A Mesh-based Earthquake Impact Assessment Tool and its Application on Disaster Preparedness and Policy Support

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Outline

Background
- Major earthquake disasters in Taiwan
- Requirements on disaster prevention

Taiwan Earthquake Impact Information Platform, TERIA

Application
- Scenario simulation for the National Earthquake Drill
- Impact analysis for policy suggestion on disaster management system
Basic Information of Taiwan

• **Geographic features**
  - 400 km from north to south
  - 145 km from east to west
  - Area: 36,000 Km$^2$ over 70% in slope land

• **Population (August, 2016)**
  - 23,516,841 in total, 67.70% in urban areas
  - Density: 647/ Km$^2$

• **Tectonic Conjunctions:**
  - Philippine Sea plate
  - Eurasian Plate

• **High risk of tropical cyclones**
  - 3.6 typhoons/year
Major earthquake disasters in Taiwan

- Meishan earthquake (1906): $M_L=7.1$, 1,258 death
- Hsinchu-Taichung (1935): $M_L=7.1$, 3,276 death
- Ch-Chi earthquake (1999): $M_L=7.3$, 2,405 death

<table>
<thead>
<tr>
<th>No.</th>
<th>Earthquake</th>
<th>Date</th>
<th>Magnitude ($M_L$)</th>
<th>Depth (km)</th>
<th>Casualties</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Doullou</td>
<td>1904/11/06</td>
<td>6.1</td>
<td>7.0</td>
<td>145</td>
<td>158</td>
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<td>2</td>
<td>Meishan</td>
<td>1906/03/17</td>
<td>7.1</td>
<td>6.0</td>
<td>1,258</td>
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<td>3</td>
<td>Nantou Series</td>
<td>1916/08/28</td>
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<td>285</td>
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<td>1916/11/15</td>
<td>6.2</td>
<td>3.0</td>
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<tr>
<td></td>
<td></td>
<td>1917/01/05</td>
<td>6.2</td>
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<td></td>
<td></td>
<td>1917/01/07</td>
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<td>0.0</td>
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<td>4</td>
<td>Hsinchu-Taichung</td>
<td>1935/04/21</td>
<td>7.1</td>
<td>5.0</td>
<td>3,276</td>
<td>12,053</td>
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<td>5</td>
<td>Chungpu</td>
<td>1941/12/17</td>
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<td>Hsinhua</td>
<td>1946/12/05</td>
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<td>5.0</td>
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<td>182</td>
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<tr>
<td>7</td>
<td>Longitudinal Valley Series</td>
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<td></td>
<td></td>
<td>1951/10/22</td>
<td>7.3</td>
<td>4.0</td>
<td>&gt;85</td>
<td>&gt;1,000</td>
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<td></td>
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<td>1951/10/22</td>
<td>7.1</td>
<td>1.0</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>1951/10/22</td>
<td>7.1</td>
<td>18.0</td>
<td>&gt;1,000</td>
<td></td>
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<tr>
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<td>1951/11/25</td>
<td>6.1</td>
<td>16.0</td>
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<td>1951/11/25</td>
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<td>36.0</td>
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<td>Hengchun</td>
<td>1959/08/15</td>
<td>7.1</td>
<td>20.0</td>
<td>17</td>
<td>85</td>
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<td>9</td>
<td>Paiho</td>
<td>1964/01/18</td>
<td>6.3</td>
<td>18.0</td>
<td>106</td>
<td>653</td>
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<td>10</td>
<td>Hualien</td>
<td>1986/11/15</td>
<td>6.5</td>
<td>15.0</td>
<td>13</td>
<td>45</td>
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<tr>
<td>11</td>
<td>Chi-Chi</td>
<td>1999/09/21</td>
<td>7.3</td>
<td>8.0</td>
<td>2,405</td>
<td>11,305</td>
</tr>
</tbody>
</table>
Are we ready for the next major earthquake?
Requirement on preparedness and management

- **Emergency preparedness**
  - The results of *scenario simulation* have not been properly applied on the Emergency preparedness in the Local Disaster Prevention and Response Plan
  - The practical *disaster scenario* of large-scale earthquakes has not been fully considered in the planning of earthquake drills

- **Disaster management**
  - Subjected to a large-scale earthquake, the *disaster resilience* of organizations should be examined
Concept of this study

Impact analysis in various levels of excitations
- Mesh-based scenario simulation
- Scan the weak point and its spacial distribution
- Examine the disaster-resistant capacity of each item

1. **Extreme scenario**
   Quantitative analysis in an extreme scenario allows the disaster resilience of organizations to be examined

2. **Operative scenario**
   Scenario simulation in various levels of excitations can be applied on the local plan to enhance the capacity
Taiwan Earthquake Impact Information Platform

Application

Analysis

Information

General Public

Academy Government

Private sector

NCDR

TERIA platform

8
TERIA Platform Framework

Academia

Techniques
- Ground motion
- Buildings / Transportation
- Casualties
- Lifeline systems
- Critical facilities
- Socio-economic consequences

Open source
- Topology classification
- Data and technology integration

Inventory
- Surface geology
- Critical infrastructures
- Emergency relief and response assets
- Dynamic population
- Critical facilities data
- Socio-economic data

Application of government and academia

Supporting
- Applications
- Scenarios
- Vulnerability
- CIP
- Natechs
- Drill
- Research
- Strategies

Government agencies

Testing
- Classiﬁcation

Providing
- Update
- Upload
- Analysis
- Decision
Geospatial meshed Data

500m x 500m Meshed Map Sheet
Number of Meshes : 13,2712
Inventory database

Building: Total 4,014,268
Population: Total 496,874
Bridge: Total 8,616
Road: Total 584,965
Hydraulic Facility: Total 1,331
Gas: Total 19,000km
Power: Total 39,366
Water: Total 36,795
## Analytical items and output

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ground motion</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Response of ground motion</td>
<td>500m mesh</td>
<td>Peak ground acceleration, velocity, and displacement</td>
</tr>
<tr>
<td>• Soil liquefaction and induced settlement</td>
<td>500m mesh</td>
<td>Liquefaction potential ($P_L$), settlement</td>
</tr>
<tr>
<td>• Landslide potential</td>
<td>500m mesh</td>
<td>Landslide potential induced by an earthquake</td>
</tr>
<tr>
<td><strong>Impact analysis</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Building</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. General building</td>
<td>500m mesh</td>
<td>No. of damaged general buildings</td>
</tr>
<tr>
<td>2. Old building</td>
<td>500m mesh</td>
<td>No. of damaged old buildings</td>
</tr>
<tr>
<td>• Casualty</td>
<td>500m mesh</td>
<td>Casualty induced by building damage in 4 time slots</td>
</tr>
<tr>
<td>• Traffic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Road</td>
<td>500m mesh</td>
<td>Interruption probability of plane roads</td>
</tr>
<tr>
<td>2. Bridge</td>
<td>point, line segment</td>
<td>Interruption probability of bridges (including elevated roads)</td>
</tr>
<tr>
<td>• Electricity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Electric facility</td>
<td>point</td>
<td>Damage probability of generation plants and substations</td>
</tr>
<tr>
<td>2. Distribution circuit</td>
<td>500m mesh</td>
<td>Damage state of power supply</td>
</tr>
<tr>
<td>• Water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Water-supply facility</td>
<td>point</td>
<td>Damage probability of wells, treatment plants, and pumping plants</td>
</tr>
<tr>
<td>2. Distribution pipeline</td>
<td>500m mesh</td>
<td>Damage state of water supply</td>
</tr>
</tbody>
</table>
Create an event for simulation

- Line source: Fault name, magnitude, depth
- Point source: Longitude and latitude of epicenter
- User-defined distribution of ground motion
Interpret the analytical results

Display detailed results

Complete damage

No. of buildings
Scenario simulation for the National Earthquake Drill

Line source: Milun Fault

Ground motion distribution

Scenario

Time: am9:21 Sep. 21, 2014
Weather: sunny, 31°C
Epicenter: Shoufeng township, Hualien county
Event: $M_L=7.0$, depth=10km, intensity exceeds Level 7 in some areas
Integration of analysis results in Hualien
The expert consultation committee requested a scenario, an urban city subjected to large-scale earthquakes, to disclose the challenges in the disaster management system.

Simulation items:
- Soil liquefaction
- Building
- Casualty
- Sheltering
- Transportation
- Mass medical care
- Lifeline system
**Simulation in various shaking intensities**

<table>
<thead>
<tr>
<th>Intensity level</th>
<th>Acceleration range</th>
<th>Scenario setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>80~250gal</td>
<td>240gal*</td>
</tr>
<tr>
<td>VI</td>
<td>250~400gal</td>
<td>320gal*</td>
</tr>
<tr>
<td>VII</td>
<td>&gt;400gal</td>
<td>450gal**</td>
</tr>
</tbody>
</table>

* Based on the building code in return periods of 475 and 2500 years

**According to the average PGA measured in the central Taiwan for the Chi-Chi earthquake**
Application on policy suggestion

Simulation results of Intensity level 6

• Serious building damage and casualty
  • Building damage > 5,000
  • Serious injure and death ~ 6,000

• Heavy medical care demand
  • Hospitalization demand > 4,000 (need 2,000 to balance)

• Shelter overloading
  • Shelter demand > 190,000 (need 30,000 to balance)

• Roads and bridges severely disconnected
  ★ Power failure in the whole city

Rescue, medical care, transportation, sheltering, communication will be interrupted

Suggestions on disaster management system

• Launch a task force for configuration and promotion
• Inter-ministry coordination and administrative mechanism
• Enhance the resilience and continuity operation of infrastructure
• Promote the application of scenario simulation on disaster management
### Future work

- Assessment of policy measures on disaster reduction
  - Performance of building retrofit on reduction of casualty

- Evaluation of economic loss
  - Consider direct and indirect losses
  - Cost/Benefit analysis of policy deployment
Thank you
for your attention