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國家實驗研究院

Progress Report on Seismic Loss Estimations in Taiwan

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承諾 · 熱情 · 創新

Presentation Outline

- Introduction
  - Seismic disaster simulation technology
  - Taiwan Earthquake Loss Estimation System (TELES)
- Database collection of general building stocks
- Hazard analysis
- Early seismic loss estimation
- Concluding remarks

Seismic Disaster Simulation Technology

Given a set of seismic source parameters (*scenario earthquake*), SDST may assess *probable consequences* due to the seismic event

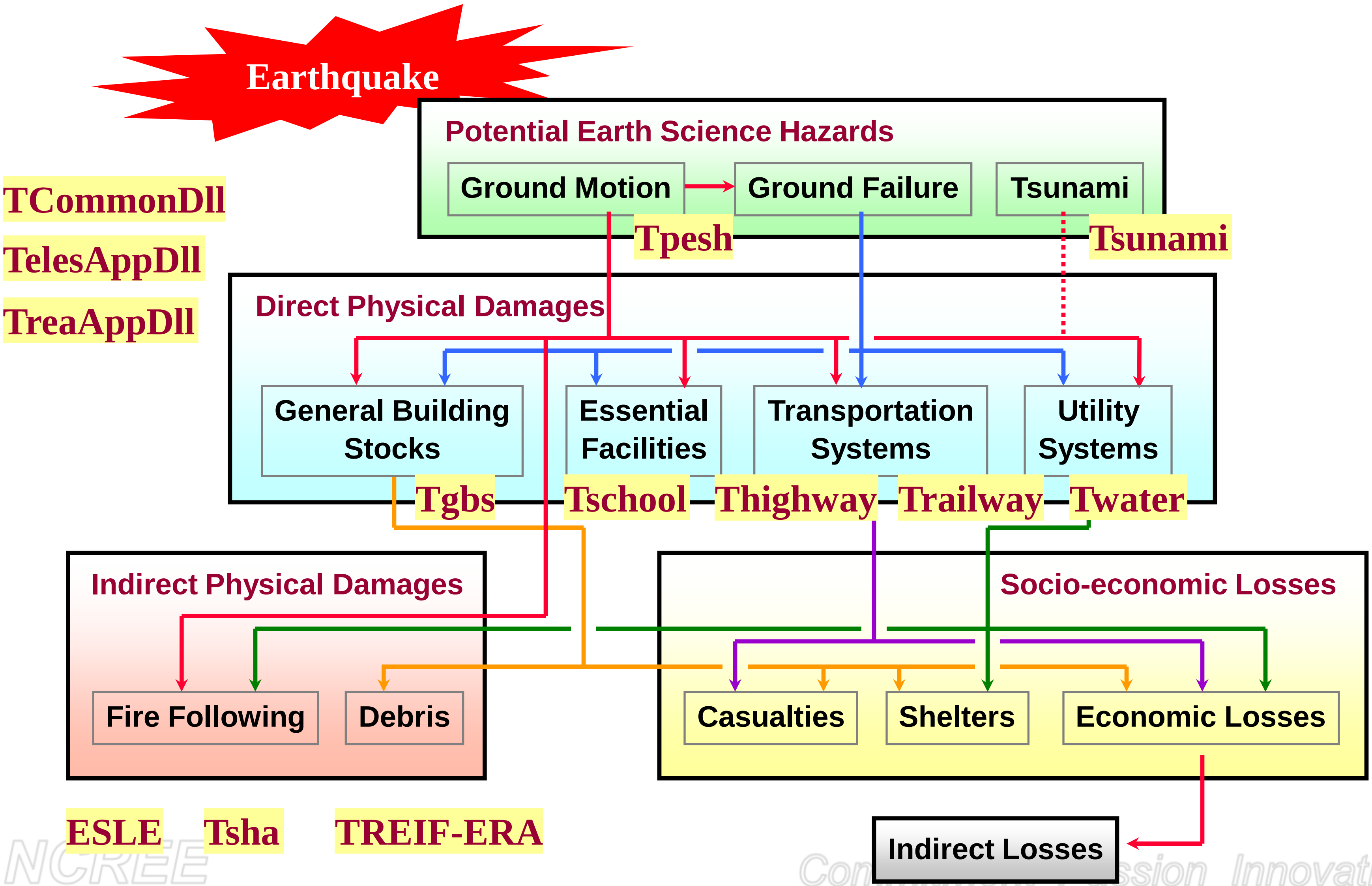
- **Database collection**
- **Specification of a scenario earthquake**
- **Seismic hazard analysis**
  - **Ground shaking** → **Intensity and frequency content**
  - **Ground failure**
    - Fault rupture
    - Soil liquefaction

    ●**Severity of ground deformation**
    ●**Occurrence (encounter) probability**
- **Damage and socio-economic impact assessment**
  - **Buildings**
  - **Bridges**
  - **Buried pipelines**

  ●**Damage-state-probabilities and/or repair rates**
  ●**Human casualties**
  ●**Post-quake fires, debris, etc.**
  ●**Resource needs for rescue, medical-care, shelter, etc.**
  ●**Restoration cost and time, interruption losses, etc.**

Analysis Framework and TELES Family

Database, Analysis Models and Application Software



Software Architecture of TELES

Common Dynamic Link Libraries

TcommonDll → TelesApp → TeraApp

Subsystems for Seismic Disaster Simulations

Tpesh, Thway, Twater, Tgbs, Trail, Tsunami, Tschool, Tgas, Tpower

- Disaster reduction plans
- Education for disaster prevention

Create seismic scenario database for ESLE

Early Seismic Loss Estimation System (ESLE)

Tesle

- Web-site for emergency response
- Push news through mobile App

TREIF-ERA

Create seismic scenario database for PSRA

Probabilistic Seismic Risk Assessment System (PSRA)

Tsha

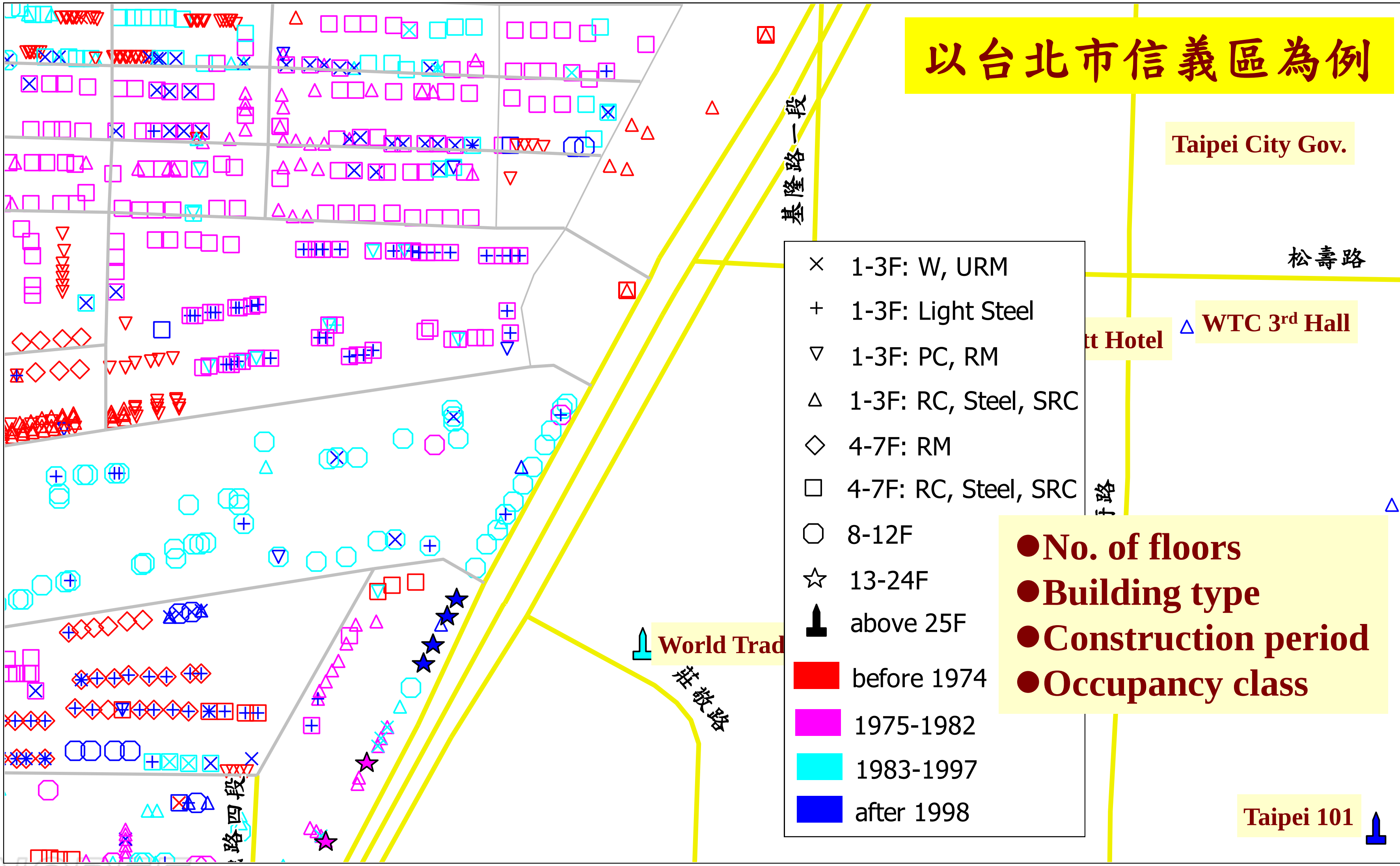
- Risk identification
- PSHA
- Probable maximum earthquakes
- Prioritization of retrofit sequence
- Risk transfer and distribution

Database Collection of General Building Stocks

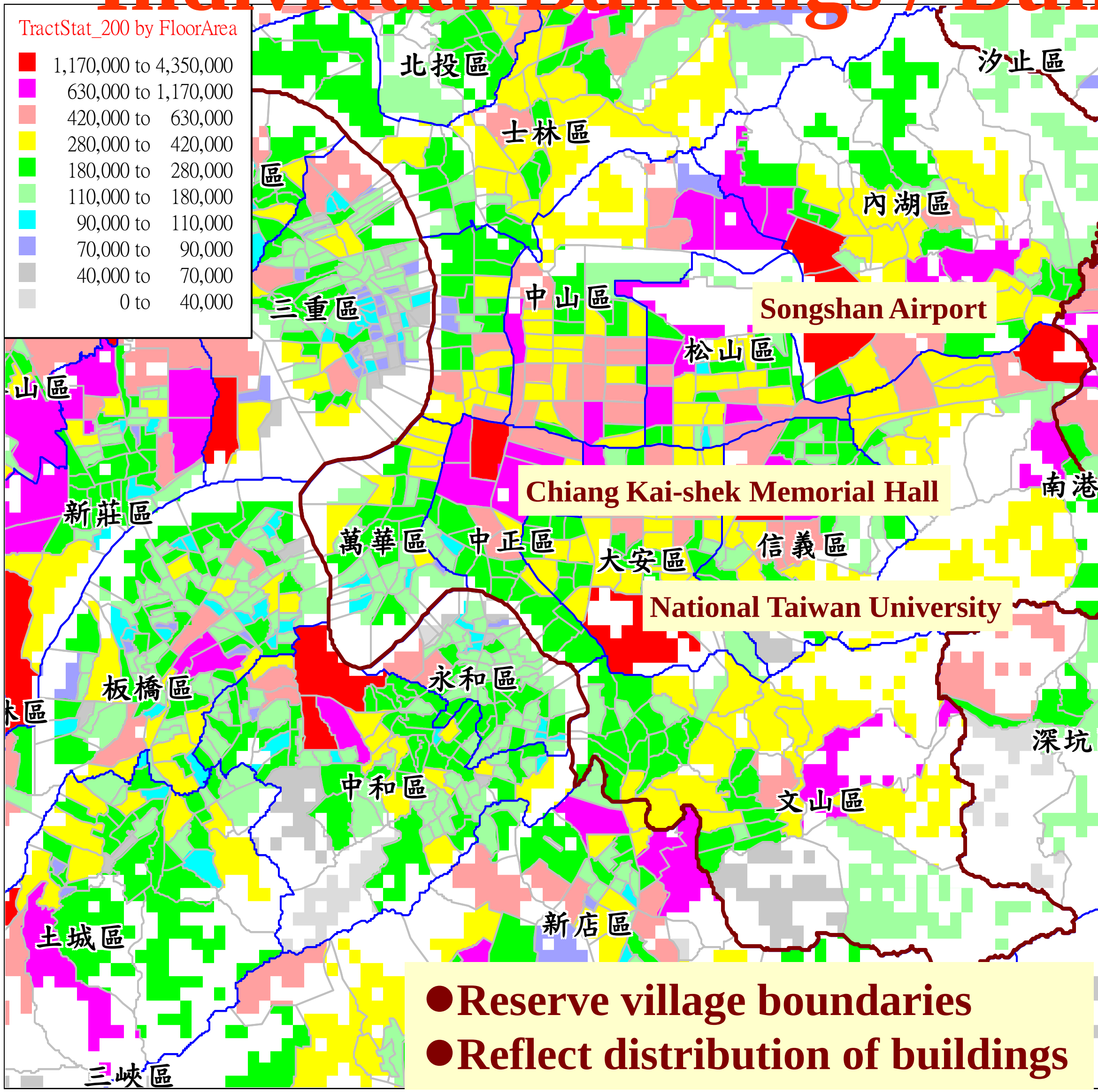
Building Inventory Database

- Based on address-coordinate database from MOI, develop geo-coding technique (*query global coordinates from an address string in Taiwan*)
- Based on building tax data from MOF, create building inventory database *per house number*
  - Original records were *per household and without coordinates*
  - Coordinates, structural type, total floor area, construction year, number of floors, seismic zone, model building type, etc.
- The geo-coding technique has been integrated in TREIF-ERA to improve location precision of insured residential houses

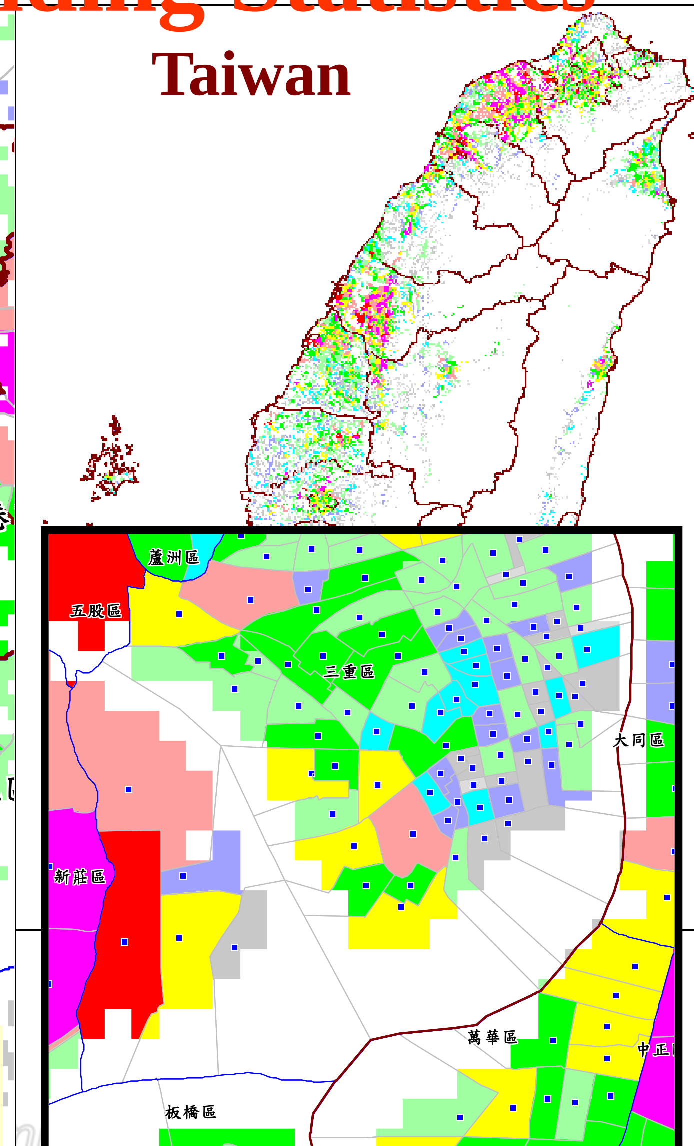
Map of Individual Buildings



Overlap Maps of Villages, Grids and Individual Buildings / Building Statistics

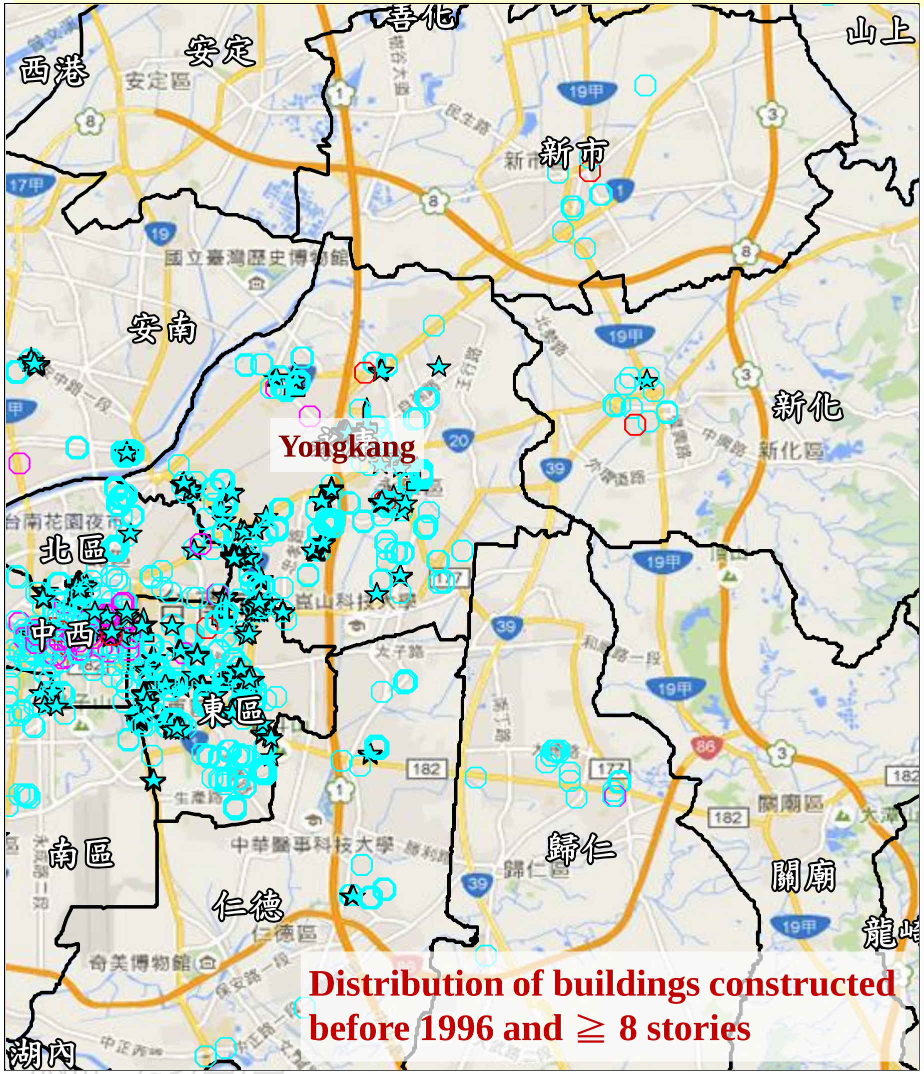


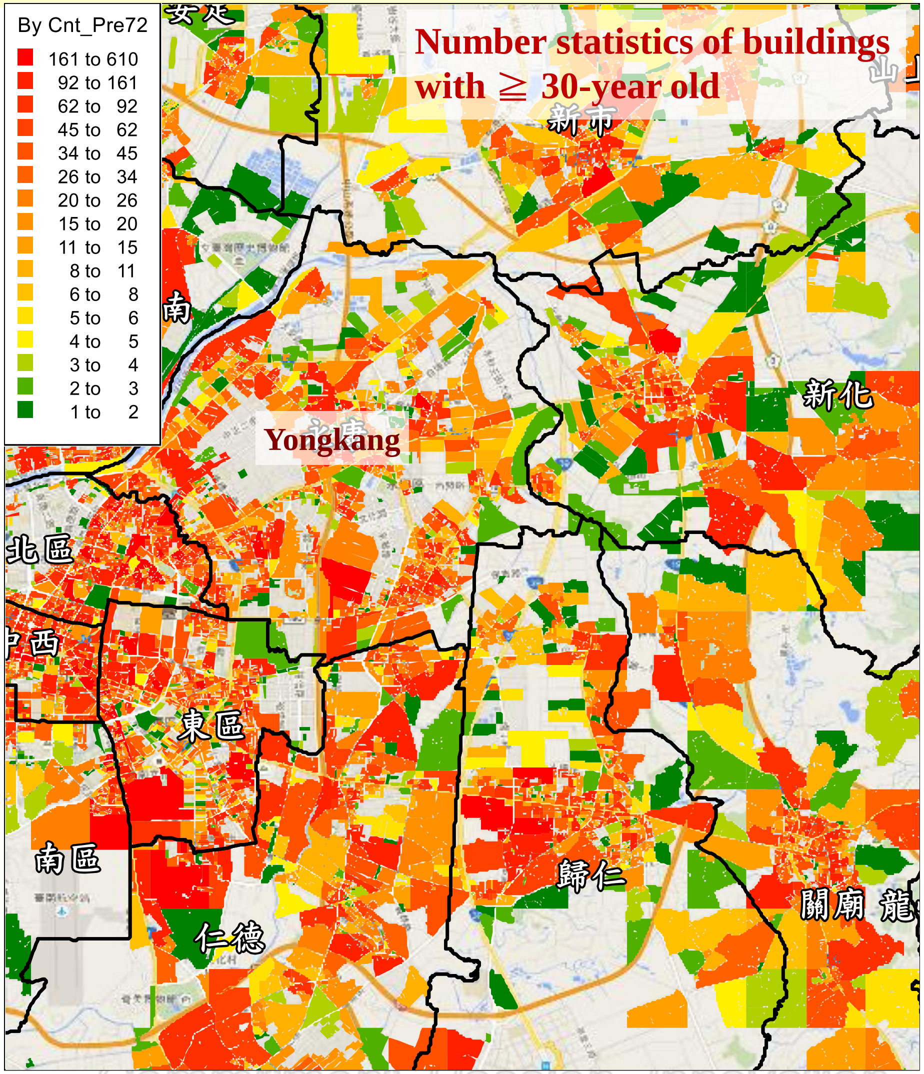
- Reserve village boundaries
- Reflect distribution of buildings



Map of Street Blocks / Building Statistics

Disastrous region (part of Tainan city) in Meinong Kaohsiung Earthquake, 2016



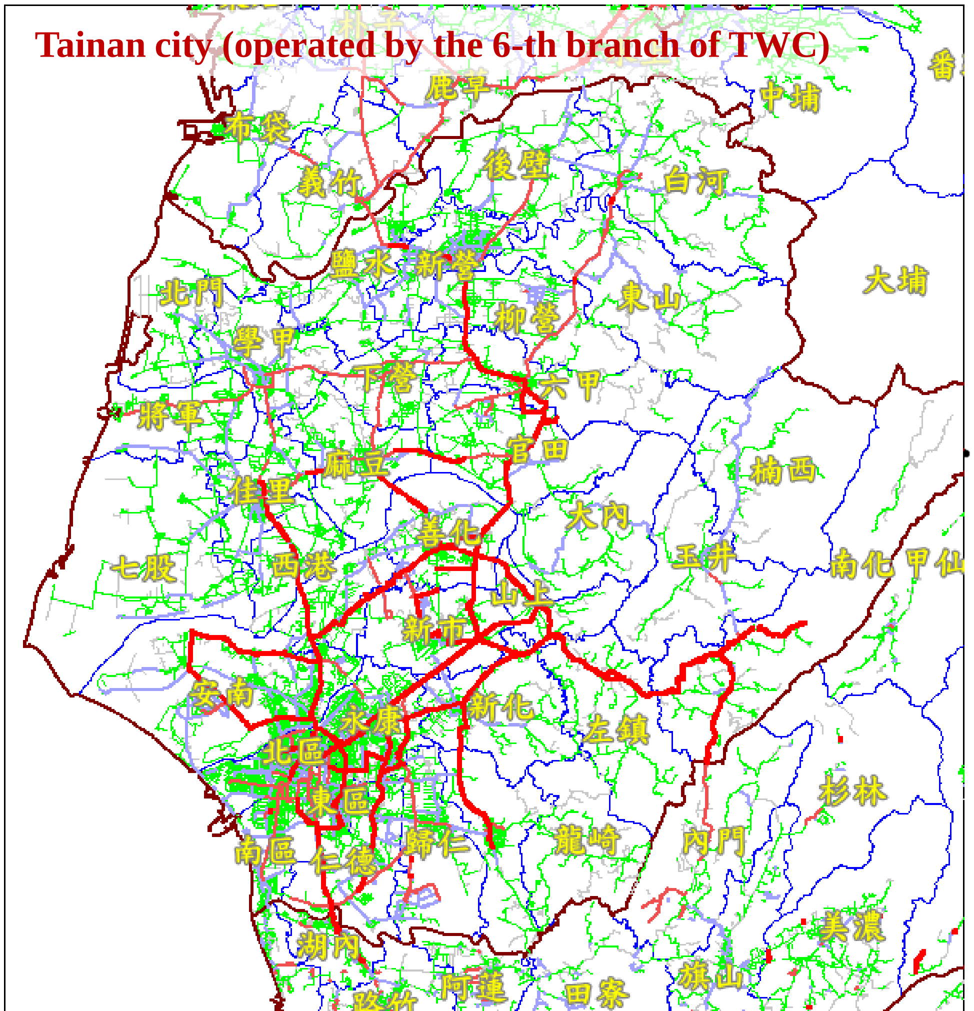


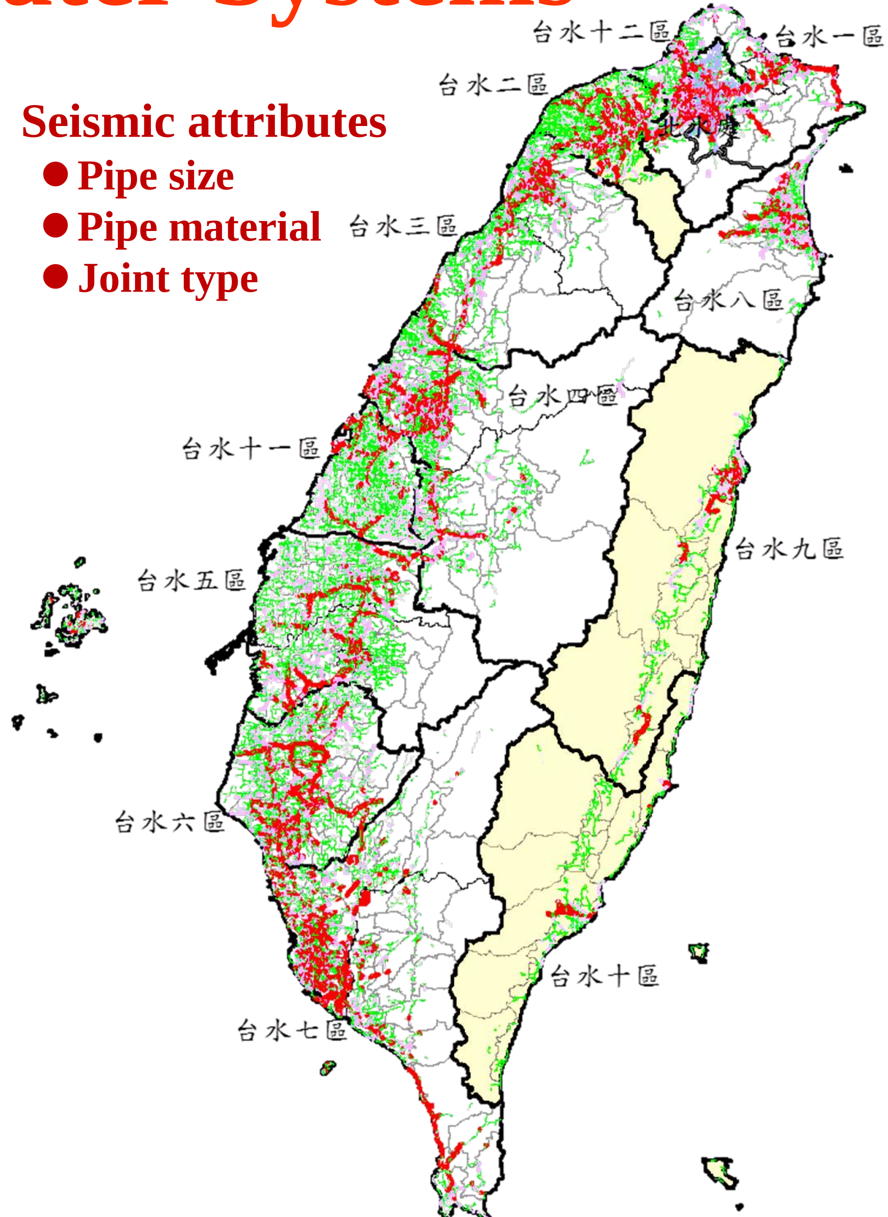
Pipelines of Water Systems

Two main water companies in Taiwan
- Taipei Water Department (TWD)
- Taiwan Water Corporation (TWC)

Seismic attributes
- Pipe size
- Pipe material
- Joint type

Tainan city (operated by the 6-th branch of TWC)

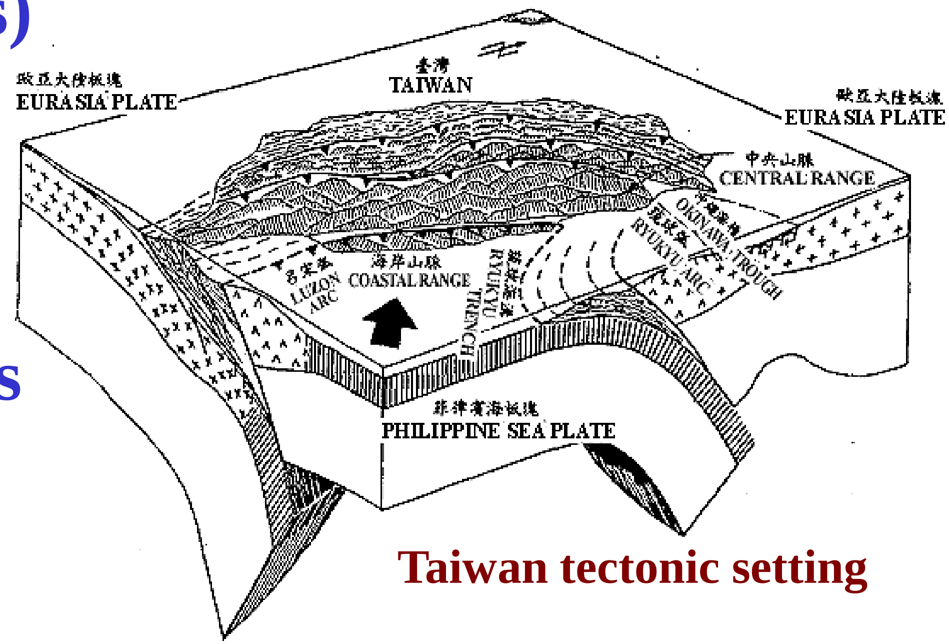




Hazard Analysis

Define a Scenario Earthquake

- **Scenario types (*point*, *poly-line* or *multi-plane* sources)**
  - **Historical events**
  - **Known active faults**
  - **Arbitrary defined**
- **Seismic source parameters**
  - **Earthquake magnitude**
  - **Epicenter location**
  - **Focal depth**
  - **Fault rupture geometry, including ground surface trace, length, width and dip angle**

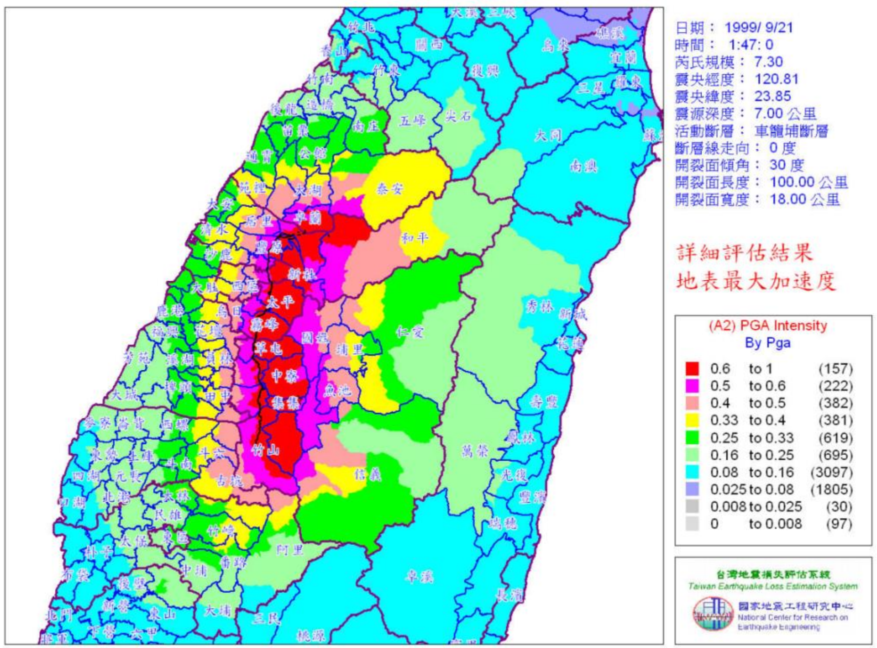


Taiwan tectonic setting

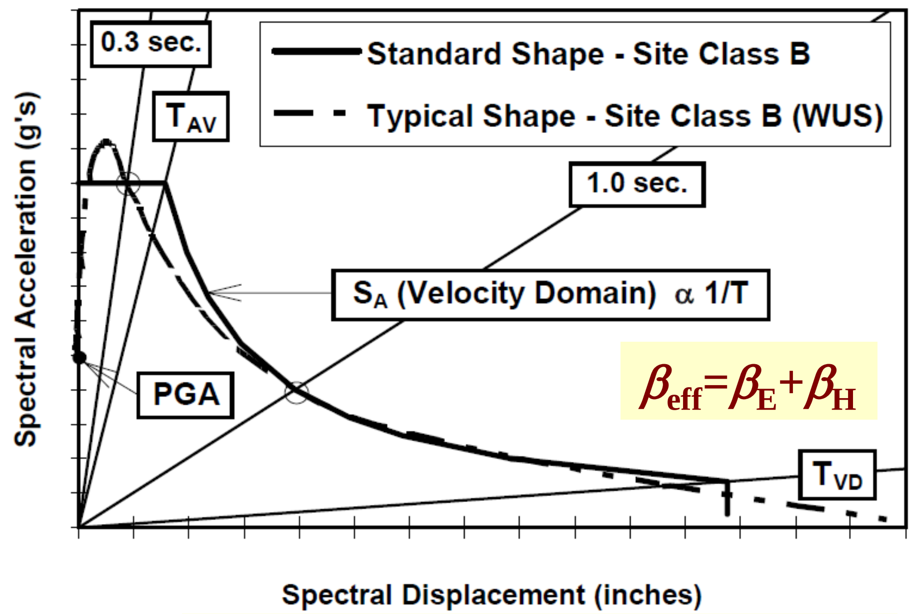
It is easy to define a *scenario earthquake*, but difficult to propose a reasonable and meaningful one to be used in a disaster reduction plan

Ground Shaking Demands

- Ground motion prediction model
  - Attenuations (*source* and *path* effects) of PGA, S_A(T=0.3 sec) and S_A(T=1.0 sec)
  - Site modification model
- Nonlinear seismic demands of engineering structures
  - Consider nonlinear responses and strength degradation



Simulated PGA in Chi-Chi EQ

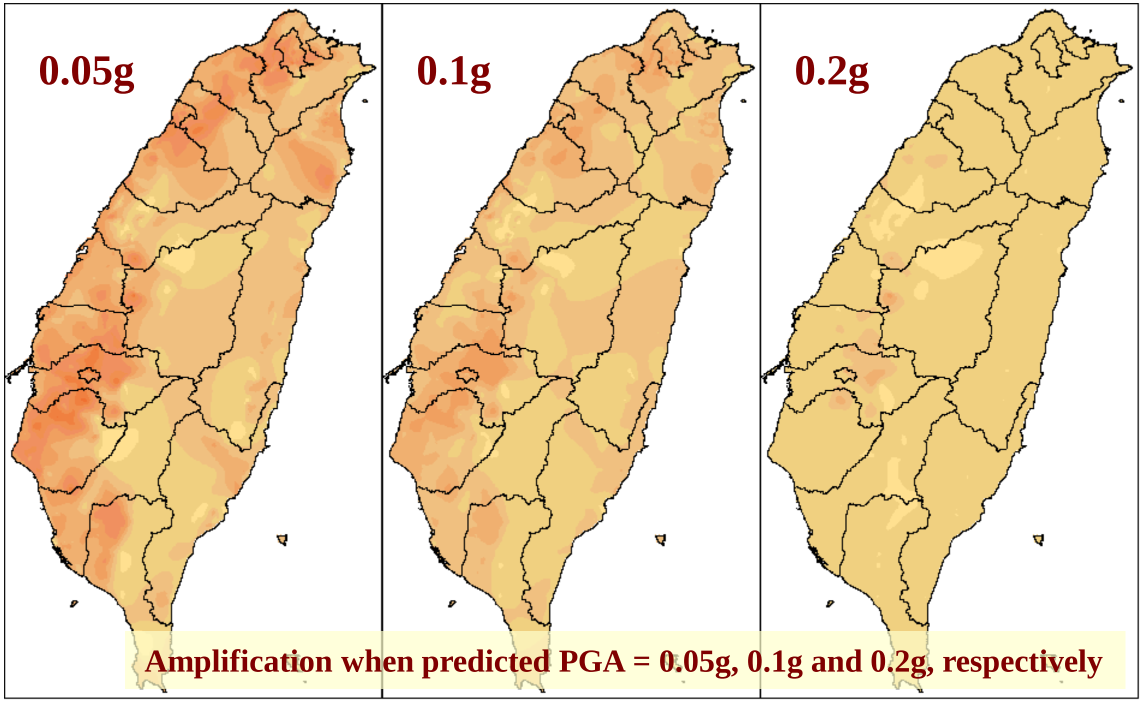


$\beta_{eff}=\beta_E+\beta_H$

(standardized response spectrum, from technical manual of HAZUS)

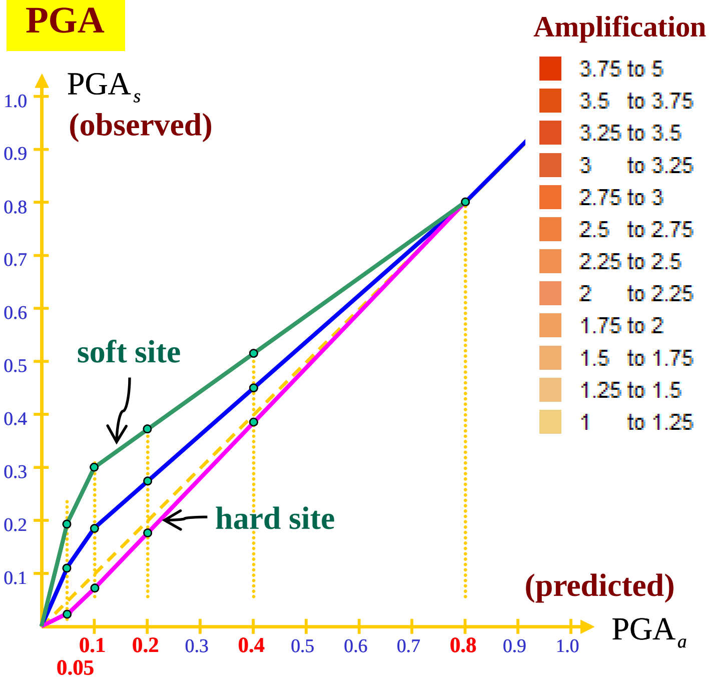
PGA and Sa10 Site Modification Models

- **Based on CWB TSMIP data**
- **Site dependent**
- **Intensity and frequency dependent**
- **Each village has its own site modification curve**

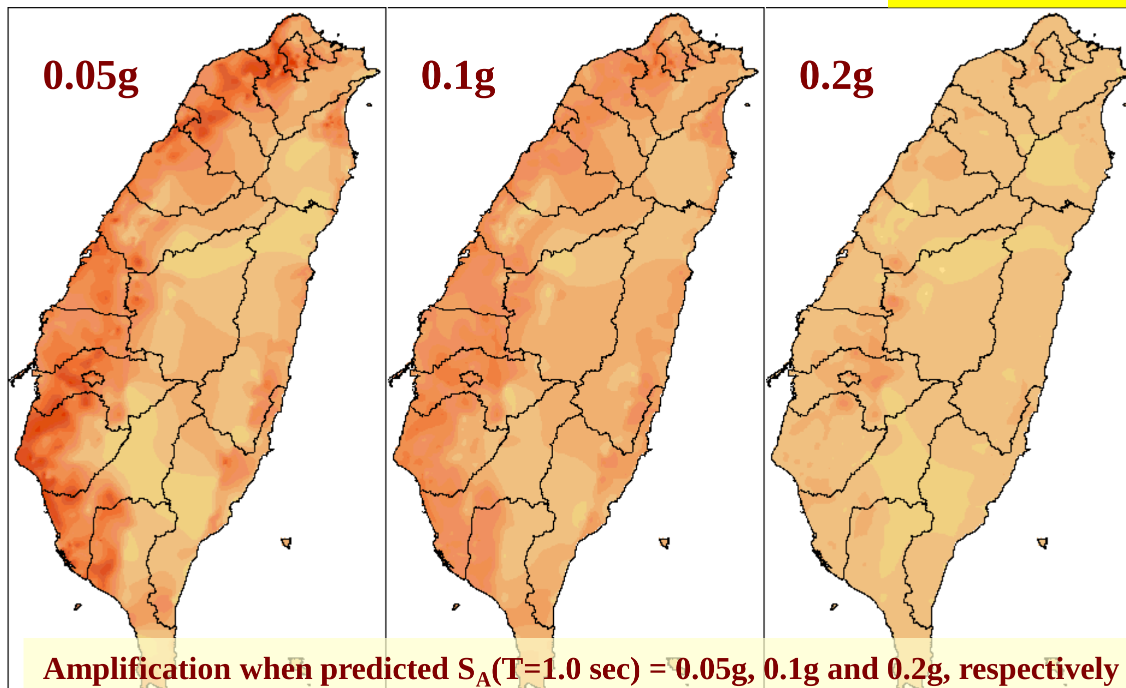


Amplification when predicted PGA = 0.05g, 0.1g and 0.2g, respectively

PGA



S_A(T=1.0 sec)



Amplification when predicted S_A(T=1.0 sec) = 0.05g, 0.1g and 0.2g, respectively

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Ground Deformation due to Fault Rupture

$$PGD = \begin{cases} D & \text{within 10 m} \\ (1/d_{sr}) \cdot f_H \cdot D \cdot \exp[-d/(d_{sr} \cdot f_H)] & \text{hanging wall (outside 10 m)} \\ (1/d_{sr}) \cdot f_F \cdot D \cdot \exp[-d/(d_{sr} \cdot f_F)] & \text{footwall (outside 10 m)} \end{cases}$$

d **: closest distance to rupture plane (km)**

α **: dip angle (degree)**

$$d_{sr} = \max(M_L/2, \quad 1)$$

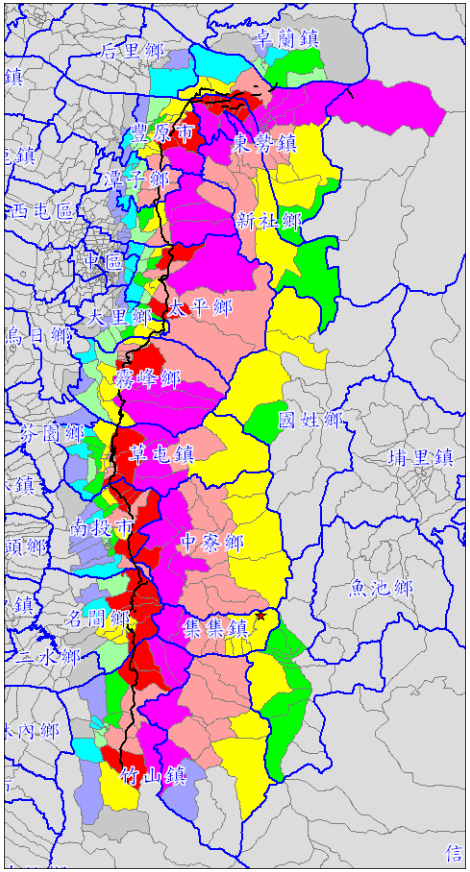
top depth of seismogenic zone (km)

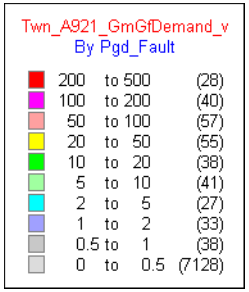
$$f_F = \text{abs}(\alpha)/180$$

$$f_H = 1 - f_F$$

$$\log D = \begin{cases} 1.03M_w - 7.03 & \text{strike-slip fault} \\ 0.29M_w - 1.84 & \text{reverse fault} \\ 0.89M_w - 5.90 & \text{normal fault} \\ 0.82M_w - 5.46 & \text{general fault} \end{cases}$$

(unit: m; Wells and Coppersmith, 1994)





Simulated coseismic ground surface deformation after Chi-Chi EQ

Most of damaged structures in Chi-Chi EQ were mainly due to fault rupture

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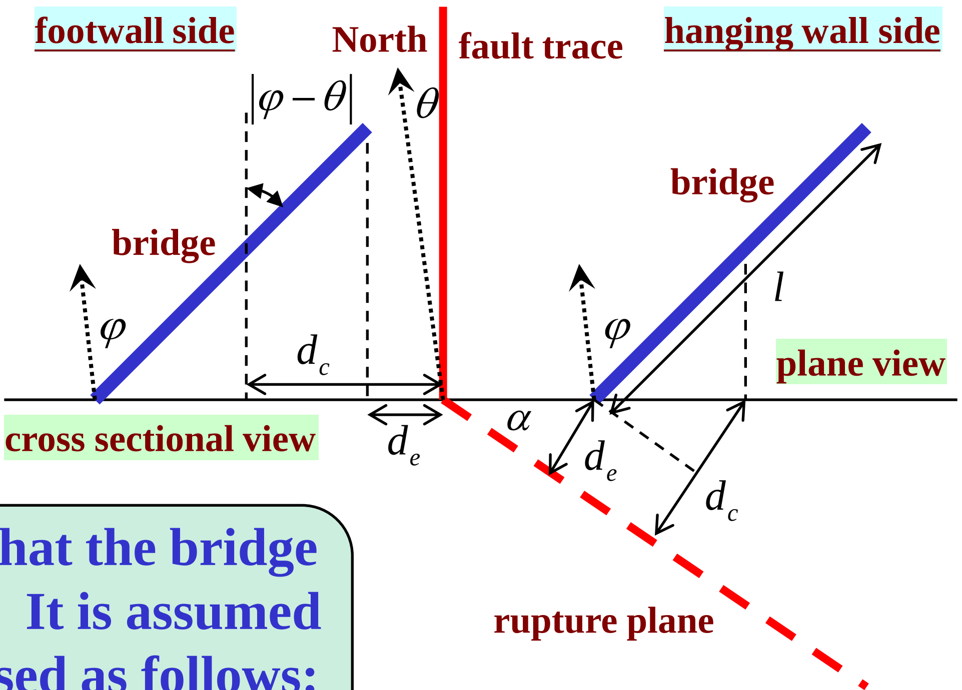
Encounter Probability due to Fault Rupture

Closest Distance Between Bridge and Fault

$$d_e = \begin{cases} \max(0, \quad d_c - 0.5 \cdot l \cdot \sin|\varphi - \theta| \cdot \sin\alpha) & \text{hanging wall side} \\ \max(0, \quad d_c - 0.5 \cdot l \cdot \sin|\varphi - \theta|) & \text{footwall side} \end{cases}$$

d_c	closest distance of mid-point to rupture plane
l	bridge length
$\lvert\varphi-\theta\rvert$	angle between bridge and fault trace
α	dip angle of fault plane
d_e=0	means the bridge may cross the rupture fault

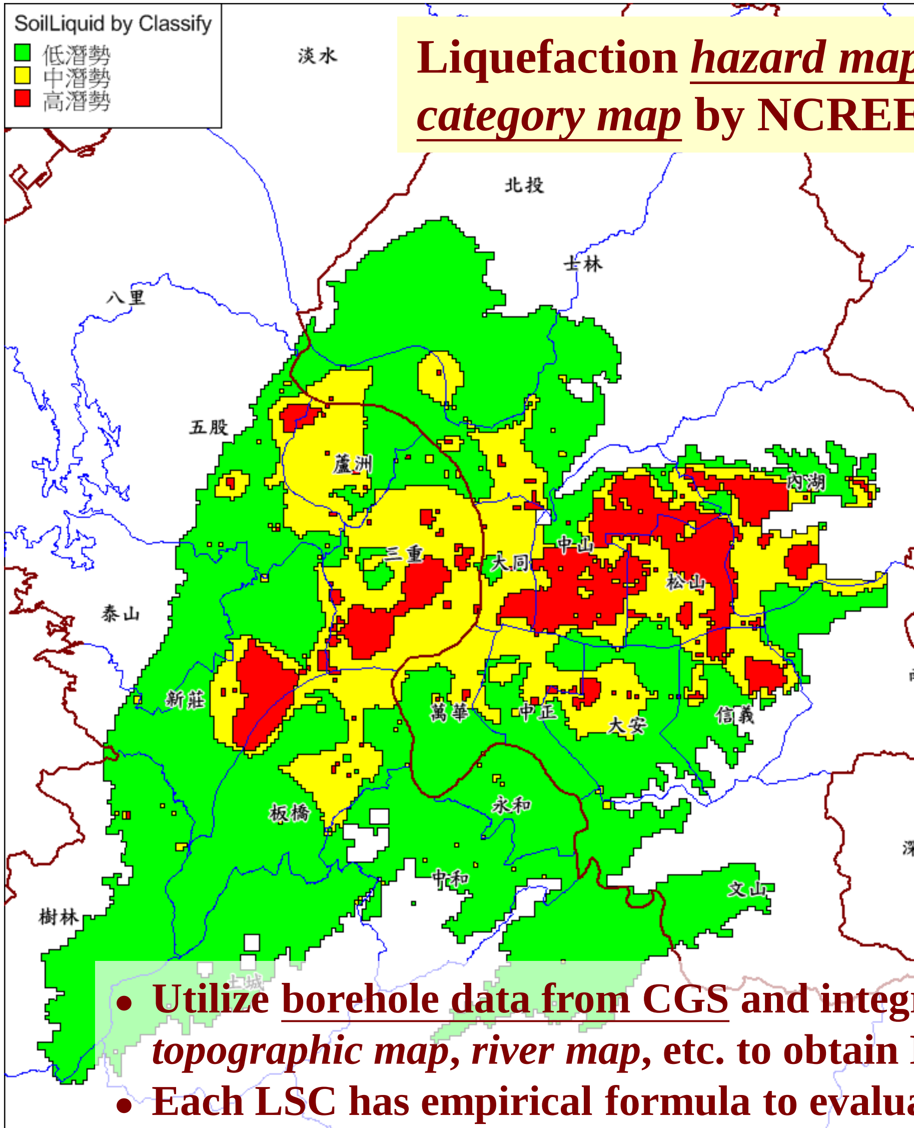


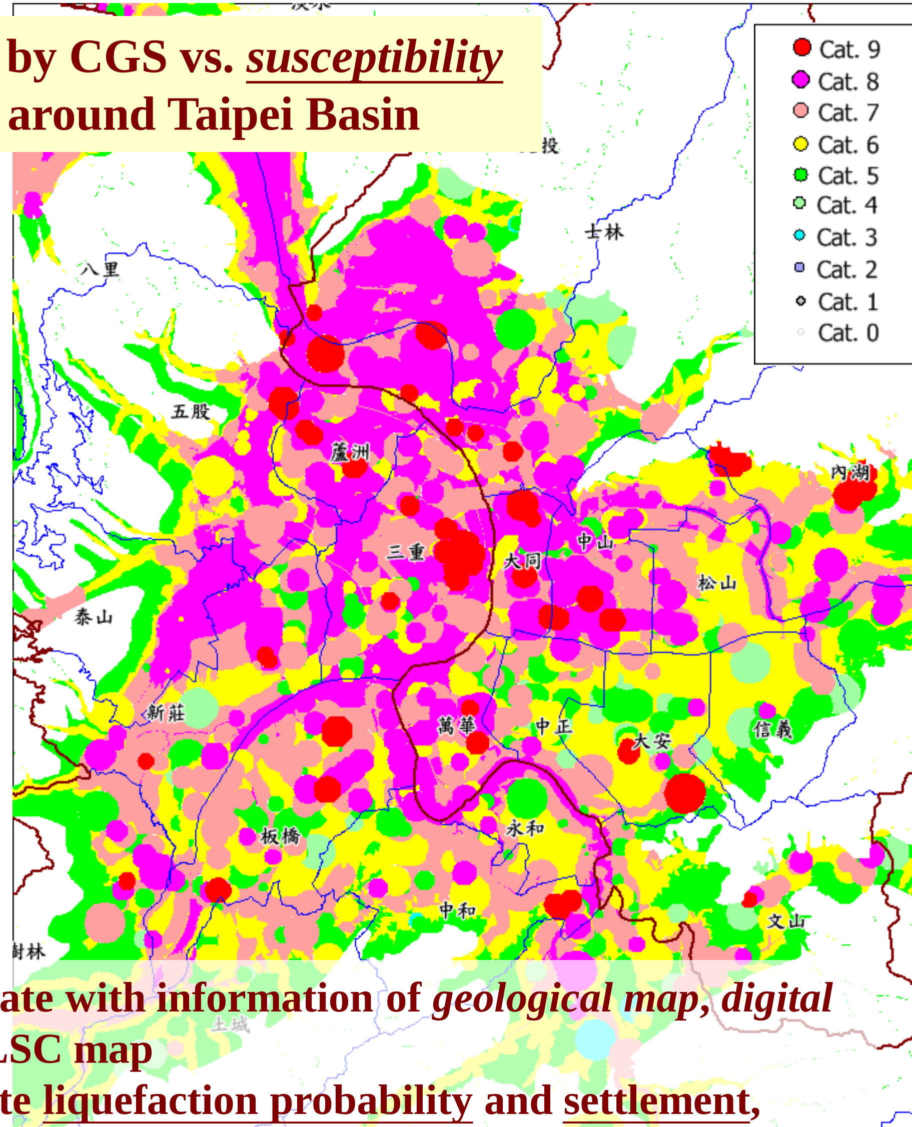
Encounter probability: probability that the bridge actually crosses ruptured fault lines. It is assumed to be related to d_e and can be expressed as follows:

$$p = 0.7 \cdot \exp(-d_e / 2)$$

Borehole Data / Soil Liquefaction Susceptibility

Liquefaction *hazard map* by CGS vs. *susceptibility category map* by NCREE around Taipei Basin





- **Utilize borehole data from CGS and integrate with information of *geological map*, *digital topographic map*, *river map*, etc. to obtain LSC map**
- **Each LSC has empirical formula to evaluate liquefaction probability and settlement, expressed as functions of *earthquake magnitude, PGA* and *ground water depth***

Early Seismic Loss Estimation

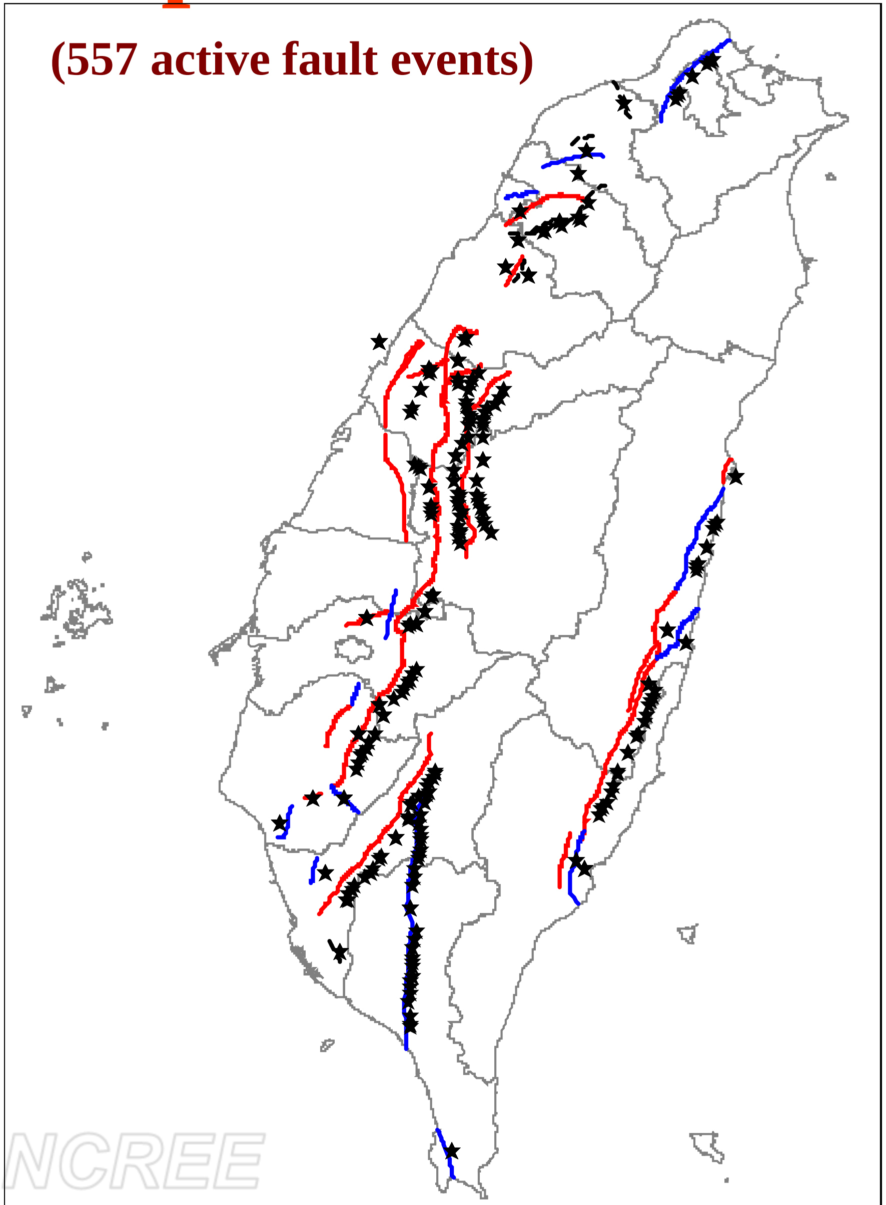
Necessity of Early Seismic Loss Estimates

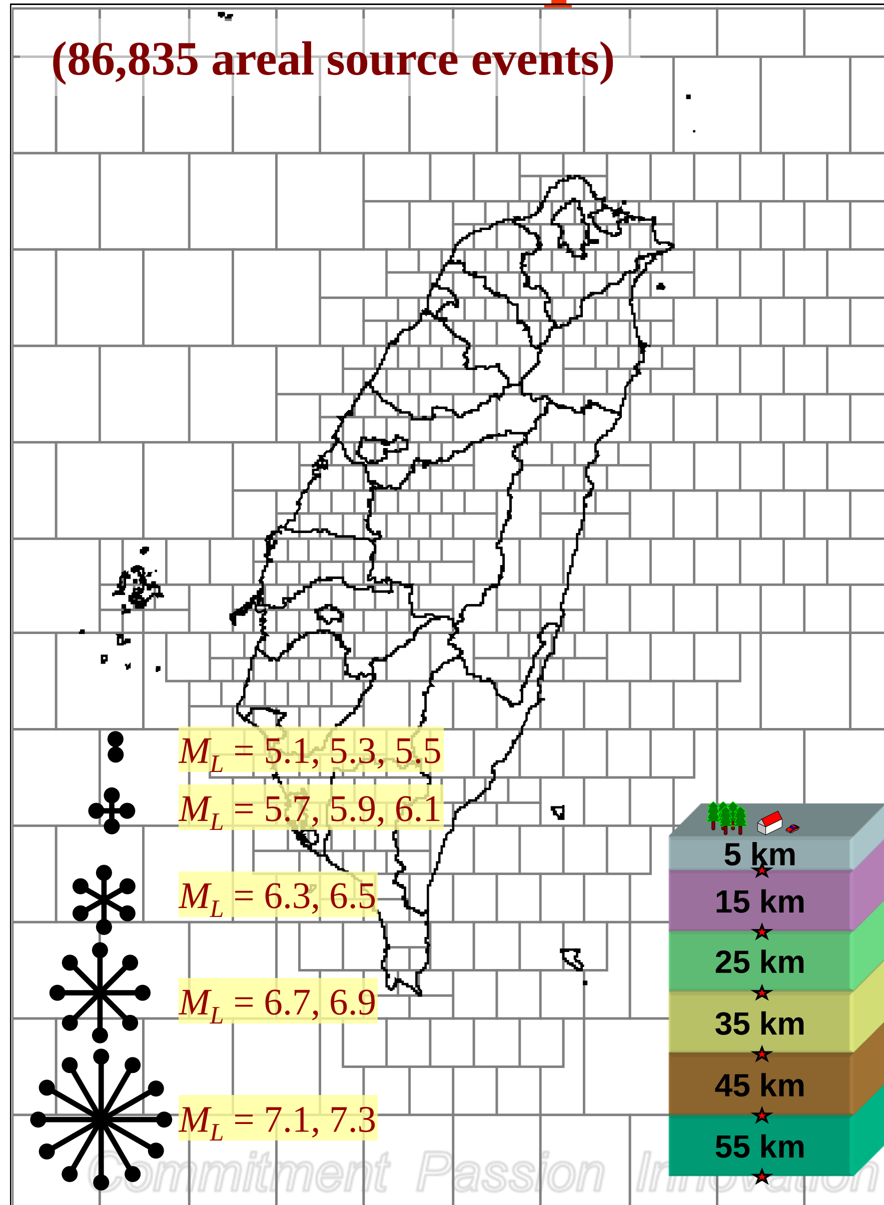
- Right after earthquakes, emergency response personnel of governments and enterprises need information to **assess severity due to the earthquakes**
- Once emergency operation centers (EOC) initiated, it is required to **assess probable distribution of disasters a.s.a.p. in order to dispatch rescue resources**
- ESLE can be **auto-triggered** by email from CWB, complete estimation and send messages to response personnel within 2 minutes

Benefits of ESLE in Emergency Response

Stage 1 (within 2 minutes)	Stage 2 (within 6 hours)
– Can be auto-triggered by email from CWB – Complete estimation of probable disasters and send messages to emergency response personnel – Save time to judge the necessity of initiating emergency response centers	– Integrate available information, such as monitoring data, fault plane solutions, aftershock distribution, etc, to propose reasonable seismic source parameters – Avoid existence of neglected disastrous regions through rigorous scenario simulation – Provide estimation results and assist in dispatching rescue, medical and livelihood resources

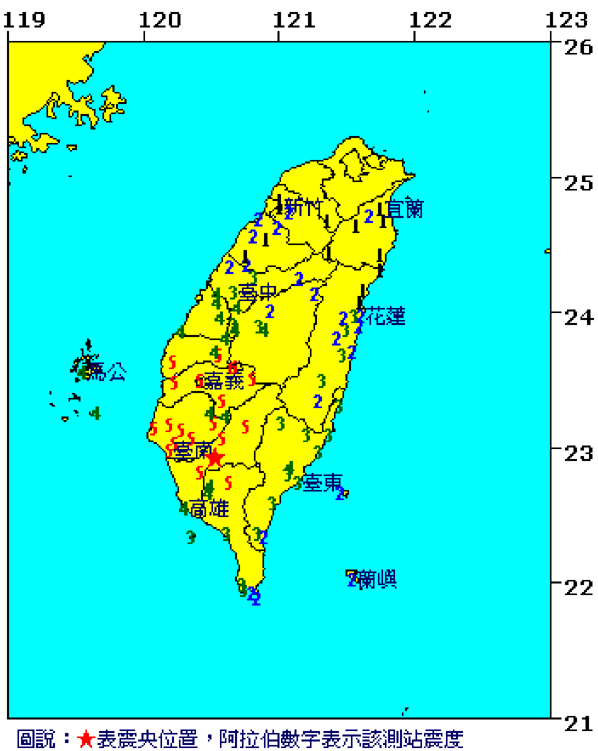
Representative Scenario Earthquakes





Case Study of Meinong Earthquake

- Time: 3:57 a.m. on 2016/2/6
- M_L=6.4 (6.6)
- Epicenter: Meinong, Kaohsiung
- Focal depth: 16.7 km
- Maximum intensity 6 in Tsaoling, Yunlin



圖說：★表震央位置，阿拉伯數字表示該測站震度

中 央 氣 象 局 地 震 報 告

編號： 第105006號

日期： 105 年 2 月 6 日

時間： 3 時 57 分 27.2 秒

位置： 北緯 22.93 度，東經 120.54 度
即在 屏東縣政府北偏東方 27.4 公里
位於 高雄市美濃區

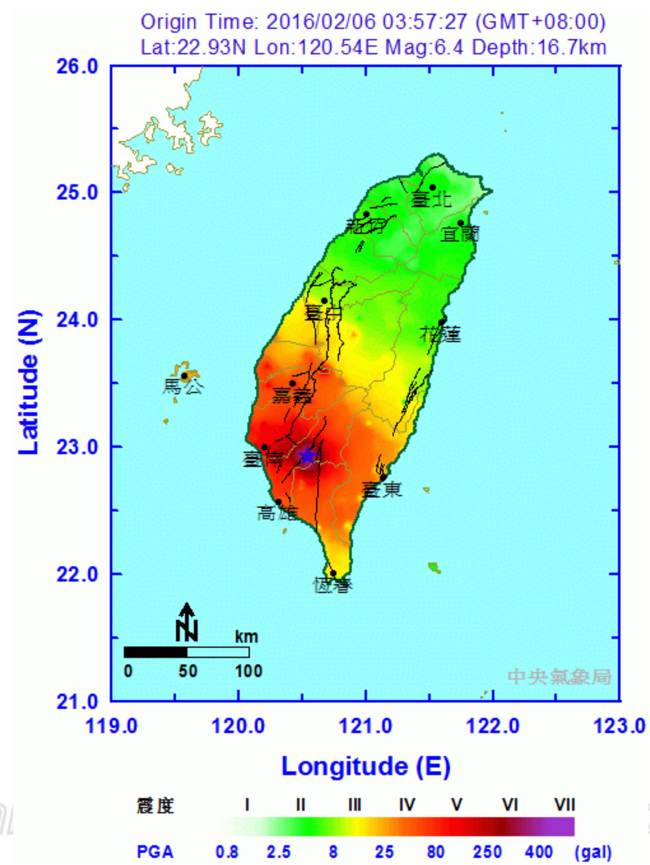
地震深度： 16.7 公里

芮氏規模： 6.4

各地最大震度

雲林縣草嶺	6級	彰化縣彰化市	4級
高雄市旗山	5級	臺東縣臺東市	3級
屏東縣三地門	5級	花蓮縣紅葉	3級
臺南市楠西	5級	屏東縣南灣	3級
臺南市	5級	南投縣南投市	3級
嘉義縣草山	5級	臺中市	3級
嘉義市	5級	花蓮縣花蓮市	2級
屏東縣屏東市	4級	苗栗縣鯉魚潭	2級
高雄市	4級	苗栗縣苗栗市	2級
臺東縣初鹿	4級	新竹縣竹東	2級
雲林縣斗六市	4級	宜蘭縣內城	2級
澎湖縣東吉島	4級	桃園市三光	1級
彰化縣二水	4級	新竹市	1級
南投縣名間	4級	新竹縣竹北市	1級
澎湖縣馬公市	4級	宜蘭縣宜蘭市	1級
臺中市霧峰	4級		

本報告係中央氣象局地震觀測網即時地震資料
地震速報之結果。



Stage 1: Automatic

- ESLE was **auto-triggered** by receiving E-mail from CWB
- Completed estimation and sent messages to emergency response personnel **within one minute**

SMS: ***brief Info.***

Customizable content in SMS and E-mail

E-Mail: ***detailed Info.***


Ar_SummaryGBS.txt - 記事本

檔案(F) 編輯(E) 格式(O) 檢視(V) 說明(H)

台灣地震損失評估系統的推估結果：
需警戒的村里數 1045
預估傷亡人數
12 (5 - 30)

*** 模擬地震事件 1； Scen_ID： kj6530
震央經度： 120.3500
震央緯度： 23.0500
芮氏規模： 6.50
震源深度： 15.00 公里
斷層走向： 北偏東 0 度
斷層長度： 25.50 公里

震災早期評估結果：
全半倒建築物
1-3層樓房 302 棟
4-7層樓房 46 棟
8層以上樓房 9 棟
總計 357 棟

人員傷亡
重傷 7 人
死亡 4 人
總計 12 人

以縣市為單元之一般建築物地震損失統計：

縣市	1-3樓（棟）	4-7樓（棟）	8樓以上（棟）	損害棟數（棟）	傷亡人數（人）	建物損失（百萬元）
台南市	228	35	5	268	8	21,435.4
高雄市	68	11	4	83	4	11,595.7
屏東縣	4	0	0	4	0	629.6
嘉義縣	2	0	0	2	0	505.9

以鄉鎮區為單元之一般建築物地震損失統計：

鄉鎮區	1-3樓（棟）	4-7樓（棟）	8樓以上（棟）	損害棟數（棟）	傷亡人數（人）	建物損失（百萬元）
台南市永康區	26	6	1	34	1	3,123.8
台南市東區	12	4	1	18	1	2,021.2
台南市安南區	15	2	0	17	1	1,667.4

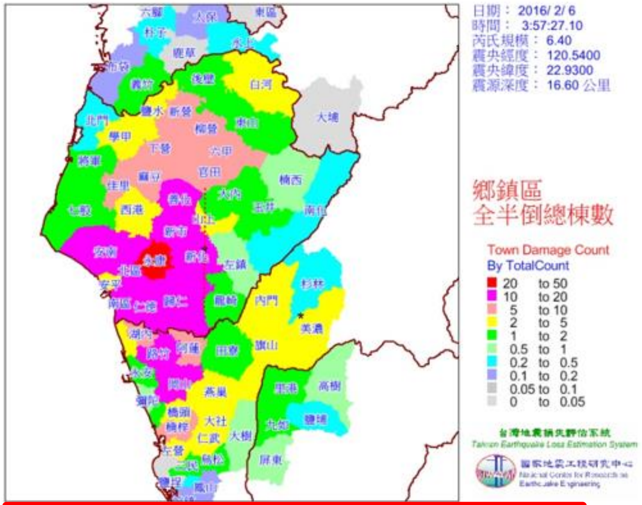
地震早期損失...
檔案 郵件
2016/2/6 (週六) 上午 04:08
ESLE@ncree.org
地震早期損失評估結果(國震中心提供)
收件者 undisclosed-recipients:
訊息 Ar_SummaryGBS.txt (31 KB)

根據中央氣象局之地震速報系統（電子郵件）：
日期： 2016/ 2/ 6
時間： 3:57:27.10
芮氏規模： 6.40
震央經度： 120.5400
震央緯度： 22.9300
震源深度： 16.60 公里
最大震度： 6
震央在 高雄市美濃區

台灣地震損失評估系統的推估結果請參考附件

ESLE@ncree.org 地震早期損失評估結果(國震中心提供)

Web Page: ***with GIS map***

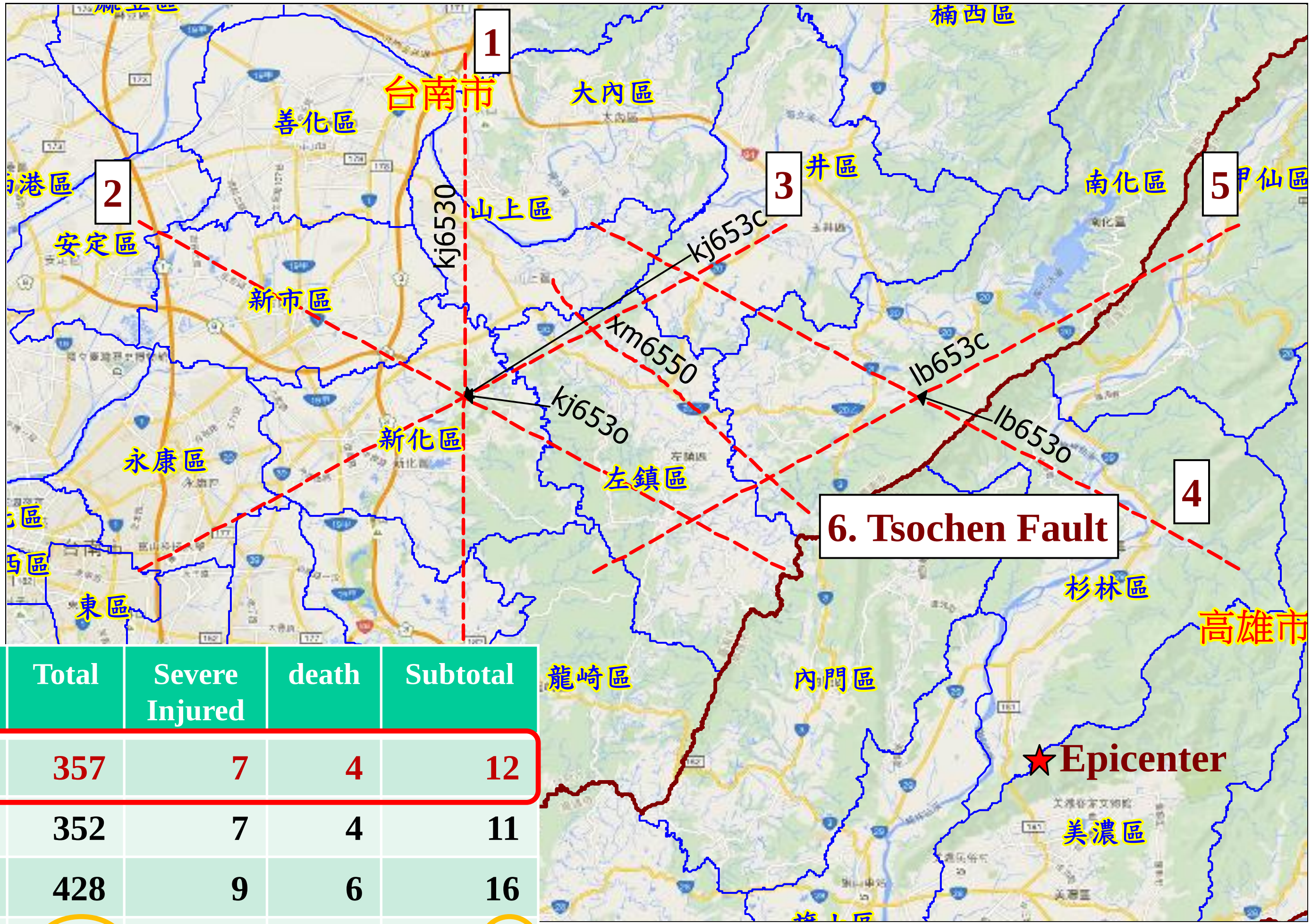


No. of building damages (357)
- **1-3 floors (302)**
- **4-7 floors (46)**
- **Above 8 floors (9)**

NCREE

Commitment Passion Innovation

Six Representative Scenario Earthquakes Selected by ESLE *within one minute*

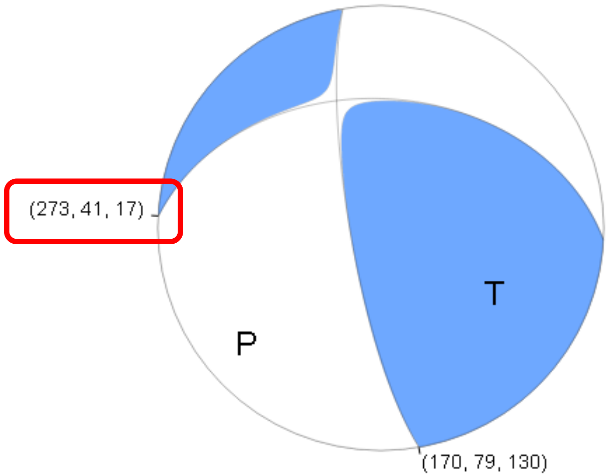


Loss estimates by ESLE

	1-3 Floor	4-7 Floor	>8 Floor	Total	Severe Injured	death	Subtotal
Evt1	302	46	9	357	7	4	12
Evt2	300	45	7	352	7	4	11
Evt3	352	66	11	428	9	6	16
Evt4	151	16	3	170	2	1	5
Evt5	159	22	5	186	3	2	6
Evt6	750	69	8	827	17	12	30

Seismic source must be located on the fault rupture plane

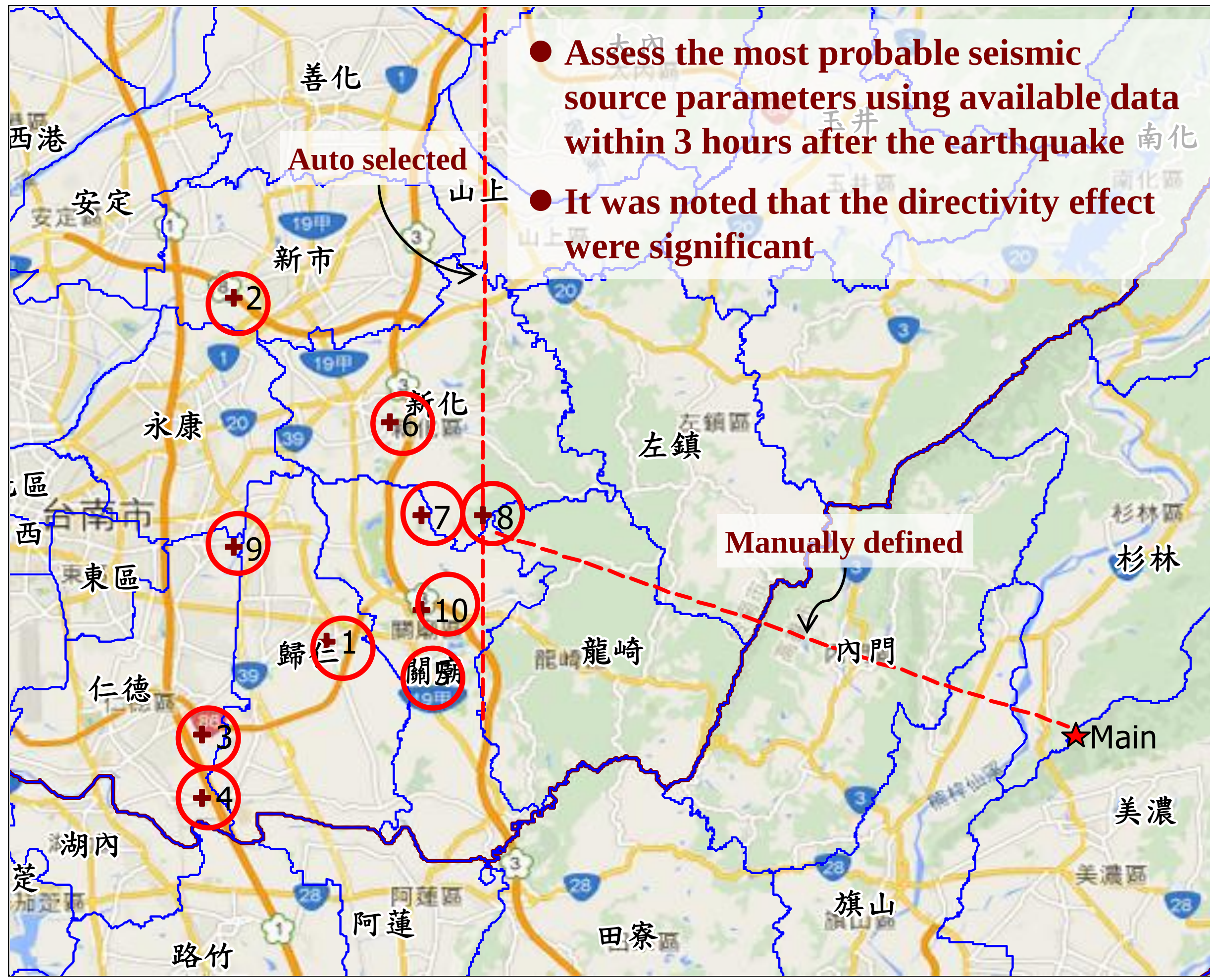
Stage 2: Manual



Obtained fault plane solution by USGS in 1 hour

Seismic source parameters

Source	Stage 1	Stage 2
Magnitude	6.5	6.4
Depth	15	15
Direction	0	110
Dip Angle	90	90
Length	25	20



Aftershock distribution in 3 hours

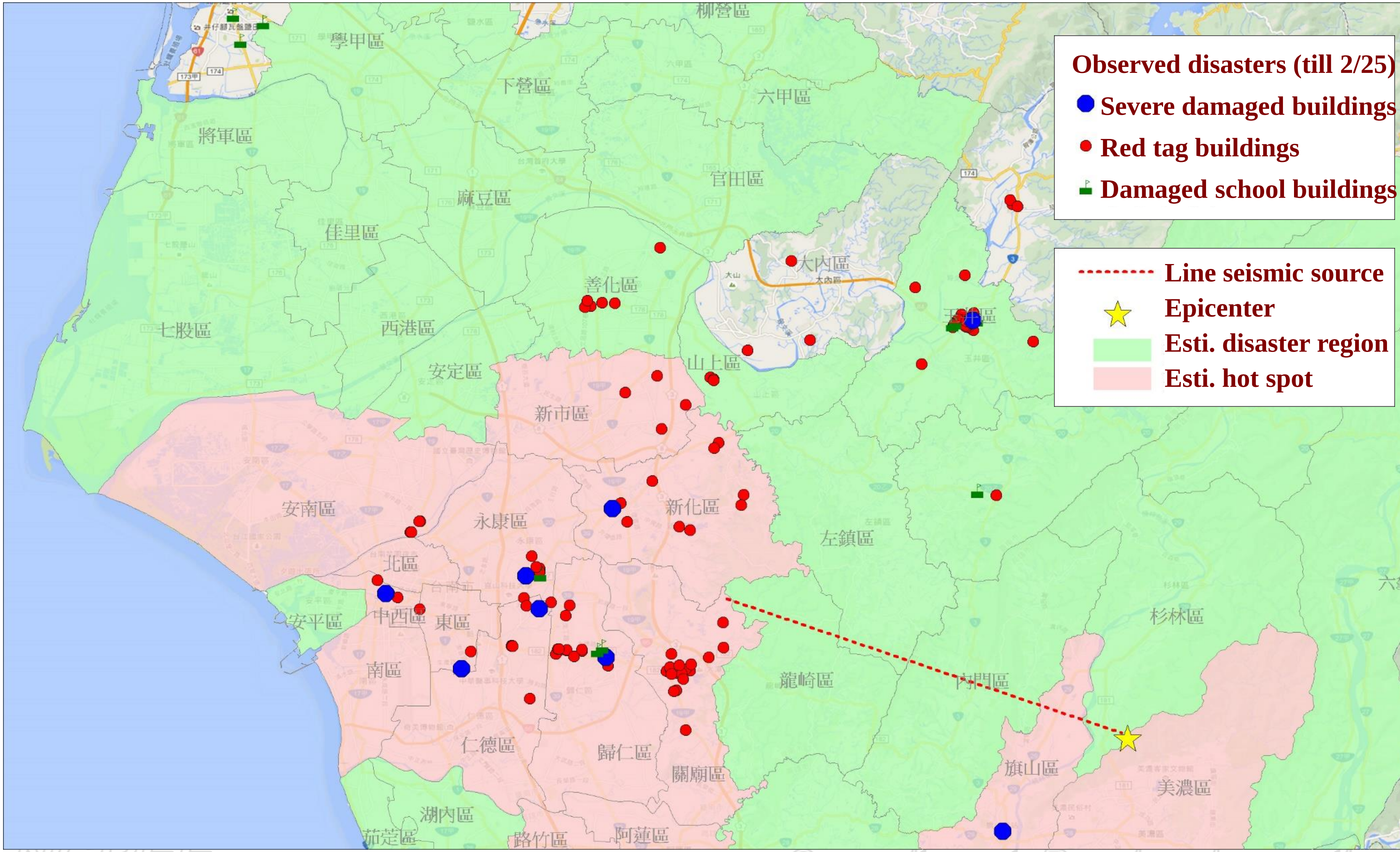
Comparison of ESLE and Observed Losses

Besides 115 persons died in Weiguan Jinlong building, the rest of death tolls was 2

	1-7 floor damaged buildings	>8 floor damaged Buildings	Total damaged buildings	Seriously injured or died	Insurance losses (million NT$)
Observed Losses	236	10	246	2 + 115	>170
ESLE Stage 1	348	9	357	12	528
ESLE Stage 2	210	6	216	6	252

note：Damaged building data was from Tainan City Government by Feb. 25, 2016

Distribution of ESLE and the Observed



Comparison of ESLE and History Observed

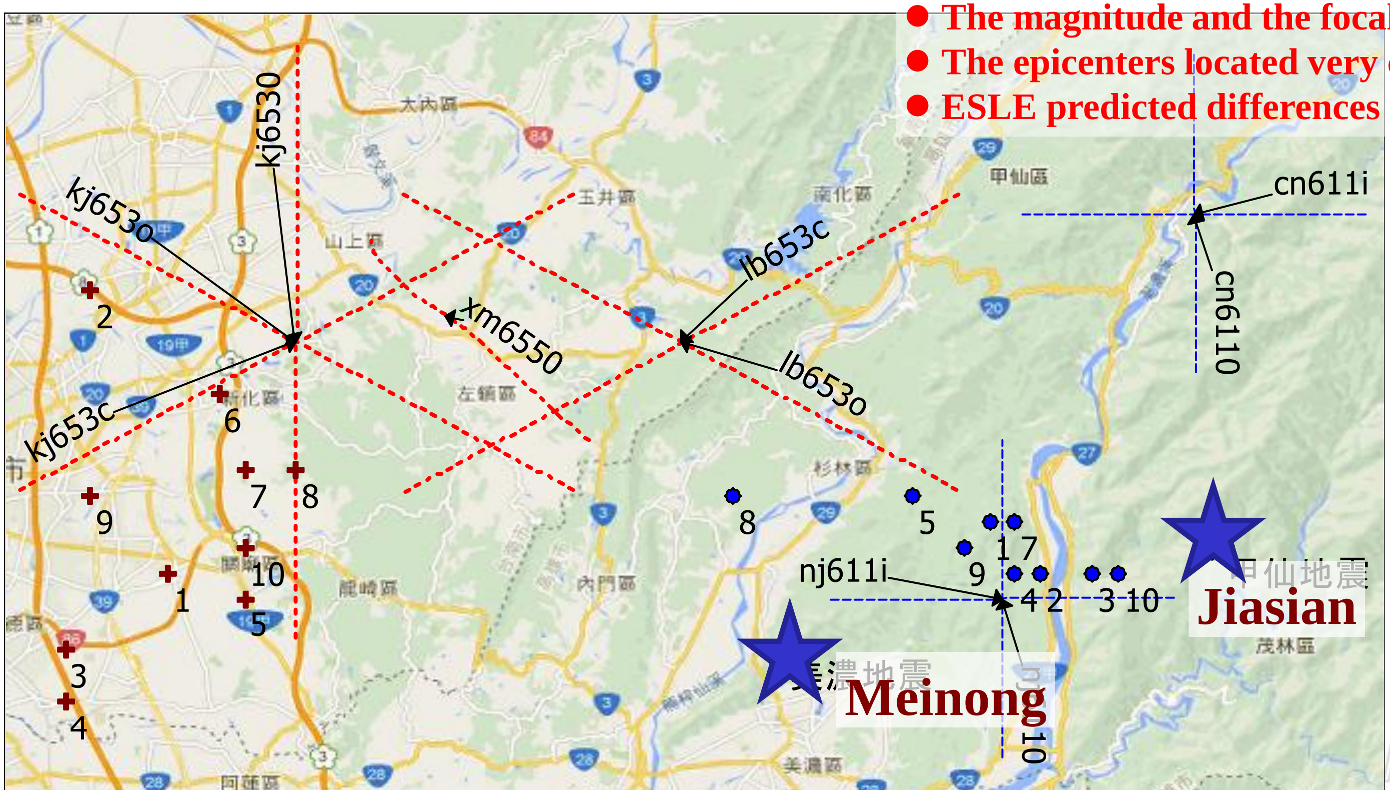
Date	Time	Epicenter	M_L	Depth (km)	Estimated Casualties	Actual Casualties	Estimated Insurance Claims (million NT$)	Actual Insurance Claims (million NT$)
2009/12/19	21:02	花蓮壽豐外海18公里	6.8	46	0 (0-0)	0	3.8 (0.1-15.7)	0
2010/03/04	08:18	高雄縣桃源鄉	6.4	5/23	1 (1-3)	0	2.6 (1.8-4.5)	2.76
2010/11/21	20:31	花蓮壽豐外海17公里	6.1	41	0 (0-0)	0	0.0 (0.0-0.0)	0
2012/02/26	10:35	屏東縣霧台鄉	6.0	20	0 (0-0)	0	0.0 (0.0-0.6)	0
2013/03/27	10:03	南投縣仁愛鄉	6.1	15	0 (0-3)	1	3.5 (0.1-25.0)	0
2013/06/02	13:43	南投縣仁愛鄉	6.3	10	2 (0-3)	5	9.3 (1.3-19.3)	0
2013/10/31	20:02	花蓮縣瑞穗鄉	6.3	19	0 (0-0)	0	0.4 (0.3-0.7)	0
2014/05/21	08:21	花蓮縣鳳林鎮	5.9	18	0 (0-0)	0	0.1 (0.1-0.1)	0
2014/12/11	05:03	台北萬里外海72公里	6.8	280	0 (0-0)	0	0.0 (0.0-0.0)	0
2015/02/14	04:06	台東外海33公里	6.1	18	0 (0-0)	0	0.0 (0.0-4.5)	0
2015/03/23	18:13	花蓮壽豐外海23公里	6.0	26	0 (0-0)	0	0.0 (0.0-0.0)	0
2015/04/20	09:42	宜蘭南澳外海69公里	6.3	18	0 (0-0)	1	0.0 (0.0-0.0)	0
2016/02/06	03:57	高雄市美濃區	6.4	17	12 (5-30)	2+115	252 (179.2-545.8)	>170

2010 Jiasian earthquake vs. 2016 Meinong earthquake

Source	Jiasian	Meinong
Date	2010/3/4	2016/2/6
Time	8:10 a.m.	3:57 a.m.
Magnitude	6.4	6.4 / 6.6
Epicenter	N22.97, E120.71	N22.93, E120.54
Depth	5 km / 22.6 km	16.7 km

ESLE Results	Jiasian	Meinong
Casualties	1 (1-3)	12 (5-30)
Insurance Claims (million NT$)	2.6 (1.8-4.5)	528.7 (179.2-545.8)
No. of Damaged Buildings	~36	~357

- The magnitude and the focal depth were similar
- The epicenters located very close (about 18 km)
- ESLE predicted differences caused by the two earthquakes



Concluding Remarks

Future Development

- Improve precision and completeness of **inventory database**
  - Integrate with National Geographical Information System (NGIS)
- Corporate with academia, industry and government to develop **analysis models**
  - Emphasize the evaluation of *system performance*
  - Emphasize the assessment of *social impacts* and *economic losses*
    - Such as casualty, repair cost, restoration time, required material and man-power, etc
- Use of **Open GIS**

Thank You for Attention