ASSESSMENT AND MANAGEMENT OF SEISMIC RISK

Risk Frontiers
Bruxelles 19 November 2015

F. Petruzzelli, Ph.D.
Loss Prevention Engineer
AXA MATRIX Risk Consultants,
Milan, Italy
Risk Consulting

✓ Quantification and qualification of your risks applying remote and on-site assessment
✓ Provide pragmatic solutions to mitigate and control your risk globally
✓ Online data access – reports with action plans, targets, and status
✓ On-going and active support of your internal Risk Management initiatives
International Network with over 160 Dedicated Risk Engineers

Major locations with expansive local teams – we have resources where they are needed.

EUROPE
- Benelux
  - France
  - Germany
- Spain
- Switzerland
- UK

CENTER of EXPERTISE for Earthquake and Tsunami
Funded in 2014
9 members coordinating local engineers
- Best Expertise;
- Innovation and Development;
- Dissemination and standardization;
- Support to other branches;

AMERICAS
- Brazil
- Canada
- Mexico
- USA

AFRICA
- Operations led from Europe

ASIA-PACIFIC & MIDDLE EAST
- China
- Dubai
- Hong Kong
- India
- Malaysia
- Singapore
IMPACT OF EARTHQUAKES ON A GLOBAL SCALE

“Civilisation exists by geological consent, subject to change without notice”

Will Durant, 1946
The impact of natural disasters on a global scale

- The number of disasters following natural events worldwide has been rising rapidly.
- Similarly, economic losses due to natural disasters show an increasing trend.
The number of disasters following natural events worldwide has been rising rapidly. Similarly, economic losses due to natural disasters show an increasing trend.
Earthquakes vs. other Natural Hazards

People killed in natural disasters from 1980 to 2015

- 876,448 EARTHQUAKE
- 581,540 DROUGHT
- 448,434 STORM
- 234,038 FLOOD
- 171,750 TEMPERATURE
- 25,641 VOLCANOS

Cost of natural disasters from 1980 to 2015

- 998 Billion STORM
- 748 Billion EARTHQUAKE
- 662 Billion FLOOD
- 129 Billion DROUGHT
- 57 Billion TEMPERATURE
- 54 Billion WILDFIRE

Earthquakes have caused the largest death toll in the last thirty-five years.

Earthquakes are the second cause of economic losses in the last thirty-five years.

Source: EM-DAT CRED

= 50,000

11/20/2015
“...earthquakes are quite harmless until you decide to put millions of people and two trillion dollars in real estate atop scissile fault zones”  

Marc Reisner, 1993
Seismic risk assessment: from a traditional qualitative approach...

**QUALITATIVE approach** = traditional approach to seismic risk in insurance and risk management, based on the observed damage from past earthquakes in a given area (measured by a macroseismic intensity scale).

<table>
<thead>
<tr>
<th>MMI</th>
<th>DESCRIPTION OF EFFECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Felt by all; many frightened; some heavy furniture moved or overturned; a few instances of fallen plaster. Damage slight.</td>
</tr>
<tr>
<td>VI. Strong</td>
<td>Damage negligible in building of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.</td>
</tr>
<tr>
<td>VII. Very Strong</td>
<td>Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture moved.</td>
</tr>
<tr>
<td>VIII. Destructive</td>
<td>Damage considerable in specially designed structures, well designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.</td>
</tr>
<tr>
<td>IX. Violent</td>
<td>Some well built wooden structures destroyed; most masonry and frame structures destroyed with foundation. Rails bent.</td>
</tr>
<tr>
<td>X. Intense</td>
<td>Few, if any masonry structures remain standing. Bridges destroyed. Rails bent greatly.</td>
</tr>
<tr>
<td>XI. Extreme</td>
<td>Total destruction – Everything is destroyed. Lines of sight and level distorted. Objects thrown into the air.</td>
</tr>
<tr>
<td>XII. Cataclysmic</td>
<td></td>
</tr>
</tbody>
</table>

This approach **cannot be applied to individual buildings**, which may exhibit extremely different seismic behaviors.
... towards a quantitative seismic risk assessment

**QUALITATIVE approach** = traditional approach to seismic risk in insurance and risk management, based on the of the **observed damage from past earthquakes in a given area** (measured by a **macroseismic intensity** scale).

**QUANTITATIVE approach** = the only one allowing to **measure the risk**, on sound, probabilistic, basis. In a such an assessment the Risk is decomposed in three main components:

\[
\text{Risk} = H \times V \times E
\]

- **Hazard (H)**: 
  **Frequency and intensity of earthquakes**  
  Seismologists, Geophysicists

- **Vulnerability (V)**:
  **Fragility of the structures**  
  Structural engineers

- **Exposure (E)**:
  **Values (goods and activities) at risk**  
  Risk Managers, Stakeholders, Planners

**CAUSE** → **EFFECT** → **CONSEQUENCE**
A scientific-based quantitative approach, which can be tailored to client’s needs.
Project history

In the aftermath of the L’Aquila earthquake, in 2009, one major client operating in the Automotive sector asked us to re-engineer their traditional EQ risk assessment approach with the following inputs:

- **Consistent** and **objective** risk assessment and prioritization methodology
- **Focused** on industrial facilities
- Applicable **worldwide**
- **Multilayered** approach (different levels/costs of investigation)

AXA MATRIX launched a four-year research project in cooperation with the University of Naples Federico II (Coordinator of the Italian laboratories of earthquake engineering) for the development of an **innovative analysis methods and practical risk engineering tools**

These tools, developed in «team work» with our partners, are now part of a single, **Integrated approach for quantitative seismic risk assessment and management**
Why a Multilevel approach?

“AXA MATRIX Integrated Approach”

Is a three-step approach that is able to take into account the specific client requirements and characteristics and to flexibly adapt to the different sizes of the portfolio, available resources, and time constraints:

**LEVEL 1:**

DESK STUDY and RISK PRIORITIZATION

**LEVEL 2:**

RAPID VISUAL SCREENING and LOSS ASSESSMENT of structures

**LEVEL 3:**

DETAILED SITE SURVEY and RECOMMENDATIONS for risk reduction of structures and non-structural elements

What are the advantages?

1) An efficient allocation of available resources.

Largest efforts can be dedicated to knowledge acquisition and to more refined analysis targeting just where real risks exist.

2) A rational and transparent support for risk management decisions.

Risk priorities among the portfolio and risk mitigation interventions can be selected on sound quantitative basis and, therefore, easily communicated.

3) A flexible approach, tailored to client’s needs and profile.

No two building portfolios are alike. The multilevel approach can encompass all of the steps or just those that best suits to the portfolio under investigation.
The AXA MATRIX Integrated Multilevel Approach

The three steps were developed in order to answer to specific client’s needs and to produce different quantitative outputs.

<table>
<thead>
<tr>
<th>CLIENT’S NEED</th>
<th>AXA MATRIX SOLUTION</th>
<th>OUTPUT</th>
</tr>
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</table>
| • Address risk priorities in portfolio  
• Limited resources to visually inspecting all facilities | **LEVEL 1 assessment:**  
Seismic Risk Gap Analysis, a quantitative approach for seismic risk prioritization analysis  
**LEVEL 2 Assessment:**  
Rapid visual screening and loss assessment through FRAME@Risk, the innovative tool able to perform advanced risk assessments of structures  
**LEVEL 3 Assessment:**  
Site Specific Risk Analysis and solution options by a structural specialist, advanced risk analysis through FRAME@Risk or dedicated structural analysis. | **RISK PRIORITIZATION**  
Global quantitative picture of the risk over a building portfolio, ideal for addressing the major risks  
**LOSS ASSESSMENT**  
Building-by-building damage and loss assessment, allowing a rational and informed decision making.  
**SOLUTIONS FOR LOSS PREVENTION**  
Loss prevention report and recommendations for the mitigation of future earthquakes impacts to individual buildings and relevant non-structural components. |

Increasing knowledge level required.

11/20/2015
LEVEL 1 assessment

- For large portfolios, **in-depth information about structures are generally unavailable** and visually inspecting all of the sites could be **unfeasible**
- Stakeholders may be interested in addressing risk priorities to achieve a **“global” overview** of exposures to **address risk priorities** among the portfolio in a **quantitative and rational way**.

LEVEL 1 assessment is the **quantitative prioritization analysis** of the portfolio, on the basis of a quantitative and structure-specific **“Risk Priority Index”**: 

\[
\text{Risk Priority Index} = \text{EI} \quad \text{Nominal Deficit}
\]

Objective of this study is to provide a quantitative and transparent seismic risk prioritization within the portfolio, taking into account not only the **“Hazard”** (where the plant is located) but also its **“Vulnerability”** (how it is built) and the **“Exposure”** (potential impact).
• Almost **70%** of Italian industrial structures erected in 60’s and 70’s, when **less than 30% of Italian territory** was seismically classified

• In many areas the **Nominal Deficit** can be significant.

• The lack in seismic design is the **most important cause for the actual seismic vulnerability** of structures as readily demonstrated by recent seismic events:
The Emilia 2012 Earthquakes

- May 20, 2012, 4:03 a.m., M 5.9 earthquake
- May 29, 2012, 9:00 a.m., M 5.8 earthquake.

The earthquakes affected a densely industrialized area, where 7,000 industrial activities and 187,000 workers produce, every year, 2% of the Italian Gross Domestic Product.

CONSEQUENCES:
- 27 casualties
- 400 injured
- 15,000 homeless
- 15 billion USD of PD and BI (Italian Department for Civil Protection estimates);
- 1.5 billion USD of Insured Losses (10% of Total Losses; in L’Aquila 2009 the 2%)

“Emilia, the infinite earthquake”

“9:00 am, the Monster enters into facilities”
• One main reason for this huge losses was the late enforcement of seismic design prescription in the Emilia Region. In fact, the area was recognized as a seismic-prone one only in 2003.

• In fact in a mechanical connection between elements of precast structures was mandatory in seismic areas only. Therefore, the loss of support of beams was the main collapse mechanism observed.
LEVEL 1 assessment - Case study

Analysis results

Current seismic hazard map

Hazard-based prioritization

NODE index
(Hazard and Vulnerability including soil)

RPI index
(H, V, and exposure)

Plant 1
- Located in the area with the highest seismic hazard
- Erected in 1971
- Territory classified as seismic prone since 1915
- Founded on good subsoil
- Made of a workshop bld. (WH) with high value and office bld. (OFF) with low value

LEVEL 1 assessment - Case study

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Risk Priority Index = EI \cdot (Demand - Capacity)
LEVEL 1 assessment - Case study

Analysis results

Current seismic hazard map

Hazard-based prioritization

NODE index (Hazard and Vulnerability including soil)

RPI index (H, V, and exposure)

Plant 9

- Located in the area with an average/low seismic hazard
- Erected in 1973
- Territory NOT classified as seismic prone until 2003
- Founded on POOR subsoil
- HIGH value at risk

Top ranking plant
The AXA MATRIX Integrated Multilevel Approach

The three steps were developed in order to answer to **specific client’s** needs and to produce different **quantitative outputs**

### CLIENT’S NEED
- Address risk priorities in portfolio
- Limited resources to visually inspecting all facilities
- Need to perform seismic loss assessments
- Need to understand the vulnerability of structures and the potential economic impact of earthquakes
- Need a quantitative loss assessment to manage mitigation strategies
- Structures to be surveyed by a structural engineer
- Portfolio is composed critical structures
- Require engineering solutions

### AXA MATRIX SOLUTION

#### LEVEL 1 assessment:
**Seismic Risk Gap Analysis**, a quantitative approach for seismic risk prioritization analysis

#### LEVEL 2 Assessment:
**Rapid visual screening and loss assessment through FRAME@Risk**, the innovative tool able to perform advanced risk assessments of structures

#### LEVEL 3 Assessment:
**Site Specific Risk Analysis and solution options by a structural specialist**, advanced risk analysis through FRAME@Risk or dedicated structural analysis.

### OUTPUT

#### RISK PRIORITIZATION
*global quantitative picture of the risk over a building portfolio*, ideal for addressing the major risks

#### LOSS ASSESSMENT
*Building-by-building damage and loss assessment*, allowing a rational and informed decision making.

#### SOLUTIONS FOR LOSS PREVENTION
*Loss prevention report and recommendations* for the mitigation of future earthquakes impacts to individual buildings and relevant non-structural components.

Increasing knowledge level required
LEVEL 2 assessment:

Fragility-based seismic risk assessment

In a LEVEL 2 approach, a rapid visual screening of structures is performed and expected loss is computed via the use of fragility functions.

A fragility function is the most comprehensive representation of the structural damage at increasing seismic action.

\[ P_{DS1} = 80\% \]
\[ P_{DS2} = 49\% \]
\[ P_{DS3} = 20\% \]

\( P \) = probability of exceeding a given damage condition.

\( PGA = 0.10 \text{g} \)
LEVEL 2 assessment:

The FRAME@Risk approach

The Expected loss computation is performed by the AXA MATRIX Center of Expertise on Earthquake and Tsunami, employing the AXA MATRIX FRAME@Risk software tool.

ADVANTAGES:

- Worldwide applicable tool for quantitative seismic loss assessment
- It uses advanced studies of seismic hazard, structural and non-structural fragility, and damage-to-loss functions
- FRAME@Risk includes a database of fragility functions that is much larger and more detailed than any other of the traditional loss assessment and catastrophe modeling tools (more than 600 data points from scientific literature, continuously updated)

OUTPUT:

- Building-specific expected damage assessment
- Building-specific expected loss assessment
- a transparent and informed decision making to implement the most effective mitigation strategies (insurance purchase, structural retrofitting, …)
A real case-study: High-tech plant in Emilia region

- Plant dedicated to the production of hi-tech materials;
- Total property value = about **100 mln Euros**
  (buildings = 27 mln; machineries=47 mil; stock=28 mln);
- 12 buildings, built from 1966 to 2011;

<table>
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<tr>
<th>Building characteristics</th>
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<tbody>
<tr>
<td>name</td>
</tr>
<tr>
<td>Bld.1-Offices</td>
</tr>
<tr>
<td>Bld.2-Production</td>
</tr>
<tr>
<td>Bld.3-Production</td>
</tr>
<tr>
<td>Bld.4-Production</td>
</tr>
<tr>
<td>Bld.5-Warehouse</td>
</tr>
<tr>
<td>Bld.6-Production</td>
</tr>
<tr>
<td>Bld.7-Production</td>
</tr>
<tr>
<td>Bld.8-Warehouse</td>
</tr>
<tr>
<td>Bld.9-Warehouse</td>
</tr>
<tr>
<td>Bld.10-Warehs.</td>
</tr>
<tr>
<td>Bld.11-Product.</td>
</tr>
</tbody>
</table>

- **VISUAL SURVEY of the site**
- **FRAME@RISK application**
  - fragility functions specifically computed for Italian precast buildings with different details in terms of member connections, reinforcement, structural regularities, cladding characteristics. ....
  - consequence functions chosen on the basis of the occupancy and content vulnerability

20/11/2015
## A real case-study: High-tech plant in Emilia region

### FRAME@Risk software loss estimates

Distribution of estimated losses inside the plant (normalized with respect to the total value of the component at risk)

<table>
<thead>
<tr>
<th>Building characteristics</th>
<th>Building exposed value [% of the total plant value]</th>
</tr>
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<tbody>
<tr>
<td>name</td>
<td>material</td>
</tr>
<tr>
<td>Bld.1-Offices</td>
<td>Cast in pl. r.c.</td>
</tr>
<tr>
<td>Bld.2-Production</td>
<td>Precast r.c.</td>
</tr>
<tr>
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<td>Bld.12-Warehouses</td>
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A real case-study: High-tech plant in Emilia region

FRAME@Risk software loss estimates
Distribution of estimated losses inside the plant (normalized with respect to the total value of the component at risk)

Bld.2 is the one for which the largest damage to building and machineries/equipment is estimated by FRAME@Risk and actually observed after the earthquakes
A real case-study: High-tech plant in Emilia region

FRAME@Risk loss estimates: what if... analysis

What if Building 2 would have been retrofitted with devices avoiding the failure due to loss of support?

beam-column connection by means of pins and steel plates

Section view:

- Possibile foro preesistente
- Barra di collegamento
- Rondella e bullone
- Distanziale
- Perno in acciaio bullonato
- Profilo di supporto alla forcella del pilastro
- Barre di ancoraggio
A real case-study: High-tech plant in Emilia region

FRAME@Risk loss estimates: what if… analysis

What if Building 2 would have been retrofitted with devices avoiding the failure due to loss of support?

Same earthquake intensity measure

\[ \text{PGA} = 0.3 \text{ g} \]

Previous fragility function

Current fragility function

Although very similar in the structural scheme (similar slight damage probabilities), the mechanical connection renders the collapse much more unlikely

Conditional expected loss:

Previous total loss expectancy = 9.86 Mln EUR

“what if” total loss expectancy = 2.15 Mln EUR
FRAME@Risk loss estimates: **what if… analysis**

Distribution of estimated losses inside the plant (normalized with respect to the total value of the component at risk)

- If Bld.2 had been adequately retrofitted, the expected loss would have been significantly lower to building, equipment and stock.
- The peculiar occupancy (white rooms) render, in any case, the machinery component the most vulnerable one.
The AXA MATRIX Integrated Multilevel Approach

Plants and structures resulting as risk priorities from Level-1, can be analyzed through more detailed assessment procedures (Level-2 and Level-3 assessments).

CLIENT'S NEED

- Address risk priorities in portfolio
- Limited resources to visually inspecting all facilities
- Need to perform seismic loss assessments
- Need to understand the vulnerability of structures and the potential economic impact of earthquakes
- Need a quantitative loss assessment to manage mitigation strategies

AXA MATRIX SOLUTION

LEVEL 1 assessment:
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OUTPUT

RISK PRIORITIZATION
global quantitative picture of the risk over a building portfolio, ideal for addressing the major risks

LOSS ASSESSMENT
Building-by-building damage and loss assessment, allowing a rational and informed decision making.

SOLUTIONS FOR LOSS PREVENTION
Loss prevention report and recommendations for the mitigation of future earthquakes impacts to individual buildings and relevant non-structural components.

Increasing knowledge level required
LEVEL 3 assessment:

LEVEL 3 approach is a **Site-specific Seismic Risk Analysis** consisting in a field visit by a structural engineer with the aim of:

- **Assessing the seismic vulnerability of structures** on the basis of a detailed analysis of documents and visual survey;
- **Assessing the seismic behavior of the major non-structural elements**, machineries and equipment, potentially leading to significant direct damage and/or business interruption in case of an earthquake;
- Performing a loss assessment of structures through **FRAME@Risk software** tool;
- **Providing loss prevention recommendations and engineering solutions** for the reduction of the impact of future earthquakes.

**ADVANTAGES:**

- It is **the most advanced risk analysis method**;
- It can take advantage of computer-simulated modelling of structural seismic fragility and loss assessment.

**OUTPUT:**

- A **full description of the structural response under probable earthquakes**;
- **Full structure-specific report** with **recommendations** for earthquake loss reduction.
"Risk assessment is all about risk management. The only reason you do an assessment is because somebody has to make a risk-management decision" - Smith, 2005.
LEVEL 3 assessment:

Seismic Risk Mitigation Solutions

The main objective of AXA MATRIX Risk Consultants is to support informed decision making with transparent, reliable and scientific-based solutions.

“Risk assessment is all about risk management. The only reason you do an assessment is because somebody has to make a risk-management decision” - Smith, 2005.

While it is impossible to reduce the seismic hazard of a site, it is possible to reduce the structural vulnerability, exposure, and/or mitigate the economic consequences of earthquakes:

Possible strategies for risk mitigation:

- Reduction of vulnerability
- Reduction of the exposure
- Mitigation of economic impacts

AXA MATRIX Risk Consultants can help clients in assessing seismic risk and choosing the best tradeoff between the wide range of available risk mitigation strategies.
LEVEL 3 assessment:

**Loss prevention recommendations:** reducing the loss in future earthquakes

Example of loss prevention action for mechanical equipment

Example of loss prevention action for structural elements
LEVEL 3 assessment:

**Loss prevention recommendations:** reducing the loss in future earthquakes

Examples of loss prevention action for structural elements
Conclusions

• Although seismic risk is not an “emerging” risk, the magnitude of the potential losses, although relatively infrequent, obligate stakeholders to prepare for their occurrence and implement informed decision making actions.

• This calls for innovative solutions supporting stakeholders based on a thorough understanding of earthquakes, their probability, and the unique vulnerabilities of facilities and business operations.

• Insurance industry and stakeholders must rely on structural engineering and geological and seismological expertise, as well as acknowledging scientific research advances to estimate potential losses using sound probabilistic-based seismic risk assessment approaches. Furthermore, risk engineering can make a big contribution to improving security for major assets mitigating earthquake impacts.

• The AXA Matrix Integrated Approach provides the right balance between accuracy, feasibility and quality of the results. This is crucial for an informed and transparent decision making aimed at finding the right balance between conservation and earthquake protection, extent of the intervention with available resources.
Thank you

Fabio Petruzzelli, Ph.D.
Loss Prevention Engineer
Center of Expertise for Earthquake and Tsunami
fabio.petruzzelli@axa-matrixrc.com
+39 02 97389 312
axa-matrixrc.com