Repair Cost And Downtime Seismic Vulnerability Assessment For RC School Buildings

L. E. Yamin\textsuperscript{1}, J. R. Rincón\textsuperscript{2}, R. I. Fernández\textsuperscript{3}, A. P. García\textsuperscript{3} and J. C. Reyes\textsuperscript{1}

\textsuperscript{1}Associate professor, Dept. of Civil Engineering, Universidad de los Andes, Colombia
\textsuperscript{2}Full time Lecturer and Researcher, Dept. of Civil Engineering, Universidad de los Andes
\textsuperscript{3}Graduate Research Assistant, Dept. of Civil Engineering, Universidad de los Andes

TT040. Risk & Loss Assessment And Public Policy

Tuesday, June 26 – Friday, June 29
What are we doing to reach the common objective of improving life safety, reducing physical damage and disruption time of critical infrastructure?
Probabilistic Component-Based Vulnerability and Downtime Assessment

1. Structural Performance Assessment
   - Select records for nonlinear analysis
   - Model geometry and nonlinear definition

2. Damage Assessment
   - Engineering demand parameters from IDAs
   - Model component and fragility curves definition

3. Vulnerability Assessment
   - Integration of probabilistic results considering uncertainties
   - Building Downtime model considering:
     - Impeding Factors
     - Repair Schedule
     - Available workers
   - Building repair cost model considering:
     - Total repair costs
     - Residual drifts
     - Maximum accepted losses by the owner
Case Study – Peruvian School Buildings  (Before 1997)

General considerations:
Material properties:
\[ f'_c = 17.5 \text{ MPa}. \]
\[ f_y = 420 \text{ MPa}. \]
Geometry configuration:
Beam span: 7.80 m. (400 m²)
Story height: 2.5 m.
Type of diaphragms.
Floors: Rigid diaphragm.
Roof: Rigid diaphragm.
Structural detailing: Intermediate

Foundations:
Structural type:
Superficial: Footings
Soil conditions: Hard soil (Type B)

(World Bank, PUCP, UNI, Uniandes, 2016)
Older buildings common issues

Original conceived building presents large displacements (pre 97 seismic code design)

No seismic gaps were built

Flexible

Captive columns

(World Bank, PUCP, UNI, Uniandes, 2016)

(Guevara & García, 2005)
1. Modeling parameters: Conceived building condition
1. Modeling parameters: Actual condition

Flexible - OC

Captive Column - CC
1. Records definitions and scaling procedure

- M > 6.5.
- PGA > 0.2g
- PGV > 15 cm/s.

- 18 records were selected
- Amplitude scaling using the IM: Sa(T1)
1. Demand parameters

Ductile Collapse

1st floor controls

Brittle Collapse

1st floor controls

Roof drift

Interstorey drift

Residual drift

Residual deformations

Residual drifts are not important
2. Components model and integration of results

Component cost model

<table>
<thead>
<tr>
<th>Story</th>
<th>Group</th>
<th>Subgroup</th>
<th>Description</th>
<th>Unit</th>
<th>Quantity</th>
<th>Fragility curve</th>
<th>EDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>E</td>
<td>C1</td>
<td>Column-One beam</td>
<td>Nodo</td>
<td>6</td>
<td>B1041.091aE1</td>
<td>drift</td>
</tr>
<tr>
<td>1</td>
<td>E</td>
<td>C2</td>
<td>Column-Two beams</td>
<td>Nodo</td>
<td>12</td>
<td>B1041.091bE1</td>
<td>drift</td>
</tr>
<tr>
<td>1</td>
<td>A</td>
<td>M1</td>
<td>Masonry walls</td>
<td>1.3x3.5m</td>
<td>6</td>
<td>C1011.006aE1</td>
<td>drift</td>
</tr>
<tr>
<td>1</td>
<td>A</td>
<td>M2</td>
<td>Masonry walls</td>
<td>2.0x3.5m</td>
<td>6</td>
<td>C1011.006aE2</td>
<td>drift</td>
</tr>
<tr>
<td>1</td>
<td>C</td>
<td>CON</td>
<td>Contents</td>
<td>5x5m</td>
<td>6</td>
<td>E2022.010a</td>
<td>drift</td>
</tr>
<tr>
<td>2</td>
<td>E</td>
<td>C1</td>
<td>Column-One beam</td>
<td>Nodo</td>
<td>6</td>
<td>B1041.091aE1</td>
<td>drift</td>
</tr>
<tr>
<td>2</td>
<td>E</td>
<td>C2</td>
<td>Column-Two beams</td>
<td>Nodo</td>
<td>12</td>
<td>B1041.091bE1</td>
<td>drift</td>
</tr>
<tr>
<td>2</td>
<td>A</td>
<td>M1</td>
<td>Masonry walls</td>
<td>1.3x3.5m</td>
<td>6</td>
<td>C1011.006aE1</td>
<td>drift</td>
</tr>
<tr>
<td>2</td>
<td>A</td>
<td>M2</td>
<td>Masonry walls</td>
<td>2.0x3.5m</td>
<td>6</td>
<td>C1011.006aE2</td>
<td>drift</td>
</tr>
<tr>
<td>2</td>
<td>C</td>
<td>CON</td>
<td>Contents</td>
<td>5x5m</td>
<td>6</td>
<td>E2022.010a</td>
<td>drift</td>
</tr>
</tbody>
</table>

Integration of results

\[
Pr(L > L_i | IP) = \sum_{e} \int \int F_L(L > l | DS = dS_i) \cdot f_{DS}(DS | EDP = edp_i) \cdot f_{EDP}(EDP | IP = ip) \, dDS \, dEDP
\]

Additional considerations:
- Max. residual Drift permitted
- Max. repair cost accepted

Monte Carlo process

Hazard uncertainty is implicit
Model (EDP) uncertainty
Damage states evaluation
Repair cost and repair time assessment
Expected value and variance

Modified from FEMA P-58

FUNVUL: Yamin et al. (2017)
3. Repair costs component-based assessment
3. Downtime component-based assessment

**Impeding times:**
- Post earthquake inspection
- Engineering mobilization
- Financing
- Contractor mobilization
- Licensing

**Repair times:**
- Component repair
- Available workers

**Time after repairs:**
- Cleaning
- Final conditioning

Application: Prioritization of intervention

Probabilistic Hazard Model Approximate Site Effects based on $V_{s30}$

Random exposure location: 20×20 km

Legend:
- Department
- Ground acceleration (cm/s²)
  - 0 - 100
  - 100 - 200
  - 200 - 300
  - 300 - 400
  - 400 - 500
  - 500 - 600
  - 600 - 700
  - 700 - 800

World Bank, UNI, PUCP, Uniandes (2014)

World Bank, Uniandes (2014)
Risk Loss Assessment

![Graph showing spectral acceleration and mean relative repair time](image)

- **Spectral acceleration**
- **Mean relative repair time (%)**

- **Legend**:
- Superseded
- Active area

- **Ts** = 0.22 s: 83%
- **Ts** = 0.45 s: 22%

---

**Risk Loss Assessment**

- **Sa(T)/g**
- **Te** - s

---

**Figure 1**: Graph displaying the relationship between spectral acceleration and mean relative repair time for different values of Ts.

- **Key Points**:
  - Ts = 0.22 s with 83% repair time
  - Ts = 0.45 s with 22% repair time
Seismic Risk of RC Framed School Buildings: Economic Losses
Seismic Risk of RC Framed School Buildings: Downtime
General conclusions

The main contribution of the proposed methodology is the integration of repair costs and downtime for archetype buildings in risk assessment as a tool for decision makers.

Vulnerability in terms of economic losses is sensible to mechanism of collapse, residual drifts and maximum accepted losses.

Vulnerability in terms of downtime is mainly controlled by initial time required to start repairs, repair schedule, maximum recovery time accepted and residual drifts.

Comparison of different interventions should be done in terms of repair costs and downtime.
Integrating Science, Policy and Engineering

THANK YOU!!