REGIONAL DISASTERS AND SYSTEMIC REACTIONS

Gerhard Chroust
Johannes Kepler University Linz, 4040 Linz, Austria (Gerhard.Chroust@jku.at)
Nadine Sturm
Research Institute of the Red Cross Austria, 1030 Wien, Austria
(nadine.sturm@w.roteskreuz.at)
Markus Roth
Creative Bits, 4050 Traun, Austria (roth@CreativeBITS.com)
Peter Ziehesberger
Ziehesberger Elektronik, 4501 Neuhofen/Krems
(peter@ziehesberger.at)

ABSTRACT

Today's catastrophes (many of them man-made or at least triggered by human activity) seemingly endanger an increasing number of humans and a spreading portion of land in numerous different ways, calling for more attention concerning appropriate reactions. We will discuss the basic question of what constitutes a 'disaster'. Consequently various alternatives are considered as to reacting in view of a "disaster" (Flight/run away, Fight/intervene, Freeze, Submit/sustain/endure, Ignore/deny). Taking a closer look at interventions as the classical reaction, we distinguish between different points of view: systemic (a system leaving its domain of dependability), process-oriented (a system of interlinked process steps), human (communication, psychology, and mental health of intervention personell and victims), and multicultural (problems of communication, trust, and habits).

Keywords: Intervention, catastrophe, dependability, First Responders, process view, Mental Health

MOTIVATION

It seems that regional emergencies and disasters (many of them man-made or at least triggered by human activities) have grown in number, in scale and also in their media coverage. Especially the last factor increases the awareness and the fear of such disasters. Disasters endanger people, society, environment, infrastructure, and economy in complex, multi-facetted, and interrelated ways. Typical examples are the volcanic eruption of Eyjafjallajökull (Iceland 2010) suddenly interrupting air traffic and thus impacting economy, the local break-down of electric transmission lines due to a tsunami (Fukushima, Japan, 2011) endangering the cooling and thus the safety of an atomic plant. We observe that today the sensibility of our structures are affected more easily by the disasters and we are not well prepared for the accumulation of multiple-source risks.

Society in general aims at mitigating the effects of possible and actual disasters. Animals and humans have five basic strategies to cope with threats (see section 2.4 for more details):

- Flight/run away
- Fight/intervene
- Freeze

- Submit/sustain/endure
- Ignore/deny

Depending on the situation and the personal disposition people choose one or the other strategy (Tierney et al., 2001).

2 DISASTERS

2.1 What is a "disaster"?

A disaster is in the eye of the beholder

There are numerous reasons for the 'growth' of the size and number of disasters: land has become more densely populated, as a consequence people also live in areas in which centuries ago nobody would have considered/dared to live. Today's catastrophes frequently endanger a growing number of humans and larger areas in diverse ways. Human interference with the natural environment weakens and/or eliminates nature's safety provisions and natural buffer mechanisms (e.g. land for inundation, protective forests...). Growing trust in the infallibility of technical systems lets us reduce safety margins.

Failures of technical artefacts cause severe catastrophes (Chernobyl in 1986, an exploding oil rig in the Mexican gulf in 2010, failing atomic reactors in 2011 in Japan, ...). Many of our technical 'achievements' often provide higher efficiency at the cost of reduced robustness (e.g. computer chips affected by solar eruptions ...). Global interactions and dependencies increase the impact of originally local disturbances (volcanic ash from Iceland disrupting air traffic in Asia ...). The advances of Information and Communication Technologies have created a large number of complex critical embedded systems. The need for dependability of such systems increases rapidly in our days.

Depending on one's personal views and one's wold view perspectives there are different ways to view disasters. Tierney et al. (2001) differentiates three perspectives:

the functionalistic or event based perspective: This perspective is represented by: *"A disaster is a natural or man-made hazard that has come to fruition, resulting in an event of substantial extent causing significant physical damage or destruction, loss of life, or drastic change to the natural environment. A disaster can be ostensively defined as any tragic event with great loss stemming from events such as earthquakes, floods, catastrophic accidents, fires, or explosions"* (Wikipedia- English, 2005, keyword=Disaster). Nowadays large financial losses and damage to property are also counted as damage.

In this vein Mortzek (Mrotzek and Ossimitz, 2008; Mrotzek, 2009) identifies a disaster as any event where the system transgresses the boundaries of what is considered a safe system (see Figure 1).

the social constructionism: This perspective argues Kreps et al. (1989) cited by (Tierney et al., 2001, p. 14) that *disasters are social constructions: that is disaster events and their impacts do not exist sui generis but rather are products of of social definition. So to speak "disasters are in the eye of the beholders".*

the vulnerability perspective: *Other definitions (see (Tierney et al., 2001, p. 20)) consider mainly the vulnerability of the built environment and the social vulnerability of exposed populations; referring to (Bolin and with Standford, L., 1998, pp. 9-10): "Vulnerability concerns the complex of social, economic, and political conservations in which peoples' every day lives are imbedded ..."*

2.2 Characteristics of Regional Disasters

Regional disaster can be classified according to many different dimensions. Some of the key characteristics of disasters are:

man-made - natural: A traditional broad distinction is between man-made and natural disasters. Manmade disasters can further be divided into technological and mass violence disasters (Norris et al., 2002). Looking at past catastrophes one has to recognize, however, that this criterion has lost most of its distinctiveness. Consequences and approaches to mitigation seem to be closely interwoven. Very often also natural disasters involve a human element: For example the volcanic eruption of Mount Eyjafjallajökull (Iceland 2010) was a purely natural disaster but the effect of the volcanic ash was that air traffic was completely interrupted and this had considerable consequences for the economy. Without air traffic it would not have been seen as a disaster. Similarly the earthquake in 2011 in Fukushima, Japan, was a natural disaster which triggered a terrible tsunami. But due to the lack of electricity (the electricity supply was severely disrupted by the tsunami) the atomic reactors came into a very critical state.

cause: A classical distinction is based on the cause of disaster, for example the acronyms by the catastrophe CBRN (chemical, biological, radioactive, nuclear (Chroust et al., 2009b)) or ABCDEF (atomic, biological, chemical, data-network, electromagnetic, release (*from the German word "Freisetzung"*) of energy etc. are used to classify the dangers and the precautions/reactions to be taken (Ossimitz and C., 2006)).

size and type of damage: Various classification system exist, identifying the 'size' of the disaster and the resulting damage (monetary, infrastructure, and humans).

geographic distribution: What is the extent of land/air area which is affected?

time evolution: How does the disaster start (e.g. slow or fast onset) and how does it develop over time?
With respect to warning the potential victims the lead time before the catastrophe's onset (warning time!) is of essential importance, e.g. slow or rapid onset (Tierney et al., 2001) (Skrbek and Kviz, 2010). This is strongly linked to the notion of recognizability (see below). Mrotzek (Mrotzek and Ossimitz, 2008; Mrotzek, 2009) discusses different temporal behavior of catastrophes (Figure 1). Also various characteristics of a disaster change over time (growing (atomic plants getting out of control), shrinking (floods receding), converting (snow get converted to water and posing a different type of threat).)

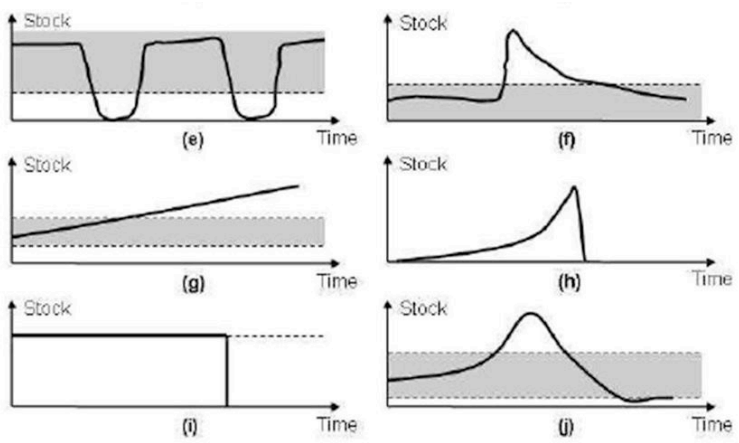

Figure 1: Time-Behaviour of Catastrophes, (Mrotzek and Ossimitz, 2008) (grey: safe domain)

recognizability: Not all disasters can be recognized by our naked sensoric apparatus. Typically atomic radiation is not felt immediately at all. Some of the disasters have only long-term detrimental effects (atomic radiation!). Thus humans do not have natural, semi-autonomous reflex patterns (e.g. as in the case of extreme heat). For these cases humans need to be equipped with special tools to recognize dangers (and have to be taught to use them properly (Chroust et al., 2009a)).

selectivity: It is interesting to understand what and/or who is affected by the disasters. Some illnesses only afflict certain species (humans, some kinds of animals, ...). The neutron bomb does not destroy any buildings or artefacts and 'only' kills humans.

media reaction: We have also to recognize the distortion of reports on disasters by the media. A speaker of the Austrian Red Cross pointed out in relation to the Fukushima-accident, that there are other disasters (even bigger ones especially with respect to human cost) which are not reported about.

2.3 Phases of a Disaster Situation

Figure 2 shows the five key phases of a disaster scenario. They are rather obvious, but due to varying types of overlap a clear delimitation is at least fuzzy, if not impossible. In the initial pre-impact phase only a general uneasiness and fear about a potential disaster exists, causing various prevention and preparedness activities. When indications of an impeding disaster show up, actual disaster preventation/mitigation activities are (hopefully) undertaken (Tierney et al., 2001). In most cases the big unknown is the impact point, the point in time when disaster actually strikes. In the case of a slow-onset disaster (e.g. flooding (Ossimitz and C., 2006)) it is even not clear when exactly the 'point of actual impact' is reached. When does high water become a flood-disaster?. To some extent it depends on the tolerance level of people and on the level of pre-impact preparatory action. As a consequence even close-together areas might be impacted to a different degree and sometimes even not at all.

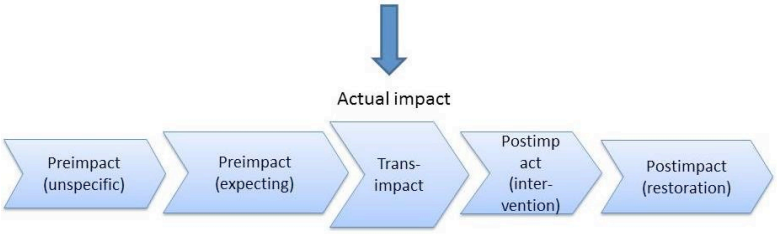

Figure 2: Phases of a Disaster

The actual impact (in the so-called transimpact phase) triggers necessary reactions (most visibly the interventions). Followed, but often with considerable overlap by a phase where the systems is restored in some meaningful and reasonable way.

In this paper we will concern ourself with reactions during the transimpact phase and will identify several measures to mitigate the effects of a disaster.

2.4 Fundamental Reactions to Disasters

In humans and animals (individuals and organizations) we observe several basic types of reactions when confronted with a dangerous situation.

Flight, Run away: This is one part of the classical response to a problem (fight-flight). A condition is, that flight is possible at all.

Fight, intervene: This reaction intends to actively reduce/mitigate/eliminate the impending or existing danger (section 3. Essentially some compensating actions are performed, which try to bring the systems or environment back to some state, which is (at least temporarily) acceptable. Systemically we speak of a compensation (cf. section 3.1). As discussed above the intervention will later (gradually?) be turned into restoration activities. The idea is that the system is only un-acceptable for a (relative?) short interval and will then be transformed into a (potentially different) acceptable system again, see Figure 3 and Figure 5.

Freeze: Many animals completely immobilize their whole body showing no reaction whatsoever. For them this is a successful strategy with respect to certain predators: they would not eat dead animals or might not notice them due to the lack of movement. For humans this does not seem to be a viable strategy and is rather considered an inadequate reaction.

Submit/Sustain/Endure: In this case people do not try to *fix, repair, change the system or situation* but to *change/adjust themselves* in order be able to live under the supposedly disastrous situation.
'Riding it out' as a strategy and sustaining a disaster (and not "running away") needs a certain frame of mind, and also includes a certain risk. Sometimes they resort to re-interpreting the status of the system as 'non-disastrous' (Dörner, 1996). The behavior is similar to Ignore/Deny, the difference lies probably in the motives. Some of the motives which induce people to stay are (Tierney et al., 2001) the disbelief in the severity, fear of looting of their properties, waiting for other clan-members, ... Obviously this approach is only sustainable if the system despite its disastrous effects has a certain kind of stability in its behavior and properties.

Ignore/deny: Sometimes people simply ignore the immediate or upcoming danger, they act as if nothing has changed. This can be interpreted as an 'inner' flight. In the worst case this can be a sign of mental disorder. In Vienna we use a phrase to describe this state of mind: *"do not even ignore it!"*. Dörner (1996, p. 105) points out that in certain obviously disastrous situations the political leaders apply verbal camouflage disturbing phenomena by coining special words like "minus growth" (=shrinking), "front line balancing" (= fallback of troops). An even stronger distortion of the truth is target inversion where a negative outcome is interpreted as the goal ("this is the 'steal-bath of the nation" (Nazi propaganda), "many enemies - much honor".

2.5 Options for Responding to Disasters

The type of reaction depends on the expectations of (the affected part of) society how the disaster should be 'mastered'. We believe that in some way society expects its environment to be dependable: the amount of expected dependability is to some extent a consequence of basic cultural predispositions.

From a stakeholder's viewpoint dependability is a highly desirable property of a system: roughly speaking dependability means that *the system behaves as expected*. The current definition of dependability in the technical sciences consist of the following subcharacteristics *safety, reliability, availability, security, survivability, and maintainability*.

For analyzing national differences Hofstede and Hofstede (2005) introduced the Uncertainty Avoidance Index. It indicates how much uncertainty, i.e. lack of dependability, a person is willing to accept. It shows considerable differences between different nations.

2.6 Choosing a Response

Obviously not all of above reactions are appropriate in all situation. In the case of danger people have to make a decision about their course of action. Freezing and Submit/sustain/endure are in most cases the consequence of the inability to make a decision. For a rational decision obviously several ingredients are needed:

understandability of information: Not only the reachability of affected persons (radio, television, public address systems, word of mouth) is of importance but also the understandability of a messages. This concerns language and semantic of the message (including culturally different ways of interpreting), credibility of the source ("you have to be believed to be heard"(Decker, 1992)), and proper understanding of the implications. Difficulties stem from language problems, from distrust in government agencies, from different cultures, etc. Tierney et al. (2001) and Skrbek and Kviz (2010) discuss the problems of informing larger sections of a population.

evaluation and deciding on the options: Using as much of the information as available and considering all the constraints and requirement everybody has to make a decision about the next steps (see (Tierney et al., 2001)) for more details. The time pressure and the psychological singularity of the situation should not be under-estimated.

flexibility of options Depending on the circumstances an option might have the potential to be changed later or not, for some options time runs out faster than for others, cf. (Chroust and Schoitsch, 2008) discussing alternatives in a technical context.

Affected persons may choose different reactions, depending on a multitude of personal/cultural predispositions (cf. (Tierney et al., 2001, chapter 5)) like gender, education, previous experience, ethnicity, minority status, gender language, social bonds, age, ... The choice of reactions depends also on the point in time during the disaster phase ((Tierney et al., 2001, Figure 1.1), Figure 2). Additionally there are persons whose duty requires certain reactions. Typically while people evacuate a certain area (flight) First Responders move in to fight the disaster, while psychologists try to help the victims emotionally.

3 FIGHT: INTERVENTIONS IN REGIONAL DISASTERS

A classical response to a disaster is to 'fight back', i.e. to try to counteract both the cause of the disaster and its consequences by a so-called *intervention*. In regional disasters it is the task of the so-called First Responders (i.e. fire brigades, ambulances, police, technical aid teams, etc.) to stage the intervention. Interventions are usually very time critical, losing time could be a 'killer' in the most serious meaning of the word. We will look at disasters and interventions from several viewpoints.

3.1 The systems view

We consider the environment from the view point of a (potential) victim as a system which went (for some reasons) out of its bounds of safety or dependability causing a disaster, in accordance to the functional/event-based perspective, see Figure 1 (Mrotzek and Ossimitz, 2008; Mrotzek, 2009). An intervention intends to bring the system back to an 'acceptable' (i.e. safe, dependable, ... state, see Figure 3).

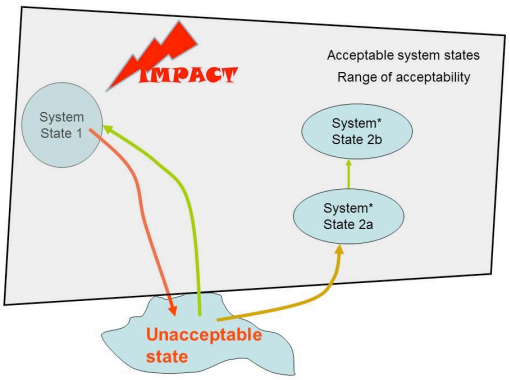

Figure 3: Resilience of a system

On a high level of abstraction we recognize a 'goal-oriented systems' in Klir's terminology (Klir, 2001, chapter 10) as shown in Figure 4. Given the low level of predictability of

most disasters only the 'fullinformation paradigm' with feed forward and feed backward can fulfil our needs. We speak of a *Compensation System*.

Following Ashbys' Law of Requisite Variety (Ashby, 1956) the Compensation System must have a greater Variety than the expected variations of the expected or actual disaster.

The term Variety was introduced by W. Ross Ashby to denote the count of the total number of states of a system. The condition for dynamic stability under perturbation (or input) was described by his Law of Requisite Variety (Wikipedia-english, 2005, keyword=variety (cybernetics)).

If a system is to be stable the number of states of its control mechanism must be greater than or equal to the number of states in the system being controlled.

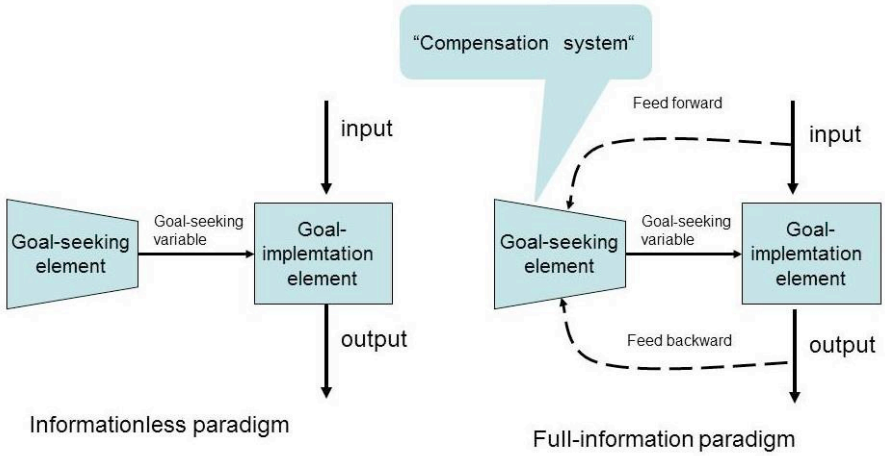

Figure 4: Goal-oriented systems (Klir, 2001, chapter 10)

Taking into account the natural, technical and societal components of a disaster together with the many emerging unknowns only a socio-technical system with strong human involvement will be able to establish an adequate Compensation System: Humans, but supported by technology.

A closer investigation of actual emergency situations shows that actually it is of advantage to split the *Compensation Systems* into two systems (Figure 5, (Chroust et al., 2010)):

the (Emergency) Intervention System for quick first responses and

the (Disaster) Restoration System for longer term restoration of the original system.

The tasks for these two types of systems differs considerably. They have different aims, purposes and as a consequence, time and efficiency requirements. In systemic terms (cf. Figure 3) in order to (re-)establish short-term dependability we introduce an Intervention System responsible for immediate, quick response (Chroust et al., 2009a). The Restoration System is charged with transforming the system into a more acceptable state which promises long-term dependability. The Restoration System does not have the burden of providing a speedy reaction. Here efficacy, efficiency, and long-term considerations take priority and the members of these systems will be specialist, while the actors in the Intervention System usually will be generalists.

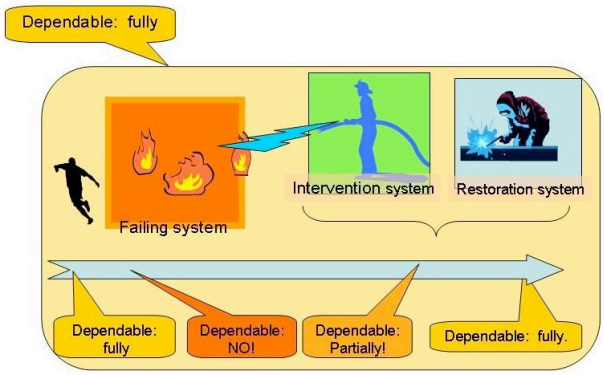

Figure 5: Compensating and Restoring System re-establishing dependability

With respect to regional disasters, may it be natural ones, triggered by human activity, or fully manmade, the classical Intervention Systems are fire brigades, ambulance services, technical support teams, etc. Already the Roman Emperor Augustus acknowledged the need for a 'human' compensation system in case of fire by establishing in 23 BC an organization of full-time, professional fire fighters (*vigiles*). As a consequence the challenge for First Responders is to be able to provide the necessary Requisite Variety for performing their tasks. The intervention is successful, if the created status is acceptable at least for a while until the Restoration Systems provides something better.

With respect to the interaction between the failing system and the Compensation System we have to take into account that the failing system may be dynamic, changing over time. This time dependency can be internal (e.g. a chemical source or a house on fire change its properties over time) and/or due to changes caused by the Compensation System, e.g. by neutralizing the chemical substance or fighting the fire.

In more abstract terms we can look at the situation as a dependability issue (see section 2.5). In the case of a disaster the system will not be dependable. First Responders attempt to bring the system back into a dependable state. The Restoration System then improves this dependable state. Systemically seen, the total system is dependable before and after an incident (if the Intervention System is successful) with some transition period where dependability is not guaranteed.

3.2 Process View of Interventions

The key to interventions (First Responders!) are humans embedded in a socio-technical system who perform numerous activities to achieve their mission, i.e. it is a complex process which consists of numerous individual processes.

The process view corresponds very nicely with the functional view of disasters (see section 2.1). An intervention is a highly complex undertaking. Reasons are the invisibility of many dangers and the comparative newness/unexpectedness of the challenges ("Facing the Unexpected" (Tierney et al., 2001). In business and in software engineering (Humphrey, 1989; Scheer, 1998; Wang and King, 2000) the identification and analysis of the involved processes turned out to be very helpful (Chroust, 1996; Chroust et al., 2009a). This view focusses on the *whole* process by identifying the subprocesses to be performed. The more complex the task

is, the more a process view is needed (Chroust and Schoitsch, 2009): *"Industrial maturity demonstrates itself in the ability to abstract the development process from the specifics related to the production of the individual product. ..."*. This also holds for interventions (replacing 'development' by 'intervention', 'production' by 'performance' and 'product' by 'intervention').

Simple processes are usually learnt once and for all in apprenticeship, more complicated ones need guidance by a written, formalized description, i.e. a Process Model (Chroust, 1996). Using a process models is our daily routine: cooking recipes, operating instructions for vending machines, video recorders, or cars, etc. are examples of process models describing (in more or less detail) a necessary process.

A process model is a concise, abstract description of the necessary activities based on the experience from past processes but abstracted to be useful for later needs (Figure 6) .

A process model offers numerous advantages: The whole intervention, can be viewed, taught, analyzed, and improved (Wang and King, 2000) based on experience (e.g. by including 'best practices'). The same process model can be applied to different interventions. Additionally one can evaluate the capability and maturity of a performed process via a capability profile (Chroust, 1999).

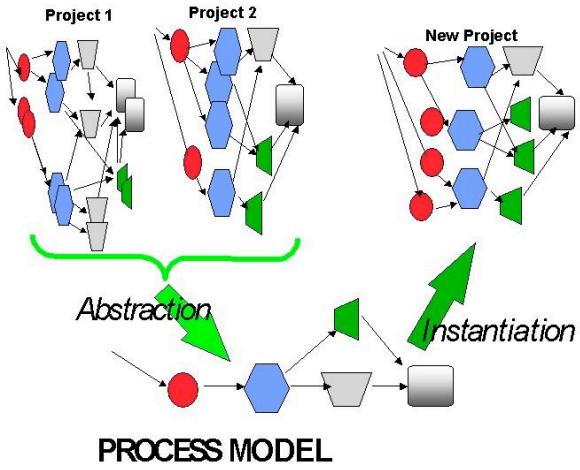

Figure 6: Process Abstraction and Instantiation

Interventions by First Responders are processes which usually follow a established process models. There are definite 'before' and 'after' relationship between activities, activities are supported by methods (e.g. how to approach a fire) and tool (pumps, ladders, ...). The 'product', however, is a service (Ing et al., 2010; Spohrer et al., 2007; Thomas et al., 2010).

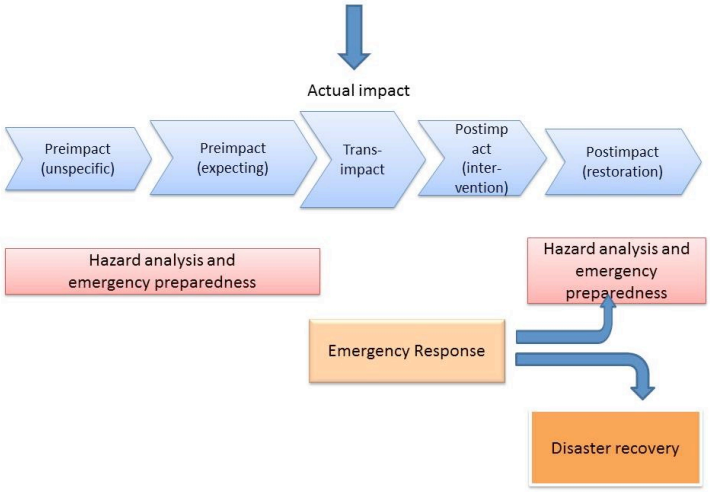

Figure 7: Disaster Phases and corresponding response processes

Following ISO/IEC 12207 (ISO/IEC, 2007) the processes to be enacted by the First Responders can roughly be classified into three essential categories (Chroust et al., 2009b,a):

Primary Intervention Processes: consist of processes that serve the primary purposes and goals of the intervention

Supporting Intervention Processes: consist of processes that support other processes as an integral part with a distinct purpose and contribute to the success and quality of the intervention.

Organizational Intervention Processes: consist of processes employed to establish and implement an underlying structure made up of associated processes and personnel by continuously improving the structure and processes.

It is essential not to forget the supporting and organization processes, because they often are the basis for successful primary intervention processes (if the fire hoses have leaks, the intervention might not be successful).

3.3 Human View of Interventions

Humans are the key to successful interventions. First responders could be professional personal, but in many instances, they are volunteers. This has be considered in all operations. The human aspects has to be considered in several ways:

Communication: A key to a successful intervention is obviously the communication between First Responders, their command units, even across organizational boundaries. Coordination and team work cannot be achieved without communication. In an actual intervention direct communication might be hampered or obstructed by physical (noise, smoke, visibility), or physiological gaps (hard hearing ...) or cultural barriers (language, taboos ...).

Figure 8 sketches many different influences which potentially create gaps in communication. A fuller discussion can be found in [Chroust-08zc].

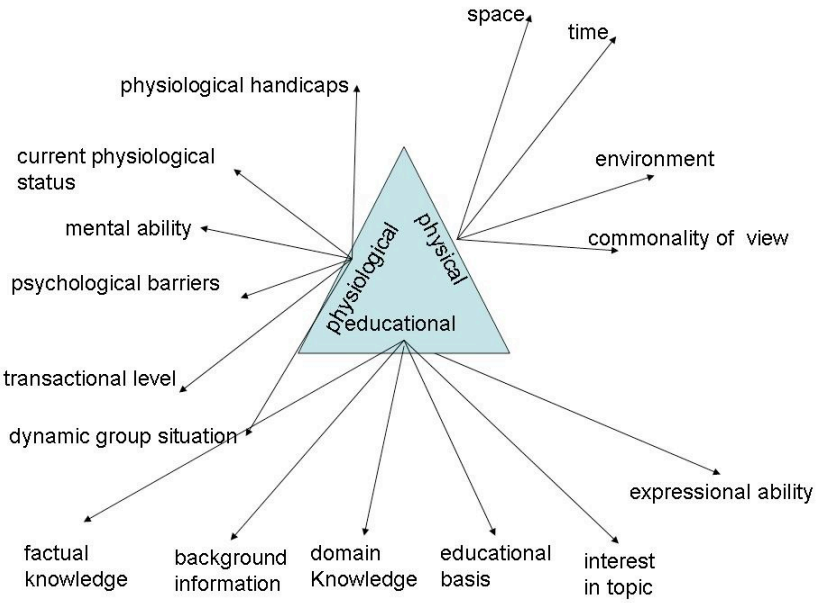

Figure 8: Dimension of gaps in cooperation

Psychological and physiological problems of personell: With respect to the First Responders we can observe (Chroust et al., 2009b):

- Humans do not posses any inborn, natural sensors to recognize dangers early enough. They are not equipped with natural, semi-autonomous reaction patterns.
- They need to be equipped with special tools to recognize/distinguish the dangers and the real sources. Special training is needed in order to operate these tools appropriately.
  - Hazardous material must be recognized (ability to understand labels and markings!).
  - Well trained and experienced emergency personnel are a key for a successful intervention.

Being a First Responder is a stressful experience. Figure 9 shows some of the stressors and the their interrelation. Psychological problems appear not only during an interventions, some of them long lasting consequences, see section 3.3.

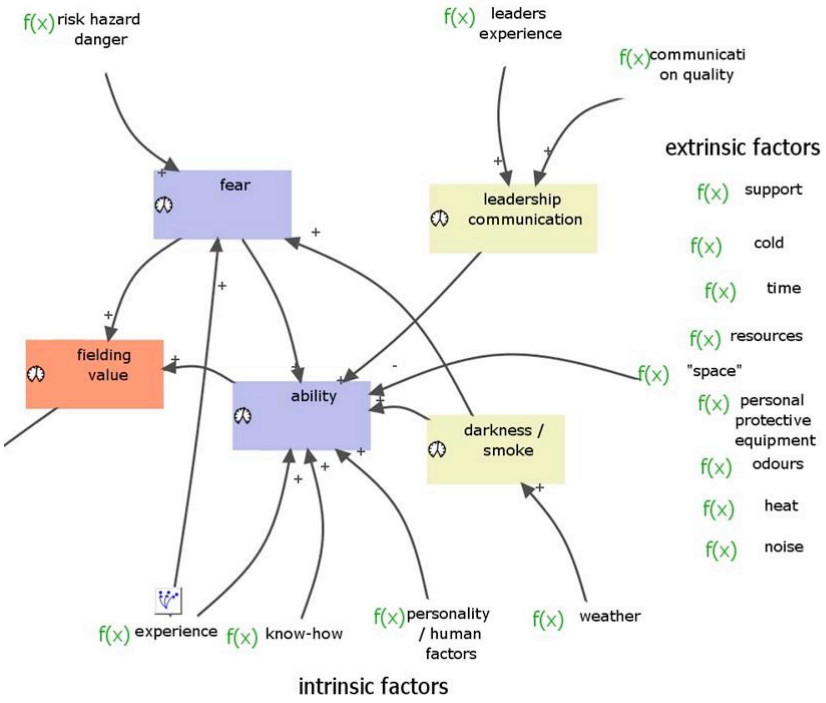

Figure 9: System Dynamics Model of a First responders

Mental Health Problems of Victims : In (IASC, 2007) one finds: *Armed conflicts and natural disasters cause significant psychological and social suffering to affected populations. The psychological and social impacts of emergencies may be acute in the short term, but they can also undermine the long-term mental health and psychosocial well-being of the affected population. These impacts may threaten peace, human rights and development. One of the priorities in emergencies is thus to protect and improve people's mental health and psychosocial well-being.*

A major concern during interventions are humans: freeing trapped people, remove them from dangerous locations, giving them medical treatment, etc. In the last few decades it was also realized that victims do not only need *immediate* psychological help (in the framework of the intervention) but often *longtime* help with respect to longtime mental health problems, most prominently anxiety, depression, and posttraumatic stress disorder (PTSD) (Norris et al., 2002; van Griensven et al., 2006). At the time of disaster unfortunately, when victims would need social and community resources, these resources themselves deteriorate or are wiped out. It should be noted that members of intervention teams themselves are also often victims of PTSD (Norris et al., 2002). Duckworth (1986) investigated psychological problems of police officers on duty during a large fire disaster: he found that approximately 60% of the officers had psychological disturbances. He labeled them the 'forgotten victims'.

During an intervention one should already identify and register potential candidates for PTSDtreatment: there is a strong correlation between PTSD-symptoms during and immediately after short duration, other victims suffer for a long time under the PTSD-symptoms. Norris et al. (2002) notes that *individuals who are most at risk for long-term effects can be identified very early in the aftermath of disasters points to a need for screening and early interventions in disaster mental health"*. This could be the basis for a follow-up psychological treatment after the intervention phase (Duckworth, 1986).

3.4 Multicultural Aspects of Disasters

The global cross-dependencies and interchange also brings about that different cultures stay in a potential disaster area together with international help personell from other countries (Daniel and B., 2008; Marsella et al., 2008). Following (Marsella et al., 2008) we can observes, that *good intentions are not enough. If you wish to help ..., you must understand [the victims] nature [and culture]"*. (IASC, 2007) points out that *"[i]nternational staff and volunteers may come from different geographic, economic and cultural backgrounds than the affected population in the host country and may have different views and values. Nevertheless, they should have the capacity to respect local cultures and values and to adapt their skills to suit local conditions. The distress of the affected population may be worsened by an influx of humanitarian workers ... Local staff and volunteers may be well acquainted with local cultures and traditions, but there can still be large socio-cultural differences, for example between urban and rural populations and between ethnic groups"*.

More details can be found in (Daniel and B., 2008; Marsella et al., 2008). A key is the cultural competence of the First Responders (Chroust, 2008; Schneider, 2001).

4 SUMMARY

This paper takes a multi-disciplinary view on reactions to regional disasters. They appear to be growing both in frequency, destructive power, and impact on people. They definitely get more media coverage in the present day. After a discussion as to what constitutes a disaster we considered basic alternatives for reacting to disasters (Flight/run away, Fight/intervene, Freeze, Submit/sustain/endure, Ignore/deny). Concentrating on interventions as the classical pivotal point of reaction to disasters we analyze interventions from varying perspectives (systemic, process-oriented, human-focussed, and multicultural).

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