

planet @ risk



Focus and Scope

GRF Davos' innovative e-journal aims to support the establishment of a worldwide risk community, committed to sharing know-how and expertise by a constant process of dialogue – a crucial but still insufficiently implemented element of a truly integrative approach to risk reduction and disaster management. Planet@Risk provides:

- inter-sectorial and inter-disciplinary information on environmental, economic, geopolitical, societal and technological risks and disasters
- theories, methods and tools for analysing, modelling and addressing these risks and disaster
- measures for integrative risk and disaster management

The journal publishes singular papers that have successfully completed the review process. Manuscripts can be submitted for one of the following seven sections:

- State of the Art Collection
- Grey Literature Summaries
- Case Studies for Good Practice
- Scientific Reports
- Working Papers
- Book Reviews
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Planet@Risk

Volume 1 Number 1 October 2013

Publisher

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The concept and realisation of Planet@Risk was generously supported by:

Swiss Agency for Development and Cooperation SDC
Freiburgstrasse 130
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Editorial

"From Thoughts to Action by closely linking practice, science, policy and decision making in the search for sustainable solutions." is the motto of GRF Davos. *Planet@Risk*, our new online journal, is taking up the stated motto of GRF Davos being conceptually designed to facilitate communication, knowledge transfer and experience exchange - all crucial for implementing successful and sustainable practice in Disaster Risk Reduction DRR.

Risk reduction and disaster management, risk analysis and assessment, prevention, mitigation, intervention, response, recovery, vulnerability, resilience, disaster preparedness, crises communication, risk governance, and the many more key-words and contents are subject to intensive, but often still sectorial and disciplinary research. However, for effectively dealing with today's risks and disasters an integrative, inter- and trans-disciplinary approach is needed, in particular if risk and disaster management are put into the context of a resilient, sustainable development process. Imminent hazards and large or frequent catastrophes strongly intervene with a broad spectrum of processes, i.e. the dynamics of population pressure and mobility, urbanisation, the various facets of globalization, economic and financial crises, climate change, environmental degradation and erosion of ecosystem services, health and food issues, and the shifts in ethical, cultural and behavioural patterns. The portfolio of risk reduction, disaster management, global change and security as a whole becomes ever more complex and interwoven.

The globally growing number of crises and disasters, and the more and more intricate, complex and multifaceted nature of risks require an innovative, integrative and problem-oriented approach to risk and disaster management. GRF Davos aims at fostering the integrative risk management approach on a global scale with this new e-journal *Planet@Risk*. The issues of risks, disasters, safety and security, development and sustainability ought to be inter-disciplinarily approached by scientist, policy makers, administrators, practitioners, and business leaders. It is only through a holistic perspective that the complexity of the risk theme and its entire phenomenology can be understood, addressed, conceptualized, and tackled.

In an age of unprecedented global change and interdependence, an integrative approach, involving all relevant kinds of risks, disciplines and stakeholders, has to be applied and taken throughout the entire risk cycle of prevention, mitigation, preparedness, response and recovery in order to be able to identify viable solutions and promote good practice. This view is now widely accepted, however, there is also consensus that sufficient knowledge

transfer and full integration of sectors, stakeholders and especially front-users involved in risk reduction and crisis management are still lacking. The rapid transition of scientific, disciplinary knowledge into applicable, interdisciplinary know-how and its dissemination are therefore key elements to improving risk and disaster management in an integrative manner. In line with GRF Davos' activities, *Planet@Risk* will cover the entire spectrum of risks, threats and disasters societies are facing today, covering environmental, economic, geopolitical, societal and technological risks. Theories, methods and tools for analysing, modelling and accessing these risks and hazards will be discussed and evaluated in this journal.

GRF Davos' e-Journal *Planet@Risk* shall become an innovative platform for knowledge and know-how sharing and for practical case studies thus contributing to a successful implementation of the integrative risk management approach. *Planet@Risk* shall contribute to bridging the gaps between science, practice, and different sectors in academia. It fosters a multidisciplinary approach, as it will in particular present results of inter- and trans-disciplinary research projects with a special focus on their applicability into practice. Being primarily focussed on the implementation of practical know-how, *Planet@Risk* is complementing our second initiative which we are realizing in close cooperation with ELSEVIER Publishing Company, the peer-reviewed and primarily science focussed "*International Journal of Disaster Risk Reduction*" IJDRR.

Planet@Risk shall also serve as a mean for assessing 'grey literature', reports, case studies, and reviews. By swiftly collecting and pooling these different types of literature, the documents shall be easier findable, accessible and citable as part of an inter- and transdisciplinary knowledge pool for the risk reduction and disaster management community.

Grey literature may be defined as "a field in library and information science that deals with the production, distribution, and access to multiple document types produced on all levels of government, academics, business, and organization in electronic and print formats not controlled by commercial publishing i.e. where publishing is not the primary activity of the producing body." . Information from local knowledge, data, or studies referred to as grey literature has mostly not gone through a review process for scientific journal publication because the main purpose of the documents is not academic but action orientated. DRR therefore is subject to a vast variety of grey literature like policy statements, technical or project reports,

government documents, annual reports, working papers, conference proceedings, diploma theses, brochures, audiovisual and online material, making it even more important for these documents to be accessible and assessed by a broad group of stakeholders strongly involved in risk and disaster management.

Planet@Risk shall also serve as a platform for “good practice” case studies, in particular addressing examples where science has provided guidance to successful implementation and has originated innovative solutions in DRR. Furthermore, many publications on successful practices are documented in other languages than in English, impeding easy and wide dissemination. *Planet@Risk* shall provide a platform to make these documents better accessible for the wide-spread, quite heterogeneous risk community.

To summarize, *Planet@Risk* shall serve as a platform for:

- *Bridging the gaps* between science and practice to accelerate the transfer of scientific findings into good practice.
- *Promoting an inter and transdisciplinary approach*, involving not only scholars in multiple disciplines (e.g. from engineering to social sciences, urban and land use planning to economics and finance), but also practitioners in the different fields, public policy makers at the national and community level, and community, NGO, IGO and UN- representatives.
- Providing a platform to assess and agree on *good practice examples* for all types of environmental and natural hazards, man-made risks and disasters.
- *Assessing ‘grey literature’* on risk reduction and disaster risk management and thereby making it available

in one location to facilitate access and citation of the documents.

- Providing and facilitate a *knowledge sharing pool* for the risk reduction and disaster management communities.
- Providing scientifically sound and approved material for *white papers*.

As an electronic and open access journal *Planet@Risk* has the advantage of providing quick publication possibilities and is freely accessible for everybody. Quality control and publication assessment is guaranteed through a short double review process by an international editorial board.

I would like to take this opportunity to heartily thank our sponsor, the Swiss Agency for Development and Cooperation (SDC), Berne, Switzerland for their financial support to design and implement the concept for *Planet@Risk*, the Editorial Board members who secure the quality of the journal and last but not least the authors for their valuable work they share with us.

I wish you lots of enjoyment with our first issue of *Planet@Risk*!

Walter J. Ammann

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Extreme Weather, Risk and 'Social Crisis': An Analysis of Un-Answerability

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Abstract – Extreme weather, especially cold waves, kills hundreds of homeless and destitute people in India every year. There has not been any effective risk aversion mechanism available to them. Existing development and disaster management frameworks are unable to address such risks. This exposes the institutional weakness of risk assessment and mitigation models. The economic limitations of victims devalue the importance of risk assessment and theorisation.

Keywords – Risk, Disaster Risk Reduction, cold wave, extreme weather, capability

1. Introduction

Beck (1992: 35) defined risk position as social inequality which would be severe in a situation wherein reflexive modernity is unequally distributed. He went to argue that the social production of wealth is systematically accompanied by the social production of risk. He further argues that risk distribution is unequal, i.e. some are more affected than others by the distribution and growth of risks. Beck's argument of unequal distribution of risk is indeed an explanation of development inequality. Douglas (1994) argues that generally risk turns to a political issue and someone who is unpopular would be blamed for it. She further explains: "An alternative way of explaining misfortune is to attribute it to the work of individual adversaries. The moral will be that a survivor needs to be smarter than her rivals: they will say that the reason she died can be traced back to her not having been quick enough or clever enough in looking after her own interests; rival magic was more powerful than hers." In short, the stronger the solidarity of a community, the more readily will natural disasters be coded as signs of reprehensible behaviour. Giddens (1991:171) has given an explanation of such behaviour with regard to risk: "Most people shut them (risk) out of their lives and concentrate their activities on privatised "survival strategies", blotting out the larger risk scenarios. Giving up hope that the wider social environment can be controlled, people retreat to purely personal occupations: to psychic and bodily self-improvement."

The risk of being exposed to multiple vulnerabilities

and disasters has social, economic and political reasons. The social and economic position of individuals plays a critical role in extending vulnerabilities. Individuals are forced to accept certain risks. The knowledge of such risk never desist people from being exposed to risks. For instance, the impacts of extreme weather conditions are different from socio-economic conditions. This paper is discussing, the impact of cold wave among urban homeless and destitute people in India. The paper argues that risk and uncertainty of these people are deep rooted in unequal development practice and the existing institutional understanding of risk management, including disaster risk reduction. Development agencies, disaster management institutions and political movements are incapable to deal with such deep-rooted social risks. The institutional understanding of the impact of cold waves is limited to offering temporary support to limited victims. This paper considers the impact of cold waves as a reflection of the persistent development inequality in India. It further argues that the victims of extreme weather impact are incapable to attract institutional interventions of state and other agencies. The incapability is structural in nature. The risk and uncertainty of these victims are remaining outside the purview of contemporary debate on risk. This paper is based on secondary data sources, existing risk assessment models and development crisis of India which have been critically assessed to study the impact of cold wave on poorest of poor in the country.

2. Cold wave impacts

Cold waves kill many more people in India than summer heat (see table 1). There were 131 people reported died in 2011 December¹, another reports said that 133 died², again in January 2012 150 people had due to cold wave³. The reasons for such deaths are seldom attract public attention. Since it is seasonal events and the people who are dying are also unable to challenge the government-socially and economically backward to put any kind of pressure on state. The risk involved in this scenario is beyond the theoretical perceptions of risk and uncertainty studies. Basically the risk of being exposed to cold wave is due to living under the open sky. This very common knowledge has many social and political implications in India. Risk mapping of the cause of death would question the development policies of the country, hence, the death due to cold wave should be studied in a larger risk perception.

Table 1: Cold Wave disasters in India from 1980 – 2008^a

No of events	156
No of people killed	11'565
Average people killed per year	400
No of people affected	6'875'103
Average people affected per year	237'073
Economic Damage (US\$ X 1,000)	5'901'560
Economic Damage per year (US\$ X 1,000)	203'502

^a Source: <http://www.preventionweb.net/english/hazards/statistics/?hid=56>.

Cold waves induced deaths are being reported mostly from urban centres. People who are dying due to cold waves are in general homeless migrant workers and other destitute people. Distress migration is one of the reasons for large scale migration of workers from rural to urban areas. There are many reasons which push people from rural to urban centres. For example (1) the surplus capital of Indian industrial sectors are being concentrated in urban centres; (2) huge inflow of capital, including foreign capital, have created new development projects in urban areas. This leads to a huge flow of (cheap) labour force from rural to urban areas. There cannot be identified any particular locality where this labour force is concentrated. It again depends on the flow of capital to urban areas. There are many critical issues associated with such capital flows. The development which this capital puts in place is not offered equal space or support for an equitable distribution of benefits. The urbanisation in India also creates urban peripheries. Those people who are exposed to extreme weather like cold waves mostly belong to these peripheries. In this case the term periphery cannot always be physically limited to certain areas or structures, the term rather means social, physical and economic isolation. The rationale of this argument is that those who are exposed to cold waves in India are excluded from the

physical structure of the urban periphery. As said before people who are exposed to cold waves in India are mostly homeless citizens. Homeless shelter manual (2010) defines homelessness as a condition of people without a regular house and whose night-times residences are public or private places not designed for using as habitual sleeping accommodation for human beings. The number of homeless people is increasing in India. (see table 2). The death of homeless citizens is accepted as a "seasonal issue" of homeless migrant workers, destitute and other marginal sections in the metros. For instance, the government of Bihar has announced an ex gratia payment for cold wave deaths. If any death reported due to cold wave, he/her family would get the compensation amount of 3846 US\$. This money comes from the State Disaster Response Fund and the Chief Minister's Relief Fund.

People who die due to cold waves are usually sleeping under the open sky and are therefore exposed to extreme weather. A study conducted by Mandir (2010) well illustrates that urban poverty and homelessness differ in many significant ways from rural poverty. The study found out that the urban homeless people's work tends to remain casual, exploited and without dignity and security in the urban areas.

Since there is no official data to assess the homeless in India, one has to depend on non-official data? and media reports to assess the severity of the issue. For instance, 85,000 homeless people have been identified in the capital of India, New Delhi and their number is double in Mumbai the economic capital India in 2010.

The life itself is under risk to these sections of the population. The social perception of risk and uncertainty does not apply to these conditions. The social reality rather than a social construction determines the risk to these sections. The institutional understanding of disaster risk reduction has nothing to do with the victims of cold wave impact. For instance, the India Disaster Management Act (2005: 2) defines disaster as a catastrophe, mishap, calamity or grave occurrence in any area, arising from natural or man-made causes, or by accident or negligence, which results in substantial loss of life or human sufferings or damage to, and destruction of property or damage to, or degradation of, environment, and is of such a nature or magnitude as to be beyond the coping capacity of the community of the affected area. According to the act, improving the standard of living of the people who are exposed to grave occurrence is part of disaster management. However, even then cold wave victims are not yet included in the Disaster management framework. The major hurdles are the institutional structure of the Disaster Management Act (DM Act) and the pervasive nature of cold wave impacts. The victims are scattered across the nation, hence, the response of the state cannot go beyond offering temporary shelters. The financial allocation under the act also does not permit the institutions of disaster management to get into the problems of these people.

¹<http://www.ndtv.com/article/india/relentless-cold-wave-continues-across-north-india-death-toll-up-to-131-160721>

²<http://www.hindustantimes.com/India-news/NewDelhi/Cold-wave-intensifies-in-N-India-death-toll-rises-to-133/Article1-787480.aspx>

³http://zeenews.india.com/news/nation/cold-unabated-in-n-india-death-toll-more-than-150_752238.html

Table 2: Number of homeless households and people by sex in rural and urban areas in India (1981, 1991, 2001) (Ministry of Statistics and Programme Implementation, Government of India; accessed through Indiatat.com 2013)^a

Particulars	Number of homeless households	Homeless people		
		Total	Male	Female
1981				
Urban	209520	618843	406154	212689
Rural	420409	1724111	970358	753753
Total	629929	2342954	1376512	966442
1991+				
Urban	216917	725592	471077	254515
Rural	305528	1281897	709291	572606
Total	522445	2007489	1180368	827121
2001				
Urban	187810	778599	502344	276255
Rural	259775	1165167	634152	531015
Total	447585	1943766	1136496	807270

^a Table 2 is based on the 2001 census. No government level study has been conducted after that.

ple. Section 46 (1) and Section 48 (1) of DM act insists on the National Disaster Response Fund at the national level and the State Disaster Response Fund (SDRF) at the state level and the District Disaster Mitigation Fund at the district level. The National Disaster Mitigation Fund spends by government and there are some guidelines for spending state disaster response funds. According to the DM Act, the SDRF shall be used only for providing immediate relief to the victims of cyclones, drought, earthquakes, fires, floods, tsunamis, hailstorms, landslides, avalanches, cloud bursts and pest attacks. The guidelines for utilising the Calamity Relief Fund (CRF) also refer to the same incidents as a calamity and are eligible for financial support from CRF. There is no institutional support in India to tackle the problems of shelter less and homeless people. For instance, the schemes such as the Slum Rehabilitation Act-1995, Jawaharlal Nehru National Urban Renewable Mission and Valmeki Ambedakar Awas Jojana arts are available for urban slum dwellers. These programmes and approaches are limited to those who live in the slums and not for floating homeless citizens. Those who are living under the open sky during extreme winter

3. Current initiatives

Many NGOs and academic institutions are engaged in running night shelters and the distribution of woollen clothes to those who sleep under the open sky. However, these ongoing support systems are not adequate enough to help the victims of cold waves. There is a miss match between demand and supply of temporary shelter and warm cloths. This is evident from the rising death toll due to extreme weather across the country. For this reason, this demand supply gap should be reduced. The only institutional option available to offer basic minimum support to homeless people in India is to declare cold waves as a disaster. The positive impact of this option would be that money will be spend under the Disaster Response Fund and the scope of current urban development programmes

in line with the needs of the homeless in the cities will be extended.

4. Discussion

There is no proper assessment of the number of people who died due to cold waves. The government of India has provided statistics on the homeless population in India in its population census 2001, and it is indeed a capability issue. The capability of individual and the state are equally important in mitigating the cold wave impact. These two are interrelated. The state is unable to break the vicious risk cycle of the individuals through its institutions. This proposition is applicable to all development projects; however, compared to other development exclusion, here the state institutions are becoming incapable to get into the issue of risk mitigation. The whole development becomes a risk for the homeless citizens.

The attempts to declare cold waves as a disaster might eventually help locate the intervention areas of the state. However, this project has not been completed. The major challenges ahead are; a) the disaster management framework does not work among scattered populations, b) inadequate programmes and projects to address the root cause of risk creation-homelessness and social exclusion.

The urban governance is also creating risk to the community. For instance, about 500 families have been forcefully displaced and their houses have been pulled down in the extreme winter of December in the capital of India, New Delhi. Human Right in India (Status Report 2012) has referred that urban renewal schemes, city beautification projects, real estate and Common wealth games had displaced 200,000 people in India. The risk models, development support systems and even the disaster management frameworks are inadequate to address homeless and seasonal migrant workers living in the metros. These people are exposed to risks and they have no single agency to blame. The root cause of risk, the social crisis, becomes unnoticed. The theoretical propositions of risk studies

are unable to conceptualise the "risk" of migrant workers. People who are already excluded are exposed to extreme weather risk. The question of structural exclusion is a political crisis. It is becoming unfit for state to intervene in relief and rehabilitation of the victims of cold wave. The institutional and policy level interventions are limited to the seasonality of risk. Lack of permanent solution to homelessness and rural impoverishment indeed increases the intensity of the problem.

Institutional support is the only solution for this kind of issues. The current Indian scenario putting extreme weather calamity under the disaster management framework offers some support. However, it is not just enough for a long term mitigation process, since, even the disaster management institutions are unable to tackle certain structural issues.

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Citation

Irshad, M. (2013): Extreme Weather, Risk and 'Social Crisis': An Analysis of Un-Answerability. In: *Planet@Risk*, 1(1): 3-6, Davos: Global Risk Forum GRF Davos.



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Dynamical Diagnosis and Solutions for Resilient Natural and Social Systems

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Abstract – The concept of resilience embodies the quest towards the ability to sustain shocks, to suffer from these shocks as little as possible, for the shortest time possible, and to recover with the full functionalities that existed before the perturbation. We propose an operational definition of resilience, seeing it as a measure of stress that is complementary to the risk measures. Emphasis is put on the distinction between stressors (the forces acting on the system) and stress (the internal reaction of the system to the stressors). This allows us to elaborate a classification of stress measures and of the possible responses to stressors. We emphasize the need for characterizing the goals of a given system, from which the process of resilience build-up can be defined. Distinguishing between exogenous versus endogenous sources of stress allows one to define the corresponding appropriate responses. The main ingredients towards resilience include (1) the need for continuous multi-variable measurement and diagnosis of endogenous instabilities, (2) diversification and heterogeneity, (3) decoupling, (4) incentives and motivations, and (5) last but not least the (obvious) role of individual strengths. Propositions for individual training towards resilience are articulated. The concept of “crisis flight simulators” is introduced to address the intrinsic human cognitive biases underlying the logic of failures and the illusion of control, based on the premise that it is only by “living” through scenarios and experiencing them that decision makers make progress. We also introduce the “time@risk” framework, whose goal is to provide continuous predictive updates on possible scenarios and their probabilistic weights, so that a culture of preparedness and adaptation be promoted. These concepts are presented towards building up personal resilience, resilient societies and resilient financial systems.

Keywords – *resilience, stress, stressor, failure, human cooperation, antifragility, illusion of control, crisis flight simulator, time@risk*

1. Introduction

Interesting systems are out-of-equilibrium and subjected to external influences. In biology, the only true equilibrium state is death (Selye, 1973). In contrast, living organisms are remarkable engines that use energy and matter to generate internal order and external entropy. Being coupled to some outside environment, any interesting biological or social system is under the influence of fluxes, their fluctuations and trends as well as perturbations of various types (Lipsitz, 2002). Under these exogenous influences, they organize endogenously, attempting to self-propagate, grow and invade all available niches. These systems attempt to stabilize, at least for a time, towards some sort of dynamical equilibrium or are man-

aged to stay close to a desirable state. Nevertheless, numerous exogenous and endogenous stress-factors continuously destabilize these systems. An outstanding question, which is increasingly crucial to modern human societies, is how to ensure survivability, sustainability, resilience as well as promise of better well-being and happiness in the presence of the many present and future stress factors. To address these questions, the originality of the present essay is to recognize the key role played by the concept of “stress”, which is the reaction of a system to some factors that tends to perturb it from a reference state. The existence of stress leads to three possible types of characteristics for a system:

- i fragility (system is prone to disability of its functions

- or even to destruction),
- ii robustness or resilience (system is able to recover from not-too-large stresses), and
- iii adaptiveness and transformation, leading to phase changes, regime shifts, modified behaviors and even to drastic structural reorganizations such as in biological mutations.

In this framework, we examine in detail the claim that stress can be beneficial and show that it is subdued within the earlier and more general concept of “adaptive systems” according to which systems evolve endogenously in symbiosis with the so-called stressors. The other essential role of stress in the evolution of systems is to promote rare intermittent rapid speciations, such as in punctuated biological evolution. We show that the concept of “antifragility” recently introduced by Taleb (2011) describes the quality of some systems that are designed to profit from particular stressors that stress other systems and to which they are not sensitive themselves. But, these so-called “antifragile” systems also exhibit vulnerability with respect to other stressors that lie outside their tailored design. Many presented antifragile systems are also much less productive than their fragile or resilient counterparts, showing the importance of recognizing the defined objectives. Hence, we conclude that antifragility does not exist per se and that the concept is misleading.

The present essay provides a rigorous definition of stress in corresponding systems. We describe how to measure stress, how to delineate the possible responses to stressors and we spell out propositions towards more resilience and sustainability. We emphasize the need for specifying the goals of a given system, from which the process of resilience build-in can be defined. We distinguish between exogenous versus endogenous sources of stress, and delineate the corresponding appropriate responses. We outline the main ingredients of resilience in terms of (1) the need for continuous multi-variable measurements and diagnosis of endogenous instabilities, (2) diversification and heterogeneity, (3) decoupling, (4) incentives and motivations, and (5) last but not least the (obvious) role of individual strengths. In this respect, propositions for individual training towards resilience are articulated. The concept of “crisis flight simulators” is introduced to address the intrinsic human cognitive biases underlying the logic of failures and the illusion of control, based on the premise that it is only by “living” through scenarios and experiencing them that decision makers make progress. We also introduce the “time@risk” framework, whose goal is to provide continuous predictive updates on possible scenarios and their probabilistic weights, so that a culture of preparedness and adaptation can be promoted. These concepts are presented towards building up personal resilience, resilient societies and resilient financial systems.

2. Definitions of stress

Defining stress is the first step towards a full understanding of risks, fragility, robustness, resilience and the devel-

opment of efficient risk management. The word “stress” is part of the common vocabulary. However, in view of the widespread misunderstanding and confusion, rigorous and precise definitions are required. Before formulating a general definition of stress, it is useful to present illustrations through examples offered by different scientific fields.

In physics and more specifically, in continuum mechanics, stress is defined as a measure of the internal forces acting within a deformable body (Chen and Han, 2007). Quantitatively, we speak of a stress field defined as the ensemble of the stresses defined over all points within the body. Precisely, the stress at one point is a tensor that allows one to determine the force per unit surface that applies on any arbitrary fictitious plane specified by its orientation and going through that point. In a simple cylindrical geometry, an external force applied along the long axis translates within the body into a stress equal to the force divided by the area of the cylindrical cross-section. In equilibrium, the internal stresses sum up to balance exactly the external forces applied to the system. One can state the general result that the internal forces (and therefore stresses) are a reaction to external forces (stressors) applied on the body.

In biology, the endocrinologist pioneer, Hans Selye, introduced the concept of stress on the basis of his observations that many different types of substances and, more generally, perturbations applied to animals led to the same symptoms (Selye, 1973). The concept of stress in biology is thus based on the existence of non-specific responses of the body to the demands placed upon it. Transient perturbations, which do not exceed the natural regulatory capacity of the organism, lead to responses that ensure the resilience of homeostasis, the dynamical equilibrium characterizing living entities. In the presence of unrelieved stress, the body often transitions to pathological states associated with a change of homeostasis. This is analogous to the initial visco-elasto-plastic response of a mechanical system to an external stress, followed by creep that usually ends in the tertiary rupture regime (Nechad et al., 2005).

Common features can be observed in the interaction processes of different systems and their environments. Thus, the concept of stress was rediscovered, reused and often modified in various applied fields: organizational science (Cooper et al., 2001), seed science (Kranner et al., 2010), climate change and food security (Parry et al., 1999) and many other areas (Aldwin, 2007).

Several important characteristics of stress can be learnt from these examples:

1. stress is an internal response/reaction of a system to a perturbation called stressor (or stress-factor);
2. a stressor is a demand applied to the body that requires its reaction and adaptation;
3. a stressor elicits a non-specific response regardless of the nature of the stress, and even whether the stressor has a positive or negative consequences in the long term.

More generally, for biological as well as socio-economical systems, the non-specific response or “symptoms of stress” to a new demand involves increased:

- i attention;
- ii mobilization of resources;
- iii concentration on key areas; and
- iv recovery or exhaustion of the adaptive response and transition to pathological or crisis states.

In adaptive immune systems, (i) T and B lymphocytes first recognize the dangers, then (ii) mobilize the generating centers of antibodies that (iii) are finally directed towards and concentrated at the loci of insult. In social systems, the three first steps of the non-specific responses are typical of military-type intervention to cope with internal or external threats. In psychology, the first step (i) is associated with alarm, the second and third steps with resistance and the fourth step with exhaustion, as classified within the so-called general adaptation syndrome (Selye, 1973). More specifically, professionals facing acute situations, such as competitive pilots, athletes, surgeons and so on, go through the three first steps during their transient stressful activities. In economics, the response to economic difficulties is associated with (i) the characterization of the symptoms (solvency problems, budget deficit, increase of debt), (ii) the identification of reserves through expense cuts and reengineering of business and risk management processes and (iii) the reallocation of resources on key business lines or subsidizing. These measures may lead (iv) to a stabilization, or to a transition to a new favorable economic regime catalyzed by economic reforms and innovations or to bankruptcies in the context of firms, or to a disruptive transition to a new political order in the context of nations.

3. Measures of stress in social science

As a consequence of the complexity of social systems and the diversity of situations and applications, measuring stress in social sciences is a non-trivial issue. In contrast, in natural sciences, one often has the luxury of observing the stresses by their direct effects. In mechanics, direct measurements of stress within a system are often performed by observations of deformations of the body. In biology, the measurement of stress is obtained by observing the response of the biological processes to a stressor. However, in social sciences, the feedback loops as well as coupling mechanisms to exogenous factors are much less understood. As a result, the quantification of the stress level is performed indirectly via probabilistic approaches that introduce metrics of risks and/or resilience. These indirect ways of stress measurement in social sciences may be at the origin of the confusion in dealing with the concept of stress, incorrectly interpreted not as an internal response of the system to stressors but as the source of difficulties faced by the system.

3.1. Risk as measure of stress

Formally, risk is defined as the triplet of

1. a probability when available, or a level of uncertainty, or in the worst situation the formulation of the ambiguity corresponding to ask the question on the possibility for the occurrence of certain stressors;
2. a potential loss quantifying the possible impacts of the stressor;
3. a vulnerability and related counter-measures and mitigation techniques, that specify how disruptive the potential stressor to the system is
(Kaplan and Garrick, 1981).

The two first properties characterize the external forces or stressors that may influence the system. Together with the third property, which is specific to the system, they control the overall losses that the stressor can bring to the system. As a consequence, risk is understood as the combination of these three characteristics of the potential stressor. Thus, risk is equal or proportional to the possible internal response of the system, and therefore is a proxy for the stress developing within the system.

The simplest response of a system to a normal stress is non-specific and non-directional, which is comparable with the biological concept of kinesis. More resilient systems need to develop targeted reactions to stress, which is analogous to taxis in biology, defined as a directional response of a system to a stimulus or stimulus gradient intensity. In this sense, “stress taxis” can be defined as a response that, in the end, tends to unload stress off the system. For example, bacteria are wonderfully evolved organisms that demonstrate incredibly high resilience by using taxis and their corresponding simple behavioral rules.

3.2. Resilience as measures of stress

Resilience comes into several levels. The first two levels of resilience can be conveniently classified by using the theory of dynamical systems.

First level of resilience: Resilience is often defined as the speed of return to equilibrium (or more generally to the attractor characterizing the system) following a perturbation (Pimm and Lawton, 1977). Technically, the first level of resilience is referred to as “engineering resilience”, which is a local concept. Engineering resilience is described by a local analysis, in terms of the stability of the linearized dynamics in the neighborhood of the equilibrium point. Indeed, resilience in this sense refers first to the stability of the equilibrium state, which occurs when all Lyapunov exponents are negative. Then, the speed of return to the equilibrium point is controlled by the largest (negative) Lyapunov exponent (i.e., the smallest one in absolute value).

Second level of resilience: In contrast, “ecological resilience” encompasses and generalizes engineering resilience by referring to the non-local dynamics occurring within the basin of attraction of the equilibrium state, defined as the set of initial conditions of the system that

converge to that equilibrium state. While engineering resilience is a local concept quantifying the response of the system to small perturbations, ecological resilience describes the fact that a system state will return to its initial equilibrium as long as the perturbations remain within the basin of attraction of the equilibrium point, thus embodying non-local finite size perturbations that can be as large as the size of the basin of attraction itself, but not larger.

Walker et al. (2004) review four main components of ecological resilience of a system in its capacity to absorb disturbance and reorganize itself in order to retain essentially the same function. Using the dynamical system analogy with attractors and their basins of attraction, these four components are:

- i latitude (controlled by the size of the basin of attraction),
- ii resistance (controlled by the height of the barriers between attractors),
- iii precariousness (controlled by the current position of the system within the basin of attraction),
- iv iv. and panarchy (controlled by the way the attractor structure and its basin may change as a function of the scale of description through cross-scale interactions) (Gunderson and Holling, 2002).

Extending the so-called resilience triangle approach (private communication of Wolfgang Kroger, ETH Zurich, see e.g. Bruneau et al., 2003; Chang and Shinozuka, 2004; Pant and Barker, 2012), one can simplify the picture offered by ecological resilience by introducing four variables characterizing the response of a system to an external shock. Considering the variable W_0 corresponding to a reference capacity, wealth or production level just before the shock, we define

- i the maximum loss $(1-\lambda)W_0$,
- ii a characteristic time τ_1 of reaction to reach the bottom level λW_0 ,
- iii the level ΛW_0 recovered,
- iv after the characteristic recovery time τ_2 .

In this simplified formulation, the resilience of the system is captured by the quadruplet of parameters $(\lambda, \tau_1, \Lambda, \tau_2)$. Note that Λ could be larger than 1, corresponding to the situation where the shock has long-term beneficial effects by increasing the overall performance above the initial baseline W_0 . Some systems may be characterized by Λ being smaller than λ , in which case, after a first loss of performance over a first reaction time τ_1 , the system degrades further over a possibly different time scale τ_2 to an even worse situation. We should also stress that the quadruplet $(\lambda, \tau_1, \Lambda, \tau_2)$ may not be unique but depend on the severity and duration (as well as possibly other characteristics) of the shock, so as to reflect the nature and amplitude of possible cascades occurring within the system.

Third level of resilience: The concept of viability (Aubin, 1991; Deffuant and Gilbert, 2011) extends further the idea by focusing on the conditions that the system must obey to remain “viable”, for instance functional or alive. These

constraints may not in general map precisely onto the set of attractors of the dynamics or may not even be attainable by the natural evolution of the dynamics and therefore may require continuous external management and control.

Fourth level of resilience: The dynamical system analogy has however its limit if taken too rigidly, because it fails to account for the fact that many biological, ecological and social systems may actually adapt, evolve and even transform fundamentally under the influence of stressors (Walker et al., 2004). This requires the consideration of other levels of resilience, which takes into account the possibility for the system to adapt its constituents so as to influence its resilience. This may correspond to a deformation of the basin of attraction, the fusion of initially distinct basins and other topological transformations. More generally, the dynamical system may incorporate stochastic components, such as deterministic, quasi-periodic or even random deformations of the attractors due to the modulation of some control parameters, as long as the conditions of viability are respected. Then, the system keeps its identity, but in a broader sense, even redefining itself while still keeping its ability to cope with the stressors. Pushed to the extreme, the system may even transform itself into a completely different structure via its capacity to evolve, as described by the theory of complex adaptive systems (Holland, 1975; Kauffman, 1993).

These considerations underline that the concept of resilience is dependent on the time scale over which the stressors act. For short-lived disturbances compared with the characteristic time scales of reactions of the system, engineering and ecological resilience are the relevant levels of description. At intermediate time scales, the issue of viability dominates, pushing for adaptation and redefinition of goals and processes. At the longest time scales, transformations may occur that are similar to natural selection and Darwinist evolution of species, seen as a transformation in response to changing geological and climatic conditions. In the context of man-made and social systems, Darwinist evolution is also relevant to understand the dynamics of human enterprises (Hannan and Freeman, 1977; Hite and Hesterly, 2001). Real life situations are likely to involve an interplay between a continuum of different time scales and thus between the different levels of resilience.

3.3. Links between risk and resilience as complementary measures of stress

To summarize, risk and resilience are two complementary revelations of stress. On the one hand, risk provides a measure of the nature and amplitude of stressors, present and future. As a consequence, from risk measurements, one can infer the possible level of stress that may develop within the system. On the other hand, resilience characterizes the internal stress response within the system, quantified by the capacity of a system to cope with stressors and remain essentially the same. In other words, resilience is the amount of stress that a system can bear without a considerable transformation.

Risk and resilience are inter-connected in another way through the concept of vulnerability (Birkmann, 2006; Cutter et al., 2008). On the one hand, vulnerability is part of risk, as a quantification of the potential amount of losses that are specific to a given system. But this vulnerability depends on the structural and adaptive properties of the system that make it either more prone to losses or less vulnerable via better mitigation techniques. In this sense, vulnerability constructs a bridge between risk and resilience. The processes favoring resilience will tend to decrease vulnerability and vice-versa.

The duality of stress expression in risk versus resilience is also apparent in the different possible responses of the system to stressors. These responses can be classified into three main classes: (i) fight, (ii) fly and (iii) transform.

- i “Fight” is the typical response under relatively small risk and large resilience, which are associated with “normal” stress developing within the system. The “fight” response can be characterized by negative feedback loops tending to stabilize the system around its previous state, such as in the homeostasis state of living biological entities.
- ii In contrast, the “fly” response corresponds to systems where risks and resilience are at comparable levels so that there is significant hazard for the system. By avoidance strategies, or some adaptation without major transformations and/or improvement of management, resilience can be improved so that the stressors can be addressed in order to ensure the preservation of the system identity.
- iii Finally, when risk is large and resilience is insufficient, “extreme” stress develops within the system. Other than its demise, its survival requires considerable transformations of the system itself via the activation of positive feedbacks that drives it towards a new state.

The rational response to the presence of risks (the potential stressors and corresponding stress of the system) would seem logically to strive for always increasing resilience (the stress that the system can bear). However, there is always a cost-benefit balance between two extremes, the *laissez-faire* attitude of no investment in resilience as one extreme, and extreme risk aversion leading to attempts to over-control at the other. Building up resilience requires indeed to increase reserves, develop excess capacity, construct alternative supply chains, ensure redundancy, as well as investing in continuous education and training. But modern optimizing firms and societies work with the just-in-time philosophy and the constraint of ever lowering costs. This is often an impediment for building up resilience, as many examples show (Sheffi, 2005). It is a general observation that management in social systems strives to optimize this cost-benefit conflict, however, with often limited or even disappointing results to show for. In contrast, it is remarkable that natural systems often tend to evolve, converge and operate close to states that exhibit such a balance. These states

are referred to in the modern literature as “self-organized critical” (Bak, 1996) or “at the edge of chaos” (Kauffman, 1993). This describes the tendency for coupled entities that interact over many repetitive actions to function close to a bifurcation point separating states that are too stable, from other states that are too unstable. A typical example is the human brain, for which there is a growing consensus that it operates close to or even functions at a critical point (Chialvo, 2006; Levina et al., 2007; Meisel et al., 2012; Plenz, 2012), separating a sub-critical state from a super-critical one. In the critical state, the brain exhibits the largest possible reactivity to novel external stimuli while, at the same time, showing stability of memory and other functional properties. If the brain was in the subcritical state, it would learn less efficiently by being not malleable enough and would be too slow to react in crucial situations. If the brain was in the supercritical state, its neural network would fire too much and too often, oscillating between extreme activity and exhaustion. Such a pathological state is actually found in epileptic patients (Osorio et al., 2010). In natural and biological systems, there are in general strong negative feedback mechanisms to stabilize the system and poise it at an optimal point between costly increase of resilience and costly neglect of the looming risks (Scheffer, 2009). The balance corresponds to a merging of the two responses - “fight” and “fly” - so that the system may combine both negative feedback reactions as well as adaptation to remain at the “edge of chaos”.

In social systems, there is a lot of lip service paid to the goal for managers and policy makers to obtain this kind of optimal state. Actually, there is often an illusion of control (Langer, 1975; Satinover and Sornette, 2007; 2011) that it is possible to remove most of the risks and obtain an ideal state of resilience. One argument for the insufficient resilience of social systems (Diamond, 2004) is that, due to their complexity, they have not had the time to evolve (Walker et al., 2004) by the forces of “natural selection”. This may be a part of the truth. However, we note that, for some social systems such as financial markets, there is ample evidence of an absence of convergence towards a stable dynamics, but rather the existence of persistent cycles of bubbles and bursts (Kindleberger, 2005; Sornette, 2003), notwithstanding experiencing many crises that, one would surmise, would have enabled investors to learn and avoid the next one (Reinhart and Rogoff, 2011). One possible explanation can be found in the incentives of investors to maximize their return on short time scales, leading to recurrent instabilities (Minsky, 2008). More generally, in many social systems, there is the ubiquitous problem that the short-term incentives are often not aligned with the long-term ones. This is associated with hyperbolic discounting (Laibson, 1998), which describes the general exaggerated preference for smaller immediate rather than larger delayed gratifications. Similarly, the incentives at the individual agent level are often incompatible with those at the society level, leading to social dilemmas (Kerr, 1983). It is also associated with the so-called public good problem and the problem of fostering social cooperation in particular in the context of socio-ecological systems (Ostrom, 1990). The

rest of this essay aims at characterizing the conditions for breaking these kinds of stalemate.

4. Can stress be beneficial?

When thinking about stress, a first attitude is to find ways of reducing it or, when not possible, of developing passive and/or active defenses. But, there is a growing recognition that moderate levels of stress may be actually beneficial, both for health and for performance (Weiten and Lloyd, 2005; Hosenpud and Greenberg, 2006; Ritsner, 2010; Contrada and Baum, 2010). Is stress really beneficial per se?

4.1. System-stressor co-evolution under normal stress

For passive systems, stress is in general destructive, as in creep of materials where microscopic tiny damage events accumulate and lead to global rupture. In contrast, active systems can detect stress and use it as a guiding signal on the way towards better fitness to novel conditions. Thus, random or intended stressors are usable for the

- i identification of the characteristics of stress by listening and analyzing reactions of the system to perturbations;
- ii measurement of stress: (a) risks (observation of event probabilities, losses, vulnerability of the system) and (b) resilience (“exploration” of the stability landscape characterized by its latitude, resistance, precariousness and panarchy);
- iii catalysis of learning, which promotes changes occurring through feedback mechanisms by adaptation towards better fitness under changing conditions, and of selection of specific features and implementation of contra-measures;
- iv excitation of the system readiness, maintaining an engaged, interested and concerned state (in the spirit of the Soviet Union pioneer’s motto “Always Ready!”).

In section 2, we identified that symptoms of stress in a system include attention, mobilization of resources, concentrations on key areas, and so on. This may be viewed as positive consequences of stress for the function of the system. But, these changes are actually occurring at a cost, in particular that of a loss of resilience because the allocation of resources to cope with the stressor makes the system more vulnerable to other stressors. Thus, the optimization to cope with a first stressor should not be seen necessarily as a benefit of the stress. In general, optimization processes and coping with stress (or strengthening resilience) should be disconnected.

We also need to mention the cases in which some stress can be caused by a “positive” stress-factor (termed “Eustress” by Selye (1973)). For example, an eustress could be an economic reform that, after a period of adaptation, would lead to increased economic growth. Or, an extraordinary good news (learning about the return of a lost one or winning a huge lottery sum) may induce strong stress in the person. Again, it is not stress itself that is beneficial. Stress is a signal of a change of conditions and is a

“guide” on the way towards adaptation or transformation to better fit to the new conditions, so that a system can survive and benefit from them.

Many situations where stress is argued to be beneficial, which we are going to cover at least partially in the following, follow the same archetype in which the system under consideration has co-evolved with the stress. In other words, the system is within an environment in which stress is unavoidable. Stress seems to be beneficial simply because the *raison d’être* of the system or of some of its key properties is precisely to cope and live with the ambient stress. Therefore, it is almost a tautology to find that the system needs stress or benefits from stress because it becomes dysfunctional if one of its main inputs, stress, is absent. We can therefore state that stress, at least up to a certain level smaller than the system resilience, is part of the normal system function and we refer to this situation as “normal stress”.

4.2. Adapted systems co-evolved with their stressors

In this section, we provide several examples illustrating the concept that so-called beneficial stress occurs when the system under consideration has co-evolved with the stress.

4.2.1. Mammal immune systems, bones and muscles

Biology and medicine have probably been the first disciplines to recognize the co-evolved nature of stressors and of the stresses that develop within living systems. The immune system of mammals, in particular, provides arguably the best example illustrating what could be referred to with perhaps some exaggeration as a symbiosis between stressors (antigens) and system (antibodies). We underline that the example of the immune system provides a particularly important illustration, since its main role is indeed to defend the organism against disruptive intrusions by pathogens, in particular, which would like to exploit the organism for their own propagation. Consider first other types of homeostasis control processes in which the target variables are kept in a narrow optimal range with small fluctuations. This describes the “stable” homeostasis control for the regulation of the amounts of water and minerals by osmoregulation in the kidneys, the removal of metabolic waste by excretory organs such as the kidneys and lungs, the regulation of body temperature, the regulation of blood glucose level by the liver and the insulin secreted by the pancreas, and so on. In contrast, “The (immune) system never settles down to a steady-state, but rather, constantly changes with local flare ups and storms, and with periods of relative quiescence” as quoted in (Perelson, 2002), and see also (Perelson and Weisbuch, 1997; Nelson and Perelson, 2002). These flares can be understood as transient nonlinear reactions to fluctuating exogenous stressors as well as to expressions of the internal stress states. A growing body of literature indeed suggests that the incessant “attacks” by antigens of many different forms have forced the immune system to develop continuing fight and adaptation pro-

cesses to ensure the integrity of the body (see Sornette et al., 2009b for a review and mathematical modeling). In this vein, the ‘hygiene hypothesis’ (Schaub et al., 2006) states that modern medicine and sanitation may give rise to an under-stimulated and subsequently overactive immune system that is responsible for high incidences of immune-related ailments such as allergy and autoimmune diseases. In this view, infections and unhygienic contact may confer protection against the development of allergic illnesses. For instance, Bollinger et al. (2007) suggested that the hygiene hypothesis may explain the increased rate of appendicitis (~6% incidence) in industrialized countries, in relation to the important immune-related function of the appendix. Sornette et al. (2009) concluded that, if the regulatory immune system was not continuously subjected to stressors, its adaptive component would decay in part and the defense would go down, thus letting the organism becoming vulnerable to future bursts of pathogen fluxes. They developed a mathematical model that demonstrates that the correct point of reference is not a microbe-free body (no stressors), but a highly dynamical homeostatic immune system within a homeostatic body under the impact of fluxes of pathogens and of other stressors (which include microorganisms such as bacteria, viruses, fungi, parasites, environmental load, over-work, overeating and other excesses, psychological and emotional factors such as anger, fear, sadness, and so on). The situation is analogous to the maintenance of healthy bones and muscles of a human being. For astronauts under zero-gravity (no weight stressor), loss of bone and muscle, cardiovascular deconditioning, loss of red blood cells and plasma, possible compromise of the immune system, and finally, an inappropriate interpretation of otolith system signals all occur, with no appropriate counter-measures yet known (Young, 1999). In other words, for bones and muscles, stress (in the real mechanical sense of the term!) is needed to avoid degeneration and ensure appropriate strength in cases of need. In all these examples, stress is beneficial only because the systems are fundamentally defined in their aims and properties by their interactions with stressors. Biological evolution has weaved a complex network of interacting feedback loops that entangled fundamentally the systems with their stressors, making the later necessary for the normal function of the former.

4.2.2. *Human cooperation, competition and risk taking*

An enormous body of anthropological and ethnographic literature demonstrates that the level of cooperation between humans is exceptional both in quality and quantity (Henrich and Henrich, 2007), which explains the remarkable success of this single mammal species that nowadays controls a major part of the whole output of planet Earth (Steffen et al., 2004). However, the origin of this cooperation is still quoted as one of the 25 most compelling puzzles that science is facing today (Siegfried, 2005). Many mechanisms and contextual factors have been proposed to explain the remarkable level of pro-social behavior and cooperation between humans, such as kin selection, in-

clusive fitness, reciprocity, network reciprocity, group-level and multi-level selection, other-regarding preferences, relative income preferences, envy, inequality aversion and altruism (Axelrod and Hamilton, 1981). Two essential ingredients emerge: (i) the presence of differences in skills, contributions, rewards and retributions among group members and (ii) how perceptions and preferences drive human decisions and actions. In other words, not only exogenous stressors resulting from the environment such as predators but also within-group stressors have been found essential to promote cooperation. This has led to a significantly higher survival efficiency and larger fitness both for the group and for the individuals. Using agent-based models and analytical theory, Hetzer and Sornette (2011; 2012) in particular have shown that cooperation evolves at the level documented for humans only under two conditions: (i) agents exhibit disadvantageous inequity aversion, which is found to be evolutionary dominant and stable in a heterogeneous population of agents endowed initially only with purely self-regarding preferences; (ii) groups are “stressed” by random perturbations in the form of strangers migrating between co-evolving groups and who introduce different cooperation levels than those that would emerge from the group consensus in absence of the random perturbations. The underlying mechanism is related to the Parrondo effect describing situations where losing strategies or deleterious effects can combine to win (Harmer and Abbott, 2002; Abbott, 2002). Here, the random behavior is rooted in the exchange between groups and the asymmetry is inscribed in the punishment rule driven by disadvantageous inequity aversion. This constitutes a telling example illustrating that stressors have selected for enhanced cooperation via higher survival rates for groups and individuals. This became possible when cognitive abilities in our homo ancestors increased sufficiently to allow the exploitation of this new “resource” of enhanced cooperation beyond that observed for our primate cousins, again illustrating the co-evolution between stressors and system’s abilities.

Another important characteristic of humans is that high male-male competition for reproductive success has been permeating the history of modern humans (200’000 years ago to recent times) and has contributed through gene-culture coevolution to create gender competitiveness-related differences. Favre and Sornette (2012) have recently introduced a simple agent-based model that explains the high level of male-male competition and risk taking as rooted in the unequal biological costs of reproduction between males and females. This cost asymmetry has promoted females’ choosy selection of alpha-males who have better chance to propagate genes via the natural selection of the fittest (Baumeister, 2010; Ogas and Gaddami). This causes male-male competition and male’s arm race for signaling their qualities, which takes the form of stronger risk-taking behavior (Diamond, 2002). This further cascades into higher male than female death rates through risky signaling and results in a smaller male than female effective breeding population, both because females select a subset of males for reproduction and because of male’s higher death rate. Re-

markably, this mechanism can be checked quantitatively through its prediction for the ratio of the Time To the Most Recent Common Ancestor (TMRCA) based on human mitochondrial DNA (mtDNA), i.e. female-to-female transmitted, which is estimated to be twice that based on the non-recombining part of the Y chromosome (NRY), i.e. male-to-male transmitted. It appears that we are all descended from males who were successful in a highly competitive context, while females were facing a much weaker female-female competition. Stresses have appeared endogenously in the human population as a response to the unequal biological costs of reproduction (itself a stressor), leading to males' arm race in risk taking (another set of stressors) and cascaded into extraordinary implications for the development of the human species and its conquer of the world (Baumeister, 2010). One can argue that the high level of risk taking of human males have been beneficial for mankind, through the exploration of unknown territories and the development of inventions, in the end making stressors, via enhanced risk-taking by males, the engine of progress. The causal flow "reproduction inequality $\Rightarrow$ female strategy $\Rightarrow$ male risk taking" of stressors can thus be seen as an intrinsic part of the making of mankind, providing another example of the entangled nature of the human system and its stressors, the latter being beneficial on the long term as a result of their co-existence and co-evolution. Pushing this reasoning, one can thus conclude that being human is to use one's superior cognitive abilities to take risks beyond the biological laws that enslave other animals.

4.3. Change of regimes under extreme stress

Nature and human societies exhibit many cases in history and in recent times when stress surpasses the resilience level of the system. We refer to such response of the system as "extreme stress" because of dramatic consequences it may lead to. Sources of extreme stress can be tracked using the measures of stress that were described above - risk and resilience - and include:

- i extreme possible stressors that are characterized by low probability and/or huge losses, for example, very rare events of enormous impact or previously unknown events (black swans (Taleb, 2007));
- ii unbearable stress that the system is not capable of coping with, showing extreme vulnerabilities (for example, disfunction of critical systems) and/or zero resilience, when even a tiny perturbation can lead to a change of regime. Examples of such systems include those (1) optimized to the edge of maximum efficiency, such as the just-in-time Toyota supply chain and inventory management system and (2) close to a tipping point due to developed endogenous instabilities, leading to dragon-kings (Sornette and Ouillon, 2012).

In the worst cases, this leads to the death or demise of the corresponding organism or system, as for instance documented by J. Diamond (2004) for human societies. In other situations, the system evolves to another regime, in

which different properties that were dormant come into play or novel ones are forced to evolve for the survival and success of the system. The following two subsections examine a number of real life examples illustrating the occurrence of regime shifts and evolution under extreme stress

4.3.1. Biological and other transitions

The existence of changes of states promoted by extreme conditions is perhaps best incarnated by biological evolution. Contrarily to the initial view held by Darwin that evolution is generally smooth and continuous, occurring by the cumulative effect of gradual transformations, the theory of punctuated equilibrium in evolutionary biology describes the evolution of species as a sequence of stable states punctuated by rare and rapid events of branching speciations occurring under the stresses resulting from climatic, geographic and other possible evolutionary stressors (Gould and Eldredge, 1993). Since its introduction (Eldredge and Gould, 1972), this theory has received strong empirical support (Gould, 2002; Lyne and Howe, 2007). It holds that most species exhibit little evolutionary change for most of their geological history, being adapted to their niches. But, something happens, such as an extreme disturbance, that pushes the species to branch into novel species, often with the demise or altogether change of the original species.

Many scientists view the abrupt changes occurring in the sequence of punctuated equilibria as due to catastrophic causes, such as the famous Chicxulub asteroid (Schulte et al., 2010) or enormous volcanic eruptions in the so-called Deccan trap epoch (Courtillot and McClin-ton, 2002), or both (Archibald et al., 2010) ending the reign of the mighty dinosaurs about 65 million years ago. Starting with Bak and Sneppen (1993), others have argued for an endogenous origin, using the analogy with the concept of self-organized criticality (Bak and Paczuski, 1995; Bak, 1996; Jensen, 1998; Sornette, 2004, chapter 15). According to complex system theory, out-of-equilibrium slowly driven systems with threshold dynamics relax through a hierarchy of avalanches of all sizes. Accordingly, extreme events can also be endogenous.

The exogenous versus endogenous explanations may actually represent two complementary view points since, in reality, they are often entangled. Indeed, how can one assert with 100% confidence that a given extreme event is really due to an endogenous self-organization of the system, rather than to the response to an external shock? Most natural and social systems are indeed continuously subjected to external stimulations, noises, shocks, stress, forces and so on, which can widely vary in amplitude. It is thus not clear a priori if a given large event is due to a strong exogenous shock, to the internal dynamics of the system, or maybe to a combination of both. Sornette et al. have advanced the hypothesis that specific dynamical signatures of precursors occurring before and relaxations following extreme events lead to a classification of possible regimes and the possibility to resolve the endo-exo conundrum. This applies broadly to many complex sys-

tems (Sornette and Helmstetter, 2003; Sornette, 2005), for which it is fundamental to understand the relative importance of self-organization versus external forcing, as documented for financial shocks (Sornette et al., 2003), commercial sales (Sornette et al., 2004), and for the dynamics of fame of YouTube videos (Crane and Sornette, 2008). More generally, in addition to biological extinctions such as the Cretaceous/Tertiary KT boundary (meteorite versus extreme volcanic activity versus self-organized critical extinction cascades), this question applies to commercial successes (progressive reputation cascade versus the result of a well-orchestrated advertisement), immune system deficiencies (external viral/bacterial infections versus internal cascades of regulatory breakdowns), the aviation industry recession (9/11 versus structural endogenous problems), discoveries (serendipity versus the outcome of slow endogenous maturation processes), cognition and brain learning processes (role of external inputs versus internal self-organization and reinforcements) and recovery after wars (internally generated (civil wars) versus imported from the outside) and so on. In economics, endogeneity versus exogeneity has been hotly debated for decades. A prominent example is the theory of Schumpeter on the importance of technological discontinuities in economic history. Schumpeter (1942) argued that “evolution is lopsided, discontinuous, disharmonious by nature... studded with violent outbursts and catastrophes... more like a series of explosions than a gentle, though incessant, transformation.”

4.3.2. *Political and economic transitions*

Consider the fall of the Berlin wall in October 1990 associated with a series of radical political changes in the Eastern Bloc. Over the period from 1989 to 1992, many east European countries engaged in a transition from a centrally planned economy to a democratic and market economy. Using agent-based model simulations and economic data, Yaari et al. (2008) discovered that all countries' GDP (gross domestic product) as well as other indicators of economic development (such as the number of privately owned enterprises) evolved through a generic J-curve, corresponding to a first phase of strong decay followed by a recovery and, for some countries, a transition to a growth rate surpassing significantly the levels under socialism before 1990. The first decay arch of the J-curve corresponds to the progressive demise of the “old centrally planned economy”, whose shrinkage dominates the rise of the “new” free market economy (Novak et al., 2000). The second rising arch of the J-curve embodies the progressive transition to the “new economy” that burgeons as a response to novel conditions (Challet et al., 2009). In the case of Poland, Yaari et al. (2008) found that the new economy principally developed around a few singular “growth centers” associated with pre-existing higher education poles, which was followed by a diffusion process to the rest of the country. The centers of education were thus the main engines of the resilience and adaptability of the Polish nation to the new conditions. In contrast, other Eastern European nations, such as Ukraine or

even Russia, have fared much less well (Guriev and Zhuravskaya, 2009): for them, the transition resulted in a long lasting economic crisis that only recently has started to show observable improvement.

Let us scrutinize the economic transition in Russia. For a decade since the Berlin wall event, Russian GDP has been declining, with continuing huge drops in output and high levels of inflation. Russia went through a Great Depression more severe than that in the U.S. in the 1930s, with a decline in industrial production of over 60% from 1992 to 1998 (vs. some 35% decline in the U.S. Great Depression from 1929 to 1933), leading among many woes to the destruction of agriculture, deteriorating social conditions, health, education, environment, law, science and technology, high inflation and the destruction of the middle-class which is often the guardian of, as well as condition for, a functioning democracy. The Russian economy has been characterized over this time period as being riddled with crime and corruption. The transition was not to a market economy but rather to a criminalized economy, where the criminals established their own institutions in a process of self-organization (Intriligator, 1998). The reasons for these problems have been identified (Intriligator, 1997; 1998): by endorsing a stabilization program of the Russian economy based on liberalization of prices and the privatization of enterprises, the Yeltsin administration neglected the well-known but often forgotten fact that free markets require strong institutions, and in particular a legal system, courts, lawyers, law enforcement; property rights, and so on, so that business contracts are enforced rather than subjected to the whim of the strongest. Moreover, a strong government is at the core of market economies, as shown by numerous anthropological and historical studies documented for instance in Graeber (2011). Russia's transition illustrates that externally imposed conditions, fundamental internal situations as well as a badly chosen design of governance (without institutions and working legal system) led to a new regime that has struggled for a very long time to recover and establish a functional state for the well-being of the people (Guriev and Zhuravskaya, 2009).

The so-called Arab spring that began in Dec. 2010 constitutes another telling illustration of our thesis. This revolutionary wave of demonstrations and protests occurred in the Arab world, leading to the ousting of the leaders of Tunisia, Egypt, Libya and Yemen and civil uprising in other neighboring countries. While media reports and scholars have often viewed the Arab Spring movements as positive steps towards more democratic governance, some skepticism is in order when examining the post-Gaddafi outcome in Libya for instance. Research at the NECSI suggests persuasively that the triggering factor for many if not most of the upheaval movements observed in Arab as well as other poor countries around the world coincide with rapid and large rises of food prices (Lagi et al., 2011; Bertrand et al., 2012). Indeed, commodity prices more than doubled in 2008 due to a combination of environmental factors, the accelerating needs of booming countries such as China as well as speculation (Sornette et al., 2009a). As a consequence, world food prices skyrocket-

eted, making many households' subsistence reach a crisis level. The inability of the governments of the concerned countries to cope with these stressors led to the transitions (or in many other cases to the search for the resolution of quite unstable states) to what can still be seen as evolving situations in search of an equilibrium. Whether the outcomes in Libya or Egypt are positive remains to be determined as the region has become very unstable and the future remains highly stressful and uncertain for most of the population.

This is reminiscent of the French revolution of 1789: more than enlightenment ideals, economic factors arguably played indeed a crucial role. As a result of bad harvest over most of the decade preceding 1789, a large part of the French population was exposed to strongly rising bread prices (the main food), leading to hunger and malnutrition. In the absence of adequate reactions by the government to the climate stresses that were adding to a very large national debt and an antiquated tax system weighting unfairly on the working class, the resulting discontent population became prone to push for major changes that culminated with the storming of the Bastille. Similarly to the situations resulting from the Arab spring, one should be cautious to claim that the extraordinary changes resulting from the food price stressors (among others) have always and systematically been for the better in all dimensions. The situation is perhaps best captured by the apocryphal statement of Chinese premier Zhou Enlai during President Richard Nixon's visit to China in February 1972: "too early to say" when referring to the assessment of the implications of the French revolution (he was in fact probably referring to the turmoil in France in May 1968 (Campbell, 2011)). Notice also that there is clear evidence that the French revolution has led to much bloodier wars in which whole nations have become involved in large scale conflicts involving many casualties (Cederman et al., 2011), showing again the relativity of the values of the regime shifts and their often unintended consequences.

These examples have illustrated two main points:

- i the ubiquity of (rare) regime shifts due to the combination of abnormally large external circumstances (that are bound to occur in any nonlinear system if one waits long enough) and internal facilitating processes limiting the build-up of adequate resilience;
- ii the value (in terms of economic consequences, change of well-being, moral level, culture) of regime shifts is open to debate, depends on the time horizon (beneficial short-term but detrimental long-term, or vice-versa) and is arguably relative.

All the examples treated in this subsection refer to situations in which scholars and observers would rate the pre-existing regimes as (to various degrees) undemocratic, oppressive and in opposition with the enlightenment ideals. As we shall elaborate in section 5 on recipes for resilience, much of the strength of a nation rests on the cohesion between its citizens that is called upon at times of stresses. In this respect, Arab countries, the countries of

the Soviet Bloc, and France under the Bourbon dynasty developed modes of governance that embodied the roots of their demise, such as increased inequity and rigidities. One should not develop however the impression that this situation is a unique attribute of countries that do not embrace the modern western version of market economy and of democracy (which, by the way, is not a unique governance process of course but comes in many kinds and degrees).

Consider the situation of the largest western economies, including the United States of America, Japan and Western Europe, whose indebtedness have reached, according to many analysts and pundits, unsustainable levels (Reinhardt and Rogoff, 2011). Scenarios for the next decades encompass the possibility for global critical transitions at worst or, at least, the need for massive readjustment of expectations (which is a polite way to say that retirees will get much less and after working significantly longer, average social coverage will shrink much further, standard of livings will at best plateau with many signs of deterioration for the median household). Here again, one can argue that the western economic systems have been built on a model of run-away indebtedness that, on the "short term" of the past several decades, brought extraordinary gains, at the cost of increasing systemic and global risks (Sornette and Woodard, 2010). The on-going crisis of debt-strangled European nations is far from finished, as nothing has been done in depth to address the problems of insufficient growth of productivity and innovations (Sornette, 2010), of the demographic bottleneck, and of reigning on wasteful over-spending beyond one's means by addicted consumers as well as nations spoiled by the failure of democracy replaced by demagogic politics (Gore, 2007). The US should not be forgotten either, if only because its financial system is effectively bankrupt, but held artificially alive by rounds of buying toxic assets by the Federal Reserve and the successive spells of so-called quantitative easing. An even greater crisis if possible is probably awaiting Japan, which relies on the policy of essentially zero-interest rate in order to cope with a total debt that dwarfs that of all other nations. The policy of ultra-low interest rate seems to become the new reference point of debt-strangled nations in order to be able to honor their interest payments, which yet not fully appreciated consequences concerning the transfer of wealth between generations and the possibility to face the huge retirement liabilities. Globally, the diagnosis is clear: these systems have built economic organizations that contain in themselves the seeds for monstrous systemic instabilities towards major re-organizations. The 2008 US crisis and the 2010-2012 sovereign European debt crisis are probably nothing but the premises of much more significant crises at the global scale. Such a prediction is warranted on the observation that none of the real causes of the crises have been addressed and only superficial short-term remedies have been offered until now (Mauldin and Tepper, 2011; see also chapter 10 of Sornette (2003) which is based on Johansen and Sornette (2001) and, more recently Akaev et al. (2012)).

Thus, we can add to the two points (i) and (ii) above a

third one:

- iii social and political systems seem to be intrinsically unstable on the long term, building up internally the mechanisms of increasing vulnerabilities via the very processes that seem initially the most favorable.

Resilience is therefore a fundamental question that needs to take into account both the conflicts between time scales (generations) and the unintended consequences of short-term innovations and improvements (Ferguson, 2011).

4.4. Debunking “anti-fragility”

It is appropriate to end the present section, discussing whether stress can be beneficial, by the extreme view proposed by Taleb (2012) summarized under the vocabulary “antifragility”. According to this concept, “antifragile” systems may not only resist and recover efficiently from stressful events but may actually benefit from them in very direct ways and on the short term. Taleb lists a number of examples illustrating this view: muscles and bones, owning insurance or financial derivatives, decentralized organization and so on. If correct, the antifragile concept would contradict our whole construction presented above. To understand the source of disagreement, we now dissect Taleb’s proposition. In a nutshell, antifragility describes the quality of some systems that are designed to profit from particular stressors that produce stress in other systems and to which they are not sensitive themselves. But, as we are going to show, these so-called “antifragile” systems have also their own vulnerability to other stressors that lie outside their tailored design.

4.4.1. The put option paradigm

The example that captures the essence of the whole “antifragility” argument is that of financial derivatives. Consider specifically a put (also called “sell”) option written on some underlying financial asset. The later has values that fluctuate more or less randomly, with sometimes large excursions in the positive (gains) as well as negative (losses) ranges. An investor owning this asset will be exposed to possible rare large losses, the so-called tail events. The investor’s investment is thus a priori vulnerable to the occurrence of financial shocks that may hit his asset and make it fall abruptly. Fragility is particularly acute if, as such time, the investor needs to cash out for some consumption needs (unforeseen medical expenses or student university tuition for his children) at the much lower asset value following the crash. Another investor, who has bought a put option of that same asset, has a diametrically opposed perception of the situation: when the asset plunges, the value of his put option sky-rockets upwards. In the terminology of antifragility, the put option investment of the second investor is antifragile, since it profits from large negative price movements that hurt most other investors. The put option paradigm is actually underpinning the whole antifragility concept when applied to gen-

eral situations, as developed in Taleb and Douady (2012). To summarize, Taleb advocates strategies and policies that construct effectively put options everywhere!

Let us clarify how a put option works. First, it needs a risky asset or a basket of risky assets that are subjected to the influence of many natural and social factors so that its value fluctuates with sometimes large amplitudes. Second, it needs a counter party, say a bank, which accepts to create the put option and sell it to the second investor. In the case when the put option is exercised, the counter party has to pay for the gain of the option owner. The put option strategy is thus conditional on others taking the other side of the risks.

It is important to realize that the put option strategy is built on the premise that it can only work when endorsed by a minority of investors, at the expenses of the others. Take the example of the so-called “portfolio insurance” strategy developed in the 1980s by Leland and Rubinstein. Large institutional investors wanted to insure their large portfolios against possible drops of the stock market. For this, the simplest and most efficient strategy consists in buying put options on the assets held in the portfolios. However, the sheer volume of put options needed was beyond what banks and other option writers would be able or willing to offer. Or, if offered, the requested prices would have been prohibitive. Leland and Rubinstein then used the replicating construction of the Black and Scholes option pricing formula to devise a simple and effective way of constructing synthetic put options just based on the underlying assets and on bonds. The synthetic put options thus created led to a flourishing business where, at the time just before the crash of October 1987, more than one third of all US institutional investors had implemented the Leland-Rubinstein so-called insurance portfolio strategy (MacKenzie, 2008). The weakness of this whole construction however was revealed as markets started to stumble the week before “Black Monday” 19 October 1987. Because the synthetic put options operate by selling the underlying stocks when the later decreases in value, as the stock values start to go down, the synthetic put option strategy led to sells, pushing prices further down, these losses aggravating the negative sentiments of the markets, leading to an avalanche of sells reinforced by the technical implementation of the synthetic put options leading to a vicious positive feedback to the bottom. After the crash of October 1987, many pundits and scholars have concluded that, with a large probability, synthetic put option strategies were responsible for aggravating strongly the severity of the crash (Barro et al., 1989). What was supposed to be a bullet-proof strategy turned out as a catastrophe due to its hidden vulnerability with respect to synchronization. In other words, buying put options works when you are in the minority and no collective herding behavior occurs. More generally, the whole business of insurance is based on diversification of exposures. This message was vividly brought home to major insurance and re-insurance companies in the aftermath of the 9/11, when the capital stored in stock markets needed to be sold to compensate clients for their losses plummeted at the same time. This illustrated an-

other mechanism of fragility of the supposed antifragile insurance strategy.

The 15 September 2008 Lehman Brothers bankruptcy and 16 September 2008 AIG official bail out demonstrate another fundamental fragility of the antifragile put option strategy. In short, major investment banks around the world had invested in CDO (collateralized debt obligations), which are securitizations of mortgages offered to millions of American households. Many of these investment institutions search for ways to insure their exposition to possible losses on the CDOs by buying massive amounts of CDS (credit default swaps) from counterparts, the most famous and by far largest being AIG, the then largest insurance company in the World. Different from what their name suggests, CDS work essentially as put options paying large amounts when the underlying CDO losses value and/or when some trenches of the CDOs start to default. Buying CDS was a perfect antifragile strategy to profit from the rather visible problems looming as a result of the enormous real-estate bubble that has developed in the US from the early 2000s to 2007. Except for one thing: the credit risk of AIG was not considered. Default of AIG was inconceivable. The problem is that the collective use of the antifragile CDS strategy led to such an enormous exposition of AIG to a downturn of the US real estate market that its total capital base became insufficient, finally leading to its quasi-bankruptcy and its final salvation by a massive injection of capital from the US treasury and a consortium of investment banks. The so-called antifragile CDS strategy backfired to systemic proportions, whose real consequences are still to be solved at the time of writing. Moreover, for an inner circle of investment banks, the CDS strategy turned out to be really profitable, though not from the intrinsic structure of the strategy but from playing the fear to the public of a global financial and economic meltdown as well as from using high-level political connections. The bail-out packages, which were put in place in September 2008 and following months, ensured the payments of most of the liabilities at 100% face value (which AIG could not longer support) to the major investment banks. The weight of these payments was in the end supported by the taxpayers.

In sum, these dramatic examples illustrate that antifragility does not exist. In general, for systems subjected to variability, noise, shocks and other random perturbations, it is possible to develop strategies that, on average, benefit from variability, but not any variability. Such strategies are designed to profit from the variability of particular stressors. Simultaneously, they are vulnerable to other stressors. The refusal to accept this fundamental characteristic (or intrinsic weakness) shared by any strategy or system is very dangerous, as it may lead to unexpected shocks or intended manipulations by insiders. For instance, in the financial sphere, antifragility is a name for the exploitation of a situation that turns losses for most into gains for some by special design, which is, however, vulnerable to non-anticipated occurrences. Moreover, the so-called antifragile strategy can contain the germs for large externalities, leading to systemic crises for which neither the strategy itself nor the system are prepared for.

4.4.2. Can antifragility be beneficial itself?

Taleb (2012) has provided many tentative examples of supposedly antifragile systems, putting them in contrast with fragile and robust systems. For each instance (i-vii) below, the antifragile system (according to Taleb) is indicated in boldface and contrasted with its opposite fragile version:

- i civilization (*nomadic and hunter-gatherer tribes* versus post-agriculture modern urbanization);
- ii production (*artisans* versus industry);
- iii science/technology research (*stochastic tinkering* versus directed research);
- iv nature of the political systems (*decentralized political systems* versus centralized nation-states);
- v decision making (*convex heuristics* versus model-based probabilistic approach);
- vi literature (*oral tradition* versus books and e-readers);
- vii reputation (*artists or writers* versus academics, executives and politicians) and so on.

In all these examples, one notices that the antifragile system is much less productive than its fragile counterpart. In example (i), the capacity to support larger and growing populations has received an enormous boost with the introduction of agriculture while hunter-gatherer tribes had zero or very small growth. A typical North American family now commands a quantity of artifacts equivalent to or larger than that of a pharaoh at the peak of the classical pharaonic civilization. This illustrates that, in example (ii), the elaborate supply chains of modern industry based on the collaboration between millions of workers delivers enormously more than the whole summed contribution of individualistic generalists. In example (iii), the classical Greek tradition let place after many centuries of “stochastic tinkering” to an organized scientific production in the last few decades that dwarfs absolutely the knowledge accumulated earlier. In example (iv), nation-states have been able to mobilize resources unheard of decentralized political systems. Clausewitz (1984) [1832] in his classic book “On war” observed that the French revolution introduced the nation state, which led to global wars with enormously more resources, an hypothesis recently supported quantitatively using statistical comparative history (Cederman et al., 2011). In example (v), heuristics may often work for simple everyday problems and when immediate quick-and-dirty solutions are required, but would be unreasonable for decision making and management in sophisticated modern systems dealt with by surgeons, airline pilots or technicians of nuclear plants. In the case of literature (vi), it is clear that oral tradition would not fail if electricity is no more available but, on the other hand, it is a very inefficient and low-density information medium, quite unsuitable to share and store the explosive amount of modern knowledge. Lastly (vii), academics, executives or politicians have developed extraordinary specialized skills that are (in principle) translated into positive reputation. A positive reputation serves the goal of producing more or delivering higher quality services and/or of being trusted. In con-

trast, some artists and writers just need any type of reputation as long as people and media speak about them, because their business is in a sense to bank on their fame. Pushing Taleb's reasoning to the extreme, one could conclude that being a beggar is one of the most desirable antifragile state to be in, since the person has nothing to lose and can only benefit (if he survives) from any change of his position. The condition "if he survives" actually demonstrates the essential hidden assumption underlying antifragile examples. Otherwise, as soon as there is something to lose, to disprove or the possibility of a disfunction, as when owning assets, possessing a reputation, using a decision model, or production scheme, there are many additional stressors that could cripple the system. Being rich, young, healthy, beautiful and loved is the ultimate fragile state, but who would exchange it for its absolute antifragile poor, aging, ill, ugly and lonely alter ego.

4.5. Can stress be beneficial? Our answer

To summarize, we have shown that stress is unavoidable and that systems co-evolve with their stressors. The survival of a system depends on its ability to cope with and adapt to numerous stressors. In this sense, the life-span of the adapting system is relatively longer than those of many of its stressors. These stressors, coming one after another, are progressively shaping the system, demonstrating sometimes a true symbiosis and an astonishing emergence of new features that can be beneficial for the system itself. In evolutionary biology, non-visible or "neutral" mutations occurring in the presence of internal stresses as well as small external stochastic perturbations, and which leave fitness unchanged, are considered beneficial because they improve the system's robustness (Kimura, 1983; Ciliberti et al., 2007). They provide a diversification by enlarging the toolbox of defense without disruption and prepare for major jumps when necessary or when ready (Wagner, 2005; Ciliberti et al., 2007). This concept seems to have broader applications, as recently proposed to quantify software robustness (Schulte et al., 2012). Finally, extreme stressors are relatively rare events, but they play an exceptional role in creating the global landscape and activating the mechanism of natural selection. Their magnificent power gave rise to legendary names - "dragon-kings" (Sornette, 2009; Sornette and Ouillon, 2012), for the extreme stressors of endogenous nature, and black swans (Taleb, 2007) that are characterized by exogenous sources.

The response of a system to stressors depends on the level of stress within it. To make the system more efficient and flexible, it is important to learn how to use normal stress as a signal of on-going changes and as a guide for needed adaptation to better fit to the evolving conditions, so that a system can survive and benefit from them. In the presence of extreme stress, resilience, that is, conservation of the status quo, may not be anymore an option and the resources should be directed towards an unavoidable transition to a new regime that can bear or even profit from the stress: in the words of Giuseppe Tomasi di Lampedusa, in 'The Leopard': "If we want everything to stay as

it is, everything will have to change."

In Section 5, we propose strategic principles for system resilience and describe some of them in details. However, the adoption of strategic principles in most cases would require global systemic changes and would face numerous difficulties, partially described at the end of section 3.3. Therefore, in Section 6, we discuss some of these limitations and propose original operational solutions.

5. Recipes for resilience

5.1. Generic recipes for resilience

The systems that were previously mentioned are very different, and so are the conditions of their functioning and the stressors they face. Nevertheless, from the fact that stress is a non-specific response of a system that depend weakly on the type of stressor, it derives that the development of generic recipes to cope with stressors is both possible and crucial for strengthening its resilience.

We propose the following brief synthesis of strategic principles for the sustainable development of any system, which borrows from a variety of risk management thinkers, from Sun Tzu's "The art of war" (circa 500 BCE), Clausewitz' "On war" (1832), John Boyd's "certain to win" strategy and his OODA (observe-orient-decide-act) loop (Boyd, 1986; Richards, 2004) and Sheffi (2005). While rooted in ancient wisdom, their modern framing and phrasing do not diminish their reach and eternal relevance.

1. Develop strategic vision; orientation and focus on the present and future, and not on the past; establish *clear goals* (subsection 5.2),
2. build up, through investment and/or education, *fundamental values, right incentives and fair remuneration* (subsection 5.3),
3. diversify and promote *heterogeneity*, as well as *decoupling* of key components for sufficient redundancy,
4. develop operational mechanisms to *enforce contracts*,
5. promote *transparency, communication and ethics*.

At the operational level, tools for quantification of stress signals and learning from them should be put in practice in order to cope with stress effectively, i.e. to improve (i) the quality of decisions in the presence of risks and (ii) the management of resilience. These tools are to serve the following goals:

- a development of individual strengths together with awareness of one's limits,
- b promotion of collective action and collaborations,
- c analysis and classification of stressors,
- d risk identification and tracking,
- e continuous measurements and diagnosis of endogenous instabilities,
- f never ending verification and validation,
- g always keeping on edge by questioning assumptions and existing processes.

This last point is easy to formulate on paper but much harder to implement in practice, if only because of the common adage that “No one sees any pressing need to ask hard questions about the source of profits, of success, or stability, when things are doing well.” Building resilience requires indeed a kind of paranoid obsession that things could go wrong, when everything appears to be fine. Sections 5.3.3 and 5.4 provide concrete examples of such operational tools.

5.2. Formulation of goals and objectives

The first step on the way towards implementing the strategic principles for the sustainable development of a system is to identify and spell out the goals and objectives, which can also be called utility functions of the system. In this subsection, the strategies and methods of resilience growth are outlined into accordance with different types of goals.

1. At the most basic level, a first goal is to ensure survival, which calls for the measures promoting viability that are described in section 3.2, in particular using stress as information and being always ready for managerial actions to ensure that the system remains in its basin of attraction.
2. A second type of goals is often the conservation of the status quo, of existing wealth, of present standard of living. This triggers what we referred to as the “fight” response, which applies when the stress is significantly smaller than the existing resilience of the system. However, many systems, human societies and organizations in particular, reach high levels of wealth, which were obtained at the cost of strong optimization, decrease of reserves, indebtedness, increase of inter-dependencies (Diamond, 2004), which result in loss of resilience. In these situations, the fight response to maintain homeostasis at such high development levels is simply not possible in the middle and long term, because even small stressors will in the end be enough to trigger a change of regime due to the endogenous build-up of a critical fragility. As a vivid and painful example, one can argue that the present ongoing sovereign debt European crisis belongs to this class. Only with a profound reassessment of goals taking into account the realities of the globalized economy and the structural unbalances underlying the artificial construction of the euro dream, can one hope to address the systemic nature of the European conundrum.
3. A third type of goals, often observed in high-tech industries for instance, is for an entity to become and stay the leader among its pairs, hence developing highly competitive attitudes and strategies. IBM, Toyota and Apple are different examples of firms that were able to get to the top and remain there for longer than thought initially possible. For IBM, this was through its evolution from a mainframe computer hardware company to a service provider offering all possible integrated solutions to a large range of customers, thus

redefining continuously what is the essence of being IBM. For Toyota, the empowerment of the factory workers, instructed to focus on the delivery of just-in-time products, led to a remarkably motivated and productive workforce delivering high quality products for more than 50 years. But the 2010 car recalls due to the sticking accelerator pedals and failing electronic throttle controls demonstrated that bureaucracy, overconfidence and weak management have lately underpinned Toyota’s fall from grace. Apple’s remarkable success can be attributed to its focus on innovation aimed at surprising and enthusing customers, by functioning as a secret organization with a self-perpetuating start-up culture. For these companies, resilience at the top requires internal engineering of their ever on-going mutation, aiming at shaping the future rather than reacting to it, in the spirit of “You don’t wait for the future. You create it.” (Hwang Chang Gyu, 2004).

4. In the modern world, the economic language and agenda dominates, with such concepts as utility function (assumed to capture people’s goals) and growth of GDP (gross domestic product) taken as the universal measure of improvement and success. But, too little attention is given on what the US founders enshrined in the US constitution as one of the three main goals of well-functioning societies, namely the pursuit of happiness. In the United States and in many other industrialized countries, happiness is often equated with money. This simplifying assumption provides a convenient way of quantifying and comparing heterogeneous preferences of different agents within a unifying framework. This money (or economic utility function) approach has shaped our culture. Only the small Himalayan kingdom of Bhutan has made its priority to grow, not its GDP, but its GNH (gross national happiness). According to King Jigme Singye Wangchuck, Bhutan’s goals are to ensure that prosperity is shared across society and that it is balanced against preserving cultural traditions, protecting the environment and maintaining a responsive government. In our context, this can also be interpreted as promoting a resilient society, based on (i) robustness anchored at the individual level (a happy and balanced person is arguably more robust in her behavioral response to stressors) and (ii) through cohesion within the society build on a common understanding that ethical behavior is fairly rewarded and equity (and not “equality” as in communism) is the standard reference.

The development of a strategy requires an out-of-the-box thinking and the consideration of multi-dimensional objectives. Setting up goals often crucially depend on the time scales of interest as well as on the size scales (individual versus group versus society). There are well-known differences in goals and welfare attained at the individual versus collective levels. It is often difficult to reconcile the preference of individuals with those of the aggregate group. This is known as Arrow’s impossibility theorem in social choice theory (Campbell and Kelly, 2002). At the extreme, the sacrifice of individuals may ensure the sur-

vival of the whole system. Lymphocytes are not resilient individually but ensure the resilience of the immune system. Such strategies are apparently at the opposite end of Bhutan's emphasis on individual happiness. This suggests that there may be several paths towards system resilience and/or that the level and type of resilience is also a matter of choice, given the conflicting requirements (costs versus benefits at different levels).

5.3. *Fundamental values and individual strength as a basis of resilient societies*

At the system level, it can be illustrated by the following examples:

- fundamental prices of assets are more stable and predictable than their bubble components, which are unstable and may lead to severe crashes;
- practical skills (farming, engineering, programming, the development of the real economy, and so on) should be better rewarded both economically and in our cultures; stakeholders should pay attention to the added-value of supporting services (financing, marketing, management, and so on) and not hesitate to shrinking and redirecting efforts when these supporting services become tyrants rather than servants of the real economy;
- hard work, persistence, tenacity and dedication should be emphasized (which is at the opposite of the common modern emphasis on the role of chance and luck, the belief in easy profits, the "American dream" now fueled by a perpetual expanding credit engine).

The implementation of the recipes for resilience designed at the system level may not all apply directly to the individual, due to differences in the goals as well as psychological and physical aspects. The rest of this subsection is focused on recipes for personal resilience and top performance, which are easy to implement by everyone. To change the world, one should start with oneself.

Section 3.3 documented that many natural systems evolved to function "at the edge of chaos", characterized by a sharp balance between the level of risks they face and costly resilience build-up. Management of social-economic systems is also striving to achieve a balance between costs of increased resilience and its benefits. But would "at the edge of chaos" be a desirable state for a human? To stay a long time close to criticality, in a kind of alarmed position, requires constant attention, give rise to worries and triggers anxiety. In the end, there is the possibility that such a critical state does not lead to an efficient allocation of resources of the body and mind, but becomes stress itself.

One should consider an additional dimension, an often neglected benefit that comes from higher resilience: resilient people are more "happy" and vice-versa. Indeed, people who feel on top of their life and who can face stress are more relaxed, enjoy more the present and live longer. More resilience promotes a more positive attitude to one's own life and to others. In contrast, those

of us who are in a continuous race to face the constraints of personal and professional life live in a state of anxiety, a condition that has been accelerating in severity in recent decades as witnessed by the exploding sales of antidepressants. Research in psychology and psychiatry confirms the existence of a strong interdependence between resilience and happiness, with positive feedback loops in which higher positive mind set promotes resilience and vice-versa (Jackson and Watkin, 2004; Srivastava and Sinha, 2005; Cohn et al., 2009). In particular, positive emotions help people build lasting resources (Cohn et al., 2009). And it is how we respond to stress and hard time that determine our successes or failures, rather than the nature of the stresses themselves. This supports again the need for generic and robust recipes for building up resilience and... happiness at the individual level. In a review covering a large body of research investigations on individual resilience, Coutu (2002) extracted the three main characteristics that are most often associated with resilient people:

- i a staunch acceptance of reality,
- ii a deep belief that life is meaningful, and
- iii an uncanny ability to improvise.

Our own experience and reflection suggest to add

- iv the ability to keep an inquiring mind that questions assumptions and the status quo and
- iv a strong belief that our project and endeavors will succeed.

The seven factors of resilience reviewed by Jackson and Watkin (2004) from the psychological point of view overlap with the two first items, that are the need of developing a realistic view of reality and finding meanings (or causality). Indeed, they cite the following seven factors: (a) emotion regulation, (b) impulse control, (c) causal analysis, (d) self-efficacy, (e) realistic optimism, (f) empathy and (g) reaching out. These are descriptors or traits of resilient individuals. In order to be genuinely useful however, the next step is to identify whether and how it is possible to acquire, nurture and augment these traits. We are here entering the controversial domains of psychological programs and even psychiatric treatments. We take a simple "mechanistic" approach based on the premise that the above traits do not reside in a vacuum but rather are properties of bodies and minds that can be trained. Take the example of will power. In a study of one million people quoted by Baumeister and Tierney (2012), most said that self-control was their biggest weakness. So can people build up their willpower? Or are some people just born that way? In their recent book, Baumeister (who directs the social psychology program at Florida State University) and Tierney (2012) argue that willpower is like a muscle, and like all muscles, can be exhausted through overuse, but also trained to be made stronger. We could say that a strong willpower gives benefits by a slow accumulation of small gains that grow over time. The build-up of willpower operated via a positive feedback pro-

cess: the more you have, the more you use “rituals” and checklist type approaches, the better the performance, the stronger is gratification for the efforts spent, the larger the willpower, the more this continues in a virtuous loop of self-reinforcement. Baumeister and Tierney also emphasize that everything is linked together and that one energy resource is used for all kinds of acts for self-control. One could then argue that, by training and augmenting the energy source, the stronger and more energetic the body and the mind, the easier it is to develop the factors promoting resilience. In this strategy, resilience has its underpinning in the strength as well as cohesion between constitutive elements found at the level of metabolism. In a recent contribution, one of us (Sornette, 2011) has laid out seven governing principles for personal resilience and performance that we repeat for completeness. We refer to the original essay and its detailed documentation and argumentation. The seven guiding recipes for individual resilience and performance are anchored in processes that control our biological and psychological well-being. Implementing these principles require willpower, which can be augmented both by the fact of being used, as in the muscle analogy of Baumeister and Tierney (2012), and by promoting the access to more energy as the source for action.

1. *Sleep*: Rest with quality sleep for a minimum of 7-8 hours per night;
2. *Love and sex*: Cultivate the romance and relationship with your special partner; interrupt your work when needed with one minute of intense focus on the loved one, perhaps using romantic pictures of him/her to trigger happiness hormones that boosts brain performance and well-being;
3. *Deep breathing and daily exercises*: Start each of your day (no exception) with 5-10 minutes of exercises, including deep breathing-stretching followed by abdominal and finishing with a very short intense workout; perform a few 2-3 minutes of intense workouts and deep breathing at different times of your day in your office or wherever you happen to be in order to oxygen your body and refresh your brain;
4. *Water and chewing*: Drink at least 2 liters of water per day (no canned juice, no coke, no beer, no sugar) outside meals and drink minimally or not at all during meals (a small glass of red wine or cup of hot green tea is fine); “drink your food” and “eat your drinks”;
5. *Fruits, unrefined products, food combination, vitamin D and sun exposure and no meat and no dairy*: Eat as much fruits with water as possible on an empty stomach during the day, avoid meat and consume only unrefined products and cereals; avoid bad food combination to avoid conflicts between alkaline versus acid foods;
6. *Power foods*: onion, garlic, lemon, kiwis, almonds, nuts, dry fruits for super-performance in time of intense demand;
7. *Play, intrinsic motivation, positive psychology and will*: rediscover the homo ludens in yourself in things small and large so that work and life become a large play-

ground, cultivate motivation as a self-reinforcing positive feedback virtuous circle.

6. Human limits and operational solutions

6.1. Intrinsic human limits

6.1.1. Identification of stress signals and reactions to them

The analysis of the major industrial catastrophes, such as the 1986 Challenger space shuttle disaster, the explosion of the Ariane V rocket on its maiden flight in 1996, the Deepwater Horizon BP oil spill disaster that started on 20th April 2010, the Fukushima-Daichii nuclear accident in March 2011 and so on, reveals common problems in the following areas:

1. gathering information;
2. aggregating and communicating data;
3. maintaining a state of attention.

These same issues, which have been documented as underlying causes of these dramatic events, are similarly found underlying most accidents and crises in different fields of human activity, including the financial crises that started to rock the world in 2007-2008.

Gathering evidence about informative incidents is a well-known challenging task in the practice of operational risk management. Employees often experience a conflict of interests with respect to reporting problems concerning the area of their own responsibility or those of their colleagues. This may rise, for example, from the fear of punishment, disapproval of colleagues and seniors, and increase of duties to correct revealed weaknesses. As a result, signals of stress are often lost, near misses are not recorded, forgotten or dismissed, and decisions are made on the basis of unrealistically optimistic data. Furthermore, from the failure of reporting and aggregating information that is in fact known within the organization, vulnerabilities are accumulated and lead to greater accidents.

The other side of the “information problem” lies in the difficulty of maintaining a constant state of attention or excitement. It is not enough to detect a signal of growing stress, but there should be measures taken to address the issue. Unfortunately, people get used to warning signals and false alarms, and lower their guard. Again, this applies to all the above mentioned industrial catastrophes and to many more.

The first step in dealing with these problems is for the top-management to accept the unavoidable nature of stress so that appropriate stimulating mechanisms can be developed:

1. for gathering and communicating information:
 - no punishment for self-reported occasional misses, as well as in the cases when all sufficient measures were taken to ensure a desired result (i.e. evaluating the process of decision-making, but not only

- an ex-post outcome);
- confidentiality;

2. for maintaining a high attention:

- “zero tolerance” to controllable misses;
- the introduction of random stressors (such as sending “fake hard customers”;
- to check the professionalism of employees);
- a rewarding system for catching a stress signal.

6.1.2. *The “logic of failure”*

In their study on the “logic of failures” (Dörner et al., 1990; Dörner, 1997), Dörner and collaborators have found that there is indeed a logic in the origins and processes leading to failures, in the sense that (a) humans experience failure more often than success when intervening in complex systems, (b) the failures are not random, but exhibit common patterns and (c) the understanding of these patterns offer operational rules to prevent the failures. The studies performed by Dörner et al. led them to formulate general recommendations taking the exact counterpoints of the negative behaviors and habits that tend to inhabit people. Unsurprisingly, these recommendations overlap and sometimes complement the generic recipes outlined in section 5.1. In order to avoid failure and develop successful management of complex systems, one should

- continue to reflect and ask questions during the evolution of the project or system,
- act after careful analysis and be multi-faceted to ensure a rich toolbox of responses,
- strive to anticipate effects of one’s actions,
- estimate possible negative feedbacks and unintended consequences,
- not shy away from adapting policies that are not working, and
- carefully assess the real goals as opposed to be over-involvement in pet projects.

6.1.3. *The “illusion of control” syndrome*

Last but not least, one should always have in mind the “illusion of control” syndrome (Langer, 1975; Satinover and Sornette, 2007; 2011), as already mentioned in the introduction. As a corollary, individuals appear hard-wired to over-attribute success to skill, and to underestimate the role of chance, when both are in fact present. Grandin and Johnson (2005) recount experiments pitting humans against rats, in which the humans, like the rats, have not been explained the rules of the game but must infer them from the situation. In such experiments, rats often beat humans, because humans tend to over-interpret randomness and find meaning in random patterns. Normal people have an “interpreter” in their left brain that takes all the random, contradictory details of whatever they are doing or remembering at the moment, and smoothes everything in one coherent story. If there are details that do not fit, they are edited out or revised for sense making, providing

a powerful mechanism for the illusion of meaning and of control. These phenomena are ubiquitous. Langer (1975) summarized the problem in a rather amusing way: “normal people’s high level of general intelligence makes them too smart for their own good.”

This problem is perhaps best illustrated in finance where, after a full cycle of rise and fall after which stocks are valued just where they were at the start before the fall, most investors lose money by over-reacting and thus selling close to the bottom before the rebound (Guyon, 1965). More recently, a very large body of academic works support the conclusion that most managers underperform the “buy-and-hold” strategy and that the persistence of winners is very rare (Malkiel, 2012). Nevertheless, managed funds and the demand for professional investment advice has never been stronger and is a multi-trillion dollar industry, dominating the world of pension funds, mutual funds, sovereign funds, private banking and so on. The “illusion of control” syndrome is thus a call for realizing and understanding our cognitive biases. The psychological as well as philosophical literatures have discussed many times the intrinsic limits faced by any investigator trying to determine whether and how her own cognitive processes may deform her knowledge construction of the “outside” world. This is typified at the extreme by the madman who concludes, from the deformed lenses of his perceptions, that it is the rest of the world who is mad. In the context of dynamical game theory, Satinover and Sornette (2007; 2011) have determined precisely the conditions under which the “illusion of control” syndrome occurs. In dynamical first-entry games (a subset of game theory), they found that low entropy (more informative) strategies under-perform high entropy (random) strategies. This typically occurs in situations where there is a large amount of randomness, of uncertainty as well as the presence of negative feedbacks of the decision makers’ actions onto the system.

6.2. *“Crisis flight simulator” for management of complex systems and resilience build-up*

The “illusion of control” and the “logic of failure” raise the following fundamental questions for practice. What is the value of management? How much management and control is needed? How can we falsify the value of control and of management, given that we do not have the luxury of playing history twice or multiple times? How is it possible to improve management skills when dealing with complex systems? Many studies and thinkers have pondered these issues. The recommendations given in the literature argue for a balance between extremes, such as strong top-down leadership to convey the goals and the vision, together with large responsibility and autonomy given to the bottom execution; a cohesive and strong backbone linking the individuals in an efficient hierarchical network of complementary abilities and trust together with a flexible adaptive organization to face changing and uncertain conditions. But how to achieve the right balance?

We propose that the answer lies in fostering a permeating and ubiquitous learning and testing environment, as

occurs during academic curricula, and which should grow within all resilient organizations. This can take the shape of the systematic development of “crisis flight simulators” everywhere.

Consider the subprime crisis that started in 2007 with epicenter in the U.S. and the on-going sovereign crisis in Europe. To stop these systemic crises, central banks and governments have resorted to extraordinary measures, such as growing the balance of central banks with amounts of so-called toxic assets at levels dwarfing all known historical precedents. It is fair to state that we now live in a world where central banks and government are performing experiments in real time that are impacting billions of people, based on dated economic models (such as the Dynamical Stochastic General Equilibrium), which until recently did not even incorporate a banking sector and could not consider the possibility of systemic financial failures due to contagion. Not much has changed, though. The “primitive” approach of policy and decision making, based on rule-of-thumbs, political agenda, demagoguery, and untested models, is still in full force. In contrast, we argue that progress requires to endow decision makers with tools to learn and to practice at the level that airline pilots or surgeons already experience in their training. These “flight” or “surgery” simulators reproduce as faithfully as possible real processes as well as all imaginable and even unimaginable scenarios to perform “what if” exercises. This approach is relevant for all kind of decision makers, including those in the financial, policy, engineering and environmental domains, and concerns also the public, students and anyone interested and responsible. A good example of an early development of “crisis flight simulators” is the approach of Dörner et al. (1990) and Dörner (1997) mentioned above. Dörner and his colleagues conducted experiments with computer simulated environments, which included two groups of participants - executives and students. Analyzing the results of the experiments and the significant better performance of the executives, the authors proposed the concept of “strategic flexibility”, which is essential in coping with uncertainty and can be learnt through practical experience or by successive computer simulations.

The goal should thus consist in developing sophisticated convivial simulation platforms that incorporate detailed physical, geological, meteorological, geological, architectural, sociological, cultural, psychological and economic data with all known (and to be tested) feedback loops. For a given simulation, decision makers are given the power to make decisions on allocated resources to develop projects and to mitigate risks according to different strategies. The simulations will then demonstrate the consequences of the decisions within a multi-period setup. Only by “living” through scenarios and experiencing them, can decision makers make progress. For instance, there is enormous evidence in the laboratory and in real life settings that veterans who have lived through financial bubbles and crashes, through environmental crises and so on, are much better at prevention and mitigation. But, in practice, the cost is too large to learn from real life crises. This calls for a methodology for resilience based on

the development of simulators that decision makers use to understand the complex dynamics of out-of-equilibrium systems whose behavior intrinsically includes changes of regimes, bifurcations, tipping points and their associated crises. This ambition is for instance shared by the FuturICT project, as embodied in its “Living Earth Simulator”, which aims at enabling the exploration of future scenarios by large-scale simulations and hybrid modeling approaches running on supercomputers (Bishop et al., 2011; Helbing and Balmelli, 2011; Helbing et al., 2011).

With such tools, the decision maker is able to understand holistically the dynamics of the system, in a systemic way, which means that he can understand the existence of systemic instabilities as one of the dynamical solutions of the system evolution. This must be complemented by a classification of the different regimes possible, a phase diagram in which the decision maker understands which control leads to the region of the unwanted regimes and which do not. He needs to understand that bifurcations and changes of regime are a natural and expected part of natural and social systems. This understanding does not occur via studying arcane mathematical theory but, instead, by experimenting as in real life, albeit with the protective comfort of the simulator and the efficiency of scaling space and time as needed. Only under this systemic structural understanding, can he interpret correctly the precursory signs in real life and use them to correct and steer the system towards resilience and sustainability.

In order to achieve effective “crisis flight simulator” platform for management and resilience, three technical goals must be achieved: (i) modeling, (ii) collective action and (iii) crowd sourcing. First, there is the need to transform complex risks scenarios from natural language into a logical, machine-interpretable description. For that, it is necessary to reach a sufficient level of abstraction to address a broad variety of scenarios and make them reusable. We envision that complex risk scenarios could be seen as electronic circuits with components acting as relays, delayers, amplifiers, dampers, transistors, and so on, connecting at-risk entities. For instance, consider three entities A, B and C. A transistor dependence would be: A fails implies that C fails if B is activated. By combining basic components, arbitrarily complicated scenarios can be built and, moreover, scenarios can be machine-tested. This first approach intends to identify elementary components from which any arbitrarily complicated risk situation can be designed and tested in real risk situations. After preliminary calibration, volunteers can be invited to play, to reuse these elements, to build and to simulate their own risk scenarios. Second, there is the need to develop a sustainable mobilization of the crowds, so as to promote a “collective action” approach to large and systemic risks (T. Maillart, private discussions). While the first proposed approach to complex risks management might interest risk researchers and professionals, its democratized adoption by users of very different backgrounds, socioeconomic horizons, age classes and cultures is critical to gather and to organize scattered information, in order to address large scale scenarios. To ensure sustainable mo-

bilization of large populations of users, focus on intrinsic motivation is key. It will be necessary to explore the factors of motivation (hedonic pleasure and personal interests) and their relative proportion from their contribution behaviors. Two kinds of behaviors are expected: in their personal sphere of interests, many individuals will gather and submit the necessary information to document and verify scenarios, while others will rather focus on technical challenges for the pleasure of making a nice design that works. Progressive migration from the first to the second category becomes a proxy of internalization of knowledge and skills by users. Intrinsic motivation ought to drive also individual efforts towards most relevant risk scenarios. As a consequence, having a large number of contributors is the assurance of more accurate design, of better testing and of increased validity. By having many people contribute similar scenarios (or pieces of scenarios), it will be possible to derive quantitative metrics out of qualitative contributions. Third, it is necessary to develop crowd sourcing to improve the perception of regime shifts and systemic crises. There is always a large part of subjectivity in the way people perceive risks, which are complex, uncertain or even ambiguous. Such biases are likely to emerge as more individuals with various backgrounds and interests will join and contribute to the simulation platform, and therefore, must be considered. In fact, the possibility to capture human perception biases regarding risks at large scales should rather be considered as an opportunity to understand the revealed preferences that, by self-fulfilling prophecies or reflexivity, condition the choices of society. Crowd sourcing is expected to reveal and address idiosyncratic perception biases and further extract systematic ones among large populations. Finally, with contributors coming from various cultural backgrounds, differences in the perception of risks should be empirically measured at large scales.

The simulation tools of the “crisis flight simulator” for resilience build-up should be extraordinarily useful for

- i scientific synthesis of different fields in a coherent framework,
- ii the training of decision makers who do not realize the unintended consequences of their decisions (many of whom are negative and often with enormously bad consequences) and
- iii the education of the public, of citizens and of students to be informed as well as to help them direct policy by voting in an informed way.

Different institutions and companies have developed initiatives that have some relationship but are in general much more limited than the presently proposed vision of “crisis flight simulators”. One can mention the Japanese Earth Simulator, the Sentient World White Paper, Google.org that utilizes “collective action”, Gapminder for monitoring and visualizing various indices and others.

6.3. Resilience by multi-variable measurement and prediction

6.3.1. Multi-variable measurement of resilience

In Section 3, it was demonstrated that resilience can be seen as one of the indirect measures of stress used in social sciences. Considering a problem from a different angle, the resilience of a system, i.e., its ability to cope with stress, and its measurement can be improved by taking into account:

1. the multidimensionality of resilience, as the development of a system can be motivated by several goals (subsection 5.2);
2. complementary (preferably direct) dynamical measures of:
 - stressors, to which the system is sensitive (e.g. risk measures are used in a probabilistic approach),
 - stress, developing within the system (e.g. crash hazard rate),
 - costs and efficiency of managerial actions.

As a system is subjected to the influence of numerous factors, which have different effects and are interconnected, it is important that the measurement of resilience would be based not on a single characteristic but include an ensemble of them. It would be very useful to track the dynamics of different stressors and their influence on the stress reaction of the system, as well as monitor how managerial actions affect both of them. Armed with this type of quantitative data, decision makers will be able to better understand the regime in which the system is functioning. They will be able to identify the true source of change in the stress level of the system. The origin of change may include some beneficial dynamics of a stressor, managerial actions, and/or the adaptation of the system to changing conditions. Decision makers may then be able to develop better policy, based on a risk-benefit analysis.

Despite existing limitations, especially in systems that include the “human factor” (see subsection 6.1), theoretical and empirical findings suggest that such a complex quantitative approach to resilience is not only possible but, in many cases, can be enhanced by the development of a predicting capacity.

The next subsection 6.3.2 proposes a more systematic classification of the type of stressors. Then, subsection 6.3.3 builds on the endogenous nature of many crises to suggest the most ambitious approach yet discussed here, namely the “time@risk” approach based on the monitoring of precursors towards the prediction of financial and economic crises. This is nothing but the operational implementation of the famous maxim “Gouverner, c’est prévoir” (governing is predicting) by Emile de Girardin.

6.3.2. Analysis of stressor types (exogenous versus endogenous and their interplay)

1. Stressors can come from external sources and the environment, beyond the direct control of the system. Some are knowable, quantifiable, in the possible losses and their frequencies. This is the favorable situations where counter measures can be build to prepare for the possible losses and to catalyze recovery, using the dynamical framework described in sections 3.2 and 3.3. Considering external stressors, responsible managers and decision makers should also consider the real surprises, such as in the Knightian uncertainty of unknown unknowns popularized by Taleb (2007)'s "black swans". Then, resilience can only be attained with the interplay between, as already said, (i) individual strength and adaptation, (ii) cohesion of the social group as well as (iii) a balance between a clear top-down vision that does not exclude the empowerment of individuals at the "bottom" to be able to inform the top and act decisively when needed.
2. Stressors are also often of an endogenous nature, even if exogenous influences and fluctuating perturbations are always present in out-of-equilibrium open "living" systems. By endogenous, we mean that there is a progressive evolution and maturation of internal interactions between constitutive elements that may give rise to surprising large-scale collective changes. Mathematically, the theory of bifurcations describes well the sudden change of regime from one state or attractor to another one or to a set of other competing attractors upon the small variation of a so-called control parameter. In the bifurcation theory applied to dynamical systems, the fundamental reduction theorem states that bifurcations between states can only occur through a limited number of ways that are known and classified (Thom, 1989; Guckenheimer and Holmes, 1983; Manoel and Stewart, 2000; Kuznetsov, 2004) and under the change of a small number of (most likely, one) control parameters. Of course, what is the control parameter relevant for a given transition is not known in general but the knowledge that this is the case empowers the decision maker to realize that a given crisis may have a "simple" set of mechanisms after all, whose understanding may be used to track the transition. More precisely, according to this view, it is possible to develop advanced diagnostics of an incoming crisis and invest in techniques to identify precursors. As a corollary, resilience involves precautionary actions that address the observed internal changes. More ambitiously, managers should consider the possibility to change the course and steer the system away from the trouble that is progressively announced by the precursors. In this vein, we claim that many, if not most catastrophes, occur as a surprise because stakeholders and managers have ignored either by lack of knowledge, insufficient commitment or on purpose, the telling signs of the incoming crisis.

6.3.3. Resilience by advanced diagnostics and precautionary actions in finance and economics: the "time@risk" approach

Imagine you had advanced warning signs (and that you listened to them) about the future occurrence of an adverse shock to your firm. Imagine that you could have access to precursory signs of diseases not yet symptomatic in your body (as is the dream of Proteomics). Imagine you could rely on an indicator diagnosing the existence of a financial bubble and indicating the probable time of its burst. Imagine that these advanced signs would be revealed years in advance. With this kind of information, you could prepare, you could reflect on what is not working and what could be improved or changed. You could start a process towards building stronger resilience, catalyzed by the knowledge of the nature and severity of the stressors forecasted to come. In contrast to ignorance or complacency, advanced diagnostics could revolutionize risk management by pushing us into action to build defenses. A working advanced diagnostic system would not be static, but would provide continuous updates on possible scenarios and their probabilistic weights, so that a culture of preparedness and adaptation be promoted. This corresponds to exploiting the concept elaborated in section 4 concerning the coevolution of systems and their stressors. Here, we go one step further by suggesting that forecasting the occurrence of crises promotes the evolution of the system towards a higher level of resilience that could not be achieved even by evolution (which is backward looking). Advanced diagnostics of crises constitutes the next level of evolution for cognizant creatures who use advanced scientific tools to forecast their future.

To be concrete, we describe how this system, which we refer to as the "time@risk" approach, would look like when targeting financial and economic instabilities. Here, the outstanding challenge is to develop predictions of systemic risk and global financial instabilities that have emerged as leading concerns in modern economies and with globalization. As Einstein said: "Problems cannot be solved by the same level of thinking that created them." Therefore, a truly interdisciplinary approach to the diagnostic of such crises is required. By leveraging on expertise in Economics, Mathematics, Statistical Physics and Computer Science, a novel integrated and network-oriented approach can be brought to bear on the issue. This would require providing

1. a theoretical framework to measure systemic risk in global financial market and financial networks;
2. an ICT collaborative platform for monitoring global systemic risk;
3. algorithms and models to forecast and visualize interactively possible future scenarios.

Consider the example of a financial crash, such as "Black Monday" 19 October 1987 mentioned in section 4.4.1. A sum of evidences suggests that it did not come out of the blue. Postmortem analysis of many financial crashes shows the development of a kind of standard scenario, as

documented for instance by Kindleberger (2005) and Sornette (2003). A financial crash is the result of increasing financial leverage developing together with social herding and the psychology of a “new economy”. Specifically, this creates bubbles, and the crashes are nothing but the termination and burst of the bubbles. Using the concept of stress developed throughout the present essay, this endogenous maturation of the financial system towards an instability can be quantified by the excess super-exponential accelerating bubble price. This excess growing price can be used as a *direct measure of the level of stress* increasing within the system. This can be shown via the theoretical linkage between the “crash hazard rate” and the excess price (Johansen et al., 1999; 2000; Yan et al., 2012).

Other *early warning stress signals and diagnostics* for the upcoming transition into the major regime shifts associated with crises include, as reported by Sornette (2002; 2004), Dakos et al. (2008), Scheffer (2009),

- i a slowing down of the recovery from perturbations,
- ii increasing or decreasing autocorrelations,
- iii increasing variance of endogenous fluctuations,
- iv appearance of flickering and stochastic resonance, and other noise amplification effects (Harras et al., 2012),
- v increasing spatial coherence, and singular behavior of metrics revealing positive feedbacks (Sammis and Sornette, 2002; Johansen and Sornette, 2010).

This is a very general problem and, in principle, the “time@risk” approach can be extended to various domains of application. The corresponding “time@risk” platform should ideally

- a signal the possible occurrence of a crisis;
- b provide insights to adopt the appropriate policy measures; and
- c allow evaluating future scenarios according to the chosen policy.

The development of a framework for a computational forecasting infrastructure must necessarily combine modeling the relevant entangled networks with empirical analysis and validation of the models. Finally, there is a need to craft the tools into an interactive platform. Therefore, the objectives of the “time@risk” approach can be stated as follows.

1. Provide novel indicators and methods to estimate the origin and dynamics of systemic risk and forecast probability of systemic crises.
2. Develop agent-based models of the interacting networks which (a) are suitable to be validated, and (b) allow to compute indicators of systemic risk.
3. Validate the models with empirical data.
4. Develop a measurement platform in which it is possible to

- a load and share relevant data about the involved institutions and their relations,
- b produce topical maps of interacting networks,
- c detect the propagation of distress, and
- d perform simulations, scenario analysis, and systemic risk estimation.

This is an ambitious and risky approach. One should be aware of the risks and difficulties in the development of such a computational forecasting framework. For this reason, tasks should be developed both at empirical and modeling levels and with resources including a collaborative team of experts in an interdisciplinary atmosphere, forecasting technologies combined with the science of networks in order to validate the results obtained. In this way, the following insights can be implemented.

1. In contrast with a majority view of the current understanding, the global industrial, economic, financial and ecological systems are complex in which (a) micro and macro behavior can be dramatically different, (b) density and heterogeneity of the links as well as the whole topology (clusters, cycles and other patterns) may play a role on the (in)stability of the system and (c) time evolution is crucial for spillover effects and externalities to cascade across the system. In this context, equilibrium approaches deliver useful but insufficient and sometimes fundamentally misleading and dangerous insights.
2. It is useful to develop an integrated micro-macro approach including an analysis of a mesoscopic scale in which the system under study is seen as a network of different sectors (e.g. business lines such as commercial banks, investment banks, mutual funds, insurance companies, etc.) with a varying degree of interdependence among them.
3. One can leverage the deep knowledge recently gained by the complex networks community about failure cascades (Buldyrev et al., 2010) and contagion in networks.
4. It is necessary to go beyond the idea, dominant for long times, that big crises need big shocks and offer quantitative understanding of endogenous mechanisms of onset and amplification of crises. In this view, systemic risk is fundamentally different and possibly at odds with individual risk (e.g. Morris and Shin 2008, Brunnermeier 2009). In particular, local shocks can also have systemic repercussions (Delli Gatti et al. 2005, Iori et al. 2008; Battiston et al 2007; Siczka, Sornette and Holyst, 2011).

In the economic and financial applications, the list can be enhanced by the following objectives.

5. A necessary goal is to challenge the mainstream economics vision that more links (and thus interdependence) make always the economy more stable (Allen and Gale, 2000; Shiller, 2004; 2008; Merton and Bodie, 2005). Unfortunately, under some not so infrequent

circumstances, financial integration may increase systemic risk (Lorenz and Battiston 2008; Battiston et al 2009). More generally, it has been shown that stronger coupling leads to increased risks of synchronization and to the occurrence of system-wide catastrophes (Sornette, 1994; Osorio et al., 2010). Such events have been termed “dragon-kings” to emphasize their special impact and the specific generating mechanisms (Sornette, 2009; Sornette and Ouillon, 2012).

6. A promising approach is to combine Minsky (1982)’s view, currently under re-evaluation, of an endogenous build-up of financial fragility in the economy with a network approach. As a result, the extent of the systemic repercussions at the Minsky moment depends not only on the distribution of fragility across the agents but also on the structure of their network of mutual financial exposures.
7. It is important to complement the panorama of projects trying to identify precursors of crises from stock prices dynamics, by focusing instead on the network of exposures among financial institutions, which play a crucial role in the spreading out of financial distress, both in the Money Market (e.g., interbank, Repo, and so on, with maturity < 1 year), in the Capital Market (e.g., bonds, long-term loans, etc. > 1 year) and possibly in the OTC derivatives market.

7. Concluding remarks

Ideally, an individual, a group or a society would like to be optimized fully for the present, enjoying now the comfort resulting from past achievements and investments while, at the same time, be prepared for the inevitable future stressors that are difficult to foresee. The concept of resilience embodies the quest towards the ability to sustain shocks, be they externally or internally generated or both, to suffer from these shocks as little as possible, for the shortest time possible, and to recover with the full functionalities that existed before the perturbation. Building up resilience is, like risk management, confronted with the eternal conflict between the long-term benefits and the short-term costs. Indeed, building up resilience is costly, as it swallows resources that would otherwise be directed towards optimal present output. And like in risk management, the benefits are visible only when a serious crisis hits the system, which sometimes occur only over time scales of decades. The level of efforts towards resilience can thus be seen to be fundamentally anchored in a kind of philosophical perspective of one’s personal life for the individual, or a choice of culture or of society for the larger group. Building up resilience can ultimately be seen as a problem of decision making in the face of conflicting evidence and goals as well as limited strengths in the presence of a complex stochastic environment, with all its complexity and entanglement with all other aspects of life and society. It is a balance between the present versus the future, between commitments for costly investments versus present enjoyments. Yukalov and Sornette (2012) have recently shown that self-organization in complex systems can be treated as decision making (as it

is performed by humans) and, vice versa, decision making is nothing but a kind of self-organization in the decision maker nervous systems. Framing the build-up of resilience as a dynamical and continuous decision making process offers novel perspectives, which beg to be explored, based on the bridge between complex pattern formation and evolutionary emergence of novel properties.

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Citation

- Kovalenko, T. and Sornette, D. (2013): Dynamical Diagnosis and Solutions for Resilient Natural and Social Systems. In: *Planet@Risk*, 1(1): 7-33, Davos: Global Risk Forum GRF Davos.



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Application of an Information Transfer Model to Evacuation Guidance during Emergencies

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Abstract – Reports related to disasters such as the September 11, 2001, World Trade Center attacks and the Great East Japan Earthquake and the ensuing tsunami have provided important lessons related to human casualty reductions. One key lesson demonstrates that agents tend to respond individually during emergencies. Individuals' responses can be categorized into three types: (1) some individuals evacuate instantly, (2) some evacuate when they hear evacuation guidance messages provided by authorities, and (3) others evacuate when they feel extreme anxiety. Evacuation announcements significantly influence human behavior during emergencies. We propose a model that illustrates the ways evacuation announcements are transferred to individuals and that demonstrates their effects on individuals' evacuation efforts. We implemented an information transfer model in an agent-based system that included an agent communication function as well as a Belief-Desire-Intention (BDI) model. The communication function provides announcements from authorities to persons, while the BDI model represents human behavior during emergencies. Simulations of evacuations from a five-story building revealed the effects of phased evacuations when noise disrupted the provision and reception of evacuation guidance. The simulation results revealed that the dissemination of messages during emergencies is useful and supports the development and application of effective evacuations plans.

Keywords – evacuation guidance, evacuation simulation, information transfer model, human behavior

1. Introduction

Emergencies such as fires, earthquakes, or terrorist attacks can occur at any time in any location. Disaster countermeasures have been deployed in a variety of countries and regions (Perry, 1984; Kitao, 1986). Many organizations engage in emergency preparations and provide trainings to save individuals during emergencies, as well as to reduce damage during future disasters. Disaster-prevention departments of governments, buildings, and other organizations develop these training programs. During these trainings, individuals learn that they must evacuate quickly and move to safer locations. They also learn to cooperate with one another to ensure smooth evacuations from buildings.

The importance of evacuations has been reaffirmed by a number of reports related to various disasters. The September 11, 2001 attacks, the Great East Japan Earthquake (GEJE) that occurred on March 11, 2011, and the

ensuing tsunami, took many lives and caused serious injuries. Detailed reports focused on occupant behavior during the World Trade Center (WTC) disaster were published by the National Institute of Standards and Technology (NIST), among other organizations (Averill, 2005, Edwin, R. G. et al., 2008). A survey examined evacuation behavior that occurred after the tsunami alarm was broadcasted during the GEJE. The results were provided in conference documents published by the Japanese Government (Japan Cabinet, 2012).

Evacuation announcements can exert significant influence on individuals' behaviors when they begin to evacuate and exit buildings (Averill, 2005). The provision of guidance by well-trained leaders can facilitate efficient evacuation (Amanda, 2008). It can be difficult to conduct physical experiments that involve large numbers of humans in real environments. Therefore, evacuation simulations have been studied and developed. In the NIST report, simulations of the evacuation of the WTC towers.

The purpose of the simulation was to model evacuation times for a number of scenarios. During the experiment, several simulation systems (EXODUS, EXIT89, Simulex, and ELVAC) were employed. Issues related to evacuees were classified into three categories: individual, interactive, and social issues. The individual issue focused on individuals' travel speeds and the obstacles that might hinder their egress. The systems used in the experiment that simulated evacuations addressed these parameters. However, they did not address interactive and social issues. The interactive issue focused on psychological aspects, as well as on interactions that occurred among agents during efforts to share information related to egress. For example, individuals' behaviors, such as seeking refuge and seeking information related to their families' safety, affected the behaviors of other individuals. The social issue focused on information related to routes to exits and methods used to provide evacuation guidance.

Agent-based simulation (ABS) provides a platform for the development of computing behaviors related to interactive and social issues (Thalmann, 2007). The occurrence of loud noises at disaster sites can increase individuals' anxiety. ABS is used to simulate the impact of agents' psychological status and knowledge on their choices of action (Pan, 2006). Nuria et al. showed communication between people improves evacuations rates by ABS (Nuria, 2006). They devised a scenario that focused on two types of agents: (1) leaders who help others and explore new routes; and (2) agents who might panic during emergencies that occur in unknown environments. Tsai et al. developed ESCAPES, a multi-agent evacuation simulation system that incorporates four key features: (1) different types of agents, (2) emotional interactions, (3) informational interactions, and (4) behavioral interactions (Tsai, 2011). These key features have been used to estimate evacuation times during building design processes or to develop prevention plans that might minimize damage and the loss of human life.

We believe that evacuation announcements exert significant influence on individuals' evacuation behaviors. Existing evacuation simulations assume that individuals evacuate concurrently. However, this does not always occur (Erica, 2005). Furthermore, simulation systems do not include announcement functions that provide information during evacuations. In this paper, we propose an information transfer model that includes an announcement broadcasted to agents. The model uses an internal process that begins with the initial broadcast of the announcement to agents and continues with the initiation of the evacuation. The agent-based simulation system replicates evacuations from a five-story building. This paper is organized in the following manner: Section 2 presents lessons learned from past disasters. Section 3 describes human behavior during emergencies. We present our information transfer model and agent-based simulation system in Section 4. Section 5 describes evacuation simulation scenarios and the results of our simulations. Section 6 provides a summary of our results.

2. Lessons learned from past disasters

A number of studies have focused on human behavior during past disasters. NIST examined occupant behavior during the attacks made on the WTC buildings. The cabinet office of Japan also reported on individuals' evacuations during the GEJE. Three common issues were discovered:

- Some individuals evacuated immediately when the disasters occurred. However, others failed to evacuate, even though they heard emergency alarms provided by authorities. Individuals used several methods to evacuate from areas or offices (Japan Cabinet, 2012). First, in the instant-evacuation category, individuals became increasingly anxious when emergencies occurred. Second, in the evacuation-after-tasks category, individuals failed to evacuate immediately. However, they did evacuate when they heard evacuation guidance provided by authorities. Third, in the emergency-evacuation category, individuals evacuated when they felt extreme anxiety.
- The evacuation-after-tasks and emergency-evacuation categories involve individuals who had family members located in remote areas, individuals who attempted to contact their families by phone, and individuals who continued to work because they believed they were safe. The provision of alarms and subsequent guidance by authorities changed the behaviors of individuals in these categories.
- Once individuals understood their situations and received information related to the emergencies, building layouts and concerns about their families' safety affected their evacuation behaviors. They applied information provided in announcements. They also benefited from communications with other individuals.

It is interesting to note that individuals' behaviors during these two disasters were similar to the behaviors of individuals during a flood in Denver, U.S.A. on June 16, 1965, even though communication methods have changed during these fifty years (Drabek, 1968). Approximately 3,700 families were suddenly evacuated from homes. The family behaviors during the flood that occurred following the provision of warnings were categorized as follows: (1) some families evacuated immediately, (2) other families attempted to confirm the threat of disaster, and (3) some families ignored the initial warning and continued with routine activities.

The NIST report indicated another issue that should be considered in models of evacuation behaviors. With respect to the WTC attacks, WTC1 and WTC2 were similar in size and layout. During the attacks, similar numbers of individuals inhabited both buildings. Individuals in both buildings began to evacuate when WTC1 was attacked. WTC2 was attacked 17 minutes later. At that time, about 83% of survivors from WTC1 remained inside the tower. About 60% of survivors remained inside WTC2. Section 10.1 of the NIST report provides changes in those percentages. Differences in evacuation behaviors between

the two buildings resulted from interactive and social issues. These issues involved leadership or announcements of evacuation guidance. Typical guidance announcements are provided in the Appendix.

During large earthquakes (e.g., the earthquake that occurred in Hanshin Awaji, Japan in 1995 and the earthquake that occurred in Eastern Sichuan, China in 2008) many people died when buildings collapsed. The GEJE and the Indian Ocean earthquakes occurred in 2004. The tsunamis that followed these earthquakes caused more deaths than the earthquakes themselves. Prior to the impact of a tsunami, a brief period transpires during which individuals can evacuate to safe places. Table 1 illustrates the time sequence for the provision of information during the GEJE. A period of about 45 minutes transpired prior to the tsunami's full impact. Once individuals realized they had 45 minutes to escape, the majority was able to do so.

3. Human factors on evacuation behaviors

3.1. Definition of evacuation process and time

The International Organization for Standardization (ISO) published a technical report that provides information related to occupant behaviors during evacuations caused by a fire emergency and their impacts on the evaluation of life safety aspects (ISO/TR 16738, 2009). This technical report addresses parameters related to life safety designs and assessments of building occupants' conditions with respect to time. The parameters range from building design to occupant characteristics to disaster dynamics. The building parameters include floor layouts, warning systems, life safety management, emergency procedures, and so on. The occupant parameters include numbers, locations, characteristics, conditions, and so on. The assessment parameters focus primarily on occupants' evacuations. They rely on two basic performance characteristics: (1) available safe-escape times (ASET), and (2) required safe-escape times (RSET). The report suggests a fire-safety engineering design guideline: ASET should be greater than RSET.

Fig. 1 illustrates how these processes occur over time, beginning with the time when alert systems first announce the emergency and continuing through the time when individuals can safely evacuate. Two types of emergencies are addressed in the figure: emergencies that can be predicted and emergencies that cannot be predicted. Tsunamis fall into the latter category. Thus, the prediction period has been added to the original diagram in Fig.

1. We assumed that fire was the cause of the emergency.

t_{pred} : The interval that occurs between the moments when alarm systems announce an emergency will occur and when the emergency actually occurs.

t_{det} : The interval that occurs between the initiation of the emergency and the moments when authorities, such as government officials, fire offices, among others, detect the occurrence.

t_{warm} : The period during which authorities provide alarms or warnings to individuals.

t_{rec} : The time individuals require to recognize that an emergency has occurred.

t_{res} : The time individuals require to respond to the situation by evacuating to safe places or contacting others to ensure their safety.

t_{pre} : The pre-travel activity time (PTAT) consists of the sum of t_{rec} and t_{res} . It represents the interval that elapsed between the moments that individuals first heard warnings until the time they begin to evacuate.

t_{trav} : The time individuals required to travel to safety.

t_{evac} : The time required for evacuation consists of the sum of t_{pre} and t_{trav} .

t_{marg} : The time elapsed until the tenability limit is reached for evacuation completion.

With respect to the GEJE, the emergency combined earthquakes and tsunamis (see Table 1). The times for prediction, occurrence, and detection were the same: 14:46. The warning time occurred at 14:49. The tenability time occurred at 15:00 (or 15:25). Thus, t_{evac} ranged between 11 and 36 minutes.

3.2. Where people evacuate during emergencies

Kitao (1986) conducted a questionnaire survey with individuals who shopped at a Tokyo department store. The survey focused on factors related to evacuation behaviors in public spaces. Three hundred subjects were selected from shoppers in the department store. The number of male and female participants was equal. Participants varied between teenagers and adults in their 60s. The number of participants in each group was equal. The questions addressed the following behaviors that occur during emergencies: the provision of evacuation instructions during emergencies, knowledge of emergency exit locations, individuals' abilities to evacuate safely, and other factors.

Table 1: Event sequence for the GEJE (March 11, 2011)

Time	Events
14:46	Emergency earthquake alert system Earthquake bulletins broadcasted. The earthquake had a moment magnitude of 9. It continued for about 6 minutes.
14:49	Tsunami warnings were issued: "A big tsunami will hit at around 15:10."
15:15	Aftershocks occurred.
15:00-15:25	An initial, relatively small, tsunami struck.
15:25-15:40	A much larger tsunami arrived.

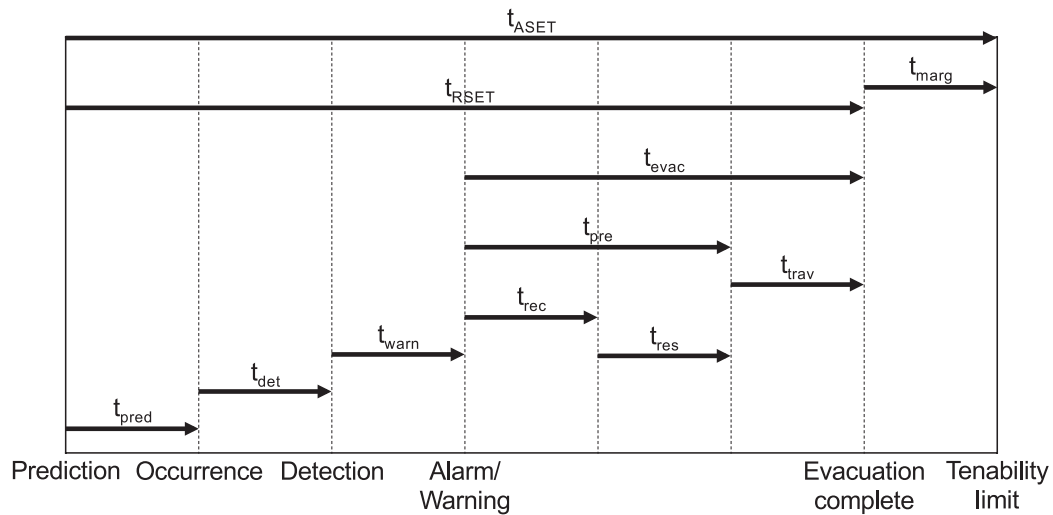


Figure 1: Diagram of processes involved in Required Safe-Escape Time (RSET) and Available Safe-Escape Time (ASET) (modified in ISO/TR 16738, 2009).

Table 2 lists evacuation strategies, as well as the percentages of subjects who selected each strategy. The results revealed:

- Individuals' intentions during emergencies were diverse. Differences were apparent between the sexes and between age groups.
- Half of all surveyed individuals stated they would follow authorities' instructions. The other half stated they would select directions by themselves, and individuals who chose the fourth and fifth strategies tended to choose opposite directions. They expressed specific purposes for their choices of strategies.

The survey was conducted during a daily life situation. However, individuals' real behaviors during emergencies may differ significantly. For example, during the experiment, individuals who decided not to follow instructions did not actually receive instructions or announcements. The instructions or announcements might also include the third category (see Appendix).

Failure to provide evacuation shelters can lead to tragedies. For example, a tragedy occurred at the Ookawa elementary school during the GEJE (Ookawa, 2011). The majority of students in the Ookawa elementary school

were engulfed by the tsunami and died. This occurred despite the fact that the students had been informed of the large earthquake one hour prior to the tsunami's impact. The school was located 5 km from the sea. As a result, they engaged in late evacuation because they did not expect the tsunami to strike the school. The school had never practiced evacuation drills. They failed to identify evacuation locations in the case of emergencies. When the earthquake occurred, all students had assembled on the ground. An hour elapsed before teachers decided on an evacuation location. During the time that teachers and students progressed towards that evacuation location, a police agent informed them that the tsunami was imminent and that their evacuation location was unsafe. The group decided to travel to a higher location but their efforts were too late.

4. Information transmission during evacuations

4.1. Communication model during emergencies

Human behavior depends on available evacuation times and the number of evacuees involved during emergencies. The provision of informational announcements during evacuations can affect human behavior. The messages

Table 2: Responses to "In which direction would you evacuate?" (Kitao, 1986)

Selected directions	All (300)	Sex	
		Man (150)	Woman (150)
1. Follow instructions from clerks or announcements	46.7	38.	54.7
2. Hide from smoke	26.3	30.7	22.0
3. Go to the nearest staircase or emergency exit	16.7	20.7	12.7
4. Follow other individuals' movements	3.0	1.3	4.7
5. Go in the direction that has fewer people	3.0	2.7	3.3
6. Go to bright windows	2.3	2.7	2.0
7. Return to the path	1.7	2.7	0.7
8. Other	0.3	0.7	-

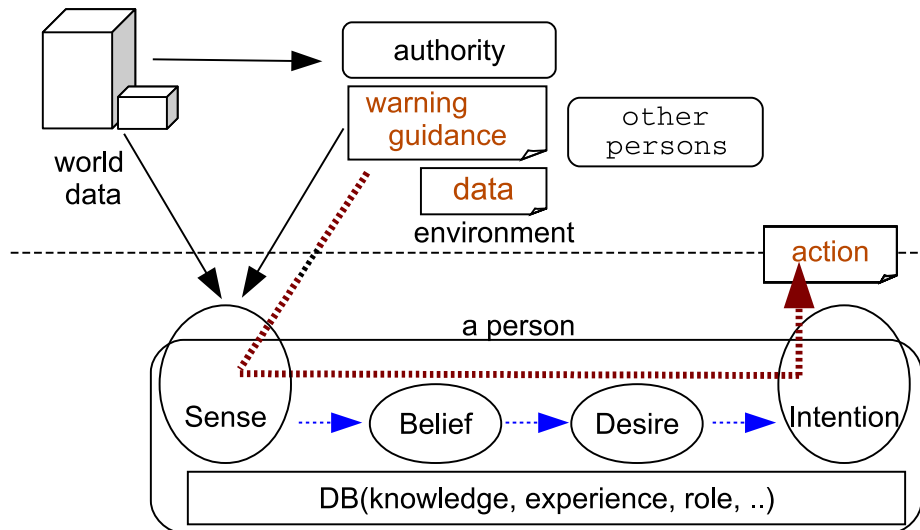


Figure 2: Model of information transfer that occurs during emergencies.

included in the announcements can exert important impacts on effective evacuation efforts:

- At the individual level, factors that influence individuals' behaviors are diverse. Selection of the appropriate strategy based on correct information is critical.
- At rescue headquarters, the first announcement may have been prepared in advance. Evacuation messages must change over time as additional data becomes available so that leaders can provide effective guidance during evacuations.

Weaver specifies that three levels are included in Shannon's communication model (Claude, 1964):

- Level A: How accurately can the symbols of communication be transmitted from sender to receiver? (The technical problem.)
- Level B: How precisely do the transmitted symbols convey the desired meaning? (The semantic problem.)
- Level C: How effectively does the received meaning affect conduct of receivers in the desired way? (The effectiveness problem.)

During emergencies, the warnings or evacuation guidance provided must be heard by individuals (level A). Once individuals have recognized the dangers involved in the situation outlined in the announcement (level B), they must move to safe places (level C).

Fig. 2 illustrates the way that individuals internally process guidance information provided by authorities. Individuals obtain data by experiencing the emergency as it unfolds around them: They hear authorities' announcements or they exchange data related to the emergency with one another through communication (these actions are represented by solid black arrows in the figure). Once they receive data, individuals attempt to comprehend the data by comparing it with their own knowledge and/or ex-

periences. Then, they plan their succeeding actions based on their comprehension (these actions are represented by dotted blue arrows in the figure). The dotted red arrow that appears in the figure corresponds with communication that occurs at Level C. The authorities, as one component of the environment, serve as an information source. Messages sent to individuals consist of warnings related to predictable emergencies or guidance that provides directions for egress. Individuals choose their actions based on their own knowledge and experiences, as well as on their roles in the community. Places that they believe to be safe are selected as their destinations.

Noise can affect the transference of information during two stages that occur in the process that begins with the provision of a warning and ends with a choice of action. Noise can prevent individuals from selecting appropriate strategies that will help them achieve safe and quick evacuations. The first stage involves individuals' abilities to sense data in the environment. Some individuals miss announcements or misunderstand messages. The second stage involves individuals' choices of actions based on their personal databases comprised of data they have compiled with their senses. Scholars have noted that, during emergencies, individuals may misunderstand situations and make faulty decisions based on their mental biases. In Fig. 2, the Belief-Desire-Intention (BDI) model is used to represent individuals' internal selection processes. Mental biases are represented by the filtering functions that operate from Sense data to the set of Belief, from the Belief to Desire, and the Desire to the set of Intention.

4.2. Evacuation simulations that address information

Evacuation guidance and human behavior play important roles in the development of models that illustrate the ways individuals process information during emergencies. Our agent-based evacuation simulation is comprised of agent, environment, and crowd simulations (Masaru, 2011).

- **Agent and inter-agents:** Human agents hear announcements provided by authorities, confirm the provided data with other agents in the area, and perform chosen actions. We adopted a BDI model to represent this process. Belief consists of the set of knowledge and information each agent possesses during every sense-reason-act cycle. Knowledge includes the layouts of buildings, locations of exits, and personal data, such as the number of agents who have families.
- **Environment module:** This module consists of data related to environments and emergencies. The environments consist of 3D CAD models of buildings. The emergency situations consist of locations in which fires occur, locations in which individuals are unable to hear announcements clearly, or related changes in those environments (e.g. corridors become obstructed by fires).
- **Crowd simulation:** The module simulates individuals' dynamics based on physical differences that might arise from sex and age. People attempt to travel to their chosen destinations based on their intentions. Rescue responders travel to assigned places to guide individuals to safety. Rescue responders' movements may act as obstacles to other evacuees' movements.

5. Evacuation simulation that addresses information

5.1. Evacuation scenarios

Fig. 3 provides an illustration of a five-story building. It provides a snapshot of a simulation that represents 1,000 people (200 people on each floor) evacuating a five-story building. The building we chose was our university library; Fig. 4 illustrates the layout. The building contains six stairways: Two stairways run from the fifth floor to the first floor. Four stairways run between neighboring floors. The building has two exits: The front exit is situated on the second floor. An emergency exit is situated on the first floor. The front exit is 3.7 m wide. The emergency exit is 1.3 m wide.

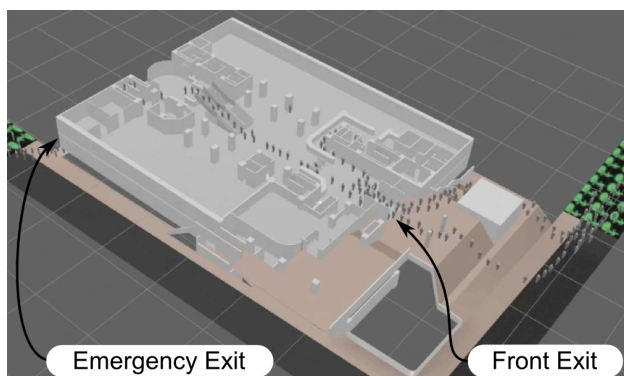


Figure 3: Snapshot of a building evacuation.

Table 3 illustrates the three simulation scenarios. Two cases were simulated for each scenario (i.e. with and without emergency announcements). The announcements were modeled on the WTC emergency guidelines (see Appendix). The contents of the announcements were

changed for each floor to smooth the flow of evacuation movement. Agents located on the first, third, and fifth floors were guided to egress by using the stairway. They were told to exit from the emergency exit. Agents located on the second and fourth floors were guided to exit from the front entrance (see Table 4). In the case in which no announcements were provided, all agents normally left from the front entrance because they were not informed of the existence of the emergency exit.

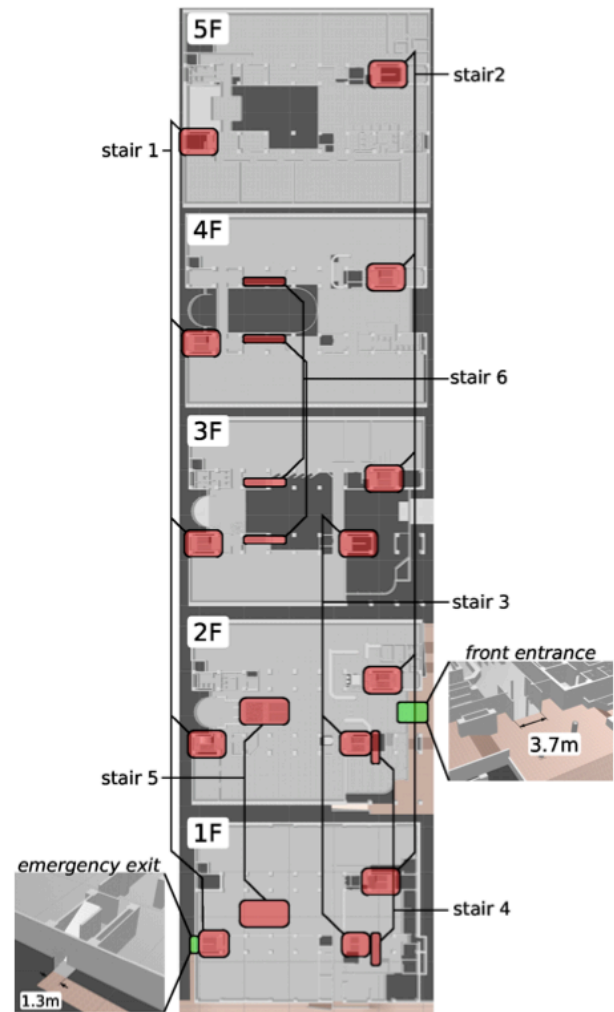


Figure 4: Floor layout of a library building that contains six stairways and two exits.

The differences among scenario 1 and scenarios 2 and 3 are based on the agent categories. Categories 1, 2, and 3 correspond to the instant-evacuation, evacuation-after-tasks, and the emergency-evacuation categories described in Section 2, respectively. In scenario 1, all agents were drawn from the instant-evacuation category. They initiated their own evacuation at the beginning of the simulation. In scenarios 2 and 3, agents were drawn from all three categories. The ratios were set to 57%, 31%, and 12%, respectively, based on GEJE reports (Japan Cabinet, 2012). Agents drawn from the evacuation-after-tasks and emergency-evacuation categories evacuated five minutes after the beginning of the simulation, or once they received evacuation guidance. The differences that occurred

between scenarios 2 and 3 depended on whether communication loss occurred. According to the GEJE reports, 82% of the individuals involved heard the emergency announcements provided by authorities. Further, 82% of the individuals who heard the announcements understood the guidance contents clearly. The remaining individuals failed to understand the messages. In addition, 18% of individuals who missed the emergency and 18% of individuals who heard the announcement and failed to understand the situation did not evacuate immediately, even if they were instant-evacuation agents. Approximately, 33% of the individuals who failed to hear or did not understand the emergency announcements acted based on their own BDI models (see Fig. 2).

In the BDI model, the agent category is determined by the degree of awareness of danger.

- Belief (B_t): $B_t = \text{belief}(S_t, B_t - 1)$

When a person hears evacuation instructions, he/she considers his/her safety more important than other jobs. Some agents who do not believe they are in danger might change their beliefs when they hear evacuation instructions. The awareness of danger and its relationship with beliefs will change based on the agent's mindset.

- Desire (D_t): $D_t = \text{option}(B_t, I_t - 1)$

Changes in beliefs will affect desires. Most individuals are performing tasks. Thus, they may want to finish their tasks normally. At emergencies, some may behave differently.

- Intention (I_t): $I_t = \text{filter}(B_t, D_t, I_t - 1)$

Agents filter one particular action from a number of suitable actions to achieve their personal desires. Agents develop their personal preferences based on their personalities and social norms. An agent might intend to evacuate or he/she might continue his/her work.

S_t is a set of sensor data that an agent receives at time t . B_t , D_t , and I_t represent the status of beliefs, desires and intentions, respectively. B_t consists of rules of action, knowledge, and states. Differences in agent types are implemented by the use of different *belief*, *option*, and *filter* functions.

5.2. Results of the simulations

Fig. 5 illustrates the simulation results for scenario 1. The average values of four simulations are plotted with standard deviations. The left graph lists the number of agents that left the building from the front exit. The middle graph lists the number of agents who left the building from the emergency exit. The right graph lists the total number of agents who left the building from any exit. All agents left from the front exit when guidance was not provided. However, agents left from different exits when guidance was provided. After ten minutes elapsed following initiation of the simulation, over 300 people had left the building after guidance was provided. In contrast, fewer agents left when guidance was not provided. These results demonstrate that the provision of announcements helped more agents evacuate the building.

Times for last agents' exits from the building were almost similar, regardless of whether guidance was provided. Fig. 6 provides snapshots of the simulated exits from the front entrance when an announcement was not provided, as well as snapshots of simulated exits from the emergency exit when an announcement was provided. The width of the passage that led to the emergency exit was about one-third the width of the passage that led to the front entrance. Congestion that occurred at the emergency exit caused almost similar total evacuation times.

Table 5 provides a comparison of the simulation results for scenarios 1, 2, and 3. In the cases of evacuation without provided guidance that occurred in scenarios 2 and 3, the number of agents who left from the front entrance was less than 500. This occurred because some agents from the evacuation-after-tasks and emergency-evacuation categories did not believe they were in danger. Hence, they did not evacuate. In the version of scenario 3 in which guidance was provided, the number of agents who left from the front entrance was higher than the numbers tabulated in the other cases. This occurred because some agents from the emergency-evacuation category who failed to hear the announcements made their exit decisions based on their personal BDI models. As a result, more agents left the building from the front entrance, rather than from the emergency exit. Therefore, evacuation times were longer for this case, rather than for the other cases.

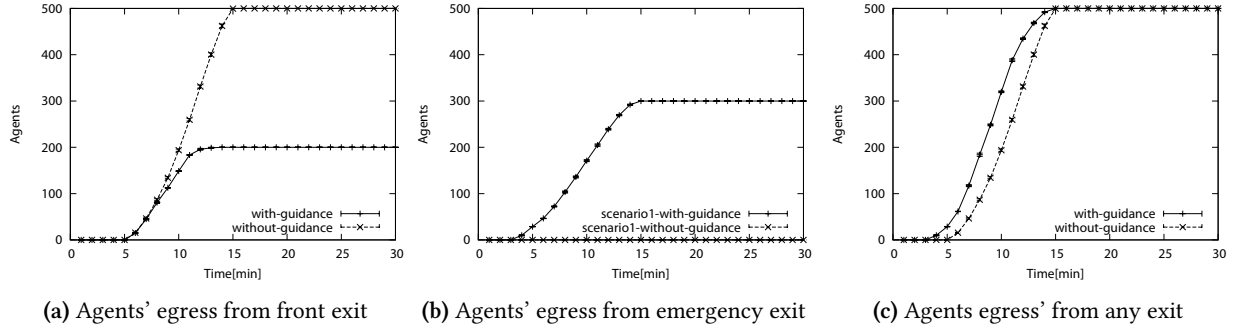
Table 3: Simulation scenarios

Scenario	Announcement	Agent category*	Data loss
1	✓	1 1	- -
2	✓	1+2+3 1+2+3	- -
3	✓	1+2+3 1+2+3	33% 33%

* 1, 2, 3 correspond to instant-evacuation, evacuation-after-tasks, emergency-evacuation categories. The ratios are 57%, 31%, and 12%, respectively.

Table 4: Exit guidance provided during phased evacuation (contents of announcements differed for each floor)

floor	no guidance		with guidance (phased evacuation)	
	exit	routes (stairs)	exit	routes (stairs)
5F	front	stair 1, 2 [↓]	emergency	stair 1, 2 [↓]
4F	front	stair 1, 2, 6 [↓]	front	stair 1, 2, 6 [↓]
3F	front	stair 1, 2, 3 [↓]	emergency	stair 1, 2, 3 [↓]
2F	front	exit	front	exit, stair 1, 4, 5 [↓]
1F	front	stair 1, 4, 5 [↓]	emergency	exit

**Figure 5:** Results of four simulations for scenario 1. (a) (b) (c) Number of agent egresses from front entrance, emergency exit, and both exits, respectively.

6. Summary

Many organizations conduct preparations and provide training for emergencies to protect against future disasters. The information provided during trainings and the processes described in evacuation manuals are designed to move individuals quickly and smoothly to safe places, as well as to ensure effective conduct of rescue operations. Reports related to disasters, such as the September 11 attacks and the GEJE, as well as the ensuing tsunami, have provided important lessons related to human behavior during emergency situations (Averill, 2005, Japan Cabinet, 2012). One key lesson demonstrates that humans behave differently during emergencies and that the provision of evacuation announcements can significantly influence human behavior during emergencies. Two different stages occur during the transfer of messages from authorities to individuals. The first stage involves a technical and semantic problem derived from Shannon's communication model. Data loss can occur because of noise interference. As a result, people fail to receive messages that convey authorities' guidance. The second stage involves the effectiveness problem. Some individuals will evacuate

immediately. However, other individuals will not evacuate despite the fact that authorities have provided evacuation announcements.

We believe that authorities' provision of announcements represents an effective way to encourage individuals to cease their tasks and evacuate to safe places. In this paper, we proposed an information transfer model that represents ways humans react when they hear emergency information. In our evacuation simulation system, broadcasted announcements affected agents' behaviors. We represented agents' mental status with a BDI model. Their mental status led to divergent behaviors. The BDI model presents three human categories of reactions based on GEJE reports: instant evacuation, evacuation-after-tasks, and emergency evacuation.

Our simulations revealed the following results:

1. Manuals compiled for use during emergencies specify the provision of announcements to guide agents based on particular situations. These phased evacuations were described in the WTC emergency guidelines to increase evacuation efficiency. In this study, phased evacuations were simulated and the effects and

Table 5: Simulation results for Scenarios 1, 2, and 3

	front entrance				emergency exit			
	without guidance		with guidance		without guidance		with guidance	
scenario 1	500 ± 0	10.65 ± 0.05	200 ± 0	8.60 ± 0.02	0	-	300 ± 0	9.26 ± 0.43
scenario 2	444 ± 5	12.47 ± 0.17	200 ± 0	9.01 ± 0.17	0	-	300 ± 0	9.37 ± 0.12
scenario 3	443 ± 5	12.70 ± 0.14	278 ± 4	9.86 ± 0.15	0	-	221 ± 4	9.07 ± 0.21

* 1, 2, 3 correspond to instant-evacuation, evacuation-after-tasks, emergency-evacuation categories. The ratios are 57%, 31%, and 12%, respectively.



Figure 6: Exit congestion.

problems in the contents of these types of guidance were indicated.

2. Scenario 1, in which all occupants were classified in the instant-evacuation category, demonstrated the shortest evacuation time. Noise interference that resulted in data loss during authorities' provision of guidance, as well as a variety of human behaviors, increased agents' egress time during evacuation.

These results reveal that our information transfer model can provide useful information for the development of building evacuation plans and for the analysis of their effectiveness.

7. Appendix

The following examples consist of texts prepared for a variety of emergency scenarios that were included in the World Trade Center Emergency Guidelines (Averill, 2005, p. 35). According to the guidelines, information and instructions to be broadcasted to buildings' occupants could be modified to suit particular emergencies.

Example 1: Prior to all emergency announcements, the following pre-announcement was made: Your attention please, your attention please. An important public address announcement will be made in the main corridor of your floor in a few moments.

Example 2: Evacuation for any reason, including fire or smoke, would have generated the following announcement, enabling a phased evacuation: Your attention please. We are experiencing a smoke condition in the vicinity of your floor. Building personnel have been dispatched to the scene and the situation is being addressed. However, for precautionary reasons, we are conducting an orderly evacuation of floors. Please wait until we announce your floor number over the public address system. Then, follow the instructions of your fire safety team. We will continue to keep you advised. We apologize for the inconvenience and we thank you for your cooperation.

Example 3: The standard evacuation announcement for a particular floor was, Your attention please. It is now time for your floor to be evacuated. In accordance with the directions from your fire safety team, please take the exit stairs nearest to your location. We remind you that communications, emergency lighting, and other essential services are in service. We will continue to keep you advised. We apologize for the inconvenience and we thank you for your cooperation.

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Citation

- Okaya, M. and Takahashi, T. (2013): Application of an Information Transfer Model to Evacuation Guidance during Emergencies. In: Planet@Risk, 1(1): 34–43, Davos: Global Risk Forum GRF Davos.



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Enhancing Forest Fires Preparedness in Portugal: Integrating Community Engagement and Risk Management

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Abstract – The growing incidence, intensity, severity, and size of forest fires and escalating economic constraints have made reliance on fire suppression activities as the main fire management strategies, in Portugal, less tenable. Recognition of this led fire and municipal civil protection agencies to include community preparedness in comprehensive risk management planning. Because this is a new element of risk management in Portugal, agencies need information on cost effective approaches to facilitate community preparedness. Using data from a study of forest fire preparedness in Portugal, this article discusses the development and testing of a model of forest fire preparedness. Data from 197 residents from several communities in northern Portugal were used to test the model. Analysis confirmed that people's beliefs about the effectiveness of preparing (outcome effectiveness) interacted with social processes and competencies (community participation, collective efficacy) to explain differences in levels of forest fire preparedness. Because the social processes and competencies identified derived from people's life and community experiences, the findings highlight the importance of integrating risk communication with community engagement and development strategies if the goal of increasing preparedness is to be effectively pursued. Activities fire and municipal agencies can use to facilitate preparedness are discussed, as is the potential for using the model in Europe and Australia.

Keywords – forest fire preparedness, risk communication, community engagement, development

1. Introduction

Forest fire incidence is high in Portugal. It has the highest frequency of fire ignitions and burned area in Europe (Catry et al., 2010; San-Miguel and Camia, 2009). In 2010, half the fires and burned area in all southern European countries were in Portugal (JRC, 2011). Since the start of the official database on the fires, in 1980, almost 572 thousands events were record although 71% burned less than 1ha. Only 4,905 occurrences (0,9%) burned 100 ha or more. Two main trends have emerged to characterize fire occurrence in Portugal (Figure 1). The first concerns the increasing in the number of fires and the area burned. Data on the number of fires is depicted by the red line in Figure 1 (scored against the right column in Figure 1 which describes the number (No.) of fires). Data on the area burned is depicted by the histogram in Figure 1 (with the total hectares (Ha.) burned measured against the left hand column in Figure 1). The maximum value of area burned was reached in 2003 (425,839 ha) and the maximum num-

ber of fire events was reached in 2005 (35,824) (Figure 1). The second trend is reflected in the occurrence of larger and catastrophic fires. The occurrence of fires larger than 20,000 ha is a 21st century reality, and some of these fires can be even considered mega-fires (Kearney and Warren, 2006; Pyne, 2007; San-Miguel Ayans, 2011; Tedim et al., 2013; Williams et al., 2011).

Forest fires represent significant ecological, social and economic threats to many communities in Portugal. The expansion of the wild land-urban interface is putting more people at risk and increasing potential damage to property. This trend results not only from the expansion of urbanization into wild lands but because forest, in many places, is coming closer to the settlements as a consequence of the abandonment of agricultural lands. The fire protection represented by the agricultural land buffer surrounding many settlements is disappearing in many places facing depopulation, ageing and a loss of value of agricultural products. The abandonment of agricultural land reflects also a significant social change (e.g., loss of

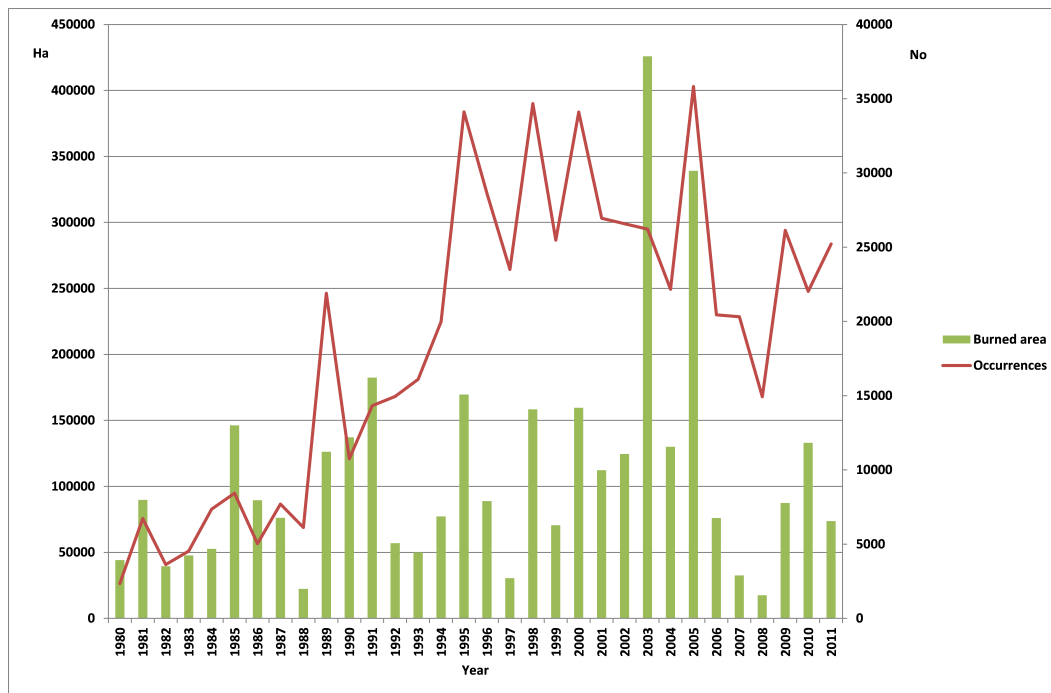


Figure 1: Forest fire occurrence in Portugal between 1980 and 2011 (Number of fire events (No) in the right hand side vertical axis; Burned area (Ha) in the left hand side vertical axis) (Source: Data available on <http://www.icnf.pt/portal/florestas/dfci/cartografia/base-de-dados>)

land management expertise and knowledge of fire culture). Despite growing increases in risk associated with social change, this has not been accompanied by changes in socially-based approaches to risk management. However, the growing incidence and severity of fires and the consequent emergent risk to people and settlements is highlighting weaknesses in the historical reliance on fire suppression methods, rather than more proactive risk management, in Portugal and the need for a shift in how fire risk is conceptualized and managed.

The traditional approach to managing forest fires in Portugal focused on suppression activities. Historically, this has resulted in less attention being given to social risk management and prevention (e.g., community preparedness). However, following the extreme fire seasons of 2003 and 2005 inadequacies in existing approaches were recognised and the National Fire Plan (2006) was established. This plan promoted fire prevention (e.g., through the establishment of municipal plans to defend forest from fire, the development of actions to protect people and goods primarily through the creation of defensible space), population sensitization using passive means (e.g., distributing pamphlets), improvement of surveillance, detection and alert, and at an operational level a better balance between the protection of people and goods and forest protection. Furthermore, the National Fire Plan was cognizant of the fact that a combination of an increasing number of fire occurrences and limited fire fighting resources, meant that it was important to advocate that communities and fire agencies work collectively to manage shared risk. The National Fire Plan also identified a need for complementary action on the part of property owners and communities. This involves people prepar-

ing in ways that reduce the risk to properties and increasing their ability to defend their properties. If people prepare and develop strategies to defend their properties, fire agency resources can focus more on fire suppression activities and suppression becomes easier if fire fighters do have to defend homes. By working collectively, more cost effective approaches to managing forest fire risk can be developed. This can be done by increasing community involvement in planning and facilitating community preparedness in ways that increase people's capacity to prevent and respond to fire events. The importance of marshalling agency and community resources in this way can also be traced to recognition that climate change will act to increase fire risk in areas in Portugal susceptible to experiencing fires. For people to play active roles in fire risk management they must know what to do.

People can prepare by, for example, creating a defensible space around their property, using fire-resistant materials for renovation or building, safeguarding their house (e.g., ensuring roof tiles fit tightly to prevent embers entering through the roof). Preparing reduces the risk of injury and death, facilitates people's capacity to cope with disruption, and helps them adapt to and recover from fire impacts. Well prepared people and homes also increase the likelihood of people being available to assist recovery efforts in their community, facilitate the maintenance of the social networks that assist social recover, and helps sustain the economic vitality of areas adversely affected by fire. Identifying what can be done and informing people of their risk and what they should do does not, however, mean that people will automatically act and prepare (see Paton and McClure (2013) for a review). The hazard preparedness literature has identified a need to develop

programs to facilitate preparedness. It has also identified the fact that these programs are most effective when based on engaging with the community rather than passively disseminating information to people (Paton and McClure, 2013). The question then becomes one of identifying how to accomplish this task. In Portugal, the challenge of doing so is complicated by the fact that the move to including a community or social dimension introduces a significant point of departure in forest fire risk management planning in Portugal (Paton and Tedim, 2012).

To facilitate preparedness, agencies need to know how to develop the community resource. This paper discusses research into identifying community predictors of preparedness. In so doing it provides agencies with guidelines for developing community preparedness within a risk management strategy designed to facilitate greater community involvement in local forest fire risk management. It discusses the testing of a model that identifies the predictors of forest fire preparedness in communities developed in Australia and in Portugal. Testing the model in Portugal serves two separate but related purposes. Firstly, demonstrating that the model can predict preparedness in different locations increases the validity of the model. Secondly, because Australia and Portugal sit at different ends of a cultural continuum (Hofstede, 2001), testing the model in Portugal will offer insights into the cross cultural utility of the model. The foundation for this belief derives from the fact that Australia and Portugal sit at almost the opposite ends of the cultural dimensions of individualism-collectivism (Australia- 90; Portugal- 24), power distance (Australia- 36; Portugal- 63), and uncertainty avoidance (Australia- 51; Portugal- 104) used to categorize cultural differences (Hofstede, 2001). By testing a theory in countries that differ substantially on their respective positions on key cultural dimensions, it is possible to make judgments about the degree to which a theory can provide insights into cross cultural equivalence of a model of preparedness and its predictors.

2. Forest fire preparedness model

2.1. Predicting community preparedness

The theory (Paton et al., 2008a) proposes that preparedness is predicted by the interaction between people's beliefs about whether or not it is possible for personal action to mitigate personal risk and social processes that influence how people develop and enact risk beliefs when faced with complex hazard events. The process starts with whether people believe that actions can be taken to mitigate forest fire risk.

Personal beliefs about the effectiveness of preparing

The theory being tested here (Paton et al., 2008a) proposed that whether or not people prepare is first influenced by their beliefs about the amenability of forest fires to mitigation through individual action. That is, whether they think that it is possible for people to influence their risk. This interpretive process is captured by the Outcome Ex-

pectancy concept (e.g., Bennet and Murphy, 1997; Paton et al., 2005). Using the outcome expectancy concept to frame understanding of this interpretive process, the theory proposes that people will be disinclined to act if they form Negative Outcome Expectancies believe that forest fires are too catastrophic for any personal action to be effective (e.g., "forest fires are too destructive to prepare for"). If, on the other hand, people believe that personal action can influence personal safety, and form Positive Outcome Expectancies (e.g., "preparing will significantly reduce damage to my home should a forest fire occur") people are motivated to start the preparedness process. Outcome expectancy beliefs are particularly important when people face intense and complex fire hazards. However, believing that it is possible for personal action to make a difference to one's safety and knowing what to do and/or how to act are not the same thing (Paton and McClure, 2013). Consequently, the major component of the theory describes the social interpretive processes that people use to guide their preparedness actions.

Peoples' perception of risk and how they might mitigate it is socially constructed (Earle, 2004; Paton and Bishop, 1996). This suggests that the ability of community members to interpret forest fire risk and prepare to manage their risk will be a function of the degree to which they possess the processes and competencies that help them to interpret their circumstances and take action to deal with novel issues facing the community. Processes and competencies that are relevant here are the degree of connectedness within a community that underpins the sense of social responsibility for managing risk, being actively engaged with others in ways that facilitates developing risk beliefs and discussing how to manage risk, and having experience of taking action to deal with issues that represent collective problems for a community.

Social influences on forest fire preparedness

Faced with complex and uncertain events, when they do not possess all the information they need themselves, peoples' perception of risk and how they might mitigate it, is influenced by information from others who share their interests and values (Earle, 2004; Lion et al., 2002; Paton and Bishop, 1996; Paton et al., 2008a; Poortinga and Pidgeon, 2004). Thus levels of community participation will influence the availability of a social context in which people can formulate risk beliefs and actions. As this will be true in any culture, the variable community participation (e.g., "I have attended a public meeting on a community issue") can be included in a cross cultural comparison. The above studies also revealed how discussion with other community members increased the ability of people to collaborate to determine what consequences they could face, work out what would be an effective response, and then consider what information and resources they require to enact their mitigation strategies. One construct that encapsulates community members' ability to identify needs and formulate questions is collective efficacy. Collective efficacy (e.g., "community groups can get something done about local problems") is a measure of co-operation and

assistance available within a community and community members' ability to assess their capabilities and resource needs and formulate plans to use resources to confront challenging tasks and it has demonstrated its utility in collectivistic cultures (Duncan et al., 2003; Paton et al., 2008b). Community participation was assessed using a measure developed by Eng and Parker (1994), and collective efficacy using a measure developed by Zaccaro et al. (1995).

Intention to prepare has been identified as mediator and has been found to be a good predictor of actual preparedness (Lindell and Perry; 2004; Paton et al., 2005; Sheeran, 2002). Intention is useful in other respects. Its inclusion permits an analysis to identify how factors such as, for example, resource limitations (e.g., time, money, physical resources, expertise) that could prevent people from converting their intentions into actual preparedness. As with the other variables, the items comprising the intention measure were examined for cultural applicability by the authors and pilot tested in each location to ensure face validity. This helped ensure that the meaning attributed to the intention variable was comparable for each population. The intention measure comprised items that assessed people's intention to acquire hazard knowledge, increase actual preparedness, and to work with other people/civic agencies to develop knowledge and capability (Paton et al., 2005).

The analysis in Australia identified that holding negative outcome expectancy beliefs had an inverse relationship on community processes. Negative outcome expectancy (NOE) had a negative influence on whether people would engage with others and so reduced the likelihood of preparing. Thus, in the Portuguese analysis, it is hypothesised that negative outcome expectancy will have a negative influence on social processes and so act to reduce the likelihood of preparing. Based on the Australian findings, it is hypothesized that if people hold positive outcome expectancy (POE) beliefs, the relationship between POE and preparedness will be mediated by the social interpretive processes (community participation and collective efficacy) used to articulate members needs and expectations. Next, it is hypothesized that the relationship between the social interpretive processes and preparing will be mediated by intentions to prepare. The theory thus proposes that outcome expectancy beliefs, community participation, collective efficacy and intentions play interdependent roles in explaining differences in level of

forest fire preparedness. In order to test the theory it is important to use an analytical technique that can assess the interdependences between variables. For this reason, structural equation modeling was used.

2.2. Testing the model

Data were collected using a questionnaire first developed for investigating forest fire preparedness in Australia (Paton et al., 2008a). Before it could be used, it first had to be translated into Portuguese. The procedure recommended by Brislin (1986) was followed. It was then back translated from Portuguese into English. The original versions and back-translated versions were compared, examined for meaning errors, and corrections were made as required to ensure equivalent content. The scales included in the questionnaire, and which are used to test the model, are listed in the left hand column of Table 1.

Data were collected from communities in northern Portugal that experience a high frequency of forest fires. The municipalities in which the questionnaires were distributed: Arcos de Valdevez, Baião, Cinfães, Melgaço, Mirandela, Montalegre, Ponte da Barca, Terras de Bouro, and Vieira do Minho. A total of 1000 questionnaires were delivered to households in these areas. From this sample, 207 participants responded by completing the questionnaire. Data screening (see below) condensed the total number of participants to 197.

In order to screen the data for missing values, and to ensure the assumptions of Structural Equation Modeling (SEM) were met, the Statistical Package for the Social Sciences, (SPSS) version 17.0 was used prior to analysis. Assumptions pertinent to the use of SEM include multivariate normality, linearity of relationships, symmetry of residual covariances, absence of multicollinearity, singularity, homoscedasticity, and extreme cases, sufficient number of indicator variables (minimum ratio of 1 per latent variable), a sufficiently large sample size (minimum ratio of five times more cases than the number of independent variables), independence of observations, and random sampling of participants (Ho, 2000; Reisinger and Mavondo, 2006; Kline, 2005).

A missing values analysis (MVA) ascertained the amount and pattern of missing data. Ten cases that had > 50% of missing values were excluded from the study on the basis that substituting the mean for participants who had over 50% of their data missing could not be justified.

Table 1: Variables used and descriptive statistics

Measure	Source	No. of items	Mean	Standard Deviation	Cronbach's α
Positive Outcome Expectancies	Bennet and Murphy, 1997; Paton et al. (2005)	3	10.41	2.92	0.71
Negative Outcome Expectancies	Bennet and Murphy, 1997; Paton et al. (2005)	3	8.81	2.46	0.64
Collective Efficacy	Zaccaro et al. (1995)	4	14.37	2.03	0.71
Community Participation	Eng and Parker (1994)	4	10.36	3.08	0.83
Intentions to Prepare	Paton et al. (2005)	3	6.69	1.74	0.74
Preparedness	AFAC (2005)	16	5.94	3.25	0.82

Mean substitution was used in the further eight cases that had less than 50% of missing values. Calculation of Mahalanobis Distance detected three multivariate outliers that exceeded the χ^2 critical value of 27.88, $p < 0.001$ which were subsequently eliminated on the basis that they were not representative of the sample. Examination of standard scores (z-scores) did not detect any univariate outliers following deletion of the multivariate outliers. The assumption of multivariate normality was assessed through inspection of values of skewness and kurtosis, histograms, normal Q-Q plots, and analysed through the Kolmogorov-Smirnov and Shapiro-Wilk tests of normality. Kline (2005) suggests that values of kurtosis greater than 10.0 and values of skew greater than 3.0 may be indicative of a lack of normality. According to these criteria, values of skewness and kurtosis did not indicate deviation from normality, with all values falling beneath 1.17. VIF and tolerance statistics were inspected and revealed an absence of multicollinearity and singularity. Examination of scatterplots and normality probability plots of the residuals also indicated that the assumptions of linearity and homoscedasticity had been met. All other assumptions of SEM were met and analysis of the Model proceeded.

Because it allows the assessment of multiple and inter-related relationships between variables simultaneously, SEM was used to test the measurement and structural models. Screening and assessment of data confirmed that the data were suitable for SEM analysis (see below). The means, standard deviations and Cronbach's α values are listed in Table 1.

The scales have acceptable levels of reliability (Cortina, 1993; Field, 2013; Klein, 1999). This was supported by testing the measurement model (confirmatory factor analysis). SEM was conducted using AMOS (version 17) and consisted firstly of verifying the measurement model through confirmatory factor analysis (CFA) in order to ensure that the measurement variables reliably reflect the latent variables (Positive Outcome Expectancies, Negative Outcome Expectancies, Collective Efficacy, Community Participation, Intentions to Prepare, and Preparedness). Secondly, the hypothesised structural model was evaluated using the maximum likelihood method of estimation.

The measurement model stipulates causal relationships between latent variables and their measured variables. Appropriate specification of the measurement model is a prerequisite of assessing the structural model, as it determines whether or not the measured variables adequately reflect the latent variable they are assigned to (Reisinger and Mavondo, 2006). The global fit of the measurement model was analysed through a confirmatory factor analysis (CFA) in order to establish that the indicator variables reliably represent the latent constructs of Positive Outcome Expectancy, Negative Outcome Expectancy, Community Participation, Collective Efficacy, and Intentions to Prepare. Each latent variable is assumed to covary in order to represent unanalysed associations, and each indicator loads on only one latent variable (Kline, 2005; Reisinger and Mavondo, 2006). As recommended by Ho (2000) and Reisinger and Mavondo (2006), for both

the measurement model and the structural model analysis, multiple fit indices were inspected.

Multiple fit indices were inspected. Absolute fit measures indicate the degree to which the model as whole, both measurement and structural together achieve a satisfactory fit to the data and the absolute fit measures in the present study indicate that the model achieved an acceptable overall fit to the data (Reisinger and Mavondo, 2006). The likelihood-ratio chi-square (χ^2) statistic is the primary measure of overall fit, and nonsignificant differences indicate a good fit of the model to the data (Ho, 2000). Because of the sensitivity of the chi squared statistic to sample size, Hu and Bentler (1999) recommend using the chi-square/df ratio (CMIN/DF). CMIN/DF ratios that are close to one suggest a good model fit, while values < 2 indicate a good fit (Hu and Bentler, 1999; Reisinger and Mavondo, 2006). The Root Mean Square Error of Approximation (RMSEA) assesses the amount of error present in the fit and is considered to produce accurate assumptions about model quality, in addition to providing precise fit values (Reisinger and Mavondo, 2006). It approximates the goodness-of-fit when per degree of freedom when the model is estimated in the population (Ho, 2000). Values that are < 0.05 suggest a good fit to the data, while values between 0.05-0.08 reflect an adequate fit (Reisinger and Mavondo, 2006). The Goodness-of-Fit Index (GFI), Normed Fit Index (NFI), Tucker-Lewis Index (TLI), Incremental Fit Index (IFI), and Comparative Fit Index (CFI) all approximate the degree to which the theoretical model is superior to the null or independence model. They range from 0 (no fit to the data; a fit that does not improve on the null model) to 1 (perfect fit to the data) and values greater than 0.90 are considered to reflect an adequate fit to the data. The first analysis discussed is that relating to the measurement model which examines if the measured variables are reliable indicators of their respective constructs.

Measurement Model Analysis

Goodness-of-fit measures and indices indicated that the measurement model was a good fit to the data (χ^2 (104, $N = 197$) = 126.50, $p = 0.07$, CMIN/DF = 1.22, RMSEA = 0.03, 90% 0.00 $\rightarrow$ GFI = 0.93, NFI = 0.88, TLI = 0.97, IFI = 0.98, CFI = 0.98, PCLOSE = 0.93) signifying that the measurement variables significantly represent their respective latent variables /constructs. In addition, all factor loadings were significant at $p < 0.001$ or $p < 0.02$. This is further evidence that the measured variables are reliable indicators of their respective latent constructs. Confirmation of the measurement model provided the basis for testing the structural model (Figure 2). The hypothesised structural model was evaluated using the maximum likelihood method of estimation.

Each latent variable was allowed to covary in order to represent unanalysed associations, and each indicator loaded on only one latent variable (Kline, 2005) to test whether the proposed model was a good fit to the data.

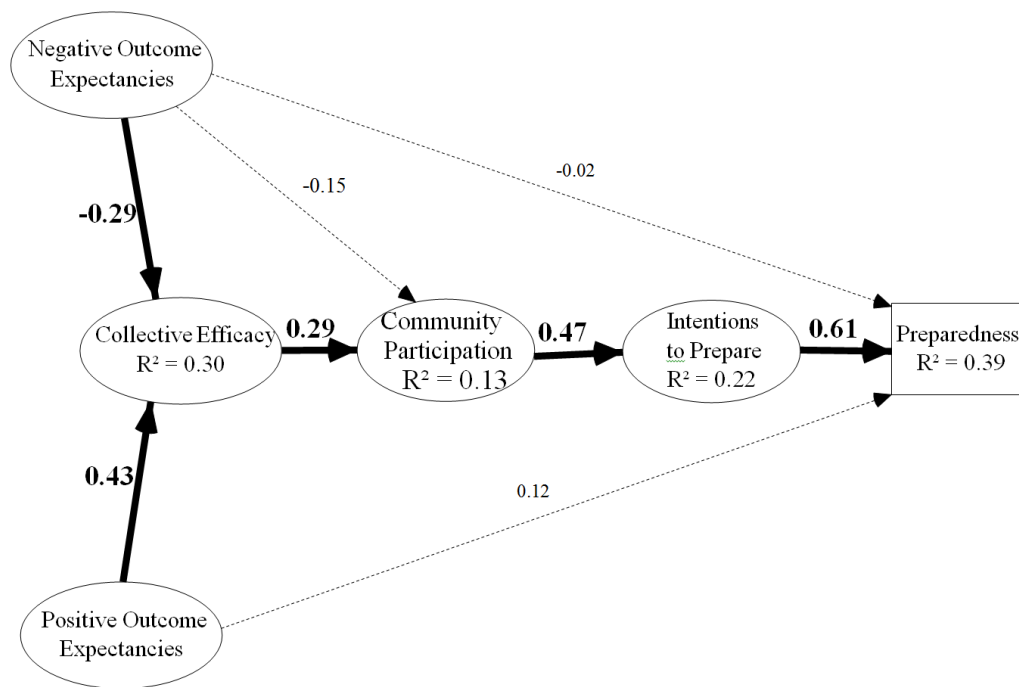


Figure 2: A summary of SEM analysis

Structural Model Analysis

The analysis demonstrated that the model was a good fit to the data, (χ^2 (123, $N = 197$) = 143.80, $p = 0.10$, CMIN/DF = 1.17, RMSEA = 0.03, 90% 0.00 $\rightarrow$ 0.05, NFI = 0.87, TLI = 0.97, IFI = 0.98, CFI = 0.98, PCLOSE = 0.97). Significant relationships are in bold. Non-significant relationships are shown by hashed lines. Overall, levels of forest fire preparedness were low. The average number of house protection items adopted was 6 (of 16). The model accounted for 39% of the variance in levels of forest fire preparation.

2.3. Discussion

The analysis confirmed that personal beliefs regarding the efficacy of preparedness interacted with social characteristics (community participation) and competencies (collective efficacy) to help explain differences in levels of forest fire preparedness in Portuguese communities. As predicted, negative outcome expectancy reduced the likelihood of people preparing (Figure 2). Even though not significant, the negative relationship between NOE and community participation provides a further insight into how such as belief can constrain the preparedness process. The analysis confirmed that the relationship between positive outcome expectancy and preparing was mediated by social processes (community participation) and competencies (collective efficacy). Not finding any direct relationship between personal beliefs and preparing is consistent with the predictions of the theory, especially when applied to a highly collectivistic country like Portugal. The finding of a good fit between the data and the hypothesised model and accounting for 39

The analysis demonstrates how preparedness results not just from providing information and resources but

also from ensuring that people can make sense of and use information and resources to meet their needs. This has significant implications for policy and practice. For example, the National Fire Plan (2006) led to focusing on encouraging community preparedness using passive means (e.g., distributing pamphlets). The analysis reveals that people's interpretation of risk and its enactment into risk management activities is socially mediated. Passive communication does not permit the engagement of people in ways that facilitate interpretation, translating information to meet local circumstances, and developing plans to meet local needs. The analysis provides the evidence base to inform policy development (e.g., to move from passive to active community engagement approaches to risk communication) and it identifies how such risk communication strategies could be developed (see below).

The analysis highlights how, from a risk management perspective, an effective public education strategy must work with and engage with the community. In this context, it is important to note that the social context factors that predicted the adoption of forest fire protective measures were pre-existing community characteristics (e.g., participation) and competencies (e.g., collective efficacy) that derived from people's engagement in daily community activities over time. This suggests that the effectiveness of risk management strategies can be increased by integrating them with mainstream community development strategies (Paton, 2008; Pearce, 2003). Thus community engagement strategies must assess and if necessary develop and encourage use of social networks (e.g., active participation) within which people can develop appropriate risk beliefs; the competencies (e.g., collective efficacy, planning) that help people identify ways to respond and that help people identify how to put strategies into action.

This work identified a need for community outreach

strategies to increase preparedness. This need was indicated by finding that, on average, only 6 or 16 preparedness items were undertaken. In particular, current preparedness activities are problematic as people were least likely to adopt the structural (e.g., defensible space, house protection) and planning (e.g., household fire response plan) activities that will make the greatest impact on helping fire agencies focus on suppression activities. If people do not adopt structural protection (e.g., defensible space), they and their properties remain more at risk and will require fire agencies to divert more suppression resources to protecting homes. Structural preparedness is particularly important if household preparedness is to effectively complement agency roles in an integrated risk management strategy.

An important aspect of the model is that it focuses on beliefs and processes that are highly amenable to change through risk management and risk communication strategies. This allows the model to be used to inform both policy development and the development of intervention strategies. For example, the model suggests that strategies to promote preparedness should focus on influencing outcome expectancy beliefs and the use of social processes to facilitate preparedness (Paton and Wright, 2008). With regard to personal beliefs, the theory identifies how negative outcome expectancy arises because people assume that forest fires are beyond personal control and are too catastrophic for personal actions to be effective. Such beliefs could be countered by presenting images that compare properties close to each other where one is damaged by fire and the other not to illustrate how actions can affect damage. This approach can be supplemented by clearly differentiating the fact that while people cannot control forest fire they can control its consequences (e.g., a defensible space reduces threat from embers and protects property) and emphasising the need to focus on the consequences of the action of fire on property and not on the causes of the fire or the fire itself.

Preparedness can also be facilitated by getting people to personalize impacts (e.g., asking them to consider what a fire might mean for them and their community) and by arranging discussions with people from communities that have prepared and who can talk about its effectiveness. Information should focus on explaining how fire affects properties and how specific actions prevent loss (Paton and McClure, 2013; Paton and Wright, 2008). These authors discuss how information is most effective when it deals with specific topics (e.g., discuss embers, how they occur, and how to protect from them) rather than covering everything at one time and when people discuss how to use this information. This can be facilitated through organising social meetings that include property assessments and showing what an effectively prepared property looks like. Workshops, consultative liaison committees, public forums are also useful approaches to promoting discussions and identify new ideas and issues from within the community.

Consistency between this study and a research in Australia (Paton et al., 2008a) introduces the possibility that the model of forest fire preparedness has cross-

culturally applicability, increasing the potential to use it to assist forest fire risk management planning throughout Europe and Australia. The fact that the findings of the Portuguese analysis are comparable to those obtained in Australia suggests the theory has cross cultural utility. While this suggestion remains tentative until examined for other hazards, the finding of cultural similarity has theoretical and practical implications. Demonstrating cultural equivalence in this way provides a common basis for collaborative learning and research across national borders and increase the scope for developing international cooperation by facilitating the development of complementary research programs in different countries and facilitate the spread of the benefits of research findings more widely. From a practical perspective, confirmation of cross-cultural equivalence increase access to information on risk management and risk communication programs in different countries.

The analysis discussed here did offer support the predictive validity of the theory and suggests that it has good cross cultural utility. However, there are some weaknesses in the approach adopted that require attention. Firstly, the analysis used scales developed for highly individualistic countries and simply translated them for use in Portugal. While the reliabilities of the scales were acceptable (though negative outcome expectancy was low), this could reflect the scales used. Future work should identify more culture-specific variables and re-test the model. Secondly, the communities selected for the study were situated in very high fire risk areas all rural in nature. This enhances the assessment of social influences by optimising social conditions (e.g., rural communities tend to be more cohesive). It will be important to examine in the applicability of the theory in more highly urbanised areas.

The support for the theory discussed here suggests it provides a good starting point for developing community engagement forest fire risk management strategies. Developing an evaluation research program around this process would provide an appropriate context for identifying and developing culture specific measures of the personal and interpretive processes that underpin sustained hazard preparedness.

3. Conclusions

This article identified the benefits of accommodating personal beliefs and social processes in developing community engagement strategies for use in facilitating forest fire preparedness in Portugal. The analysis suggested that this can be cost effectively by integrating risk management with community development initiatives. This fosters social capital and will result in enduring benefits for communities and not just in the context of their experiencing forest fires. This increases the cost effectiveness of this aspect of risk management, an important and pragmatic consideration at a time when financial constraints need to be accommodated in risk management planning.

Acknowledgements

The authors would like to acknowledge and thank the Portuguese Science Foundation (FCT- Fundação para a Ciência e a Tecnologia) for supporting the research under the project PTDC/GEO/65344/2006.

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Evaluating Disaster Preparedness in West Sumatra through Media

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Abstract – Since the Indian Ocean Tsunami, disaster preparedness has been acknowledged as a key need in communities near the Sumatran fault line. This article presents the results of an evaluation of community disaster preparedness in Padang, West Sumatra. The disaster preparedness of the community was measured from interviews with key informants focusing on disaster matters. Even as awareness campaigns conducted by local media have improved disaster preparedness, more disaster simulations are needed in districts outside Padang. The interviews show that the local government officials and the NGOs think the community has learned disaster preparedness via media, including television, radio, leaflets and billboards. The topics focused on construction, evacuation routes, and what to do when an earthquake happens. Key individuals still see many needs remaining in the development of disaster preparedness for the community. Key informants recommend that the efforts of the local government to implement disaster preparedness programs should be based on public-private partnerships; it is noted that media and NGOs, as well as other interested stakeholders, should participate.

Keywords – disaster preparedness, campaign, community, resilience, media

1. Introduction

The Padang Pariaman area was hit by an unusually strong earthquake on September 30, 2009 at 5:16 pm local time. The epicenter of the 7.6-magnitude quake was located 60 km off the coast of Padang, and at a depth of 80 km. It took place along the same Sumatran fault line that caused the 2004 Indian Ocean Tsunami¹.

As a result of the Indian Ocean tsunami, followed by the earthquake in Padang in 2005, the need for raising the awareness of disaster preparedness became obvious. Volunteer-based groups were formed in Padang. The government improved their organizational operations towards better disaster preparedness planning and readiness on all levels. In addition, the Padang earthquake prompted the local government, private sector organisations, and the media to work together to educate the communities on disaster preparedness.

This disaster preparedness research is part of a wider Disaster Mitigation and Preparedness (DMP) project launched in Aceh in 2007, with the purpose of develop-

ing disaster preparedness radio programs together with communities. The first evaluation of the DMP project showed that radio educates local communities in disaster preparedness; however, village leaders voiced their need for more disaster preparedness education on a community level (Romo-Murphy et al. 2011:812).

This evaluation was conducted in Padang in November 2010, one year after the earthquake. Key informants were interviewed about the disaster preparedness of the local community. Padang residents had experienced several recovery and construction programs organised both by local and international agencies. One of them was a media campaign towards better construction methods. Australia-Indonesia Facility for Disaster Reduction (AIFDR) and the National Agency for Disaster Management (BNPB) organized a building project and media campaign 'It's not the earthquake but it is the construction' ('Bukan gempanya, tapi bangunannya') from February to June 2010. This multimedia 'Build Better' -campaign transmitted the slogan via several media outlets².

¹<http://www.earthobservatory.sg/files/resources/files/graph-origin-sumatran-earthquake.pdf> (8 October 2013), https://www.eeri.org/site/images/eeri_newsletter/2009_pdf/Nov09.pdf (8 October 2013)

²<https://sites.google.com/site/rumahamangempa/cerita-dari-lapangan/integrating-build-back-better-campaign-into-local-culture> (8 October 2013)

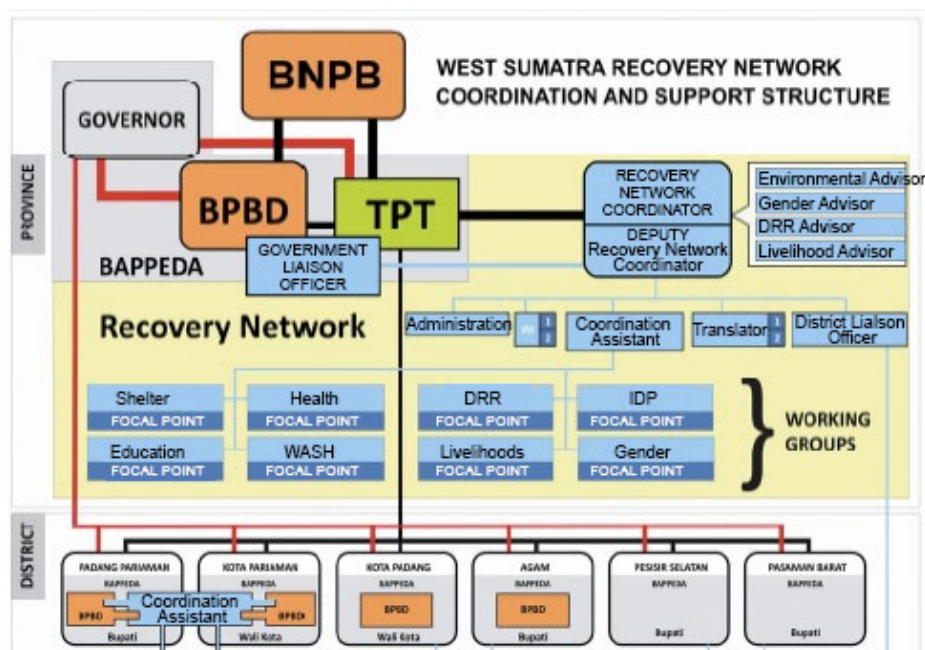


Figure 1: Framework of Early Recovery Network

2. Methodology and data

For this study, two groups of key informants were chosen by discretion; one group were officials from the district government level, and the second group consisted of representatives of non-governmental organizations. Informants of each group were knowledgeable about Padang and Pariaman disaster preparedness coordination and recovery. Key Interviews were carried out at first to those in the local government who are responsible for disaster preparedness education in the community, and secondly to representatives of NGOs who had been active in DRR. The questions were the same as those used in a similar evaluation in Aceh 2009 (Romo-Murphy, 2012:127).

Local research assistants conducted the interviews during November 2010. Three of the interviewers were post-grad students, who possessed experience in face-to-face interviews, while the other three were Respon radio programmers, and were trained in using the interview questions.

2.1. District key informants

The Indonesian government has reorganised its network of response to natural disasters. Each province has its district agency, since a district-based coordination mechanism is considered more relevant in the early recovery process, in comparison to having several agencies using different approaches. District coordination is a means to facilitate the early recovery process (Ratnanto, 2010: 71). Figure 1 (Ratnanto, 2010:73) identifies the West Sumatra early recovery coordination model. The purpose of the framework is to interlink various stakeholders from working groups, districts and levels of authority. The model

covers eight working groups and the six most-affected districts with the purpose of making it easy for the information to flow in between the districts, and between the districts and financial bodies. Near the top level there is BPBD (Badan Penanggulangan Bencana Daerah = Disaster Management District Agency), with the BNPB, at the very top, which is the equivalent at the national level. Identifying other actors at the district level; 'Bupati' or 'wali kota' is leading, while 'camat' leads the subdistrict, and 'nagari' or 'kepala desa' leads the village. BAPPEDA (Badan Perencana Pempangunan Daerah) is equivalent to the Regional Body for Planning and Development.

One option was to look for key informants from the top levels within the Framework of the Early Recovery Network; such people as the BNPB representative, the DRR advisor, the DRR working group advisor, and the district coordination assistants of Kota³ Pariaman and Kota Padang. Based on the local researcher's advice, the key informants were not chosen from officials at the Kota level, but from the Kabupaten⁴ level. These district officials were chosen since they know the Padang and Pariaman Districts best.

For this research, five district coordinators were interviewed from four districts; two from the Padang Pariaman District, and one each from Pariaman City, Agam District and the Pesisir Selatan District with no interviews conducted in the Padang City District and the Pasaman Barat Districts. The informants interviewed represent the views of the district coordinators in the four districts. (Kota Pariaman and Pesisir Selatan did not have a district disaster management agency at the time of the interviews). In addition to the five district coordinators, another three officials were interviewed from the Padang Pariaman legal office, the tourism planning board and the BPBD.

³Kota (Indonesian) = Municipality

⁴Kabupaten (Indonesian) = District

2.2. NGO key informants

The NGO key informants interviewed represented six organizations; Habitat for Humanity, Handicap International, the Ibu Foundation, KOGAMI, Mercy Corps, and World Vision. I interviewed Disaster Management Program Manager Endang Trisna from Mercy Corps, while the local research assistants interviewed all the others.

3. Data analysis

The interviews consisted of ten questions focusing on two main aspects: the level of disaster preparedness in the community, and what media has accomplished in educating the citizens. The interviews were transcribed and translated for the researcher to be analysed, using content analysis. From the interviews, patterns and themes were identified from the answers to the questions that follow. While reading the interviews several times, topics were listed from each informant. The researcher then categorized the topics into larger issues according to each question.

Questions asked are as follows:

1. How has community preparedness to disasters changed in the past year in this area?
2. What have the residents of Pariaman / Padang learned about DRR?
3. What else does the community need to learn about DRR?
4. How do you see the media in Pariaman/Padang contributing to DRR?
5. Have you seen DRR related messages on TV? What kind?
6. Have you seen/listened DRR related messages on radio? What kind?
7. Have you read DRR related messages on papers or leaflets? What kind?
8. How do you see the role of Respon Radio 94.7 in helping to improve disaster information dissemination?
9. What kind of action does the government take with media to improve the people's awareness about disasters?
10. What do you think: What is the response of the public towards DRR radio programs?
11. What kind of information has the government given about earthquakes and tsunamis to the public?
12. What do you think: Has the information about earthquakes and tsunamis that has been given by the officials reached all the residents of Padang and Pariaman?

4. Results

According to the district officials, community members use various media to learn about earthquakes, including television, radio, and local papers, as well as mobile communication. To make community disaster preparedness more effective, district officials suggest cooperation between the local government and the media.

Among all districts, Padang is a positive exception in that the Mayor uses RRI Padang (Radio Republic Indonesia Padang) to disseminate earthquake information. NGO informants agreed with this view in that they have noticed RRI Padang organising radio specials in response and recovery (R&R). However, on a wider scale, in other districts there is no disaster cooperation shown between the local government and the media.

Media's accomplishment of educating the community in disaster preparedness was recognised by both groups of informants, as there had been a media campaign on construction practises a few months before the interviews. The campaign message 'It's not the earthquake, but it's the construction' was delivered via posters, notice boards, banners, several radio stations, TVRI (television station), newspaper, bus, and film. The entire community was informed on how to build houses that withstand earthquakes.

The media gathered two negative mentions among the NGOs: first, the information given by the media has increased stress and led to panic in the community. (This actually took place just before the research project, when inaccurate information was aired after the Mentawai tsunami in October 2010.) Secondly, NGO informants evaluated the television messages claiming they tended to exaggerate the impact of disasters, and discuss details of less importance.

According to local officials, the districts seem to be at different levels of disaster preparedness. For example, the district of Agam is still dealing with reconstruction following the September 2009 earthquake. The district of Pesisir Selatan established its disaster management agency (BPBD) one year after the earthquake, while the district of Padang Pariaman had their BPBD established a few months after the earthquake. On a positive note, the BPBD of Padang Pariaman has been very active in co-operating with the NGOs and has even organized disaster simulations in Ulakan Tapakis and in other disaster-prone areas. There are also plans to install evacuation route signs. In addition to this, a rapid response team has been established in Padang Pariaman, consisting of government agencies, the health department, the department of transportation, RAPI (Radio Antar Penduduk Indonesia) and ORARI (Organisasi Amatir Radio Indonesia).

District officials have emphasized the fact that even though they realize that community members have a low level of preparedness for disasters, the local governments of the four districts (Padang, Padang Pariaman, Pariaman and Pesisir Selatan) do not have the funding to pay for such preventive activities. Officials suggest that one way of solving the financial issue is to team up with the NGOs in construction, and together supply materials as well as instruction. Currently, the community sees the NGOs, along with the private sector, as being active in disaster preparedness, which in turn decreases trust in the local government to carry out preventive activities. Yet, since there is such an obvious need for community based disaster preparedness programs, officials felt the government should work together with the media and the NGOs to build effective public-private partnerships.

NGO informants pointed out that the local government has provided notifications to keep the public alert, and has asked schools to instruct students on disaster preparedness. According to the NGOs, the government has carried out simulation drills to include the media, the army, the schools, the private sector, the community, and four villages. On the other hand, some NGO informants were critical about the government's actions saying there is a lack of systematical preparation in achieving proper results. When disaster occurs, there is emergency response, however, it lacks follow-up and simulations, and in addition to this the information delivered is not uniform throughout the various media outlets.

5. Discussion

This study confirms media's importance before disasters. Media, especially community media, can take the role of an educator and facilitator for citizens' disaster preparedness. Similar research was conducted in Aceh in 2009, showing that both local government and NGO representatives viewed disaster preparedness education positively. However, in Aceh, village leaders expressed discontent with the disaster preparedness education in villages. In this study, it would have been interesting to hear the opinions of village leaders from outside Padang.

These interviews resulted in the recognition of the need for disaster preparedness in communities. Both local district officials as well as NGO informants unanimously agree that Padang, and especially the surrounding districts still need preparedness education, even though much has been accomplished through the media campaign. District officials welcome NGOs and private organisations to partner with local governments in organizing disaster preparedness education, especially in districts outside the city of Padang. There is a crucial need for construction funding for those households desiring to improve construction methods. In addition to proper construction planning, all coastal areas need preparedness education on how to utilize evacuation maps, and on how to mark the evacuation routes effectively.

6. Conclusion

Two groups of informants were interviewed to evaluate the level of the society's disaster preparedness. On the dis-

trict government level, one group was actually involved in the West Sumatra recovery network coordination and support structure. The second group consisted of NGOs who had been working in disaster preparedness and in the recovery process.

In conclusion, the interviews show that both local government officials and NGOs affirm the community has learned disaster preparedness via media, including television, radio, leaflets and billboards. The topics covered were construction, evacuation routes, and what to do when an earthquake happens. The RRI Padang has been recognized by officials as educating in disaster preparedness. NGOs also approved of the Journalistic Network for Disaster Preparedness that was established to promote awareness campaigns. Both local officials and the NGOs voiced concerns that the media must give accurate information when reporting disasters, and to do so in such a manner as to avoid creating panic and undue stress within the community.

Local officials seem to appreciate all the disaster preparedness efforts organized by the NGOs, and see them as good partners for local governments to cooperate in DRR matters in the future. Although Padang Pariaman is acknowledged as being prepared as far as disaster simulations, both officials and NGOs agree the government needs to carry out additional simulations in other districts.

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Citation

- Romo-Murphy, E. (2013): Evaluating Disaster Preparedness in West Sumatra through Media. In: *Planet@Risk*, 1(1): 53-56, Davos: Global Risk Forum GRF Davos.



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Wildfire and Community: Facilitating Preparedness and Resilience by Paton and Tedim (2012) (Book Review)

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There is increasing acknowledgement that social and community factors are fundamental aspects of disaster resilience. This book brings together recent research concerned with the ways that individuals and communities make choices impacting on risks associated with wildfire, alternatively known as bushfire or forest fire. A key theme of this edited book of 17 chapters is that new approaches are required if notions of shared responsibility for disaster are to be taken seriously. Where previously responders were seen as the primary actors, this book brings together a range of research demonstrating that the relationships people have with each other in communities, relevant disaster agencies, and with the hazards themselves, are paramount to effective disaster risk reduction.

Using research conducted in Australia, Chile, Cyprus, Greece, India, Portugal and the United States, the social dimensions of risk are examined by eminent researchers. Many important messages are delivered, such as the importance of pre-existing relationships and socio economic circumstances for people's resilience. The book highlights the need to deal with differences in gender roles in emergency situations, the importance of appropriate community participation, and acknowledgement that people cannot be understood as passive populations upon whom disasters have impacts, but as diverse and dynamic sub-

jects with a range of vulnerabilities that can often be improved. For example, working on people's outcome expectancy, whether or not they think preparing will affect their chances of survival, can significantly improve resilience alongside modifying actual competencies. New technology is shown to be an important factor in people's decision making, and the research demonstrates the need for agencies to engage with new media to ensure decisions are based upon good quality information. Clearly written, this book will be a valuable resource for those working with communities at risk from a range of hazards, even while it focuses on wildfire.

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Paton, D., and Tedim, F. (Eds.). (2012). *Wildfire and Community: Facilitating Preparedness and Resilience*. Springfield: Charles C Thomas. ISBN 978-0-398-08842-2.

Citation

March, A. (2013): *Wildfire and Community: Facilitating Preparedness and Resilience by Paton and Tedim (2012) (Book Review)*. In: *Planet@Risk*, 1(1): 57, Davos: Global Risk Forum GRF Davos.

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