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# An evaluation of data sources for entry decision support in rapid-onset disasters

*Daniel P. Eriksson*
*Unit for Support to External Security*
*Institute for the Protection and Security of the Citizen*
*DG Joint Research Centre*
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European Commission
Directorate-General Joint Research Centre
Institute for the Protection and Security of the Citizen

Contact information
Address: Via Fermi 1, 21020 Ispra (VA), Italy
E-mail: ipsc@jrc.it
http://www.jrc.cec.eu.int



EUR 215550 EN



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# An evaluation of data sources for entry decision support in rapid-onset disasters

*Daniel P. Eriksson*

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***Abstract***

If time-sensitive relief is to be dispatched to a far-away location, the decision to do so – the "entry" decision – has to be taken within hours after the disaster for the relief to make an impact. This paper aims to identify which information sources that become available to the decision maker at what time after a potential disaster, and to establish how the provided information can be best utilized based on its inherent and accumulated quality. The research encompasses 46 case studies in central Asia in the period from 1993 to 2003. The study makes clear that a decision-maker will only benefit from satellite imagery if the time required to deliver a digested product to the decision maker is reduced to a matter of hours or if the area of interest is so remote or widespread that the time necessary for on-site reports exceeds that of acquiring and interpreting remotely sensed imagery. In conclusion, model-based decision support systems are important since they provide an early alert that enables other sources to quicker provide information that is more refined.

# Contents

# 1 Introduction

It is widely accepted that pre-emptive measures in disaster prone regions, such as causal oriented institutional support for mitigation and preparedness efforts, is arguably a more cost efficient form of aid compared to traditional palliative post-disaster response (Smillie *et al*. 2003:25). Nevertheless, as shown by Olsen *et al* (2003) the media attention given to disasters, and the political incentive to respond to them, will continue to create a popular interest in donor nations to provide immediate help to those suffering. Accepting that international responses will continue in one form or another, this study investigates how existing channels of information could be used to provide optimal support to the decision-making process in the responding international organisations, from the beginning to the end of the emergency phase following a rapid-onset disaster.

When a natural disaster strikes in a developing country, the undeveloped state of local information infrastructure in remote areas may delay the start of any international or regional intervention. The delay can reach to a point, usually within the first couple of days (Alexander 2000:46; Alexander 2002:198; Shakhmanranian *et al.* 2000:148), after which certain forms of emergency response, such as Search And Rescue (SAR), are no longer beneficial. It is questionable whether it ever will be possible for expatriates to arrive in time, given that in rapid-onset disasters, where SAR is a valid relief alternative, the number of people saved drops dramatically after only 6-8 hours. Examples of this dilemma are the Bam earthquake in Iran 2003 in which 1.200 expatriate SAR experts saved only 30 people, and the Armenia earthquake in 1988 in which 1.800 expatriate SAR experts saved only 60 people.

Consequently, if time-sensitive relief is to be dispatched to a far-away location, the decision to do so has to be taken within hours after the disaster for the relief to make an impact. If there is no direct communication to a source with precise and reliable information on the disaster situation, decision-makers will have to resort to using information from subjective sources, such as the media and local contacts, for developing an informal needs assessment[1].

## 2 Objective and assumptions

An underlying assumption for this study is that information with a known accuracy can be beneficial to the decision-making process even if the accuracy is low. Supplying decision-makers with a schematic overview of the information flow enables the selection of a moment when the information envelope — i.e. the difference between the estimated minimum and maximum — is of an acceptable breadth to be considered as a trustworthy enough foundation for action.

Among the case studies are events in which an international response took place as well as events that involved no international response. The study does not intend to answer the question of whether a response was unwarranted or whether a response should have been made in a situation where there was none. The focus, rather, is on the information flow and information availability building up to a decision to take action, or to not take action.

In essence, **it is the objective of this paper to identify which information sources becomes available at what time after a potential disaster, and to establish how that information can be best utilized based on its inherent and accumulated quality**.

[1] As opposed to a formal needs assessment as described by Darcy and Hofman (2003)

# 3 Definitions

The decision to engage in a crisis is termed by European Commission Humanitarian Office (ECHO) as the "*entry*" and the decision to terminate an intervention is termed as the "*exit*". ECHO (2003) aims to concentrate relief in the areas with the highest humanitarian needs. ECHO uses five groups of factors closely tied to vulnerability to indicate humanitarian need. In this document *need* is defined as the quantitative requirement of assistance. The definition of *vulnerability* is close to that of IFRC (1999) combined with the social and hazard dependent vulnerability aspects as presented by Schneiderbauer and Ehrlich (2004). *Loss* means the sum of the damage that a hazard causes on the affected society, e.g. the loss of life, structures, or financial means. *Hazard data* are the attributes and characteristics of a hazard. In the case of earthquakes these include epicentre location, magnitude, hypocentral depth, and time.

## *3.1 Data quality*

All data has an inherent quality. Data quality can be divided into Accuracy and Completeness. *Accuracy* relates to the lack of errors in the data — i.e. the difference between the stored value and the measured reality. *Completeness* refers to the lack of omission errors in the database — i.e. if all desired aspects of an object are stored. (Vereign 1998)

The data quality also depends on the intended use of the data. If the basic seismic data is intended to be used for describing where an event took place, it could be seen as complete, but if the intention is to say whether the event requires an international response, it can be considered incomplete.

# 4 Method

In this study, earthquakes are examined as an archetypal form of rapid-onset disasters. The limited geographical impact and the general availability of information, software tools, and models make earthquakes well-defined and tangible phenomena compared to other forms of natural disasters. In addition, earthquakes are a truly rapid onset type of disaster. Earthquakes are thus a suitable choice in relation to the more abstract and complex disasters such as food-security crises and conflicts. As the data and models used in loss and needs assessment in other types of natural disasters are in many ways different from those used in earthquakes, a more inclusive approach would have made the task of analysing data quality too vast.

This study entails 46 earthquake events that occurred in the central Asian region in the period from 1993 to 2003. The central Asian countries considered in the study are Afghanistan, Iran, Kazakhstan, Kyrgyzstan, Pakistan, Turkmenistan and Uzbekistan. The Xinjang and Xizang provinces of China are also included. Its high seismicity and the high vulnerability to earthquakes of its vernacular housing and infrastructure make the region a suitable choice for case studies to fulfil the objective of the research. These cases were selected with the aim of including all earthquakes for which information existed in any one source. Multiple areas and cases were selected with aim of providing a base of events that allow for generalisation, as described by Thomas (1998). The study uncovered no cases where advanced forms of decision support systems had supported operational decisions. Several such systems were field-tested in the 2003 Boumerdes earthquake in Algeria. The Boumerdes earthquake is consequently included in the study in order to fill the gap.

**Table 1: Studied earthquakes per year and country**[2]

| Country/Year | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | Sum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Afghanistan | 0 | 1 | 0 | 1 | 0 | 2 | 1 | 1 | 2 | 3 | 0 | 11 |
| China[3] | 1 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 6 |
| Iran | 1 | 3 | 0 | 0 | 3 | 3 | 3 | 2 | 1 | 3 | 0 | 19 |
| Kazakhstan | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| Kyrgyzstan | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Pakistan | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1[4] | 2 | 0 | 5 |
| Tajikistan | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 2 |
| Turkmenistan | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| Uzbekistan[5] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ***Annual Sum*** | ***2*** | ***5*** | ***0***[6] | ***3*** | ***7*** | ***5*** | ***4*** | ***5*** | ***4*** | ***9*** | ***2*** | ***46*** |

The reference dataset for events in central Asia is based on information derived from the Centre for Research on the Epidemiology of Disasters (CRED), the United Nations Office for the Coordination of Humanitarian Affairs (UN OCHA), the world's news media, various donors[7], seismological institutions, national and international NGOs, and scientific institutions[8]. Before 1999, the main media source used in the study is a database constructed for this purpose with articles produced mainly by AFP, AP, Reuter, and UPI. From 1999, the Internet has served as the main source of news articles since by that time it had matured and contained a broad selection of archived material. For each case study, information was gathered on the information technology and data usage over time, similar to Comfort (2000), as well as the change in the reported data over time for all sources.

2 The country is determined by the location of the epicentre even in cases where the major impact was in a different country. The 2003 Algeria earthquake is not displayed in this table.
[3] Only Xinjang and Xizang provinces.
[4] This epicentre was in Gujarat in India.
[5] The 2003 earthquake in Kazakhstan had an impact on Uzbekistan, but no events of interest with epicentres in Uzbekistan were identified during the period.
[6] No events of interest during 1995.
[7] Mainly ECHO and member states of the European community.
[8] For instance EERI (2003) and Kaji (1998)

A set of decision support tools and methods were reviewed as part of the study. The selected routines are:

- the Disaster Alert Tool of the European Commission Joint Research Centre (de Groeve 2002),
- the UN Risk Assessment tool for Diagnosis of Urban areas against Seismic disasters tool - also known as the RADIUS tool (UN ISDR 2001),
- and the Quakeloss[9] method (Shakhramanian *et al.* 2000) of the World Agency of Planetary Monitoring and Earthquake Risk Reduction (WAPMERR).

These tools were selected based on their availability and relative ease of application on a global scale. The tools were applied on a subset of the case study events with the aim of testing the usability of their output. Their operational time-constraints were estimated by applying them, in real-time, on events that occurred during the course of this study[10]. The review did not focus on the underlying logic of the tools and methods but rather on the required input and the usability of the output — assuming a black box approach. The possibility to include alternative methods such as the statistical models created by Gutierrez *et al.* (2004) and Badal *et al.* (2004) was investigated. However, those methods had not yet reached the maturity required to apply them to the selected case studies.

## 5 The entry decision

The occasions in which "entry" decision support is of importance are not the high impact humanitarian cases for which the necessity of an international response is obvious, but rather the intermediate humanitarian-impact events where the demand for an international response is not immediately apparent. The remoteness of an area or aspects such as vulnerability or reduced local coping capacities can obscure the need. Sending needs assessment experts to a disaster location takes time. The intention is that a needs assessment

[9] Only a set of output data was analysed. The method as described by Shakhramanian represents the core of the Quakeloss method.

team should reach a disaster area within 24 hours (UNDAC, 2003) after the relevant authorities have taken the decision to send them. The more time-sensitive form of relief, such as SAR teams or medical supplies that needs to be purchased and shipped, can do little good past the first couple of days after an event (Shakhramanian *et al.* 2000) has taken place.

Simplified, the situation for the decision-makers immediately after a disaster is the following: The decision can be taken based on the available information or one can wait for information with higher quality. However, the longer the waiting time, the lower the benefit of a potential response effort. Benini *et al.* (2005) suitably term this equilibrium, that is seen in several domains of development and disaster management, as "Speed kills vs. Victims cannot wait". In these cases, making an extemporaneous decision, thus shortening the response time and using information of lower quality, increases the risk of a suboptimal decision. Moreover, the commitment of valuable assets, including needs assessment experts, to an event that turns out not to be a disaster could result in a reduction of the resources available for future disasters.

The lack of high quality information is not always the source of a temporal bottleneck in disaster response. Political agendas in both the responding nation(s) and the affected nation(s) can postpone the acceptance of an event as being a disaster. Olsen *et al.* (2003) argued that media attention could occasionally add confusion and delay or distort the response even further by giving disproportioned exposure to an event. However, Koethe (2003) show that a rule-driven automated analysis of data provides an objective platform to inform political decision-makers in affected nations, media, and the public of the probable need. Thus, high quality information has the potential to accelerate and improve the response effort in many regards.

[10] The February 2004 earthquake in Moroco and the December 2003 earthquake in Iran.

## *5.1 Decision support*

One mean of facilitating the decision process is to apply Decision Support Systems (DSS). A DSS can help a decision maker in various aspects. In the field of business administration Andersen and Gottschalk (2001) divide DSS users into *Strategic, Tactical,* and *Operational* decision-makers — see Table 2.

Table 2 DSS in business management (*Gottschalk 2002, modified*)

| Type of DSS | Users | Users' requirements | Questions |
|---|---|---|---|
| Strategic control | Very few | Unstable, not known in advance | What kind of business, product, and market? |
| Tactical control | Not so many, but in different dept. | Mostly stable | Given the business, what kinds of resource is needed and how it is best developed? |
| Operational control | Many, in different dept. | Stable, except for changes in products | Given the business and resource, how it is best utilized? |

Drawing an analogy from business management to disaster response, what is the role of the users of DSS in the international disaster relief organisation? Darcy and Hofman (2003) see needs assessment as a process of informing the decision-maker in relation to four main questions:

- Whether to intervene;
- The nature and scale of the intervention;
- Prioritisation and allocation of resources; and
- Programme design and planning

These four questions are reiterated down through the hierarchy of the relief organisation. The "Humanitarian Charter and Minimum Standards in Disaster Response"(McConnan 2000:58) lists further, more detailed, questions encountered by staff in the field. Combining the questions posed by McConnan (2000) and by Darcy and Hofman (2003) with the theories of Andersen and Gottschalk (2001) the approximate roles of the decision-makers in an international relief organisation can be deduced.

Comparing disasters in several countries, the strategic decision-maker decides to which type of disasters and in which locations his or her organisation can provide the best quality of intervention and determines the appropriate nature and scale of such an intervention, often in financial terms. In line with what Comfort (1993) describes, a re-iteration occurs when the tactical decision-maker encounter the same questions but on an on-site level where given physical resources such SAR assets have to be assigned on a priority basis among cities, blocks, and buildings. The two types of decision-makers do not have to be members of the same organisation. A strategic decision-maker can be part of an organisation that does not have direct access to relief material, but supports relief actions through funding. In small organisations, the strategic decision maker may also be the tactical decision maker. In other words, the person deciding whether to respond to a disaster is also the one who manages the response of the organisation on-site.

A generic strategic DSS bases its calculations on contextual support methodology as explained by Kersten (2000) with focus on "*analysis & reasoning*" combined with "*judgement refinement*". In contrast, the tactical DSS assists by keeping track of what has been done, what is left to do, and how to do it in an optimal fashion —much in line with a *structural support method* (Kersten 2000).

Table 3 clarifies the decision sequence during the phases immediately before and after a disaster based upon the combination of the theories of Darcy and Hofman (2003) and Andersen and Gottschalk (2001). Being the actor that takes the initial decisions, **the strategic decision-maker is in focus in this study**.

Table 3: The decision sequence in international disaster response (own)

| Time | Phase | Task | Decision-maker | Question/Decision |
|---|---|---|---|---|
| ↓ | Disaster impact | Event alert | Phenomena Experts | What is the nature and location of the event? |
| | | Loss assessment | **Strategic level** | **Is the event a humanitarian disaster?** |
| | | Needs assessment | | **Is an international response required?** |
| | | | | **What is the optimal nature of the response?** |
| | | | | **What is the optimal scale of the response?** |
| | Response | Coordination | Tactical level | Which are the affected areas? |
| | | | | How should the aid be prioritised between the areas? |
| | | | | How should the aid be delivered? |
| | | | | When is the emergency phase over? |
| | Recovery/ Mitigation | Policy creation | Policy maker | What were the lessons learned from the response? |
| | | | | Should policies with regards to Response, Recovery, Mitigation, and Prevention be changed? |

## *5.2 Data criteria*

Table 3 contains a list of the questions that requires answers after a disaster strikes. What data is valuable in order to answer those questions in the entry decision-making process? Information inundation of the decision maker is not better than a lack of information (Currion 2003). It is hence of importance to identify which types of data that are relevant. Take the first question: "Is the event a humanitarian disaster?". The philosophical constituents of a disaster are something that has been analysed in depth in other studies (Quarantelli 1998) but what are the quantifiable aspects of a disaster that could support an entry decision? For the entry decision maker, a disaster is an event that requires international intervention. The quantifiable aspects of a disaster can be assigned into four distinct categories: (a) hazard data, (b) vulnerability data, (c) loss data, and (d) needs data.

In the case of earthquakes, seismological institutions provide *hazard data* (a). Selecting the most accurate institution is a challenge, but it is clear that those institutions as a group represent the most authorial source for impact data. Examples of earthquake hazard data are epicentre location, magnitude, and hypocentral depth.

It is possible to collect and store *Vulnerability data* (b) before the hazard strikes. ECHO applies its in-house Global Needs Assessment (GNA) index, which they update on an annual basis. Schneiderbauer and Ehrlich (2004) investigate how vulnerability relates to different natural hazards and identifies sets of indicators that can be collected before a disaster strike to form an estimate of the vulnerability of the affected population. Other vulnerability data can be gathered from spatial data warehouses, one example being the LandScan population density raster (ORNL 2002). In essence, since vulnerability data can be available before a hazard strikes and since this type of data does not change significantly as the event develops, vulnerability data evolution will not be of interest to this study.

In the mass media, the most common reported *indicators of loss* (c) are the number of deaths, the number of injured, and the number of structures damaged or destroyed. These measures should not be directly translated to a requirement for entry since:

- These are measures of loss and not of needs;
- De Groeve and Eriksson (2005) showed that loss indicators, individually or aggregated, only have a weak correlation to the reported need and resulting response;
- The definition of the measures can be interpreted in several ways. For instance, it is not always clear that an earthquake is the cause for the death of a person that already was in ill health;

The alternatives to traditional loss measures are not plenty. Olsen *et al.* (2003) show that other factors such as media coverage, donor interest, and the presence of NGOs are good indicators of the level of delivered emergency assistance. By definition, those factors come about after the point at which an "entry" decision has to be taken and are hence not of benefit to the decision process. In the absence of better alternatives loss data will continue to have a role in the decision making process and is hence seen an constituent group of information.

In *needs assessment* (d), the measurements are more concrete than in loss. Government bodies and international coordinating organisations often produce lists in which they express needs in absolute numbers of items or personnel deemed to be required. However, as the estimated loss forms the basis for the calculation of the amount of need, the reports of needs will not come available before the reports on loss. In addition, quantified needs vary over time. The amount of needs at a particular time is a function of the amount of aid received in the area and the amount on its way there. In an ideal situation, by knowing the actual losses sustained by the affected population, and its coping capacity, it would be possible to estimate the absolute needs before any external response process is initiated. Even so, as de Ville de Goyet (1993) argues, if the response is not coordinated and well-structured with regards to information sharing, the ability to correctly estimate the actual need in the disaster area at an exact point in time diminishes as relief arrives in the disaster area.

Since it is the objective of this paper to find the time versus quality dependencies of sources, an inclusive approach has been opted for and all available sources containing data on hazard, vulnerability, loss, and needs were incorporated.

# 6 Data source typology

Adopting a data source typology facilitates the macroscopic analysis and comparison of the available data sources. By observing an archetypal earthquake, the chain of events can be the following. After an archetypal earthquake occurs in a developing country seismological institutions will record the *seismic data*. At the site, the affected population will be the first to notice the effects of the event. *Mass media* and *local government* will receive initial information from the population. Occasionally, large organisations have permanent *on-site representatives* that dispatch situation reports to their employers. To minimise the delay and increase the objectivity of the information in the early stages, one may refer to one of several existing *techniques for conducting formal loss and needs assessments remotely*. In the last stage, data from *satellite platforms* becomes available.

As presented in Table 4, the information sources can be grouped into (a) On-site source such as organisation representatives, local government and reporters, (b) Remotely sensed seismic data from seismological institutions, (c) Automated loss and needs assessments from models, and (d) Remotely sensed data from satellites.

**Table 4 Data source typology**

| On site sources | Remote sources |
|---|---|
| Eye witnesses | Seismological institutions |
| Media | Loss and needs model output data |
| Government | Satellites |

## *6.1 On-site sources*

Some time after the disaster strikes accounts based on *eyewitness reports* will flow out of the country through conventional channels such as *mass media* or word of mouth. The delay and objectivity of these reports will depend on factors like the skill of the reporter, the extent of the event, the remoteness of the event, and the dedication of the local and national authorities in sharing information (Keen and Ryle 1996; Cate 1994).

Benini (1998) point out that the highest quality data come from the experts, trained in making loss or needs assessments, working on the ground in the disaster area. These assessments commonly require days for completion since the experts have to travel to the disaster area to collect the sought after information and then compile and disseminate their report[11].

Mass media often provide the bulk of the information in the initial stages after an event. Even though the media report themselves tend to be inaccurate it is possible to benefit from them by adopting a macroscopic approach. This can be done by observing the frequency of the reports on the subject or the location of the reporters i.e. how many reports

[11] Personal communication in November 2003 with P.A Berthlin, rapid response asset manager, Swedish Rescue Services Agency (SRSA)

have been released. In addition to the frequency, the location of the reporter can provide clues as to the severity of the event. Responders refer to this as the "black hole" situation[12]. A black hole situation is when it becomes evident that all reports are emanating from around the affected area and that the potential media sources in the affected area remain silent. This may indicate that the impact is severe enough to prevent reporting.

## 6.2 *Remotely sensed seismic data*

In the case of earthquakes, for those not directly affected by the event, the first indication that something has occurred comes from seismographs. Seismic data become broadly available minutes after the event (USGS 1997). Initial seismic data lack hypocentral depth, but there will be estimates of the epicentral location and magnitude of the event. If an earthquake is of high magnitude, one can expect that the data is accurate and that the approximate focal depth will be known within an hour after the event (USGS 1997) depending on the distance to the epicentre from the sensors. However, even when complete and accurate, seismic data alone are not sufficient to judge whether an event will require international intervention. Due to an apparent lack of alternatives, some responding organisations[13] rely on pure seismic data for providing themselves with an initial alert of the occurrence of a potentially serious event. This gives an alert every time an earthquake occurs, even in areas with very low vulnerability, such as those with low population densities. A very imprecise early warning routine is an inappropriate basis for a response, but it might still be appropriate for alerting experts of an event that could need further investigation.

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[12] From presentation made by P.A. Berthlin at the GDAS Conference in Geneve, December 2004.

[13] Personal communication in November 2003 with P.A Berthlin, rapid response asset manager, Swedish Rescue Services Agency (SRSA) and in February 2004 with Fidel Suarez of the Spanish rescue service.

## 6.3 *Automated Loss and Needs assessment models*

In order to rapidly obtain more complete information on the loss in an event, without having to access the affected area, models can be applied. The models are commonly based on some function of spatial, or merely numerical, seismic and vulnerability data that produce an estimate on one or more of the following variables: population affected, number of injured and dead, and structural impact. The methods applied to arrive at an estimate differ from one another, but are either fully automatic or require the involvement of a human expert – see Table 5. For an automated system, the accuracy of the output can never exceed that of the input data. The first and simplest models which could be used after an event combine seismic data with proxy data for vulnerability, such as spatial demographic data, to form an estimate of the number of affected individuals around the epicentre. Combining these two sets of data is an uncomplicated operation that can be performed automatically without human involvement. This approach gives an estimate of population within a set radius of the epicentre. An example of a tool, reviewed in this document, which applies this model is the JRC's Disaster Alert Tool (de Groeve 2002). The radius within which the population is affected is actually better defined as a simple function of magnitude and hypocentral depth (Yuan 2003). Without the latter, a model output cannot exceed the quality of the estimates calculated based on the seismic data alone. The requirement to include hypocentral depth forces these models to await the updated seismic reports that contain such data.

In order to provide more accurate outputs, models that are more intricate incorporate additional data to better represent the seismic phenomena and the vulnerability of the area. Applying models that depict the seismic aspects of the earthquake through intensity raster diagrams or isoseismic curves improves the representation of the seismic pattern of the event. However, as the number of included factors increases, the task of automating the model becomes ever more complex. This is particularly true when including factors that lack a direct objective relation to the seismic phenomena. An example of this is that the shape and attenuation pattern of the seismic representation can be improved by taking into account the proximity of fault lines, the faulting type, the soil type, and the topography in the area (Yuan 2003). It is a very challenging task to incorporate the effect of these factors into the seismic picture using an automated model. A solution is to use human experts to refine the seismic representation, at the cost of time and resources.

To improve the representation of the overall spatial vulnerability, population distribution can be combined with data on either structural or social vulnerability. Such data are rarely found with a resolution on sub-national level. If direct data are not available, proxy indicators of vulnerability, such as GDP per capita or the UN's human development index (HDI) can be applied (Chen *et al.* 1997;Yong *et al.* 2001). The level of subjectivity in modelling vulnerability is arguably higher than for the seismic models and consequently more complex to model automatically. Despite the difficulty, Shakhramanian *et al.* (2000) showed that it is possible to accomplish. Nevertheless, the use of human experts is still necessary to derive full benefit from the existing ability to model vulnerability.

**Table 5 Reviewed Decision Support Systems according to modelling approach**

| Tool | Approach | Inherent Baseline Data | Coverage | Output |
|---|---|---|---|---|
| Disaster Alert Tool (JRC) | Simple spatial arithmetic | Demographics | Global | Affected population |
| Quakeloss (WAPMERR) | Expert enhanced spatial analysis | Demographics, Building quality | Global | Building loss; Injured and dead; Intensity field |
| RADIUS (United Nations) | Spatial analysis leading to a risk assessment | None | Can be used globally if local baseline data exist. | Building loss; Injured and dead; Intensity field |

In order to use interrelated factors to re-evaluate the input data, the final combination of seismic representation with local vulnerability might require human involvement — i.e. a seismic characteristic might exert a disproportionate impact on the vulnerability or the likelihood of secondary disasters. Using human experts requires time and, in the end, what governs quality of the output of the models is the readiness to invest time and human expertise to refine the quality of the input and output data.

## *6.4 Remotely sensed satellite data*

Since this study focuses on disasters in areas with poor infrastructures, the only source of remote sensing to produce results in such areas within reasonable time are sensors on satellite platforms. Other platforms such as airplanes and helicopters have to be hired and sent to the affected area. This can be very costly with respect to both time and money. Satellites have another advantage in that they circumvent the unwillingness of some states to have their territory examined by airborne means. There are two main possible uses for remotely sensed imagery in the response phase following an earthquake: -

- navigation: in case of insufficient access to up-to-date maps, remotely sensed images can help rescue organisations navigate their way through the disaster area; and
- loss assessment: using manual and automated methods, the images can be analysed in order to detect where damage has been inflicted.

When replacing the use of a map, optical images are better suited than radar imagery, as the former are easier for an inexperienced user to comprehend. However, optical remote sensing requires daylight and the absence of clouds. These limitations can cause a delay in the delivery of the image. If the image is to be used solely for navigation or as a pre-event reference image, it is often possible to find copies in the archives of the image providers. The main weakness of non-optical, radar, images are that they require expert interpretation before being used for any purpose and that the resolution is lower than that of many optical sensors. Their main benefits are that they function in all light conditions, regardless of the presence of clouds and smoke.

When performing loss assessment, the two main methods entail using a post-event image only or a pair consisting of pre- and post- event images. Independently from the method applied for loss estimation partial damage and damage to the vertical parts on structures can seldom be detected. Al-Khudhairy *et al.* (2002b) apply a semi-automated method for detecting severely damaged structures in a post-event image and concluded that even though the method is feasible the commission errors are considerable[14]. However, one important conclusion of their study is that automated damage detection is more accurate when applied in rural areas where structures are relatively isolated. If the inaccuracy of automated loss estimation using only a post-event image prevents the information to be used for decision support, expert interpretation is required to improve the accuracy. Even with expert input only totally collapsed structures that are not hidden in shadows can be accurately detected (Shinozuka 2003).

By applying change detection algorithms on an image pair and using expertise it is possible to detect collapsed or even severely damaged buildings with high accuracy depending on the method used (Shinozuka 2003; Al-Khudhairy *et al.* 2002a). A considerable difficulty lies in finding a pre-event image that is compatible with the acquired post-event image. This is particularly true in rural areas and developing countries since image archives seldom contain images of such regions.

Considerable amounts of precious time elapse from when a disaster has occurred to when a post-event image – including image acquisition, reception, processing, and delivery – is ready to be used by the decision-maker. Al-Khudhairy and Giada (2002) showed that, not including analysis, the total delivery time in an optimal case can be 48 hours but more realistically be at least three or four days depending on revisit time of the platform and the metrological conditions in the area. Even though there are many weaknesses in applying remote sensing for initial loss assessment, the sensors and methods are constantly improving and the reliable detection of damage to complex structures such as bridges and roads will soon be possible (Shinozuka 2003; Eguchi 2003). It is important to remember that even under

[14] Using selective object oriented image classification to detect severely damaged or collapsed structures in a rural environment the omission errors were 0-25% and the commission errors 14-92%

optimal conditions, remote sensing can at best only assist navigation or loss estimation. Needs assessment will have to be conducted based on the losses estimated using remote sensing combined with other techniques.

# 7 The case study results

Table 6 is produced based on all the information collected on the earthquakes in Table 1. There are many factors affecting the quality and delay in availability of the data. Examples of such factors are the state of the local infrastructure and the remoteness of the location. By making the extremes of the case studies visible, a clearer picture emerges. The collated set of information sources for loss and needs assessments found in the case studies and their time-versus-quality dependencies are shown in Table 6. The quantitative definitions of the columns *Accuracy* and *Completeness* are presented in Table 7. *Accuracy* indicates how well the data collected at a certain stage corresponds to the reality intended to be measured, i.e. how well the reported hypocentral depth corresponds to the actual depth. *Completeness* is divided herein into two indicators. One related to whether it is possible to answer if an international response is required – the first question of Darcy and Hofman (2003) – whether there should be a response to an event – and another indicator related to how effectively the accumulated data can form the basis for a complete formal needs assessment as described by Darcy and Hofman (2003).

## *7.1 Data availability in the case studies*

It was impossible to pinpoint the time of availability for some of the reports. In addition, even if a report contains meta-data on when it was produced, in no case does meta-data indicate when the decision-maker received it. For instance, reports from the media rarely contain more time-related meta-data than the date of release. In such cases, Table 6 indicates only the unit of time within which data were made available to decision-makers. The information produced by the sources in Table 6 is not uniquely divisible. The later in time after an event that a source releases information the more information from preceding sources tends to be included. For instance, academic studies, which are among the last to appear, will include information from all sources. Marked with red in the table are those sources that fully depend upon preceding sources in order to provide value-added information. For those sources, the time-frame availability is in addition to the time required for acquiring the data that the source is based upon.

A common source of information for responders is the situation reports produced by UN OCHA[15]. These reports are a medium for information from other sources, such as seismological institutions and governmental appeals, to be disseminated. This is an example of a situation when the information source is different from the information medium.

[15] Personal communication in November 2003 with P.A Berthlin

Table 6: Data availability and Quality over time

| Data | Source | Time-frame of availability | | Data Quality | | |
|---|---|---|---|---|---|---|
| | | Min | Max | *Accuracy* | *Completeness* | |
| | | | | | *Disaster?* | *Needs?* |
| Epicentre, Magnitude, Time | Remotely sensed seismic data | Seconds | Minutes | Intermediate | Low[16] | None |
| Depth and improved Epicentre and Magnitude | Remotely sensed seismic data | Minutes | Hours | High | Low[16] | None |
| *Affected population estimate* | *Automated loss and needs assessment* | *+ minutes* | *+ hours* | *Low* | *Low* | *Low* |
| *Mortality estimate* | *Automated loss and needs assessment* | *+ minutes* | *+ hours* | *Low* | *Intermediate* | *Low* |
| *Mortality, Injury and Building loss estimates* | *Automated loss and needs assessment*[17] | *+ minutes* | *+ hours* | *Intermediate* | *Intermediate* | *Low* |
| Situational accounts | On-site representatives | Minutes | Hours | High | High | Intermediate |
| Textual eye-witness accounts | Media | Minutes | Days | Low | High | Intermediate |
| Injured; dead; homeless; buildings and/or villages damaged or destroyed. | Loss assessment by Government | Hours | 13 days | Intermediate | High | Intermediate |
| Injured; dead; homeless; buildings and/or villages damaged or destroyed. | On-site loss assessment by Coordinating body | 3 days | 4 days | High | High | Intermediate |
| List of needed relief items and expertise. | National Government appeal | Hours | 16 days | Intermediate | High | High |
| List of needed relief items and expertise. | On-site needs assessment | 3 days | 4 days | High | High | High |
| List of dispatched material and shortfalls | Coordinating body | 1 day | 6 days | High | High | High |
| Post disaster maps for navigational purposes | Remotely sensed optical imagery | 2 days | Weeks | High | High | High |
| *Post disaster maps with estimated structural damage* | *Expert interpreted Remotely sensed optical and radar imagery* | *+Hours* | *+Days* | *Intermediate* | *High* | *High* |
| Building damage type and cause | Structural survey | Weeks | Months | High | High | High |
| | Academic reports | Weeks | $\infty$ | High | High | High |

[16] The Completeness is High if taking into account the non-disaster events that could be excluded.
[17] With human expert enhancement.

Table 7 Definition of applied terminology for data quality

| | Definition | None | Low | Intermediate | High |
|---|---|---|---|---|---|
| **Accuracy** | Percentage of the studied cases where the reported value (when taking into account the reported confidence interval) did not correspond to the final value. | N/A | <60% | 61-80% | >80% |
| **Completeness** | Percentage of the studied cases where the accumulated data would have been sufficient to form the basis for: 1. answering whether there will be a need for a international response —i.e. is the event a disaster? 2. a formal needs assessment. | 0% | <60% | 61-80% | >80% |

Figure 1 shows how the difference between the available minimum and maximum values of a generic indicator changes over time. The only general rule for the difference between the maximum and minimum is that it eventually reaches zero when a definite value is agreed upon. The average time for this is in the cases studies were, depending on the severity of the event and the variable in question, about a week. Before reaching that state, the difference fluctuated. Based on the earthquakes studied it is impossible to identify consistent errors in the reporting of a given group of sources. A source that gives the minimum in one disaster might not do so in another.

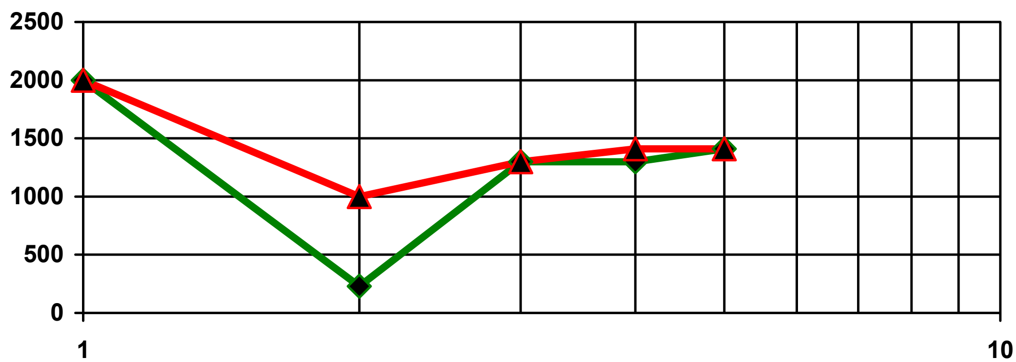


Figure 1: Envelope of indicator value, days after a case study event[18]

[18] Minimum and maximum number of injured reported in the 2002 Quazvin, Iran earthquake.

## 7.2 Decision process in the case studies

No indications of decision makers having used advanced DSS operationally in any of the case studies were found. There are cases where DSS were used for research purposes. Examples of this are the 2003 Boumerdes earthquake in Algeria, and the 2001 Badin earthquake (epicentre in Gujarat, India). However, in those events the DSSs were only tested and thus not used for making operational decisions. The natures of the systems applied in the two events were such that they would not have worked without supervision and interpretation by experts. Instead it was found that several organisations[19] use the simplest forms of DSS — an alert system based on magnitude alone.

The absence of evidence of the use of advanced DSS tools accounts for not only the model-based tools reviewed as part of this study, but also to other common applications such as the HazUS (FEMA 2003), CATS (Swiatek and Kaul 1999), and EPEDAT (Goltz *et al.* 1997)[20]. Instead, the most important sources of information, based on how the actions of the international organisations corresponded to information from a certain source, seem to have been either local government or an international co-ordinating body, often the UN OCHA.

Through interviews with relief organisations, it became clear that the most valued sources for estimating initial need are in-country contacts, such as country representatives paired with information from relief networks, such as the OCHA Virtual Operations On-Site Coordination Center (Virtual OSOCC) and the more general ReliefWeb.

## 7.3 What governed the decision in the case studies?

No clear correlation was found between any of the measured aspects of the studied events and the response reported by OCHA. Intense media attention tended to accompany large financial responses, but the direction of this correlation is not clear.

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[19] Personal communication in November 2003 with P.A Berthlin, rapid response asset manager, Swedish Rescue Services Agency (SRSA) and in February 2004 with Fidel Suarez of the Spanish rescue service.
[20] None of these systems provides global operability as standard.

# 8 Discussion

From Table 6, it is clear that a strategic decision-maker will seldom be able to take advantage of remotely sensed imagery in the immediate aftermath of a disaster. This is mainly due to the amount of time required to acquire and then to interpret an image. To benefit from remotely sensed imagery within hours after a disaster, one currently has to resort to using a pre-event image, if available, of high-resolution. Such an image will only be useful for navigation purposes, and, possibly, to provide an overview of settlements located in remote areas.

In cases where existing mapping is inadequate, remotely sensed imagery can be useful in supporting the tactical decision-makers in logistic tasks. There can be situations where more time is available. If a decision to respond is not taken within a couple of days, it will be feasible to consider the use of analysed image pairs. An example of a situation where a decision can drag on time is a case with a widespread affected area or a case with damage on local infrastructure that inhibits the ability of launching reconnaissance efforts on the ground. In such a case, the days that are required to process and analyse the images are inferior to the number of days that would be required to reach all the areas by land. If suitable pre-disaster imagery is unavailable the post-disaster imagery will be virtually useless for loss assessment since the accuracy of the loss assessment models that build solely on a post-event image is still too low unless the structural damages are extreme.

If remotely sensed imagery is not useful for supporting decisions in the initial phases of international response to a typical rapid-onset disaster, the alternative solution is to make the most out of on-site sources combined with loss and needs assessment models. The models require human analysis in order to achieve high accuracy. Since it is impossible to wait for all sources to agree on the loss and needs created by a disaster, how much time is optimally spent on acquiring information from the sources that precedes the remote sensed imagery - such as the opinions of human experts and more advanced DSS? Sources, other than needs assessment models such as those presented in Table 5 and remote sensing, that possibly could deliver information include media, government, and country representatives. However, the subjectivity and accuracy of media, and, sometimes, local government, are questionable. In the first hours after a disaster it is unrealistic to expect that a country representative, in a context with imperfect infrastructure, will be in a position to both have an overview of the situation and be able to communicate with a decision-maker on another continent. Nevertheless, these sources can be useful for calling off a disaster alert. If the initial sources —i.e. models —indicate it being possible that an event is a disaster whilst the media reporters, government officials, and ambassadors claim that little or no damage has occurred, one could conclude that the on-site sources are more likely to be correct. If on the contrary are direct indications from the on-site sources of damage or if a "black hole" situation arise there is good reason to put response resources on alert while the investigation continues.

The sources becoming available, between model output and the satellite-based assessments can therefore assist in excluding non-disaster events or indicate potential disaster events, but it is not certain that they will be able to provide an accurate needs assessment if international relief is required. It is important to be clear that though information sources provide output of differing quality, a source with higher quality is not necessarily better than sources of inferior quality. The purpose of the faster sources can be seen to be to alert the more exact and time consuming sources of an event that perhaps could be a disaster.

# 9 Conclusion

To be effective, a decision on whether to intervene and how to intervene in the aftermath of a disaster, an “entry” decision, has to be taken within a limited amount of time. This amount of time is a function of the window of time in which the supplied type of aid is effective minus the reaction time of the responders - which includes the travel time to the disaster zone. If no direct communication with a source that has correct and indisputable information on the disaster situation is possible, an “entry” decision has to be taken based on the information at hand. Model-based decision support systems are hence of importance for “entry” decisions in that they provide an early alert that enables other sources to provide more refined information. Human experts can improve the output of the models, but this will be at the cost of time.

Remotely sensed imagery will only be useful for the strategic decision-maker if a.) the time required to make the analysed material available to the decision maker is reduced to a matter of hours; or b.) the area of interest is so remote or widespread that the time required for on-site reports exceeds that of acquiring and interpreting remotely sensed imagery.

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Abstract

If time-sensitive relief is to be dispatched to a far-away location, the decision to do so – the "entry" decision – has to be taken within hours after the disaster for the relief to make an impact. This paper aims to identify which information sources that become available to the decision maker at what time after a potential disaster, and to establish how the provided information can be best utilized based on its inherent and accumulated quality. The research encompasses 46 case studies in central Asia in the period from 1993 to 2003. The study makes clear that a decision-maker will only benefit from satellite imagery if the time required to deliver a digested product to the decision maker is reduced to a matter of hours or if the area of interest is so remote or widespread that the time necessary for on-site reports exceeds that of acquiring and interpreting remotely sensed imagery. In conclusion, model-based decision support systems are important since they provide an early alert that enables other sources to quicker provide information that is more refined.

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