Facing the Actual Disaster Landscape.
A trend towards more Disasters out of the Box?

Hans De Smet[1], Bert Schreurs[2] and Jan Leysen[3]

Abstract:

Given recent disaster research, it seems that our planet has become a more dangerous place to live than ever before. Despite the rapid progress of knowledge and technology, millions of people have been killed, seriously injured or materially afflicted by some kind of disaster, which is the consequence of important changes in the current disaster landscape. On the one hand, disaster statistics indicate that there has been a general increase in the quantity of disasters since the second half of the latest century. On the other hand, disaster researchers also mention a qualitative shift in the disaster landscape, challenging the existing emergency management skills and capacities. Unfortunately, no academic study has been found in disaster literature proving such an evolution. In order to be better prepared for future disasters, it is indispensable to study the qualitative change in the disaster landscape further in depth. In this chapter, we first discuss the changing nature of hazards and the ensuing disasters, as well as the driving forces behind this evolution. Then we concentrate on the existing theoretical

[1] Belgian Royal Military Academy, Department of Economics, Management and Leadership, hans.de.smet@rma.ac.be
[2] Maastricht University School of Business and Economics, Department of Organization and Strategy, B.Schreurs@MaastrichtUniversity.nl
[3] Belgian Royal Military Academy, Department of Economics, Management and Leadership, jan.leysen@rma.ac.be

approach regarding the evolution of the disaster landscape and essentially focus on the main characteristics of modern disasters as described in literature. These characteristics are then used for the development of the Disaster Impact and Complexity Diagram, a tool which examines disasters from the perspective of impact and complexity in order to determine trends over the years. The last section of the chapter deals with a study of a set of randomly selected disasters from 1900 until 2010, using the DI&C-Diagram. Findings are discussed and important points of interest in dealing with modern disasters are highlighted.

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Introduction

On Friday March 11, 2011, at 02:46 p.m. JST (00:46 a.m. EST), a 6-minute undersea megathrust earthquake occurred in the western Pacific Ocean. The epicentre of the earthquake was situated at approximately 70 km east of the Pacific coast of the Tohoku region (north-eastern portion of Honshu, the largest island of Japan) and its hypocenter at an underwater depth of circa 30 km. This Great East Japan Earthquake is the most powerful known earthquake in recent history of Japan and one of the five largest earthquakes of the modern era (Ammon et al., 2011). The tremor triggered a 'merging tsunami' (Song et al., 2012), i.e. a tsunami where two or more wave fronts join to form a single wave capable of traveling long distances without losing power and amplifying its destructive power at landfall. The tsunami, characterized by double high waves up to 40 meters traveling up to 10 km inland, impacted approximately 350 km of the Japanese coastline and caused exceptional and dramatic consequences. By May

2011, the Japanese National Police Agency confirmed 13,013 fatalities, 4,711 injured and 14,921 missing persons, as well as major devastation in several areas (Sakai, 2011). Many electrical generators were taken down leaving around 4.4 million households without electricity. Important failures at three nuclear power plants were reported. The most important one happened at the Fukushima Daiichi Nuclear Power Station, resulting in public concern over long-lasting environmental contamination and human injury from radioactivity.

The Great East Japan Earthquake is considered as one of the worst disasters ever. Unfortunately, it is not an isolated event. Since the beginning of the twenty-first century, we have witnessed similar major disasters such as the Haitian earthquake (2010), the Deepwater Horizon oil spill (2010), Hurricane Katrina (2005), the Southeast Asia Tsunami (2004), the 9/11 disaster (2001), etc.

Since the second half of the latest century, the disaster landscape has experienced important changes. So, despite the rapid progress of knowledge and technology, millions of people are still killed, seriously injured or materially afflicted by some kind of disaster. On the one hand, disaster research proves that there has been a general increase in the quantity of disasters since the second half of the last century. On the other hand, several academics also mention a qualitative shift in the disaster landscape. They state that there is a strong notion that several modern disasters, which they define as *Disasters of the 21st Century* (Rosenthal, 1998; Boin & Lagadec, 2000; Lagadec, 2009) or *mega-crises* (Rosenthal, 2009; Helsloot et al., 2012), are structurally different from those we had to deal with in the past. According to the same authors, the qualitative change in the disaster landscape challenges the existing emergency management skills and capacities, or as Rosenthal states: "*[These events are] not just more of the same – they are also about something else. 'Something [that] may very well be among the many unknown's*" (2009, p. 4). Unfortunately, no academic study has been found in disaster literature proving such an evolution. In order to be better prepared for future disasters, it is necessary to study the qualitative change in the disaster landscape further in depth.

In this chapter, we first discuss the changing nature of hazards and the ensuing disasters, as well as the driving forces behind this evolution. Next we concentrate on the existing theoretical approach regarding the evolution of the disaster landscape. We essentially focus on the main characteristics of modern disasters as described in literature, and then use these characteristics as a basis for the development of the Disaster Impact and Complexity Diagram (DI&C-Diagram), a tool permitting to study disasters from the perspective of impact and complexity in order to determine trends over the years. The last section of the article deals with a study of a set of randomly selected disasters from 1900 until 2010, using the DI&C-Diagram. Findings are discussed and important points of interest in dealing with modern disasters are highlighted.

The shifting nature of hazards and disasters

Paraphrasing Guiberson, there is no denying that natural phenomena are in fact magnificent events; although to a certain extent (2010, p. 1): "*Drops of water glistening on a spider web are a delight. A stream of water gushing through a forest is a wonder. But a 40-foot surge of water created by a colossal earthquake [can be the cause of an enormous] disaster*." As a matter of fact, natural phenomena such as volcanic eruptions, earthquakes, tsunamis, storms, floods, etc. have always made our planet a hazardous place to live on. Yet, such occurrences only become potentially dangerous to humanity once they threaten people and the things they value. Normal natural events then become hazards (Cutter, 2005). Still, not every hazard evolves into a disaster. Disasters only occur when the human system intersects with a hazardous situation (Perry, 1998). If no humans had been around, the eruption of Mount Vesuvius on August 25, AD 79, would just have been another volcanic eruption. Unfortunately, at the time of the outburst, people had settled in stable communities near the supposedly inactive volcano. Even though the exact population in Pompeii in AD 79 is not known, it is certain that thousands died almost instantly just after the eruption occurred (Genzmer, Kershner, & Schütz, 2007; Gunn, 2008).

When people got organized in sedentary communities, villages and cities, a social shift providing them an important degree of safety and resilience, they became at the same time more vulnerable to natural phenomena because a lot of the societies were located in hazard-prone regions such as coastlines and deltas (Mileti, 1999; Lagadec, 2009). Due to this societal evolution and the ensuing process of expanding urbanization, there has been a constant and considerable increase of areas that are particularly vulnerable to hazards (Quarantelli, 1996). Natural events such as earthquakes, heavy storms or hurricanes then often evolve into devastating disasters causing heavy loss of life and property.

As human societies progressively evolved, additional types of hazards emerged (Quarantelli, Lagadec, & Boin, 2006). From the beginning of the industrial revolution at the end of the 18th century, humans maintain a sustained strive for modernity which is characterized by new industries (e.g. nuclear and chemical plants), revolutionary scientific technologies (e.g. genetic engineering, robotics, Artificial Intelligence, etc.), modern infrastructure (e.g. giant dams, skyscrapers, etc.) and mass transportation means (e.g. high-speed trains, huge tankers, giant cruise ships and airplanes such as the Airbus A-380, etc.). At the same time, the new systems increase the risk for users, operators, bystanders and even future generations and become high-risk technologies, having a potential for disaster not present in the past (Perrow, 1999). According to Beck, development and modernization not only have to be understood in a positive way, there is a dark dimension too. He states that "*the consequences of scientific and industrial* *development are a set of risks and hazards, the likes of which we have never previously faced*" (1986, p. 2). Some researchers even argue that the attempt to cope with the increasing risks indirectly generates new hazards. Tenner (1996) concludes that the law of unintended consequences can be a brutal tyrant. The solution to one problem often turns out to be the cause of another (e.g. the use of agricultural pesticides enhances crop production but also causes harmful effects to humans and the environment if not properly used).

According to the Organisation for Economic Co-operation and Development (OECD) important changes to major risks and hazards are expected to take place in the coming decades. Based on the findings of 'The Futures Project on Emerging Systemic Risks', a two year project (2000-2002) conducted within the framework of the OECD International Futures Programme (IFP)[4], the authors classify the driving forces behind the evolution into four major categories (OECD, 2003)

- Demographics
  The constant growth of the world population, particularly in the developing regions such as Africa, Asia and South-America, results in more urbanization and the ensuing emergence of a growing number of mega-cities. The UN estimates that by 2025 there will be over 8 billion people on earth and that over 60% of them will be living in cities (Britton, 1998). Due to this concentration of population, a growing number of people becomes vulnerable to hazards at the same time and at the same place (Quarantelli, 1993; Mileti, 1999; Hunter, 2004).
- The environment
  The environment undergoes major changes which can in part be related to natural evolution (natural climate variability). Nevertheless, there is an increasing concern about the impacts of socio-economic development (e.g. worldwide population and economic growth, consumption patterns, etc.), as well as about the irresponsible use of natural resources (e.g. massive deforestation) on environmental change and especially on global warming. It has become evident that the global climate is changing and will continue to change over the coming decades and centuries, and that anthropogenic greenhouse gas emissions and increased pollution are largely to blame (Raggatt, Butterworth, & Morrissey, 1993; van Aalst, 2006). Recent research

[4] The IFP is the OECD's forward studies group that has provided strategic, long-term thinking and horizon scanning for the organization since 1990. IFP events offer a platform where policy makers can freely confront their visions and concerns about the future, seek the views of others, and engage in a stimulating dialogue.

demonstrates that climate change will not express itself primarily through slow shifts in average conditions over a long period, but that it is extreme events (e.g. storms, floods, heat waves etc.) that we should focus on (Helmer & Hilhorst, 2006; IPCC, 2013).

- Technology
  Technological progress makes modern societies and their interconnected infrastructures very complex and interdependent. Consequently they become subject to rapid and cascading failures with devastating consequences (Castells, 1996; Perrow, 1999).
- Socio-economic structures
  Globalization considered in all its dimensions integrates regional economies, societies and cultures into a global network through communication, transportation and trade. Globalization not only enhances coping capacities (e.g. international aid), it also puts societies at a higher level of risk (Rosenthal, 2009).

The driving forces, which are numerous and diverse, reshape conventional hazards and often create new ones. As a consequence, societies face important challenges with regard to future risk and hazard management and with regard to the management of the ensuing emergencies and disasters.

Towards Disasters of the 21st Century

Reliable knowledge and research about what happened in past disasters may help disaster policy makers, disaster managers and emergency workers in planning for future events (Kar-Purkayastha, Clarke, & Murray, 2011). As a consequence, the need for systematic disaster data has been a growing concern for disaster researchers (Guha-Sapir, Hargitt, & Hoyois, 2004). However, disaster data should be handled with care for multiple reasons (Guha-Sapir et al., 2004). Before discussing disaster data and statistics, we first draw attention to the most important pitfalls related to the use of disaster figures.

Disaster data and statistics

Initially, the general approach to disaster management remained reactive in nature and data were collected on an ad hoc basis, mainly at the time of a new event. Consequently, the information was far from complete, mostly outdated and for the greater part unusable (Guha-Sapir & Below, 2002).

In the 1970s, a shift in disaster management emerged and the concept of comprehensive emergency management was developed by the National Governors Association (1978). The new approach implies that a state has the responsibility and must have the capacity to manage all types of emergencies and disasters considering the four phases of contemporary disaster management: mitigation, preparedness, response and recovery. Due to this holistic disaster management approach, the demand for statistics on disasters was augmented considerably. In such a context, policy makers, disaster managers and academics need accurate data, commensurable across countries and consistent over time in order to develop efficient and effective disaster mitigation and prevention plans. Accordingly, the first efforts of systematic data gathering by means of disaster databases emerged and the continuous improvement of modern information systems, even in developing countries, has greatly facilitated access to disaster data.

In spite of this favorable evolution, the quality of the disaster databases remains a major weakness. According to disaster researchers the main causes are the lack of standardized methodologies for data gathering and the nonexistence of an unambiguous definition of the concept disaster (Quarantelli, 1998; Perry & Quarantelli, 2005). Besides, until present day, no single institution has taken on the role of prime provider of verified data and no internationally standardized method for assessing disaster damage has been put forward for global use. As a consequence, data on disaster outcomes remain rather patchy (Guha-Sapir & Below, 2002).

The original data used by the different disaster databases are collected from diverse sources such as newspapers, reports elaborated by governments or insurance companies, case studies, aid agencies and NGOs, etc. A lot of the information used is unreferenced and is not linked to any distinguishable document. Furthermore, most of the data are not gathered for any statistical or academic purpose. There often is another rationale behind the data gathering which may bias the information available. As a consequence disaster statistics should always be looked at with some restraint as specified by Quarantelli (2001):

- Figures concerning the number of fatalities after a disaster are in general trustworthy. However, it is not always clear where to draw the line on when a fatality can be directly attributed to the disaster.
- Fatality counts are often affected by deliberate distortions. Authorities of developing countries may exaggerate casualty rates in order to increase the level of relief or they may reduce or deny casualty rates when the truth may be embarrassing (OECD, 1994). Such socially constructed data (Mileti, 1999) are thus very imprecise.

- Data on injured or affected people have to be interpreted with even greater caution. A key problem is the ambiguousness of concepts and variables. Pollander and Rand (1989) pointed out that even in the medical disaster literature there is no generally accepted definition of what exactly constitutes an injury (e.g. heavily or lightly wounded, need to be hospitalized or not, etc.).
- Generally, the most unreliable data are the estimates of property damage and economic losses. We must recognize that the information is collected by various organizations and agencies each having their own specific motive (e.g. insurance companies, interest groups, governments, etc.). Additionally, there is no universally agreed economic currency standard with regard to disaster losses. Making reliable comparisons between suchlike datasets is thus almost impossible.

Due to the dubiousness of many data and figures, disaster statistics must be used with great caution. As a consequence, they should be regarded as indicative. Relative changes and general trends are by and large more useful to look at than absolute and isolated numbers.

More disasters per time frame, a known evolution

Different scholars (Rasmussen & Batstone, 1989; Granot, 1998; Eshghi & Larson, 2008) and research reports (International Federation of Red Cross and Red Crescent Societies, 2007) record a steady increase in the quantity and frequency of disasters since the second half of the last century, a trend which is validated by the statistics of three major disaster databases.

- EM-DAT: The Emergency Events Database was created in 1988 at the Centre for Research on the Epidemiology of Disasters at the University of Louvain in Belgium, and contains core-data on the occurrence and effects of over 18,000 mass disasters in the world from 1900 to present.
- NatCad: A private international level disaster database, maintained by the Munich Reinsurance Company. It collects information on natural disasters and covers a period from AD 79 to the present and contains over 20,000 entries.
- Sigma: The Sigma database is maintained by the Swiss Reinsurance Company. It gathers figures on global natural and man-made events from 1970 to the present with more than 7,000 entries.

Disaster statistics indicate that there has been a general increase in the quantity of disasters per time frame during the last decades. First, the number of disasters related to natural hazards has risen considerably since the second half of the last century. Second, from the beginning of the 1970s, societies have been stricken more frequently by technological disasters. This man-made form of disasters is even growing at a much greater rate than natural disasters (Coppola, 2011). Third, disasters related to health (e.g. infectious diseases and epidemics) and terrorism have gained ground in recent years. The statistics also indicate that, even if the number of disasters has tripled since the 1970s, disasters are becoming less deadly. But then again, the total number of people affected each year (people who lost their home, their crops, their animals or their livelihoods, at least temporarily) and the economic losses have increased significantly (UN/ISDR, 2002).

Qualitative different disasters, an underexplored issue

Since the end of last century, several academics mention a complementary shift in the disaster landscape. In addition to the quantitative upward trend, they refer to a qualitative change of disasters. They assume that there is a strong notion that several disasters we face today are structurally different from those we had to deal with in the past and define these modern disasters as *Disasters of the 21st Century* (Rosenthal, 1998; Boin & Lagadec, 2000), crisis emergencies (Leonard & Howitt, 2007) or *mega-crises* (Rosenthal, 2009; Helsloot et al., 2012).

Disasters of the 21st century can no longer be considered as just more of the same. They add to the older ones, which have not disappeared, but they are intrinsically different. A new ball game (De Smet, Lagadec, & Leysen, 2012) which, according to the disaster literature, is characterized by two general features: impact and complexity. In the following paragraphs, we clarify these general features by means of some typical cases.

First of all, *Disasters of the 21st century* demonstrate a qualitative jump in severity (Lagadec & Carli, 2005). They are of an increasing magnitude and have a more devastating impact on societies, with more infrastructure destroyed and more people affected at the same time. The 2004 Indian Ocean undersea subduction earthquake with a magnitude of 9.1 on the Richter scale generated a series of devastating tsunamis, affecting many countries in Southeast Asia and causing serious damage and deaths as far as the east coast of Africa. More than 230,000 deaths as well as over 1.5 million people displaced were reported (Hyndman, Hyndman, & Catto, 2008). Hardly eight months later, one of the five deadliest hurricanes that ever struck the United States seriously affected the Gulf region (Knabb, Rhone, & Brown, 2005). Although the eye of Hurricane Katrina passed east of the city of New Orleans, the enormous storm surge caused multiple levee breaches which led to the flooding of about 80% of the city to varying depths up to over 6 meter (Graumann et al., 2005). It is by and large accepted that the global region affected by the storm is approximately the size of England (more than 230,000 km²) and that the total damage cost amounts to $125 billion (2005 USD). According to the White House report about the Federal Response to Hurricane Katrina – lessons learned (Townsend, 2006, p. 65) "*[w]e must expect more catastrophes like Hurricane Katrina–and possibly even worse […] We cannot undo the mistakes of the past, but there is much we can do to learn from them and to be better prepared for the future*", a vision shared by several academics (Quarantelli, 1993; Mileti, 1999).

A second overall feature of *Disasters of the 21st century* is that they evolve towards very complex events which become extremely hard to manage in an effective way. Intervening emergency managers and responsible policy makers are pushed to the limits of their capacities, policies and even their imagination. According to the disaster literature, the complexity can be explained from three different angles:

- The changing limits of impact in space and/or in time (Beck, 1986).
  On April 25, 1986, the explosion of the overheated reactor 4 of the Chernobyl Nuclear Power Plant in Ukraine blew off the lid of the reactor hall and started a giant graphite fire producing a protracted release of large quantities of radioactive substances into the air. The radioactive fall-out reached most of the European states. The Chernobyl disaster made researchers understand that there is something substantially new about modern disasters (Birkland, 1997). Their impact often generates cross-border spillover effects which reach far from the trigger event (Perrow, 1999; Mongillo & Zierdt-Warshaw, 2009)
  Also, *Disasters of the 21st century* more often affect future generations. In 1984, the Bhopal gas tragedy caused death to approximately 2,000 people in the first few days. Many thousands more died later on from the consequences of intoxication due to the disaster. The exact number of the total death toll will never be known. According to Dinham and Sarangi (2002), over hundred thousand chronically ill survivors were still in desperate need of medical attention at the end of last century and an estimated 30 of them were dying every month from exposure-related illness.
- The possibility of multiple cascade effects.
  The increasingly interconnected nature of current social infrastructures such as information systems, transportation networks, utility supply systems, etc., have an important impact on the effects of current disasters. Our growing dependence on technology and IT-networks makes our lives easier and more comfortable. Yet, at the same time this

evolution enlarges the probability of fast spreading disasters and of multiple cascade effects occurring after the initial trigger event. In addition, such interconnected networks can amplify minor emergencies and transform them into major disasters in no time (Quarantelli, 1996; Smith, 2005). On August 14, 2003, a line failure in combination with human errors in a small power generating plant in Eastlake, Ohio caused an enormous power failure. The blackout affected an estimated 50 million people in parts of Ohio, Michigan, New York, Pennsylvania, New Jersey, Connecticut, Massachusetts, Vermont, and the Canadian provinces of Ontario and Québec. States did not have power for two days and parts of Ontario experienced rotating blackouts for up to two weeks (NERC Steering Group, 2004).

- Unprecedented, unknown and unconceivable aspects of disasters.

  Although each disaster is characterized by a high amount of uncertainty, more and more we find ourselves confronted with events for which we do not have readymade responses. In such circumstances, we cannot fall back on pre-established plans and procedures, making the third angle of complexity the most destabilizing one, or as stated by Lagadec (2009, p. 478): "*[w]hen the map is lost, the best specific solutions vanish*". On September 10, 2001, few Americans would have believed that their economic and military hubs would be attacked by terrorists, merely armed with box cutters and using U.S. commercial airplanes, notwithstanding the fact that the best-selling author Tom Clancy used this scenario as a plot for his 1994 novel 'Debt of Honor'. The Americans were expecting missiles.

  Even if we think that global epidemics were something of the past (e.g. smallpox, bubonic plague, etc.), the spectre of major outbreaks of infectious diseases (e.g. H5N1 outbreak) has returned. Such events greatly concern emergency workers because of the overwhelming demands it would make on health systems and especially because of the consequences to society as yet unknown.

  The possibility of occurrence of unprecedented, unknown and even unthinkable (inconceivable) disasters is growing, mainly due to the complexity and interconnectivity of today's societies and the growing dependence on modern technology. In such a complex environment, the side effects of disasters will exceed the level of traditional chain reaction of second order effects (Quarantelli, 1993; Perrow, 1999).

Disasters Out of the Box and the Disaster Impact and Complexity Diagram

During history, humans have systematically developed means to cope with and survive disasters by putting in place specific “emergency management procedures”. As the hazard and disaster landscape evolved, they have continually adapted their mitigation, preparedness and intervention measures based on successful and less successful experiences (Kirschenbaum, 2004), in order to be more resilient to the situation. Formal Emergency Management Organizations (EMOs) fitted out with specialized equipment and trained personnel have been installed gradually on and since World War II, there has been a professionalization of disaster planners and managers. Their main assignment is to establish and constantly maintain and improve procedures for emergency management organizations to deal with emergency situations and disasters (Quarantelli et al., 2006).

As demonstrated in the previous paragraph, the actual disaster landscape is subject to important changes. On the one hand, existing disaster statistics clearly demonstrate a significant quantitative shift, which in itself is a worrisome evolution. On the other hand, the assumed evolution towards more qualitatively different *Disasters of the 21st Century* is far more alarming. If such a trend is real, we can expect that our societies will be more severely affected in the future, and more importantly, that the work of the intervening EMOs will be more challenged, notwithstanding the improved disaster and emergency management capacities and procedures.

Although a trend towards more *Disasters of the 21st Century* is very credible (e.g. the media coverage on current major disasters, the cases described in the previous paragraph, etc.), no academic study has been found in the existing disaster literature substantiating such a general qualitative evolution. In order to be better prepared for future disasters, it is indispensable to address this gap in disaster research and to investigate the qualitative change in the disaster landscape in depth. To this purpose, we introduce the notion *Disasters Out of the Box* and subsequently develop the *Disaster Impact and Complexity Diagram* (DI&C-diagram), a tool which examines trends in the qualitative evolution of disasters over the years.

Disasters Out of the Box

A well performing organization is an “*organization that realises its present objectives (ongoing business) while at the same time preparing itself to realise its objectives of and in the future*” (Leysen & Van Nuffel, 2006). An organizational risk therefore, is a possible event which may compromise the realization of the organization's objectives and therefore its performance. When the organization's performance is compromised, the organization goes through an organizational crisis (Davies & Walters, 1998).

The main objective of EMOs intervening during a disaster is to manage the event in the most efficient and effective way. Yet, the performance of the EMOs can be jeopardized in different ways. If an intervening EMO is hit and affected partly or even completely by a disaster itself, the EMO loses necessary capacities (i.e. resources, processes and/or knowledge). Also the disruption of supporting infrastructures external to an EMO can compromise its work (e.g. the breakdown of a power station may disrupt the communications, destroyed bridges complicate the accessibility to the disaster zone, etc.). Finally, disasters may be of such complexity or that inconceivable, that the intervening emergency workers are confronted with an event for which they do not have readymade responses and cannot fall back on pre-established plans and procedures.

In each of the above mentioned situations, the disaster jeopardizes the performance of the intervening EMO, which goes through an organizational crisis. In such case the disaster becomes *Out of the Box* to the considered EMO. The notion *Disasters Out of the Box* is thus related to intervening EMOs during disasters.

DI&C-Diagram

The major goal of the current research consists in determining whether the disaster landscape is characterized by a trend towards more *Disasters of the 21st Century* and consequently more disasters *Out of the Box*. Therefore, it was decided to develop the *DI&C-Diagram* as a tool to study disasters over the years in order to determine a qualitative trend. The following method, consisting of three steps, was used.

During the first step, six academics working at the Risk, Crisis and Disaster Management research pool of the Faculty of Social and Military Sciences at the Belgian Royal Military Academy were gathered in a meeting room and received an explanatory briefing about *Disasters of the 21st Century,* the two main features of such events as described in literature (impact and complexity) and the concept of disasters *Out of the Box*. Following the briefing, the researchers were asked to determine different variables which can be related to the main features of *Disasters of the 21st Century* during a 30-minute brainstorm session. The technique, developed by Osborn (1963), permits the use of the full experience and creativity of all participants in a free and open environment. Each person was asked in an alternate way to note a potential variable on a post-it, which was then put on a white-board. After the brain storm session, a total of 80 potential variables were identified.

In the second step, the 80 potential variables were further discussed and specified by the six researchers applying the *estimate-feedback-talk-estimate method* (EFTE method), which is a variant of the Delphi technique. The method, also referred to as the Interactive or Mini Delphi procedure (Nelms & Porter, 1985; Puglisi, 2001), includes open debate phases (Talk) between the different rounds. In this research, we essentially concentrate on the Emergency Phase of the Disaster Life Cycle (National Governor's Association, 1979), the phase during which the EMOs intervene. The Emergency Phase begins at the moment the event leading to a possible disaster is detected and usually ends when the situation has stabilized (De Smet, Leysen, & Lagadec, 2011). Consequently, the participants were asked to:

- Find a consensus about relevant variables applicable to the Response phase (e.g.: the potential variable 'cost of the catastrophe' is largely related to the reconstruction phase of the Disaster Life cycle and therefore was not taken into further consideration) .
- Cluster similar items into unambiguous variables (e.g.: the identified potential variables 'probability of the event', 'ignorance', 'without precedent' and 'recurrence' were grouped in the variable 'inconceivability').
- Relate the remaining variables to one of the two general features of *Disasters of the 21st Century*, representing the two dimensions of the *DI&C-Diagram*: Disaster Impact Consequences (DIC) and Disaster Management Complexity (DMC).

After an EFTE-process of three rounds, a consensus was reached about seventeen appropriate and unambiguous variables; five related to DIC and twelve to DMC (appendix A).

The last step consisted in the development of the *DI&C-Diagram*, in which studied disasters can be positioned as a function of impact and complexity. The position should be interpreted as following: the further the disaster is positioned away from the origin, the more severe (impact) and/or complex it is, and the bigger the probability that it becomes *Out of the Box* to the intervening EMOs. During a final EFTE-process, the researchers were asked to further analyse the variables in order to develop an appropriate scale for each of them and to determine a way to calculate the position of a studied disaster into the *DI&C-Diagram*. They agreed on the following:

- For each of the 17 variables, an appropriate scale was defined (for details, see appendix A).
- The purpose is to represent a studied disaster in the two-dimensional *DI&C-Diagram* as a function of impact and severity. The participants therefore agreed about using the following procedure:
  For each variable a score is calculated using formula 1. The score represents the position of the center of the allocated category on a scale between 0 and 100.
  When all the scores for the studied disaster are computed, the arithmetic mean is calculated for both the scores related to DIC and DMC. The obtained values represent the coordinates of the position of the studied disaster in the *DI&C-Diagram* (an example of the calculations is represented in appendix B).

$$Score = \frac{100}{n}\left(a - \frac{1}{2}\right) \qquad (1)$$

n: number of categories for the considered scale
a: allocated category for the considered variable

A study of the qualitative shift in the disaster landscape

Method

In order to examine the qualitative evolution of the disaster landscape throughout time, we decided to study 100 disasters between 1900 and 2010 considering the following five time frames: 1900-1924, 1925-1949, 1950-1974, 1975-1999, and 2000-2010. As reference we used the Disaster Database Project, developed by Dr. W.G. Green III (Associate Professor of Emergency Management – School of Continuing Studies at the University of Richmond). In addition to quantitative data (e.g. number of fatalities, people injured, buildings destroyed, etc.), the database disaggregates each disaster into phases as defined by Fink (2002): the prodromal stage, development, impact, response and recovery. The user obtains a detailed description of the factors involved in each stage, as well as a narrative of the event during each particular phase. At the time of consultation, the database was still[5] a living information source containing data of more than 2,500 disasters and covered natural disasters, human system failures and conflict based disasters. For inclusion into the database, events are considered disasters if "*(1) they represent a threat to life, property, or the environment, (2) they would have required the use of emergency procedures for the limitation of their impact, (3)*

[5] Through lack of funding, professor Green was compelled to close the database at the end of 2011.

they reasonably could have caused a responsible jurisdiction, agency, or organization to invoke or declare the existence of an emergency situation or to mobilize its resources in response, and (4) some significant degree of community or organizational impact was present" (Green III, 2011).

For each of the considered time frames, we randomly selected twenty disasters out of the Disaster Database Project to investigate in detail using the *DI&C-Diagram*. Indispensable information necessary for the study of the 17 parameters, which was not available within the database, was collected using different types of complementary data sources (online sources, articles, reports, etc.). The studied disasters are represented in appendix C.

Results and discussion

The results of the study are represented in the figures 1 and 2. Figure 1 gives a representation of the individual positions of the 100 studied disasters within the *DI&C-Diagram*. Figure 2 depicts the positions of the means of the different scores DIC and DMC (coordinates) per time frame, while the radius of the bubbles is proportional to the overall standard deviation of the considered scores DIC and DMC.

Figure 1: DI&C-Diagram - Results for the individual disasters

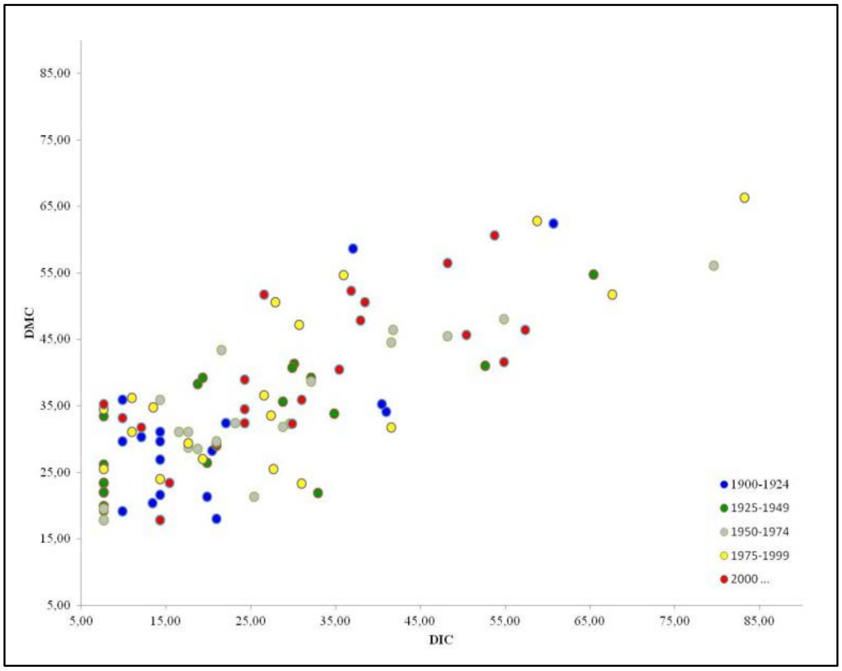


Figure 2: DI&C-Diagram - Results per time frame

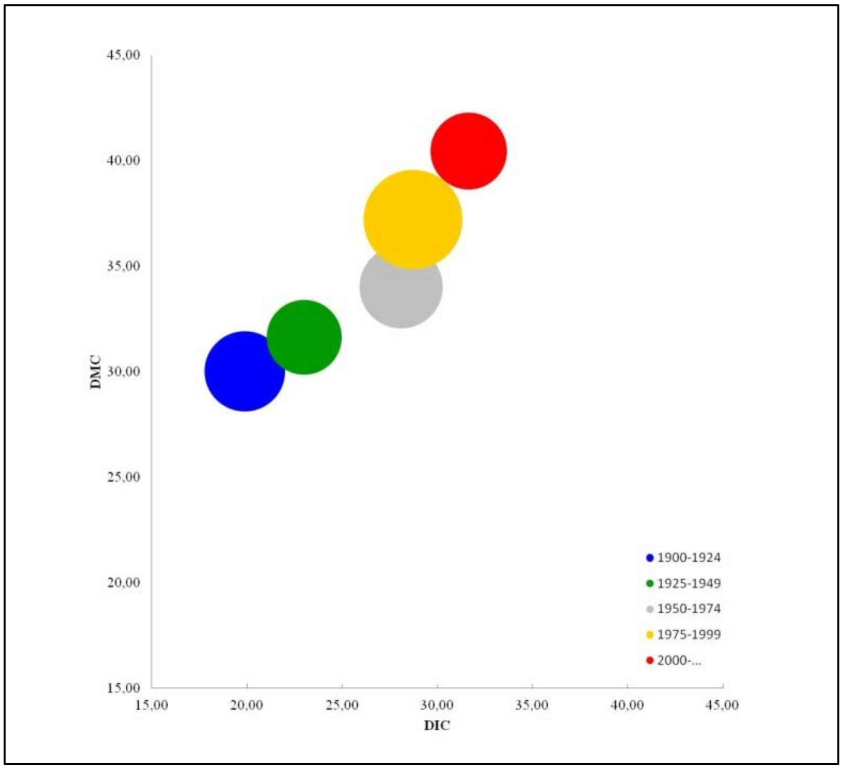
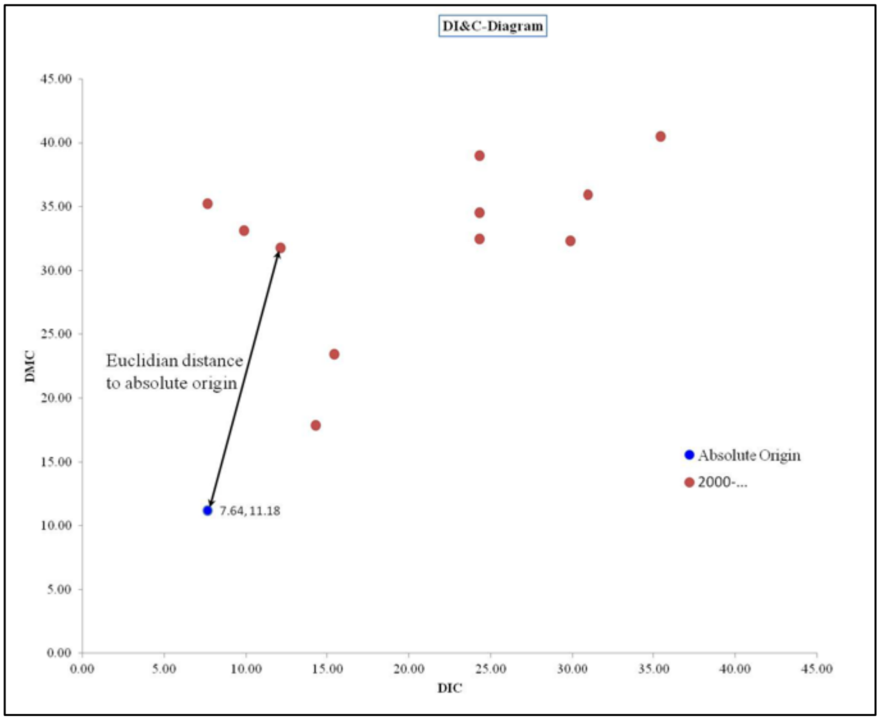


Figure 1 clearly indicates that the majority of the studied disasters between 1900 and 1949 (blue and green dots) are essentially centered in the lower left side of the *DI&C-Diagram*, whereas those from 2000 on (red dots) are spread from the lower left side to the upper right side. This conclusion is confirmed in figure 2. We observe a jump in severity and magnitude (DIC) since the 1950s, whereas from the mid-seventies disasters obviously become more complex to manage (DMC). Figures 1 and 2 give a qualitative, visual indication that disasters evolve towards more *Disasters of the 21st Century* and consequently become more *Out of the Box*.

To confirm the previous conclusion, we further analysed the obtained results in a statistical way. First, we calculated the values of the absolute origin of the *DI&C-Diagram.* By applying formula (1), a score of zero can never be obtained. To illustrate this, we use the scales with the highest number of categories (human impact – see appendix A) and calculate the smallest possible score (i.e. for category 1), which is 5.56. By extension we then determined the absolute origin of the *DI&C-Diagram*. The absolute origin is the smallest coordinate possible by considering category 1 for each of the 17 scales. As absolute origin, we obtain 7.64 (DIC) and 11.18 (DMC).

Next, we classified the studied disasters in a chronological way by considering the year in which the disaster happened, and then calculated the Euclidian distance of each pair of values (DIC and DMC) of the studied disasters to the absolute origin of the *DI&C-Diagram* (figure 3). The Euclidian distance is the measure of a disaster being *Out of the Box*.

Figure 3: Euclidian distance to absolute origin

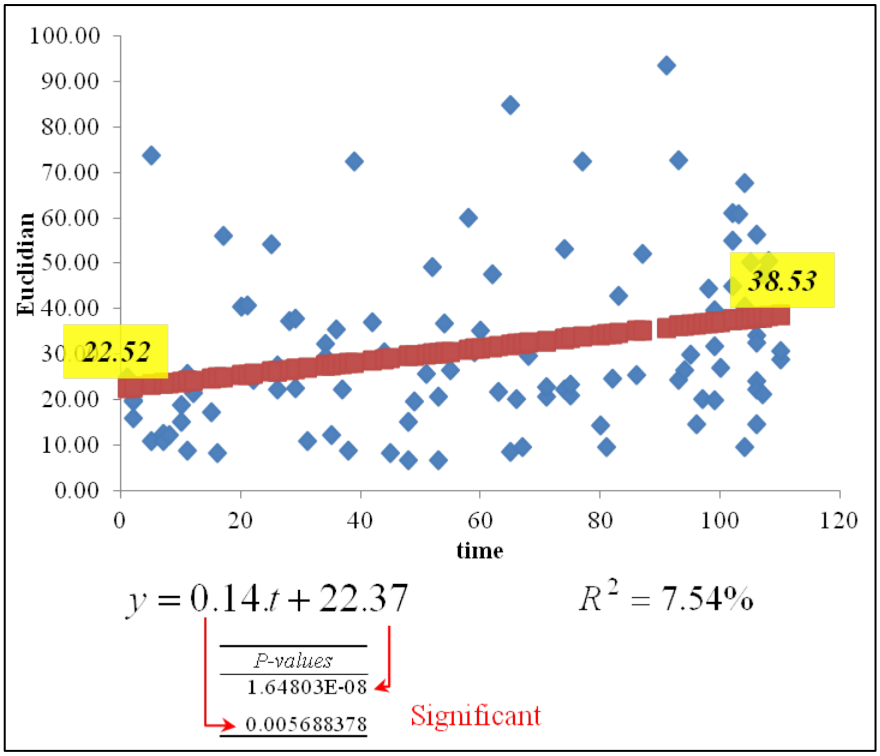


The results, represented in figure 4, clearly demonstrate that there is a significant annual increase of the Euclidian distance of 0.14 per year. The small value of R^2=7.54% can be explained considering the following remarks:

- Extreme events have always existed even in ancient times: the eruption of super volcano Toba 74,000 years ago, the tsunami generated by an earthquake in Greece which destroyed Alexandria in AD 365, the Shaani earthquake which killed over 800,000 people in 1556, etc.
- Not all disasters we face today are extreme in nature and can be considered as disasters *Out of the Box*. We still are and will always be confronted with the more traditional disasters for which we can easily fall back on pre-established plans and procedures, even if we take into account that there is no such thing as a routine disaster (Boin & Lagadec, 2000).

Based on the results of the study, we can conclude that there is an obvious trend towards Disasters of the 21st Century, entailing the possibility that more disasters will evolve into disasters *Out of the Box*.

Figure 4: Regression analysis of the Euclidian distance



An additional important finding concerns the correlation between DIC and DMC values. Looking at the data in figure 1 already gives a good indication of the correlation between the two variables. Calculation of the Pearson correlation coefficient and R^2 confirms this indication ($r = 0.786$; $R^2 = 0.62$). Given this high correlation between 'impact' and 'complexity', we can assume that the larger the impacts are, the more complex the disasters.

Conclusion and discussion

The management of disasters has always been a very challenging task for policy makers, disaster managers and emergency workers. In the context of a continuously changing hazard and disaster landscape, people have always been forced to adapt their capacities and policies to deal with emergencies and disasters in an efficient and effective way. When dealing with traditional disasters, the policy of adjusting the existing and known procedures and textbooks in accordance with lessons learned appears to be rather effective. However, the study of a randomly selected set of disasters from 1900 until 2010 demonstrates that we are facing a trend towards more *Disasters of the 21st Century*, which have an increasing potential to become disasters *Out of the Box*.

In the context of *Disasters of the 21st Century* characterized by an increasing impact and complexity, the conventional military wisdom to 'never prepare for the last war' (Granatt, 2014) holds all the more. Recent events such as the Southeast Asian Tsunami (2004), Hurricane Katrina, the catastrophic Haitian earthquake (2010) and the Great East Japan Earthquake (2011) have shown that ruling practices are no longer that efficient and effective.

For that reason, disaster managers at the policy level and emergency managers at the operational level should pay more attention to thinking creatively about the unprecedented, the unknown and the inconceivable aspects of modern disasters if they want to stay well prepared for future events and do not want to lose legitimacy (Ripley, 2008). They must all learn to reason Out of the Box because we have to accept that we will be more and more confronted with events for which we have no readymade answers. Creativity will become crucial if we want to be prepared to manage today's and future disasters. As a consequence, the acquisition of these competences must be stimulated during training sessions. As LaPorte states (2007, p. 62): "*Leaders must prepare to be very surprised and no longer rely exclusively on existing plans which aim mainly at avoiding surprise*".

Appendix A: The Disaster Impact and Complexity Diagram – Variables and Scales

Disaster Impact Consequences (DIC)	**Human impact**	**1. Number of fatalities** *Only the immediate death toll is taken into consideration.* **2. Number of injured people** *Only the immediate number of injured people is taken into consideration.*	***9 categories*** 1. $x \leq 50$ 2. $50 < x \leq 100$ 3. $100 < x \leq 200$ 4. $200 < x \leq 500$ 5. $500 < x \leq 1{,}000$ 6. $1{,}000 < x \leq 5{,}000$ 7. $5{,}000 < x \leq 10{,}000$ 8. $10{,}000 < x \leq 100{,}000$ 9. $100{,}000 < x$
	Material impact	**3. Material destruction** *Magnitude of the material destruction and/or contamination after the impact of the event*	***4 categories*** 1. *Small*: one destructed or contaminated site (plant, building, …) 2. *Medium*: more than one destructed or contaminated site, partial destruction of a village, small town or small region (<50 km²) 3. *Big*: partly destruction or contamination of more than one town 4. *Very big*: destruction or contamination of a large region (several towns are heavily disrupted or affected)
	Geographical impact	4. **Area of the stricken zone** (in km²)	***8 categories*** 1. $x \leq 50$ km² 2. 50 km² $< x \leq$ 100 km² 3. 100 km² $< x \leq$ 500 km² 4. 500 km² $< x \leq$ 1,000 km² 5. 1,000 km² $< x \leq$ 10,000 km² 6. 10,000 km² $< x \leq$ 100,000 km² 7. 100,000 km² $< x \leq$ 500,000 km² 8. 500,000 km² $< x$
	Time impact	**5. Duration of the (trigger)event** *A long-lasting trigger event generally causes a more devastating disaster.*	***6 categories*** 1. $x \leq$ 1 Min 2. 1 Min $< x \leq$ 5 Min 3. 5 Min $< x \leq$ 1 Hr 4. 1 Hr$< x \leq$ 1 day 5. 1 day $< x \leq$ 1 week 6. 1 week $< x$

Disaster Management Complexity (DMC)	**Aspects related to evacuation of victims**	**1. Number of victims to evacuate** *A larger number of people to evacuate complicates emergency operations.*	***6 categories*** 1. x ≤ 100 2. 100 < x ≤ 1,000 3. 1,000 < x ≤ 5,000 4. 5,000 < x ≤ 10,000 5. 10,000 < x ≤ 100,000 6. 100,000 < x
		2. Complexity of evacuation *Besides the number of victims to evacuate, other aspects complicate evacuation and consequently emergency operations (e.g. contamination of the disaster zone, the willingness of people to evacuate, etc.).*	***4 categories*** 1. *Fluent*: no difficulties 2. *Minor*: minor difficulties 3. *Complicated*: hindered evacuation causing important difficulties 4. *Difficult*: very difficult evacuation
	Time aspects	**3. Length of forewarning** *A timely forewarning implies a longer preparation time for both people and emergency management organizations, permitting a better preparation of emergency operations.*	***5 categories*** 1. 1 week < x 2. 1 day < x ≤ 1 week 3. 6 Hr < x ≤ 1 day 4. 1Hr < x ≤ 6 Hr 5. x ≤ 1 Hr
		4. Duration of the emergency operations *The longer the emergency operations last, the more difficult they become to manage (e.g. effect of fatigue, working in shifts, etc.).*	***6 categories*** 1. x ≤ 12 Hr 2. 12 Hr < x ≤ 1 day 3. 1 day < x ≤ 3 day 4. 3 day < x ≤ 1 week 5. 1 week < x ≤ 2 weeks 6. 2 weeks < x
	Geographical aspects	**5. Geographical aspect** *Difficult approachable or remote disaster grounds complicate emergency operations.*	***4 categories*** 1. *Easy*: no hinder 2. *Medium*: hindered accessibility 3. *Difficult*: accessibility is hindered in a major way 4. *Very difficult*: accessibility is hindered in a major way during a long period
…		**6. Cross-border event** *Cross-border events involve emergency management organizations belonging to different jurisdictions complicate emergency operations.*	***5 Categories*** 1. not a cross-border event 2. cross-border event (*more than one state/province*) 3. more than one country on the same continent affected 4. more than one country on different continents affected 5. worldwide event

⋮	**Evolution of the disaster**	**7. Cascade effects** *Cascade or domino effects complicate emergency operations.*	***5 categories*** 1. No cascade effects 2. Minor cascade effects (limited in time and space) not hampering the work of the emergency management organizations 3. Cascade effects (limited in time and space) hampering the work of the emergency management organizations in a considerable way 4. Multiple cascade effects hampering the work of emergency management organizations in a considerable way 5. Important cascade effects spread in time and space
		8. Simultaneous events *Simultaneous events complicate emergency operations.*	***4 categories*** 1. No simultaneous events 2. Limited simultaneous effects within the intervention zone of the emergency management organizations, not hampering their work 3. Simultaneous events within a limited zone (operational zone), hampering the work of the emergency management organizations 4. Very important simultaneous events on a strategic level
	Aspects related to supporting infrastructure	**9. Impact on supporting infrastructure and/or services** *Destruction or disruption (even if minor) of supporting infrastructure (e.g. roads, bridges, energy supply facilities, telecommunications, etc.) complicates emergency operations.*	***4 categories*** 1. *Insignificant*: no impact on emergency operations 2. *Medium*: destruction of supporting infrastructure and/or services hampering the intervening emergency management organizations 3. *Important*: destruction of supporting infrastructure and/or services causing important difficulties to emergency operations 4. *Massive*: major destruction/affection of supporting infrastructure and/or services causing massive complications tot emergency operations
	Coordination aspects	**10. Impact of legal, procedural and/or political features** *Features such as legal and/or procedural aspects, political regimes, language barriers etc., generally have a negative impact on emergency operations.*	***4 categories*** 1. *Insignificant*: no impact on coordination 2. *Medium*: minor impact on coordination 3. *Important*: coordination is hampered in a considerable way 4. *Massive*: coordination is very much complicated or even hindered
	Emergency organization aspects	**11. Capacities of the intervening emergency management organizations** *The more levels of authority involved, the more complicated the emergency operations will be.*	***4 categories*** 1. Local capacities 2. Regional reinforcement 3. National reinforcement 4. International reinforcement
		12. Inconceivability *Unprecedented and thus unknown events negatively influence emergency operations.*	***4 categories*** 1. *Low*: rather normal events, normal consequences 2. *Medium*: rather normal events, big consequences 3. *High*: seldom happening events 4. *Very high*: exceptional events

Appendix B: Generation of the statistics, an illustration

To illustrate the calculations and the generation of the statistics, we randomly selected a disaster out of the list of studied disasters: the Knickerbocker Theatre Collapse (Nb 20 - see appendix C).

Determination of the values of the variables

The table below reports the values of the 17 variables as well as the corresponding categories, the calculated scores and the arithmetic means for both DIC and DMC (representing the coordinates of the position of the studied disaster in the DI&C-Diagram). The calculation of the score of variable 1 is illustrated in figure 5.

Variables		*Values and categories*	*Calculated scores*	*Means*
DIC	Human impact	1. Number of fatalities: 98 – Cat 2	16.67	14.31
		2. Number of injured people: 133 – Cat 3	27.78	
	Material impact	3. Material destruction: The theatre was destroyed (one building) – Cat 1	12.5	
	Geographical impact	4. Area of the stricken zone: The area of the building – Cat 1	6.25	
	Time impact	5. Duration of the (trigger)event: Witnesses have reported that there was no hint of danger such as cracking or loud noises beforehand (sudden collapse) – Cat 1	8.33	
DMC	Aspects related to evacuation of victims	1. Number of victims to evacuate: The roof collapsed on the concrete balcony, which in turn collapsed onto the orchestra seating section, – Cat 2	25.00	31.04
		2. Complexity of evacuation: A blizzard lasting for 28 hours resulted in significant accumulation of snow and ice throughout the Washington, DC area, paralysing much of the city – Cat 3	62.50	
	Time aspects	3. Length of forewarning: There was no hint of danger such as cracking or loud noises beforehand (sudden collapse) – Cat 5	90.00	
		4. Duration of the emergency operations: No information of exact duration, but estimated less than a day – Cat 2	25.00	
	Geographical aspects	5. Geographical aspect: Due to accumulation of snow and ice a lot of streets were nearly impassable, paralysing much of the city – Cat 1	12.50	
		6. Cross-border event: No – Cat 1	10.00	
	Evolution of the disaster	7. Cascade effects: No – Cat 1	10.00	
		8. Simultaneous events: No – Cat 1	12.50	
	Aspects related to supporting infrastructure	9. Impact on supporting infrastructure and/or services: Due to accumulation of snow and ice a lot of streets were nearly impassable, paralysing much of the city – Cat 3	62.50	
	Coordination aspects	10. Impact of legal, procedural and/or political features: No – Cat 1	12.50	
	Emergency organization aspects	11. Capacities of the intervening emergency management organizations: Local capacities (police, firemen, and military personnel) – Cat 1	12.50	
		12. Inconceivability: Rather normal disaster, but with big consequences – Cat 2	37.50	

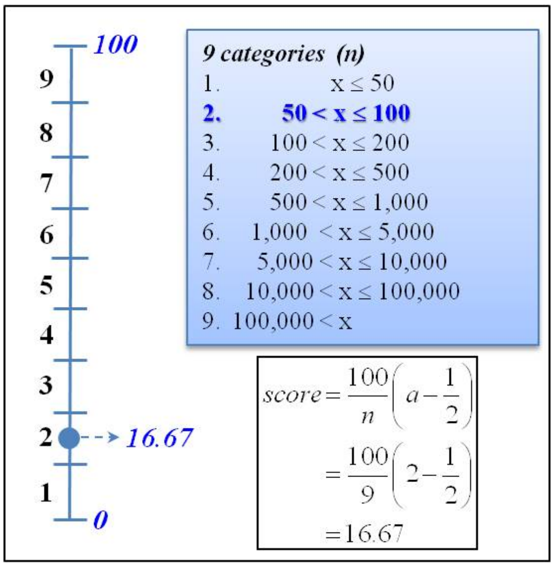


Figure 5: Calculation of the score

Appendix C: List of the studied disasters

N°	Description of the disaster	Date
1	***Senghenydd Coal Mine explosion*** Underground mine explosion in the town of Senghenydd (Wales, UK), killing 82 miners.	May 24, 1901
2	***Ibrox Stadium collapse*** A partial stadium collapse that caused 25 deaths and 517 injuries among the supporters watching the 1902 British Home Championship match between Scotland and England (Glasgow, Scotland).	April, 5 1902
3	***Fraterville Mine disaster*** Underground mine explosion near the community of Fraterville (Tennesee, USA) killing 216 miners. The explosion was caused by a build-up of methane gas which had leaked from an adjacent unventilated mine.	May 19, 1902
4	***Coal Creek Number 2 And 3 Mine explosion*** Explosion in the Coal Creek Mines (British Columbia, Canada) killing 128 miners. The mines were reported to have been very gassy with significant quantities of fine coal dust.	May 22, 1902
5	***Towboat Defender explosion*** Sudden explosion of the boilers of the steamboat on the frozen Ohio River (West Virginia, USA) causing 9 fatalities and 6 badly injured people.	January 3, 1905
6	***Kangra earthquake*** A major earthquake (magnitude 7.8) in the Kangra Valley (Himachal Pradesh region, India) killing almost 20,000 people and causing widespread destruction.	April 4, 1905
7	***Steamboat City of Troy fire*** Shortly after departure from New York, a fire started in the galley of the steamboat which became quickly out of control. The captain landed the ship at the Gould Dock in Ardsley (Westchester County, New York, USA). The passengers were safely evacuated but the ship burned to the waterline and ignited the dock.	April 5, 1907
8	***SS Cyprus sinking*** The lake freighter SS Cyprus sank during a gale storm on Lake Superior about 8 miles north of Deer Park (Luce County, Michigan, USA). All but one of the 23 members of the crew perished.	October 11, 1907
9	***Coal Creek Number 2 Mine bump*** Sudden mine bump (a seismic jolt occurring within a mine, often due to the explosive collapse of a wall or one or more support pillars) near the town of Fernie (British Columbia, Canada). 20 miners were trapped for 8 hours and 3 were killed.	July 31, 1908
10	***Wellington avalanche*** An enormous avalanche engulfed the railroad depot of Wellington (Washington, USA) and swept a stranded passenger train with 100 persons aboard into a 150 foot deep gorge. Only 26 survived.	March 1, 1910
11	***Loss of Airship America*** Due to an engine failure, the airship was no longer manoeuvrable and drifted for more than 2,200 km over the Indian Ocean. All 6 crew members could be rescued in the vicinity of Bermuda (USA).	October 20, 1910
12	***Taff Vale Railway accident*** A signalling failure caused a collision between a passenger train and coal train on the Taff Vale Railway line at the town of Hopkinstown, near Porth (Wales, UK) and resulted in the loss of 11 lives.	January 23, 1911
13	***Sinking of the SS Yongala*** The passenger ship sank nearby Cape Bowling Green (Queensland, Australia) on its way from Melbourne to Caims when steaming into a severe cyclone. The ship couldn't be warned in time because it was not yet equipped with a wireless communication system. All 122 people on board perished.	March 23, 1911

N°	Description of the disaster	Date
14	***Regina tornado*** A violent tornado of 400 m wide and an estimated wind velocity of 500 km per hour devastated huge parts of the city of Regina (Saskatchewan, Canada). 28 persons were killed.	June 30, 1912
15	***Explosion of the HMS Princess Irene*** Being loaded with mines in preparation for a minelaying mission during the war, the ocean liner exploded (Medway Estuary, Kent, UK). 377 people died.	May 27, 1915
16	***Quebec Bridge collapse*** During the construction of the second Quebec bridge (Canada), the prefabricated center span dropped into the Saint Lawrence River at the moment it was being hoisted into place.	September 11, 1916
17	***Halifax explosion*** Due to the explosion of the SS Montblanc (a French cargo ship fully charged with wartime explosives) much of the city of Halifax (Nova Scotia, Canada) was devastated. About 2,000 people were killed and it is estimated that nearly 9,000 others were injured.	December 6, 1917
18	***Mendoza earthquake*** The earthquake (magnitude 6.0) affected the provincial capital Mendoza (Argentina). It caused huge material damages and about 400 fatalities.	December 17, 1920
19	***Oppau explosion*** Workers attempting to break-up solidified ammonium nitrate in silos using permissible dynamite, triggered two blasts. The explosion excavated an enormous crater and damaged most of the buildings in the town of Appau (Germany).	September 21, 1921
20	***Knickerbocker collapse*** During a severe northeastern storm in the District of Columbia (USA), snowfall reached up to 26 inches causing the roof of the Knickerbocker Theater to collapse onto the balcony which failed and fell onto the spectators seated on the floor.	January 28, 1922
21	***Tri State tornado*** The tornado is considered as one of the deadliest tornados in U.S. history. Its continuous track of more than 350 km was the longest ever recorded and crossed from southeastern Missouri through southern Illinois into southwestern Indiana. About 700 people were killed.	March 18, 1925
22	***Eastern Storm of 1926*** A violent storm, lasting for four days, hit the San Diego region (USA), destroyed several buildings and caused considerable human distress.	April 5, 1926
23	***San Luis Obispo Oil Refinery fire*** A stroke of lightning started a fire at the Union Oil tank farm. The oil overtopped dikes and ignited most of the facility. The ensuing firestorm generated multiple small tornados, complicating the work of the fire fighters.	April 7, 1926
24	***St. Francis Dam collapse*** The St. Francis dam (California, USA), designed between 1924 and 1926, would provide water to the city of Los Angeles. During the filling of the reservoir, the dam collapsed and the resulting flood killed up to 600 people.	March 12, 1928
25	***Coal Creek Number 1 East Mine fire*** After the collapse of a roadway, signs of fire were detected in the mine nearby the town of Fernie (British Columbia, Canada). The effort to remove the burning coal started immediately, but lasted for three weeks.	March 25, 1929
26	***Placentia Bay tsunami*** A 7.2 earthquake in the Atlantic Ocean triggered a large submarine landslide and led to a tsunami that struck the coast of the Burin Peninsula (Newfoundland, Canada).	November 18, 1929
27	***HMS Poseidon sinking*** Despite good visibility, the Poseidon collided with the Chinese merchant steamer SS Yuta after a series of misjudgements whilst exercising in the Bohai Sea (China). The vessel sank immediately causing 22 fatalities.	June 9, 1931

N°	Description of the disaster	Date
28	***SS Moro Castle event*** During a storm the luxury cruise ship, en route from Havana to New York, caught fire and burned. 137 passengers and crew members were killed.	September 8, 1934
29	***Gresford Colliery event*** A series of major explosions caused by ignition of methane gas by a shot at the coalface produced a fire which ruptured the Dennis Main Deep nearby the town of Gresford (Wales, UK). Over 250 people were killed.	September 22, 1934
30	***Groβheringen collision*** As a local Erfurt to Leipzig train crossed the main line on the bridge over the River Saale nearby the town of Groβ-Herringen (Germany), it collided with the Berlin to Basel express as a result of human error.	December 24, 1935
31	***Tupelo tornado*** The Tupelo (Mississippi, USA) tornado was one of several from a severe thunderstorm. The tornado, with a total ground track of approximately 15 miles destroyed the major part of the city. Over 200 people were killed.	April 5, 1936
32	***New London School explosion*** The New London School (Texas, USA) was destroyed by a gas explosion. Over 450 people were killed. The school had illicitly tapped wet gas from a drilling site to save costs of heating, a practice not explicitly authorized by local oil companies, but widespread in the area.	March 18, 1937
33	***Natal Number 3 Mine explosion*** During a thunderstorm, lightning struck the rails used by mining cars and ignited an explosion within the mine nearby the town of Natal (British Columbia, Canada).	July 15, 1938
34	***Erzincan earthquake*** A severe earthquake of seven violent shocks (the biggest one measuring magnitude 8.0) hit the province of Erzincan (Turkey), killing over 30,000 people.	December 27, 1939
35	***Honkeiko Colliery explosion*** A huge explosion in the coal mine at Benxi (Lianoing province, China) killed over 1,500 Chinese miners.	April 26, 1942
36	***East Ohio Gas Company event*** One of the three 240-million-cubic-foot liquefied natural gas tanks of the Cleveland company (Ohio, USA) started to leak. During reparation, the leak ignited and caused a series of explosions.	October 20, 1944
37	***SS Harmonic event*** The Canadian steam ship was completely destroyed by a fire at the dock of Point Edward (Ontario, Canada).	July 17, 1945
38	***Eastern Airlines flight 572*** The DC-3 departed from Winston-Salem (North Carolina, United States) for a flight to Washington. The plane crashed after having struck the top of a tree. The probable cause of the accident was the failure of the flight crew to follow the prescribed instrument procedure during the course of an instrument approach.	January 13, 1948
39	***BSAA Star Tiger disappearance*** The passenger aircraft disappeared without trace over the Atlantic Ocean while on a flight between Santa Mari (Azores) and Bermuda. The loss remains unsolved to this day.	January 30, 1948
40	***Holland Tunnel fire*** The fire in the tunnel under the Hudson River between New York and New Jearsey (USA) started after a truck lost one of its eighty 55-gallon drums of carbon disulfide. At the moment of the fire, approximately 125 vehicles were in the tunnel.	May 13, 1949
41	***New Orient Number 2 Mine explosion*** A methane gas explosion devastated the New Orient Mine Number 2 near the town of West Frankfort (Illinois, USA). At the moment of the explosion 218 miners were down. Almost all of them were killed.	December 21, 1951

N°	Description of the disaster	Date
42	***Kern County earthquake*** The magnitude 7.5 earthquake which was felt in Reno, Nevada, and in the upper floors of buildings in San Francisco, caused major devastation in the city of Kern County (California, USA).	July 21, 1952
43	***Nutts Corner Crash*** A Vickers Viking en route from London to Dunrod (Ireland) with 31 passengers and 4 crew crashed at the airport of Nutts Corner at night. 7 people died.	January 5, 1953
44	***Conneaut collision*** A freight train, fully loaded with pipes of 30 cm in diameter, lost its cargo nearby the town of Conneaut (Ohio, USA). One of the pipes shifted an adjacent track out of position. A passenger train derailed and collided with the freight train. Later, a second passenger train collided with the resulting wreckage. There is evidence that the pipes were incorrectly secured.	27 March 27, 1953
45	***Kumbh Mela stampede*** The stampede occurred in Allahabad in Uttar Pradesh (India) during the main bathing day of Mauni Amavasya (New Moon). During a failure of crowd control (over 4 million pelgrims were in the city) over 800 people were killed.	February 3, 1954
46	***Novorossysk explosion*** In the harbor of Sevastopol (USSR), the Soviet battleship exploded and capsized less than 3 hours after the explosion. A large number of crew members were entombed in the capsized hull. More than 600 sailors drowned (only 9 were rescued after 36 hours).	October 29, 1955
47	***Ida (Kanagawa) typhoon*** The typhoon made landfall in Kanagawa Prefecture, 15 miles south of Tokyo (japan). It deposited 15 inches of rain which caused the Kano, Meguro, and Arakawa rivers to flood. Flooding and landslides damaged or destroyed over 2,000 buildings and 244 bridges. Over 1,200 people were killed.	September 26-27, 1958
48	***Roseburg explosion*** A truck loaded with 4.5 tons of nitro carbonitrate and 2 tons of dynamite was parked overnight behind a hardware store in the center of the town of Roseburg (Oregon, USA). Apparently, a trash can fire ignited the truck, causing the load to explode. 7 city blocks were destroyed and buildings in another 28 were damaged.	August 7, 1959
49	***La Coubre explosion*** The French freighter, loaded with over 70 tons of grenades and ammunition, exploded when being unloaded at a pier in Havanna harbor (Cuba). During the initial emergency operations, 3 warehouses stored with munitions also detonated. The entire waterfront district sustained severe damage. The probable cause for the explosion was poor ammunition handling.	March 4, 1960
50	***Huascarán avalanche*** 3 million tons of ice broke loose from Mount Huascaran and slid down the Callejon de Huailas (Andes, Peru). It destroyed about ten villages and killed over 3,500 people.	January 10, 1962
51	***Holiday on Ice explosion*** At the end of a Holiday on Ice show in the Indianapolis Coliseum (Indiana, USA), liquefied petroleum gas that had leaked from a popcorn machine detonated. At the time of the explosion, over 4,300 people were in the theatre. Over 60 were killed.	October 31, 1963
52	***Hope slide*** The collapse of the south-western slope of Johnson Peak nearby the town of Hope (British Columbia, Canada), covered a 3-km section of the Hope-Princeton highway with 47,000,000 cubic meters of debris up to a depth of 85 meters. Four drivers were crushed in their vehicle.	January 9, 1965
53	***Barisal cyclone*** A tropical cyclone with maximum winds of over 16 km per hour and a 3.7 m storm surge killed almost 20,000 people in the Barisal Division (People's Republic of Bangladesh).	May 11, 1965
54	***SS Daniel J. Morrell event*** The Great Lakes freighter SS Daniell J. Morrell en route from Buffalo, New York to Taconite, Minnesota (USA) broke apart and sank in a Lake gale during a severe storm.	November 29, 1966

N°	Description of the disaster	Date
55	***Le K3*** A fire broke out on board of the nuclear submarine K3 which was en route on the Norwegian Sea. Almost 40 of the crew members were killed.	September 8, 1967
56	***Ferry Wahine sinking*** Approaching Wellington Harbor (New Zealand) in reduced visibility and with the radar inoperable, the steamer Wahine was hit by a very large wave. The ship was blown off course and grounded on Berrett Reef. Wave action freed the damaged Wahine from the reef and started to carry her into the harbor. During the evacuation, over 50 people were killed	April 10, 1968
57	***Ibrox stadium disaster*** The disaster occurred when crush barriers collapsed at the moment thousands of fans made their way out of the Ibrox Park Stadium in Glasgow (Scotland) during a match between the Celtic Football Club and the Rangers Football Club.	January 2, 1971
58	***Salvador stadium stampede*** Fans stampeded as a fight erupted in the grandstand of the Salvador stadium (Brazil) during a football match.	March 4, 1971
59	***Quebradablanca Canyon landslide*** A massive landslide of rock and mud in the Quebradablanca Canyon (Colombia) buried 6 buses and 20 other vehicles.	28 juin 1974
60	***Cyclone Tracy*** The tropical cyclone with hurricane wind force caused major damage to the village of Darwin (Australia). Although Tracy was very compact (the eye of the storm was 4 miles in diameter), it lasted for 6 days. Over 70 people were killed and more than 160 were reported missing.	December 20, 1974
61	***SS Edmund Fitzgerald event*** The Fitzgerald sunk in Lake Superior (USA) during a severe storm. No survivors were reported.	November 10, 1975
62	***MV Berge Istra explosion*** The modern bulk carrier loaded with 188,000 tons of iron ore, was en route from Tubarao (Brazil) to Kimitsu (Japan) when a series of 3 massive explosions caused the Berge Istra to rapidly sink in the Molucca Sea (Indonesia).	December 30, 1975
63	***Vrancea earthquake*** The 7.2 magnitude Vrancea (Romania) earthquake was felt throughout the Balkans. Over 1,500 people were killed and more than 11,000 were reported wounded. About 35,000 buildings were damaged.	March 4, 1977
64	***Ferrell Number 17 mine explosion*** Inadequate ventilation controls in the Westmoreland Coal Company's mines nearby the town of Uneeda (West Virginia, USA), allowed methane gas to accumulate and caused an explosion.	November 7, 1980
65	***Winter Park sinkhole*** During a period of record-low water levels in Florida, a massive sinkhole opened up in Winter Park (Florida, USA). In a single day the hole widened to 98 m and to a depth of 27 m. A two-story home and a number of vehicles disappeared into the sinkhole.	8 May 8, 1981
66	***Luzhniki disaster*** The deadly human crush took place at the Grand Sports Arena of the Luzhniki Stadium in Moscow (USSR) during a football match between Spartak Moscow and Haarlem (Netherlands). The number of fatalities was not officially revealed until seven years later.	October 20, 1982
67	***Coalinga earthquake*** The magnitude 6.5 earthquake which struck the Coalinga region (California, USA) was caused by an unknown fault. More than 5,000 aftershocks were recorded of which almost 900 had a magnitude of 2.5 or larger.	May 2, 1983
68	***K-219 event*** The Soviet Navy Yankee class nuclear ballistic missile submarine K-219 suffered a missile fuel explosion and fire, causing damage to the nuclear reactor controls. Nitric acid fumes compromised compartment seals and the crew was unable to contain the fire. The vessel sank in 18,000 feet of water.	October 3, 1986

N°	Description of the disaster	Date
69	***Goiânia radioactive contamination*** The contamination occurred after an old radiotherapy source was stolen from an abandoned hospital site in the city of Goiânia (Brazil). It was subsequently handled by many people resulting in 4 deaths. About 112,000 people were examined for radioactive contamination and 249 were found to have significant levels of radioactive material in or on their body.	September 27, 1987
70	***02B cyclone*** The 1991 Bangladesh cyclone was among the deadliest tropical cyclones ever measured. It struck the Chittagong district in the southeastern part of the country. Winds of 250 km per hour forced a 6 m storm surge inland, killing over 150,000 people.	April 29, 1991
71	***Latur earthquake*** A 6.4 magnitude earthquake struck the Maharastra state in the western region of India. Over 50 villages were demolished and more than 10,000 people were killed.	September 29, 1993
72	***Collision between the Balsa 37, the B-155 and the Ocean 255*** The Tank Barge Ocean 255 and the Tank Barge Bouchard B-155, two vessels carrying million liters of fuel oil, collided with the freighter Balsa 37 near the entrance of Tampa Bay (Florida, USA). Over 1.3 million liters of oil were spilled into the bay.	August 10, 1993
73	***Maracaibo National Jail riot*** During a riot, which lasted for six days, an estimated 100 people died in the vastly overcrowded Maracaibo National Jail (Venezuela). Inmates shot and stabbed each other and set fire to the prison.	January 3, 1994
74	***Soufrière Hills volcano eruption*** After a long period of dormancy, the Soufrière Hills volcano on the Caribbean island of Montserrat became active in 1995 and has continued to erupt ever since. Its eruptions have rendered more than half of Montserrat uninhabitable and destroyed the capital city. About two thirds of the population left the island.	July 18, 1995
75	***Khobar Towers bombing*** A terrorist attack on a housing complex in the city of Khobar (Saudi Arabia). At that time the towers were being used as quarters for American military personnel.	June 25, 1996
76	***Anzob Pass avalanche*** Over 40 people were killed when a sudden avalanche buried 15 trucks and cars under more than 10 m of snow on the 3,352 m-high Aznob Mountain Pass (Tajikistan).	October 23, 1997
77	***Jesse Oil Pipeline explosion*** The sabotaged pipeline had been leaking fuel for three days at a steady rate. When hundreds of people were trying to scoop the leaking fuel for personal use at the community of Jesse (Nigeria), the oil pool suddenly ignited in an explosion and fire.	October 17, 1998
78	***Oklahoma tornado outbreak*** On May 3, a series of 66 tornados broke out in Oklahoma and Kansas (USA). The events of this day were the beginning of a vigorous severe weather event that lasted for three days and brought violent tornado storms to Oklahoma, Kansas, Arkansas, Texas, and Tennessee.	May 3, 1999
79	***Whatcom Creek fire*** A pipeline rupture in the city of Bellingham (Washington, USA) spilled 230,000 gallons of gasoline into Whatcom Creek and ignited.	June 10, 1999
80	***Sinking of the MV Asia South Korea*** The ferry which was en route from Cebu City to Iolo City (Philippines) sank near Bantayan Island in rough seas. Over 50 people were killed.	December 23, 1999
81	***Capsizing of the ferry Arlahada*** The wooden hull cargo vessel Arlahada, en route to the Province of Tawi-Tawi (Philippines), picked up approximately 200 passengers from small boats. The passengers boarded the Arlahada from one side which caused the capsizing of the vessel.	April 12, 2000
82	***Igandu railway accident*** A passenger train en route from Dar es Salaam to Mwanza (Tanzania) either went out of control or suffered a brake failure. It hit a freight train and 14 of the 15 coaches derailed and overturned.	June 24, 2002

N°	Description of the disaster	Date
83	***Texas floods*** A week of intense rainfall in the region of the watersheds of the Guadalupe, San Antonio and Neuces Rivers caused a major inundation in a larger part of Texas (USA).	June 29, 2002
84	***South and North Carolina Winter Storm*** A winter storm with ice, snow and freezing rain caused the loss of power to over 1,600,000 residences and businesses in central North and South Carolina (USA). Some families were without power for 10 days or more.	December 4, 2002
85	***Jiashi earthuake*** Due to a 6.8 magnitude earthquake, with its epicenter in Jiashi county (Xinjiang Province, China), several thousands of houses and buildings collapsed. A huge number of people were killed and injured.	February 24, 2003
86	***Cyclone Heta*** The category 5 tropical cyclone caused major damage on the islands of Tonga, Niue and American Samoa (Polynesia).	January 7, 2004
87	***Al Hoceima earthquake*** A magnitude 6.4 earthquake at a depth of 13 km caused heavy casualties in the Al Hoceima region (Morocco). In no time over 2,000 buildings, mainly constructed on mud brick, were destroyed or severely damaged.	February 24, 2004
88	***Interstate 75 pileup*** A chain reaction accident involved approximately 50 vehicles on Interstate 75 in the vicinity of Clarkston (Michigan, USA). Bright sunlight combined with icy road conditions resulted in multiple collisions when traffic stopped and automobiles collided at slow speed.	December 1, 2004
89	***Moscow blackout*** A fire and explosion in one of the substations of the city's energetic company caused massive electric generating plant failures and created a widespread electric power outage in the wider Moscow region (Russia).	May 25, 2005
90	***Bad Reichenhall collapse*** The roof of the skating rink at Bad Reichenhall (Germany) collapsed under a heavy snow load. At the time of the collapse, approximately 50 skaters were in the building. More than 10 of them were killed.	January 2, 2006
91	***KTS Textile Mill fire*** At least 500 workers were inside the 4 story KTS Textile Mill (Dhaka, People's Republic of Bangladesh) when a fire started. Witnesses reported that the single main gate of the mill was locked.	February 23, 2006
92	***Tommy Waste Dumping*** The Panamanian-flagged vessel Probo Koala discharged over 500 metric tons of toxic waste in the port of Abidjan (Ivory Coast). The Ivorian company Tommy, contracted to dispose of the cargo, dumped the sludge at 17 public locations in Abidjan.	August 19, 2006
93	***Iran Air tour Mashhad crash*** During landing at Mashhad airport (Iran), the left wing of an aircraft hit the ground. The plane caught fire and 29 people died.	September 1, 2006
94	***Esperanza fire*** The vegetation fire, most likely been set by an arsonist, started on October 26th near Palm Springs (California, USA). Winds up to 80 km per hour contributed to the rapid spread and an estimated 163 km² were burned before containment.	October 26-30, 2006
95	***Belakoba train bombing*** A bomb, placed by terrorists, exploded in a passenger coach of a train en route from New Jalpaiguri to Haldiguri (India). The explosion caused a fire which generated such heat that one of the sides of the car was reported to have melted.	November 20, 2006
96	***Ulus bombing*** The bombing was a suicide attack that occurred outside a shopping centre in the Ulus quarter of Ankara (Turkey). 5 people were killed and over 100 were reported injured.	May 22, 2007

N°	***Description of the disaster***	***Date***
97	***Kerch Strait storm*** During a very heavy storm on the Black Sea, four oil tankers sank in the Kerch Strait (between Russia and Ukraine), resulting in a major fuel oil spill.	November 11, 2007
98	***Lac Kivu earthquake*** The 5.9 magnitude earthquake, with its epicentre at Lake Kivu (Democratic Republic of Congo) shook several counties in Africa's Great Lakes region.	February 3, 2008
99	***L'incendie des « Teachers Apartments High Rise »*** A 28-storey high-rise apartment building in the city of Shanghai (China) caught fire. Almost 60 people were killed.	November 15, 2010
100	***La Gabriela mudslide*** After a period of extensive rain, a mudslide struck the city of Bello (La Gabriela Districk, Colombia) killing over 20 people.	December 5, 2010

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