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Learning Lessons From Natural Disasters and the Derivation of Related Disaster Reduction Techniques

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Cover Pictures
Left picture "2009 Earthquake in Central Italy", courtesy by Anna Bosi (EC/JRC)
Right picture "Landslide along a protection wall, Varese, 2009", courtesy by Varesenews

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Executive Summary

Inspecting the effects and consequences from natural disasters discloses opinions and facts on the way how a natural disaster has been managed throughout all disaster management phases. Identified deficiencies and inadequacies can be laid down in form of lessons learned in the aftermath of a natural disaster.

Lessons learned can be viewed on a single basis thus making it feasible to categorize a lesson and to elicit its significant features in a structured way. The intrinsic value of a structured lesson is to draw conclusions insomuch as clear benefits can be formulated that should be achieved if a lesson gets implemented. Thus apparent improvements in terms of risk reduction should be attained in case that a similar natural disaster may strike again.

The implementation of a lesson can be performed in multiple ways. It is based on the information structured so far, and it is done through a brainstorming exercise that should take into account any possible kind of intervention towards fostering risk reduction. A particular implementation forms a particular disaster risk reduction measure. It can be a concrete tool, or a process or even simple knowledge.

Introduction

Investigating on sources of failure after a disaster has happened is quite a natural process. This applies to all kind of technological, social, and natural disasters; though natural disasters cannot really be avoided, there are many ways of mitigating the effects from these.

Usually, in the aftermath of a natural disaster, related reports can be compiled making reference to all circumstances of this disaster. By doing this special focus can be put on lessons learned from this natural disaster.

In a subsequent step lessons can be further grouped and, in particular, analysed with regard to any context, background or circumstances in which they have happened. The variety of contextual aspects will reveal further insights into ways of possible improvements while implementing these lessons.

Basic aim of implementing a lesson should be the mitigation of effects and consequences as they had been experienced so far. The way in doing this is through the definition of a measure, method or technique, also called risk reduction measure or technique.

From Report-Inherent Lessons to Standalone Lessons

In the past years activities with regard to collecting lessons have been undertaken by the NEDIES project (Krausmann, Scheer, 2007). Central part of this database platform is a set of compiled reports each referring to a specific disaster in the past. Hence these reports are written after the disaster (in the case that a specific disaster can be limited to a certain time period) has happened. Ideally these reports are based on multiple sources (e.g. internet, dedicated reports, media, bilateral information, etc.); the variety of information, as one can imagine, can be contradictory on details. Therefore it is up to the compiler to write down the most correct[1] or most obvious[2] facts.

Lessons are built-in part of a report which is written in natural language (predominantly English) though there were some attempts to propose a standardized language to be used. Nevertheless all lessons remain firm part of an event report.

What is a Lesson Learned?

In general, lessons can be learned by humans and from human behavior. Though no lesson can be learned from the effects and consequences of a natural disaster as such, they can, however, be learned from human behavior (through the right or wrong human intervention to mitigate effects and consequences from a natural disaster).

Human behaviour and human interventions with regard to the mitigation of the effects from a natural disaster will be prevalent in each phase of the classical disaster cycle: prevention, preparedness, response. Hence failures from human behaviour or from the functioning of an intervention may occur in each of these phases.

Lessons (in the context of this document) are insights into wrong behaviour and/or into mal-functioning of interventions; typically lessons are written down or otherwise communicated in order to enhance the learning effect.

The NEDIES-type learning scheme foresees that lessons could be learned in each of the classical phases of disaster cycles, including a prediction "phase" and an all-cycle-wide "information deployment phase".

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[1] The difficulty in obtaining "true" information about a disaster can be huge (1) as many reports are written too soon thus having an insufficient view of the magnitude of the disaster, or (2) as report writers tend to be subjective with regard to their own perspective towards a disaster.

[2] Another difficulty has been experienced in writing down failures made by governments or similar organizations; the NEDIES approach was to express such failures in the most diplomatic way.

Lessons from prediction

Though lessons within this "phase" are quite rare, it could in theory be the case. Nevertheless real predictions are difficult to make, and if there is a high probability that a disaster may occur (e.g. volcanic eruption, storm, earthquake, etc.) it can easily overlap with the prevention or even the preparedness phase.

Lessons from prevention phase

Interventions in this phase concern anticipations of possible effects and consequences to happen at a certain location but with much less specificity in terms of time. Hence lessons learned in this phase should make reference to possible preventive measures (to be applied at a certain location). Typically, preventive measures are put in place before one knows of a certain disaster to happen. For example, a tsunami preventive measure would be the planting of a mangrove forest. One can assume that such a forest could prevent tsunami waves up to a certain height from entering inland; however, one has no guarantee in case that a tsunami wave may exceed this height.

Knowledge on potential prevention measures has to be derived on the outcome of modelling or simulation exercises (taking into account worst-case scenarios) or be based on long-term or multi-source experiences. However, any such outcome is limited to certain conceivable thresholds: for example, if one has never experienced a tsunami wave exceeding 5m height, the next tsunami protection will not be much higher than 5m.

Consequently failures in human interventions may be verified if the magnitude of a disaster exceeded the capabilities or functionality of a prevention-type intervention.

Lessons from preparedness phase

Usually in the preparedness phase a disaster has more or less started happening. One knows, for example, of an increased volcanic activity, one knows when and where a hurricane will affect the coastline. Hence lessons learned in this phase should make reference to possible preparedness measures. With the installation of preparedness measures one tries to mitigate the effects and consequences of an inevitable disaster.

While for prevention-type measures one assumes reasonable worst-case scenarios to happen, one probably knows much more details in the preparedness phase about the magnitude of the forthcoming disaster. One knows for example that a hurricane with certain intensity will inevitably hit the coastline and can thus start necessary preparatory measures.

Consequently failures in human interventions are disclosed if a preparedness measure was insufficient with respect to what would have been necessary.

Lessons from response phase

The response phase is rather broad and focused on long-term interventions starting with the first consequences after a disaster has happened[3]. One knows for example that there are victims whose lives have to be saved. One knows that lifelines (water, electricity, roads, etc.) have been cut and to be restored as soon as possible. Response actions can be manifold; nevertheless their effectiveness and efficiency can be assessed. Response actions are measures or techniques that also mitigate the effects and consequences from natural disasters, and as such they fall under the category disaster risk reduction measures.

The overall goal of response phase interventions should be to save lives, to avoid injuries, to recuperate dead corpses, to re-install lifelines, and, more general, to come back to normal pre-disaster

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[3] Obviously in cases in which a disaster strikes over a period there could be an overlap between the disaster phases; for example, response actions may already have been started while preventive or preparedness actions are still ongoing.

living conditions as soon as possible. Such response phase interventions could fail due to inaccuracy, bad organisation, insufficient or incapable resources. Hence lessons could be learned if deviations of that kind have been encountered.

Lessons learned from information deployment

NEDIES-inherent functionality addresses the whole range of information to the public as a separate section/phase. In general, information which is given to the public may be issued in any phase, and in many cases it is phase-overlapping or not clear to which disaster cycle phase it can be attributed. Hence lessons drawn from information issuing are collected apart.

In the disaster cycle it is crucial that all parts of populations are well informed about their potential of being affected by the effects and consequences of a natural disaster. This can be the placement of roads sign, the information about a tsunami hazard zone but also the announcements of rescue operations or search for experts during the response phase.

Disaster reduction techniques or measures should also address the importance of informing the public of ongoing activities of general interest. Hence lessons can be learned if failures in doing so become evident.

Towards standalone lessons

Report-inherent lessons could be extracted from a report thus becoming stand-alone lessons. In a first step, for each lesson it is sufficient to copy from an event report those texts that describe this lesson. However, this exercise does not really take into account how it came to this lesson and which could have been the circumstances making it a valid lesson. Therefore it would make more sense if for each lesson its contexts and circumstances are analysed as well, and subsequently classified, formatted and put into a database. In particular, a lesson is the more valid the more it contributes to clear improvements (within the disaster management cycle) to be achieved in case this lesson will be implemented.

Knowing about a lesson's context, circumstances and validity the users can better handle the lesson's assets (comparing this lesson with similar lessons). In fact, the classification and formatting exercise will bear ultimate advantages: it will become better to compare implemented lessons among each other, in particular by referencing their effectiveness, applicability, re-use within different settings, and benefits to society.

The outcome of the lessons learning process will be maximized if humans really implement lessons so that at least – taking into account a future disaster of similar magnitude – some improvements might be achieved: e.g., less victims, less economical damage and loss, less time for recovery, better organization, better legal frameworks. Thus in a long term it would be interesting to know whether the effects that are achieved during the implementation of a lesson are good for the society, effective with respect to the promised future mitigation of disaster consequences, efficient in terms of costs and resources, potentially applicable by anybody and anywhere, and whether the implementation of this lesson can under certain circumstances be "done again", in particular, re-used for solving similar mitigation problems.

Lessons Learned and Their Contexts

Experience with managing the NEDIES system revealed the feasibility of a supplementary, context-driven classification of lessons (NEDIES, 2005). The additional concept grants a self-determining focus on lessons each of which can be searched for independently of a specific disaster. Obviously, a single lesson has to be portrayed much more thoroughly than it is done now. Several aspects of information will describe the entire context and all necessary parameters that may depict and characterize that particular lesson.

Different types of contexts exist, among which are references to the hazard and the various types of the lesson learned itself. On the other hand, genuine contexts describe all circumstances under which a particular lesson has been learned. Explicit contexts have a direct link to the disaster happened while implicit contexts describe more background information essential to explain a disaster and its implications from a wider perspective

The final structuring of a lesson leads to the definition of information sections that could be further managed as data fields within a lessons learned database. Apart from administrative information those data fields should keep information expressing the initial situation (including explicit and implicit contexts) as well as illustrating the way forward (the envisaged benefits when implementing a lesson and the necessary objectives to be fulfilled and actions to be done).

Contexts or What Is Inside a Lesson Learned?

Hazards context

Main reference for a lesson learned is a reference to a hazard though referencing more than one hazard makes still sense. Sometimes a further sub-reference could be helpful in order to reference a specific type of a hazard; this is, for example, the case for flash floods as a special type of a flood, or for hurricanes, typhoon, snow storms, blizzards, etc. being a sub-type of hazard type 'storm'. Contrarily to normal floods, a flash flood "disappears" rapidly, and a blizzard has an attribute referencing cold temperatures which is not needed for hurricanes.

In general, the consequences of hazards may be overlapping in terms of vulnerability and damages to assets thus making it difficult to draw a clear borderline between one hazard type and another. The consequences of a tsunami may be heavy impact to buildings which could also be the consequence of a coastal storm, and the flooding caused by a tsunami could also be caused by high waves due to a storm. Nevertheless a certain distinction among hazards types should be made.

As a matter of fact, quite a few lessons, though derived from one hazard type, could be attributed to various potential hazard types. A lesson learned that should protect a local community from high sea waves entering its harbour, and that should be implemented through the construction of water breakers, could well be attributed to both tsunami and storm (possible sub-type: coastal storm) hazards. The link to more than one hazard can be done manually when structuring a lesson; however, such a link could also be gained through new insights while comparing two lessons (see later on): for example, "protect from sea water intrusion" could be a benefit listed under the lesson learned from the tsunami disaster and also listed under the lesson learned from a coastal storm disaster.

Other administrative contexts and data fields

For administrative purposes it makes sense to handle a lesson learned as an independent entity (from an IT point of view). Thus each lesson learned should be recognizable through an identifier; ideally this is a unique title attributed to each lesson. Further structuring of a lesson learned should also reveal some kind of explanatory texts, ideally a description data field that contains a more detailed explanation of the whole lesson learned contexts.

Other types of structuring make references to the type of the lesson learned, as well as to its sub-type if applicable. Mostly the lessons learned type is a link to one of the six phases of the disaster cycle (see above); furthermore a sub-type makes a hint how this lesson learned is practically be treated or ideally be re-used, e.g., as an (official) guideline, a recommendation, a good practice, a best practice, an experience, or as a so-called similarity insight.

Explicit contexts

Those contexts that play a direct role to make a disaster happen are considered explicit contexts. Obviously these are

- Triggers / facts: this section contains all kind of triggers (e.g., weather conditions, earthquakes, volcanic activities, etc.) and current facts (e.g., high tide, water level, dry soil, but also man-made constructions, etc.) that could somehow have played a role in a certain disastrous situation.

- Geography (topology) / people affected: this section makes references to the particular geography, (e.g. altitude, dry regions, seaside), topology (e.g., inhabited areas, lifelines), and people affected (e.g., number of persons affected, type of persons affected).

- Time: time is a factor in case of daytime or night-time, or in case time needed (e.g. for evacuation measures, for response measures, etc.).

It is obvious that these three explicit contexts are somehow interconnected and that relevant conclusions – depending on each singular case - should be drawn carefully taking into account these contexts in a parallel way.

Moreover, as a disaster usually is not a rather singular event, it makes sense to investigate more on aspects like

- Sequence / complexity: certain disasters may trigger other disasters within short time and/or within certain distances thus making it difficult to consider it as "one" disaster or as a sequence of many disasters. The south-east Asia tsunami could be seen as such a disaster. In addition, complexity could become an important feature in terms of resource allocation and response planning. Typically, heavy (and probably local) precipitation may lead to landslides, immediately followed by flooding, etc., which may make all organisational activities rather complex.

Implicit contexts

During the writing down of lessons learned it turned out that often implicit contexts are used and easily mixed up with those explicit contexts (see above). Implicit contexts do not directly contribute to a disaster; however, they may influence the perception one has of a disaster; implicit contexts may be the hidden reasons and factors why a disaster has happened. Hence other reasons and factors that could play a role during the disaster lifecycle are:

- Climatic / Climate change: climatic factors are among the most used implicit contexts within lessons learned. Though they often depend on individual perceptions, there are more and more factors that are proven indicators of upcoming climate change. Typical examples are rock-falls in the Alps: the number of rock-falls above 2000m has dramatically increased because of ongoing melting in regions that were previously known as permafrost regions.

- Economical / coping capacity: economical activities play more and more a role when it comes to assess the consequences of a disaster with respect to the interruption of subsequent activities both geographically and in terms of time. Economic activities at the place of the disaster may be interrupted thus having consequences in other (non-affected) areas; in the case that recovery takes too much time, consequences on other activities may be long lasting. Closely linked to economical issues are coping capacities of local communities. For example, whoever is covered by insurances has better chances to recover than those whose lifelines have to function on a daily basis.

- Organizational / complexity: organisational issues play a role when it comes to resource allocation and to general emergency planning activities. Such activities should ideally be done during the prevention and preparedness phases; however, ignorance of the hazard or even

budgetary problems could severely constrain the preparedness activities of a local community. In addition, complexity issues, taking into account all kind of consequences, in particular consequences happening at the same time, may easily exceed the planning capacities of a local community.

- Educational: the educational background may play a role under certain circumstances: the way how people live their daily lives (e.g. cultural and religious aspects), the way how people construct their houses (e.g. adobe houses), the land-use (e.g., having a sound nature around), the working environment, but also to mention illiteracy.

The way forward: benefits and objectives

A lesson learned would not be a lesson learned without indicating a frame towards improvement (Krausmann, Mustaq, 2010). Supposed that a similar disaster may happen in future, it would be desirable that – assuming that lessons have been learned – the disaster will have less severe consequences: less lives lost, less injured persons, less damage, less economical and ecological consequences.

Hence it makes sense to structure goals to be achieved when implementing a lesson. Such goals should be accomplishable. The way to define specific benefits (e.g., to the local community) could help in getting a clear picture for implementing a lesson. In addition, objectives could be defined that may sub-structure several steps to be done in order to reach those benefits in the best way.

The Structuring of a Lesson Learned (LL)

Based on an analysis of all applicable contexts it is possible to create a fully-structured version of a LL. Within NEDIES such an IT application has been implemented allowing to generate a LL and to fill in all its data fields. The current version of NEDIES supports the following data fields (in brackets: indications of data types).

Header information / LL classification

All hazard contexts and other administrative contexts (see above) are gathered within the header information:

- LL title [type: text];
- reference to hazard [type: selection list], and
- reference to sub-hazard [type: selection list] if applicable;
- description of the LL [type: long text];
- type of LL [type: selection list], and
- sub-type of LL [type: selection list] if applicable.

Situation / facts

The name of the data field is

- situation [type: long text].

In this data field decisive aspects of the situation should be kept. They should provide answers to questions like: "why was it necessary to derive this lesson?", or "which was the basic problem that led to writing down this lesson?" Experience with NEDIES lessons turned out that entering data into this data field was either straightforward or that it was extremely difficult to find an appropriate text.

Although not mandatory to fill in this data field, it always turned out to be a good exercise to think carefully about the necessity of writing down a particular lesson.

Concerning flood disasters a "rapidly rising water level in town", for example, is per se part of the situation; however, a careful inspection of the disaster reveals that, at the time, too many resources had been used contemporarily and that there was a lack of resources available. This could lead to another aspect within the data field "situation", possibly described as "all resources (response crews, material) used elsewhere".

Triggering events

The name of the data field is

- triggering event [type: text].

This data field supplies a list of triggering events that may have been present prior to or somehow connected with the disastrous event for which lessons have been deduced. In that way a triggering event is decoupled from the situation as it has been formulated within the 'situation' data field.

Practically, heavy precipitation could trigger rapid flooding; an offshore earthquake could trigger a tsunami. However, on the other hand, rapid flooding could be the trigger organizing rescue operations properly and in time. Hence entering data into this field can become tricky in the sense of where to draw the borderline to data in the "situation" field. The triggering event in the "flood in the city" case is "Rapidly rising water level" rather than "Heavy rainfall" (see example below).

Characteristics / validity

All other circumstances, properties, and observations that have not explicitly been mentioned in the first two data fields could be kept in the

- characteristics [type: long text]

data field.

Main purpose of this exercise is to identify the particular background that makes this LL a valid LL. The validity of a LL is the degree to which extent improvements can be achieved in the case this LL will be implemented. For example, to protect an uninhabited area from being flooded is not a real improvement, unless some particularities have to be considered. On the other hand, to protect critical infrastructure from being flooded is an important feature not to be neglected.

Another point to reflect on is to identify the range for further re-use of this LL within various environments. It is the clear intention of systems like NEDIES to disseminate further all kind of knowledge on LL to any stakeholder and to a maximum number of similar but different applications. Hence the 'characteristics' data field provides a platform for suggesting (or disregarding) the re-use of this LL within a different environment. In that way, this input field serves the user as main guidance to know more about the applicability of a specific lesson.

Mangrove forests, for example, to be used as tsunami-protection measure cannot be planted in regions where they simply do not grow. Therefore a context like "tropical region" needs to be mentioned necessarily. Flood-related lessons concerning protection measures in cities should explicitly mention contexts like "Flooding in inhabited area" or "Critical infrastructure" in order to make clear the range of applicability.

Benefits

Benefits are parts of the goals to be achieved when implementing a lesson learned. Hence benefits mirror desired situations.

The name of the data field is

- benefits [type: text].

By some means this is the "opposed" data field to the "situation" field; now it should be recorded what could be the potential benefits if this lesson is going to be implemented or realized. One can try to "reformulate" points mentioned in the 'situation' field and subsequently deduce a possible benefit.

For example, a "limited number of resources available" could be "reformulated into "having available a sufficient number of resources. "Risk of uncontrolled outflow of water" can be transformed into a benefit formulated as "controlled outflow of water".

Objectives / actions

In analogy to benefits, objectives are parts of the goals to be achieved when implementing a lesson learned. Usually, the implementation of a lesson requires an active involvement in order to arrive at points where the above mentioned benefits can be seen. Hence objectives define the various ways to come to the benefits. It can be constructive to elaborate on objectives and then formulate possible actions on that basis. Internally, there can be many actions expressed within a list of various actions to be suggested.

The name of the data field is

- actions [type: long text]

in general, a huge range of potential actions can be considered, from purely behavioural measures to elaborated procedures and even to concrete instructions to be undertaken. In most of the cases, however, an action will probably be formulated in a more abstract way rather than described in a detailed manner.

An action in the flood case could be to "Define beforehand objects (critical infrastructures) to be protected", probably correlated with water levels passing certain thresholds.

Addressees

Benefits should reach those who suffered most from previous disasters and who may suffer again. Moreover, actions to be done require the authorisation and/or involvement of (local) stakeholders. Hence it could be worthwhile to mention, in a separate data field, possible addressees for the implementation of a specific lesson, named

- addressee [type: multiple selected list].

As not all actions listed in the 'action' data field could be done by one organization or one individual, it is possible to select multiply from the list. The current list of addressees contains the following entries: "local decision maker", "local communities", "local decision makers", "public administration", "public authority", "civil protection", "house owner".

Examples[4]of Structured Lessons Learned

Flood in the city

Background: In summer 2005 heavy rainfall led to a rapidly rising level of the Central-Swiss Vierwaldstätter lake. This lake has a huge catchment area situated on Northern slopes of the Central Swiss Alps. The lake has one outflow located at the city centre of Lucerne. Heavy precipitation was accompanied by heavy wind which caused additional problems to infrastructure by fallen trunks. Moreover local landslides caused problems, too.

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[4] These examples show the main parts of a LL structuring without mentioning header and hazard information.

For the civil protection authorities the situation became really severe when it became obvious that allocated resources (manpower, normal intervention material, elevated bridges, etc.) were running short. In addition, from an organizational point of view, it seemed that priority setting was continuously overtopped by new requests of intervention (Bezzola, Hegg, 2007).

It was clear that, at the end, infrastructural measures around the city centre were classified as highest priority.

Lessons learned

- From prediction made

- From prevention phase

- From preparedness phase

"The situation in town became chaotic due to the fast rising lake level; there was a lot of uncertainty which building to evacuate first … it would have been better to plan beforehand"

- From response phase

- From "information to the public"

Figure 1: from lessons learned "Central Switzerland floods" (NEDIES, 2005)

The structuring of this lesson has been done as follows[5]:

Situation: town with critical infrastructures; fast and complex decisions to be taken; limited resources (human, material) bound in various locations

Triggering event: rapidly rising lake level

Characteristics:

1. **abnormal precipitation / time / lake level;**

2. **town with a lot of critical infrastructure situated at lake**

Benefits: avoid chaotic situation → increased preparedness level; shorter and better coordinated response time

Actions:

1. **prepare ready-made warning, response and evacuation plans, dependent of lake level increase**

2. **improve resource allocation plans by taking into account complex situation that several interventions may be necessary (in different places at similar times)**

Addressee: public administration; civil protection

Discussion: The two benefits listed can be deduced more or less directly from the lesson: the "chaotic situation" can be turned into "avoid chaotic situation", and "better to plan beforehand" can directly be interpreted as "increase preparedness level". In addition, the wording "evacuate first" deduces a time factor which gets an interpretation in form of "shorter and coordinated response time".

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[5] Please, note that there could many ways of structuring a lesson; this examples tries to set out an optimum.

The two actions mirror the two directions for possible improvements: one referring to the organizational issue of reviewing the plans, especially with regard to the lake level increase over time. The other direction refers to review the available resources (material, human) to be allocated in various places at similar times.

Floods in Mozambique

<u>Background:</u> In 2000 and 2001 heavy rainfall led to floods which, due to the huge plains of the Búzi river in central Mozambique, covered a significant part of the whole country. Hundreds of local people lost their lives and the economic loss to livelihoods and assets was significant.

Survivors complained that they had not been warned in time, and that, even if been warned, it would have cost significant time to escape to higher grounds. In addition, it seemed that local persons were extremely surprised about the flood level, mainly also because they had not been confronted so much with preceding precipitation which more or less has happened in other regions of the country (MunichRe 2007).

Lessons learned

- From prediction made

- From prevention phase

- From preparedness phase

"If the people had been warned in time, they could have escaped. Many fatalities could have been avoided. Many assets could have been saved."

"Local people were totally surprised to be surrounded by water and did not know what to do or where to escape."

- From response phase

- From "information to the public"

"No type of warning was issued to local people."

Figure 2: excerpt from lessons learned "floods in Mozambique" (NEDIES, 2005)

The structuring of this lesson has been done as follows:

Situation: flat region; water comes abruptly from all directions; illiteracy

Triggering event: heavy rainfall all over the country

Characteristics:

1. **heavy rainfall / time in other regions of the country**

2. **difficult evacuation situation: warning, escape routes**

3. **many illiterates**

4. **no supra-regional warning mechanism**

Benefits: saved the lives and the assets of illiterate local people; improved warning delay; improved warning communication

Actions: warn local illiterate people in time and in an understandable way and tell them what to do

Addressee: local communities (in Mozambique)

Discussion: Apparently an easy-to-use system is needed that warns local people from a hazard they do no count with; the heavy precipitation took mainly place in other regions of Mozambique; therefore locals were not warned "so much".

The three benefits listed refer directly to "fatalities" and "assets not saved" as well as to "not warned in time" and "no warning issued".

The only action is quite compositely verbalized; in one way or the other, the action expresses the warning itself, the inherent time aspect and the illiteracy of the local people. Hence the formulation of this action is still quite abstract without going too much into detail how its implementation could be achieved.

Glacial lake outburst

Background: Between 2005 and 2009 the Lower Grindelwald Glacier (Central Switzerland) was causing significant troubles with regard to rock falls and flash floods. The reasons for these events are quite specific though the overall cause can be seen in ongoing climate change which leads to melting up of higher located permafrost regions.

Due to continuous heavy rock fall above the glacier tongue tons of new rocks were loaded on the lower part of the Grindelwald glacier leading to a dam effect on that part. Interestingly, this part of the glacier was much less melting than central and upper parts of the glacier. Hence the normal water outflow on the surface has been interrupted in the lower parts leading to an ever increasing lake at the surface in the middle part. Such glacier lakes will start discharging huge volumes of water once the water pressure becomes too high. The effects of such a flash flood will be disastrous for people living in Grindelwald and even further down the main valley.

In fact, in May 2008, with a lake volume of 800,000m^3, a breakout did occur releasing 110m^3/s which, fortunately, caused no devastating effects (Swissinfo, 2008; Grindelwald glacier lake, 2009).

Lessons learned

- From prediction made

- From prevention phase

"A glacial lake has formed over the years with no overground drainage. From time to time the water makes its own way through the ice leading to the abrupt emptying of the lake. As a consequence there is the permanent hazard of (local and) unpredictable flash floods."

"A sudden water release occurred leading to a flash flood further down in the valley, which however did not cause any severe damage to life and assets."

"There should be ways to steer the water drainage in a more controlled manner."

- From preparedness phase

- From response phase

- From "information to the public"

Figure 3: excerpt from lessons learned "Grindelwald glacier lake outburst" (NEDIES, 2005)

Parts of the lessons learned show how the authors try to suggest potential solutions to the overall problem. Apparently the water discharge should be done in a *controlled manner* and possibly through the installation of a *water drainage*.

For the time being this lesson is structured as follows:

Situation: glacial lake with no natural outflow; uncontrolled and abrupt lake emptying through the glacier's underground drainage channel

Triggering event: water accumulation/pressure in the glacial lake has reached a threshold

Characteristics: only during summer months happening; lake level difficult to predict (due to precipitation / melting / mass movements)

Benefits: saved lives and assets down the valley by flash flood mitigation

Actions: control the outflow of glacial lake water

Addressee: local decision makers; civil protection

Discussion: Obviously, at first glance, there is not any immediately preceding triggering event; however, water accumulation as such can be considered as cause thus increasing the water pressure which leads to a triggering event once the water pressure exceeds a certain threshold. The 'characteristics' section reveals interesting constraints: first, the problem as such appears only during summer months, and secondly, there is no real mechanism to predict in an approximate way any changes in the lake level which means that a sudden lake level rise and a subsequent abrupt water discharge may happen any time (during summer months).

The benefit mentioned refers to the (high) possibility to have devastating flash floods further down the valley. Based on mitigating the consequences from flash floods or on mitigating flash floods as such, the action is formulated in a rather vague way ("control the outflow …") letting it open how this could be implemented.

Lessons From Lessons

The structuring process shows the whole range of aspects to consider when implementing a lesson learned. It is now possible to learn from a lesson and to derive a clear product or method which – once applied in the right way and in the right context – implements that lesson in that particular context. Some driving forces build up the frame in which a product or method is going to operate. The derivation of a product or a method is the outcome of a brainstorming exercise based on the analysis of the structuring process (see chapter "the structuring of a lesson learned"). Any product or method has as aim the mitigation of risks; hence the whole range of these products or methods is called disaster reduction measures/techniques or disaster risk reduction measures/techniques.

Driving Forces

The definition of disaster reduction techniques should be motivated and guided through basic principles: First principle should be to prioritize on life saving aspects. Implementing a disaster reduction technique should clearly show the way to a reduction of fatalities and injuries. Other principles should focus on risk reduction in a broader sense. As risk is the product of probability of hazard occurring and its consequences, risk reduction commences in decreasing the probability and/or in reducing the consequences. Most of the disaster reduction techniques cannot really succeed in decreasing the probability of hazard occurring; hence these techniques have mainly to stress on reducing the consequences.

Efficient response mechanisms should also play a role among the driving forces as the organization and coordination of efficient response actions has turned out to be a key element in mitigating the effects and consequences from natural disasters.

Analyzing Lessons

Basis for an analysis of a lesson are those sections identified in chapter "the structuring a lesson learned". In particular, the 'actions' and 'benefits' data fields are among the most interesting sections as they will be the basis for further examinations. Together with the overall driving forces these two sections should provide clear directions for further exploration eventually leading to a disaster reduction technique. The 'addressees" data field provides some hints on usability and on skills needed by potential implementers and practitioners.

On the other hand, special information out of the 'situation' and 'triggering events' data fields could become useful for defining limitations to potential disaster reduction techniques. Similarly, for assessing particular local characteristics (see 'characteristics' data field) one could derive interesting insights with regard to further re-using a technique in a different context. Particular attention could possibly be put to time-dependent characteristics as they are an indicator for the overall complexity a disaster reduction technique has to cope with.

In parallel to this analysis, the identification of bad practices could be useful as well; again, knowing more about a bad practice, could underpin the assets of a good practice implemented as disaster reduction technique.

Implementing Lessons / Good Practices

With all that information available a brainstorming exercise can start. What is needed now and what could be helpful during the brainstorming is to think of interventions that – when implemented - lead to positive achievements as laid out in the 'benefits' section as well as demanded by the driving forces. It is important not to be too stringent when it comes to the definition of interventions; hence it may be useful to consider any type of intervention.

The implementation of disaster reduction techniques could be done in three directions:

- A <u>constructional intervention</u> stands for something physically built: something that is built usually close to other constructions that need protections; or some mechanical tool helping to deviate from physical impact on those constructions.

   Typically, a protection wall against landslides happening is a constructional intervention. Also the generation of a mangrove forest could be interpreted as a tsunami mitigation measure of type constructional intervention.

- On the other hand, an <u>organizational intervention</u> stands for planning tools that help to organize any kind of planning, resource allocation, time of intervention, etc.

   Typically, the creation of a flood cadastre is of type organizational intervention as well as the elaboration of a system of resource allocation and response plans.

- The type <u>behavioural intervention</u> has been added to the list of possible achievements, mainly also to bring in teaching practices and similar techniques.

   For example, the teaching of school children of how to behave during an earthquake is a mitigation measure of type behavioural intervention.

Any elaborated intervention is considered to become a disaster reduction measure.

The Elicitation of Disaster Reduction Measures

Disaster reduction techniques are ready-to-use interventions in order to mitigate the effects from natural disasters. As such each of these techniques presents a good-practice function with clear distinctions to bad practices. Within a system of best practices a certain technique may be adapted towards different contexts to operate.

Types of Disaster Reduction Measures

In alignment to the global disaster reduction initiative (Kameda, 2007) three different types of disaster reduction measures exist: tools, processes, and knowledge.

- Tool: the category 'tool' comprises any kind of concrete, built or constructed measure. In addition, this category also subsumes any kind of IT tool.

- Process: a process is a kind of written down procedure in order to achieve or guarantee certain behaviour. Moreover the category 'process' subsumes meta-type processes: processes that describe the execution of subsequent interventions, e.g. a sequence of processes or a list of tools to be used or a mixture of both.

- Knowledge: any acquaintance of skills or expertise not yet realized within a tool or process could be considered as knowledge at this point. Mostly knowledge exists in the brain of people; typically, a behavioural intervention that is not written down rather than applied frequently is considered as knowledge.

  To the category knowledge is added another important sub-category called indigenous knowledge. It has turned out that indigenous knowledge exists all over the world, mainly with indigenous peoples and mostly with illiterate persons; over time it has also turned out that some of this knowledge has great capacities to be further exploited. As such, indigenous knowledge is primarily knowledge which, after further analysis, could be transformed into tools or processes.

It is clear that each of the above mentioned interventions is mirrored as one of the three disaster reduction measure types. Typically, a constructional intervention is a tool, an organizational intervention could be a process, possibly also a tool, etc.

Issues to Consider

Each disaster reduction technique has an underlying function according to which it transforms an initial situation into a desired output situation. It should be clear that, by far, these functions are not mathematical functions rather than functions that operate with fuzzy logic. Hence input and output values can be descriptive rather than exact.

As a function each technique has a list of parameters to be included in order to start the function's calculations or procedures at the initial situation. Input to the function is generated through the parameters and, optionally, through human-based input.

As output the function creates values that – once the function has been applied successfully – satisfy the objectives or benefits, respectively (see 'benefits' data field in the lesson structure).

Limitations are added to the function as long as they represent a range of values (within parameters, human input, or within the function itself) that ascertains the bounds of the function's operability.

Identification of Bad Practices

Bad practices illustrate the negative aspects of good practices; it is worth to make these aspects known in order to delimit correct and optimal functioning. Thus bad practices are described in separate data fields attached to a disaster reduction measure[6].

System of Good and Best Practices

A good practice is a well-elaborated and well-acknowledged disaster reduction technique. As such it is undergoing continuous commenting from users, practitioners and scientists. Hence a good practice may receive modifications and amendments that may change its functioning and performance. As long as improvements are achieved it is clear that a good practice will be exchanged with its improved version. Thus a list of acceptable and acknowledged versions of a good practice will be generated.

A good practice is considered a best practice within a certain environment and field of application. However a good practice may also get modifications and amendments towards a different environment or different field of application which may alter the whole function of the good practice without really modifying the overall goals to be achieved. Hence another best practice in a different but similar field may be created.

It is obvious that – on basis of one (initial) disaster reduction technique – a two-dimensional system of both good practices (= sub-system of improved versions) and of best practices (= sub-system of different applications) will be generated.

Examples of Derived Disaster Reduction Techniques

Generation of Flood Cadastres

Based on the example "Flood in the city" one outcome[7] of the brainstorming exercise was to generate a system of flood cadastres. This is an organizational type of intervention leading to a 'process' type disaster reduction technique.

Based on the identified action "ready-made warning, response and evacuation plans" one has, first, to know which parts of critical infrastructures will be flooded in relation to the water height, and, in a second step, what has to be done and secured at this water level. Flood cadastres (Bezzola, Hegg, 2007) could be generated for a whole range of water heights with a granularity of approximately 20 – 50 cm difference between one water level and another.

The application of this disaster reduction measure will definitely enhance the level of preparedness with the local authorities and probably also help to improve response time (see under 'benefits' in "Flood in the city"). A summary of this disaster reduction technique's functions is given below:

Parameters:
- **Various flood maps per lake level granularity**
- **Infrastructure to be evacuated and secured & priority setting**

Output:
- **Per each identified flood level: warning plan, response plan, evacuation plan**

Limitations:
- **The time aspect (time pressure) can become important; therefore try to link these plans in the most efficient way.**

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[6] Not handled in this report.
[7] In fact, another disaster reduction measure could be derived as well, focusing more on resource allocation plans.

Installation of simple but effective early warning system

The lessons structured within the example "Floods in Mozambique" could be implemented through a behavioural intervention leading to a 'process' type disaster reduction technique.

Objective is to warn local, illiterate people in the fastest and most unambiguous way and make them escape in the right moment and in the right direction. Hence in Mozambique it has been proposed the installation of a simple but nevertheless effective early warning system (MunichRe, 2007). This is done by establishing in local Mozambique-based communities a decision matrix (e.g. wooden tiles each showing one of three pictures, "stay", "prepare", "escape") which tells the community people what to do in this moment.

The currently valid tile is the cross-point of precipitation-based value, on one hand, and of a river level value on the other hand. Responsible persons of the local community have to watch at to which level the river water has risen along a marker installed at the shores of the river. Subsequently they mark one dimension in the decision matrix. The precipitation-based value in this matrix is determined by having a look at rain water collected in a separate community-owned container. The level is measured along a vertical marker in the container and, subsequently, the other dimension in the decision matrix - the precipitation dimension - is marked accordingly.

The installation of markers, the location of the markers as well as the definition of appropriate range and their colouring code is developed by field specialists. The currently valid tile's symbol is developed in such a way that it gives the local people sufficient time to act. In most of the communities the escape route is a predefined route which has been taught to the local people by those field specialists.

The function of this disaster reduction measure can be summarized as follows:

Parameters:

- **identify precipitation over time and get colour code (human input)**
- **identify raise of river level and get colour code (human input)**
- **mark both colour codes in a community-based decision matrix**

Output:

- **each day/half-day an update of the symbol in the decision matrix (currently valid tile in the cross-point) is generated telling the people whether to stay (do nothing), to prepare for escape, or whether to escape**

Limitations:

- **One or more responsible person(s) needed**
- **Avoid manipulations of markers**
- **Availability of pre-established escape routes**

The correct application and right functioning of this disaster reduction method should definitely warn illiterate local people in time and thus save the lives and assets of those people.

Construction of drainage gallery

The lessons structured within the example "Glacial lake outburst" could be implemented, taking into account a constructional intervention leading to a 'tool' type disaster reduction technique.

The action demands a controlled outflow of glacial lake water which can be done in various ways: in a buffered way or in a continuous way. While the buffered way would foresee buffering of flash floods in containers further down the valley, it is the continuous way that discloses more promising results.

The brainstorming process revealed a possible implementation to be done as installation of a drainage gallery (Tunneltalk, 2009). Superfluous glacial lake water, once it exceeds a certain level, would enter the drainage gallery through which it gradually flows down the valley (until it reaches the normal valley outflow).

The function can be summarized as follows:

Parameters:

- **Dimensions of drainage gallery in correspondence with expected water level increase**
- **Inlet of drainage gallery at glacial lake level so that glacial lake is not in critical state yet**
- **"Smooth" outlet of drainage gallery, i.e. avoid further erosion etc.**

Output:

- **Superfluous glacial lake water is taken away from the glacial lake**

Limitations:

- **Drainage gallery inlet may have to be "adjusted" to ever moving glacier height (surface level of glacial lake**
- **Drainage gallery inlet may have to be "adjusted" to ever moving glacial lake**

Supposed the limitations can be handled correctly, the application of the disaster reduction technique will definitely contribute to a controlled drainage of excessive glacial lake water. With this one can significantly diminish the possibility of flash floods and thus enhance the safety further down the valley.

Construction of high-temperature vertical drainage channels

The structured lesson "Glacial lake outburst" reveals also a different implementation of the action "control outflow of glacial lake water". The proposed disaster reduction technique "Construction of a vertical drainage channel" (Grindelwald glacier lake, 2009) is based on a constructional intervention leading to a tool type technique.

Brainstorming has revealed another way of letting flow superfluous glacial lake water in a continuous way. It is done through establishing vertical access to the glacier's natural outflow which lies at the glacier's bottom. Hence vertical drainage channels could be created through which the glacial lake water would continuously reach the bottom outflow.

The underlying function can be summarized as follows:

Parameters:

- **Dimensions and number of holes in correspondence with the expected water level increase**
- **Height of inlets to be put in such a way that glacial lake is not in critical state yet**

Output:

- **Superfluous lake water is taken away from the glacial lake**

Limitations:

- **Manual intervention necessary which can be done only during summer season**
- **Has to be "renewed" every year (because new holes have to be created)**

This disaster reduction technique, obviously, has the same output as the previously mentioned techniques; as such it is another possible implementation of the lesson learned on "glacial lake outburst".

Ongoing Considerations

Fundamental to the implementation of lessons learned is information sharing, in particular through the creation of information exchange platforms and the involvement of all stakeholders, and the continuous monitoring of effectiveness of implemented lessons (Krausmann, Mustaq, 2010).

Even disaster reduction techniques and measures can be further deployed by gathering such techniques on a publicly available IT platform. Knowledge transfer in that sense is on both directions: from any user and to any user. In the case of non-expert users, obviously, the intervention of field experts may become necessary. As an example, the worldwide operating DRH (disaster reduction hyperbase) initiative (see for example (DRH project, 2009)) has produced several regional and sub-regional nodes each of which allows for collection of (sub-)regional knowledge on disaster reduction techniques on one hand and for the propagation of such techniques to (regional) users on the other.

Interestingly, the administration of disaster reduction techniques insinuates structuring of such techniques. Similarly to the structuring of a lesson, a disaster reduction technique can be further structured analysing it and collecting relevant information in data fields (read more under (Scheer, Ranguelov, 2008)). Main data field chapters regard

- availability of a technique: all information about acquisition, copyrights, accessibility;

- applicability of a technique: all information about costs of installation, the installation itself, impacts and consequences within the particular context, training needed;

- usability of a technique: all information on running the technique, costs of maintenance, required skills of operators;

- implementation of a technique: all technical, organisational and other details about the implementation itself.

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Abstract
This paper describes the way how lessons that have been learned in the aftermath of a natural disaster can be analyzed and subsequently structured in order to elicit inherent information important for making a lesson valid. A valid lesson – once it gets implemented – will contribute to a reduction of risk in case that a similar disaster will strike again.

In a second step, this paper shows how – after thorough inspection – a lesson can be implemented in various ways thus leading to the definition of different disaster risk reduction techniques.

The paper also illustrates three examples of lessons and the mechanism to derive relevant disaster reduction techniques, each implementing its lesson in a specific manner.

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