Worldwide CATDAT Damaging Earthquakes Database in conjunction with Earthquake-report.com - Presenting Past and Present Socio-Economic Earthquake Data

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SUMMARY:

The worldwide CATDAT damaging earthquakes and secondary effects (tsunami, fire, landslides, liquefaction and fault-rupture) database has been created since 2003, with greater effort in the last few years, using over 20000 information sources to present loss data from 12000+ historical damaging earthquakes, with 7000+ since 1900 examined and validated before insertion into the database. Each validated earthquake includes many parameters, including seismological information, building damage data, ranges of social losses to account for varying sources (deaths, injuries, homeless, and affected), and economic losses (direct, indirect and insured), as well as secondary effect and sectoral disaggregation, including the production of many historical socio-economic indices.

Since 2010, earthquake-report.com has been used to deliver the latest CATDAT earthquake data and news for every damaging earthquake worldwide. This catalogue is the largest known cross-checked global historical damaging earthquake database and should have far-reaching consequences for socio-economic earthquake loss analysis and the global insurance field.

Keywords: CATDAT, Socio-economics, casualties, economics, earthquake-report.com

1. INTRODUCTION

The need for a worldwide damaging earthquakes and secondary effects (tsunami, fire, landslides, liquefaction and fault rupture) database has been explored by many authors in the past (NGDC, PAGER, Utsu, EM-DAT, MunichRE). However, the CATDAT Damaging Earthquakes 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.

CATDAT provides a significantly increased database of historic earthquake information combined with socio-economic analysis not before undertaken, including the creation and collection of indices not only spatially or for current conditions, but also back through time. This provides a unique view of historic losses and creates more comparisons between events. Globally, 8.5 million recorded deaths have occurred from 12400 recorded damaging earthquakes. In addition, over $4 trillion USD (2012 HNDECI adjusted) economic losses can be attributed to earthquakes.

Each validated earthquake includes many parameters, including seismological information (magnitude, hypocenter, intensity, spectral values), building damage data (damage levels, important infrastructure etc.), ranges of social losses to account for varying sources (deaths, injuries, homeless, and affected), and economic losses (direct, indirect, aid, and insured).

Of importance, however, is not only the collection of trends from socio-economic loss data from

earthquakes, but also the collection and quantification of spatio-temporal indicators on a country-by-country basis (with province and county level where available), levels of information from 1900-2012 for the human development index (life expectancy, literacy rate, GDP per capita, enrolment ratio), gross domestic product (PPP and Nominal), Consumer Price Index, wages, exchange rate, urban and rural population, building inventory, codes and practice, as well as construction based indices. In addition, 120+ social indicators and 90+ economic indicators are utilised on a country level.

Another key tool is the disaggregation of socio-economic losses of deaths from over 2000 fatal earthquakes since 1900 into deaths from various building typologies, non-structural deaths related to shaking, and secondary effect and indirect effect deaths.

Since 2010, earthquake-report.com, in combination with CATDAT, has been used to deliver the latest earthquake data and news for every damaging earthquake worldwide. Data is collected in near real-time from many different agencies and then is inputted into the database. The CATDAT rating system of historic earthquakes is also presented to show the impact of the most significant past world events.

2. THE DETAILS OF THE DATABASE

The worldwide CATDAT damaging earthquakes and secondary effects (tsunami, fire, landslides, liquefaction and fault rupture) database has been produced since 2003, starting at a class at the University of Adelaide and in the author's spare time, with a more concerted effort in the last few years (Fig. 2.1), using over 20000 sources of information in over 50 languages to present socio-economic loss data from 12000+ historical damaging earthquakes, with 7000+ damaging earthquakes since 1900 examined and validated before insertion into the database. For full details of the history of the database, refer to Daniell et al. (2011c). The current version is v5.1001 as of April 17th 2012.
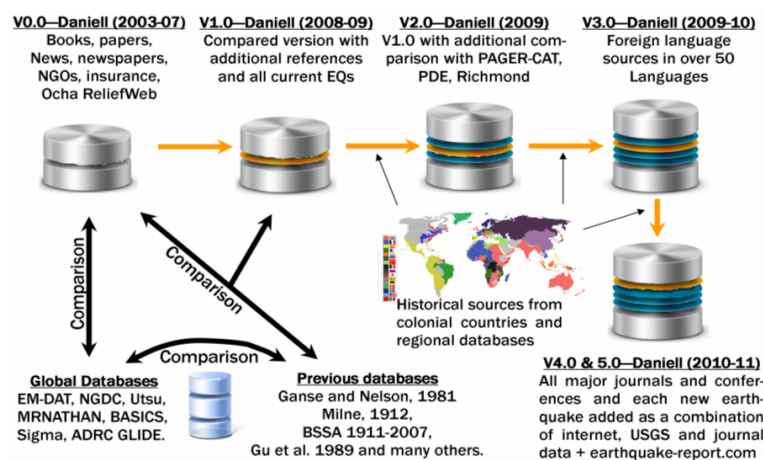

Figure 2.1. The Process used to create the Damaging Earthquake Database

2.1. Criteria for entry of an earthquake into the database

The criteria for an earthquake to be inserted into the database is as follows and forms the CATDAT Orange ranking explained in Section 4:-

- Any earthquake causing death, direct injury or homelessness (structural-related).
- Any earthquake causing damage or flow-on effects exceeding 105,000 international dollars, Hybrid Natural Disaster Economic Conversion Index adjusted to 2012.
- Any earthquake causing disruption to a reasonable economic or social impact as deemed appropriate.
- A requirement of validation of earthquake existence via 2 or more macroseismic recordings and/or seismological information recorded by stations and at least 1 of the 3 definitions above.
- Validation via external sources if Corruption Index < 2.7, subject to Polity ranking.

The number of damaging earthquakes has been increasing since 1900 due to better recording of small losses and also increasing population and exposure to earthquake losses. In addition, the author has created the first worldwide Human Development Index (a combination of life expectancy, education and GDP per capita) through time from 1800 to 2012 for each nation (Daniell, 2010b). This gives a unique view of the number of damaging earthquakes occurring in highly developed nations versus developing nations (Fig. 2.2). In 1900, most of the world was still developing, and therefore the comparison of earthquakes with those of 2012 must be undertaken with caution.
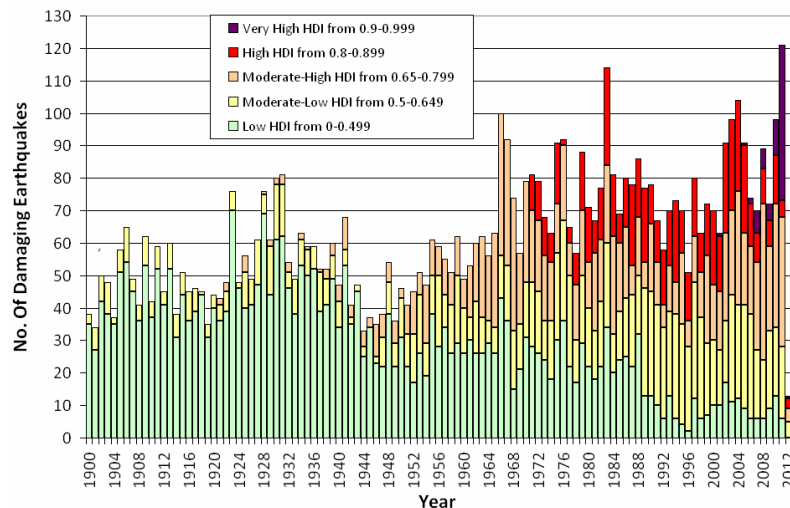
Figure 2.2. The Number of Damaging Earthquakes in the CATDAT Damaging Earthquakes Database as compared to the HDI of the nation at the time of the disaster.

2.2. Parameters collected in the Database

Each validated earthquake entry into the database includes the following parameters to the best given amount of detail. A combination of seismological, socio-economic, infrastructure and ranking systems is used as shown in Table 2.1.

Table 2.1. The parameters included in the CATDAT Damaging Earthquakes Database for each earthquake.

Information Theme	Variables in Database
Seismological Information	EQ Hypocentre Latitude; Longitude; Depth (km); Intensity (MMI); Magnitude; Magnitude type
Date Information	Date (Day, Month, Year, Time (Local and UTC)).
Country Data	ISO3166-2 Country code, including Kosovo, South Sudan; ISO Country Name.
Socio-economic Event Indicators and Indices	At time of event:- Human Development Index of country; HDI Classification; Economic Classification; Social Classification; Urbanity Index; Population; Nominal GDP – split into developed or developing countries, 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.
Social Loss Parameters	CATDAT Preferred (Best Estimate) Deaths; Secondary Effect Deaths; Ground Shaking Deaths; CATDAT Upper and Lower (U/L) Bound Death Estimates; Global Literature Source (U/L) Bound Death Estimates; Severe Injuries; Slight Injuries; CATDAT (U/L) Bound Injury Estimates; Global Source (U/L) Bound Injury Estimates; Homeless (and U/L Bound); Affected (and U/L Bound); Missing.
Infrastructure and other Loss Parameters	Buildings destroyed; Buildings damaged – L4, L3, L2, L1; Infrastructure Damaged (Bridges etc.); Critical and Large Loss Facilities; Lifelines damaged. NaTECH losses, HAZMAT, Essential Services, Cascading effects. Sectoral Analysis of Losses.
Secondary Effect Parameters	Secondary effects that occurred (Tsunami, Seiche, Landslide (mud, snow, rock, soil, quake lake), Fire, Liquefaction, Flooding, Fault Rupture); % of the social losses caused by each secondary effect; % of economic losses caused by secondary effects; Tsunami Deaths; Fire Deaths; Landslide Deaths; Liquefaction Deaths; Disease & additional long-term problems.

Economic Loss Parameters	CATDAT Preferred (Best Estimate) Total Economic Loss (Direct and Indirect); 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 2012 HNDECI-Adjusted; CATDAT Economic Loss 2012-country based CPI adjusted; Insured Loss; Insured Loss in 2012 dollars; Insured estimate source; Estimated Insurance Takeout at time of event. Indirect and Intangible economic losses for given events, Estimated life cost given social values, working wages etc. at the time.
Rankings of Earthquakes	CATDAT Earthquakes ranked via the PAGER colour methodology CATDAT Socioeconomic earthquake disaster Rank – word (4 types), number (10 types).
Other Tools and Parameters	Link to ReliefWeb archive where available. Aid contribution; Aid delivered; Aid Source. Split country impacts (social and economic) where earthquake affects > 1 country. Various ratios between components for trends analysis. Normalisation strategies for current conditions (Daniell et al. 2010c) Links to the author's PhD rapid loss estimation model (Daniell, 2011d)

3. SOCIO-ECONOMIC LOSSES FROM EARTHQUAKES (1900-2012)

From 1900 to 2012, over 7000 damaging earthquakes have been recorded, with over 2000 causing fatalities and an additional 1000 causing injuries (around 3 trillion USD (2012 HNDECI adjusted) in direct and indirect losses and around 2.381 million fatalities). The number of damaging earthquakes per country as compared to total fatalities and total monetary loss is shown in the following diagram. This allows for an economic loss per fatality relationship to be produced giving a loose measure of economic vs. social risk. It can be seen in Fig. 3.1 that developed nations generally have greater economic losses per fatality and the range comes because, although the economic losses have been converted to 2012, the fatalities have generally occurred in the now highly developed nations when they were still developing (i.e. Japan 1923, USA 1906), thus skewing the results.
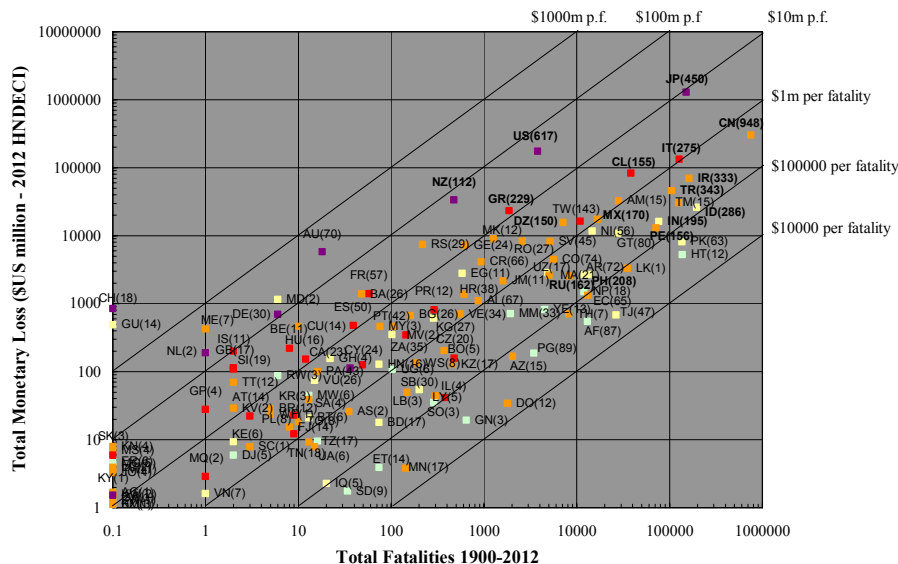

Figure 3.1. Total cumulative Monetary Losses (2012 adjusted) and Total Fatalities from earthquakes between 1900-2012 for each ISO-code country, together with the number of damaging earthquakes.

3.1. Historical Casualties from Earthquakes

From 1900 to 20 April 2012, 146 earthquakes (and their associated effects) have caused over 1000 deaths, with the latest being the Tohoku event in March 2011. There exist huge discrepancies in existing databases due to lack of research, non-updating of sources, lack of use of foreign languages, copying errors, government censoring to a given time and general uncertainties as to the death toll of a particular event. The database has been built to include all non-error estimates with the establishment

of a global upper and lower value including all sources on a particular event. Through re-analysis of the event, a preferable difference in estimates is given by the CATDAT upper and lower value. The median value is the preferred value in the database. This is in some cases a subjective process where expert judgement has been used in reviewing past literature and sources. The difference between this global upper (diamonds) and lower (squares) value as compared to the CATDAT death toll is shown in Fig. 3.2. There exist huge differences in some existing earthquakes such as Turkmenistan 1948 and Haiti 2010 (Daniell et al. 2011b) in global databases as seen in the large number of earthquakes outside the error bounds. The Messina earthquake in 1908 shows a range in literature of between 38,000 deaths and 200,000 deaths and can be deemed as under- and over-estimates of the accepted value of around 85,000 deaths.
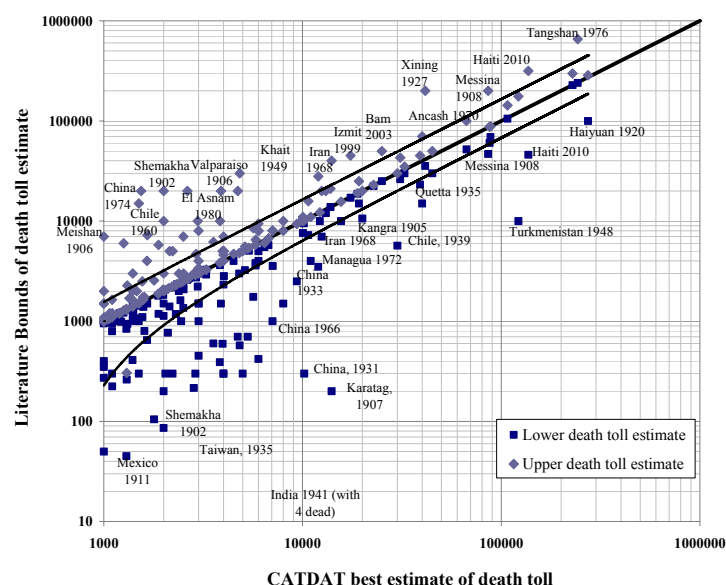
Figure 3.2. The upper and lower bound death toll estimate of earthquakes in global literature compared to the median CATDAT death toll.

The 10 highest death tolls since 1900 in the database are shown as follows. The Haiyuan earthquake in 1920 in China killed the most people, with new research in 2010 by Zhang et al. (2010) showing that 273,400 people died in this event, with a large proportion of these deaths due to landslides. Similarly, the Great Kanto earthquake in 1923 killed 105,000-107,500 people, with 94,000 of these killed by fire. The Indian Ocean earthquake of 2004 killed nearly all of the victims via the tsunami. These 10 events, shown in Table 3.1, have contributed to about 60% of the fatalities in earthquakes since 1900.

Table 3.1. The parameters included in the CATDAT Damaging Earthquakes Database for each earthquake.

| Rank	Earthquake	Main Country	Date	Median Fatalities	CATDAT Lower/Upper	Pref. Source
1	Haiyuan	China	16.12.1920	273465	258707-283407	Zhang, 2010
2	Tangshan	China	27.07.1976	242419	240000-255000	Yong et al., 1989
3	Indian Ocean	Indonesia etc.	26.12.2004	228194	227640-230210	Indiv. Country Reports
4	Haiti*	Haiti	12.01.2010	137000	122000-167000	Daniell et al. 2011b
5	Aschgabad	Turkmenistan	05.10.1948	122000	110000-176000	CATDAT
6	Great Kanto	Japan	01.09.1923	107385	105385-143000	Moroi et al., 2004
7	Sichuan	China	12.05.2008	88287	87476-89000	Govt.
8	Kashmir	Pakistan etc.	08.10.2005	87364	73338-87364	ReliefWeb
9	Messina	Italy	28.12.1908	85926	80000-90000	CATDAT
10	Ancash	Peru	31.05.1970	66794	52000-96794	CATDAT

*subject to further confirmation from non-government sources, due to Corruption Perceptions Index

In-depth analysis has been undertaken to disaggregate fatalities from earthquakes into the different causes of the fatality, whether it be from direct structural collapse or secondary effects such as

tsunami, landslide or otherwise in the 2020 fatal earthquakes from 1900-2012. It has been found that over 57% of deaths have occurred in masonry buildings either by falling structural members, roof collapse or falling debris (Fig. 3.3). An additional 8.5% have died in concrete buildings and 3.0% in timber buildings. In total, around 71% of fatalities have occurred due to direct earthquake shaking, and 29% to other earthquake secondary effects. The database is a dynamic entity and this continues to change as further reanalysis of past events takes place, including separating heart attack deaths and non-structural deaths. This study agrees well with the work of Marano et al. (2010) in PAGER on 749 fatal earthquakes from September 1968 to June 2008, which demonstrated that 25% of fatalities from earthquakes were due to secondary effects of earthquakes (tsunami, landslide, fire, liquefaction). 913 fatal earthquakes were recorded in the CATDAT database in the same time period. Both studies are much lower than the study of Bird and Bommer (2004) on 50 earthquakes from 1980-2003, which showed that 90% of earthquake deaths are due to shaking. These fatalities relative to the human development index of the country per year is shown in Fig. 3.4.
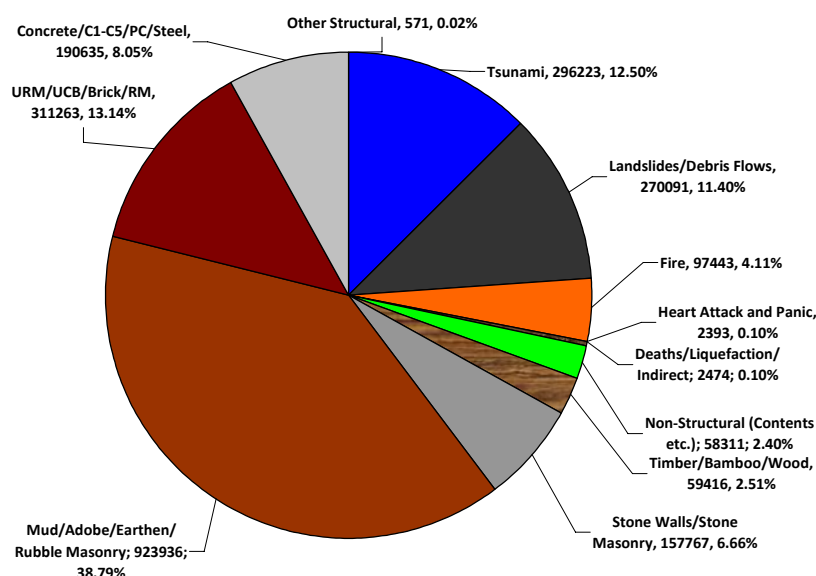
Figure 3.3. The upper and lower bound death toll estimate of earthquakes in global literature compared to the median CATDAT death toll (current as of 20 April 2012).
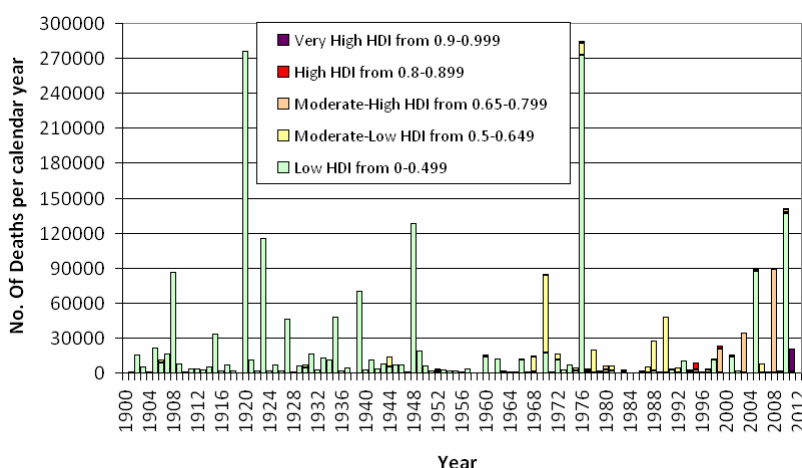
Figure 3.4. Fatalities per year based on the HDI of the country at the time of event.

The number of fatalities per country as a result of earthquakes has been normalized against population at the time of the event for Fig. 3.5. to show the relative risk from earthquakes for fatalities. Turkmenistan, Armenia, Haiti and Guatemala can be seen to have a very high proportionate loss, as expected, from the major events occurring in the time period. China, due to the large population, has a lower relative risk but the highest absolute risk.

Earthquake Fatalities divided by Population at Time of Event Cumulated from 1900-2012
(division by 112.35 gives the Fatality Probability percentage per year)

0.000 - 0.00015 | 0.00015 - 0.000822 | 0.0008221 - 0.00256 | 0.002561 - 0.005083 | 0.005084 - 0.009734 | 0.009735 - 0.01823 | 0.01824 - 0.03307 | 0.03308 - 0.05601 | 0.05602 - 0.1461 | 0.1462 - 0.2456 | 0.2457 - 0.3647 | 0.3648 - 0.7958 | 0.7959 - 1.489 | 1.490 - 2.322 | 2.323 - 10.28

Figure 3.5. Number of event fatalities divided by population at time of event cumulated from 1900-2012 giving a view of relative fatality risk from earthquakes.

3.2. Historical Economic Losses from Earthquakes

A total of $3 trillion USD has been lost in the last 113 years due to earthquakes. Given a global GDP during this time of $2400+ trillion USD (2012-adjusted), only around 0.125% of global GDP has been lost due to earthquakes and their effects. However, within different countries this percentage has been greater and crippling losses have occurred in many nations given the once-off major loss of infrastructure, assets and livelihood in various regions. Japan has had the highest economic loss from earthquakes within the time period, with $1.421 trillion+ (2012 HNDECI Adjusted Dollars) economic losses compared to the nation with the second highest losses, China, with $478 billion. However, the GDP of the respective countries must be examined in order to see the countries that were at highest economic risk from earthquakes in the last 113 years. In Fig. 3.6, the GDP (PPP) was used at the time of the event, and this was cumulated over the time period to give a consistent approach to economic losses per country. It can be seen that countries such as Macedonia, Armenia, Nicaragua, Chile, Haiti and Turkmenistan have extremely high losses exceeding 1 year of GDP in 113.

% GDP (PPP) Total Economic Losses cumulated from 1900-2012

0.000000000 | 0.00100 - 0.00513 | 0.00514 - 0.0169 | 0.0170 - 0.0347 | 0.0348 - 0.0730 | 0.0731 - 0.165 | 0.166 - 0.331 | 0.332 - 0.516 | 0.517 - 0.941 | 0.942 - 1.58 | 1.59 - 2.63 | 2.64 - 4.05 | 4.06 - 5.27 | 5.28 - 8.43 | 8.44 - 13.4 | 13.5 - 19.5 | 19.6 - 37.0 | 37.1 - 54.8 | 54.9 - 114 | 115 - 597

Figure 3.6. Economic earthquake event loss divided by GDP (PPP) at time of event, cumulated from 1900-2012

The concepts of the Hybrid Natural Disaster Economic Conversion Index (HNDECI) have been explained in depth in Daniell et al. (2010a) and refer to the conversion of a natural disaster loss in the past into today's dollars, given that CPI (Consumer Price Index) is not a reasonable measure to convert historic losses to today. The HNDECI uses a composite index of wage, income, GDP, country-based CPI to convert to 2012 international dollars. These indices are essential for accurate trends to be produced from historic earthquakes as seen in Table 3.2 for the 10 highest relative economic losses of all time. A focussed paper on the HNDECI economic losses is also presented at this WCEE (Daniell et al., 2012b), with further analysis on economic losses, including insured and indirect losses in historic earthquakes. Much work has been undertaken to produce a standardised database through time of these indices.

Table 3.2. The highest 10 economic losses in terms of nominal GDP at the time of event since 1900

Rank	Earthquake	Date	Median cost at 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	7.804 bn	70.8	120.6
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	0.500 bn	32.3	64.4
7	Concepcion, Chile	17.08.1906	0.260 bn	47.8	55.0 to 82.9
8	Wallis and Futuna	12.03.1993	0.014 bn	51.9	54.0
9	Great Kanto, Japan	01.09.1923	3.840 bn	21.1	52.8
=10	Jamaica	14.01.1907	0.013 bn	23.9	45.9
=10	Nicaragua	31.03.1931	0.030 bn	26.5	51.0

4. THE CATDAT RATING SYSTEM OF EARTHQUAKES

In conjunction with the earthquake-report.com danger rating system (combining initial data before losses are known) from earthquakes, explained in Daniell and Vervaeck (2012c), the CATDAT rating system refers to a relative or absolute amount of damage from an event. From the 7000+ damaging earthquakes worldwide, dark red, red, orange, yellow and green colour codings have been used in Table 4.1. These have been integrated with earthquake-report.com for each new earthquake. A ranking system allows for comparison of earthquakes for aid organisations, the insurance industry and research institutions. This ranking system is also designed to be used before employing forensic disaster analysis, such as in the case of the CEDIM Forensic Disaster Analysis in the Van Earthquake of 2011 in Turkey (Daniell et al., 2011e). An average of 3 dark red events have occurred per year as seen in Fig. 4.1, with 338 since 1900 showing that for dedicated studies from large worldwide earthquakes, the ranking system gives a good proxy for research into larger events.

An important difference between the CATDAT Ranking System and other ranking systems, such as the PAGER ranking based on their rapid loss estimation, is the use of a relative measure for losses proportionate to the metrics of a country. This is an important distinction for small nations such as Wallis and Futuna where the 1993 earthquake caused a high proportionate amount of damage but would only classify as Green or Orange under all absolute methodologies.

Table 4.1. The CATDAT Word Ranking System for earthquake losses

Classification	Criteria
CATDAT Green	**Non-Damaging – not included in database**
Absolute/Relative	Non-damaging events (nearly all earthquake events)
CATDAT Yellow (0)	**Insignificant Damage**
Absolute/Relative	criteria below CATDAT Orange indicating a non significant-damaging event or panic that has occurred or disruption to a minor extent. This is not included in the database.
CATDAT Orange (1-4)	**Minor Damage, Damage, Moderate Damage, Major Damage**
Absolute/Relative	Any earthquake causing direct injury or homelessness (structural-related). Any earthquake causing damage or flow-on effects exceeding 105,000 international dollars, Hybrid Natural Disaster Economic Conversion Index adjusted to 2012. Any earthquake causing disruption to a reasonable economic or social impact as deemed appropriate.
CATDAT Red (5-7)	**Minor Disaster, Moderate Disaster, Major Disaster**
Absolute	Any earthquake causing direct fatalities. Any earthquake causing over $100 million USD total or insured losses. Any earthquake causing over 10000 people homeless.

	Any earthquake causing over 500 injuries, including 20 serious injuries.
Relative	Any earthquake causing over 0.1% of GDP total or insured losses with losses exceeding $1 million USD.
	Any earthquake causing greater than 1 injury per 100000 (country population) with injuries exceeding 30 injuries total.
	Any earthquake with greater than 0.08% of population become homeless
CATDAT Dark Red (8-10)	**Severe Disaster, Very Severe Disaster, Catastrophe**
Absolute	Any earthquake causing greater than 1000 deaths.
	Any earthquake causing greater than $8 billion USD loss.
	Any earthquake causing over 200000 people to become homeless.
Relative	Any earthquake causing over 3% of GDP (PPP) total or insured losses with losses exceeding $30 million USD.
	Any earthquake causing greater than 1 death per 100,000 with deaths exceeding 30 deaths.
	Any earthquake causing greater than 0.8% of the country population to become homeless.

The word ranking of CATDAT provides an indication to the number version also used within the database which has much more discretization based on historic earthquakes from 1-10.
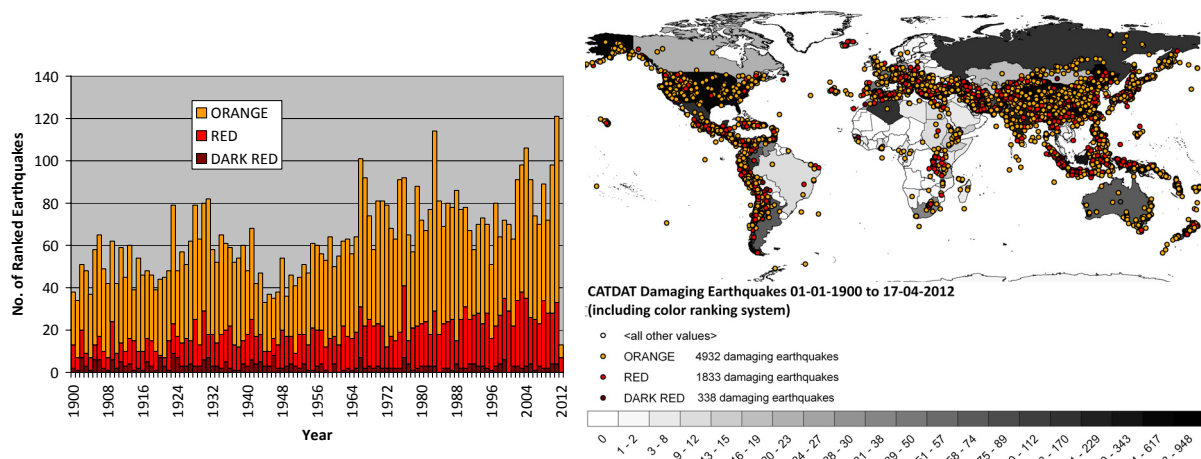
Figure 4.1. Left: The number of orange, red and dark-red earthquakes registered in CATDAT over the last 113 years (square=absolute criteria highest, round=relative criteria highest); Right: Worldwide View

5. CONCLUSION

Given the 20,000+ sources used in more than 50 languages within the collection of the CATDAT Damaging Earthquakes Database in conjunction with the socio-economic databases, other CATDAT natural disaster databases and normalisation methodologies, the quality and depth of data allows for more in-depth and accurate trends than ever before. It has much data suitable for use in many sectors, including insurance purposes, risk mapping, and earthquake loss estimation. The greatest use is the fact that it is a validated dataset which reduces erratic values of socio-economic losses quoted wrongly through literature and includes more earthquakes than other traditional databases. This leads to better populated trends based on not only the CATDAT single median value, but also an upper and lower bound value, as the socio-economic effects of large earthquakes can generally not be expressed in just one number.

Annual reviews of CATDAT are freely available (Daniell, 2011a; Daniell and Vervaeck, 2012a) and each new earthquake and review is added on earthquake-report.com. Given the relative and absolute rankings, every country in the world is given equal rights to inclusion should similar earthquakes occur around the world. The database is a dynamic entity which grows daily with each new earthquake, daily socio-economic changes (population, development, exchange rates, CPI, GDP, wages) and as new research is carried out to look at the effects of previous earthquakes.

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