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Why Are We Not Prepared For Extreme Natural Events?

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Abstract

In 2005, hurricane Katrina severely damaged New Orleans, which has not completely recovered yet. In 2010, an earthquake destroyed Port Au Prince leaving Haiti in shambles until this date. In 2004, the Indian Ocean tsunami killed thousands even as far as Africa, only to be followed in 2011 by the Tohoku tsunami that triggered one of the worst nuclear disasters in history. Each and every one of these extreme natural events was foreseen or foreseeable, given our knowledge about their nature. That knowledge also tells us that this will happen again and again and our losses will rise. What is keeping us from being prepared?

Before the advent of natural sciences, people believed that these events are an act of god to punish the wicked and humble mankind. In many so-called "developing" regions, this belief still exists and may be a reason for fatalism and lack of preparedness. Not so in the US and Japan, which also have been hit hard and have trouble recovering.

Modern societies over-emphasize short-term economic gains, which is certainly one major reason behind this un-preparedness. But economic principles also have the potential to change this in the future.

Key Words & Phrases: *Disaster, Tsunami, losses, short term gains.*

1. A sad history with a warning

The recent history of disasters triggered by natural events must serve as a warning to mankind that, if we continue on this path, irrecoverable losses will be incurred, especially by extreme natural events. Here is a short list of such events only during the last 10 years (data from MunichRE):

2004 Indian Ocean Earthquake and Tsunami

A rarely expected but possible moment magnitude M_w 9.0 earthquake triggered a tsunami with wave highs of more than 10m throughout the Indian Ocean. It probably killed around 4,00,000 people. There was no official warning and no evacuation plan in the affected regions. International tourist centers were destroyed as well as industrial facilities like harbors and petrochemical plants. More than 1,00,000 fishing boats were lost

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severely affecting the livelihood of millions of people. Within a coastal strip of about 2 km, the infrastructure (roads, rail roads) was largely destroyed.

Many regions have not recovered yet!

2005 Hurricane Katrina

A category 3 hurricane (can go up to 5, therefore not un-expected) hit New Orleans. Dykes failed and about 80% of New Orleans was flooded. 1300 persons died and 1.5 million had to be evacuated. 90% of all oil production in the Gulf of Mexico stopped. With 125 billion US$ estimated damage, this is so far the costliest disaster in US history.

Complete recovery has not been achieved!

2010 Haiti Earthquake

A M_w 7.0 earthquake (not un-expected) destroyed the capital, Port Au Prince killing an estimated 3,16,000 people and injuring another 3,10,000. 1.85 million were without homes. Many more were killed later due to an outbreak of cholera. More than 1/3 of the population of Haiti was directly affected. It was a "strategic" hit at the heart of a developing nation. Important infrastructure, like the port and government buildings were destroyed.

Complete recovery has not been achieved!

2011 Tohoku Earthquake and Tsunami

A M_w 9.0 earthquake (not un-expected) hit the northern shores of Honshu, the main island of Japan. It triggered a 10m tsunami with run-up heights of more than 40m. Tsunami warning worked, but shelters and protective measures were inadequate. About 16,000 people died and more than 3,00,000 homes were destroyed. The coastal infrastructure (ports, roads, rail lines etc.) was destroyed. A refinery as far away as Tokyo was destroyed by fire. Production was affected world-wide due to modern just-in-time supply concepts (especially car industry). The tsunami caused core melt-downs in 2, maybe 3 of 4 reactors at the Fukushima Daiichi nuclear power plant followed by several hydrogen explosions that resulted in wide-spread radioactive contamination, in particular in the Ocean due to the desperate cooling efforts. With an estimated damage of 210 billion US$, it is the most expensive disaster in history so far.

The long-term effects are still unknown and total recovery may not be possible!

These recent events highlight a development, which in its essence can be traced back to a rapidly increasing exposure of more and more people to natural events within a short period of time. A look at the growth of Istanbul (Fig. 1) emphasizes this fact. Other major urban centers around the world developed similarly within the last 50 to 100 years.

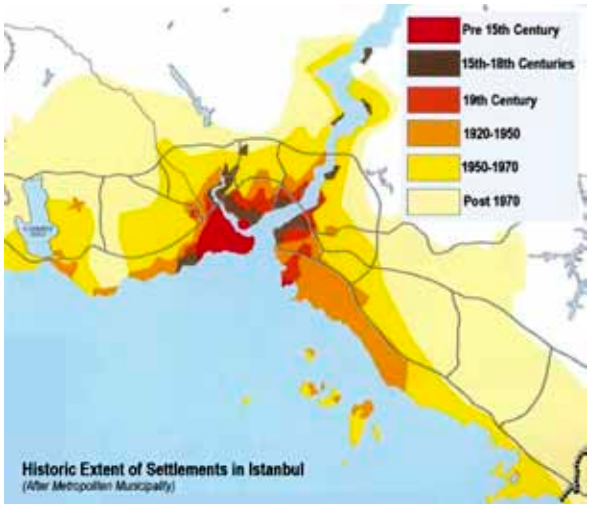


Figure 1: Growth of Istanbul metropolitan area (from Istanbul Earthquake Master Plan).

A focus on short-term economic gain paired with an almost religious belief in natural science made us more vulnerable especially to rare, extreme natural events, since they do not fit into human time scales and they do not obey the usual event statistics of natural scientists. This is particularly true for large earthquakes where the typical seismological hazard models seem to fail time and again.

Rare, extreme natural events like
- Mega quakes
- Mega tsunamis
- Large volcanic eruptions
- Mega storms

are obviously not properly considered and this has already resulted in irrecoverable losses, regardless of whether a developed (US, Japan) or developing nation (Haiti) was hit.

The warning is clearly written on the wall:
If we do not react properly to this challenge from nature, we will not prevail!

This danger was already recognized in 1994, when the Yokohama strategy was developed and further elaborated in a plan for action after the Indian Ocean Tsunami: The 2005 Hyogo framework for action. Unfortunately, it failed!

2. What went wrong with the Hyogo framework?

The Hyogo framework for action was designed to achieve the following outcome until 2015:

The substantial reduction of disaster losses, in lives and in the social, economic and environmental assets of communities and countries.

Looking at the numbers and past events during these 10 Hyogo years, this has not been achieved. Losses, especially from extreme events keep rising exponentially (Fig. 2).

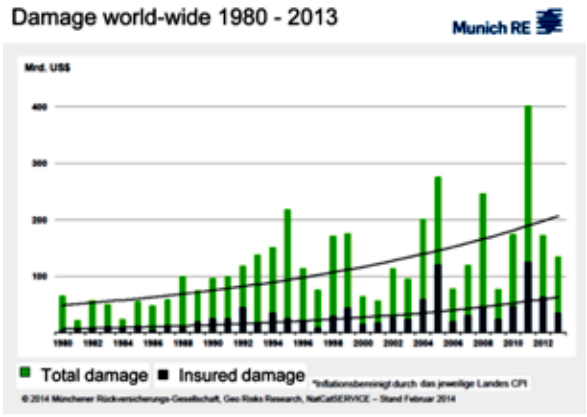


Figure 2: Damage in billion US$ world-wide (MunichRE).

A closer look at the distribution reveals that earthquakes cause most deaths and metrological events the most economic damage, but closely followed by earthquakes and hydrological events. Climate is a distant 10% (Fig. 3). This tells us the following:

- Because of its suddenness, there is no short-term reaction to earthquakes, like it is to flooding now, where warning systems have become very effective. People cannot "run away" from earthquakes, so the death toll is much higher.
- Meteorological and hydrological events (especially flooding) are more frequent and usually affect larger areas than earthquakes. Thus, their economic impact is larger. Economic losses due to earthquakes are rising rapidly and soon may break even with the other hazards, once large urban centers are hit more frequently.
- Climate change is the major topic for many years now and a lot of resources are spent. These numbers clearly call for a change of focus.

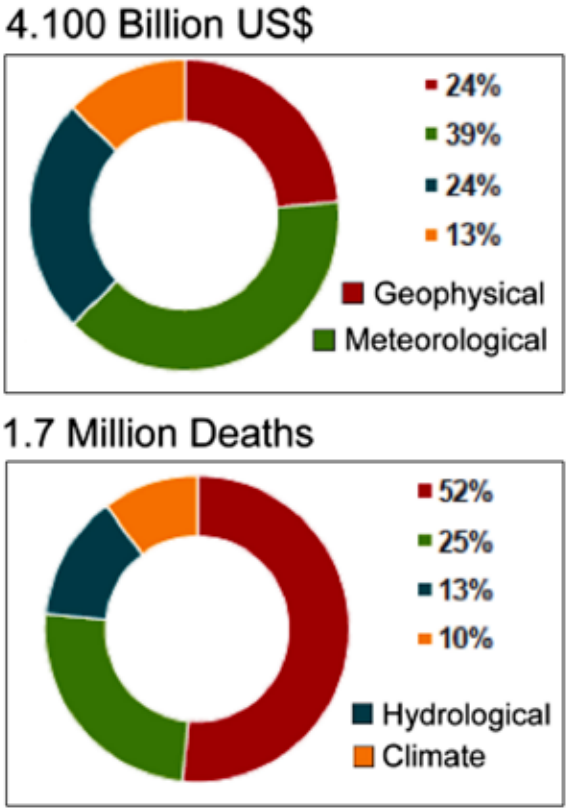


Figure 3: Distribution of losses according to natural hazards 1980-2013 (MunichRE).

Another important aspect is regional distribution. It can be seen from Figure 4, that

- Asia suffers the most, especially in terms of lives lost (earthquakes!).
- The US is hit hardest economically, but Asia is rapidly gaining. The past ten years have seen an unprecedented economic development, especially in India and China. This has magnified the economic exposure to natural hazards there.

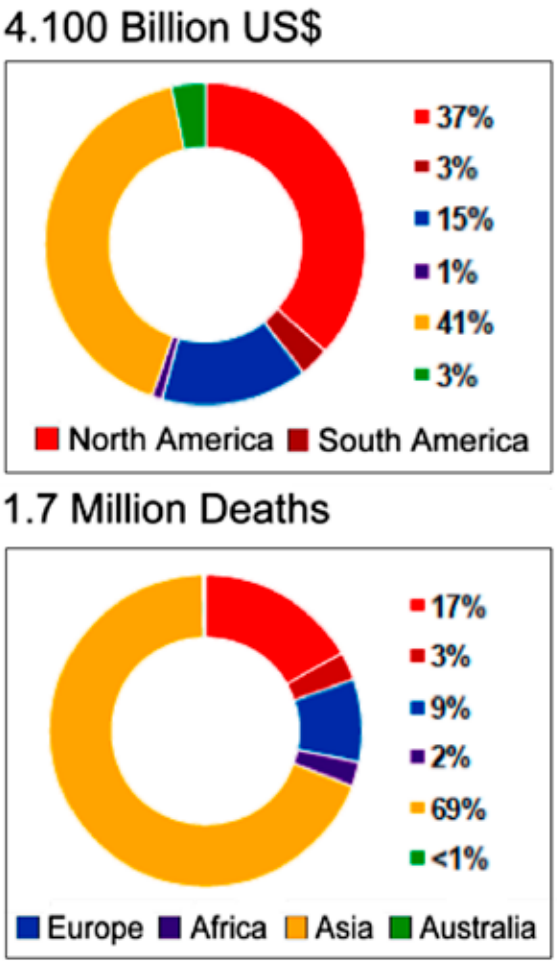


Figure 4: Regional distribution of losses due to natural events 1980-2013 (MunichRE).

The numbers tell us that we need to put more attention to earthquakes and to Asia, if it makes a real difference within the next decade!

Analyzing the Hyogo approach in light of these numbers reveals a peculiar shortcoming. Based on the 1994 Yokohama strategy, the Hyogo framework identified specific gaps and challenges in five main areas for the period 2005-15:

a) Governance: organizational, legal and policy frameworks;
b) Risk identification, assessment, monitoring and early warning;
c) Knowledge management and education;
d) Reducing underlying risk factors;
e) Preparedness for effective response and recovery.

The resulting key activities focused on *risk assessment, information, education, management* and *institution building* with its main focus still on *reaction,* not *pro-action.*

In particular, no specific actions for **Risk Reduction** were defined!

It is well known that any risk is a function of

Hazard - Vulnerability - Loss

Since the hazard in this case is natural and cannot be reduced, **Vulnerability Reduction** is the only key to risk reduction under natural hazards. In the Hyogo framework, there is no mentioning of **effective engineering concepts** and **economic mechanisms** that are capable of reducing such vulnerabilities, although they exist!

That's why Hyogo had to fail!

3. Vulnerability reduction cannot be achieved through disaster management

If our societies become serious about the reduction of vulnerabilities due to natural hazards (and they should: remember the warnings!), very different approaches are needed than Hyogo had to offer. This is too complex a task for disaster managers to shoulder. Other players in society must take over. The following is just a short list, where vulnerabilities exist:

- Buildings (residential, administrative, educational, commercial, health, historical)
- Transportation infrastructure (roads, railroads, bridges, waterways and harbors, airports)
- Other life lines (water, waste water, electricity, oil, gas)
- Regular industry (SMEs, large manufactures)
- Industry with large hazard potential (chemical, petrochemical, nuclear)
- Agriculture (life stock and crops)
- Economy (business interruptions, loss of income, short and long-term market impact, financial market reaction)
- Environment (industrial spills, waste water spills, oil spills, radioactive contamination)

Each of these poses particular challenges in different regions subjected to their particular natural hazards and this short paper obviously cannot address them all: Only concerted efforts involving all relevant players in a region are able to shed light on these issues and come up with successful regional actions for vulnerability reduction. In order to achieve this, it is suggested here that regional governments create standing vulnerability reduction conferences involving all stakeholders. Needless to say that, relevant international expertise will be very helpful in defining such actions.

Such actions will not come easy or cheap. Let me highlight this by just addressing the vulnerability of buildings under earthquakes. Certainly, this is one of our most pressing problem in this context, with millions of buildings and their inhabitants at risk, and the wellbeing of many urban centers and their respective countries at stake. How can we achieve a substantial reduction here within a reasonable amount of time, say within 20 years?

4. How to achieve large-scale reduction of seismic vulnerability of building stock?

The first task is *vulnerability assessment*. In terms of earthquake vulnerability of buildings, one must know how the buildings in a region behave during an earthquake. This is mostly unknown, because real damage data is mostly missing and design criteria and procedures in building codes are misleading: They are prescriptions for a limit state design of new structures, not criteria to assess the performance of existing ones. And they are changing with every major earthquake and will continue to do so in the foreseeable future, emphasizing the fact that even they have not been perfected yet. Just to highlight one of the issues we are facing here:

If buildings would behave according to code, their safety would not depend on the number of storeys. They would be equally safe. The undisputable fact from damage data is though, that buildings with more storeys are less safe (reliable data exists in some regions for up to 7 storeys, see e.g. Sucuoglu, Yazgan, Yakut).

So the first step must be the creation of a realistic regional damage database, where it does not exist. This can only be done through sophisticated numerical engineering models that are validated with large-scale testing of real buildings. Such testing should be done on site (see e.g. recent efforts in Turkey: ITÜ-Report) and supplemented by full-scale tests, especially on the large E-Defense shaking table near Kobe, Japan (up to 7-storey buildings can be tested full-scale, see www.bosai.go.jp/hyogo/ehyogo), or one of the large pseudo-dynamic testing facilities in the world (the European facility ELSA is at the JRC in Ispra, Italy: https://ec.europa.eu/jrc/en/research-facility/elsa?search). Considering the various building types that exist, just performing such experiments is not a small task and requires an international effort. But this could and should be done!

Once developed, the engineering models can be used to create "virtual cities" (Fig. 5) based on rapid local "walk through" observation (which already has been performed in many regions) and/or using commonly available satellite based tools with some of them even providing street views.

Source: Author

Figure 5: A "virtual city ward" with engineering models for buildings created by the BPS-tool under development at Kassel University, Germanyin cooperation with MunichRE (Mühlhausen, Dorka, Smolka, Stupazzini).

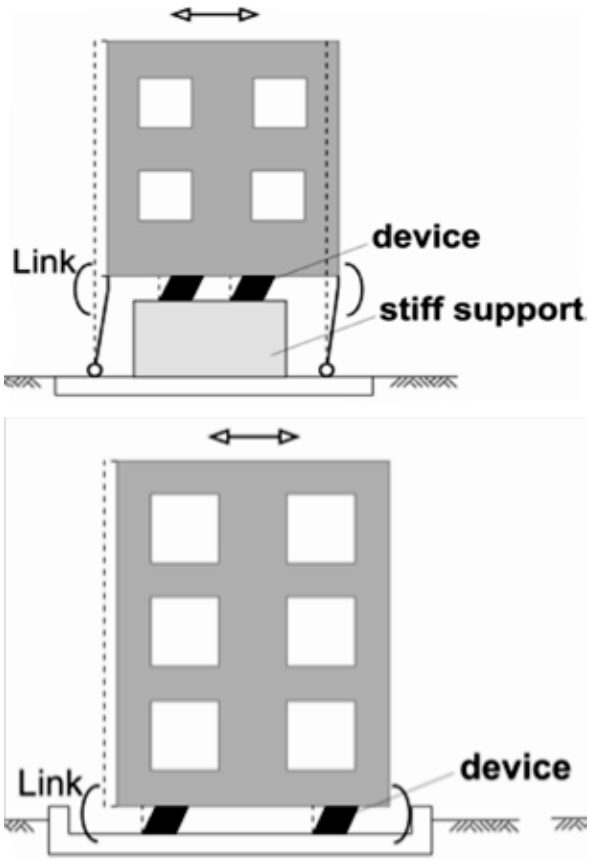
These "virtual cities" would now behave very similar to the actual ones in structural terms, thus providing realistic vulnerability scenarios for different regions.

The next step is *vulnerability reduction*. This has a *technological* as well as *economic* component.

The *technological component* calls for more robust structural concepts that have proven (or can be proven) to be more robust, yet not more costly than the typical reinforced concrete frame with masonry infill, which comprises roughly 90% of all modern buildings and

has been proven to be very vulnerable, mainly due to a lack of proper execution, but also due to typical and widespread design flaws.

Such seismically robust concepts do exist, some of them even for a long time. Among them are *reinforced masonry, confined masonry* and *seismic control concepts,* especially *Base Isolation* and the *Hyde-System* (Fig. 6), the latter being particularly suitable for retrofitting of so-called soft-storey buildings, which are among the most dangerous structures in the world.



Source: Author

Figure 6: Seismic control concepts like Base Isolation (right) and Hyde-System (left) are not only more robust than conventional structures, but also less expensive to build.

Rebuilding residential quarters in L'Aquila, Italy with Base Isolation (Calvi, Spaziante) and retrofitting an administrative building in Seattle, USA with a Hyde-System (Dorka, Conversano) have already demonstrated their superior economy and robustness. Still, widespread promotion is lacking, especially in Asia.

This brings us to the economic component. It is obvious that a short-sighted demand and supply cycle is mainly driving construction, often leading to un-checked urban sprawl, especially in Asia. Seismically robust structural concepts take a backseat, even though they are less expensive, simply for lack of knowledge and the capacity of local builders and their workers to apply them. That way, large urban regions have sprung up (and are still springing up!) that are seismically unsafe and potentially very dangerous.

Only urban renewal can cope with this and must do so within an economically and socially feasible environment. The Istanbul Earthquake Master Plan (MMI) is pointing in the right direction, although the recent urban renewal projects there, which are politically motivated in part, have drawn some serious criticism (e.g. Letsch in "The Guardian"). Despite of this, the underlying economic ideas outlined in the Master Plan by economic and financial experts are sound and applicable to other regions.

One drawback that is addressed in the Master Planis the lack of suitable financial instruments. Among those suggested are CAT bonds (CAT for catastrophe). Traded on the international bond market, this instrument can raise the necessary capital for large urban renewal projects: A regional Real Estate Investment Trust (REIT) can issue CAT-type bonds based on an economic disaster risk profile. This can be made very attractive to investors, if it is based on the application of robust building technologies that reduce vulnerabilities substantially or even eliminate them.

A regional Land Development Agency, which should be a public entity with strong involvement of local citizens to minimize graft and account for the necessary social input (something that is amiss in Istanbul!) designates areas for urban renewal. The REIT then provides credit to developers for buy-outs and new buildings. The REIT can also provide financial backing for "property swaps" old against new, which is a powerful tool to get current owners to support the renewal, and it can sell disaster risk insurance to future owners.

Thus a regional economic cycle with a win-win situation for all participants is created and fueled through international investment. Obviously, this will not only reduce the local seismic risk substantially, but also create economic growth and added value to the region and its people.

5. Summary and Conclusions

The past ten years must serve as a warning that we are not prepared for extreme natural events and that our losses will be irrecoverable, regardless whether a developed or developing nation is hit, unless there is a change in approach towards natural risks fundamentally. The Hyogo framework with its focus on disaster management could not deliver because *vulnerability reduction* was not properly addressed.

Being the key component on the way to acceptable natural risks, vulnerability reduction is a complex issue beyond the capabilities of disaster managers. It requires a concerted effort of all relevant players in a region and it has a strong engineering and economic component. Standing regional conferences on vulnerability reduction involving all stakeholders in society are therefore suggested here, which could develop and implement actions that are in line with the region's social, cultural and economic setting.

Taking earthquakes as one important example, this paper demonstrates that just the seismic vulnerability assessment of the existing building stock is a complex and costly engineering issue, which still lacks the necessary scientific backup to be reliable. In this case international cooperation, especially the use of existing large scale research facilities, can close this knowledge gap quickly and facilitate the necessary confidence in and spread of, already existing seismically robust and economically competitive structural concepts.

To deal with the large-scale urban sprawl created by shortsighted interests mainly in the last few decades, and which has created many seismically dangerous urban settlements around the world, urban renewal is the basic approach. As outlined in the Istanbul Master Plan, financial instruments like CAT bonds can fuel a local economic cycle for renewal that, if based on robust and economic technologies, not only reduces the seismic vulnerability drastically, but also creates economic growth and added value for a region.

Vulnerability reduction is not about costs, but must be seen as a motor for economic growth and wellbeing in order to succeed! This is also true for the other, non-seismic natural risks.

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