The CATDAT Damaging Earthquakes Database

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Abstract

The newly built global CATDAT damaging earthquakes and secondary effects (tsunami, fire, landslides, liquefaction and fault rupture) database was developed to validate, remove discrepancies and expand greatly upon existing global databases; and to better understand the trends in vulnerability, exposure and possible future impacts of such historic earthquakes.
Over 14500 sources of information have been utilised primarily in the last few years to present data from over 11600 damaging earthquakes historically (including over 90 from Australia), with over 6500 earthquakes since 1900 examined and validated before insertion into the database. Each validated earthquake includes seismological information, building damage, ranges of social losses to account for varying sources (deaths, injuries, homeless and affected) and economic losses (direct, indirect, aid and insured).
Globally, a slightly increasing trend in economic damage due to earthquakes is not consistent with the greatly increasing exposure. This could show the improved impact of better building practice due to earthquake building codes. The 1923 Great Kanto ($204 billion USD damage (2010 HNDECI-adjusted dollars)) compared to the 2008 Sichuan and 1995 Kobe earthquakes show the increasing concern for economic loss in urban areas as the trend should be expected to increase. Many economic loss values not reported in existing databases have been collected. Historical GDP, exchange rate, wage information, population and insurance information have been collected globally to form comparisons.
This catalogue is the largest known cross-checked global historic damaging earthquake database and should have far-reaching consequences for earthquake loss estimation, socio-economic analysis and the global reinsurance field.

Keywords: CATDAT, socio-economic analysis, damaging earthquake, deaths, economic loss.

NOTE:-A version of this paper is in submission to a journal.

Introduction

The uncertain nature of earthquakes can cause rapid stresses on a country's ability to function; whether it be due to economic, social or disaster management reasons. Through history, there have been numerous earthquakes that have affected nations.

Globally, depending on which book, website or information source is opened, the Xining earthquake which affected China in 1927 can be found to have caused anywhere between 40000 and 200000 deaths. The exact number of deaths can never be exactly quantified post-disaster due to quick burials, decomposition, inaccurate counting and other reasons; however, with careful analysis of all sources detailing effects relating to an earthquake, an educated judgement can be made as to a range of fatalities. This can be similarly undertaken for estimates of injured, homeless, affected, building damage, economic losses and other socio-economic consequences of earthquakes.

However, it is only by knowing the past, that one can ever predict the future. Thus, knowledge as to the seismological and socio-economic effects of previous damaging earthquakes is required for risk and vulnerability quantification.

Methodology

The first step was a list of socio-economic details for various earthquakes that the author had collected online (OCHA ReliefWeb archives, NGOs, insurance companies), from news reports (globally and historical), from earthquake-related books (Stein and Wysession 2003, Kramer 1996, Gutenberg and Richter 1948) and from papers (Ambraseys et al. 1982, 1991 etc., Samardzhieva and Badal 2002, BSSA 1911-2010) over a number of years due to the author's interest in natural disaster effects.

It was then realised that a detailed review and comparison was needed with other existing global databases. A review of existing global earthquake socio-economic effect databases was undertaken to see the completeness of these earthquake databases as well as to source all the known lists of earthquake data worldwide. During this process, a report by Tschoegl et al. (2006) was very useful detailing information about existing Natural Disaster databases globally. It contains information on 6 international databases (EM-DAT, MunichRe NatCat, SwissRe Sigma, ADRC: GLIDE, University of Richmond: Disaster Database Project and BASICS) and a number of regional, national and sub-national databases. In addition, a comparison of 3 of these – EM-DAT, MunichRe, Sigma – revealed that there were major gaps in these databases (Guha-Sapir et al. 2002).

Also reviewed were many other global earthquake catalogues that have been created around the world, including the Utsu catalogue (2002), NGDC/NOAA (2010 searchable version), EM-DAT and a comparison of 8 of these databases for certain earthquakes through PAGER-CAT (2008). However, it was found that these earthquake databases lacked consistency and omitted or had erroneous earthquake details pre-1980. Since the return period of most earthquake sources is much more than 30 years, increased knowledge of socio-economic effects pre-1980 was deemed to be required.

Thus, it was decided to expand the global CATDAT damaging earthquakes and secondary effects (tsunami, fire, landslides, liquefaction and fault rupture) database to validate, remove discrepancies and expand greatly upon the existing global databases; and to better understand the trends in vulnerability, exposure and possible future impacts of such historical earthquakes.

Four main databases (PAGER-CAT, NGDC, Utsu and MRNATHAN) were compared and checked earthquake by earthquake against the initial database. Although PAGER-CAT uses some Utsu and NGDC values, it was decided that a check was needed due to the possibilities of transmitting errors and misprints from these databases. To delve further into the databases, where possible, the precursors to the databases were explored. In the case of the 2010 NGDC Significant Earthquakes Database, the precursor was the Dunbar et al. (1992) catalogue, which was based on the Ganse and Nelson (1981) catalogue. These two databases combined PDE and USGS data with famous databases as Mallet (1852), Montandon (1953), Milne (1912), Sieberg (1932), Karnik (1969) and many regional databases like precursor versions of Gu et al. (1989), Kondorskaya and Shebalin (1982), Coffman et al. (1982) etc.

NGDC is similar to the Utsu catalogue that reviewed the Dunbar et al. (1992) catalogue and added to the database using additional sources (CERESIS 1985, Papazachos et al. 1997, Gu et al. 1989 etc.). Utsu also noted the erroneous nature of figures and locations in the NGDC database. The Utsu database has a number of errors, and is limited to deaths, injuries, a word description of damage and seismological information. However, it does have the largest number of damaging earthquakes out of all databases, including over 10000 up to 2002. Many of these were doubtful, repeated and erroneous and thus were not added to the CATDAT database. Each earthquake was audited with the original sources, or other sources where found. It was discovered through this study when going back to the original sources, that many errors in copying, values and assumptions had been made for many earthquakes worldwide.

A good example of this is the Shemakha earthquake of 1902 in Azerbaijan in the NGDC, MunichRe NATHAN, Utsu, EM-DAT and PAGER-CAT databases. EM-DAT does not include this earthquake in its database, having only the El Salvador, Guatemala and Uzbekistan (Andizhan) earthquakes for 1902. Utsu includes 86 deaths and 60 injured as its main estimate but does have a note that it could have caused 10000/20000 deaths. PAGER-CAT uses the Utsu catalogue value of 86 deaths and 60 injured due to the algorithm that they use to choose between databases. NGDC also gives a value of 86 deaths and 60 injured. However, with CATDAT a large number of different sources are used, including the initial source in the database of Ganse and Nelson – Kondorskaya and Shebalin (1982); it is seen that the description says that the value of 86 deaths comes about by only including deaths from villages around Shemakha and not the city itself. 20000 deaths is a probable exaggeration from newspapers combining the number of homeless with deaths and people injured. Thus, 2000 deaths from many sources is the accepted death toll with a CATDAT accepted range of 2000 to 5000 deaths (Kondorskaya and Shebalin 1982, London Times 1902, New York Times 1902). Russian and Azerbaijani websites and records were also consulted.

This expert validation procedure has been undertaken for each earthquake and hence a range of social and economic losses is gained. It was also seen that regional and country based databases and reports need to be used as only using English-speaking references reduces the volume and accuracy of the earthquake record collection. Thus, by using foreign sources i.e. Silgado 1968, 1978 (Spanish), Rothe 1965 etc. (French), Stuttgart 1933-1998 etc. (German), Postpischl et al. 1980 etc. (Italian), Gu et al. 1989 (Chinese), KOERI 2010 (Turkish) as well as Portuguese, Russian, Dutch (old Indonesian records) etc., the number of discovered earthquakes, social losses, economic loss values and building damage, as compared to other databases, was significantly increased. The colonisation through time was examined to view in what language the old earthquake records of certain countries could be (Figure 1). Searches were made in both the language of colonisation as well as the official current languages of the respective countries. In this way, many old records were sourced.

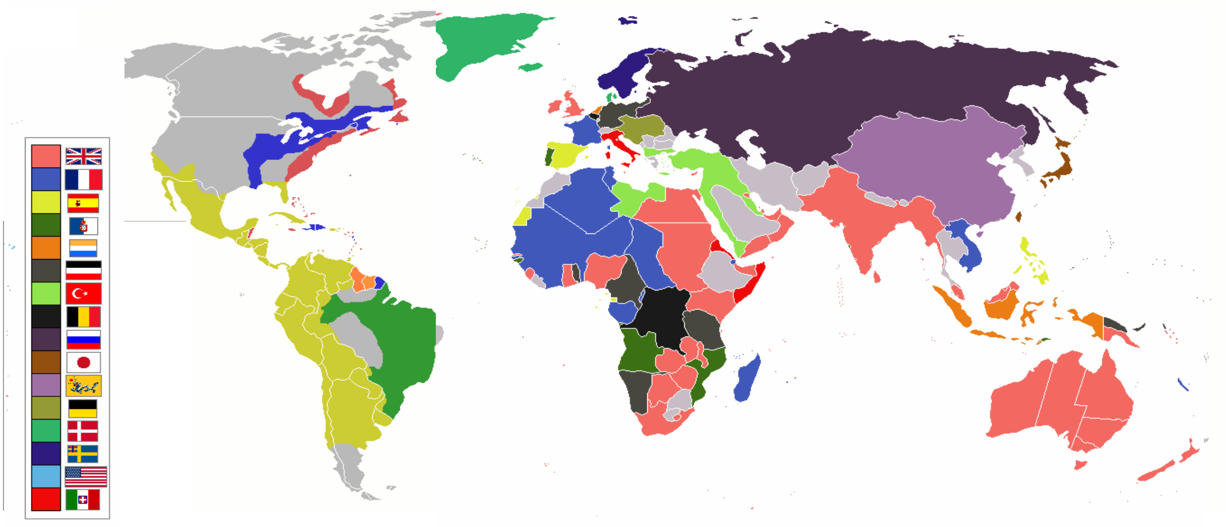

Figure 1 – The colonisation of countries used to determine languages required for searching for historic earthquake records (adapted from Wikipedia Commons 2010)

Criteria Used in the CATDAT Database

A damaging earthquake is entered into the CATDAT database by the following criteria:-

- Any earthquake causing collapse of structural components.
- Any earthquake causing death, injury or homelessness.
- Any earthquake causing damage or flow-on effects exceeding $10,000 international dollars, Hybrid Natural Disaster Economic Conversion Index adjusted to 2010.
- Any earthquake causing disruption with a reasonable economic or social impact as deemed appropriate.
- A requirement of validation of the earthquake existence via 2 or more macroseismic recordings and/or seismological information recorded by stations and at least 1 of the 4 definitions above.

Each validated earthquake includes the following parameters filled in to the best available detail:-

- Date (Day, Month, Year, Time (Local and UTC)).
- Seismological Information (EQ Hypocentre Latitude; Longitude; Depth (km); Intensity (MMI); Magnitude; Magnitude type)
- ISO3166-2 Country code, including Kosovo; ISO Country Name.
- Human Development Index of country; HDI Classification; Economic Classification; Social Classification; Urbanity Index; Population at time of event; Nominal GDP at time of event – split into developed or developing countries.
- CATDAT Preferred (Best Estimate) Deaths; Secondary Effect Deaths; Ground Shaking Deaths; CATDAT Upper and Lower Bound Death Estimates; Global Literature Source Upper and Lower Bound Death Estimates; Severe Injuries; Slight Injuries; CATDAT Upper and Lower Bound Injury Estimates; Global Source Upper and Lower (U/L) Bound Injury Estimates; Homeless (and U/L Bound); Affected (and U/L Bound); Missing.
- Buildings destroyed; Buildings damaged; Buildings damaged – L4, L3, L2, L1; Infrastructure Damaged; Critical and Large Loss Facilities; Lifelines damaged.
- Secondary effects that occurred (Tsunami, Seiche, Landslide (mud, snow, rock, soil, quake lake), Fire, Liquefaction, Flooding, Fault Rupture); % of the social losses that were caused by each secondary effect; % of economic losses that were caused by each secondary effect; Tsunami Deaths; Landslide Deaths; Fire Deaths; Liquefaction Deaths.

- Disease and additional long-term problems.
- Full word description of various sources contributing to the data, including associated references.
- Country-based CPI at time of disaster; Country-based Wage Index at time of disaster; Country-based GDP Index; USA CPI for comparison; Hybrid Natural Disaster Economic Conversion Index.
- CATDAT Preferred (Best Estimate) Total Economic Loss; CATDAT U/L Bound of Economic Loss; Global Source U/L Bound of Economic Loss; Additional Economic Loss estimates from varying sources; CATDAT Economic Loss 2010 HNDECI-Adjusted; CATDAT Economic Loss 2010-country based CPI adjusted.
- Insured Loss; Insured Loss In 2010 dollars; Insured estimate source; Estimated Insurance Takeout at time of event.
- Indirect and Intangible economic losses.
- Estimated life cost given social values, working wages etc. at the time.
- Total Economic Loss as a percentage of country's GDP; Social losses trended by population.
- CATDAT Earthquakes ranked via the Munich NatCat Service methodology.
- CATDAT Earthquakes ranked for the CATDAT Economic Disaster Ranking and CATDAT Social Disaster Ranking based on relative values and not absolute values. This will be explained further below.
- Link to ReliefWeb archive where available.
- Aid contribution; Aid delivered; Aid Source.
- Split country impacts (social and economic) where earthquake has affected more than 1 country.
- Various ratios between components for trends analysis.
- Normalisation strategies for current conditions. (Daniell et al. 2010b)
- Links to EQLIPSE.

This is contained in a Microsoft Excel framework with external links to other resources.
A quick summary of historical socio-economic trends will now be presented to aid the understanding of the usefulness of such a database and to compare CATDAT to other existing databases.

The Number of Earthquakes contained in the CATDAT Database

As of July 2010 in CATDAT v4.12, over 14500 sources of information have been utilised to present data from over 11600 damaging earthquakes historically, with over 6500 earthquakes since 1900 examined and validated before insertion into the CATDAT damaging earthquakes database.

The database significantly extends the socio-economic effect record in the period from 1900-1980. Figure 2 depicts a trend between the number of damaging earthquakes in countries of differing development levels. The author has developed the first complete Human Development Index for all 244 nations through time from 1900 to 2010 (Daniell, 2010b). This meant the creation of life expectancy, GDP (PPP) per capita, literacy rate and enrolment rate tables for each country through time, in order to create this index. It also required the knowledge of wars, history of countries, and country border changes. Thus with CATDAT, for the first time, a standardised look at natural disaster losses as a function of country status can be gleaned. It can be seen that a proportion of the earth is still developing, and that a large proportion of high seismic risk countries have an HDI which is still less than 0.8 as of 2010.

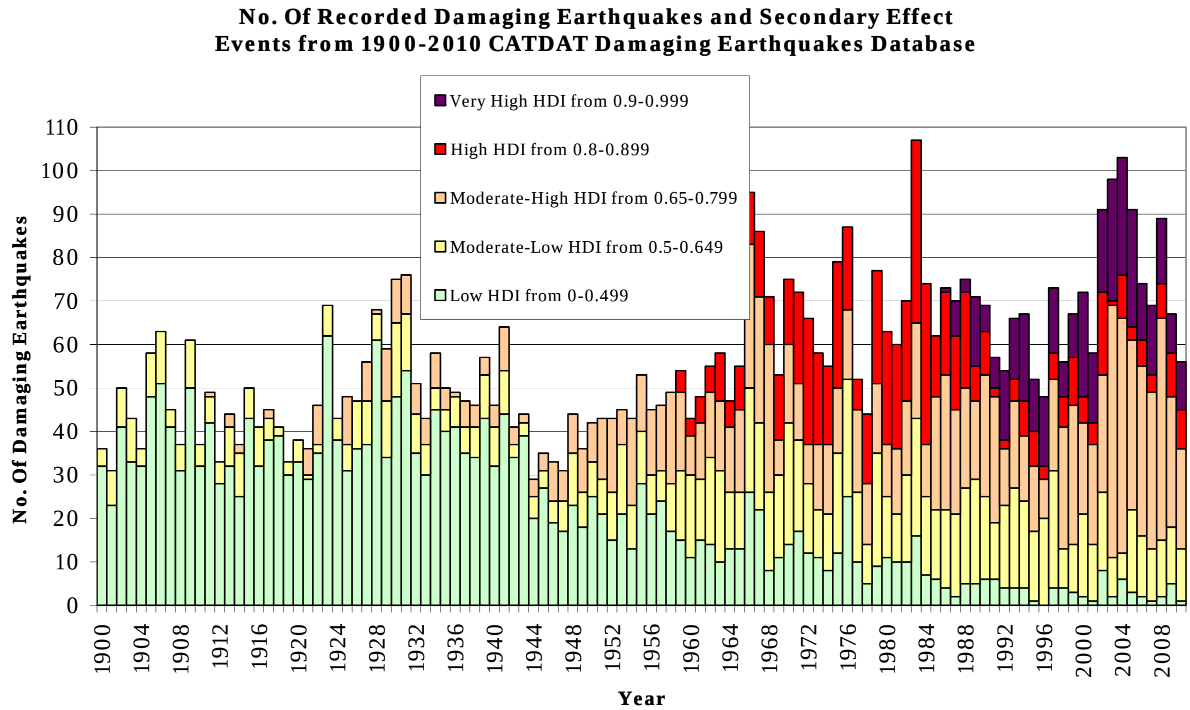

Figure 2 – As of CATDAT v4.12, the number of included historic earthquakes in the database showing development status of the nations they affect.

In Figure 3 the comparative number of damaging earthquakes between three databases is examined. It can be seen that the CATDAT database fills in the gaps in recording in the early 20th century through detailed examination and hunting for details of these earthquakes.

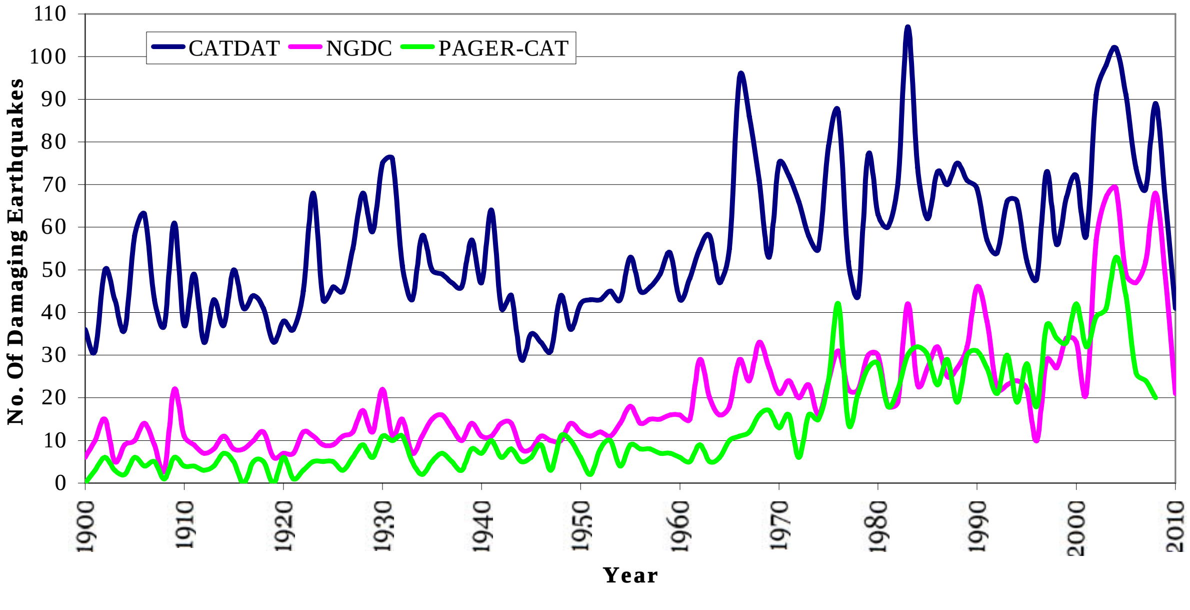

Figure 3 – A comparison of the number of damaging earthquakes included in major databases.

It is interesting to note that the number of damaging earthquakes has an average of approximately 45 up until 1960, and approximately 70 from 1960 onwards. This could be due to the increase in media coverage around the world, proliferation of seismic networks or better reporting procedures of earthquake damage.

Spatially, in Figure 4, is the view of the world according to CATDAT in terms of the number of damaging earthquakes since 1900. It can be seen that Papua Province (Indonesia) has a different number of historic damaging earthquakes to Papua New Guinea. Thus, this country-based view is only shown to show relative distribution of recorded damaging earthquakes.

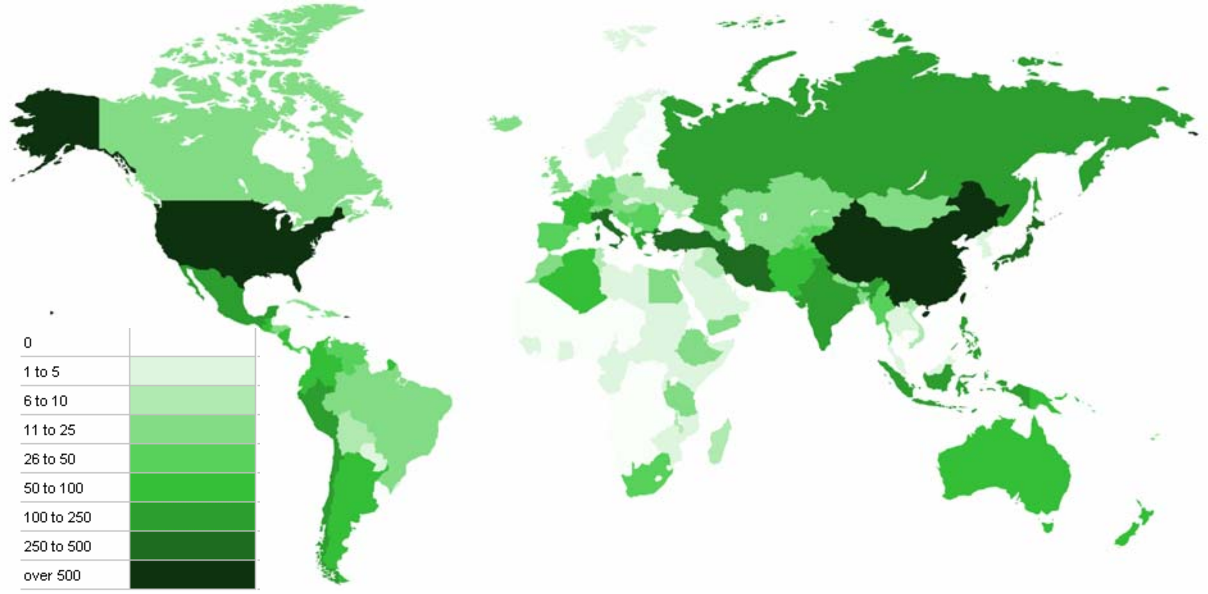

Figure 4 – A comparison of the relative number of damaging earthquakes in the database per country (the darker the area, the greater the number of damaging earthquakes).

Global Social Losses due to earthquakes

The number of deaths in all countries since 1900 has been found to be approximately 2.47 million (2.219-2.714 million). There have been approximately 3.8 million injuries recorded; yet the trended value of injured (accounting for where injury data is unavailable) is towards 10 million injured. Assuming 6 billion deaths worldwide from 1900-2010, earthquakes have caused approximately 0.041% of fatalities. There have been over 3000 damaging earthquakes globally since 1900, causing either death or injury, and a great number more have caused homelessness or affected the lives of the population.

It can be seen from Figure 5 that approximately 8.48 million people have been recorded as having died from earthquakes through time. When compared to the global population, it can be observed that the fatality rate is not rising, even considering the greatly increased population. Trends referring to 1900 onwards are shown in Daniell et al. (2010a).

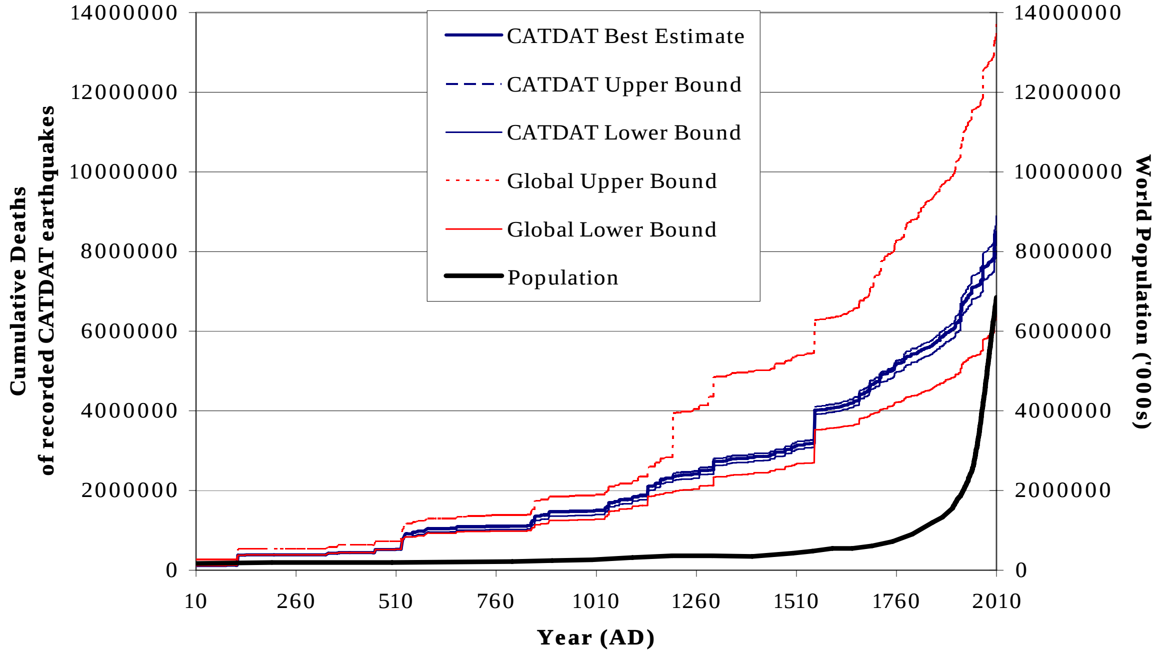

Figure 5 – The CATDAT estimates versus the smallest plausible and largest plausible fatalities from earthquakes from various literature sources. This is compared with the global population.

Below is a table of the number of earthquakes since 1900 causing one death or greater recorded in different international databases. It must be noted that the values in Utsu should be slightly less, as the errors found in each database have not been removed, only noted. Although the fact that there are more fatal earthquakes collected in CATDAT is good, it is the validation of the earthquakes and removal of errors that makes the CATDAT database so useful. It also should be said that the criteria in NGDC and EM-DAT is different from CATDAT; however, these two databases seem to include any damaging earthquake despite the cutoff criteria they set at the start.

Table 1 – The number of fatal earthquakes from 1900-2008 as shown in earthquake databases

	CATDAT	**Utsu IISEE Hara**	**PAGER-CAT**	**NGDC**	**EM-DAT**
TOTAL	1921	1635	1108	1272	743

Bilham (2009) presents approximately 1000 fatal earthquakes for the period 1900-2000. This value is slightly greater than the PAGER-CAT estimate and mimics closely the NGDC database due to the use of Dunbar et al. (1992). Nichols and Beavers (2008) present 1010 fatal earthquakes from 1900-1999. During this time period from 1900-1999, the author's value in CATDAT is 1673 fatal earthquakes, showing the difference in collection methods.

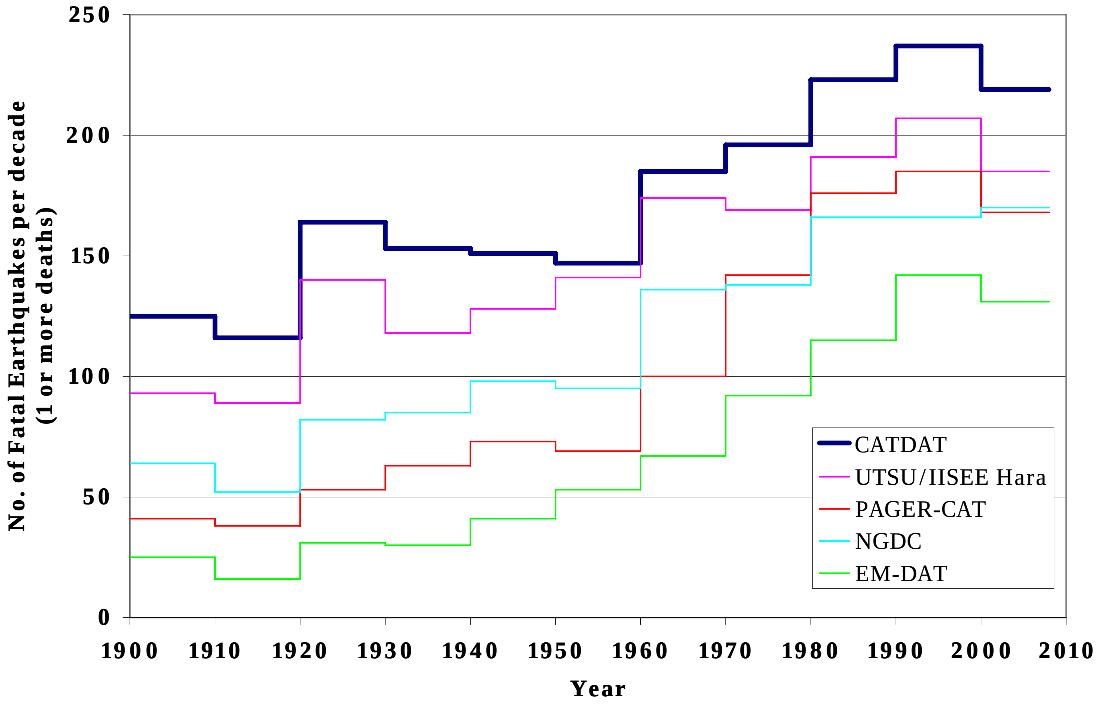

Figure 6 – The number of fatal earthquakes per decade in each of the major international earthquake databases as compared to CATDAT v4.12.

Another useful comparison can be seen in terms of the maximum and minimum plausible values of fatalities and injuries compared to the CATDAT best estimate. This allows us to see which major earthquakes are generally overestimated or underestimated in terms of death tolls. In Figure 7 below, all earthquakes since 1900 with a CATDAT best estimate death toll of 1000 persons or more are compared on the y-axis, the upper bound (diamond) and lower bound (square) literature value (with removal of obvious errors) from various global sources. Where there is not much variability, the upper and lower bound value should lie on the middle black line. Where there is a deemed overestimated death toll in literature sources the earthquake appears as a diamond above the best estimate line. Where there is a deemed underestimated death toll in literature sources the earthquake appears as a square below the best estimate line. Earthquakes can have a wide range of death toll estimates so in some cases, such as the Shemakha 1902 earthquake (previously mentioned), or the Messina 1908 earthquake, for which both the upper (around 200000 deaths) and lower estimate (38000 deaths) can be deemed as over- and underestimates on a true death toll (likely about 85000 deaths).

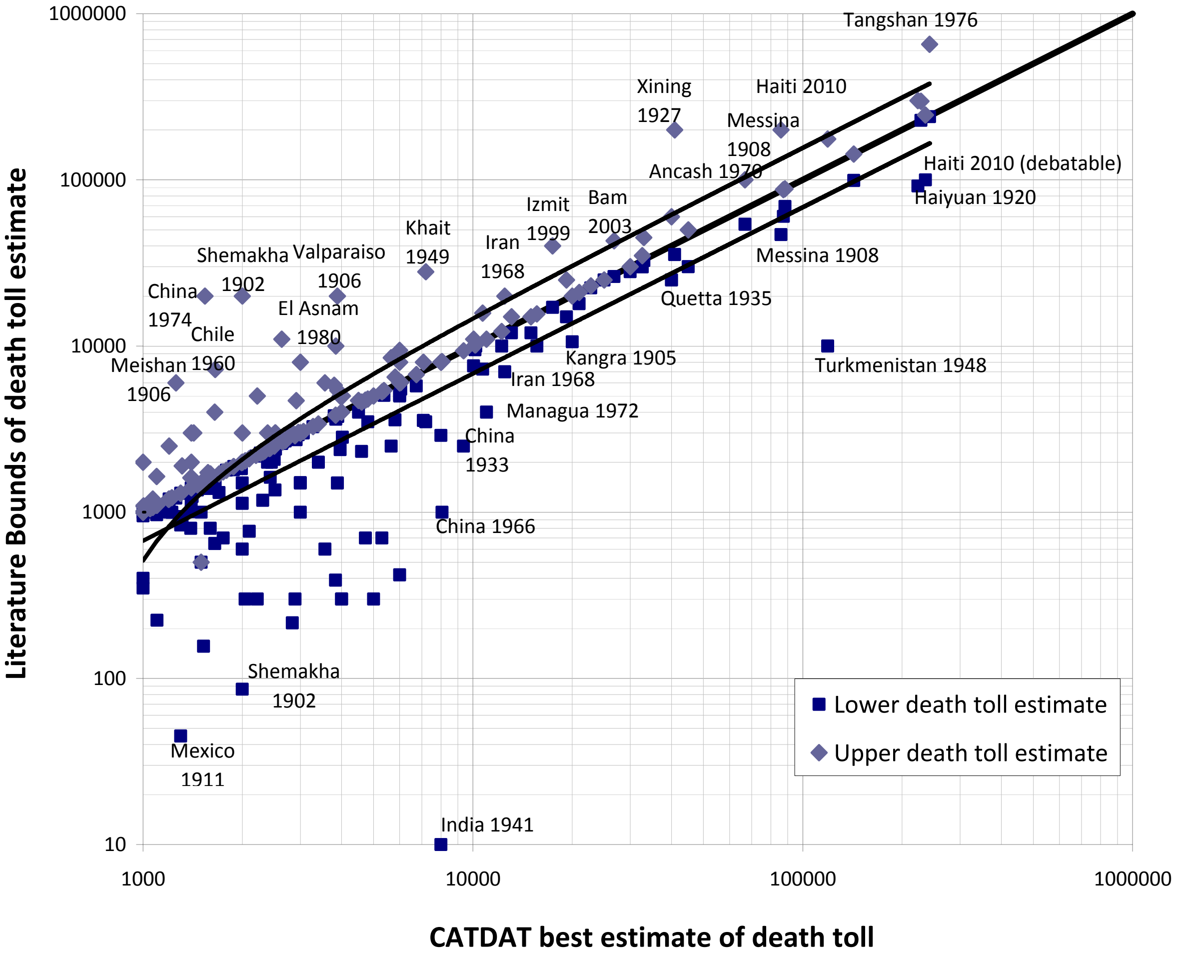

Figure 7 – CATDAT v4.12 Damaging Earthquakes median death toll as compared to the upper and lower death toll estimates in global literature.

It can be seen in Figure 8 that there is a very low value of deaths from 1900 onwards in developed countries when compared to developing countries. This is in part due to the increasing development of countries through the time period. In Figure 8, the annualised global fatalities are presented. The average deaths per year are approximately 22000. Trends as to affected, aid, homelessness and injuries are also included in the CATDAT database. It can be seen that there is virtually no deaths for earthquakes occurring in countries with HDI over 0.8. This is due to two reasons:- 1) as these countries develop, more attention is paid to disaster management, 2) there are comparatively less damaging earthquakes that have occurred since 1900 in these nations (as seen in Figure 2) due to development status of countries. To counteract this discrepancy in number of damaging earthquakes it can be standardised to a deaths per damaging earthquake (Figure 9).

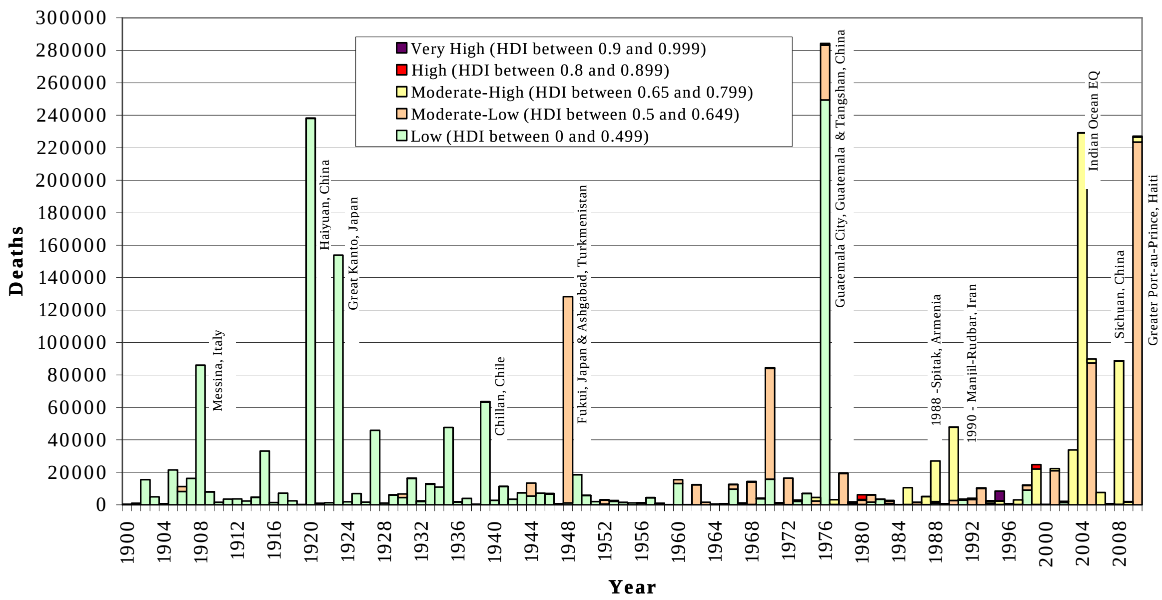

Figure 8 – CATDAT v4.12 Damaging Earthquakes – Best estimate of yearly deaths for events from 1900-2010

The following Figure 9 shows that as countries develop, generally better enforcement of building codes, research into earthquake hazard and effects, and thus better earthquake building practice and risk reduction measures are present. This has been explored through the use of Daniell, 2010c.

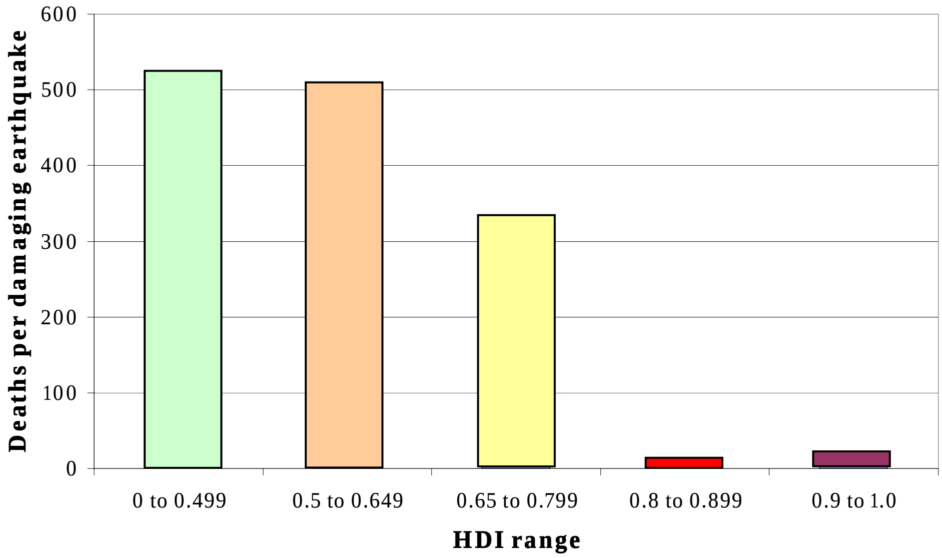

Figure 9 – Median deaths per CATDAT v4.12 damaging earthquake for a particular Human Development Index bracket.

Figure 10 is the number of deaths that have occurred due to earthquakes in each country divided by the population (in millions) at the time of disaster, integrated over the entire time period from 1900 to 2010. It can be seen that Turkmenistan and Armenia have the highest relative fatality rates globally. These have been caused primarily by the 1948 and 1988 earthquakes respectively. In absolute values, China, Haiti, Indonesia, Iran, Japan and Turkmenistan have had the highest death and injury counts since 1900. In terms of homelessness, China dominates statistics due to the large building losses in Haiyuan 1920, Xining 1927, Tangshan 1976 and Sichuan 2008.

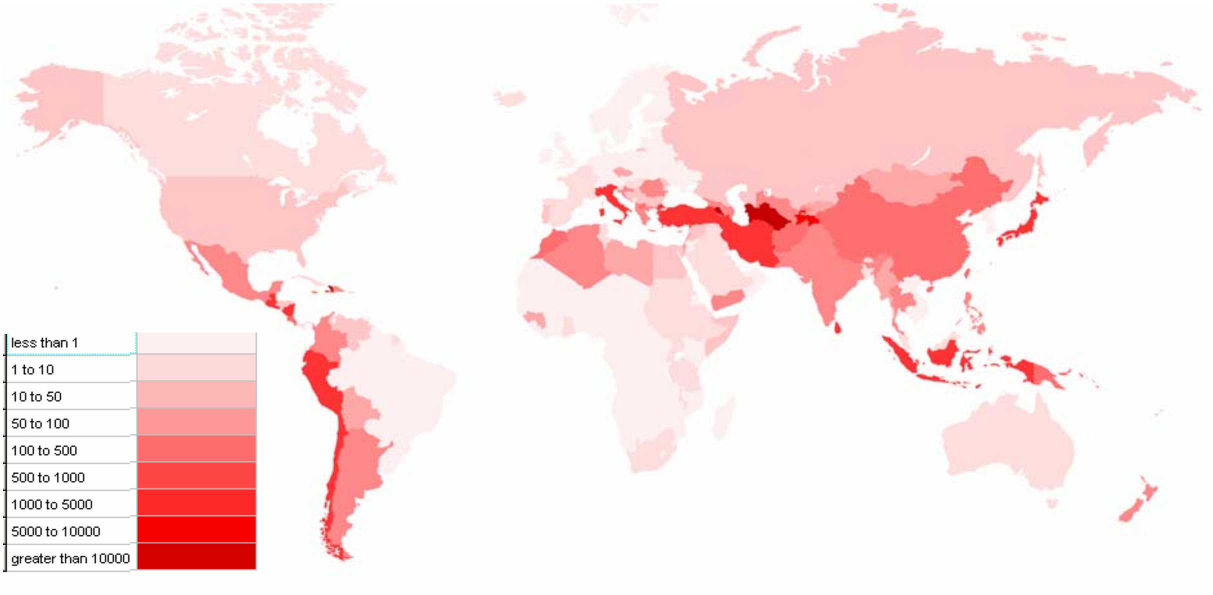

Figure 10 – Number of deaths for each country as a proportion of millions of population at the time of disaster integrated from 1900 to 2010. CATDAT v4.12, 2010.

The secondary effects of earthquakes

The secondary effects of 6500 earthquakes since 1900 were separated from the ground shaking effects. The economic losses, building damage and social losses have also been separated and will be presented in a future paper. The following diagram differs significantly from Bird and Bommer (2004) and is closer to Marano et al. (2010). It can be seen that the effects of fire (mostly 1923 Great Kanto), tsunami (mostly 2004 Sumatra) and landslides (1920 Haiyuan) dominate the fatalities. However, it is important to also take region into account. Through the following diagram, a higher percentage of secondary effect deaths has been seen in the Asia-Pacific when compared to the entire world picture.

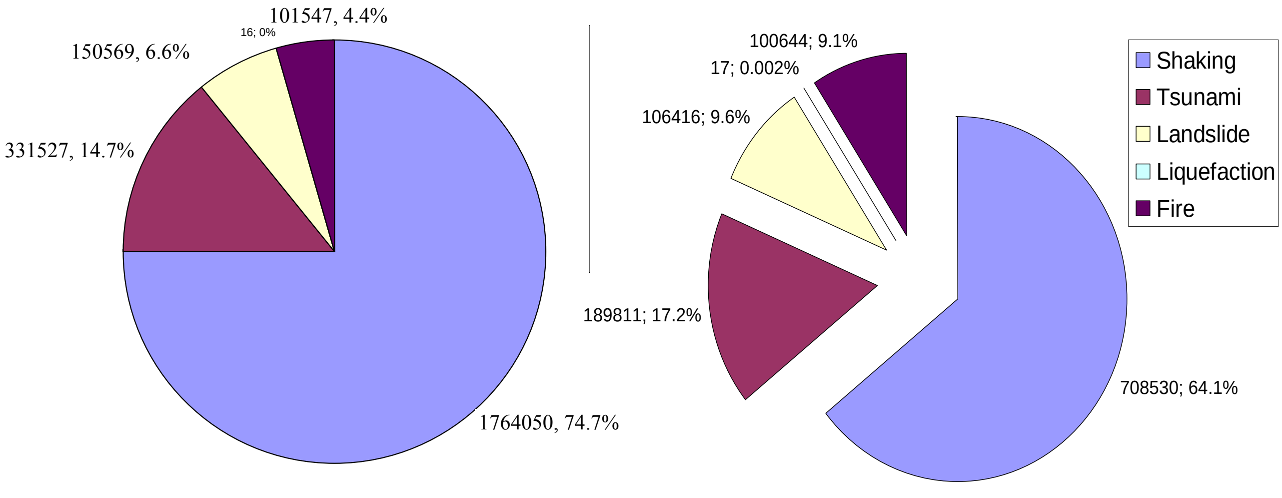

Figure 11 – Left – Shaking and Secondary Effect Deaths Worldwide, Right – Shaking and Secondary Effect Deaths in the Asia-Pacific Region (Daniell et al. 2010c, Daniell 2010a)

Global Economic Losses due to earthquakes

As mentioned previously, a significantly increased database of economic losses from earthquakes has been created during this process. Much collection of building damage details and other infrastructure losses has occurred for the CATDAT entered earthquakes. In order to analyse and rank earthquakes due to economic criteria, an extensive global database of exchange rate, CPI and GDP (nominal and real) information was created in order to be able to adjust and compare foreign earthquake loss estimates. Global databases of wage rate and other parameters such as purchasing power parity (PPP) were also created as part of the study, from sources such as Maddison (2003), World Bank (2010), and IMF (2010), as these details are required to effectively convert loss estimates from around the world into present-day costs.

A comparison of economic losses in major international databases is shown below. CATDAT is compared to NGDC, EM-DAT, MRNATHAN and others. The number of exact economic estimated earthquakes since 1900 has been compared. The NGDC has a cutoff criteria of approx. $1m US; however, it can be seen that this is not adhered to, given values of $0.04m US etc. MRNATHAN is only a part of the full MunichRe database but this is the only open source component to test. EM-DAT also has estimates from $0.1m US. PAGER-CAT takes into account a combination of EM-DAT and NGDC data.

Table 2 – The number of earthquakes from 1900-2010 with exact economic loss values

	CATDAT	**NGDC**	**PAGER-CAT**	**EM-DAT**	**MRNATHAN**
TOTAL	754	398	338	389	199

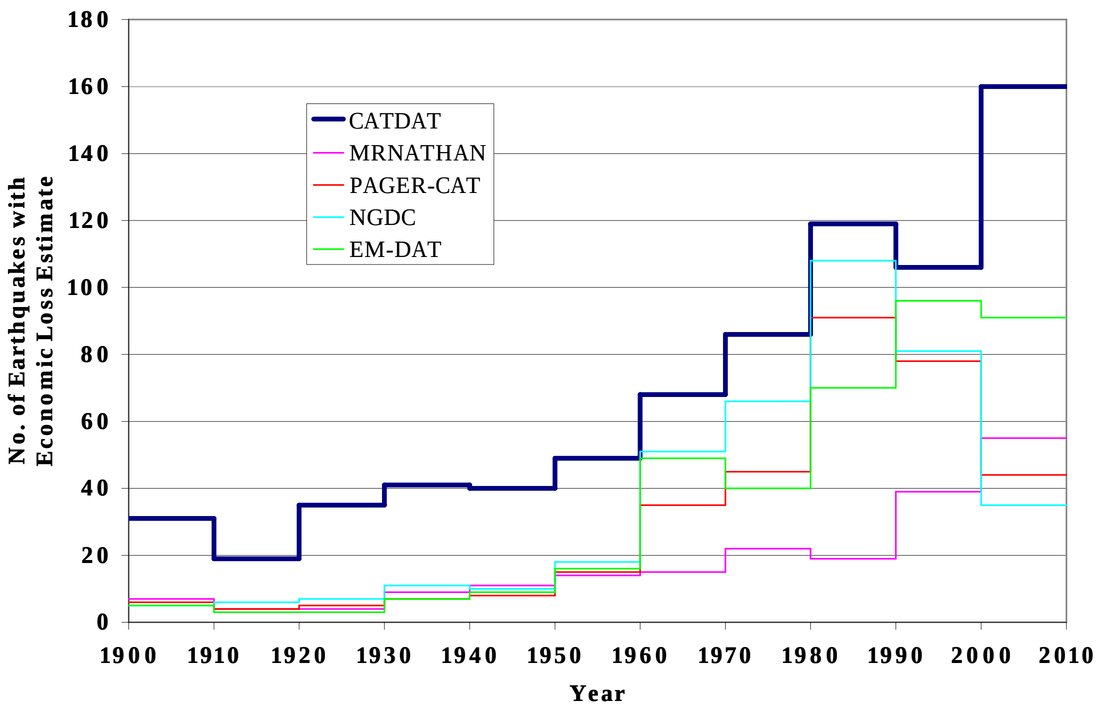

Figure 12 – The number of earthquakes with exact economic loss estimates per decade in each of the major international earthquake databases as compared to CATDAT v4.12.

For earthquakes in CATDAT where there is no estimate from a previously written source, separate analysis has been done to calculate an order of magnitude for the economic losses based on historic construction costs, wages as a proportion of building damage and then reanalysing losses. Using the economic status of a region, a reasonable estimate has been established. In some cases, the range description developed by Ganse and Nelson (1981) in 1979 dollars, and Dunbar et al. (1992) based on 1990 dollars was used; however, in many cases it was found to be erroneous. Every one of the 6500 earthquakes in the CATDAT database from 1900 onwards has an economic loss range associated with it. This is used to fill in the gaps in earthquake economic loss knowledge worldwide, to account for previously unquantified earthquakes.

The economic losses in absolute values are reasonably consistent with previous estimates showing the most losses in the following countries; Japan ($683 billion 2010 HNDECI-adjusted dollars), United States ($271 billion), China ($204 billion), Italy ($132 billion) and Chile ($109 billion). However, it is important to take into account the changing GDP in countries and to determine the impact based on this. The relative values between nations based on a division of economic losses incurred at time of disaster as compared to GDP in 2010 constant billion dollars, are shown in the following world map. This was then integrated over the time period from 1900 to 2010. Armenia, Turkmenistan, Haiti, Nicaragua, Wallis and Futuna, TFYR Macedonia and Chile have been seen to have the highest relative ratios, as shown in Figure 13.

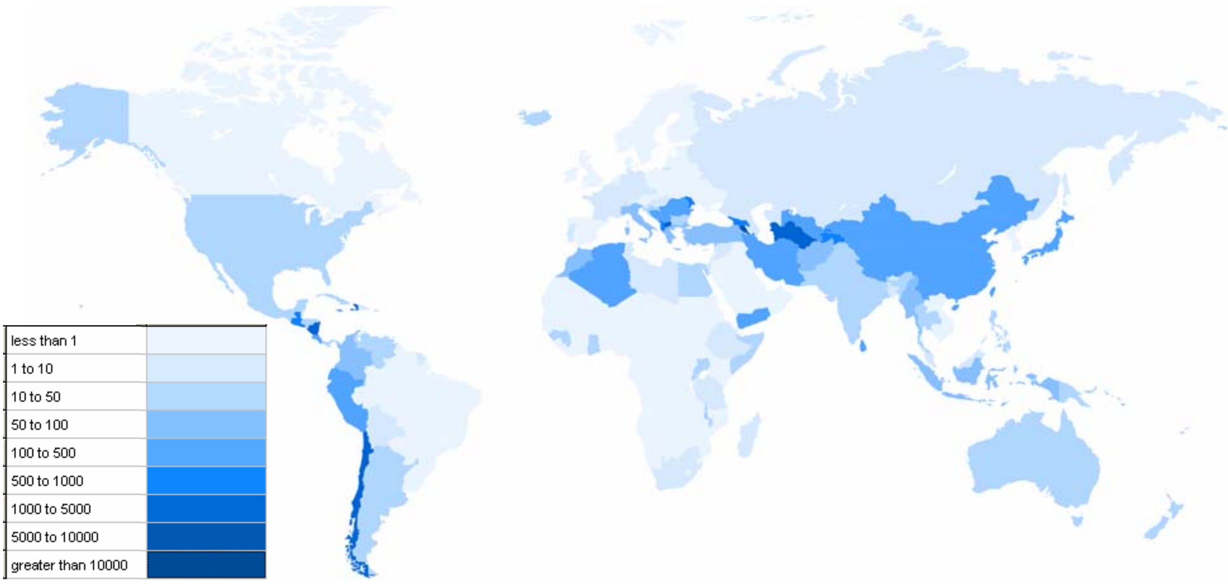

Figure 13 – Economic Losses for each country as a proportion of billion GDP in constant 2010 dollars at the time of disaster integrated from 1900 to 2010. CATDAT v4.12, 2010.

The following is a list from CATDAT of the top 10 greatest economic losses as a function of GDP (Nominal) and GDP (Nominal, PPP) to compare the total economic loss at the time of disaster to the economy of the time. The median cost shown in Table 3 presented in US dollars is the most accepted value of total economic loss at the time of the earthquake as found from CATDAT through the literature. This is classified as the median cost of the event. In the full CATDAT database, there is a range of accepted loss estimates for each earthquake that are not included in this paper. This was generally presented in US dollar values in the literature (converted from local currency using time-of-event exchange rate). For more detail refer to Daniell et al. (2010a).

Table 3 – The top 10 highest ranked earthquake losses since 1900 in terms of percentage of nominal GDP (both unadjusted and purchasing power parity) – Daniell et al. (2010a)

Rank	**Earthquake**	**Date**	**Median cost at time of event in $US**	**% of Nominal GDP (PPP)**	**% of Nominal GDP**
1	Spitak, Armenia*	07.12.1988	16.20 bn	92.3*	358.9*
2	Port-au-Prince, Haiti	12.01.2010	7.754 bn	70.3	119.8
3	Guatemala	04.02.1976	3.900 bn	44.6	98.0
4	Managua, Nicaragua	23.12.1972	0.845 bn	19.7 to 38.3	67.1 to 96.2
5	Cartago, Costa Rica	04.05.1910	0.025 bn	63.5	≈90.0
6	Maldives Tsunami**	26.12.2004	0.603 bn	50.1	77.7
7	Concepcion, Chile	17.08.1906	0.260 bn	47.8	55 to 82.86
8	Wallis and Futuna	12.03.1993	0.014 bn	51.9	54.0
9	Great Kanto, Japan	01.09.1923	3.840 bn	29.8	52.8
=10	Nicaragua	31.03.1931	0.030 bn	26.5	51.0
=10	Jamaica***	14.01.1907	0.013 bn	23.9	45.9

*Accounts for a partial Soviet Union response – doubling the 1990 Nominal GDP and GDP (PPP) of Armenia. Hyperinflation and devaluation made it very difficult to properly determine the GDP of the time; thus, a range has been given incorporating different sources from 1988-98 using an average value through this period, consistent with the reconstruction payout through time.
**Only accounts for the Maldives losses in the Indian Ocean Tsunami
***Jamaica included as equal 10th due to the uncertainty in values. Up to $30 million USD has been estimated which would push Jamaica into the top 5 in terms of Nominal GDP.
****1902 Guatemala (up to 25 million USD, up to 35% GDP(PPP)), is difficult to discern which losses are earthquake and which losses are volcano-related (Santa Maria).

In the Hybrid Natural Disaster Economic Index (HNDECI) developed as part of the CATDAT database to compare earthquakes, components of the earthquake loss (direct and indirect) are assigned an inflation adjustment measure to bring it to present day value in much the same way as a project escalation index. In this way, the total earthquake loss will be defined to present day value, eliminating the error of CPI adjustment. Through the descriptions of major earthquake damage costs in CATDAT and through reconstruction costs it can be seen that 33% of the cost of an earthquake comes from under reconstruction unskilled wages. Thus, the HNDECI is primarily based on unskilled wage and building material trends as well as relative utility trends, life costs and other inflation measurements to bring the value forward and needs to be calculated on a country-by-country basis. Refer to Daniell et al. (2010a) for information as to the HNDECI.

Using the HNDECI for all worldwide earthquakes to adjust them to 2010 dollars, Figure 14 shows the results of cumulative economic loss for each year. In this case, 2010 Human Development Index is used to classify the country losses with developing countries (defined as a 2010 HDI<0.87 shown in orange) and developed countries (defined as a 2010 HDI>0.87 shown in blue). The black line shows the approximate trend of cumulative annual HNDECI economic loss.

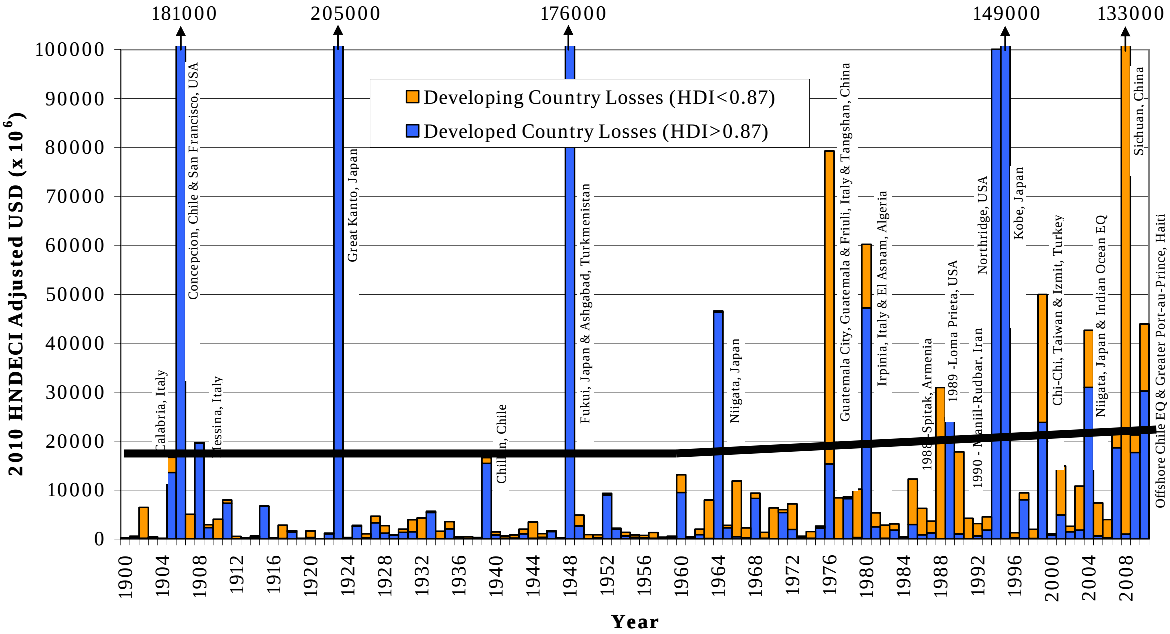

Figure 14 – CATDAT v4.12 Damaging Earthquakes – Economic Losses (2010 Hybrid Natural Disaster Economic Conversion Index adjusted) for 6400 earthquakes from the year 1900-2010 worldwide

It can be seen from the above figure that the baseline of annualised economic losses from earthquakes is slightly increasing; however, this increase is not as marked as in some other studies (MunichRe 2000, 2002; Vranes et al. 2009, Swiss Re 2009) when different economic conversion indices are used and an underestimate of Japanese earthquakes based on US CPI occurs. This could show the improved impact of better building practice due to earthquake building codes. The error can be seen in EM-DAT (2004), where the original disaster is quoted in US dollars, but has been converted from another currency. They then use US inflation figures to bring forward this value into 2003 dollars. However, this is not correct, as the disaster did not occur in the United States (see Daniell et al. 2010a). The use of CPI adjustment based on one economy is therefore outdated in a natural disasters forward costing context.

CATDAT versus NatCat Service in terms of socio-economic rating of catastrophes.

The MunichRe NatCat service is one of the most comprehensive databases on natural disasters. It classifies natural disasters using the following method as shown below in Table 4 (Hoeppe 2009).

Table 4 – MunichRe NatCat Service Natural Disaster definitions – adapted from Hoeppe (2009)

Catastrophe and Property damage class		**Overall losses *losses adjusted to decade avg.**			**and/or fatalities**
		1980s*	1990s*	2000 – 2008*	
0	Natural event	-	-	-	none
1	Small-scale event	-	-	-	1-9
2	Moderate	-	-	-	> 10
3	Severe	US$ >25m	US$ > 40m	US$ > 50m	> 20
4	Major	US$ > 85m	US$ > 160m	US$ > 200m	> 100
5	Devastating	US$ > 275m	US$ > 400m	US$ > 500m	> 500
6	Great	Region cannot help itself, interregional/international assistance necessary, 1000s of fatalities and/or 100000s homeless, substantial economic losses (UN definition). Huge insured losses.			

Defining disasters in this way, the 1993 Wallis and Futuna earthquake which caused $14 million US damage and 5 deaths would be most likely defined as a 1 – small-scale event. It may be able to be defined as 'great' under the classification that the region cannot help itself, but as far as can be seen it was not. However, when the 1993 earthquake was further examined, it was seen that the economic loss caused was approximately 54% of nominal GDP – the 7th highest since 1900.

This index is reasonable for any United States disaster; however, economic conditions differ in each country and therefore a $276 million damaging earthquake that occurred in 1980 could actually only be $199 million in 2010 US dollars, depending on inflation conditions. Thus, if exactly the same earthquake occurred with the same loss in 2010, it would be only defined as a severe earthquake instead of a devastating earthquake. Yet, due to deflation in the theoretical country, it is possible that the same earthquake has a much greater impact than the 1980 earthquake as a percentage of output and infrastructure.

Similarly, an earthquake with 99 deaths in China, which has a population of over 1.34 billion, is extremely different from an earthquake that could occur with 99 deaths in a country like Palau (with 20000 people). As a percentage of deaths to population, the theoretical Chinese earthquake would be 0.0000074% whereas the Palau earthquake would be 0.5%. Both would be classified as 3 under the catastrophe rating.

This shows the simplification and bias shown with a simple absolute value based ranking system. Of course, the absolute values should also be taken into account but on a higher scale. CATDAT defines losses based on other definitions, using the nominal GDP through time as a descriptor with overall losses trended to this value to define a damage class from 0 to 10. Similarly, social losses are defined based on population in the region affected. Currently in v4.12, only country populations are used; however, this will be regionalised in coming versions of the CATDAT database.

A great catastrophe is assigned a value of 10 in CATDAT and includes a split economic and social ranking. This is shown below in Table 5.

Table 5 – CATDAT definition of a great catastrophe

CATDAT Ranking	Damage Class	Criteria
10	Great	For the **social ranking**:- Deaths in event year / event year population > 0.1% Injuries in event year / event year population > 0.35% Homeless in event year / event year population > 3% Region cannot help itself and requires interregional/international assistance Over 10000 deaths in any country (absolute) For the **economic ranking**:- Economic Losses / nominal GDP (PPP) of country over 2 years > 2% Insured Losses as per the same method. Significant impact on future output as defined using complex economic analysis. Over $5 billion 2010 HNDECI-Adjusted dollars (absolute).

Conclusion

The CATDAT Damaging Earthquake database contains much data suitable for use in many sectors from earthquake loss estimation, to risk mapping, for insurance purposes and simply as a validated dataset to reduce the erratic values of socio-economic losses quoted wrongly throughout a number of sources. It has been shown that the traditional view that social and economic losses are increasing exponentially should be treated with caution. The dataset contains many more earthquakes with socio-economic data than other earthquake databases on trend analysis with earthquakes and hopefully this has led to more populated trends. Large natural disaster losses are extremely difficult to quantify using a single number. Thus, CATDAT uses a lower bound, upper bound and best estimate value, using expert judgement; yet also presenting all data to the user.

Over 11600 earthquakes show over 8.47 million deaths since the beginning of earthquake records. Earthquakes in the 20th and 21st centuries have already caused approximately $1.8 trillion (2010 HNDECI-Adjusted int. dollars) damage. Collection of building damage for historic earthquakes demonstrates the vulnerability of traditional building stocks such as masonry, adobe and badly constructed reinforced concrete.

It should also be noted that traditional databases making trends based on year-of-event dollars or adjusting using a mass United States Consumer Price Index trend over earthquake losses worldwide are incorrect. Economic loss should be calculated on a country-by-country basis and then compared. This is the same for absolute versus relative loss. Currently, trends are skewed to absolute loss; however, earthquakes such as the Wallis and Futuna 1993 earthquake can have a huge impact on a country, even though it would rate as a 1 on a MunichRe NatCat catastrophe scale.

This catalogue is one of the largest known cross-checked global historical damaging earthquake databases and should have far-reaching consequences for earthquake loss estimation, socio-economic analysis and the global reinsurance field. Given the amount of data collected, much future research can be done and development of the links with other global entities (government, insurance and NGO) will be a priority. The database is a dynamic entity and will continue to grow as each earthquake with socio-economic loss occurs around the world.

Man sagt oft : Zahlen regieren die Welt.
Sicher ist nur: Zahlen zeigen wie sie regiert wird.

It is often said: Figures rule the world. The only sure thing is: Figures show how it is ruled.

J.W. Goethe (1749-1832)

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