



liquefact

This research has been carried out within the framework of the European LIQUEFACT project. The LIQUEFACT project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No. 700748



IL PROGETTO LIQUEFACT IN EMILIA-ROMAGNA - webinar, 17/02/2021

9:30 – 9:50 Saluti e introduzione

9:50 - 10:05 **Il progetto europeo LIQUEFACT** - *Lai C.G.*

10:05 - 10:20 **Il supporto a LIQUEFACT della Regione Emilia-Romagna e delle Amministrazioni Locali** - *Martelli L.*

10:20 - 10:40 **Zonazione multi-scala del rischio di liquefazione sismo-indotta. Microzonazione del Comune di Cavezzo (Modena)** - *Lai C.G., Meisina C., Bozzoni F.*

10:40 - 11:00 **Valutazione della vulnerabilità di strutture ed infrastrutture alla liquefazione sismo-indotta dei terreni. Sviluppo di modelli di fragilità empirici per edifici in muratura utilizzando i dati della Regione Emilia-Romagna.** - *Di Ludovico M., Chiaradonna A., Bilotta E., Flora A., Prota A.*

11:00 - 11:20 **Analisi del rischio liquefazione sismo-indotta a scala urbana: applicazione al Comune di Terre del Reno.** *Modoni G., Spacagna R.L., Paoletta L., D'Apuzzo M., Evangelisti A.*

11:20 - 11:40 **Tecniche di mitigazione del rischio liquefazione sismo-indotta dei terreni.** *Flora A., Bilotta E., Chiaradonna A., Fasano G., Lirer S., Mele L., Nappa V.*

11:40 - 12:00 **Modellazione fisica in centrifuga delle tecniche di mitigazione del rischio liquefazione sismo-indotta** *Fioravante V., Giretti D., Airoldi S., Moglie J.*

12:00 - 12:20 **Valutazione dell'efficacia delle tecniche di mitigazione: il campo prova di Pieve di Cento** *Pingue L., Siepi M.*

12:20 - 12:40 **LIQUEFACT software, a tool for liquefaction risk assessment, mitigation planning, and decision support** *Meslem A., Iversen H.*

12:40 – 13:00 Discussione e chiusura lavori

Analisi del rischio liquefazione sismo-indotta a scala urbana:
applicazione al Comune di Terre del Reno

Bologna, 17 febbraio 2021

IL PROGETTO LIQUEFACT IN EMILIA-ROMAGNA

Webinar
Mercoledì 17 febbraio 2021

Assessment and mitigation of liquefaction potential across Europe: a holistic approach to protect structures/infrastructures for improved resilience to earthquake-induced liquefaction disasters

ANALISI DEL RISCHIO LIQUEFAZIONE SISMO-INDOTTA A SCALA URBANA: APPLICAZIONE AL COMUNE DI TERRE DEL RENO

Giuseppe Modoni, Anna Baris, Mauro D'Apuzzo, Azzurra Evangelisti,
Luca Paoella, Rose Line Spacagna



Esposizione

E

x

Vulnerabilita'

V

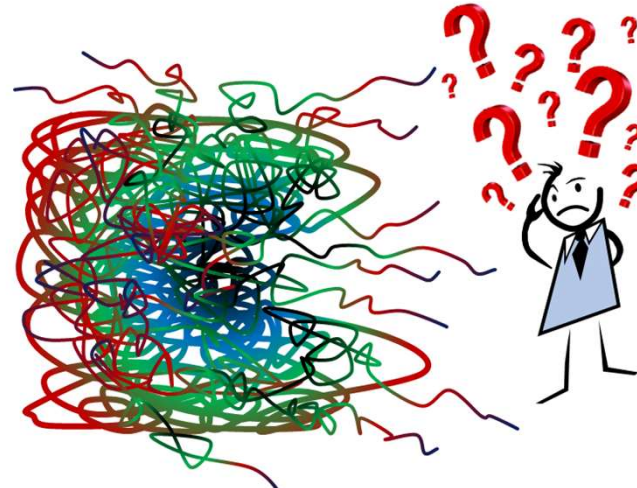
x

Pericolosità

H



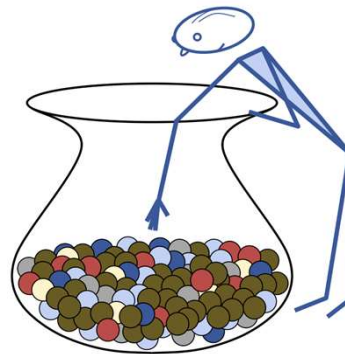
UNCERTAINTY



TIME

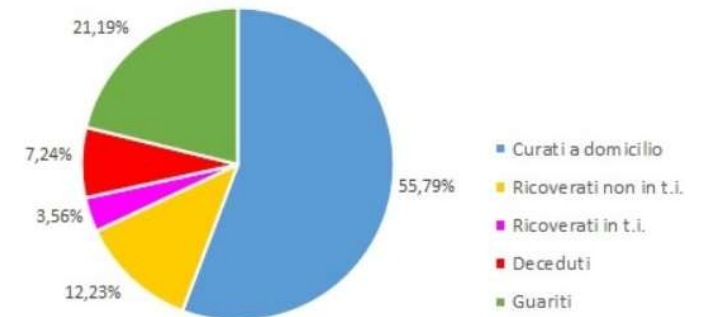


HAZARD OCCURRENCE



LIKELIHOOD OF DAMAGE

Distribuzione dei contagiati totali (%)





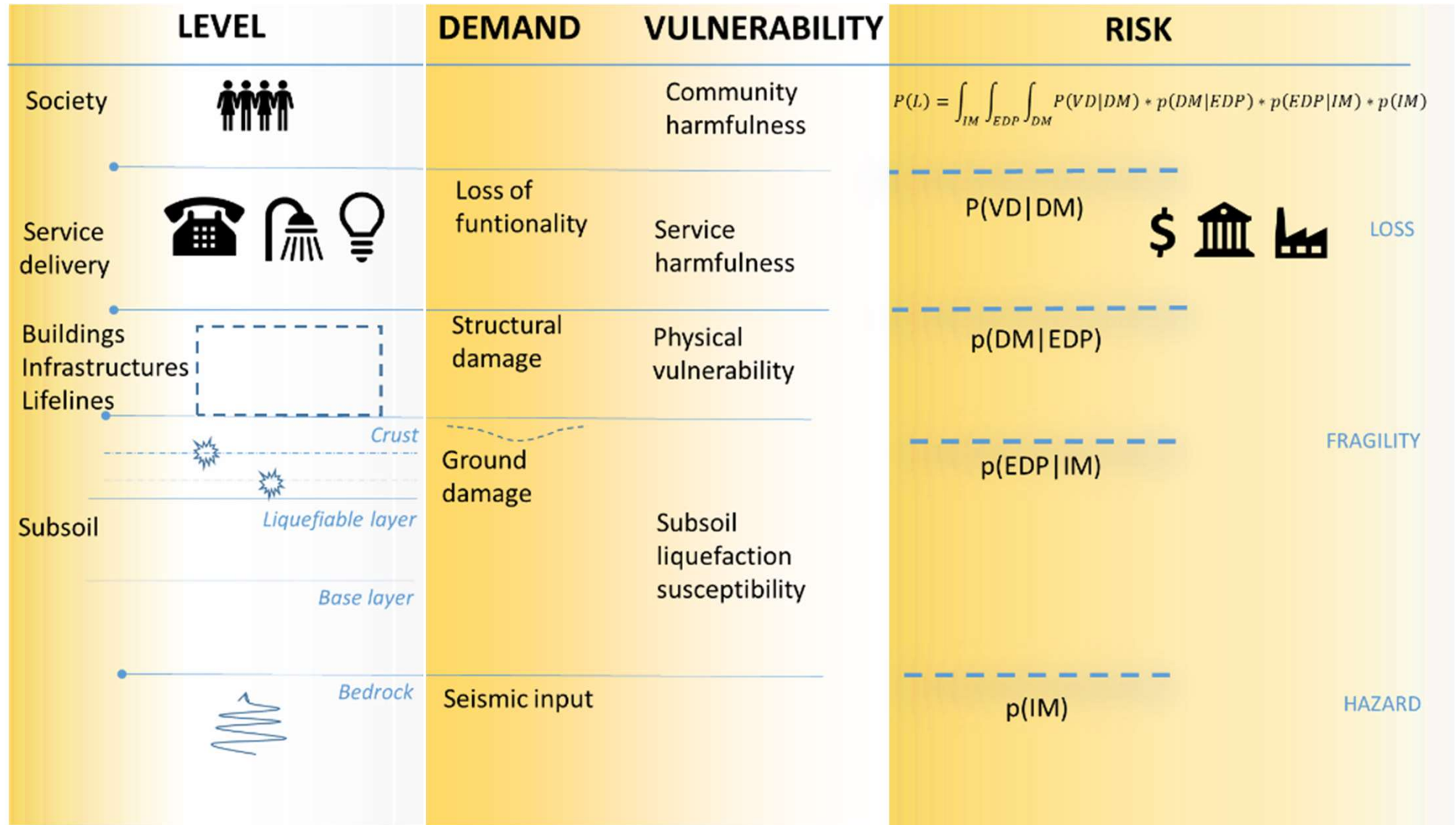
PROBABILISTIC RISK

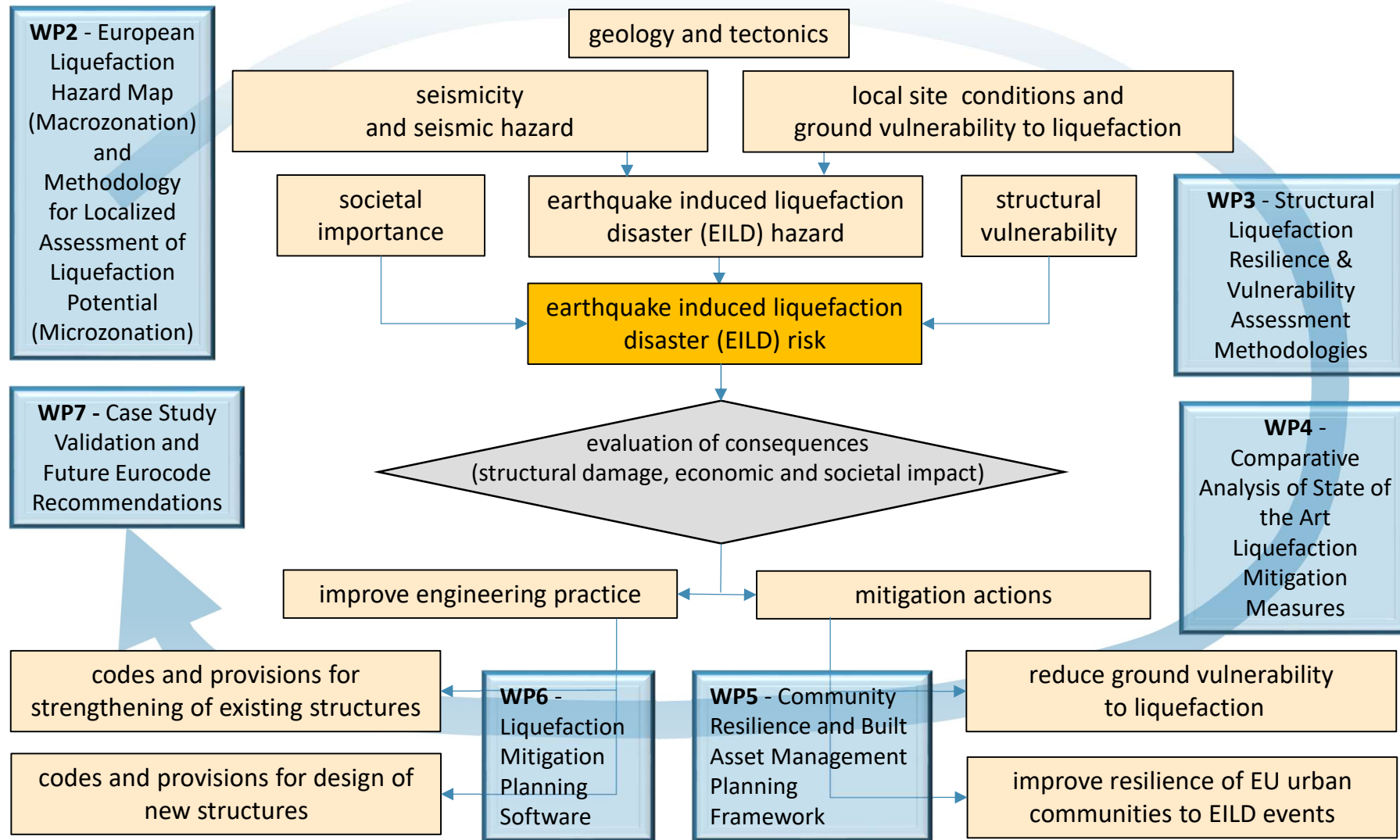
$$p(IM)$$

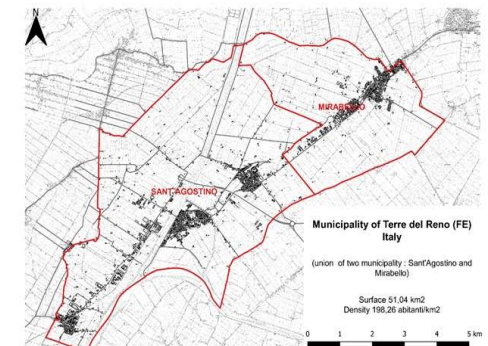
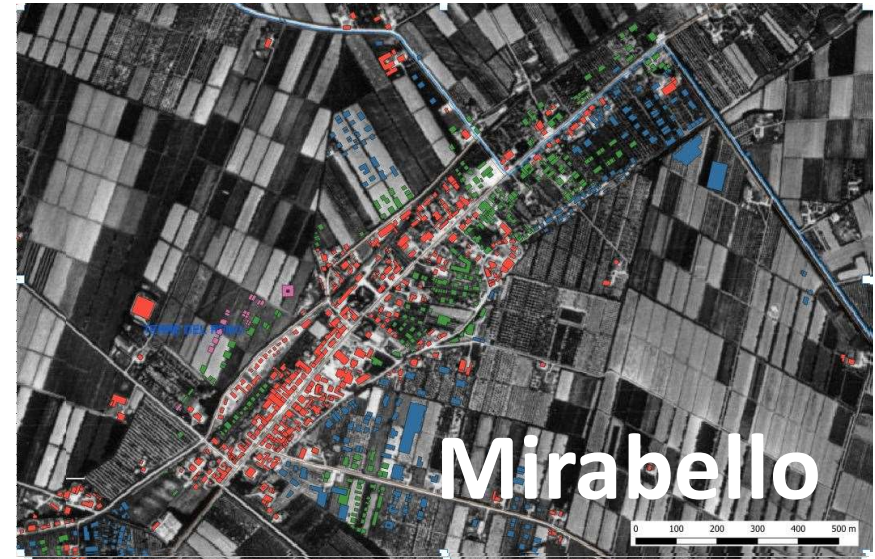
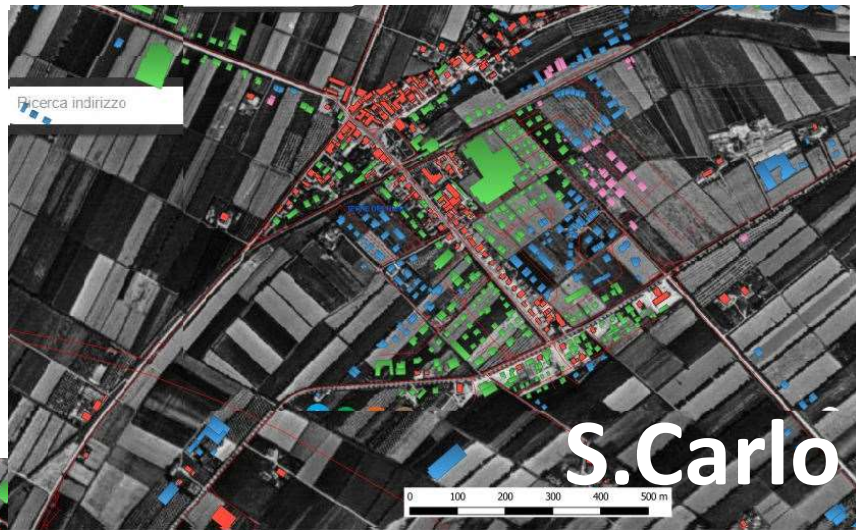


PEER - Cornell & Krawinkler (2000)

HOLISTIC LIQUEFACTION RISK: A CASCADE ANALYSIS







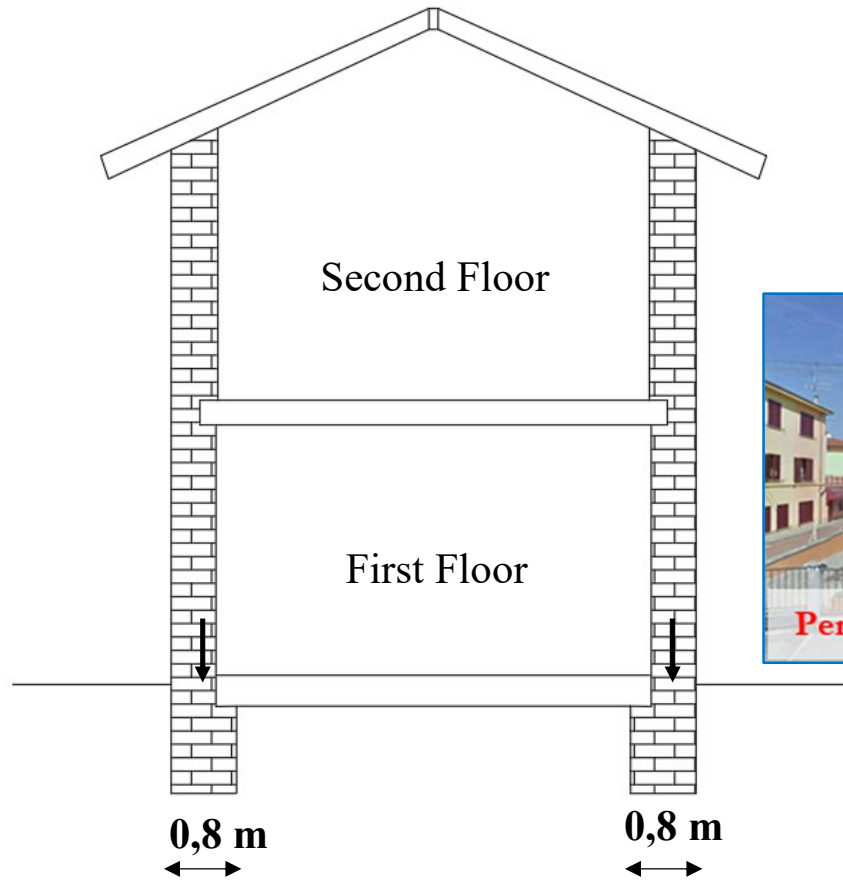
Aerial Imagery 1954



Analisi del rischio liquefazione sismo-indotta a scala urbana:
applicazione al Comune di Terre del Reno

Bologna, 17 febbraio 2021

TERRE DEL RENO (ITA) May 20th 2012 $M_w=6.1$



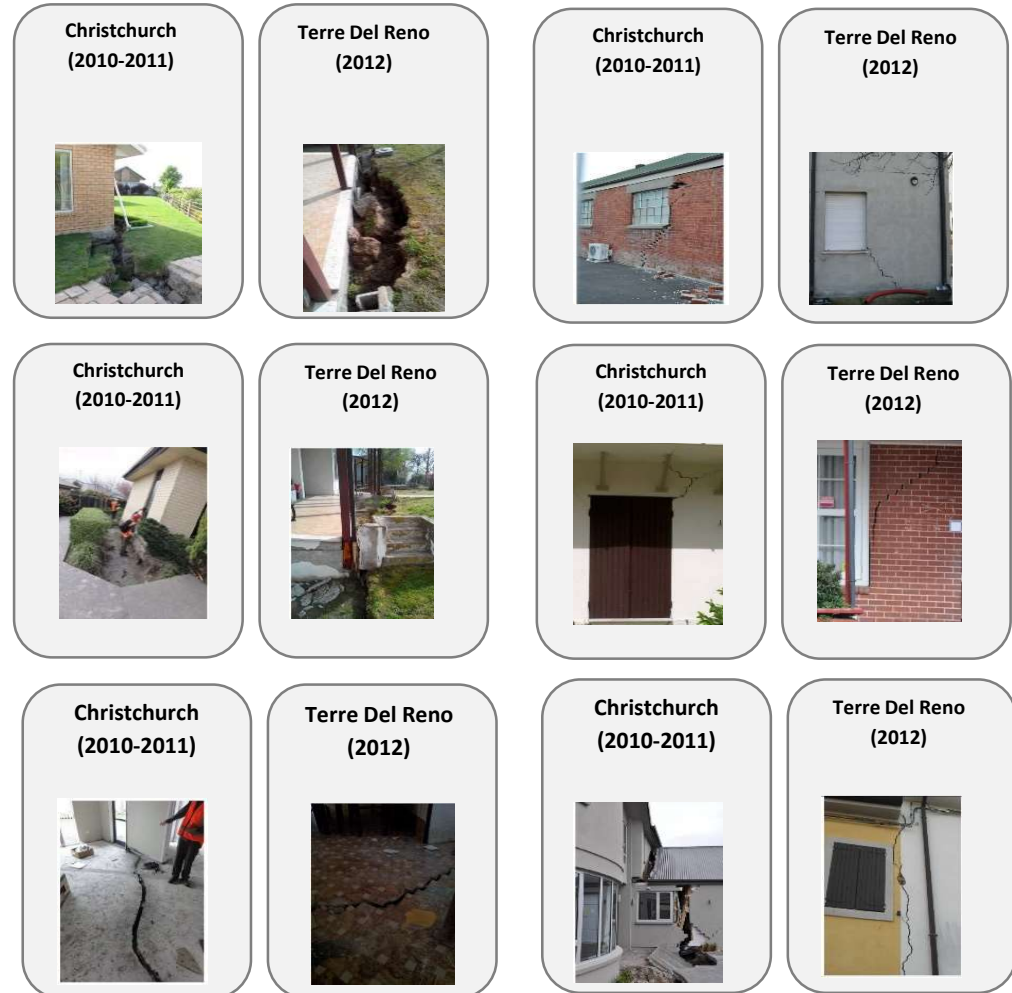
**SAMPLE BUILDING IN THE
MUNICIPALITY OF TERRE DEL RENO**

Modello Unico Digitale per l'Edilizia MUDE

TERRE DEL RENO (ITA) May 20th 2012 $M_w=6.1$

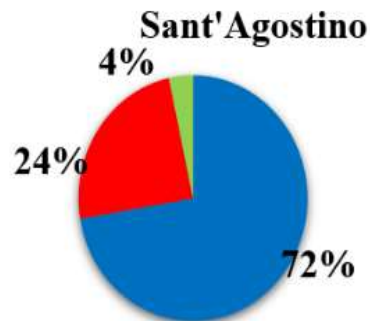
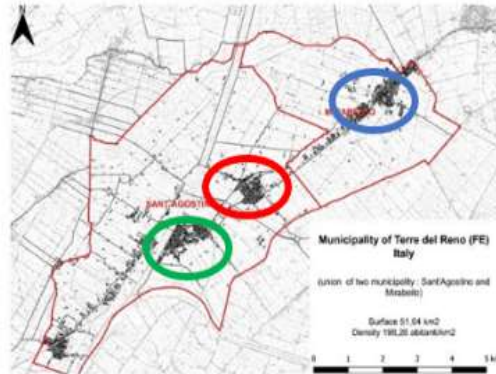
Dwelling Foundation Damage Categories			
Type of Damage	Minor	Moderate	Major
Stretching 	0 to 5mm	5 to 30mm	>30mm
Hogging 	0 to 20mm	20 to 50mm	>50mm
Dishing 	0 to 20mm	20 to 50mm	>50mm
Racking/Twisting 	0 to 10mm	10 to 30mm	>30mm
Tilting 	0 to 20mm	20 to 50mm	>50mm
Abrupt Differential Movement 	0 to 10mm	10 to 20mm	>20mm
Global Settlement 	0 to 50mm	50 to 100mm	>100mm

VAN BALLEGOOY (2014)

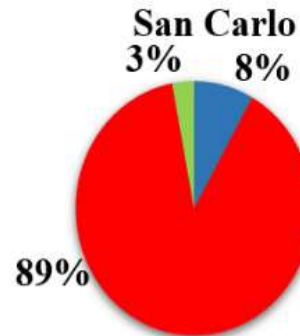


Modello Unico Digitale per l'Edilizia MUDE

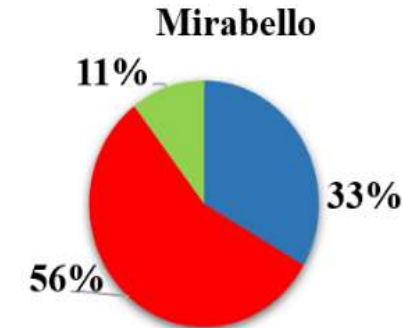
TERRE DEL RENO (ITA) May 20th 2012 $M_w=6.1$



Type of damage	Euro	%
Total	43000000	100
shaking	31000000	72%
liquefaction	10500000	24%
combined	1450000	3%



Type of damage	Euro	%
Total	35000000	100%
shaking	2900000	8%
liquefaction	31000000	89%
combined	1100000	3%



Type of damage	Euro	%
Total	36500000	100%
shaking	12000000	33%
liquefaction	20500000	56%
combined	3800000	10%



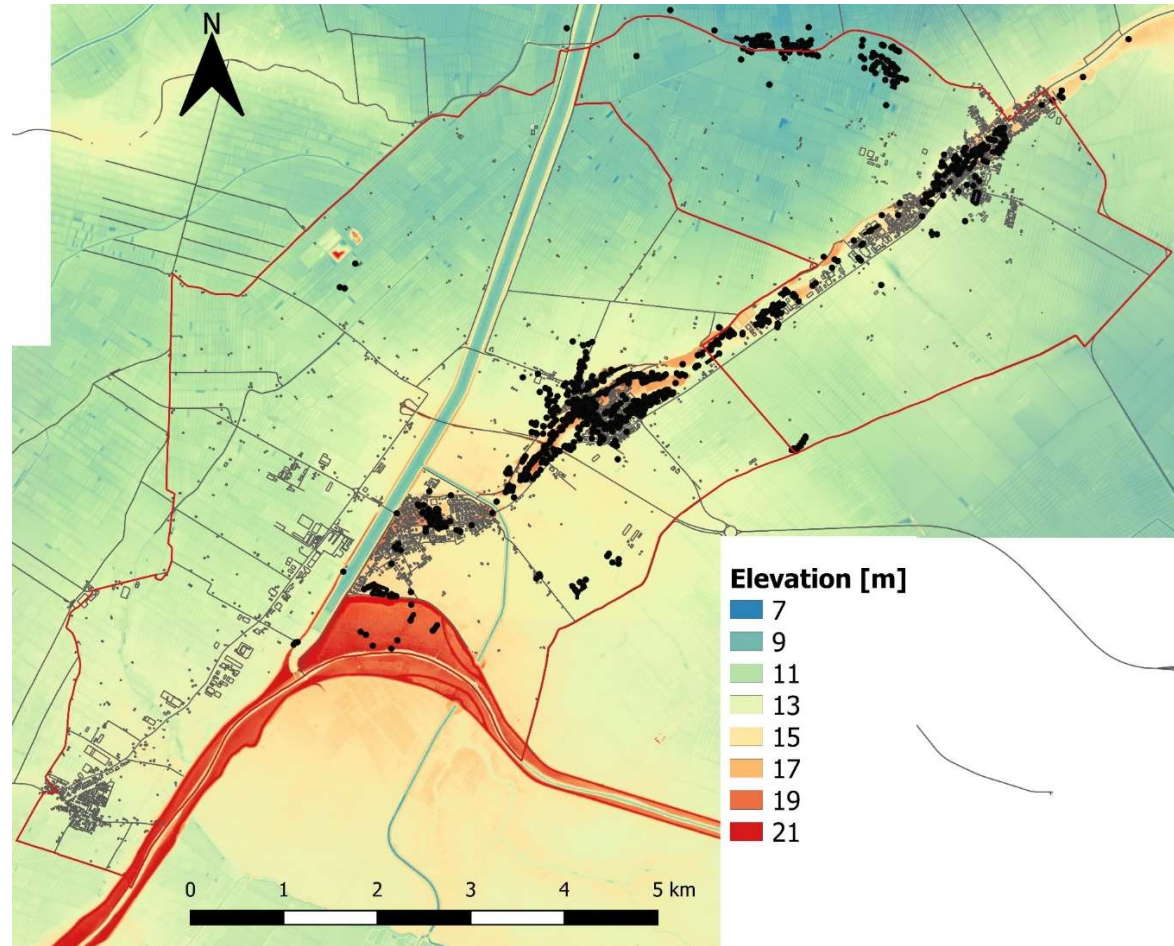
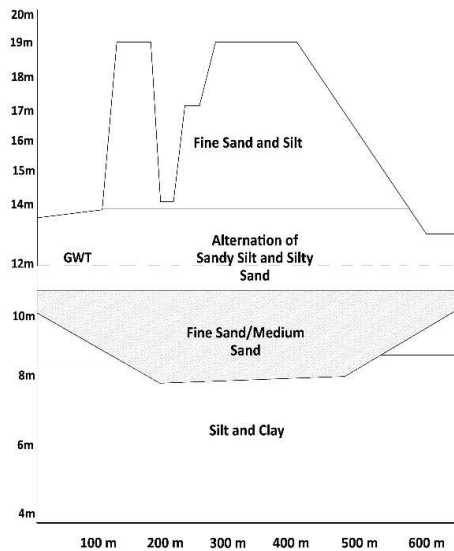
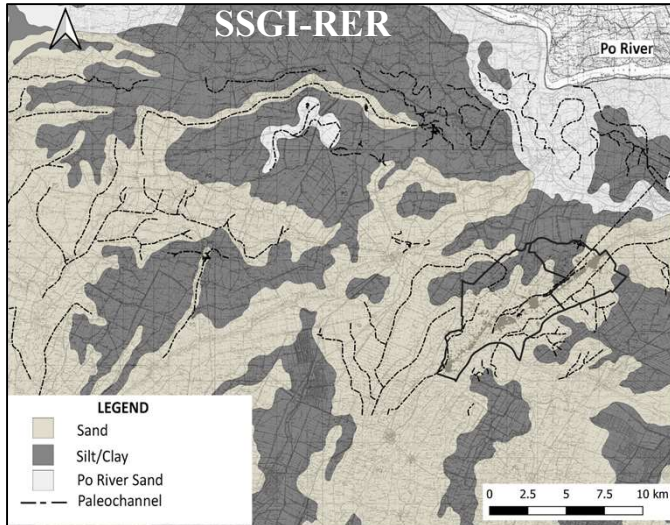
OPEN RICOSTRUZIONE

Monitora gli interventi per la ricostruzione in Emilia-Romagna

<https://openricostruzione.regione.emilia-romagna.it/>

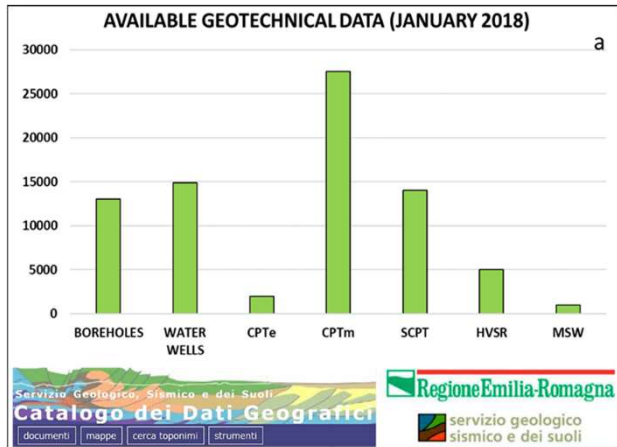
Update: November 30, 2018

TERRE DEL RENO (ITA) May 20th 2012 $M_w=6.1$

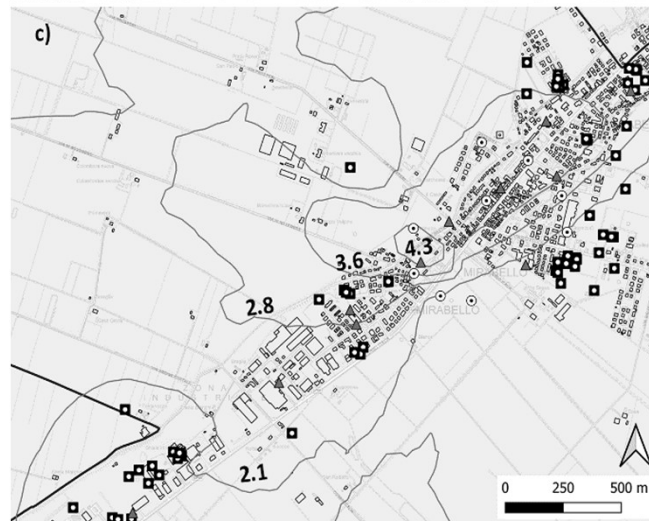
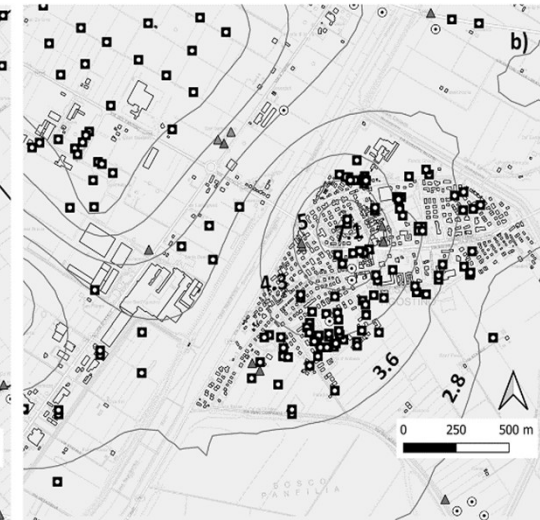
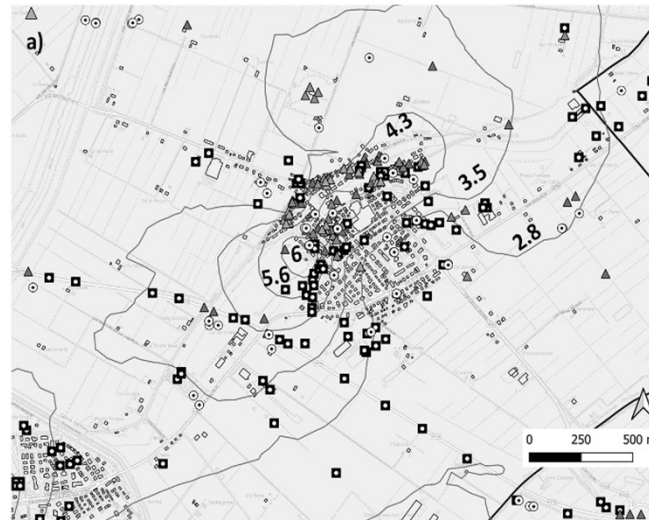


1457 - 1767/95

TERRE DEL RENO (ITA) May 20th 2012 $M_w=6.1$



≈85000 investigation

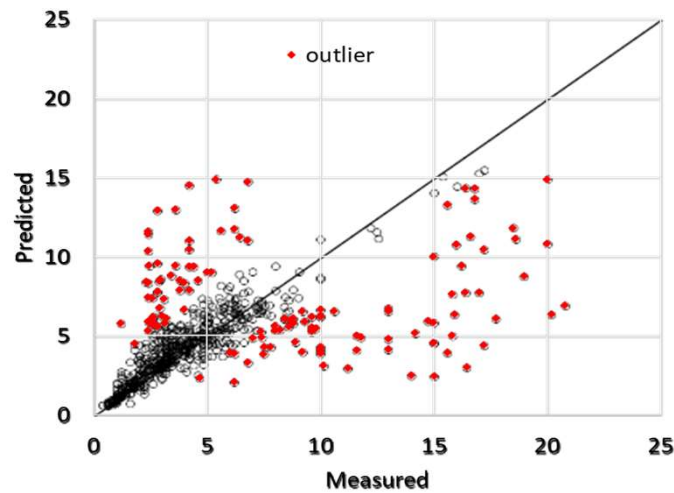
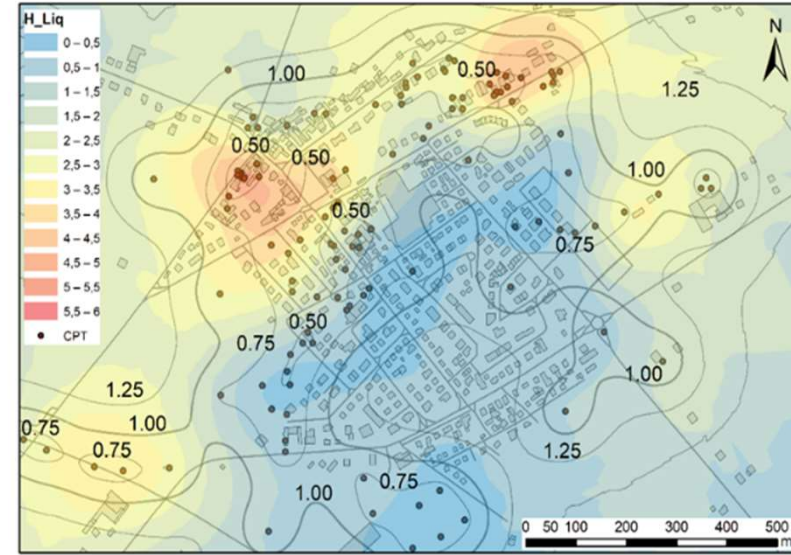
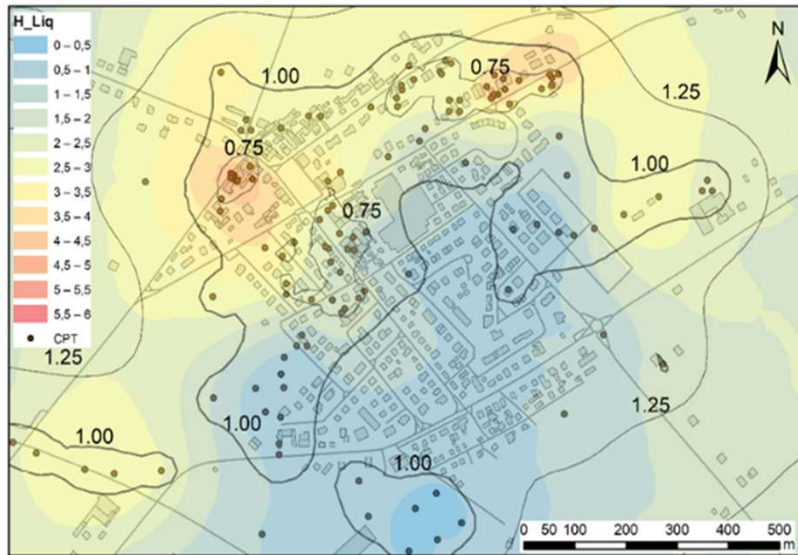


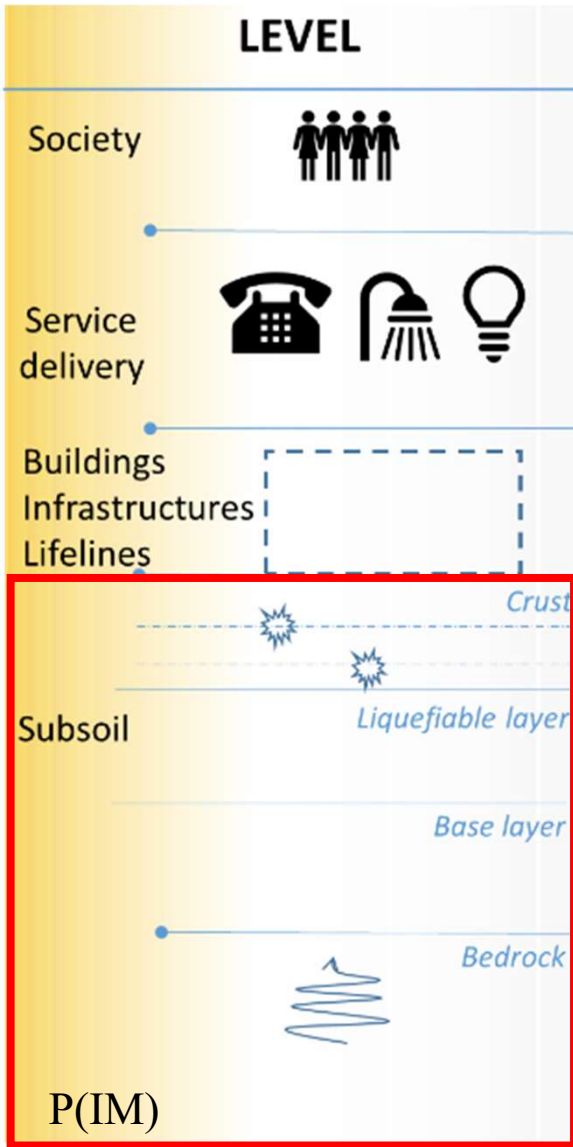
LEGEND

- CPTm
- ▲ CPTe/CPTu
- Borehole
- Groundwater depth

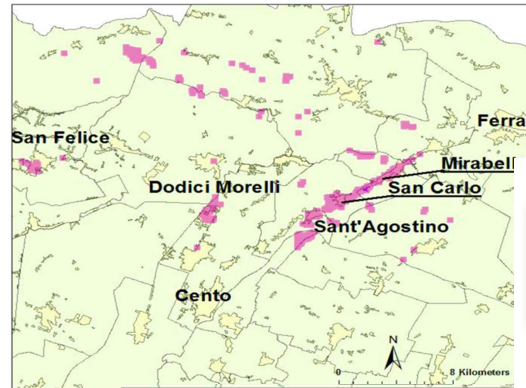
≈200 boreholes logs
 ≈ 800 CPTm or CPTe

TERRE DEL RENO (ITA) May 20th 2012 $M_w=6.1$

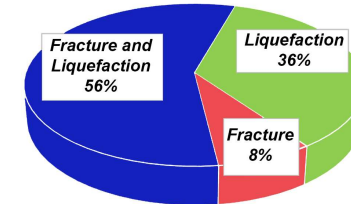




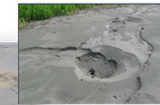
LAND DAMAGE CLASSIFICATION



EMERGEO (INGV, 2012)



Sand boil



Fracture

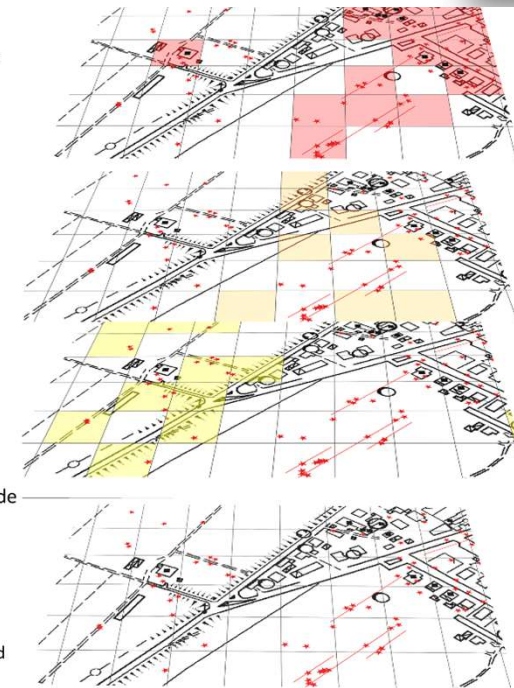


Damage Level 3: building damage, major cracks

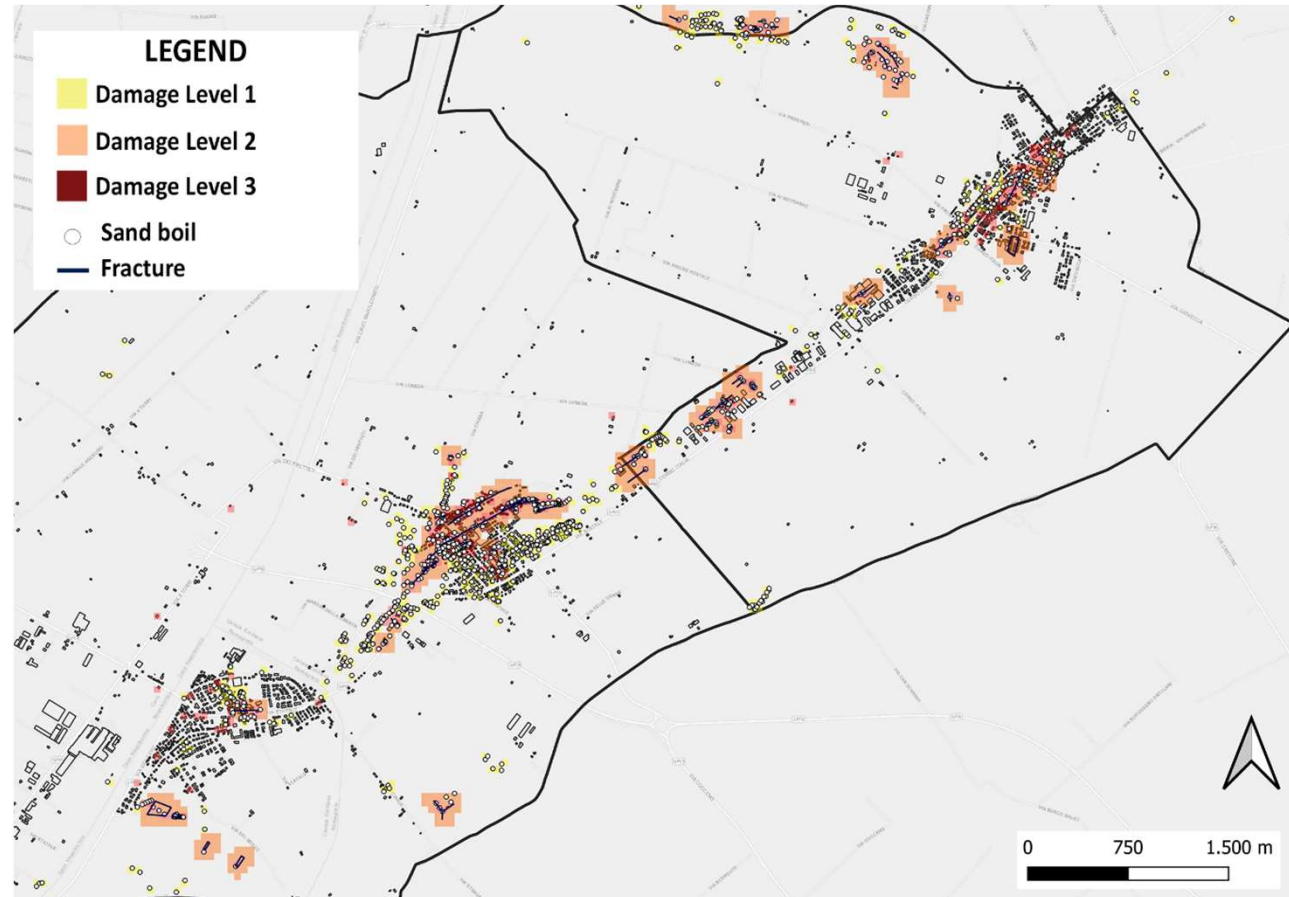
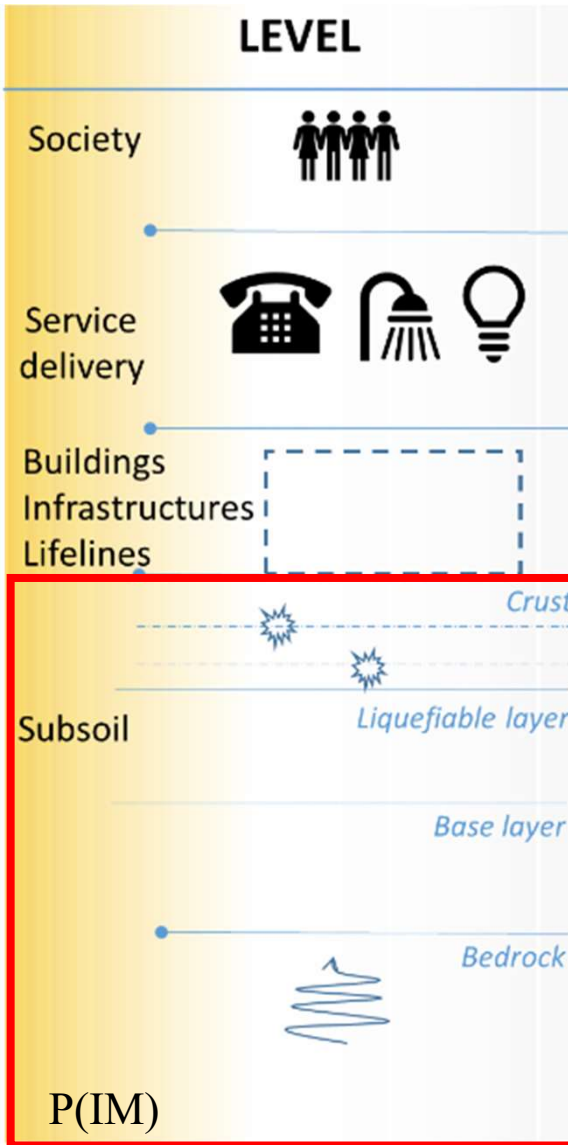
Damage Level 2: sand boils + minor crack

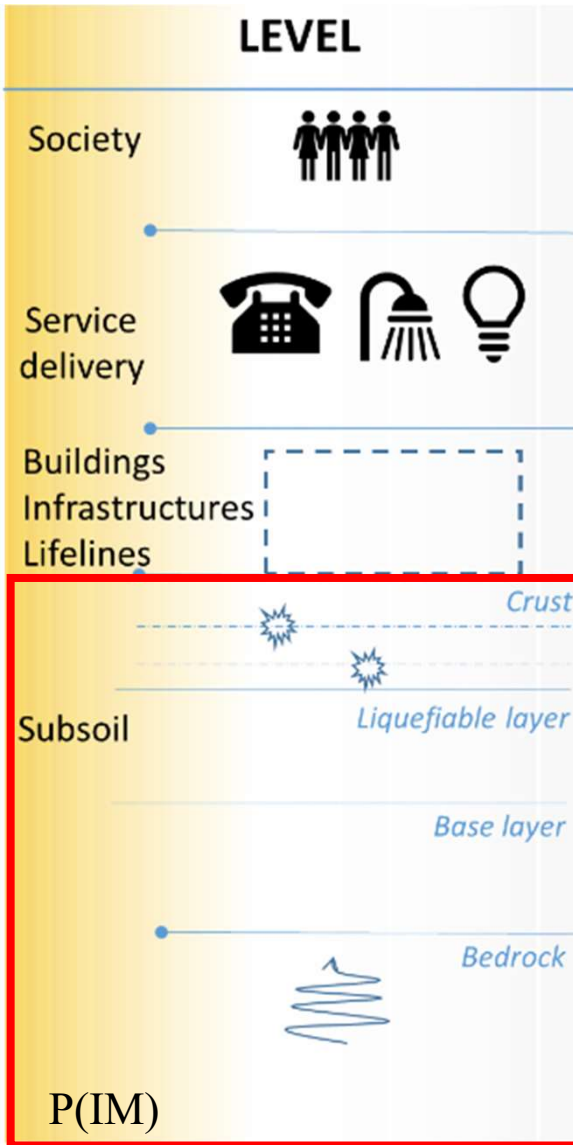
Damage Level 1: at least 1 sand boil is found inside the cell.

Overlapping of a 50x50 m grid to the liquefaction-induced damage observations.

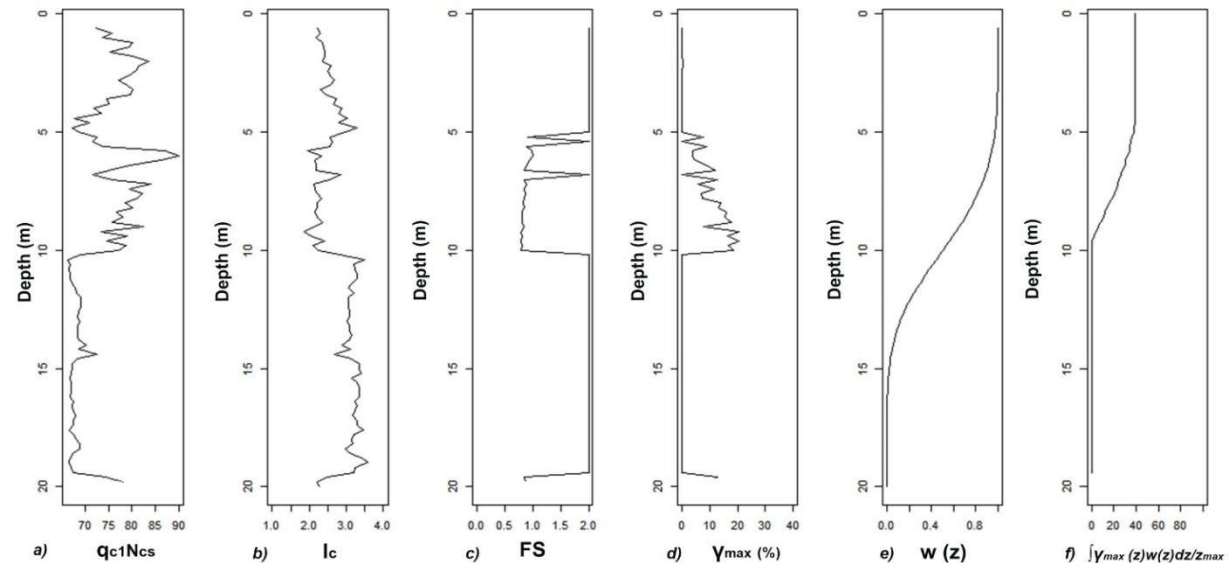
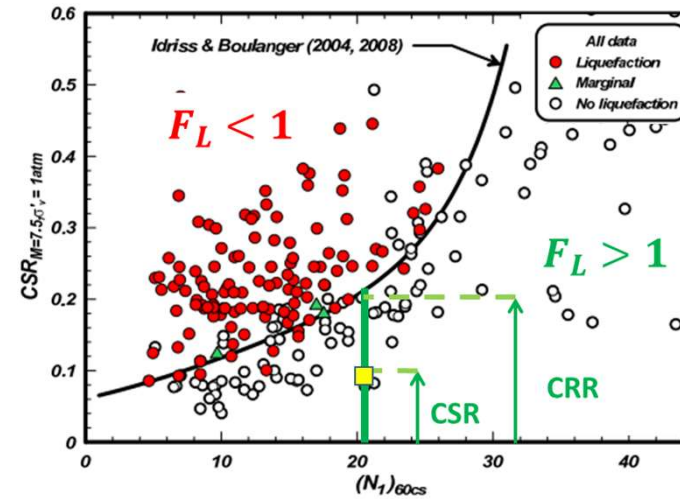


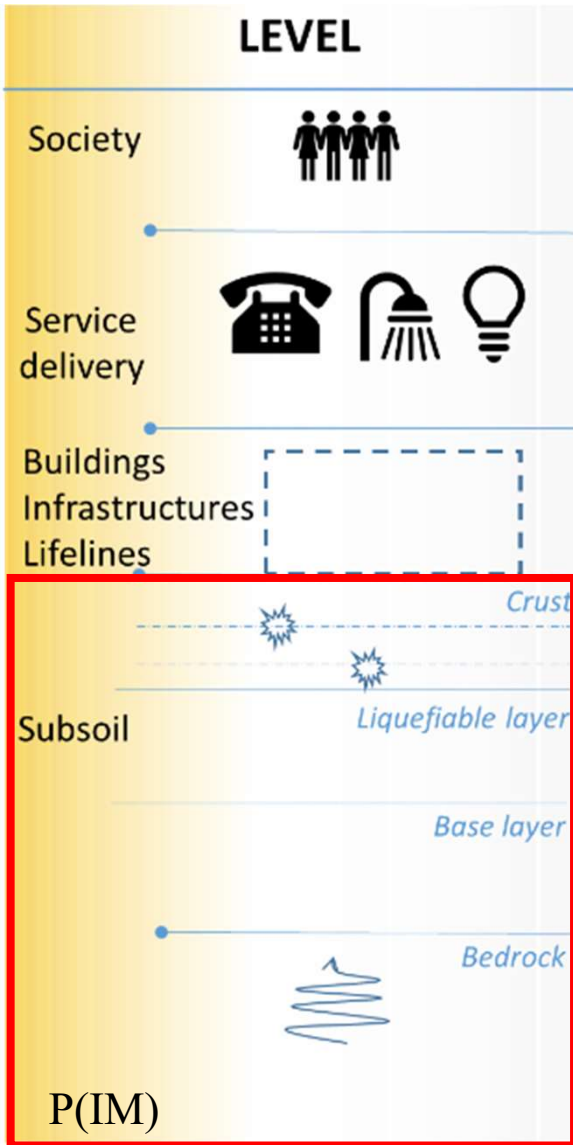
LAND DAMAGE CLASSIFICATION





LAND DAMAGE PREDICTION



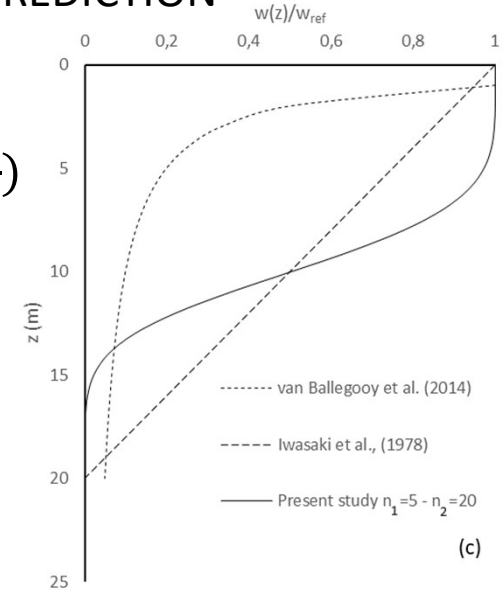


LAND DAMAGE PREDICTION

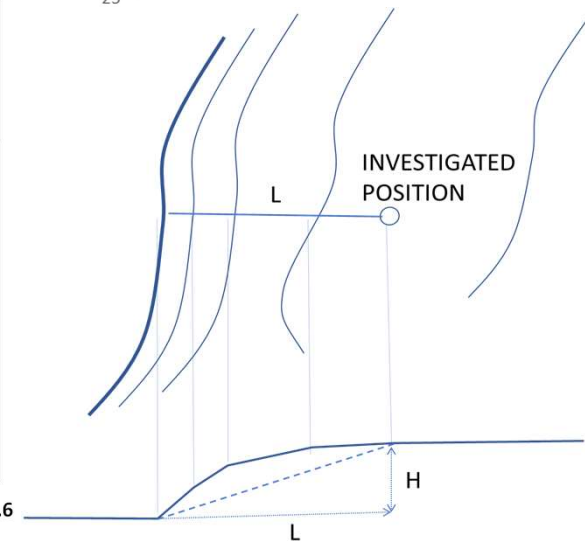
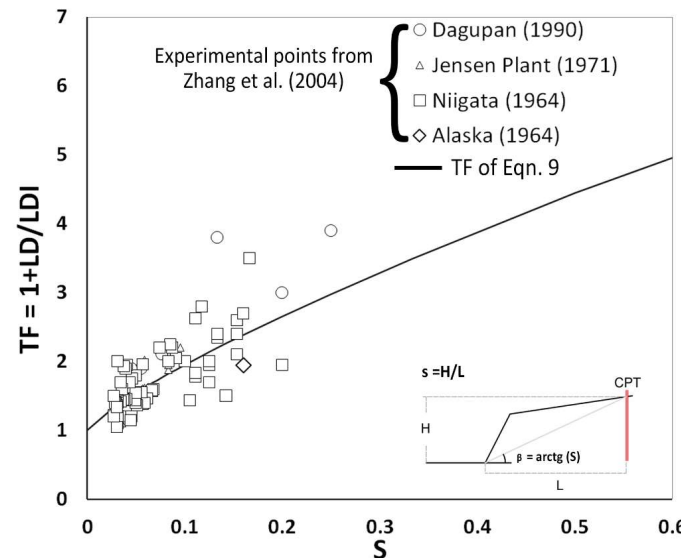
Stratigraphic effect

$$GLSN = TF \int_0^1 \gamma_{max} * w\left(\frac{z}{z_{max}}\right) d\left(\frac{z}{z_{max}}\right)$$

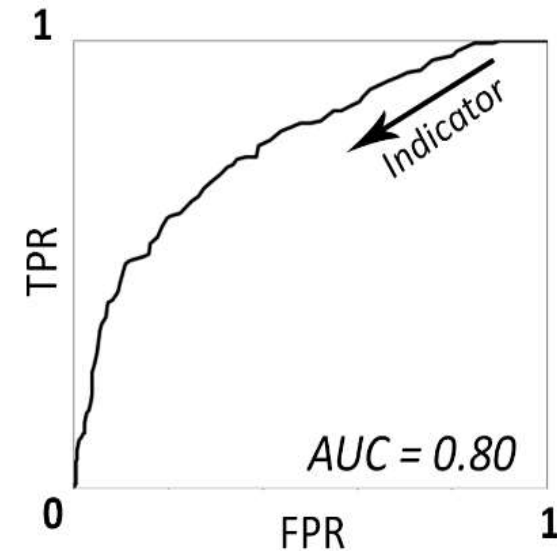
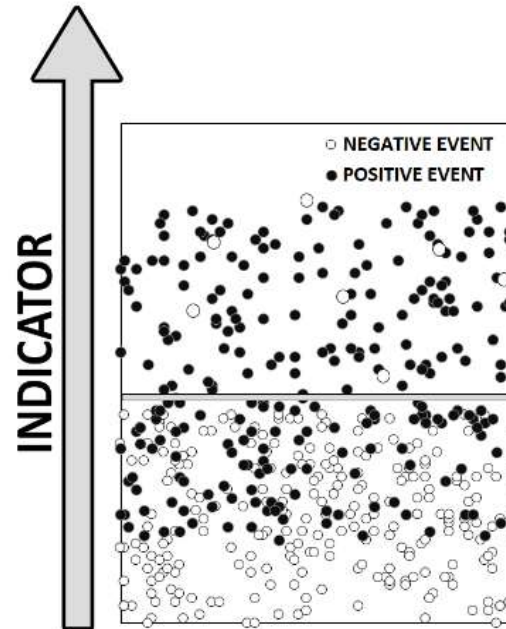
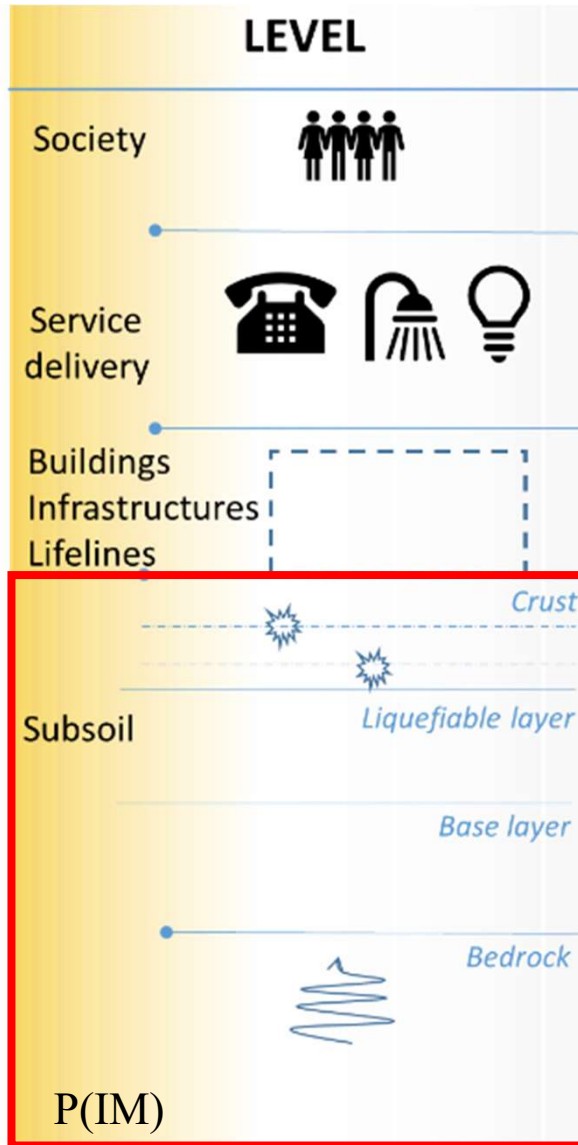
$$w\left(\frac{z}{z_{max}}\right) = 10 \cdot \left(1 - \frac{\pi}{2} \cdot \left(\arctan\left(\frac{z}{z_{max}}\right)\right)^{n_1}\right)^{n_2}$$



Topographic effect



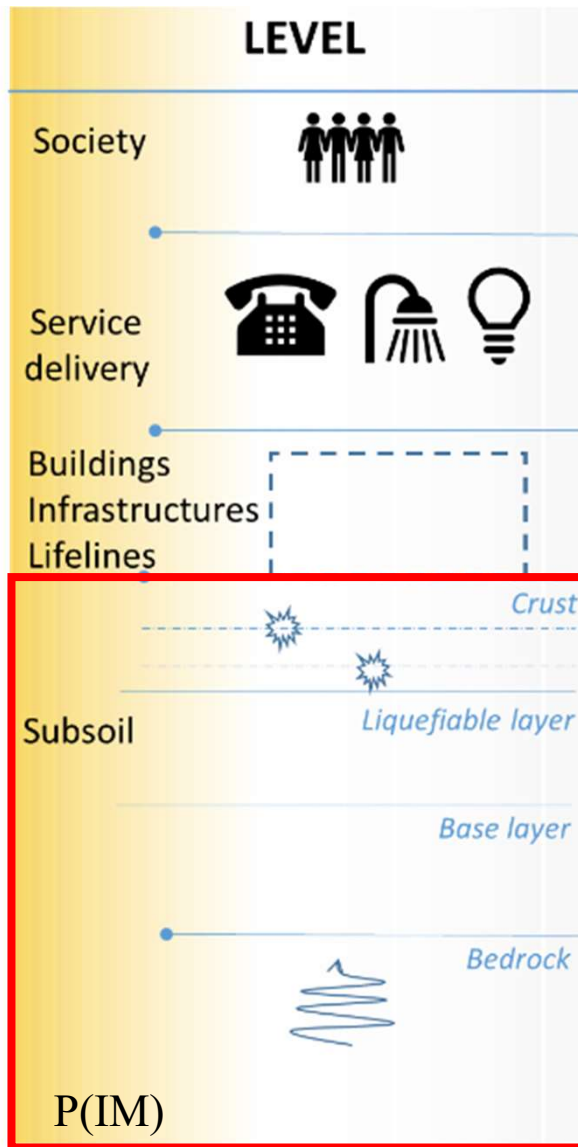
LAND DAMAGE PREDICTION



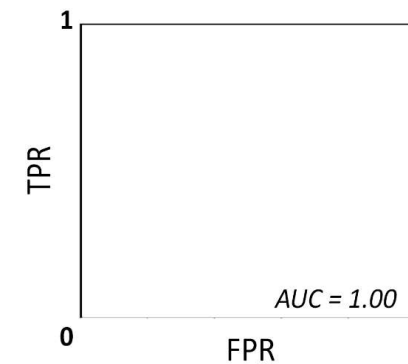
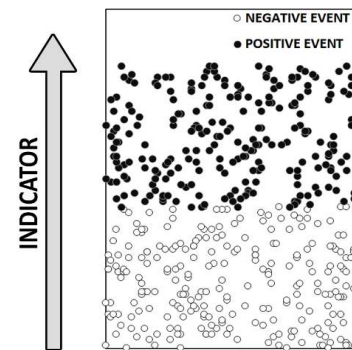
Kongar et al., 2015

$$MCC = \frac{TP \times TN - FP \times FN}{\sqrt{(TP + FP)(TP + TN)(FN + FP)(FN + TN)}}$$

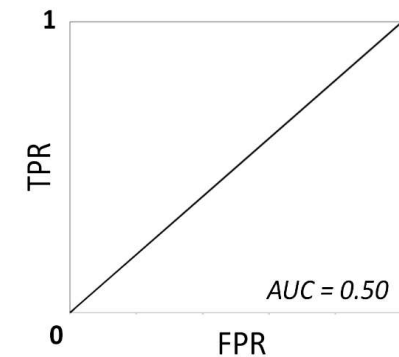
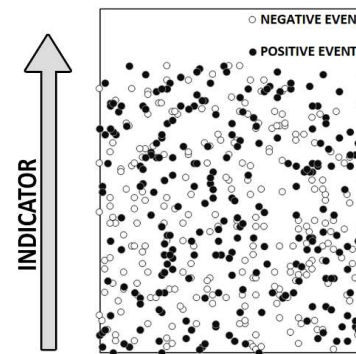
LAND DAMAGE PREDICTION



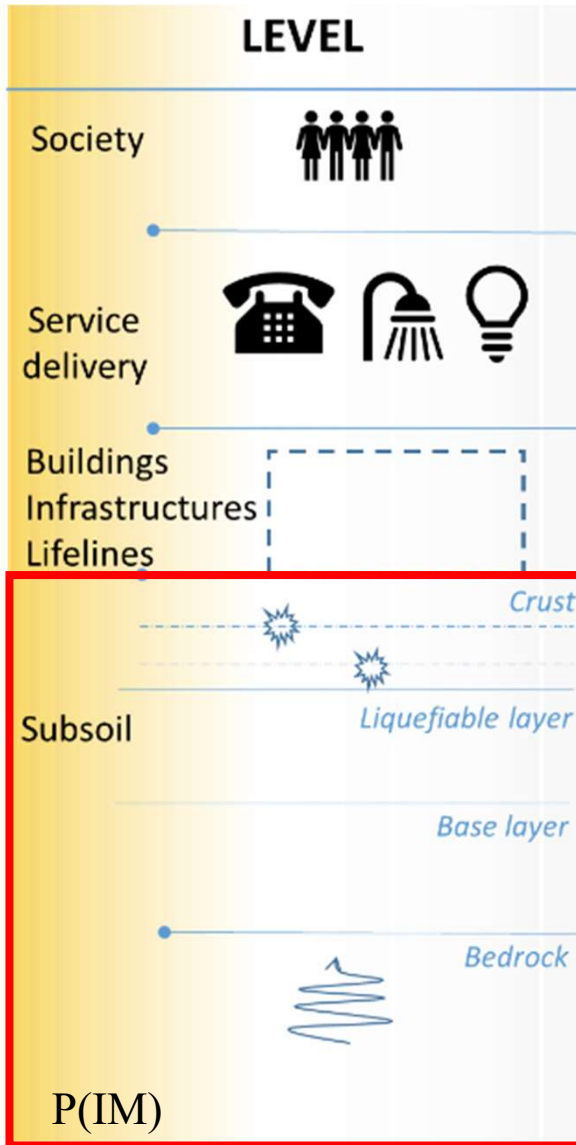
CASE A



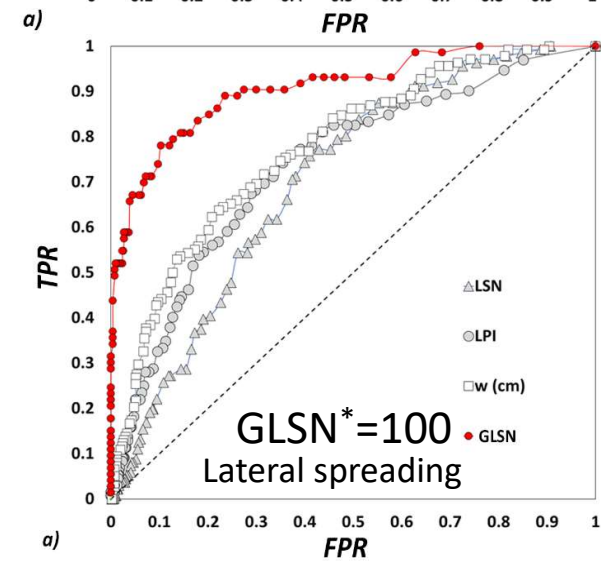
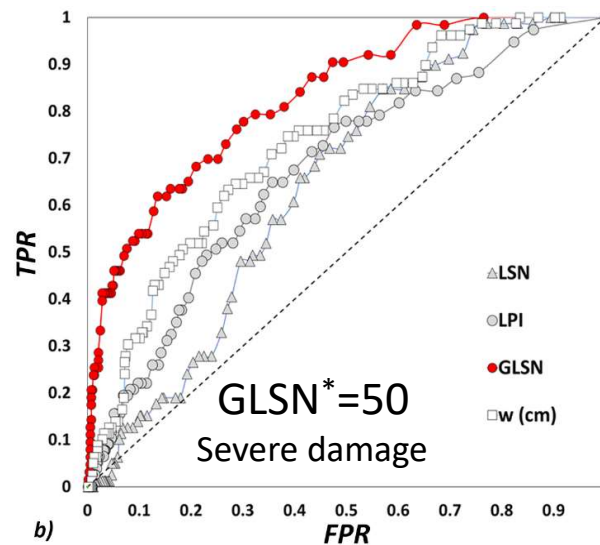
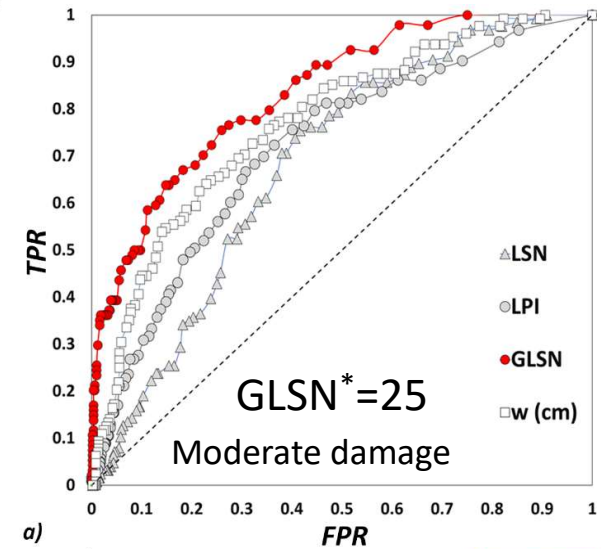
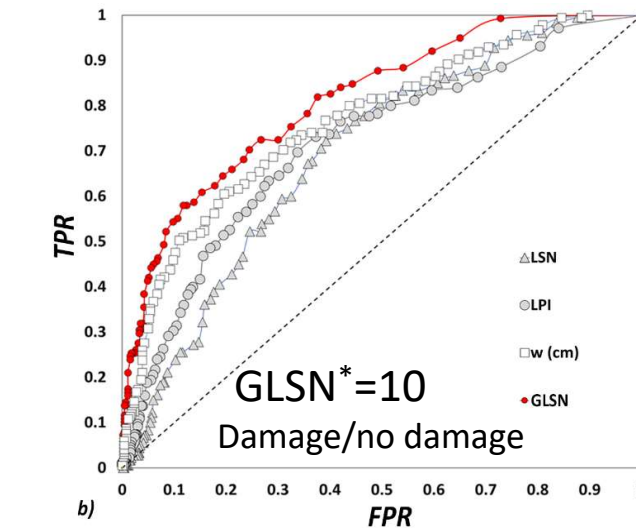
CASE B



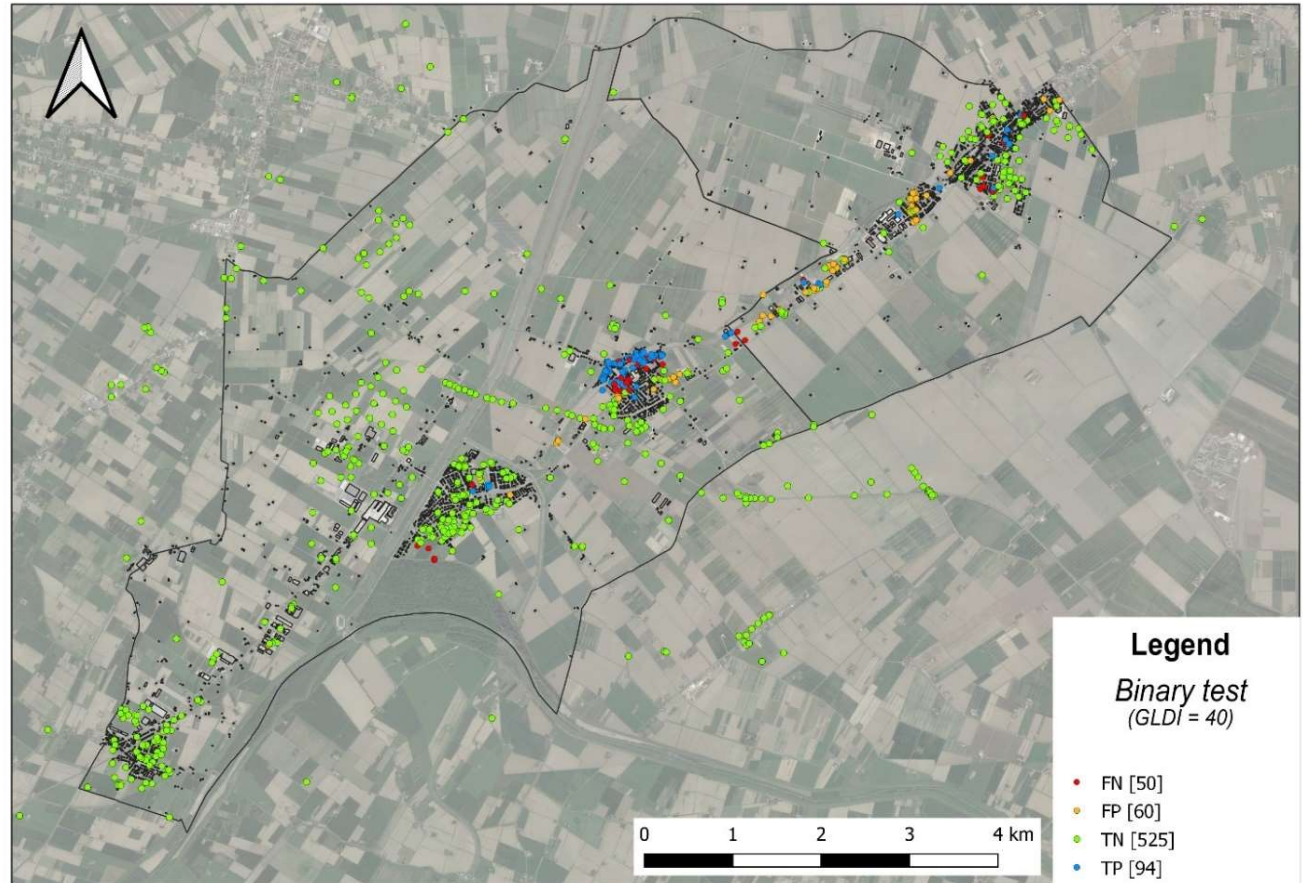
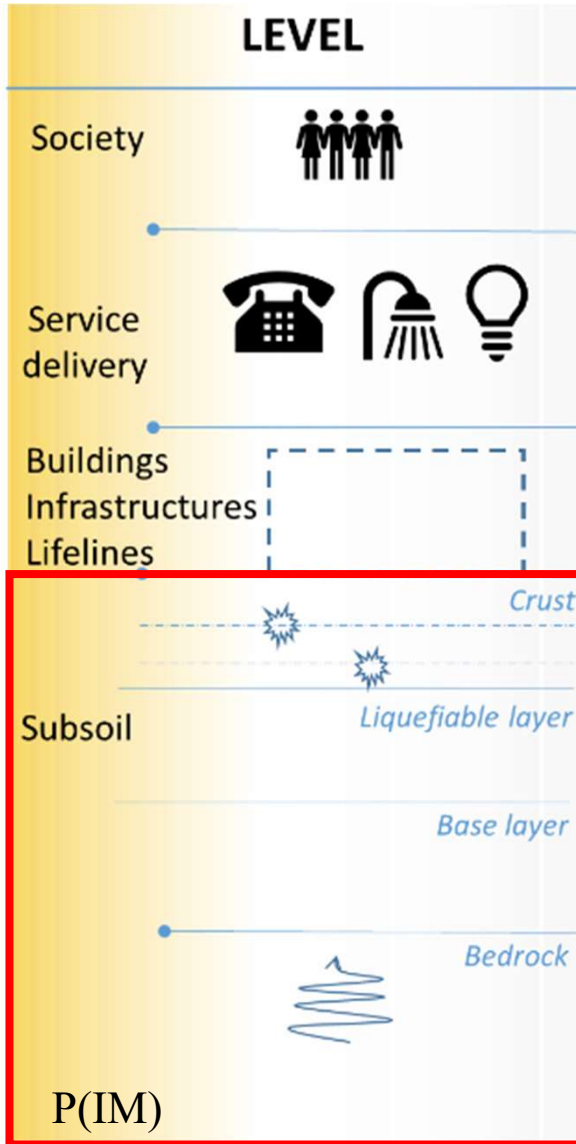
Kongar et al., 2015

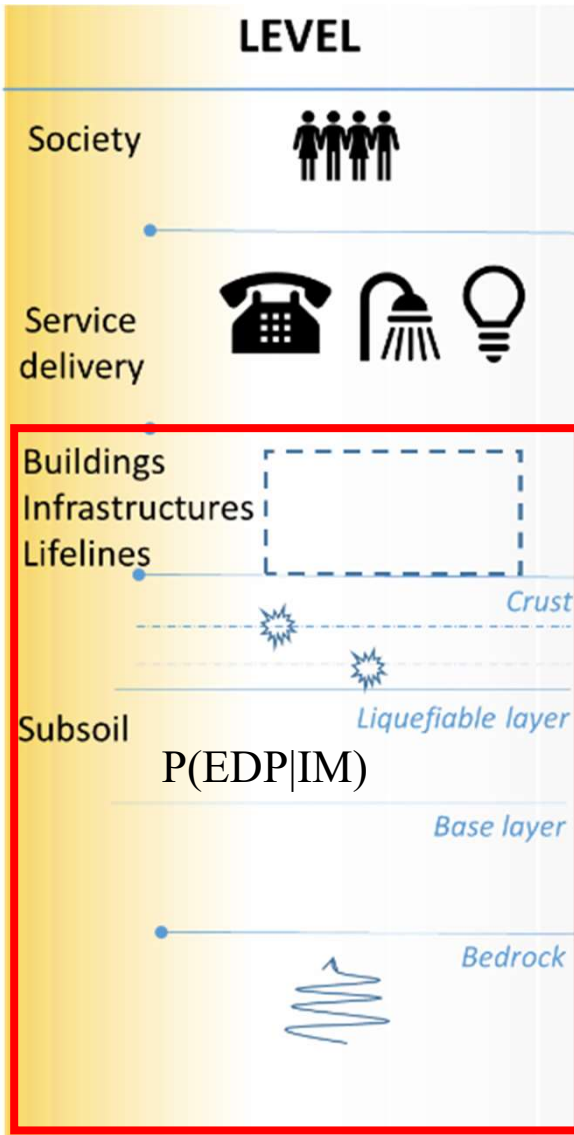


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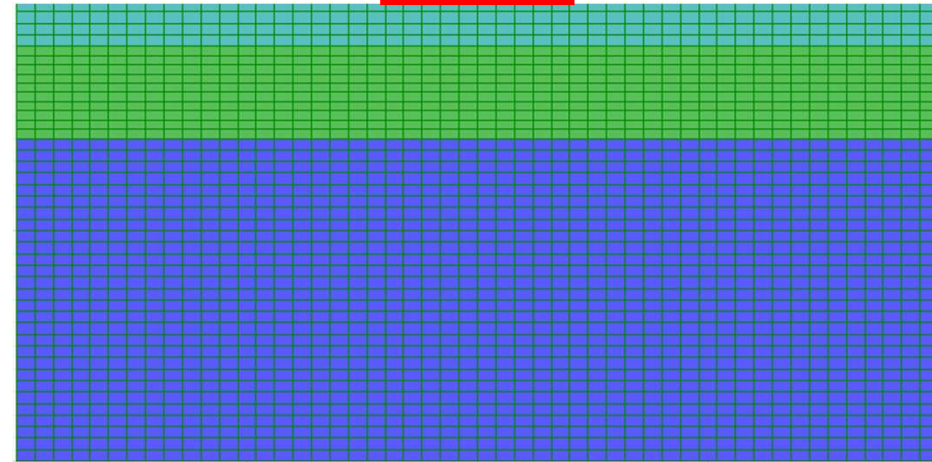


LAND DAMAGE PREDICTION



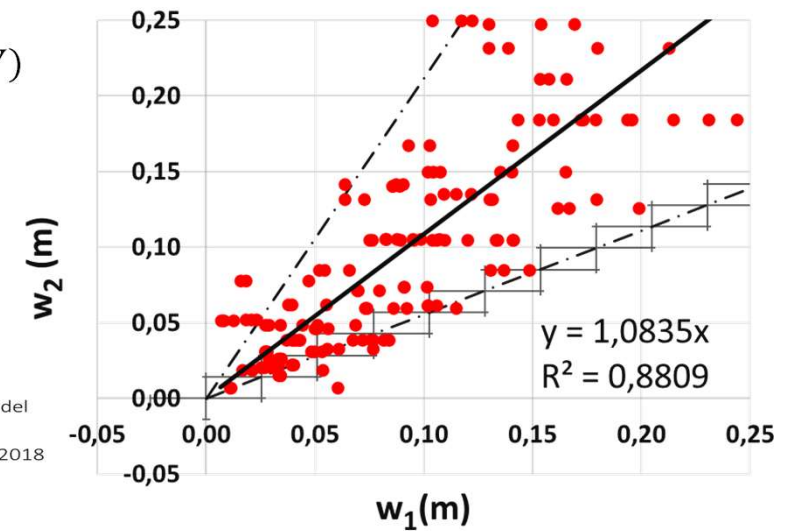


BUILDING DAMAGE PREDICTION

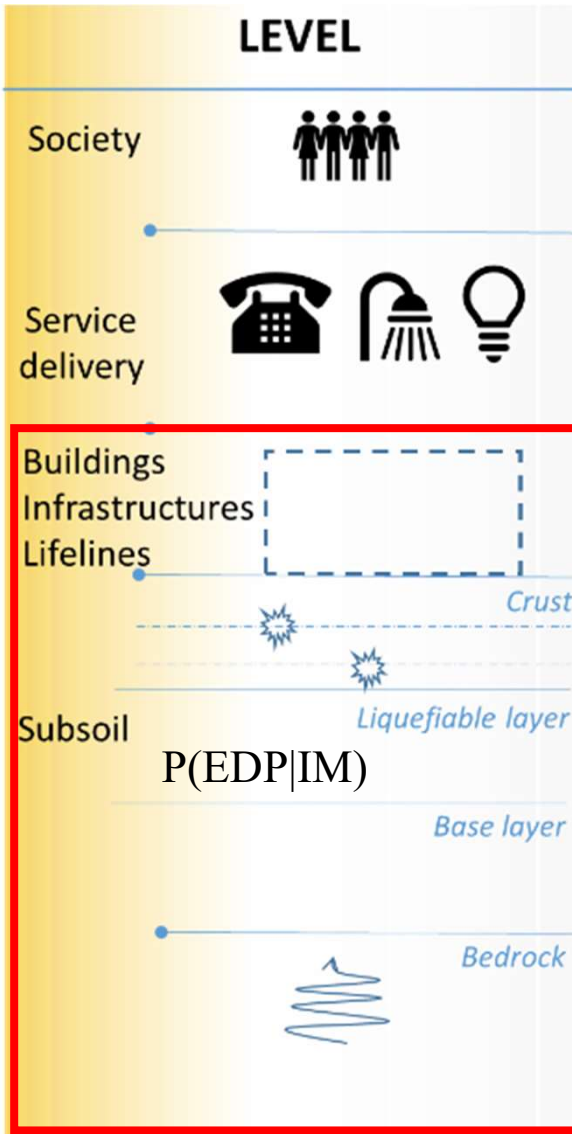


$$\ln(\bar{S})_{num} = f_{so} + f_{fnd} + f_{st} + s_0 \ln(CAV)$$

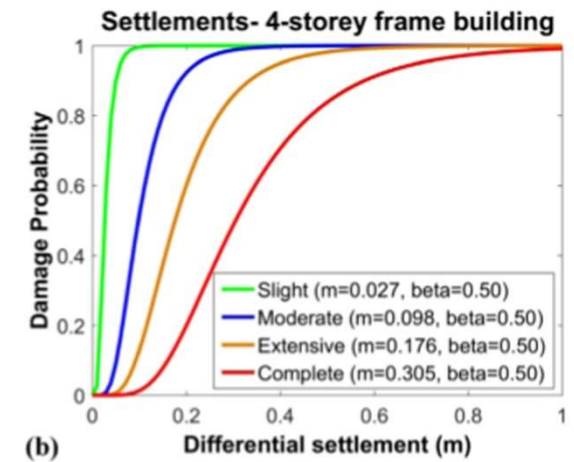
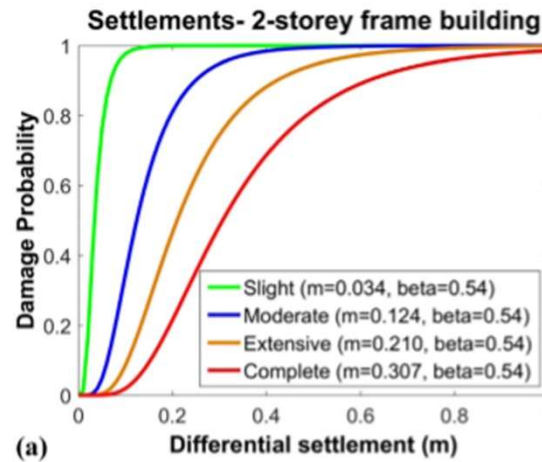
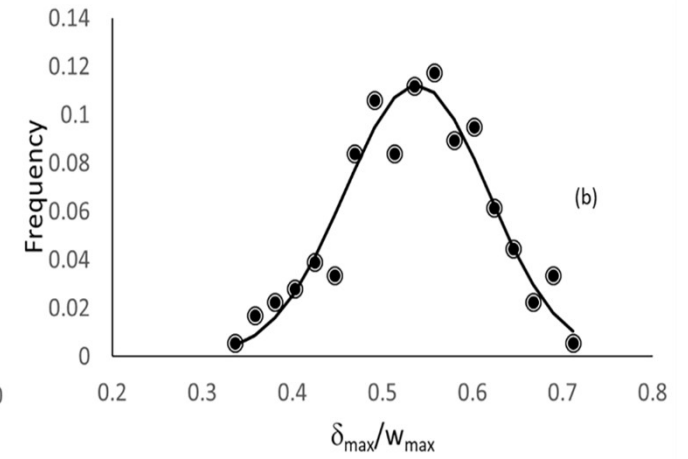
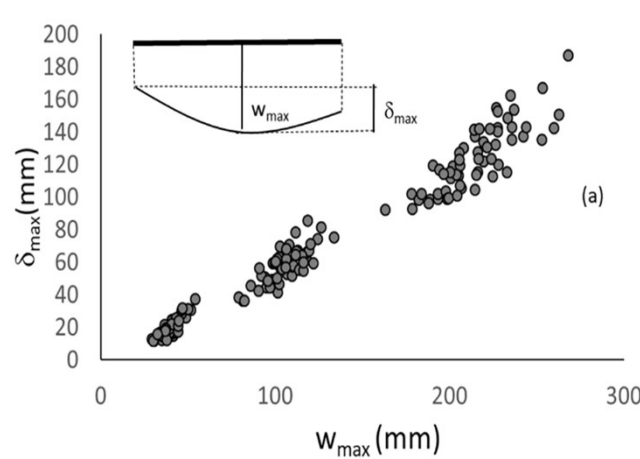
- Computed settlement
- Linear interpolation
- - - Acceptability range according to Bullock & Dashti, 2018
- w_1 Settlement computed using the numerical model
- w_2 Settlement computed using Bullock & Dashti, 2018



Bullock & Dashti, 2018



BUILDING DAMAGE PREDICTION



Fotopoulou et al., (2018)



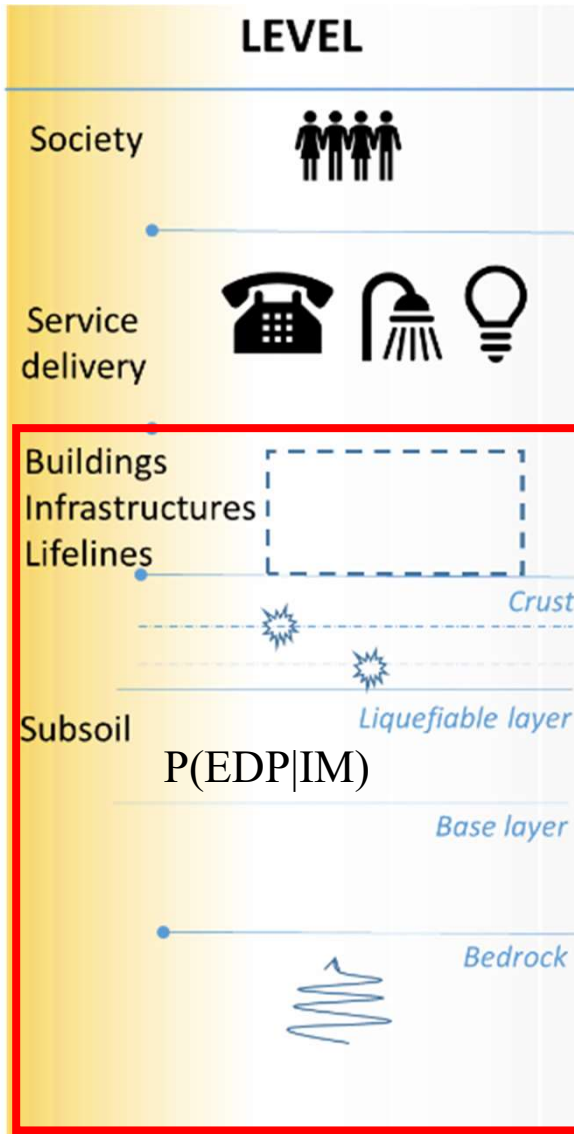
EXPOSURE

Direct damage



Indirect damage





BUILDING DAMAGE PREDICTION

		<i>Slight</i>	<i>Moderate</i>	<i>Extensive</i>	<i>Complete</i>
Edifici Residenziali	<i>rc/RC</i>	0.02	0.10	0.45	1.00
	<i>INV/PROD</i>	-	-	-	-
	<i>INV damage</i>	-	-	-	-
	<i>BRT (giorni)</i>	5	120	360	720
	<i>SIM</i>	0	0.5	1.0	1.0
Edifici Industriali	<i>rc/RC</i>	0.02	0.10	0.355	1.00
	<i>INV/PROD</i>	0.05	0.05	0.05	0.05
	<i>INV damage</i>	0.0	0.0	0.0	0.50
	<i>BRT (giorni)</i>	10	90	240	360
	<i>SIM</i>	0.5	1.0	1.0	1.0

Hazus
 (FEMA, 2003)

**PHYSICAL DAMAGE
 REPAIR COSTS**

$$\begin{aligned}
 \text{tot_rc}_i &= \text{rc}_i + \text{INV_DAM}_i \\
 &= \text{RC}_i \left(\sum_{ds} P_{ids} \cdot [(rc_i/RC_i)_{ds_i}] \right)
 \end{aligned}$$

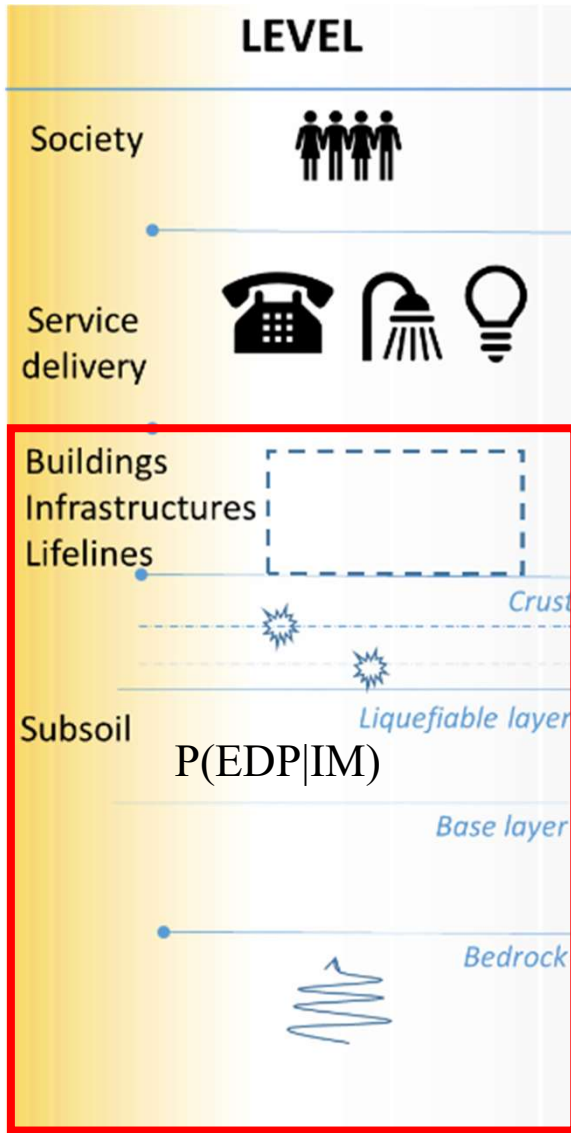
LOSS FACTORS

**TOTAL ECONOMIC LOSS
 LOSS OF BUSINESS INVENTORY**

TEMPORARY RENT/ LOSS OF INCOME

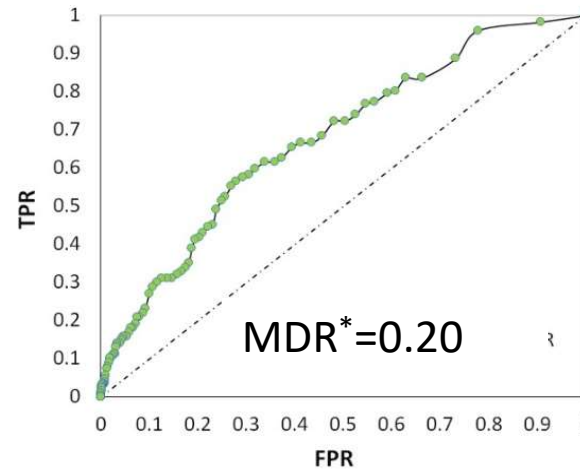
$$ul_i = \sum_{ds} (\text{INC}_i \cdot \text{FLT}_i) \cdot P_{i_ds}$$

RESTORATION TIME $\text{FLT}_i = \text{BRT}_i \cdot \text{SIM}_i$

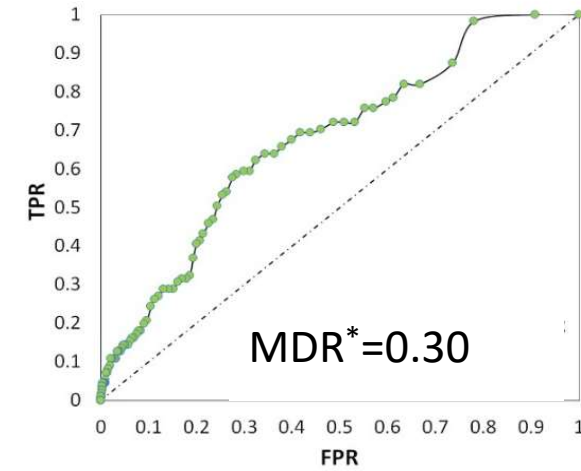


BUILDING DAMAGE PREDICTION

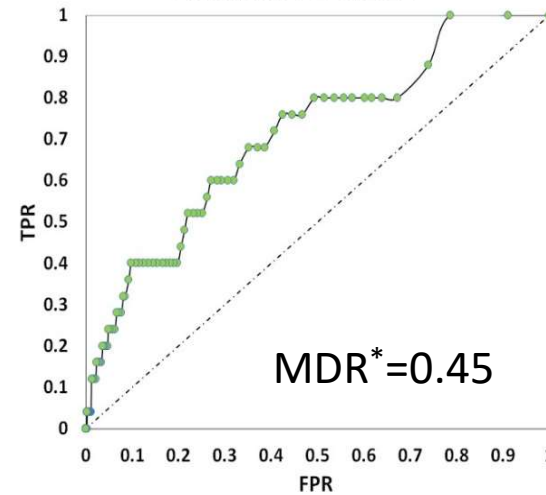
DAMAGE LEVEL 1



DAMAGE LEVEL 2

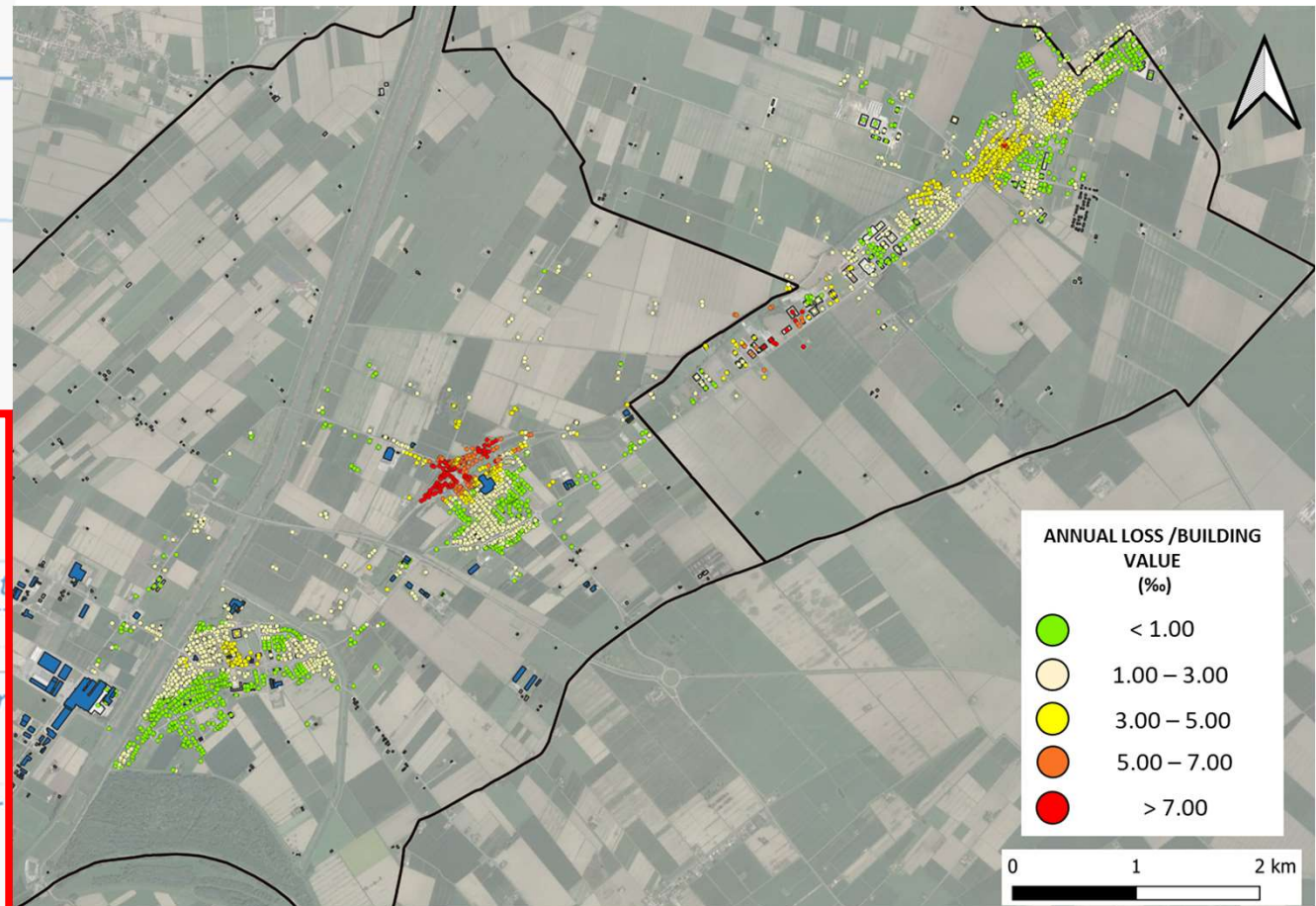
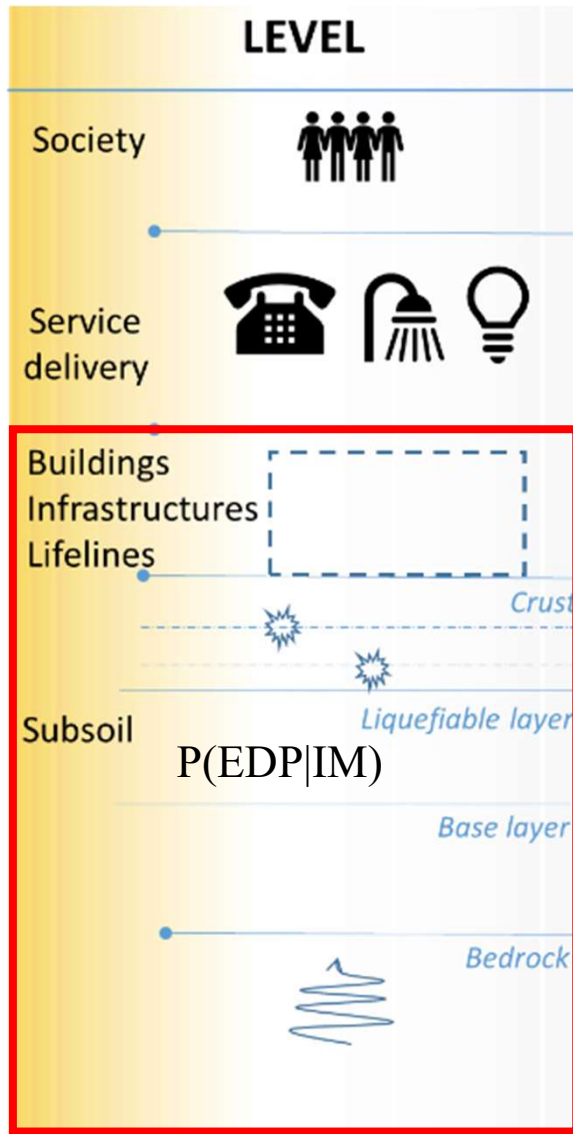


DAMAGE LEVEL 3



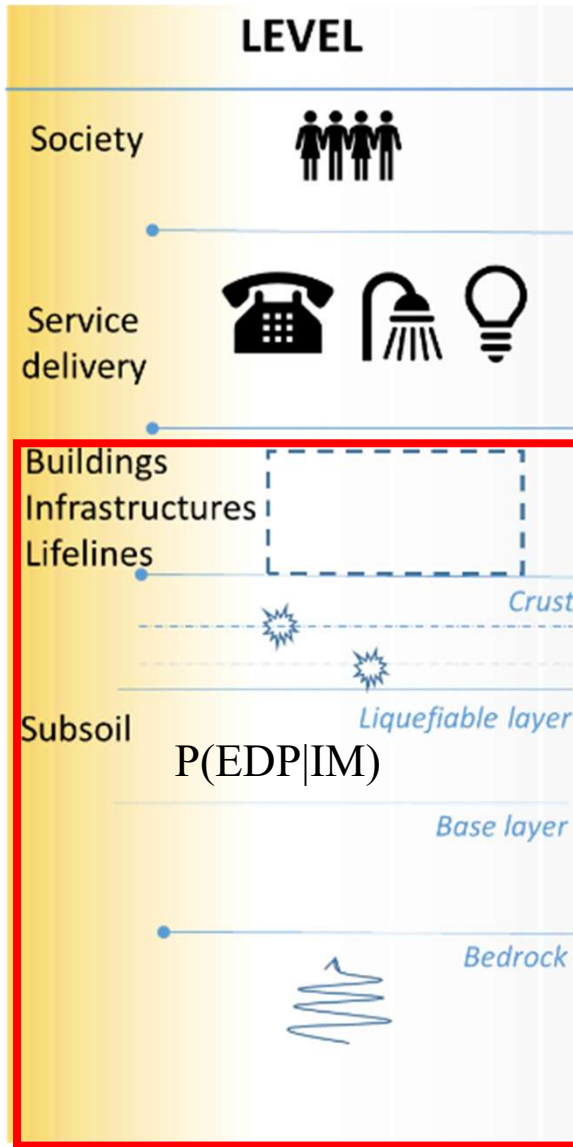
COST/BENEFIT



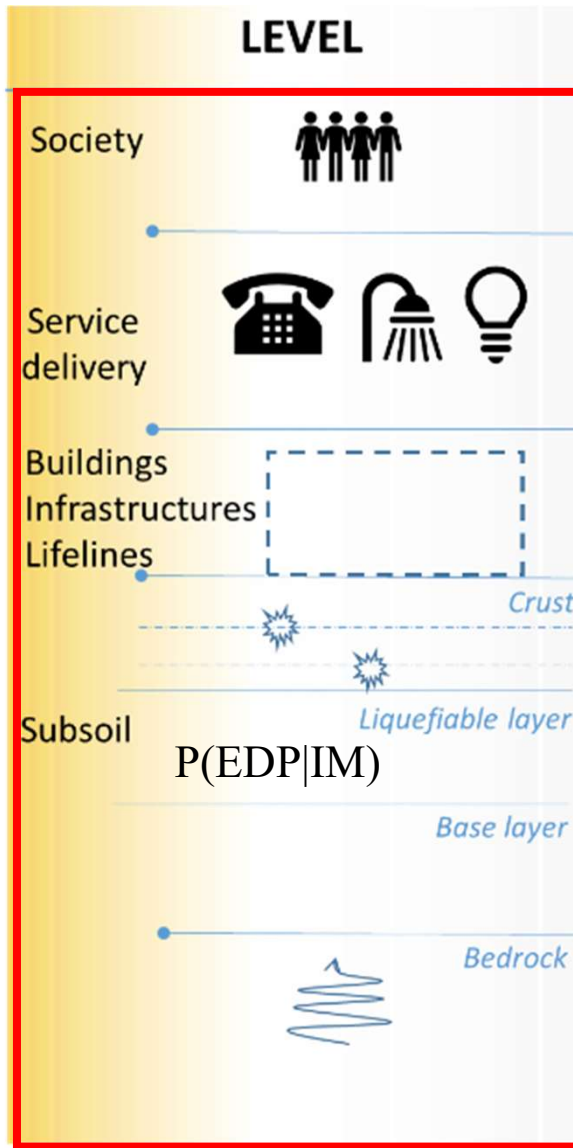


Reconstruction cost "RC" € 2 500.00/m²
Building Value= € 1 000.00/m²
Utility loss cost "ul"= € 6.00/(m²*month)

<https://www.regione.emilia-romagna.it/terremoto/mudemodello-unico-digitale-per-ledilizia>

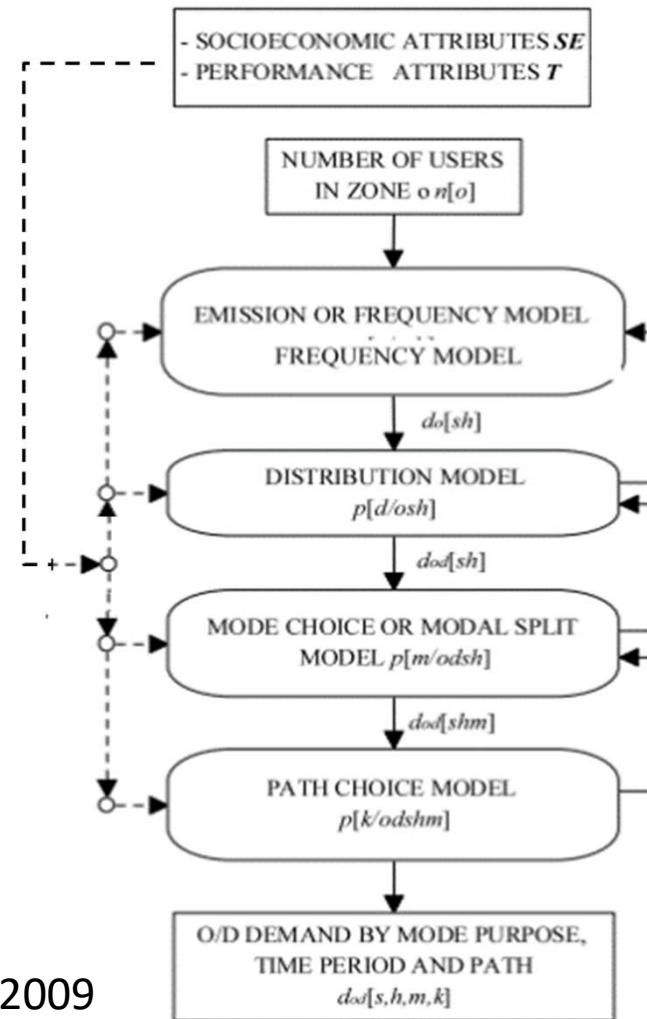


MITIGATION COST
 € 100,00 /m³

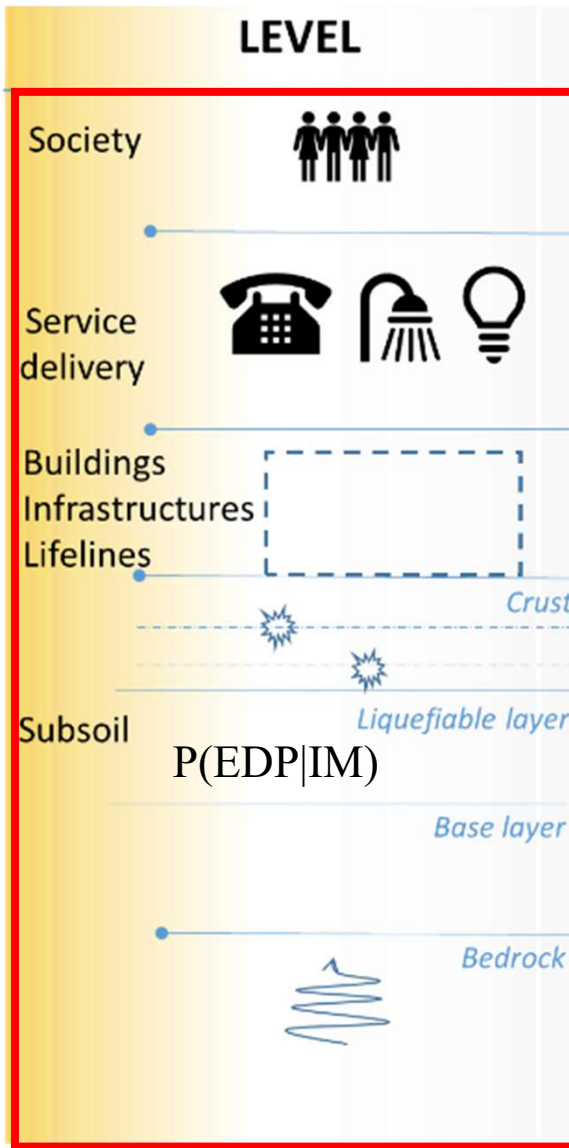


ROAD SERVICE DELIVERY

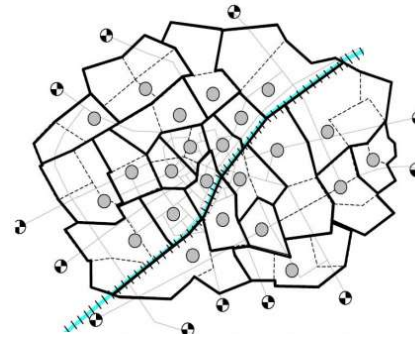
*Travel
 Demand
 Forecast
 Model*



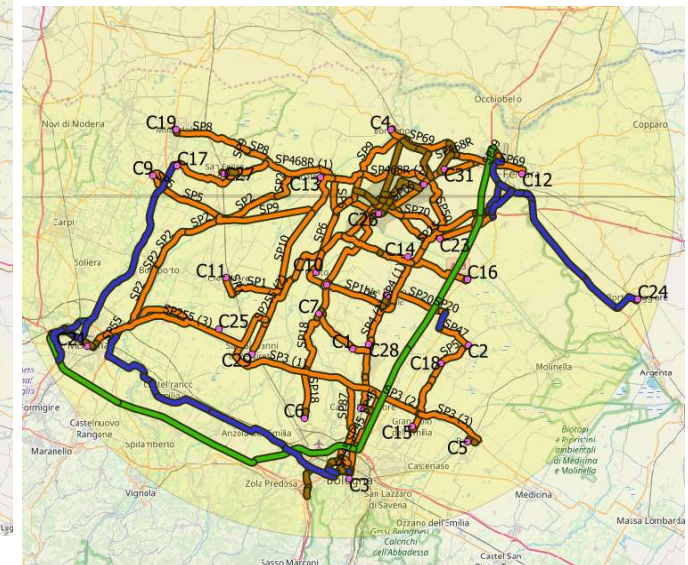
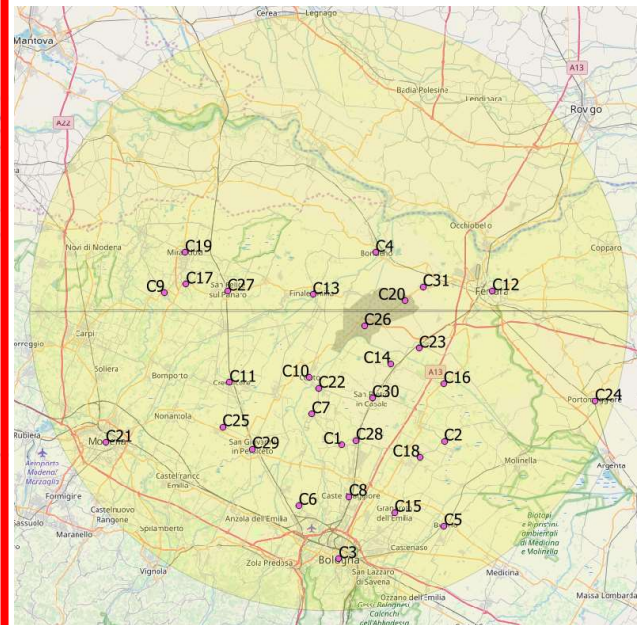
Cascetta, 2009



ROAD SERVICE DELIVERY

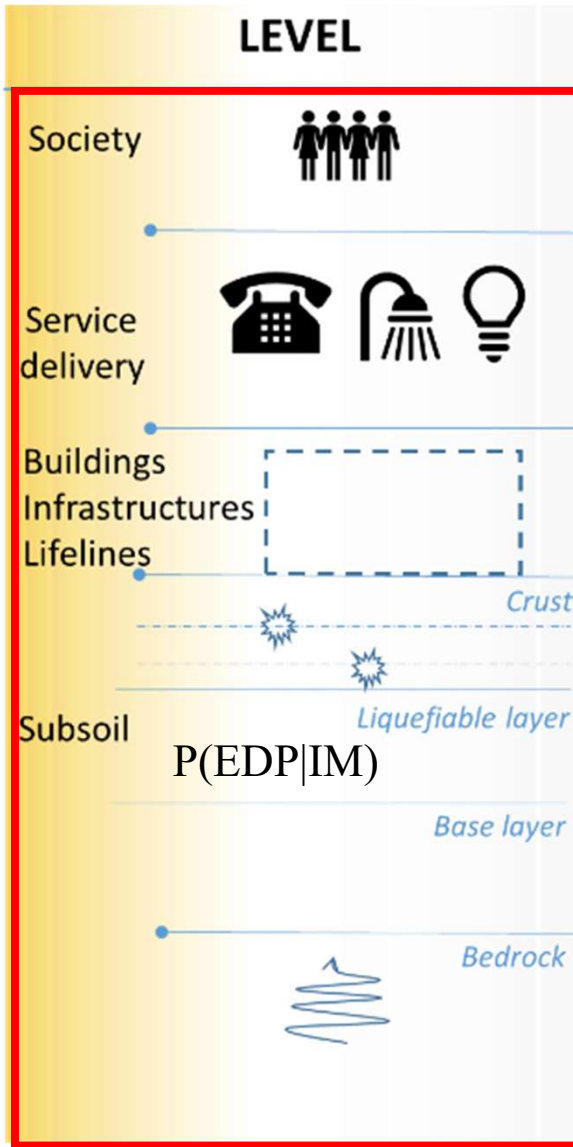


- Zone centroid
- External centroid
- Cens. Section boundary
- Zone boundary
- Basic Road Network
- Railway line



Analisi del rischio liquefazione sismo-indotta a scala urbana:
 applicazione al Comune di Terre del Reno

Bologna, 17 febbraio 2021



ROAD SERVICE DELIVERY

Damage State	PVG Displacement [m]			Serviceability limit State
	min	max	mean	
minor	0.02	0.08	0.05	useful road with speed reduction
moderate	0.08	0.22	0.15	road partially blocked -alternating direc. of travel
extensive	0.22	0.58	0.40	road totally blocked



Minor
 Speed reduction
 $V = 30 \text{ Km/h}$

Syner-G, 2014

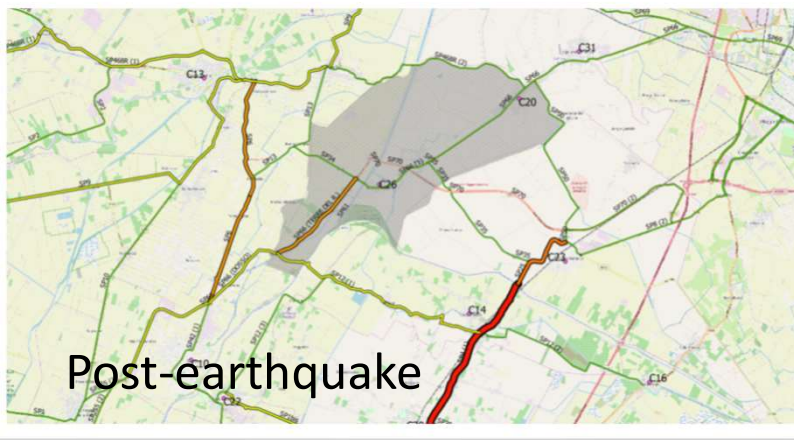
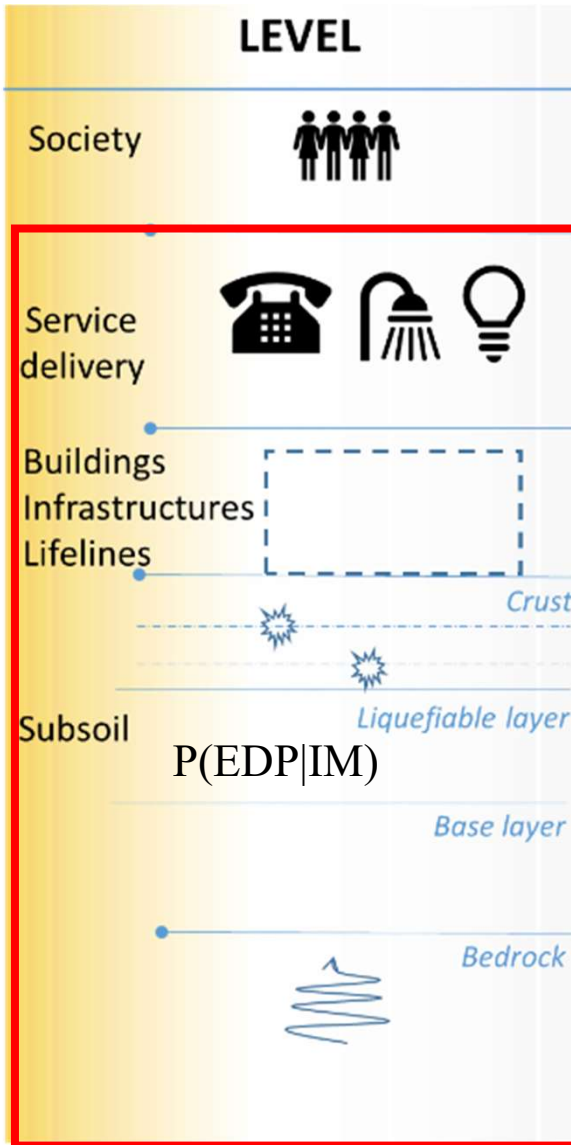
Extensive
 Path deviation



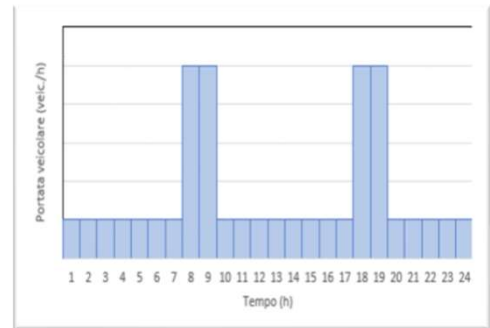
Moderate
 Alternating
 travel
 direction



ROAD SERVICE DELIVERY



Average Daily
 Traffic Delay



16 700 min

8060 euro/day



European Commission

Horizon 2020
European Union funding
for Research & Innovation

liquefact

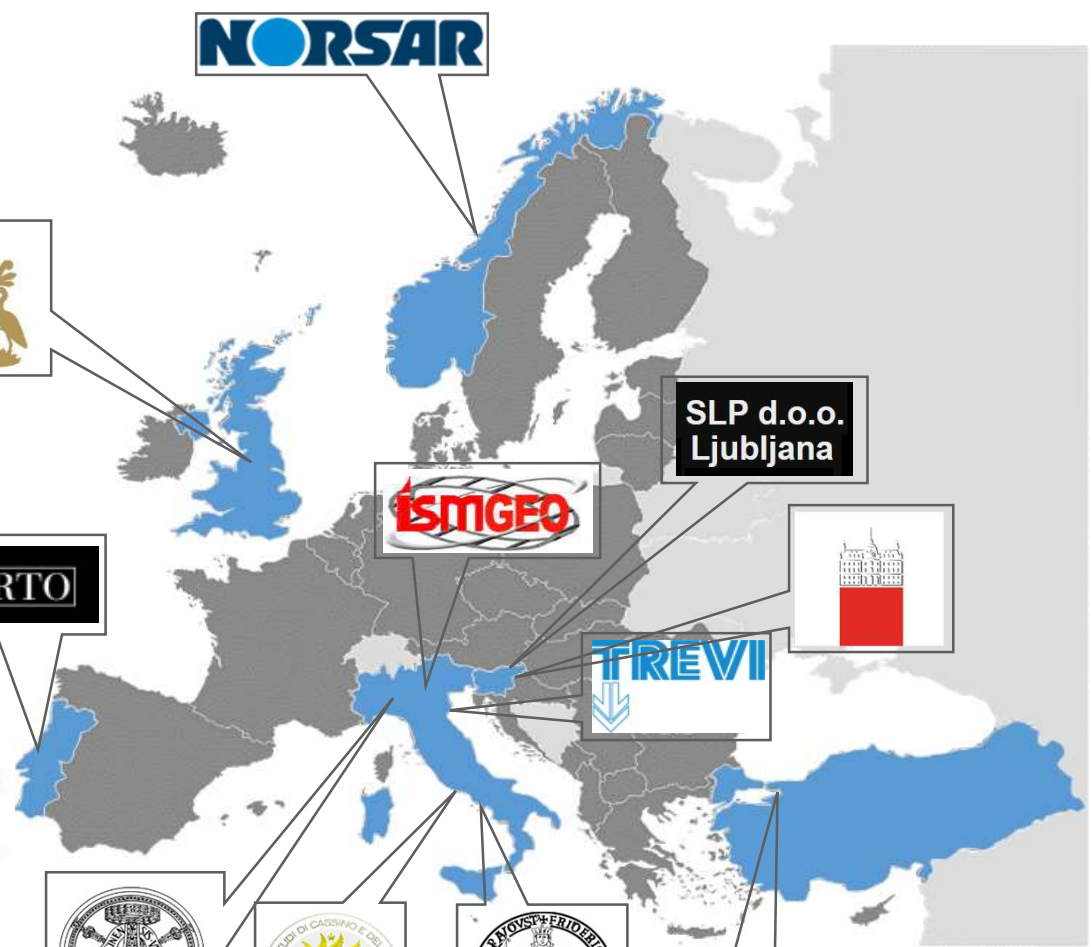
<http://www.liquefact.eu/>



YouTube



PARTNERS

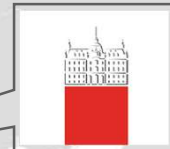


NORSAR



SLP d.o.o.
Ljubljana

ISM GEO

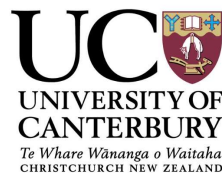


U.PORTO

TREVII

Expert group/stakeholders

Regione Emilia-Romagna



IL PROGETTO LIQUEFACT IN EMILIA-ROMAGNA

Webinar

Mercoledì 17 febbraio 2021



PERL

Protocollo Emilia

Romagna

Liquefazione



European
Commission

Horizon 2020
European Union funding
for Research & Innovation

liquefact



Università degli Studi di Cassino
e del Lazio Meridionale