, Folke et al. 2005).

Figure 6: The Proposed Governance Context and Framework Conditions for EWS (Source: Author)

3.2.2.Element of Surprise, Threshold and Uncertainty

The capacity to cope with non-linearities or other forms of surprise and uncertainty requires openness to learning, an acceptance of the inevitability of change, and the ability to treat interventions as experiments or adaptive management (Gunderson 1999, Adger 2000, Pahl-Wostl and Hare 2004, Adger and Vincent 2005). For instance, the mega earthquake and tsunami in the Indian Ocean in December 2004 was widely viewed as an element of surprise in terms of magnitude and intensity. Theoretical academic knowledge and understanding did not clearly capture the issues of uncertainties and critical thresholds of such systems. For example, the famous Ruff and Kanamori earthquake models (1980) indicated that the Sumatra subduction zone's maximum earthquakes were predicted to be of around 8.3 moment magnitude based on the age of the subducting plate in millions of years and the convergence rate in centimetres/year. This theoretical earthquake threshold was surprisingly exceeded on 26th December 2004. The element of surprise from such a large magnitude earthquake and tsunami in the Indian Ocean was neglected, and was not factored in regional and national EWS and early warning processes.

Similarly, the ability to detect and set critical thresholds for a range of hazards is a key challenge to address for improving EWSs. A key question of interest is as follows: Is the EWS properly designed to capture the critical thresholds for the purpose of issuing the different levels of warnings to motivate the correct and appropriate response. For example, in Indonesia, following the December 2004 tsunami catastrophe, the newly established tsunami EWS was activated in the event an earthquake reached or exceeded 6.6 moment magnitude. This initially caused many false tsunami alerts undermining trust and the credibility of the tsunami EWS. The threshold has been re-evaluated and raised to 7.0 moment magnitude. However, elevating the threshold to 7.0 moment magnitude can lead to a complete miss or no alert for lower magnitude earthquakes which can actually generate tsunamis. Hence, enhancing EWS requires also an improved consideration of critical thresholds and preparing for the extreme or worse case scenarios where existing structural defence measures might fail.

In addition, in the context of slow-onset hazards, the ability to detect hard-to-reverse thresholds in a timely manner is important because it could allow societies to take measures to prevent systems from crossing thresholds and ending up in another undesirable basin of attraction (Holling 1978, Carpenter et al. 2001, Scheffer and Carpenter 2003). While EWSs for evident disaster risks only need to warn people at risk, climate change-related hazards – such as sea level rise, drought – often imply uncertainty as part of the climate prediction services. The higher the level of uncertainty and complexity, the higher the need to base decisions on how to respond to these on a broader and consensus-oriented approach. Currently, uncertainty is being addressed by employing a variety of methods and techniques. This includes inter-model simulations and comparison, ensemble predictions or projections, scenario analysis, probabilistic forecast, etc. Even with substantive improvements in current scientific knowledge, the key challenge includes information dissemination, communication, and interpretation at the local level particularly in less developed countries. In this context, it is important to establish the degree of uncertainty or skill of the forecast in relation to slow onset hazards such as drought. In addition, it should also be established how current experiences are treated with respect to climate change variability and climate change predictions or projection and how this should be factored and understood by decision-makers. This implies that there is a need to simplify these methods as much as possible so that information regarding uncertainty can be communicated in a more meaningful way to various users for proper application and use at various levels and scales. In this sense, particularly in the context of climate change, this would require the involvement and dialogue of stakeholders (Renn 2005, IRG 2009).

3.2.3.Diversity and Scales

Following a major crisis, the capacity to build and maintain social and ecological diversity provides the opportunity for renewal and reorganization (Peterson 2000, Ostrom 2005). Our capacity to successfully combine or integrate understanding gained from different sources and forms of knowledge, including tacit and formal knowledge, increases the likelihood that the key thresholds and components of diversity will be acknowledged (Berkes and Folke 1998, Berkes 1999).

Furthermore, it is crucial to have the abilities to engage effectively at multiple scales to deal with regional trans-boundary hazards such as tropical cyclones, tsunamis, drought because they are subject to cascading impacts and are also related to powerful external influences, including changes in operational procedures, norms, and regulations (Berkes 2002, Young 2002).

3.2.4.Knowledge and Fit

The ability to improve knowledge about social-ecological processes in institutions should improve the fit between rules and social-ecological systems even as they go through dynamic cycles (Holling 1986, Walters 1986, Berkes 1999, Gunderson 2000, Young 2002, Folke et al. 2003). For example, in terms of fit, the questions which are of interest are as follows: Is the early warning chain properly designed to ensure a timely warning to trigger the correct response in the case of a rapid onset of hazards such as near field tsunami. Is the national top-down technocratic warning system more effective compared to a local community based EWS? Does the design of the EWS fit to the norms of the culture and society?

3.3. Architecture and Actors Perspective of Governance

3.3.1.Architecture

According to Earth System Governance (2009), architecture includes questions relating to the emergence, design and effectiveness of governance systems as well as to the overall integration of global, regional, national and local governance. In this paper key aspects of architecture to consider include institutional arrangements and norms, organisation design and structures.

It is important to understand that the term "institution" includes more than agencies and organizations, and extends to laws, legislation and management behaviours. Firstly, traditional theories view institutions as the rules of the game (Ostrom 1990), or the regulations or conventions imposing constraints on human behaviour to facilitate collective action (e.g. North 1990). They are grounded on Common Pool Property (CPR) theory, which in turn is based on game theory. They are centred on collective action dilemmas and institutions which are designed or crafted to produce collective action. Mainstream institutional applications have focused on local situations of natural resource management which are subject to boundaries and to relative socio-economic homogeneity among users (Ostrom 1990, Wade 1998). On the other hand, the New Institutional Economics (e.g. North 1990), views institutions as representing formal rules and conventions, including informal codes of behaviour, or norms in the context of transaction costs with effort of moving towards efficiency, but ignores history, socio-culture and political economy. Others view institutions as more processual and dynamic. They are more than just rules or regulations but are what people do or how people behave, endowing actors as agentive roles (Cleaver 1998). Of particular contrast to mainstream institutionalists, Mehta et al. (1999) argue that institutions emerge to embrace, moderate or exacerbate uncertainty, and they are embedded in social relations, being symbolic and interlinked with knowledge and power that span temporal and spatial scales which are not self-evident in terms of formality and informality, rather than institutions that work to mitigate uncertainty as in the case of mainstream theories.

UN-ISDR (2006) stated that multi-institutional arrangements include legislative, policy frameworks, institutional capacities, government funding, multi-hazard approach, etc that supports the implementation and maintenance of effective EWSs. In this context, the paper empathises on the issue of multi-hazard approach, multi-institutional arrangements, mix- institutional approaches (Formal and Informal), and organisational structures (i.e. Polycentric -Multilayered Institutions) for improving EWS.

Multi-Hazard Approach

The rationale for developing a multi-hazard–risk approach should be seen as a matter not only for effectiveness, but also for efficiency and sustainability. Multi-hazard approach should help in addressing both rapid and slow onset hazards because a society will be faced with diverse risks from multiple hazards characterised with different temporal scale of recurrence.

Practical experience shows that most institutional actors address natural hazards such as floods, tropical storms and weather-related hazards such as heavy precipitation and heat waves. However, although there are a number of studies on the subject, much less attention has been paid to slow and creeping hazard processes such as salinization and rises in sea level (Birkmann and von Teichman 2010). Even less attention is paid to accumulated shocks from non-extreme events (Birkmann, Chang Seng, Suarez 2011).

This implies that developing an approach that addresses all relevant hazards in an integrated fashion, and not as separate unconnected systems, is an important challenge for improving the capacity of societies to deal with environmental shocks and creeping environmental changes. According to Basher (2006) such a ‘multi-hazard’ or ‘all-hazard’ approach should provide synergies and cost-efficiencies, e.g. in data gathering and processing, and in public preparedness efforts, and should assist in improving sustaining warning capabilities for the more infrequent hazards such as tsunamis. The infrequency of certain hazards such as tsunami suggest that it would make little sense to operate a standalone tsunami EWS due to the high cost of maintaining such an expensive system. It is underlined that a multi-hazard approach does not mean or imply all the natural hazards are managed by a single institution but rather there is a coordinated ‘system of systems’. Much remains to be elaborated in the practical implementation of these ideas.

However, key ideas are emerging regarding hydro-meteorological multi-hazard EWSs, both at the national and global level. For example, Shanghai has become the first mega-urban city to showcase a multi-hazard EWS in an urban setting with the support of WMO and partners. Shanghai as an urban city meets the basic requirements of a demonstration project of the WMO multi-hazard early warning systems, namely, (1) frequent occurrence of natural hazards, (2) complete infrastructure of hazard detection and early warning, (3) commitment from the local government and national-level meteorological departments. It is part of the process to initiate a worldwide, all natural hazard early warning system from its concept and design. The initiative can be traced back to a symposium on Multi-Hazard Early Warning Systems for Integrated Disaster Risk Management in May 2005, where the leading experts and officials (UNDP, ISDR, OCHA, IFRC, UNESCO, World Bank) came to recognize that a worldwide multi-hazard demonstration and pilot project should be established that would assist and encourage the development of multi-hazard early warning systems in all countries. However, the Shanghai Multi-Hazard EWS needs to be developed and tested in the context of multi-risk and crisis conditions so that lessons can be learnt in other countries.

Mix- Institutional Arrangements and Approaches

A mix-institutional arrangement may include the incorporation of a combination of ‘bottom-up’ and ‘top-down’ elements, utilization of awareness techniques that populations can relate to whatever their level of formal education. It also involve where possible the local communities, in the process of data collection, monitoring and warning, embedding warning functions within systems that serve multiple purposes and building awareness into the structure of communities.

Therefore, depending on the hazard and governance context, early warning processes may need to be initiated at the local level. This implies that a mixed-institutional arrangement is needed, depending on the risk. In this context, a local- adaptive EWS approach involves the people at risk starting some kind of anticipated response once a threat is perceived or observed. The local approach may consist of a combination of (1) social micro level reaction and response, (2) the legitimate response of the Emergency Operation Centres once a hazard is felt or anticipated, and (3) the use of religious-cultural based structures and norms. The concept is that the EWS does not start only with observation and monitoring with instruments, but also from the correct reaction-response of the people. In this context, a combination of formal and informal institutional approaches can be used to improve the overall governance of EWSs. In a rural and low technological environment, informal institutions would be particularly important when designing and operating an EWS. Traditional knowledge should not be overlooked: it can provide added value to technical or scientific capacities. However, traditional knowledge should be assessed on the basis of its effectiveness, flexibility, equity, efficiency and sustainability. It will be necessary to improve the visibility and acknowledgement of bottom-up approaches in national policies, as policies and programmes are validated in terms of their effectiveness and relevance at the local level (Birkmann, Chang Seng and Surez 2011). In this context, a combination of institutional arrangements characterised with top-down, and bottom-up, formal and informal approaches should be seen as important elements of the Last-Mile and people centred EWSs. Thomalla and Larsen (2010) discusses about the different concept, definitions and understanding of the Last Mile in the context of EWS, and in this regard it can be seen as the link between technology and communities at risk, and to deal with issues of risk knowledge and potential response of the people in the EWS (Chang Seng and Birkmann 2011)

Organisation-Polycentric -Multilayered Institutions

Of particular relevance to EWSs is polycentric-multilayered structures and institutions. Polycentric institutions, by definition, have multiple centres or authorities (Lebel et al. 2006). Such organisations’ structures have been argued (Imperial 1999, McGinnis 1999, Cash 2000) to enhance and contribute to opportunities for understanding and for servicing needs in spatially heterogeneous contexts. Polycentric systems are often multilayered, but do not necessarily have neat hierarchical structures. Multilayered institutional arrangements are important for handling scale-dependent government challenges as well as cross-scale interactions (Young 1994, Berkes 2002, Lebel 2005). Multilayered governance facilitates vertical interplay among institutions (Berkes 2002, Young 2002, Lebel 2005).

Multilayered institutions are often viewed as decentralisation. It is widely argued that decentralisation process will result in greater efficiency and equity and responsiveness centred on local people’s participation through greater autonomy in local decisions on programs, projects, investment and management and ultimately more socially and environmentally sustainable development (Ribot et al. 2006, Manor 1999, Fox & Aranda 1996 etc). However, the conventional criticism of polycentric and multilayered arrangements is that there is inefficient overlapping of co-ordination and administrative responsibilities. Polycentric and multilayered institutions and structures are highly important factors to consider when designing EWSs. It will shape the information-warning chain from the national level to the local level and the community.

3.3.2. Actors

The actors affect the structure of action arenas, the incentives that individuals face, and the resulting outcome (Ostrom 2005). An actor is any person, social group or institution that has an interest or stake in a development activity, project or programme, such as use of ocean resources (i.e. fisheries), or providing services and products (i.e. early warning information). Actors have the potential to influence a specific state of affairs or a process by act, intervention or by refraining from intervening or participation (Giddens 1984). This definition includes intended beneficiaries and intermediaries, winners and losers, and those involved or excluded from decision-making processes. However, actors' behaviour has been theoretically debated around the rational choice theory and the new institutionalism debate on collective decision theory or Collective Action "Prisoner's Dilemma". In this context, the rational choice theory for understanding and modelling social, economic behaviour is a central theoretical paradigm in microeconomics and political science, and is sometimes used in sociology and philosophy. It hinges on the analysis of the choices made by rational actors under conditions of interdependence. Rational choices are diverse, but all assume individuals choose the best action according to stable preference functions and the constraints facing them (Immergut 1998). On the other hand, collective actions imply that actors make the best choices collectively. However, the 'Prisoner's Dilemma', with the precondition that all actors possess complete information, illustrates the benefits and limitations of collective action in decision situations because in reality, not all actors have all the information necessary to enable them to make the best decision. Under such circumstances, it is individually beneficial not to cooperate with each other even though collaboration by all actors would entail acceptable benefits. In that way, actors consider that they need to defect due to vagueness about other actors' actions. Nonetheless, it is important to note that both theoretical debates have weaknesses in terms of explaining fundamental social attributes such as trust, altruism and the prevailing and binding issues of norms and obligations. The divergence of actors' motives is of importance and is not necessarily based on rationality or collective choice or action as discussed above. In that sense, one may view the actors' goal in terms of achieving utility rather than achieving power, convenience and reputation. The key attributes of actors of concern includes their participation, deliberation, negotiation strategies and capacities, transparency, accountability, equity, injustice. These are further described as follows:

Participation

Multi-stakeholder participation is a mechanism for coping with plural values and interests (IRGC 2005). It addresses the issue of inclusive governance by providing guidance, which is based on the assumption that all stakeholders have something to contribute to the process and that their inclusion improves the final decisions rather than impedes the decision-making process or compromises the quality of scientific input. In that sense, IRGC has recommended that stakeholder involvement is a function of risk. The involvement of stakeholders is both to ensure that the risk handling process is inclusive and responsive to those affected by it and to maximise the effectiveness and acceptability of the decisions that are made (IRGC 2005) and actions taken. People-centred early warning promotes participation of a variety of actors, including those affected by events.

Deliberation and Negotiation

Deliberation and negotiation should be seen as important aspects, particularly when designing EWS. Additionally, it serves as an important mechanism aspect to account for EWS effectiveness. It does not imply actors and the community need to deliberate and negotiate on the issue of warning at the time of an approaching or developing hazard or during the actual event. Deliberation is discussion and consideration of all sides of an issue. It is characterised by a process of open communication, discussion, and reflection among actors who have different political viewpoints and understandings (Leeuwis 2000, Röling 2002).

Bäckstrand (2003) suggests that such a process helps both citizens and scientists to understand each other better. On the other hand, negotiation is often viewed as a dialogue intended to resolve disputes, to produce an agreement upon courses of action, to bargain for individual or collective advantage, or to craft outcomes to satisfy various interests. It is the primary method of alternative dispute resolution. A common issue which is often highly contested requiring deliberation and negotiation between actors and the community at risk involves the issue of who, when, how, what in regards to warning information and evacuation as part of the response component of EWSs.

Transparency and Accountability

Transparency often implies openness, communication, and accountability. One may be transparent, but not see oneself as accountable. In that sense, authorities are obliged to provide information and explain decisions and actions or inactions and whether they can be sanctioned when those answers are unsatisfactory (Agrawal and Ribot 1999). The lack of these elements may often lead to corruption. Transparency and accountability are important aspects in EWS. For example, the community will lose their trust and provide less support if the concerned authorities consistently fail to provide satisfactory explanations to why warning information were not timely and accurate.

Equity and inclusiveness

A society's well being depends on ensuring that all its members feel that they have a stake in it and do not feel excluded from the mainstream of society. This requires all groups, but particularly the most vulnerable, to have opportunities to improve or maintain their well being. Inclusiveness in the context of the research implies that every individual at risk receives early warning information and knows how to respond to the threat or risks and in the distribution of benefits and involuntary risks.

3.4. Broader Systems Perspective of Governance

In this paper, the author proposes that the role of: (1) political (2) economic (3) social and (4) technological systems of governance as key aspects that will affect the effectiveness and sustainability of EWSs. World Bank provides a comprehensive account of the different systems and indicators of governance. Overall, the experience of different countries related to the different indicators in terms of good governance is far less in the developing countries compared to the western-developed countries. In this section and thereafter, the author discusses on some key selected indicators of the four main systems of governance.

3.4.1. Political Systems

The specific indicators that define the political system of governance include political stability, absence of violence, government effectiveness, regulatory quality, rule of law, accountability, and corruption. Considering for example the aspects related to political stability, violence government effectiveness, Birkmann, Chang Seng & Suarez (2010) underlined that in some rare cases and extreme conditions; there is an urgent need to build a level of governance (i.e. political stability, violence) and institutional capacities to enable EWS development. It was reported that in Somalia, good management and governance does not really exist. The government is not recognized outside the city because of severe lack of political stability, etc. A national, multi-sectoral platform for DRR and national EWS does not exist. There is no national- international participation because Somalia is not internationally recognized and the local capacities of NGOs are weak. On the other hand of the spectrum, Lassa (2008) highlighted

that in Indonesia, the establishment of tsunami EWS depends on the government effectiveness which reflects the quality of services delivered by the Indonesian state bureaucrats who would be involved in the EWS and process.

3.4.2.Economic Systems

The economic system of governance includes indicators such as the Gross Domestic Product (GDP) Growth, investments, property rights, insurance local competition, and external debt etc. Overall, there is a general consensus that economic development mitigates the effects and impacts of natural disasters (Kahn 2005, Raschky 2008), particularly through preparedness activities (UN-ISDR 2004 2006; UN-ISDR 2011). It is argued that if economic development is exclusively planned and has a collective social purpose with due consideration of widespread security of livelihoods and environmental enhancement then the result can be a reduction in disaster risk (Wisner et al., 2004). For example, the investment climate indicator covers institutional rules such as the risk of expropriation or contract laws. Raschky (2008) argues that property rights are key determinants for an efficient allocation of resources, which is also important to natural hazard management. Globally, much work is now devoted to a societal risk transfer mechanism through disaster insurance and relief to reduce financial losses (Birkmann, Chang Seng& Suarez 2010). In regions without institutionalised insurance regimes, risk-transfer against natural hazards depends on the individuals and politicians and on where government disaster assistance can lead to the problem of “charity hazard” management (Raschky 2008).

3.4.3.Social Systems

The social systems of governance indicators include for example the public health, education, income level, poverty, transportation, communication system, innovation systems etc. Considering some key aspects related to the social systems, it is widely established that poverty (e.g. Chambers 1989 etc), low income level, lack of public health, poor educational level (e.g. Cardona 2003; Birkmann, Fernando, 2008; Chang Seng &Birkmann 2011) are related to vulnerability; however the concept of vulnerability has a broader remit that also embraces cultural and social components. Other social factors of exposure such as living in a nation with a higher level of educational attainment and openness for trade are less vulnerable to disasters (Skidmore and Toya 2007).

3.4.4.Technological Systems

The technological systems of governance indicators include for example the communication system, innovation systems, transportation, etc. A country’s technological capacity and the people’s access to technology and information systems such as radio, telephone, mobile, computer, internet, free press are very important in early warning.

Chang Seng&Birkmann (2011) highlighted the importance of technology in EWS, and disaster risk preparedness such as the use of a phone networks in Bangladesh to alert the communities at risk to storm flooding. Bangladesh is one of the world’s most densely populated countries, and is highly vulnerable to natural disasters. The people at risk have low access to basic technology. In this regard, Bangladesh has recently adopted early mobile phone and flag alerts to mitigate the negative impacts caused by natural disasters, primarily floods. This will enhance its capacity for forecasting floods through early mobile phone and flag alerts. Tens of thousands of mobile phone users in Bangladesh's flood and cyclone-prone areas will now receive advance warning of an impending natural disaster through an alert on their mobile phone. This will allow the people at risk to evacuate their homes and seek shelter in assigned locations; thus preventing the devastating effects of natural disasters. The mobile phone EWS have already helped in reducing disaster-related fatalities and loss of private and public assets in the five pilot areas. The 2008

post-flood survey in these flood affected areas showed that through early warnings, local people were able to save livestock, capital savings, agriculture, and fisheries per household compared to the losses experienced before. Similar developments are reported in other countries.

4. EWSs Governance in the context of Integrated Disaster Risk Management

The key question which has been raised is how to carry out integrated disaster risk management in different contexts, and across different hazards, etc. This paper does not specifically address Integrated Disaster Risk Management. However, the proposed governance approach and framework conditions in the context of EWSs emphasises the role of various actors and rules at multi- levels and scales in order to address various risks as an integral part of disaster preparedness, hence disaster risk management. Moreover, incorporating the governance aspects of EWS as part of the preparedness phase of the disaster risk management cycle, as shown in Figure 7, should be seen as an important development towards Integrated Disaster Risk Management. It requires integration between disciplines, stakeholders, levels of government, and between global, regional, national, local and individual efforts.

Figure 7: EWSs governance as part of Disaster Risk Management

5. Conclusion

In the last decade, there have been significant efforts towards improving EWSs concepts and frameworks. EWSs framework has evolved substantially from the traditional three phase element with linear chain typology to a more complex and integrated framework characterised with a cyclic typology, as well as additional elements such as participation, feedbacks of different actors and the community and the driving incentive structures for sustainability. More attention is now paid to vulnerability and risk factors as part of the EWS process. However, until now EWSs do not address social-ecological aspects in the framework conditions, and there is insufficient and inadequate attention paid to the governance perspectives to improve EWSs.

In this paper, the governance context and framework conditions for EWS are discussed. In order to address the challenges in relation to hazard risks and their uncertainties which are often outside the scope and capability of an individual or institution, the framework conditions includes the EWS core elements (i.e. risk knowledge, monitoring and warning, dissemination and communication, and response), centred with communication as a key element at all times, levels and scales of the process. Additionally, the paper proposes that it is very important to pay attention to the: (1) broader social, economic, political, and technological systems of governance (2) socio-ecological perspective of governance (3) EWSs governance perspective in terms of the architecture and actors in shaping the design, effectiveness and sustainability of EWS. In this regard, EWSs as part of preparedness should be seen as an important development towards Integrated Disaster Risk Management.

The EWS governance framework was developed for examining, assessing tsunami related governance, concentrating on the development of the Tsunami Early Warning System (TEWS) in Indonesia at multiple-levels and scales. However, the framework needs to be tested in different contexts and for different types of hazards. A key observation is that it is important to exercise flexibility when applying the framework depending on the availability of data.

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