Proceedings of the Tenth Pacific Conference on Earthquake Engineering
Building an Earthquake-Resilient Pacific
6-8 November 2015, Sydney, Australia

The value of life in earthquakes and other natural disasters: historical costs and the benefits of investing in life safety

J.E. Daniell, A.M. Schaefer, F. Wenzel, T. Kunz-Plapp

Geophysical Institute and Center for Disaster Management and Risk Reduction Technology, Karlsruhe Institute of Technology, Karlsruhe, Germany.

ABSTRACT: The economic cost of fatalities and injuries is a contentious concept in a disaster. There are many methods used to evaluate this: willingness to pay, human capital or hybrid approaches. However, this value is very important for decision-making in cost-benefit analyses and also in looking at the total cost of an earthquake. The costs from earthquakes are examined from 1900-2014 using a simple hybrid value of a human life in each country through time showing over $1 trillion USD impact.

The reanalysis of each damaging event from 1900-2014 in CATDAT shows stand-out events such as the 2004 Sumatra earthquake which shows the significant GDP impacts that large death tolls have on a country (besides the human toll). In total, an additional 30% of losses can be added to the effects of earthquake deaths through history.

The effect of life costing also has far-reaching implications for cost-benefit ratios and casualty insurance models in earthquakes and other disasters in terms of retrofit, loss or implementation costs of seismic resistant building code decisions. The preliminary examples undertaken in this paper include: 1) small scale retrofits to a single unreinforced masonry house in Adelaide, Australia; 2) government savings in terms of large scale changes to a seismic resistant code in Turkey and Croatia.

1 INTRODUCTION

1.1 Background

The value of a life is immeasurable in a disaster or so it is commented upon in many cases. At the same time, this topic is important for earthquake loss analysis, as infrequent events with major life loss potential should be taken into account in cost-benefit decision-making. Life loss potential can have a major impact, yet, it is often not calculated or considered.

A short analysis is presented based on historical evidence and global exposure metrics using the CATDAT Socioeconomic databases, in order to create a global distribution of the cost of life in a disaster using various metrics. CATDAT is a database of compiled socioeconomic metrics and socioeconomic loss effect databases for natural disasters (Daniell et al., 2011a, 2014). With respect to this study, there are a few key components of the databases that have been used which are most important to valuing the life potential loss from an earthquake event:- the Damaging earthquakes database of over 7500 events since 1900; life expectancy through time, including age structure; wage information over time. The data has been collected from various national, provincial and research studies with details given in Daniell (2014) and Daniell et al. (2014).

There are two general approaches to human life costing: the first is based on human capital (Hansen, 1970) which looks at the production capacity and potential output as a proxy for future earnings of the victim of the natural disaster; the second looks at willingness to pay (Dreze, 1962; Viscusi, 2009) which estimates people’s value on risk surveys and reducing compensation payouts.

A human capital approach has readily available data, given the data on productivity and wages generally collected by a government. A disadvantage is, however, that it often overestimates economies where there is a lot of part-time work, and variability in life expectancy and earnings, and it also values some lives higher than others. The willingness-to-pay approach is generally based on payouts via courts for deaths and injuries and is very subjective in its evaluation of payouts. The problem is often a disconnect between the reality of a loss total (it can be much greater than the total people can pay out), and the collection of surveys of value of life and the calculation of equity, the cost of joy of living etc. is time-consuming. The value of a statistical life (VSL) is usually calculated via a willingness-to-pay approach (WTP).

Many values in literature have been postulated for the cost of a life, be it a death, serious injury or slight injury. In most cases, the quality of life, lost labour cost to the workplace and lost labour cost to the family and community are the key criteria, with incidentals such as medical and legal costs and disruption playing minor roles. The difference of the cost for a fatality vs. that for a severe injury is the long-term care aspect, with a severe injury often having higher costs than a fatality for loss purposes.

1.2 Studies for Natural Disasters and Life Valuation

The most comprehensive study in Australia was done by BTE (2001). BTE (2001) showed a systematic human capital approach for Australian and NZ life costs by applying the findings to bushfire and storm victims. In the case of BTE (2001), road death and injury data comparisons were made with natural disasters using the main following human capital elements: workplace labour lost (time left in working life); household labour lost (the contribution to the household/community of the individual); lost quality of life (this figure takes into account the lost quality of life left – a non-traditional addition to the usual methods of loss analysis). For the purposes of this study, dollar values are adjusted using the most relevant cost indices for each parameter. This is shown here for the BTE cost method for natural disasters which is adjusted to $2.7m AUD in 2015 using average wage, CPI and GDP per capita adjustments.

Depending on the parameters, average wage (workplace labour), unskilled wage, CPI (general product costs), GDP per capita (quality of life and production) or other conversion indices are most relevant. This full methodology is described in the paper for adjusting natural disaster losses (Daniell et al., 2010).

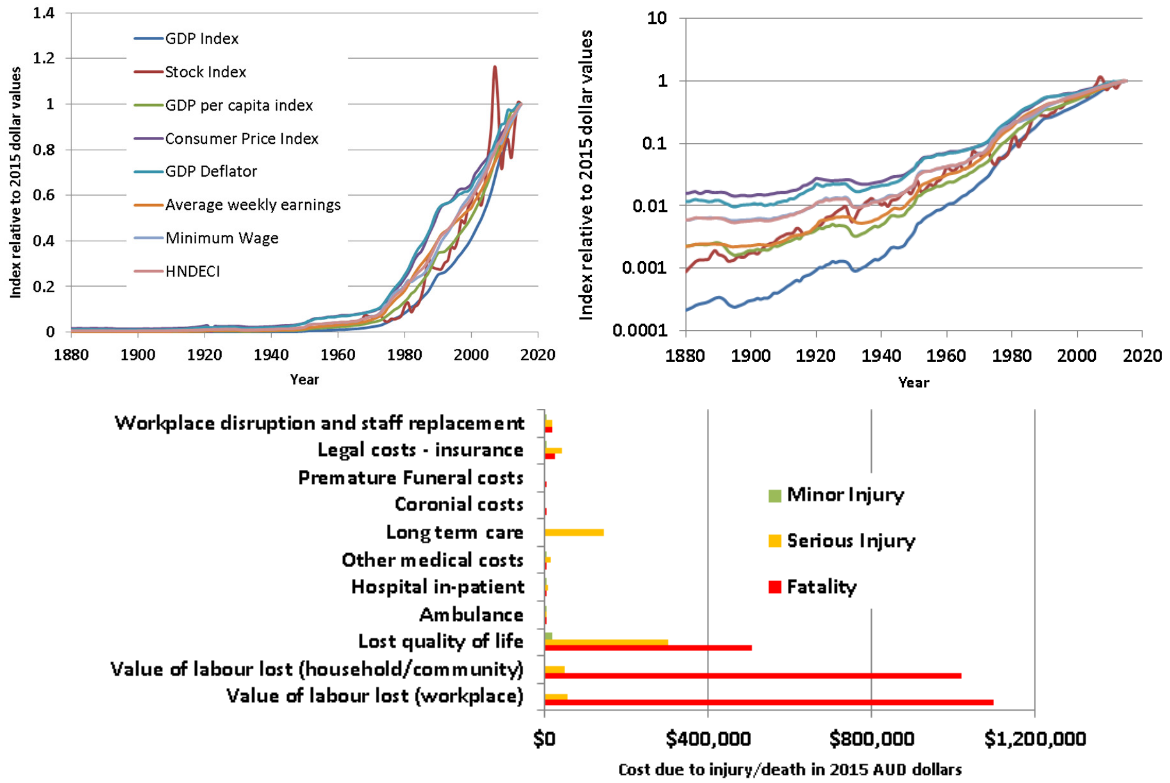


Figure 1: BTE (2001) in 1996 dollar (ca. $1.3m), with the values indexed for 2015 AUD ($2.7m) Australian deaths, serious and minor injuries in natural disasters

The second method (WTP) results of the value of a statistical life (VSL) are generally in the order of 1.25-4 times higher than direct income methods. The Australian Safety and Compensation Council (2008) reviewed 244 VSL estimates from 1960-2006, characterising them into Occupational Safety, Transport and other studies with huge variability within countries as well as between countries and with 3 studies having values over $50 million AUD (2006), and 13 studies over $30m, with a mean of $9.4m and median of $6.6m per life. Miller (2000) found that the VSL and GDP per capita from studies was typically in the order of 120 to 160 times; however, examining estimates in various studies, this can differ wildly.

Viscusi and Aldy (2003) detail over 100 studies up to 2001, with mostly labour market survey estimates shown. For the purposes of this study an average estimate is wanted between high compensation payouts as often seen in transport VSLs vs. the low human capital and productivity estimates from a few authors such as Andersson and Treich (2011). A 10-fold scatter was shown between various methods, with subjective opinions often causing the differences or worker's compensation payouts. In addition, age differences caused larger changes. The Lindhjem et al. (2012) has also created estimates via a database for statistical life. These and other individual studies, were combined into a database and normalised. A regression was then undertaken to look at the range for each country. This study does not intend to compare WTP methods with human capital methods, but to use an approximate value of life method across the globe for calculating the loss from earthquakes based on remaining age.

All in all, VSL estimates have been collected for ca. 51 nations with 372 individual estimates (often based on the average of labour surveys etc.) which can be compared to GDP per capita, HDI and wage information to see their relationship.

2 METHODOLOGY

A robust combination approach is used which can be refined in future studies. For each of the 245 nations, a value of life is estimated using the following parameters defined as key from the literature: (1) Age of people in a country using the life expectancy and distribution data in CATDAT via World Bank, UN and other estimates (Daniell et al. 2011); (2) Output of the economy and wage distribution (GDP per capita as well as unskilled wages); (3) Lost quality of life via factors associated with compensation payouts. To do this, the relative ratios of BTE (2001) are kept constant and a GDP per capita, unskilled wage and life expectancy derived value of VSL is chosen via calibration against WTP results. It can be seen that there is significant scatter. The BTE (2001) natural disaster cost was $1.28m AUD in 1996 (ca. $1m USD in 1996, PPP coeff. AUD-USD 1996: 1.0045). Taking the ratio of payout to GDP per capita at time of event (PPP), a ratio of around 48 is found. Similarly using the WTP regression in 1996, a VSL to GDP per capita (PPP) ratio of 93 is found.

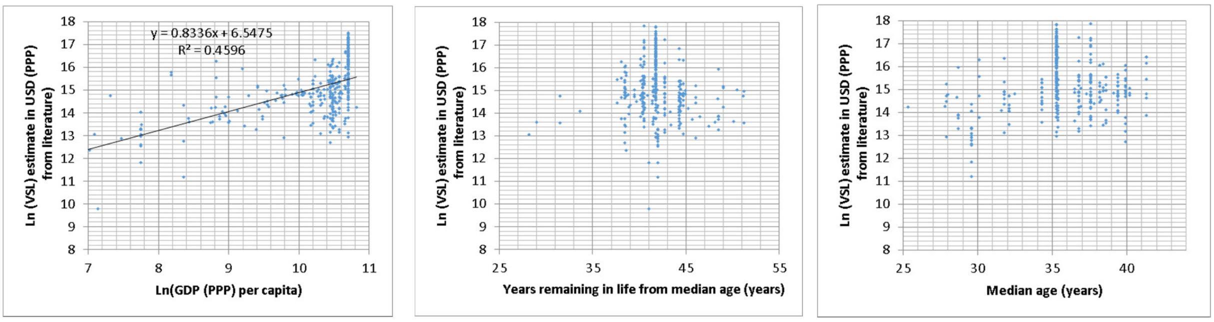


Figure 2: Median of 372 WTP and indemnity payout studies done by authors in 51 countries adjusted to USD (PPP) vs. Left: GDP (PPP) per capita in int. dollars; Center: Years remaining in life from median age; Right: Median age (years)

As a test, the regression would give an average in $6.04m in 2006 in AUD (current dollars) for an Australian VSL. This is approximately the mean estimate shown for Australia by Australian Safety and Compensation Council (2008), however is likely too high at over 100 times GDP per capita (current AUD in 2006).

The values from 1900-2015 are then hindcasted using life expectancy integrations from 1850 onwards, where the age distribution in each country can be calculated via the population-life expectancy integration. In this way, a life cost can be derived for each year based on the changing life length through time (i.e. a lower production lifespan and lower GDP per capita should give a lower VSL than a longer production lifespan).

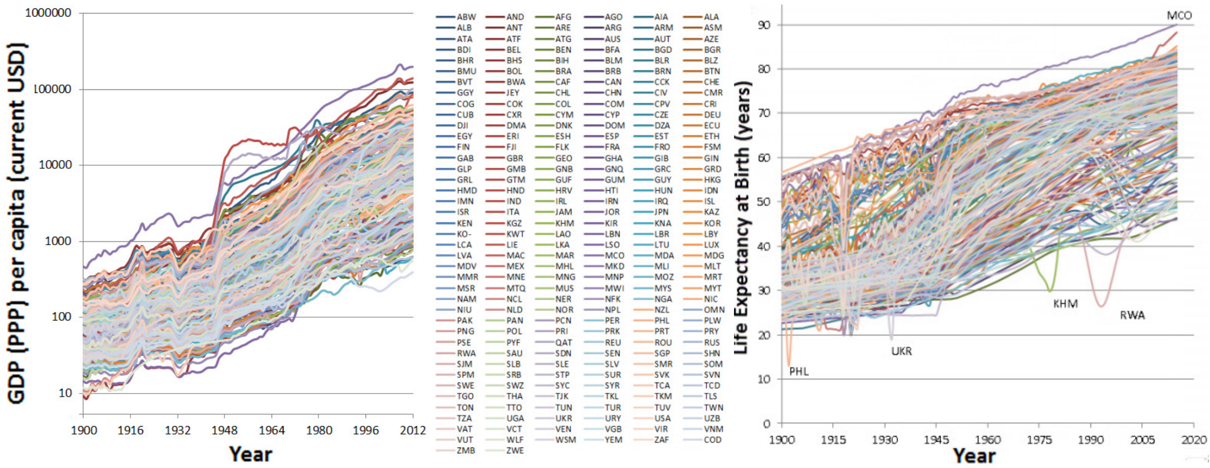


Figure 3: Left: GDP (PPP) per capita through time as used as a proxy for income; Right: Life expectancy in years for each nation; via WDI, IMF and other data sources as produced in CATDAT, Daniell (2014)

The production life in each country is adjusted via the original linear equation and the median age remaining. There is no clear trend when examining the years remaining from a median age, therefore it is reasonable to calculate based on the GDP per capita estimate. The OECD (2012) estimate for VSL is based on log regression of a risk reduction factor and GDP per capita. Although the WTP estimates seem reasonable, the difference between the BTE (2001) calculation and the WTP regression, was used to reduce the regression equation to a value that was deemed reasonable for earthquake losses.

Depending on the age of the individual killed, there should be a reduction based on the years of life left in terms of their value to society. It cannot be said that the remaining production impact is the same for a 30 year old and a 70 year old, thus it is important to take into account the age difference. Median age is determined via age profile data through time including the life expectancy at birth and through time in order to integrate the average number of years left per human.

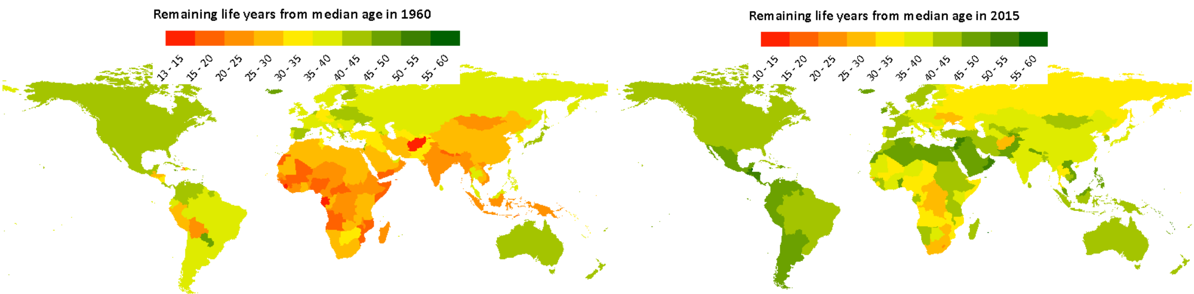


Figure 4: The average years from Left: median age to death in 1960; Right: median age to death in 2015.

The VSL is thus the regression calculation of the remaining life span as a percentage of 40 years (this is taken as the productive lifespan median for full VSL), a reduction is thus brought into the VSL calculation. It can be seen there is a huge range of uncertainty and that more results are required in developing nations. A linear trend has thus been established taking into account the decrease of productivity after a certain point (defined as 40 years from median).

The final regression is as follows:-

$$y = (a * \ln(GDPpcppp) + b) * (1 - 0.025 * (40 - (Ll - Lmed)))$$

where GDPpcppp is the current international dollar GDP (PPP) per capita; Ll-Lmed = Life expectancy of entire cohort present in country (Ll) at the time minus median age of country population (Lmed), a=0.9412, b=4.7821.

For instance, the estimate for Australia in 2015 would be equivalent to $2.82m USD (PPP). In USA, it would be $3.52m USD (PPP). This model is quite close to that of OECD (2012) which undertook a meta-regression analysis with coefficients a=1.1826 and b = 2.6659, with current GDP.

A Murphy and Topel (2005) style relationship is preferred for the distribution of the life cost values from this VSL as this gives the best assumption of children having dependency on elders, yet still having working life ahead of them, as well as taking into account consumption. Consumption data has unfortunately not been collected for each nation at this point, thus a simplification is used. It should be noted that there is still much discussion about whether VSL is actually age dependent (OECD, 2012).

In terms of calculating the net present value, a discount rate has to be applied. A discount rate of 4% was used for the net present value of a life from median expectancy to life expectancy at median age. For Australia, this would be the equivalent of a ca. 150000USD VSLY (Yearly-Value of Statistical Life). Although, this parameter is very sensitive to subtle changes, this fitted best with studies such as Aldy and Viscusi (2007). A linear regression is then used from the point of 0.125 times the VSL at median to the life expectancy of 120. The consumption at median age is given as 1.5 times the total wage. A wage increase is expected after median. More study is needed for a full consumption style approach along the lines of Martinez and Aguilera (2013).

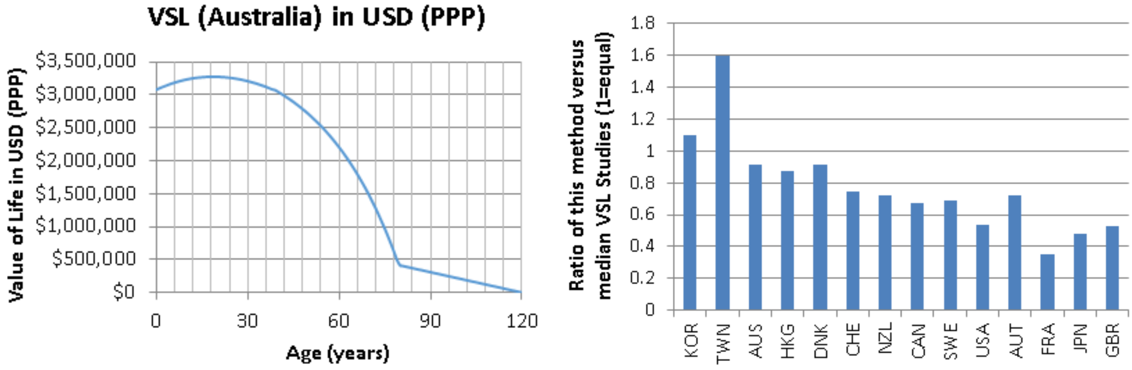


Figure 5: Left: A Murphy-Topel formed relationship and the calculation. Right: Comparison of this study with preferred VSLs from each country (built from the median estimates of the various studies)

The range of statistical life costs is examined globally from different sources, with the range of a life value being from $35,000 USD PPP (Central African Republic) up to in the order of $11.7 million USD PPP (Monaco) between different countries as defined through the median value.

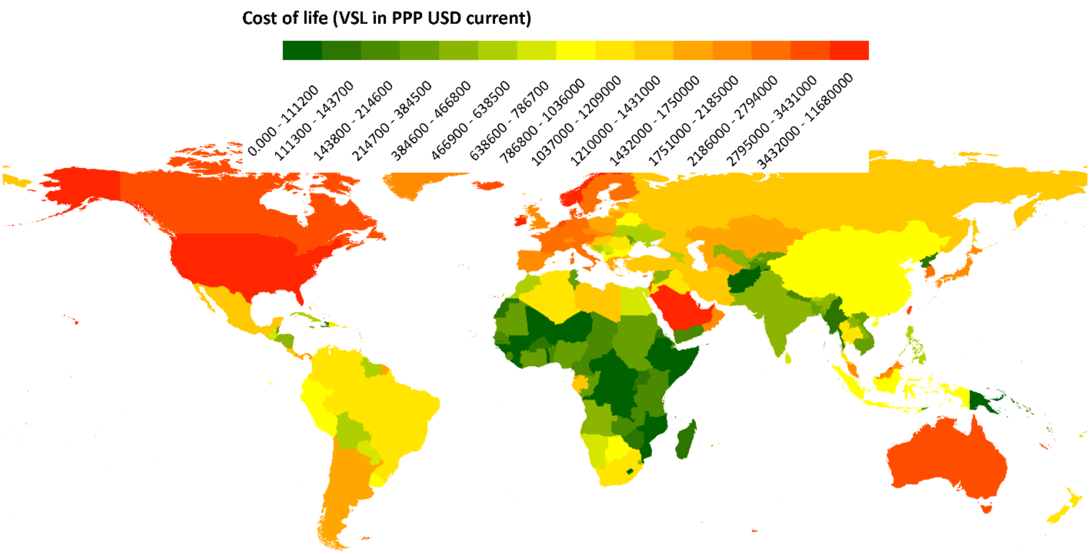


Figure 6: The global VSL estimates (mean) from this study for each country in 2014 USD in the year 2014

The influence of socioeconomic status and education will be adapted in future work once further study has been undertaken into these parameters globally. In addition, the interactions of injury costing globally will be examined.

By directly calculating human capital losses and comparing income vs. GDP values, a rapid method for life costing is proposed for use in decision-making pre- and post- disaster. This method has been calibrated with willingness-to-pay and indemnity payment data to provide a lower, but hybrid, value of life taking into account consumption, productivity influence and future earnings.

As shown above, these values in turn have been also hindcasted back to 1900 for each nation in order to put a value of life loss for each earthquake historically from 1900 onwards. In terms of injuries, there is unfortunately no definitive database that has accurate figures of injuries; thus, the best that could be done was for recent events to use the severe and slight injury figures within CATDAT, and for older events to use an average injury basis (where available).

3 EARTHQUAKE LOSSES

The losses in terms of historical earthquakes are examined, with the percentage of life cost shown as a proportion of total losses. The death tolls collected in each event from the CATDAT Damaging Earthquakes Database have been examined in great detail, with the death tolls being reviewed with each new source of data (Daniell et al., 2011a). When compared to the global death toll (either due to old age, or other disasters), it can be seen that the death percentage from earthquake is constant as a % of the global deaths. As the cost of a death is increasing, it means that in the 21st century a higher cost due to life losses will be seen than has previously occurred.

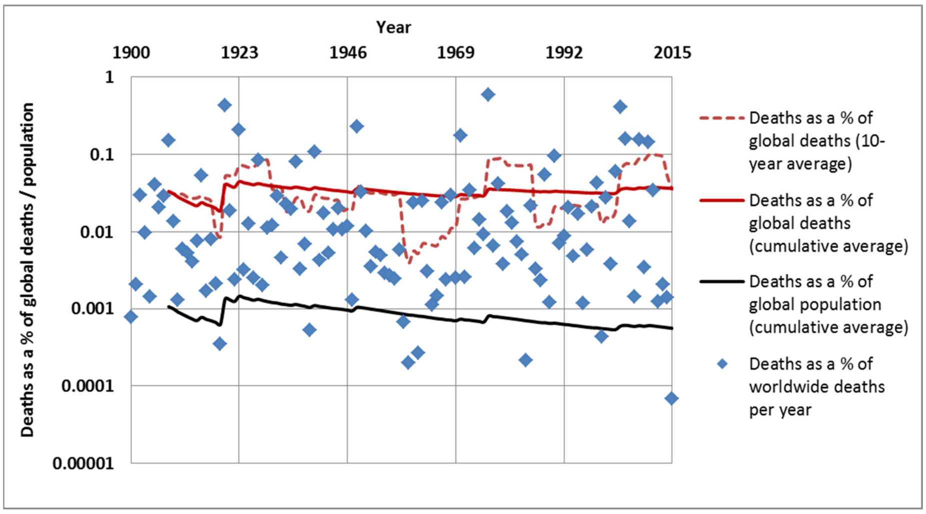


Figure 7: CATDAT Death tolls from 1900-2014 from earthquakes vs. metrics (2.32 million deaths) (Daniell, 2014)

The Newcastle Earthquake in 1989 had 13 fatalities and 160 injuries, and thus around $50 million AUD (1989) in life losses (only around 5% of the total event). However, if the earthquake had occurred when the often-quoted Newcastle Workers' Club had been in full session, the death toll could have been in the order of 200-300; and studies conducted by Hughes McNaughton consultants in conjunction with The Centre for Earthquake Research (Hughes, 1991) examined the fact that if the earthquake had occurred 2 months earlier in a time of peak traffic (schools and universities not being on summer holidays), in light of the damage/potential movement of people, there could have been between 700-950 deaths and between 6800-10,000 people injured. This would have been a cost (not counting the obvious emotional and suffering) equivalent to $2.5-3.2 billion AUD (1989), or far in excess of the insured losses of the event, and approximately the same or exceeding capital stock losses from the event.

The 2008 Sichuan EQ had $80 billion USD in terms of life cost (deaths and injuries). The 2011 Tsunami in Japan was taken into account with age distributions showing a lower life cost than other disasters, given the high percentage of the elderly in the death toll using the functions described above for reduction of VSL (Daniell et al., 2011b).

A foray into other disasters shows similar calculations of loss for moderate events in very developed nations. Porter (2006) estimated the cost of deaths around $2.6m USD in the 1994 Northridge earthquake event (this matches quite well with our estimate of $1.8m USD). Indeed, the total life loss for 33 deaths and the 138 hospitalised people with severe injuries totalled around $120m USD. It was the 24600 hospital cases and the 221000 self-treated people, which had a cost of between $1.2 and 2.1 billion USD.

In most cases, however, the injury costs are not often taken into account in this detail in other events.

These individual event death tolls in each country are then aggregated via the multiplication of the "life loss cost" at the time of the event by the death toll in order to estimate the life loss portion. This is then aggregated in year 2014 dollars to give a reasonable comparison. In the recent Nepal earthquake, the death toll of around 9000 people caused a life cost equivalent of around 1.9 billion USD (PPP) (approx. 35% higher than the reconstruction costs).

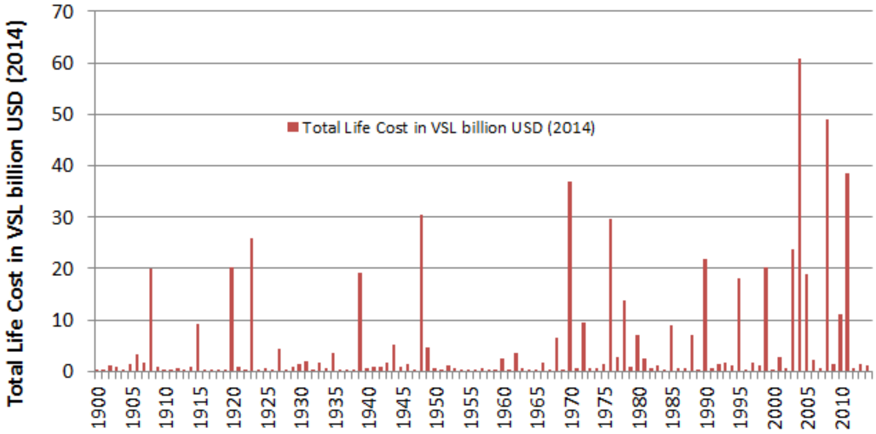


Figure 8: Life costs from all earthquakes from 1900-2014 (deaths only)

When looking at the fatalities and injuries from 1900—2014 in terms of fatalities from earthquakes, much age data is missing. However, by using average distributions in terms of the life expectancy at the time of the event and of the fatalities, a life cost of over $750bn (2014 USD HNDECI adjusted) has been calculated (over $1 trillion AUD).

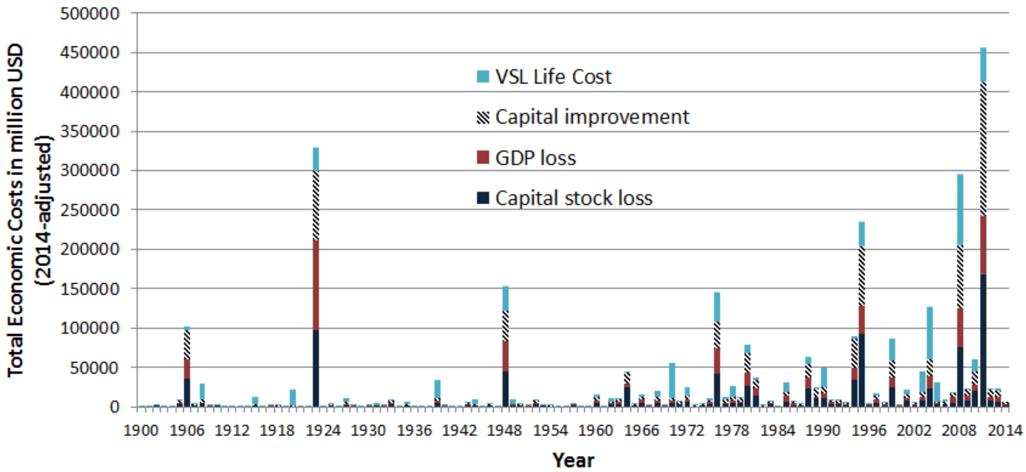


Figure 9: The total costs from all earthquakes from 1900-2014 showing life cost proportion

A constant distribution for each country is given, however the age distribution of earthquake deaths and the influence of VSL needs more study. In terms of injuries, over $350bn (2014 USD) can be counted using the same proportions as in the BTE (2001) study; however, it can be seen that authors such as Porter (2006) estimate much higher costs where earthquakes occur with a high injury to death ratio (as were likely not counted earlier in the century). This will be added in subsequent studies.

The losses of a future major earthquake in a low seismicity region show some of the largest potential life cost losses; with that of a Mw6.8 at night in Adelaide, Australia, having around $160 billion USD (current) in life costs (25,000 deaths, 15,000 severe injuries), calculated using the methodology in Daniell et al. (2015). Such an earthquake located along a fault line close to the city would cause ground shaking in the order of 0.3g across the city with local soil effects giving higher values of ground motions (Schaefer et al., 2015). Given the large number of double brick (very vulnerable) and brick veneer structures, catastrophic collapse rates around 30% or higher would be seen in the near suburbs with extensive damage also to other building typologies using relationships such as EQRM or Kappos et al. (2006). Given the heavy structure, fatality rates around 5%-7% would be expected in these collapses, with additional fatalities in other extensively damaged buildings (1.5-3%) (Khazai et al., 2014). Using these algorithms a value of between 19,000-27,000 fatalities would result. There are various studies such as Coburn and Spence (2002) or Davey and Shepherd (1995) which would give fatality rates of 17.5% or 28% for URM in the near field which would lead to fatality estimates around 60,000-100,000 for this event (taking lower rates for brick veneer). Cousins (2013) for New Zealand, gives much lower fatality rates for URM with 6% in collapsed and 0.6% in extensive – This would result in around 15,000 deaths.

The 25,000 deaths is calculated through the empirically derived fatality rates from Daniell (2014) and represents around 2% of the population of Adelaide. All fatality methods however have much uncertainty given the grouping of countries globally given the lack of data.

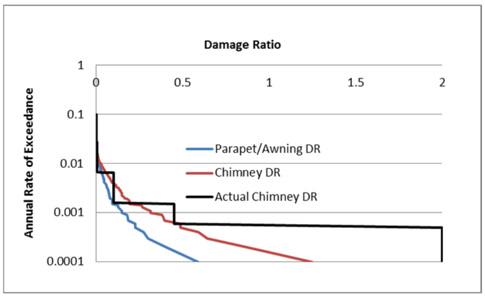
4 THE APPLICATION OF LIFE COSTING TO 2 CASE STUDIES

Two case studies are discussed with their application to including the cost of lives in decisions for public safety.

4.1 Structural Changes to Chimneys and Parapets in Adelaide, Australia.

The first is in the costing of decisions for making minor structural changes to houses in Australia as detailed in the Daniell et al. (2014) paper. Using this analysis, the impact of taking potential fatality life costing into account can be examined, in more detail.

Destruction (+ toppling effects)	1 in 2000
Major damage (sliding, foundation)	1 in 666
Minor damage (cracking)	1 in 160
Very minor damage (hairline cracks)	1 in 40



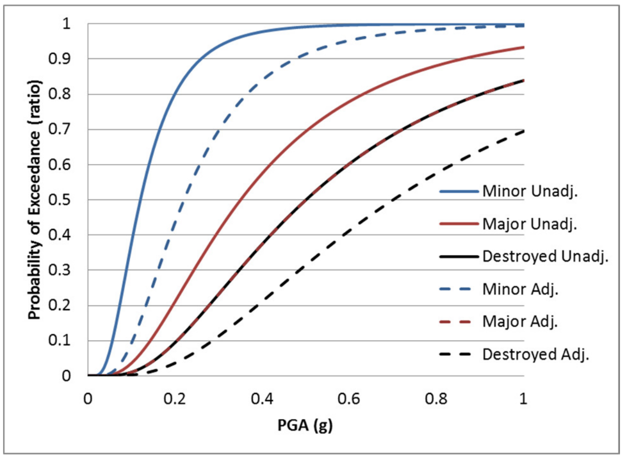


Figure 10: The chimney and parapet/awning damage ratios for Adelaide; Adjusted fragility functions from the data of Ingham and Griffith (2011) for Right: Retrofit of chimneys

The retrofit options for the AAL of chimneys, including the cost of work, are calculated for a 'lifetime' ownership of 20 years. For chimneys, the cost was calculated to be between $350 + labour and $2000 + labour. Without life costing, the retrofitted AAL with respect to the non-retrofitted AAL is in the order of 5 times less, but with work included is in the order of 8 times greater for parapets and around 2-4 times more for chimneys. This does not, however, take into account life safety. In Adelaide, 15 times in 10,000 years, there will be a dangerous situation occurring with major to full loss. For the toppling chimney case, one could assume around 0.7% chance of death due to bricks falling through the house (total fatality rate around 8% for masonry building collapses). For the major damage, there is around 0.08% chance. In total, the chance of death in 10,000 years is around 4.3% (5 toppling, 10 major). Calculating the average value of life at ca. $4.9 million AUD (2015 VSL value adjusted for PPP and exchange rates), and if 3 people were living in a brick house for Adelaide (average family size in Adelaide = 3.8, average occupancy in Adelaide metro area = 3.0), the total AAL for life costing would be around $63/year with a reduction of chimney related death losses to $15/year if retrofitting is implemented. Of course, this calculation is very sensitive to many uncertainties. Depending on the cost of the chimney retrofit, even with life costing, the AAL is not reduced enough to justify work. The median solution saves around $20 of losses a year with most of this coming from life costs, thus it is probably not necessary for a family to undertake this.

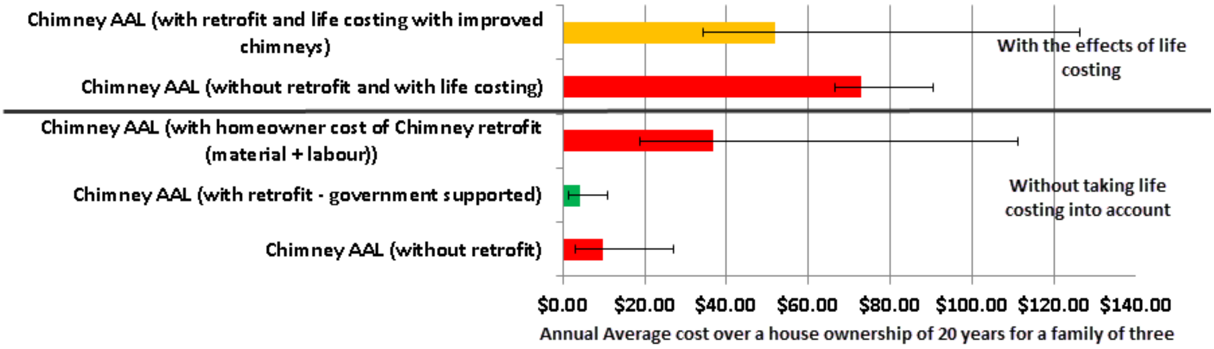


Figure 11: The cost-benefit ratios when examining retrofitting chimneys in Adelaide for earthquake shown for an occupancy of 3 in a brick house

4.2 Life costing in a country when looking at reductions in economic loss

When making changes to public structures by building the quality better or enforcing seismic codes, the total number of expected fatalities can be improved greatly. Along with economic loss improvements, there are added benefits of the reduction of fatalities.

The country of Croatia has had a significant number of earthquakes throughout history but very little activity in recent history, despite earthquakes such as the 1969 Banja Luka earthquake, the 1979 Montenegro earthquake and the 1963 Skopje, Macedonia, event. Thus, stochastic risk assessments are one of the only ways to examine the risk. As part of Eastern Europe risk assessments, Daniell and Schaefer (2014) examined PML curves for Croatia and 32 other nations for earthquake.

For an improvement from pre-code to the current new buildings in 15% of older buildings, much work is needed at a high retrofitting cost. By calculating the effect of change on the PML, a reduction of around 30% is seen in the AAL for an improvement in 15% of the buildings. The reduction, however, in terms of AAL is one from 23 deaths per year to 10 deaths per year. In terms of value to the country, the reduction is around $72 million USD per year. The additional life loss saving, however, is $14m.

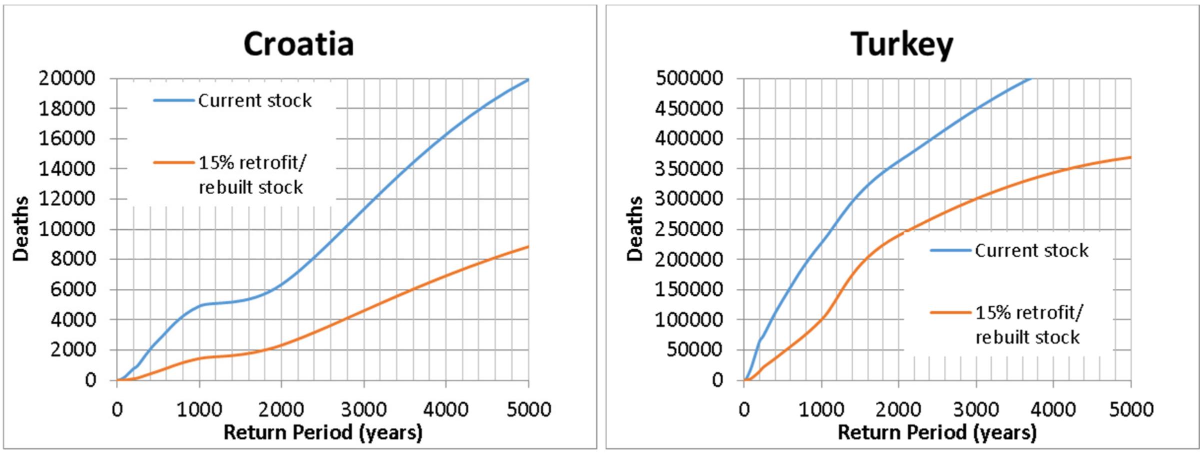


Figure 12: Left: Stochastic Death curves for Croatia (10000-year simulation), Right: Death curves for Turkey

For other countries such as Turkey with around 1280 fatalities on average per year, a similar improvement in code quality adherence would give a saving of around 850 million USD per year of a total $2 billion USD AAL. However, when also taking the AAL into account with life costing for fatalities (711 deaths vs. 1280 fatalities per year; 570 fatalities @ $775,190 per fatality), a saving of $441m is made; however it should be noted that across Turkey there will be large differences in VSL.

5 CONCLUSION

This work shows the importance of life costing, and shows the influence over the past century with losses from VSL life losses approaching the cost of the disaster. At the end of the day, the loss of a human life is immeasurable and should be morally the same across countries, but using WTP and human capital procedures is key to creating plausible loss results for use in analysis. Some countries with high personal risk natures will be overestimated by this methodology, and others with risk averse natures underestimated. The average life factor is ca. 75 times the GDP per capita of a country in present terms. Much more work is required in order to create a more dedicated disaster life loss estimate in most countries based on individualised consumption statistics.

This study has benefits post-disaster for quantification of human capital losses in major disasters, and pre-disaster for the analysis of insurance and mitigation options in terms of cost-benefit options. It can be seen that for earthquakes, life costing should be taken into account when making decisions, and that fatality analyses also have an economic consideration for governments. Every decision over $100 million in USA requires a cost benefit analysis; and similarly, extreme events should be either designed for as a single value, or at least the AAL (depending on the analysis). In this way, the costs and benefits of extreme events can be made understandable in terms of decision-making. Around a 25-30% increase in economic losses can be seen in earthquakes when taking life costing into account; however, this is of course only as a percentage of the total, with life loss cost often exceeding the total in major death toll events.

This study is ongoing, and represents a part of a review of statistical life estimates globally and their future influence on cost-benefit decision-making for disasters.

REFERENCES:

Abelson, P. (2008). “Establishing a monetary value for lives saved: issues and controversies.” Canberra: Office of Best Practice Regulation, Department of Finance and Deregulation.

ABPR (2014). “Best Practice Regulation Guidance Note Value of Statistical Life,” December 2014.

Aldy J. E., and W. K. Viscusi. (2007). Age differences in the value of statistical life: revealed preference evidence. Review of Environmental Economics and Policy 1, no. 2: 241–60.

Andersson, H. and Treich, N. (2011). “Value of Statistical life, in A Handbook of Transport Economics”, edited by Palma et al, Edward Elgar Publishing Limited: US

Australian Safety and Compensation Council (2008). “The Health of Nations: The Value of a Statistical Life.”

BTE (2001) “Economic Costs of Natural Disasters in Australia,” Bureau of Transport Economics Report 103, Canberra. BTE (2001). Road Crash Costs in Australia, Report 102, Bureau of Transport Economics, Canberra.(https://bitre.gov.au/publications/2001/files/report_103.pdf)

Coburn, A. W., & Spence, R. J. S. (2002). “Earthquake protection (2nd ed.)”. Chichester, West Sussex, England, Hoboken, NJ: J. Wiley.

Cousins, W.J. (2014). “Estimated damage and casualties from earthquakes affecting Auckland. GNS Science Consultancy Report 2013/324. February 2014

Daniell, J.E., Khazai, B., Wenzel, F., & Vervaeck, A. (2011a). “The CATDAT damaging earthquakes database.” Natural Hazards and Earth System Science, 11(8), 2235-2251.

Daniell, J.E., Vervaeck, A., & Wenzel, F. (2011b). “A timeline of the Socio-economic effects of the 2011 Tohoku Earthquake with emphasis on the development of a new worldwide rapid earthquake loss estimation procedure.” In Australian Earthquake Engineering Society 2011 Conference.

Daniell J.E., Schäfer A.M. (2014). “Eastern Europe and Central Asia Risk Profiling for Earthquakes,” World Bank, Washington DC.

Daniell J.E., Wenzel F., Khazai B., Santiago J.G., Schaefer A. (2014) “A worldwide seismic code index, country-by-country global building practice factor and socioeconomic vulnerability indices for use in earthquake loss estimation,” Paper No. 1400, 15th ECEE, Istanbul, Turkey.

Daniell, J.E. (2014). “The development of socio-economic fragility functions for use in worldwide rapid earthquake loss estimation procedures,” Doctoral Thesis, Karlsruhe, Germany.

Daniell, J.E., Schäfer, A., Wenzel F. (2015). “A tale of eight cities: earthquake scenario risk assessment for major Australian cities”, Australian Earthquake Engineering Society Conference, Sydney, Australia.

Davey, R. A., Shephard, R.B. (1995). “Earthquake Risk Assessment study: Study area 1, Wellington City.” Wellington: Works Consultancy Services.

Drèze J. (1962). “L'utilité sociale d'une vie humaine.” Revue Française de Recherche Opérationnelle, 23, 93-118.

EQRM: Robinson, D., Fulford, G., & Dhu, T. (2005). EQRM: Geoscience Australia’s Earthquake Risk Model:

Technical manual: Version 3.0. Commonwealth Government of Australia. Canberra, Australia: Commonwealth Government of Australia. Retrieved from http://sourceforge.net/projects/eqrm/files/

Hansen, W.L. (1970). Introduction to “Education, Income, and Human Capital". In Education, Income, and Human Capital (pp. 1-8). NBER.

Hughes, P. (1991) “What if the circumstances were different?”, The Macedon Digest, Vol. 6, No.4, Summer 1991/92, p3.

Ingham, J. and Griffith, M. (2011). “Damage to unreinforced masonry structures by seismic activity,” The Structural Engineer, The Institution of Structural Engineers, 89(3): 14-15.

International Monetary Fund (IMF). (2015). “World Economic Outlook Databases (WEO).” Retrieved from http://www.imf.org/external/data.htm#data

Kappos, A. J., Panagopoulos, G., Panagiotopoulos, C., & Penelis, G. (2006). “A hybrid method for the vulnerability assessment of R/C and URM buildings.” Bulletin of Earthquake Engineering, 4(4), 391-413.

Khazai, B., Daniell, J. E., Düzgün, Ş., Kunz-Plapp, T., & Wenzel, F. (2014). “Framework for systemic socio-economic vulnerability and loss assessment”. In SYNER-G: Systemic Seismic Vulnerability and Risk Assessment of Complex Urban, Utility, Lifeline Systems and Critical Facilities (pp. 89-130). Springer Netherlands.

Lindhjem, H., Navrud, S., Biausque, V., & Braathen, N. A. (2012). “Mortality risk valuation in environment, health and transport policies”, OECD Report.

Martínez, G., & Aguilera, N. (2013). “The Value of Longevity in Mexico”, Economía Mexicana NUEVA ÉPOCA, 22(4, Cierre de época (II)), 341-359.

Miller, T.R. (2000). “Variations between countries in values of statistical life.” Journal of transport economics and policy, 34 (2), 169-188.

Murphy, K. M., & Topel, R. H. (2005). “The value of health and longevity (No. w11405)”. NBER.

OECD (Biausque, V.) (2012). “The value of statistical life: A meta-analysis”, Environment Policy Committee, ENV/EPOC/WPNEP(2010)9/FINAL.http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=ENV/EPOC/WPNEP(2010)9/FINAL&doclanguage=en

Pandey, M. D., & Nathwani, J. S. (2004). “Discounting models and the life-quality index for the estimation of societal willingness to pay for safety.” 11th IFIP WG7. (pp. 87-94).

Porter, K., Shoaf, K., & Seligson, H. (2006). “Value of injuries in the Northridge earthquake”. Earthquake Spectra, 22(2), 555-563.

Schäfer A.M., Daniell, J.E., Wenzel F. (2015a). “The seismic hazard of Australia - a venture into an uncertain future”, Proceedings of the Tenth Pacific Conference on Earthquake Engineering, Building an Earthquake-Resilient Pacific, Sydney, Australia.

Viscusi, W.K. (2009). “The devaluation of life”. Regulation & Governance, 3(2), 103-127.

Viscusi, W.K., & Aldy, J.E. (2003). “The value of a statistical life: a critical review of market estimates throughout the world. Journal of risk and uncertainty, 27(1), 5-76.

WBI: World Bank. (2015). World Development Indicators (WDI). Retrieved from http://databank.worldbank.org/data/views/variableSelection/selectvariables.aspx?source=world-development-indicators