CONSEQUENCES OF EARTHQUAKES AND EARTHQUAKE INSURANCE

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Summary

Rising values, growing investments and populations in terms of number and density, as well as the increasing number of elements at risk which are actually exposed or which represent critical installations because of particular risks associated with them, put an increasing demand on qualified scientific assessments of the consequences of earthquakes. Until now, practically only the physical damage has been considered and not indirect damage or what we shall call consequential loss. These losses very often weigh heavier than direct physical damage; their effect on the society and national economy can be profound and lasting. This paper presents an introduction to assessment technology and insurance issues.

Introduction

As there is practically no special literature quantifying consequential loss caused by earthquakes, we shall treat some important aspects here. In view of the many parameters which must be considered we must, however, limit ourselves to a general discussion of indirect loss and damage, and the respective parameters .

It is the author's opinion that an assessment of the consequences of earthquakes must allow for probabilistic aspects at all stages in order to put risk assessment, risk mitigation,and risk management on an economic basis. An assessment of the economic consequences of earthquakes must therefore consider probability distributions of earthquake magnitude or intensity of the area under study as well as those related to direct and indirect damage and loss levels.

It must be noted that the same conditions apply to insurance because a modern professional handling of exposure assessment, etc. does not depend on who is shouldering the risk. The additional parameters to be considered in earthquake insurance are briefly described. It should be noted that insurance of the most modern professionalism available can be of great assistance in risk mitigation, extending far beyond indemnifying losses.

The Direct and Indirect Cost of an Earthquake

We offer two simple examples to illustrate a method which can be used to analyze the economic consequences of earthquakes, including the economic loss from direct damage. The examples illustrate a general procedure without providing specific figures which can later be adapted to special conditions in the simple form shown or in a more refined form, using data given in the various references.

For these examples we have selected a town of about 100,000 inhabitants, founded on medium-hard alluvium and containing modern buildings which are moderately asymmetrical of a quality corresponding to 2 - 3% g. The example covers only the MM VIII zone and is based on MDR's (Mean Damage Ratio expressed as a percentage of the new replacement value of the elements at risk) and not on maximum loss levels. All values are in US dollars.

Low Income Level	
DIRECT LOSSES	$/Inhabitant
Residential buildings: constr. cost about $4,000 per inhabitant, MDR 30%	1200
Commercial bldgs. & equip: 40% of working population of 30,000 , 50 m^3 per person, $15 per m^3, MDR 30%	270
Factories: 50% of working pop. 150 m^3 /per. $100/$m^3$, MDR 30%, 10% of the working population	675
Machinery: about 1/3 of factory buildings	225
Contents: Private $2,000/inhab., MDR 10% Merchandise in stock $100/inhab, MDR 10%	200 10
Vehicles: prob. of damage = 0.2, $5,000/car, 1 car/4 inhab., MDR 12%	30
People killed: about 1,300 people, $20,000 each	260
Injuries: about 6,500 persons, $1,000 each	65

(Casualties will be re-evaluated below)

INDIRECT LOSSES	$/Inhabitant
General loss of production: about 15,000 people affected for 3 months, $15,000 each Wages, salaries, social security, interest, depreciation, continuing expenses, loss of markets, tourism, etc. (depending on actual case)	562
OTHER LOSSES/DAMAGE	
Transport, power, water, sewage, telephones, roads, bridges, medical & health services, schooling, art collections & museums, cultural heritage, etc. (These losses can be very heavy but are difficult to estimate specifically as they depend on the local setting. Detailed stock-taking is therefore required.)	

High Income Level

DIRECT LOSSES	$/Inhabitant
Residential: $40,000/inhab., MDR 30%	12,000
Commercial: 40% of 30,000, 200 m^3/pers., $150/$m^3$, MDR 30 %	9,000
Factories: 50% of 30,000, 300 m^3/pers., $100/$m^3$, MDR 30%	9,000
Machinery: 1/3 of factory bldgs.	3,000
1 HPI Plant: $500,000,000, MDR for shock, fire & explosion 40%	2,000
Contents: Private $10,000/inhab., MDR 10% Merchanize in stock $200/inhab., MDR 10%	1,000 20
Vehicles: prob. of damage = 0.2, $7,500/vehicle, 1car/lorry/2 inh., MDR 12%	180
Loss of Life: 1,300 pers., $50,000 each	650
Injury: 6,500 pers., $2,500 each	130

INDIRECT LOSSES	$/Inhabitant
General Loss of Production: 27,000 pers. affected for 3 months, $25,000 each	1,700
Interest, etc.: as in earlier example	....
OTHER LOSSES/DAMAGE	
Transport (incl. shipping & aviation), etc.: as described in earlier example	....

Even in the absence of aggravating factors, the mean total loss from damage to buildings, commerce and factories can reach or even exceed $30,000 per inhabitant in the strongly shaken area (MM VIII). This figure is supported by observations. For a population of about 1 million in the epicentral region the total mean loss could add up to some 30 billion (30,000 million). Quite obviously the MPL (Maximum Probable Loss) and in particular the PML (Possible Maximum Loss) can be substantially higher, and the probability of such a catastrophe is not necessarily small.

We shall now return to loss of human life, since the above list of losses includes the cost of injuries and loss of life only on the basis of a single figure, like a life insurance claim or a single course of medical treatment. In fact, the loss to society and the national economy is very much greater, not to speak of the human misery caused by the casualties. The parameters which determine casualties are discussed below in a separate section.

The 1,300 people we assumed were killed by the earthquake are in fact a permanent loss to the economy. Applying actuarial methods and considering: the average age in the region, the average production per person, the retirement age, and the life expectancy, one can calculate the total additional loss to the national economy. A very simple example must suffice here. Assuming a current productivity of about $15,000 per person (GDP divided by population), a median age of 30 years and therefore an average loss of about 30 working years, the 1,300 people killed correspond to $585 million, i.e. $5,850 per inhabitant, not taking into account normal mortality, interest and other indirect losses related to permanent loss of productivity and buying power.

To this, the cost of permanent disablement must be added which is estimated at $300 million, i.e. $3,000 per inhabitant. Returning to general examples, we will now briefly discuss indirect losses due to interest on idling capital, loss of rent, wages and salaries and other overhead expenses which continue during the period of interruption of trade and industry, and including the cost of those persons permanently lost (killed and disabled).

For the first example (low income level) these indirect monetary losses add more than $1,000 per inhabitant to the bill, i.e. more than $100 million for these 100,000 inhabitants. The above figures do not take into account losses to the infrastructure, utilities, tourism, nor losses due to emigration because of unemployment created by the earthquake, etc. Moreover, the cost to life insurers and for medical care of the injured and temporarily disabled has not been included. If in a large town or region 100,000 people were killed by collapsing buildings, falling non-structural elements, fires, explosions, and perhaps even tsunami, at the average insurance amount of $25,000 and density of about 40%, the total amount of disbursements would amount to about $1,000 million. A loss of life of 100,000 is far below the maximum loss scenario for many places around the globe.

The contribution of the various loss categories in our simple example is therefore approximately as follows: Direct loss and damage accounts for 23%, indirect losses (LoP, BI) for 9%, permanent loss of productive capacity because of people killed for 41%, and permanent disablement for 27%. As loss of life, permanent disablement, and business interruption and therefore general overheads are decisively affected by the vulnerability of the buildings, it is evident that any improvement in this field will reduce the impact of an earthquake enormously and that it should therefore receive proper attention. This, however, also means that the total loss to the national economy due to death or serious injury of victims assumes gigantic proportions if the number of casualties is much larger than assumed in these examples. The Spitak, Armenia, earthquake killed about 25,000 people and many more were crippled. The Guatemala earthquake of 1976 killed a similar number of people. These earthquakes cannot be taken as a worst case scenario. The Tangshan earthquake killed about 255,000 people and about 800,000 were injured. The number of those disabled is not known. An even higher percentage was killed by the M 5.9 earthquake which hit Agadir in 1960.

Should there be any high value production in the town (the high income level example considers such a case) indirect losses would rise dramatically. It may take longer than a year to get a petrochemical or HPI plant back into operation after it has been gutted by an explosion and conflagration following an earthquake. During the Mexico earthquake of 1985 the steelmill in the epicentral region fortunately did not suffer much. There is, however, no question that such installations could be paralysed for a year or longer by a strong earthquake. This shows that each particular location must be assessed carefully by someone with adequate experience. We shall now discuss a few additional aspects which can be important at specific sites.

If, for instance, about 2,000 tourists cannot be accommodated for an average period of 6 months, a loss of income of about $36 million will result. To this we have to add the interest on investments lying idle. We must be prepared for the complete interruption of business for most hotels because there will be not only some severe structural damage but also cracks in the walls of most rooms. Guests will not feel at home with bricklayers, plumbers and electricians swarming all over the place. The loss of interest alone may be something like $7 million or more. Expenses for wages and salaries, bills for utilities and other overheads must be added. Moreover, such earthquake damage may frighten tourists away for a long period, particularly if a hotel collapsed killing many foreign guests.

Indirect losses can even be graver if there is a chemical plant near the town using large quantities of inflammable, explosive, or toxic materials, or if the area is hit by a devastating tsunami. No great earthquake is required to produce loss levels and indirect losses as discussed in the examples. A large earthquake happening near a high value region can cause much higher losses. The loss levels stated in the respective tables and used in the examples do not allow, for instance, for damage caused by shaking of abnormally long duration. Moreover, the first example in particular assumed a rather homogeneous mix of risks. The second example shows that one large exposed plant, if installed in a low income area, can cause as much loss as all the buildings, commerce and factories taken together.

Earthquake Risk and Insurance

In most countries it is possible to cover an essential part of the various earthquake risks by some form of insurance, private or not. The following short discussion will try to illustrate the most essential issues related to earthquake risks and to their insurance. Because of the limited space available this article will concentrate on general aspects and not discuss details especially those which are too specific or particular to a country or region. Apart from earthquake risks involving death, injury, or lasting disablement which can in general be insured through insurance policies covering life, health, accident, and some form of social security, insurance coverage is mostly sought for physical loss and damage involving property. In the latter area, the commonly encountered coverage deals with buildings and industrial production facilities and we shall therefore base the following discussion on such elements at risk.

The importance of buildings in earthquake disasters and therefore in insurance is illustrated by the fact that earthquake construction codes are unfortunately so far developed for this group of elements at risk only. If we group buildings according to their use, we find that about 30% of all earthquake damage, i.e. direct and indirect property and financial damage, loss of life and injury, is due to residential buildings. In non-technological societies, commercial and factory buildings combined produce damage which is in general about one third above that of residential buildings. If one adds earthquake damage to all types of buildings, i.e. residential, commercial, administrative and factories in non-technological societies, it is found that this group accounts for somewhat more than 50% of the grand total of earthquake loss and damage. Finally one must know that loss of life and injury and socio-economic effects of earthquakes are decisively influenced by the performance of buildings.

Risk Analysis

The basis of professionally sound earthquake insurance is proper risk analysis. The most important parameters to be considered are the vulnerability functions for the important types of buildings and the probability distributions of earthquakes considering their magnitude and/or intensity. As the damage caused to buildings by certain earthquake intensities depends on many details the assessment of the damage potential must consider many parameters. To cite only some of the important damage parameters, buildings founded on soft subsoil, like alluvium and particularly on soft alluvium with the ground water level near to the surface, will in general suffer much more severer damage than those founded on hard alluvium or, in particular, on rock. The damage to asymmetrical and irregular buildings is much heavier than to symmetrical and regular ones. To establish the weight of the respective parameters, adequate experience with earthquake characteristics of all older and modern categories of buildings must be available. This may be a difficult task for any party working in one region or country only, in particular if seismicity is low and experience is therefore lacking.

As regards seismicity, one requires a reliable indication of the probability of the occurrence of earthquakes of certain magnitudes or of certain intensities. The reason here-to-fore is self-evident. We assume that the average damage to a certain category of buildings from a specific earthquake intensity is about 30% of their value. If such an intensity must, for instance, be expected about once every 300 years the net insurance premium rate to cover a building against damage from this single earthquake would be 30% divided by 300 years, i.e. 0.1% per year. As the buildings are, however, not only exposed to one single earthquake but, according to the intensity probability distribution, to several events their contribution must be considered and the net rate must therefore be several times higher than the one calculated for a single earthquake. Moreover, to the net rate overheads, safety margins and a profit compatible with the exposure of those granting insurance must be added. This brings us to one of the main problems of earthquake insurance.

Spreading the Risk

The consequences of a devastating earthquake may amount to a national catastrophe. The Armenian earthquake of December 1988, for instance, affected a population of about 700,000 people in a moderately developed region. Still, the total provisional cost of this earthquake amounted to more than US$ 20 billion. Translating this to a scenario were a much larger population is exposed is a simple arithmetical task. Should such a region be technologically more developed, or, in simple words, enjoy a substantially higher GNP, the total loss potential can be several times higher, even if buildings were less vulnerable than those in Armenia. This simple approach shows that the impact of a devastating earthquake must be distributed optimally within a country and internationally, the latter being accomplished via reinsurance. Therefore a national solidarity which avoids a negative selection is extremely essential. The latter may, for instance, be caused by insuring selectively in those areas where seismicity is pronounced, or contain elements at risk which are very vulnerable, or which constitute extreme individual values. Such a selection will not only raise the cost of insurance because of the lack of "good risks" which balance the insurance portfolio but because the lack of insurance capacity will be the likely consequence. It should be noted here that negative selection also increases the many uncertainties inherent to an earthquake insurance portfolio.

In the example given above, a return period of about 300 years was selected. As an earthquake may happen tomorrow resulting in a pay period measured in terms of centuries, any insurer or reinsurer risking heavy disbursements for negatively selected, that is imbalanced risks, will think twice before accepting a large share. If, however, insurance is bestowed in a well-balanced, co-ordinated, nation-wide manner, the ratio of premium to exposure is optimized, the insurance portfolio is much better balanced and the uncertainties are substantially reduced. Such situations, therefore, attract insurance to lessen the burden of an earthquake catastrophe.

General and Special Problems

Earthquakes often come as a surprise, not only to the inhabitants of a town but to the insurance community as well. Building standards are often not adequate. Moreover, it must be noted that it is not their purpose to avoid losses to insurers. They try to protect against loss of life and to avoid structural damage. More than 80% of the damage is, however, non-structural. One may also wonder whether insurers read and interpret the respective standards carefully. Using the Newcastle earthquake as a warning we cite the Australian standard. On the first page of the text proper it is stated under C1.1 SCOPE "This standard is ... to safeguard against major structural failure and loss of life". Did insurers try to find out how much damage is already present before "major structural failure" sets in and before loss of life becomes important?

A region may have been shown as a zone of low seismicity. This does not mean that damaging, and in fact, even catastrophic earthquakes are not possible there. The insurance companies should therefore ask themselves whether they took the trouble to find out what the risk may be. The Newcastle earthquake occurred in a zone designed "zero" in the Australian building code. Still, this moderate event of about M 5.5 which fortunately occurred at some distance from the town caused an insured loss of many hundred million dollars, in fact the second largest insurance loss since the San Francisco earthquake of 1906. Another important question is whether efforts are made to find out whether and to what extent the insured elements were vulnerable to earthquake shaking. Is it wise to insure elements worth billions of dollars without obtaining an expertise on the exposure? If life insurers cover a substantial sum they generally ask for a medical checkup .....

Is earthquake underwriting approached from the angle of fire underwriters, for instance not realizing that earthquakes do not follow fire block rules but can devastate very large areas? If losses caused by the moderate intensity of the Newcastle earthquake (affecting an area where not much more than 100,000 people live) amount to several hundred million dollars, imagine the losses from a really strong earthquake if it devastates a region where ten times as many people have their home? The values of the elements at risk present another problem. Depending on the terms of the insurance contract and the conditions under which the claims are indemnified, great care may be required. At any rate, the general rule holds; the older the risks insured the more problematic it is to establish proper values.

Underinsurance is another nearly universal problem. In particular in regions where ordinary buildings are comparatively old and/or where inflation is pushing up the prices of real estate, sums insured must be checked and revised constantly. Neglecting this is not in the interest of insurers in other regions or of other insurance branches who may be called upon to "close the gap". Another issue which needs careful attention in the field of catastrophe insurance, related to natural phenomena, is indemnification on the basis of "new for old", and whether this happens knowingly or without appreciating its extent. Here too the problem grows with the age of the building population. If this aspect is not well controlled it may happen that the long-term premium income of insurers, although once commensurate with exposure, is eventually quite inadequate to cover outgo. This may lead to penalizing other branches of insurance and their clients and this is not necessarily fair.

The Newcastle earthquake has again shown that earthquake damage results in repair problems even with "normal" buildings, unknown in fire insurance and therefore, in general not fully appreciated. If a building is affected by fire, damage to its actual structure is very rare; the roof may be damaged, its replacement or repair is a comparatively simple matter, but the walls are not shattered and in particular the foundations are untouched. Not so in the case of earthquakes. Non-structural earthquake damage may be costly to repair, e.g. the fixing of suspended ceilings, the replacement of roof tiles and the replacement or repair of fill-in walls. If, however, walls of brick, in particular cavity walls, are cracked or shattered, repair not only becomes a very costly but also a very difficult operation. After all, the structural integrity and future safety of the building is at stake.

A wise underwriter working in the field of catastrophe exposure will also remember that such perils are not free of political tinge. The opinion of an electorate, irrespective of how well or ill-founded such an opinion may be, is more important to the general politician than the well-being of insurance companies. The Newcastle earthquake has brought out a number of specific problems which we shall discuss briefly because they can be lessons for many other regions in the world where similar conditions prevail. Old buildings which represent cultural heritage, churches, etc. present particular problems as regards the correct sum insured and the cost of repair of earthquake damage. This case will illustrate what problems are caused by the specific kind of repairs required after earthquakes and what bearing this has on sums insured.

It is by now common knowledge that assembling a car from spare parts would result in a vehicle several times more costly than its normal counterpart rolling off the assembly line. The situation is not very different if a house requires extensive repairs after an earthquake. The work is far more costly than the original construction price which may have been taken as the sum insured. Even a strong earthquake will not destroy more than a percentage of all buildings outright and repairs will therefore contribute most to the compensation paid by insurers for building damage. One can allow for repairs "overshooting" the respective part of the "new replacement value" of the building either by including a margin for such "contingencies" or by adjusting the premium accordingly. It should be mentioned that the inclusion of a margin for contingencies is nothing new in the insurance of civil engineering projects under contractors' all risks coverage (CAR).

The situation is even more complex if we look at outstanding examples of old architecture, like churches, museums, universities, government buildings, etc. The repair of such buildings often requires special skills which may be difficult to find today. If large sections must be repaired or reconstructed the expenses may be enormous. Do the sums reflect this? Should such buildings and in fact other large risks be insured without a qualified inspection? Buildings, whether old or new, often have cracks or may otherwise be slightly damaged without the owner having noticed it. Buildings in mining districts are particularly exposed because of the unavoidable differential settlement associated with mining. Very often damage from such settlement goes unnoticed, to be discovered only after an exotic event like a large explosion, subway construction in the vicinity or an earthquake. In theory it is often not difficult to differentiate between an old and a new crack. Translating the theory into practice may, however, become a problem if tens of thousands of claims have to be inspected.

This brings us to a particular problem if a large number of elements at risk are damaged, leading to a deluge of claims. It can be taken for granted that it will be very difficult to muster the number of qualified inspectors needed to inspect earthquake damage expertly. It can be expected in such cases, what the inspectors who are experienced, for instance, in the field of fire or windstorm losses will do. This is not the case if somewhat more difficult cases have to make their settlement on the basis of the bills presented by workmen, builders and contractors. This brings us to another human facet of claims. The repair of damage caused by an earthquake catastrophe not only puts great strain on the labour force but also may be a blessing in disguise for the building trade and related suppliers. In a free market. in particular where unions are very strong, the temptations are strongest.

Conclusions

There are many conclusions to be drawn. We shall touch upon only the most salient ones. The seismicity of a region is often underestimated if only because one "judges" by past experience, which is bound to be incomplete. For proper risk evaluation one should not only work with seismic maps indicating the probability of different magnitudes or intensities but should also be aware of the possibility of seismic gaps. All such data employed should incorporate a safety factor commensurate with the exposure. The vulnerability of elements at risk is in general inadequately known and very often much underestimated. One should try to familiarize oneself not only with general vulnerability data but also with the many parameters which contribute to damage and losses. Proper risk assessment, rating, underwriting, risk optimization and disaster management should not be based predominantly on assumptions and theoretical models but on the pragmatic application of experience derived from as many earthquakes possible. Here too one must realize that past experience will probably not include a real disaster. In this field also, therefore, one should not work without safety factors. The direct and indirect economical effects of an earthquake can only be assessed if highly skilled stock-taking has been performed, and whether a society, governments or insurers wish to determine the exposure.

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