LIQUEFACT software, a tool for liquefaction risk assessment, mitigation planning, and decision support

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Il progetto LIQUEFACT in Emilia-Romagna – Webinar 17 febbraio 2021

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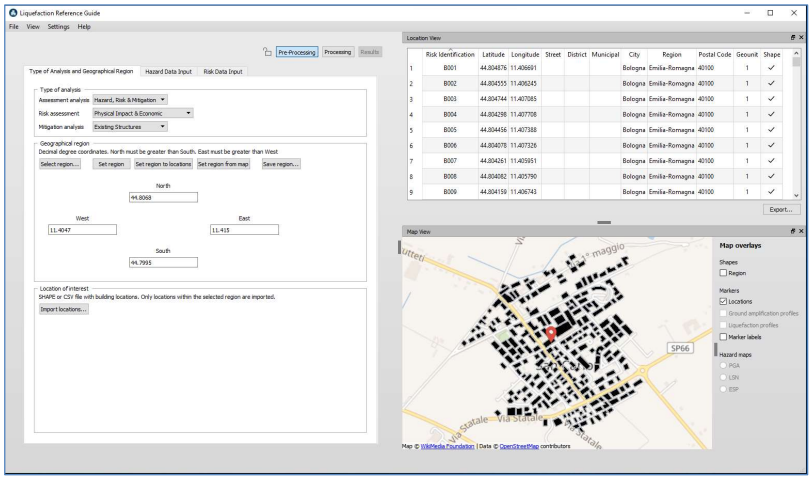
LIQUEFACT Software

One of the key outputs from the project is the LIQUEFACT software. A user-friendly toolbox for liquefaction mitigation planning and decision support, able to estimate and predict the likely consequences of an earthquake-induced liquefaction damage at individual structure /infrastructure, at regional or city level

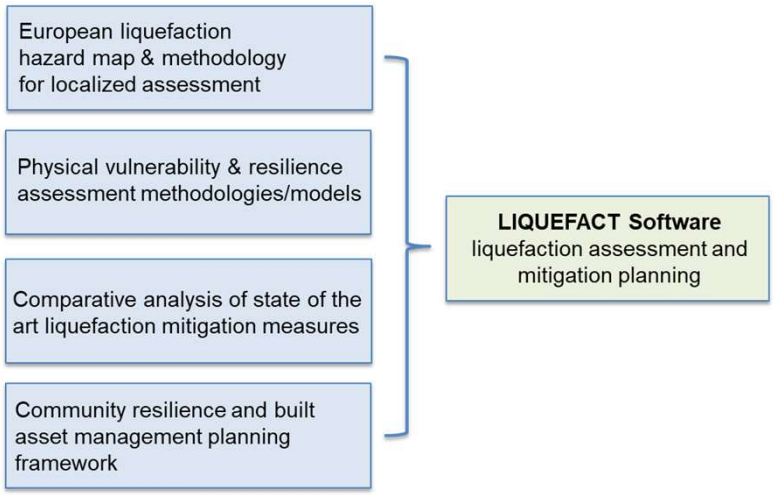


By using LIQUEFACT software, civil engineers and relevant stakeholders involved in the design and implementation can be guided to assess the feasibility and cost-benefit of certain liquefaction mitigation techniques or compute the socio-economic impacts of risk reduction and resilience improvement strategies.

2

LIQUEFACT Software

The basic for the development of the LIQUEFACT software consists in integrating methodologies, procedures and models from different partners



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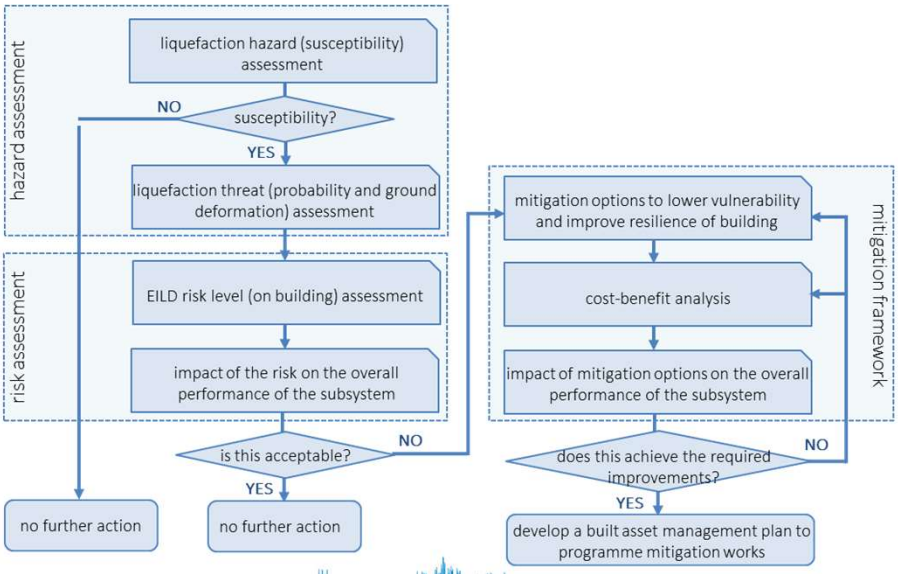
Processing and Analysis Concept



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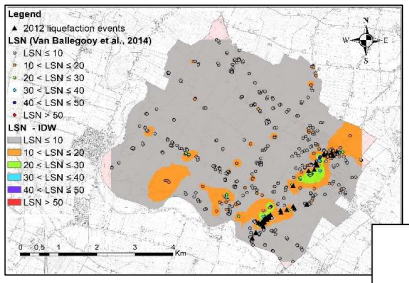
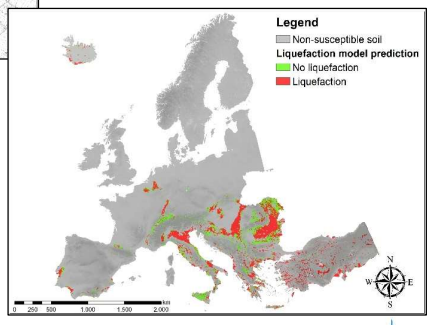
Liquefaction Hazard Assessment



Regional/national maps

susceptibility? YES



European map

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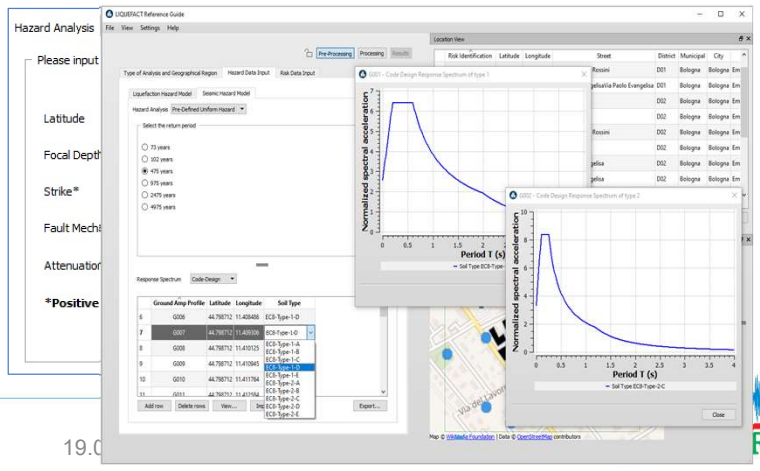
Liquefaction Hazard Assessment

- Scenario Earthquake
- Regional/National Uniform Hazard

susceptibility? YES

Seismic ground shaking



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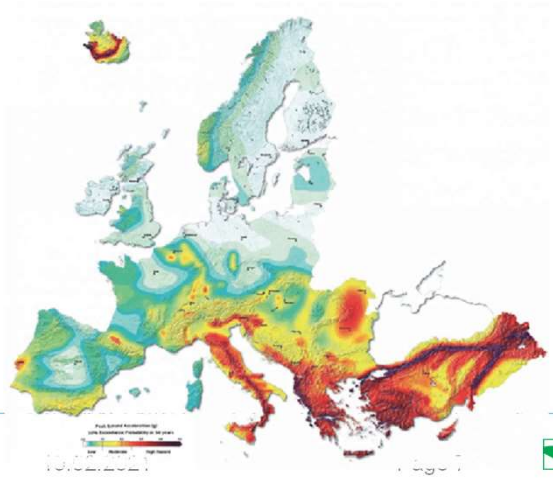
Liquefaction Hazard Assessment

- Scenario Earthquake
- Regional/National Uniform Hazard



susceptibility? YES

Seismic ground shaking

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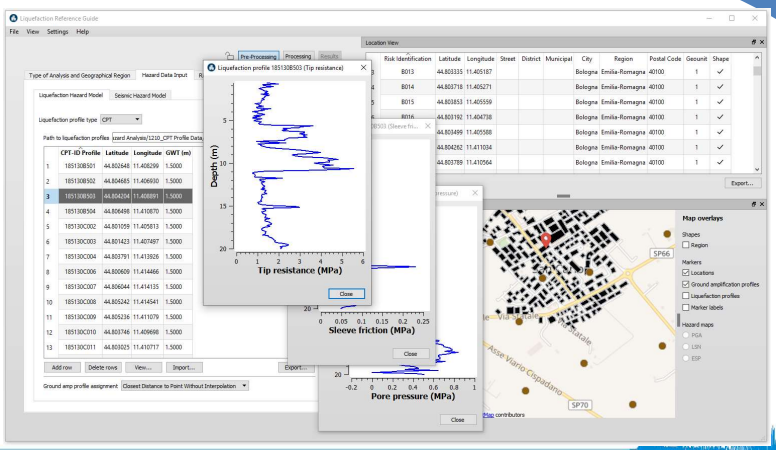
Liquefaction Hazard Assessment

susceptibility? YES

Seismic ground shaking

CPT, SPT, Vs profiles



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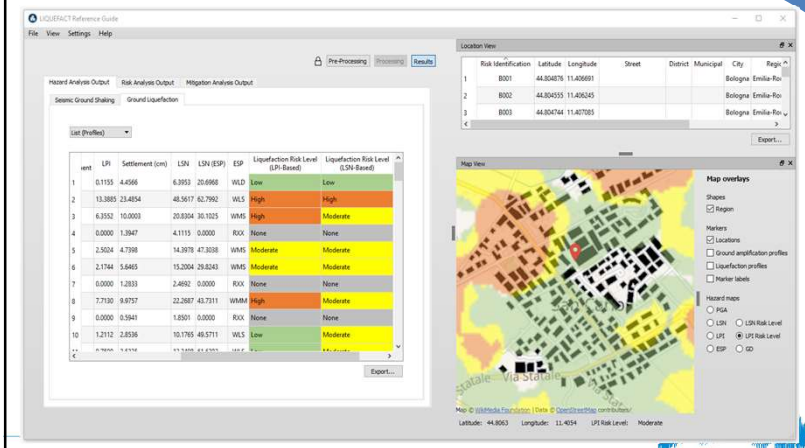
Liquefaction Hazard Assessment

susceptibility? YES

Seismic ground shaking

CPT, SPT, Vs profiles

Liquefaction threat



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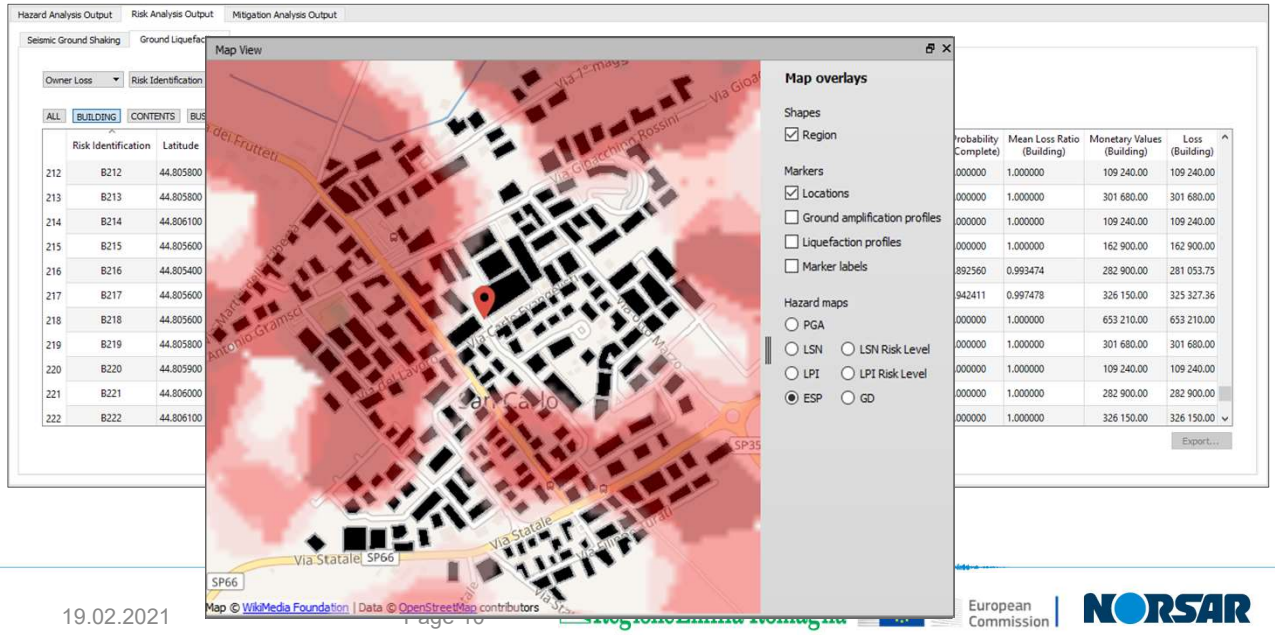
Liquefaction Threat: Outputs for technical user



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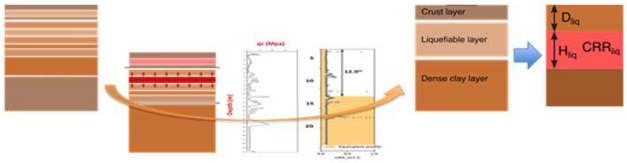
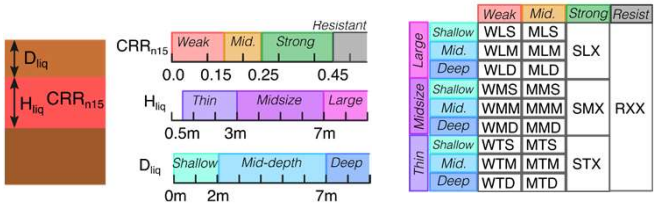
Liquefaction Threat: Outputs for technical user





Strength - Size - Position

		Weak	Mid.	Strong	Resist
Large	Shallow	WLS	MLS	SLX	RXX
	Mid.	WLM	MLM		
	Deep	WLD	MLD		
Midsize	Shallow	WMS	MMS	SMX	
	Mid.	WMM	MMM		
	Deep	WMD	MMD		
Thin	Shallow	WTS	MTS	STX	
	Mid.	WTM	MTM		
	Deep	WTD	MTD		

Soil Resistance (CRR_{liq})	Liquefiable Layer (H_{liq}) Thickness	Crust Layer (D_{liq}) Thickness	ESP profile
Weak	Large	Shallow	WLS
Weak	Large	Mid	WLM
Weak	Large	Deep	WLD
Weak	Midsize	Shallow	WMS
Weak	Midsize	Mid	WMM
Weak	Midsize	Deep	WMD
Weak	Thin	Shallow	WTS
Weak	Thin	Mid	WTM
Weak	Thin	Deep	WTD
Midium	Large	Shallow	MLS
Midium	Large	Mid	MLM
Midium	Large	Deep	MLD
Midium	Midsize	Shallow	MMS
Midium	Midsize	Mid	MMM
Midium	Midsize	Deep	MMD
Midium	Thin	Shallow	MTS
Midium	Thin	Mid	MTM
Midium	Thin	Deep	MTD
Strong	Large		SLX
Strong	Midsize		SMX
Strong	Thin		STX
Resist			RXX

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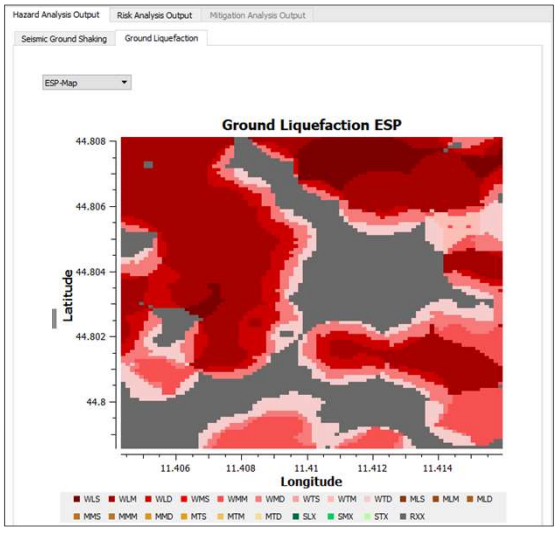
Liquefaction Threat: Outputs for technical user



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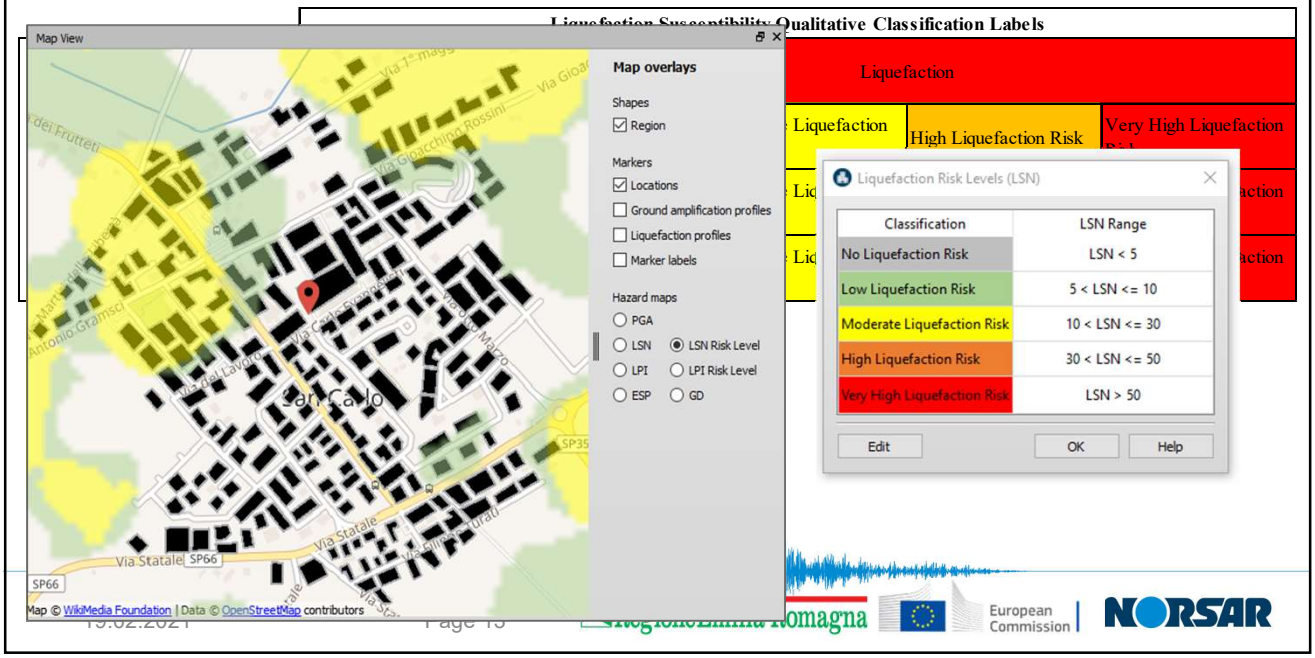
Liquefaction Threat: Output for non-technical user



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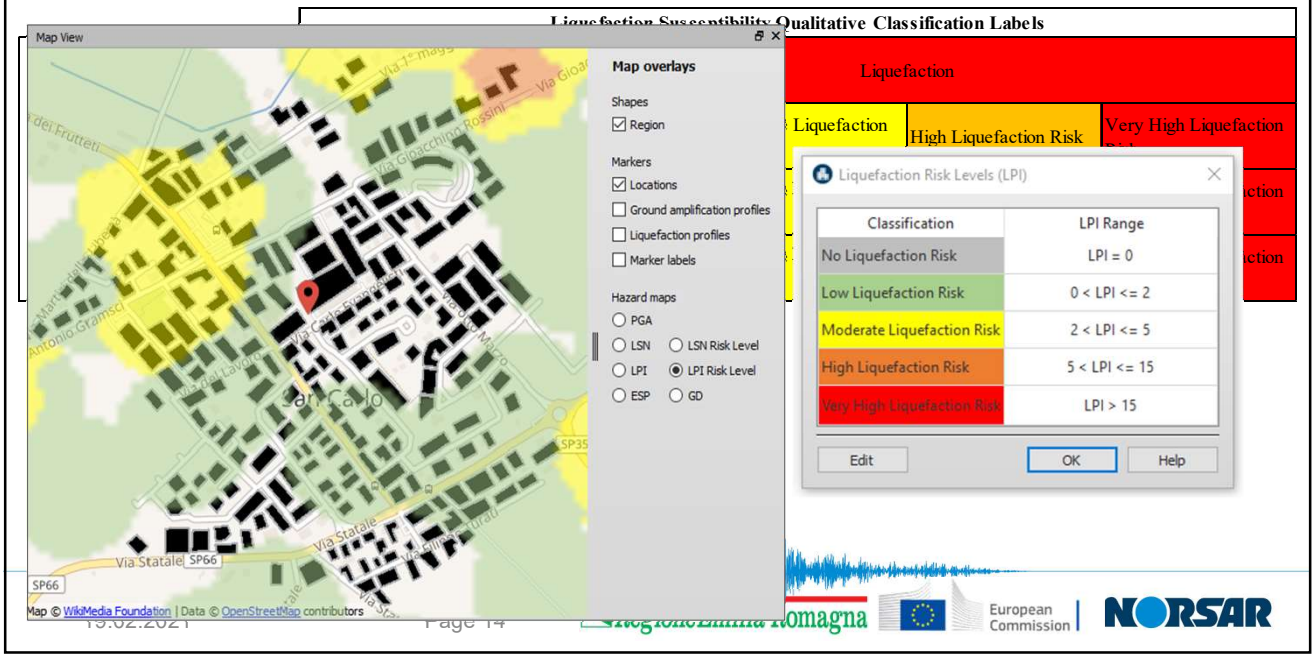
Liquefaction Threat: Output for non-technical user



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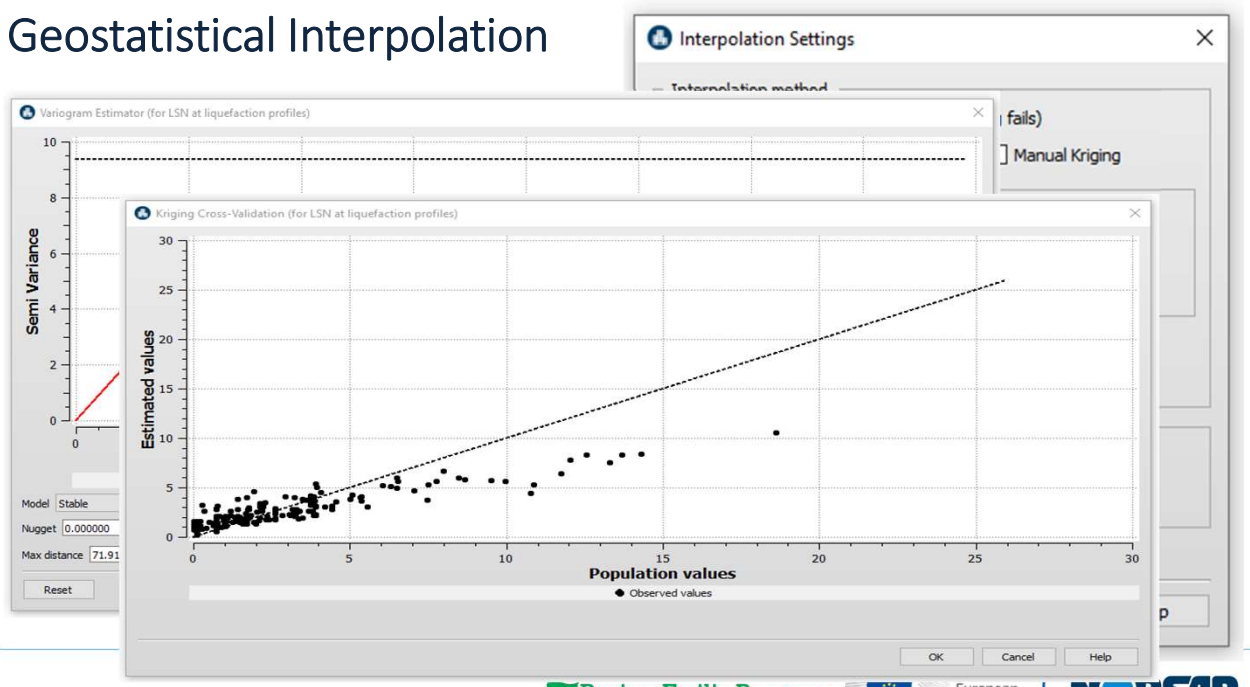
Geostatistical Interpolation



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Risk Assessment: Damage and Economic Loss

Hazard Analysis Output | Risk Analysis Output | Mitigation Analysis Output

Seismic Ground Shaking | Ground Liquefaction

Ground Liquefaction-related Risk Analysis Output Parameters for Owner Loss at Asset level	*Description*
BUILDING	
Mean Loss Ratio (Building)	Is the mean of building loss ratios of a given number of buildings of same Typol located in same Geo-code.
Monetary Values (Building)	Input Data of monetary value of a given building
Loss (Building)	Is computed as Monetary value (Building) multiplied with the Mean Loss Ra (Building).
CONTENTS	
Mean Loss Ratio (Contents)	Is the mean of content loss ratios of a given number of buildings of same Typol located in same Geo-code.
Monetary Values (Contents)	Input Data of monetary value of a given content in a given building
Loss (Contents)	Is computed as Monetary value (Contents) multiplied with the Mean Loss Ra (Contents).
BUSINESS INTERRUPTION	
Mean Loss Ratio (Business Interruption)	Is the mean of content loss ratios of a given number of buildings of same Typol located in same Geo-code.
Business Revenue	Input Data of business revenue of a given building
Loss (Business Interruption)	Is computed as Business revenue multiplied with the Mean Loss Ratio (Busin Interruption).

evenues	Loss (Businesses)	Total Loss
.90	4 684.90	6 006 036.29
.86	4 991.60	6 896 866.53
.10	4 118.01	5 422 474.37
.74	3 973.74	5 814 937.72
.40	7 738.40	10 682 938.40
.32	3 533.32	4 771 745.32
.24	5 508.24	8 117 387.77
.71	9 184.71	13 015 748.71
.17	5 127.17	7 100 167.16
.27	4 855.27	6 214 811.06
.16	9 349.82	13 159 906.67

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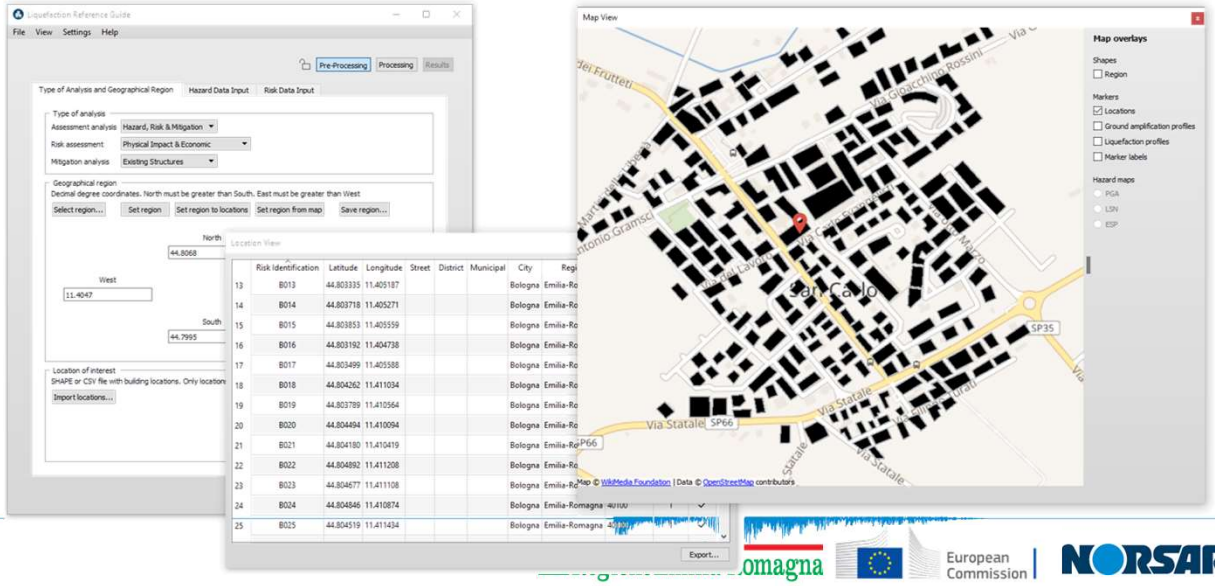
Risk Assessment: Damage and Economic Loss

Risk Analysis - Portfolio



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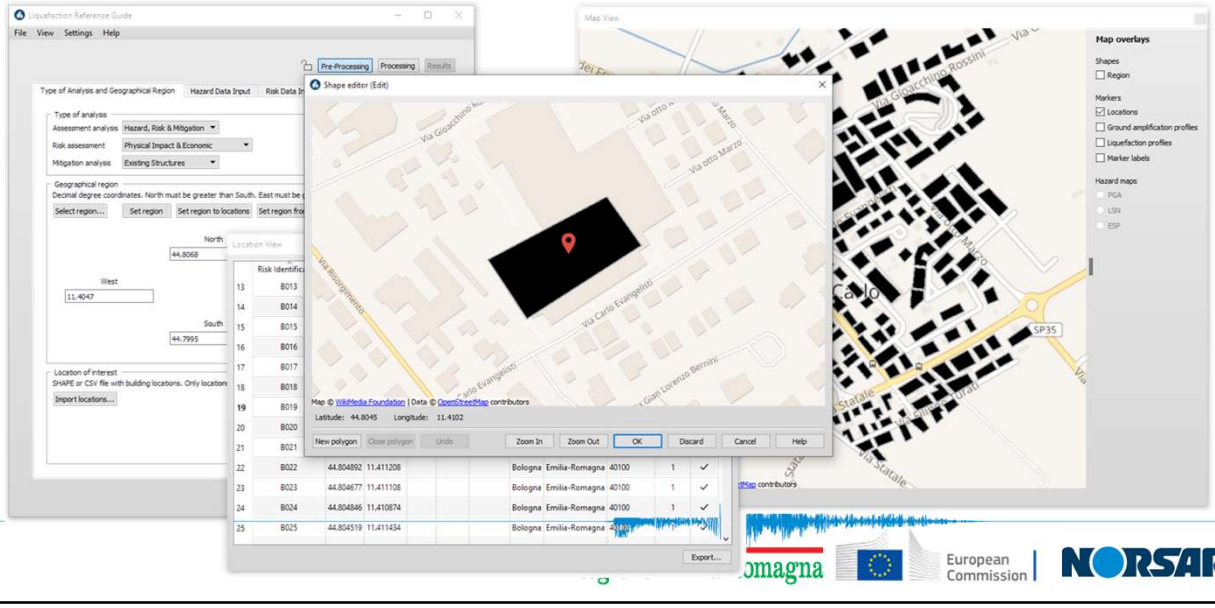
Risk Assessment: Damage and Economic Loss

Risk Analysis - Portfolio



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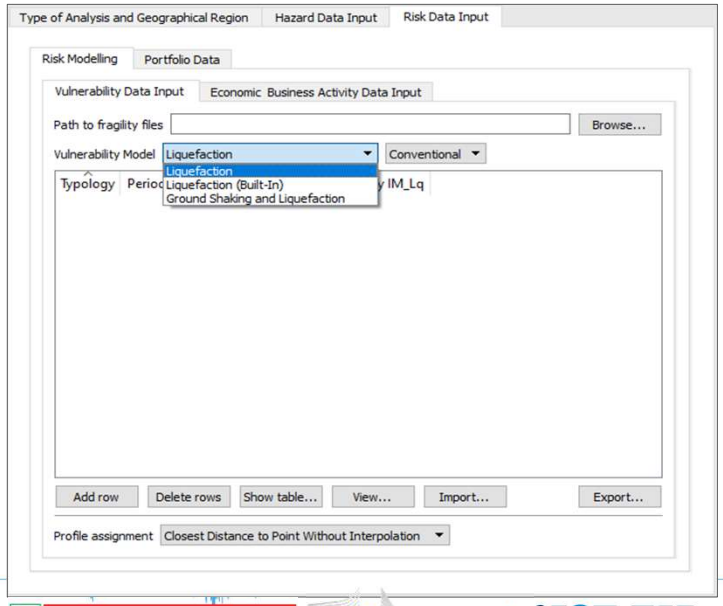
Risk Assessment: Damage and Economic Loss

Liquefaction Vulnerability Analysis

Type of vulnerability analysis

- Liquefaction
- Liquefaction and Ground Shaking
- Liquefaction (Buit-In)



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Risk Assessment: Damage and Economic Loss

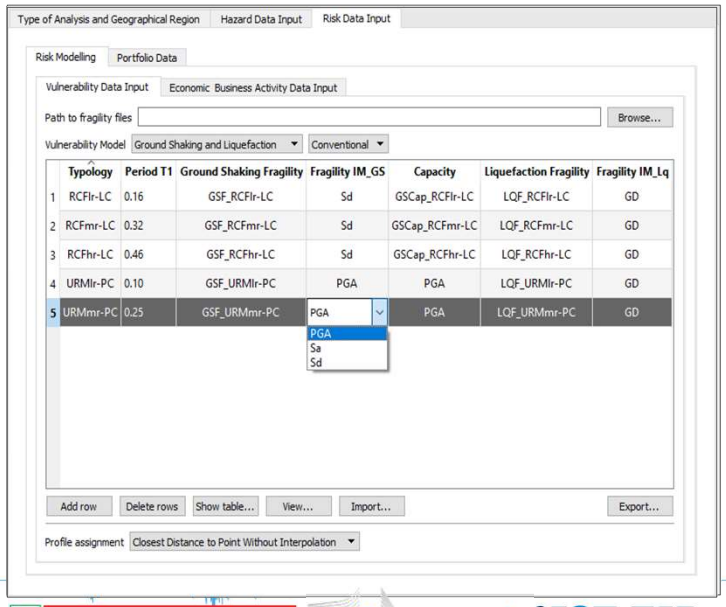
Liquefaction Vulnerability Analysis

IM for Liquefaction Fragility Curves

- PGA
- LSN
- Sa
- GD –Differential Settlement

IM for Ground Shaking Fragility Curves

- PGA
- Sa
- Sd



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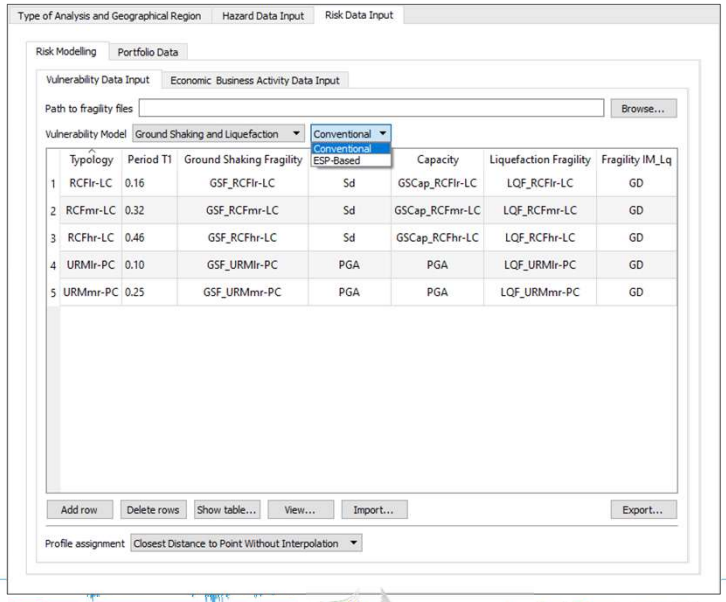
Risk Assessment: Damage and Economic Loss

Liquefaction Vulnerability Analysis

- ESP-based Procedure
- Conventional Procedure



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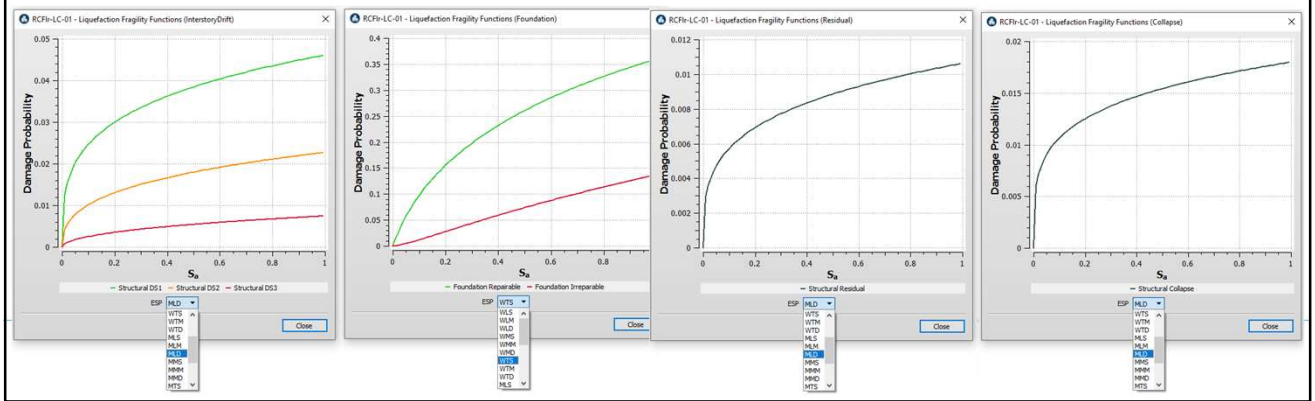
Risk Assessment: Damage and Economic Loss

Liquefaction Vulnerability Analysis

- ESP-based Procedure
- Conventional Procedure

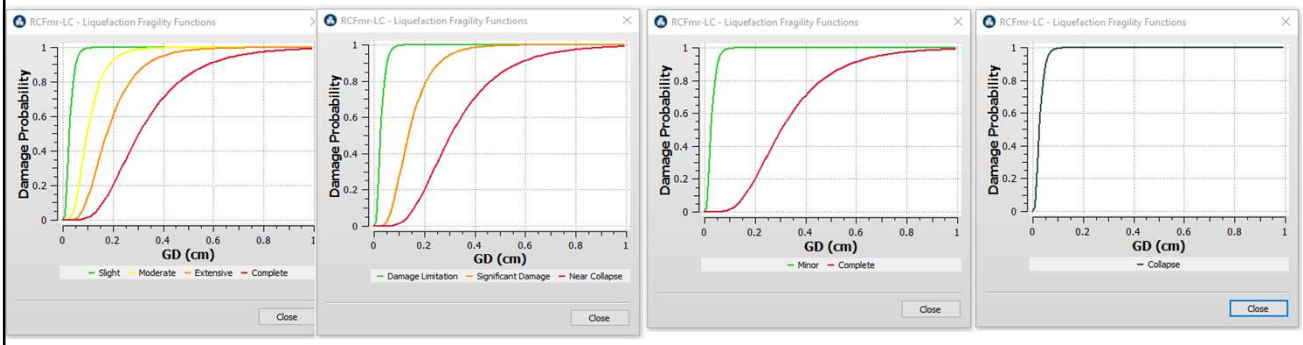
ESP-based Liquefaction Fragility model for a given typology is a combination of fragility functions representing: Intersotrey Drift of the Superstructure, Residual, Collapse, Foundation Titling.



Risk Assessment: Damage and Economic Loss

Liquefaction Vulnerability Analysis

- ESP-based Procedure
- Conventional Procedure



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Mitigation Analysis

Hazard Analysis Output | Risk Analysis Output | Mitigation Analysis Output

Applicationable to Existing Buildings/Infrastructure

ALL | MITIGATION TECHNIQUES APPLICABILITY SCORE | MITIGATION COST | EXPECTED BENEFIT | COST BENEFIT RATIO (CBR)

	Risk Identification	Latitude	Longitude	EARTHQUAKE DRAINS (Score)	DEEP DYNAMIC COMPACTION (Score)	VIBRO COMPACTION (Score)	BLASTING COMPACTION (Score)	VIBRO REPLACEMENT (Score)	INDUCED PARTIAL SATURATION (Score)	COMPACTION GROUTING (Score)	LOW PRESSURE GROUTING (Score)	JET GROUTING (Score)	DEEP SOIL MIXING (Score)	HEIGHEST RANKED G. I. TECHNOLOGY
15	B015	44.803853	11.405559	173	141	192	90	128	236	227	256	209	191	LOW PRESSURE GROUTING
16	B016	44.803192	11.404738	173	141	192	90	128	236	227	256	209	191	LOW PRESSURE GROUTING
17	B017	44.803499	11.405588	173	141	192	90	128	236	227	256	209	191	LOW PRESSURE GROUTING
18	B018	44.804262	11.411034	173	141	192	90	128	236	227	256	209	191	LOW PRESSURE GROUTING
19	B019	44.803789	11.410564	173	141	192	90	128	236	227	256	209	191	LOW PRESSURE GROUTING
20	B020	44.804494	11.410094	173	141	192	90	128	236	227	256	209	191	LOW PRESSURE GROUTING
21	B021	44.804180	11.410419	173	141	192	90	128	236	227	256	209	191	LOW PRESSURE GROUTING
22	B022	44.804892	11.411208	173	141	192	90	128	236	227	256	209	191	LOW PRESSURE GROUTING
23	B023	44.804677	11.411108	173	141	192	90	128	236	227	256	209	191	LOW PRESSURE GROUTING
24	B024	44.804846	11.410874	173	141	192	90	128	236	227	256	209	191	LOW PRESSURE GROUTING
25	B025	44.804519	11.411434	173	141	192	90	128	236	227	256	209	191	LOW PRESSURE GROUTING

Results of mitigation analysis system is provided for guidance only and should be critically reviewed by an experienced engineer with sufficient expertise and understanding of the underlying assumptions and limitations of the software. The validity of the results cannot be guaranteed as correct and the mitigation framework results should be independently cross-checked. This software is offered without warranty or promise of support of any kind either expressed or implied. This software is offered as is, without warranty or promise of support of any kind either expressed or implied.

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Mitigation Analysis

Liquefaction Mitigation Techniques

Ground improvement technologies for liquefaction mitigation	Earthquake drains
	Deep dynamic compaction
	Vibro-compaction
	Blasting compaction
	Vibro-replacement
	Induced partial saturation
	Compaction grouting
	Low pressure grouting
	Jet grouting
	Deep soil mixing

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Mitigation Analysis

Liquefaction Mitigation Techniques

Factors	Level of Importance	Weight	Relative Weight (%)
1. Site conditions	Very important	4	18.2
2. Soil type	Very important	4	18.2
3. Stratigraphy	Medium important	2	9.1
4. Depth of the treatment zone	Very important	4	18.2
5. Size of area to be improved	Less important	1	4.5
6. Foundation type	Less important	1	4.5
7. Project constrains	Medium important	2	9.1
8. Presence of subsurface obstructions	Medium important	2	9.1
9. Environmental compatibility	Medium important	2	9.1
		TOTAL	100 %

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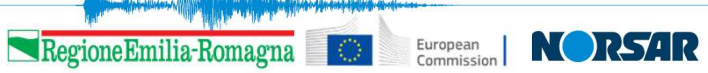
Mitigation Analysis

Factors	Details
1. *Site conditions*	Free-field or existing structure is one of the major factors that can influence the process of ground mitigation technologies selection, as some technologies could damage structures.
1.1) Free field	
1.2) Existing buildings	
2. *Soil type*	In general, any ground improvement technologies that can effectively improve the shear and compression resistance of liquefiable soil can be used for liquefaction mitigation, but each remedial technology has its own suitable soil type to which it should be applied (if is gravel, sandy or inorganic/clays silts of low to medium plasticity).
2.1) Gravel soils	
2.2) Sandy soils	
2.3) Inorganic silts, clays silts of low to medium plasticity	
3. *Stratigraphy*	Link the suitability of ground improvement technologies to the presence or not of soil crust.
3.1) Soil crust	
3.2) No soil crust	
4. *Depth of the treatment zone*	The suitability of ground improvement technologies is subject to the specified depth of the liquefiable soil layer. Based on extensive review and several studies the following depths have been determined for the applicability of the various ground improvement technologies.
4.1) <3 m	
4.2) 3-12 m	
4.3) 12-18 m	
4.4) 18-25 m	
5. *Size of area to be improved*	The suitability of ground improvement technologies is also subject to the size of area to be improved. Some ranges defining the economic size associated to ground improvement technologies have been established based on case
5.1) Small (<1000 m^2)	
5.2) Medium (1000-5000 m^2)	



Mitigation Analysis

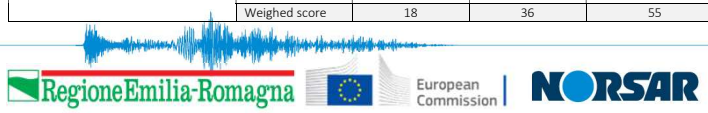
Ground improvement technologies applicability and score rating for the factor of Site Conditions

Ground Improvement Technologies	Applicability Factors	1. Site conditions	
		1.1) Free field	1.2) Existing buildings
EARTHQUAKE DRAINS	Applicability	Good	Good
		3	3
	Weighed score	55	55
DEEP DYNAMIC COMPACTION	Applicability	Good	Not Applicable
		3	0
	Weighed score	55	0
VIBRO COMPACTION	Applicability	Good	Not Applicable
		3	0
	Weighed score	55	0
BLASTING COMPACTION	Applicability	Good	Not Applicable
		3	0
	Weighed score	55	0
VIBRO REPLACEMENT	Applicability	Good	Not Applicable
		3	0
	Weighed score	55	0
INDUCED PARTIAL SATURATION	Applicability	Good	Good
		3	3
	Weighed score	55	55
COMPACTION GROUTING	Applicability	Good	Good
		3	3
	Weighed score	55	55
LOW PRESSURE GROUTING	Applicability	Good	Good
		3	3
	Weighed score	55	55
JET GROUTING	Applicability	Good	Medium
		3	2
	Weighed score	55	36
DEEP SOIL MIXING	Applicability	Good	Good
		3	3
	Weighed score	55	55

Mitigation Analysis

Ground improvement technologies applicability and score rating for the factor of Soil Type

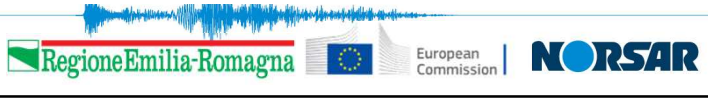
Ground Improvement Technologies	Applicability Factors	2. Soil Type		
		2.1) Gravel soils	2.2) Sandy soils	2.3) Inorganic silts, clays silts of low to medium plasticity
EARTHQUAKE DRAINS	Applicability	Low	Good	Low
		1	3	1
	Weighed score	18	55	18
DEEP DYNAMIC COMPACTION	Applicability	Medium	Good	Low
		2	3	1
	Weighed score	36	55	18
VIBRO COMPACTION	Applicability	Good	Good	Not Applicable
		3	3	0
	Weighed score	55	55	0
BLASTING COMPACTION	Applicability	Medium	Medium	Not Applicable
		2	2	0
	Weighed score	36	36	0
VIBRO REPLACEMENT	Applicability	Low	Medium	Good
		1	2	3
	Weighed score	18	36	55
INDUCED PARTIAL SATURATION	Applicability	Medium	Good	Low
		2	3	1
	Weighed score	36	55	18
COMPACTION GROUTING	Applicability	Medium	Good	Low
		2	3	1
	Weighed score	36	55	18
LOW PRESSURE GROUTING	Applicability	Good	Good	Not Applicable
		3	3	0
	Weighed score	55	55	0
JET GROUTING	Applicability	Good	Good	Medium
		3	3	2
	Weighed score	55	55	36
DEEP SOIL MIXING	Applicability	Low	Medium	Good
		1	2	3
	Weighed score	18	36	55



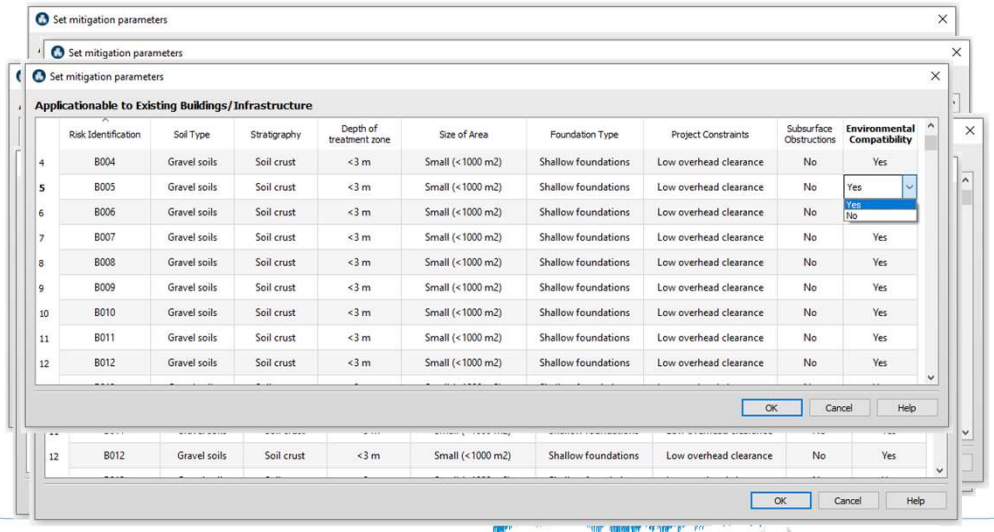
Mitigation Analysis

LEGEND		
APPLICABILITY	Good	3
	Medium	2
	Low	1
	Not applicable	0
WEIGHT	Very important	4
	Important	3
	Medium important	2
	Less important	1
	Not applicable	0

Question		Weight	Relative weight (%)	EARTHQUAKE DRAINS		DEEP DYNAMIC COMPACTION		VIBRO COMPACTION		BLASTING COMPACTION		VIBRO REPLACEMENT		INDUCED PARTIAL SATURATION		COMPACTION GROUTING		LOW PRESSURE GROUTING		JET GROUTING		DEEP SOIL MIXING	
				Applicability	Weighed score	Applicability	Weighed score	Applicability	Weighed score	Applicability	Weighed score	Applicability	Weighed score	Applicability	Weighed score	Applicability	Weighed score	Applicability	Weighed score	Applicability	Weighed score	Applicability	Weighed score
1. Site conditions	1.1) Free field	4	18.2	3	55	3	55	3	55	3	55	3	55	3	55	3	55	3	55	3	55	3	55
	1.2) Existing buildings			3	55	0	0	0	0	0	0	0	0	3	55	3	55	3	55	2	36	3	55
2. Soil type	2.1) Gravel soils	4	18.2	1	18	2	36	3	55	2	36	1	18	2	36	2	36	3	55	3	55	1	18
	2.2) Sandy soils			3	55	3	55	3	55	2	36	2	36	3	55	3	55	3	55	3	55	2	36
	2.3) Inorganic silts, clays silts of low to medium plasticity			1	18	1	18	0	0	0	0	3	55	1	18	1	18	0	0	2	36	3	55
3. Stratigraphy	3.1) Soil crust	2	9.1	3	27	1	9	2	18	1	9	1	9	3	27	3	27	3	27	3	27	3	27
	3.2) No soil crust			2	18	3	27	3	27	3	27	3	27	3	27	3	27	3	27	3	27	3	27
4. Depth of the treatment zone (based on case histories)	4.1) <3 m	4	18.2	1	18	3	55	3	55	2	36	3	55	2	36	2	36	3	55	2	36	2	36
	4.2) 3-12 m			3	55	3	55	3	55	3	55	3	55	3	55	3	55	3	55	3	55	3	55
	4.3) 12-18 m			3	55	2	36	2	36	2	36	2	36	3	55	3	55	3	55	3	55	3	55
	4.4) 18-25 m			3	55	1	18	1	18	0	0	1	18	3	55	1	18	3	55	3	55	2	36
5. Size of area to be improved	5.1) Small (<1000 m^2)	1	4.5	3	14	3	14	3	14	2	9	3	14	3	14	3	14	3	14	3	14	3	14
	5.2) Medium (1000-5000 m^2)			3	14	3	14	3	14	2	9	3	14	3	14	3	14	3	14	3	14	3	14
	5.3) High (>5000 m^2)			3	14	3	14	3	14	3	14	3	14	3	14	3	14	3	14	3	14	3	14
6. Foundation type	6.1) Shallow foundations	1	4.5	3	14	0	0	3	14	0	0	3	14	3	14	3	14	3	14	3	14	3	14
	6.2) Deep foundations			3	14	0	0	1	5	0	0	0	0	3	14	1	5	3	14	2	9	3	14
7. Project constrains	7.1) Low overhead clearance	2	9.1	0	0	0	0	1	9	0	0	1	9	3	27	2	18	3	27	1	9	0	0
	7.2) Adjacent structures			3	27	0	0	0	0	0	0	0	0	3	27	3	27	3	27	2	18	3	27
	7.3) Existing utilities			1	9	0	0	1	9	0	0	1	9	3	27	2	18	3	27	1	9	2	18
8. Presence of subsurface obstructions		2	9.1	1	9	0	0	0	0	0	0	0	0	3	27	1	9	3	27	1	9	2	18
9. Environmental compatibility		2	9.1	3	27	3	27	3	27	0	0	1	9	3	27	3	27	1	9	2	18	3	27
Total			100.0																				



Mitigation Analysis



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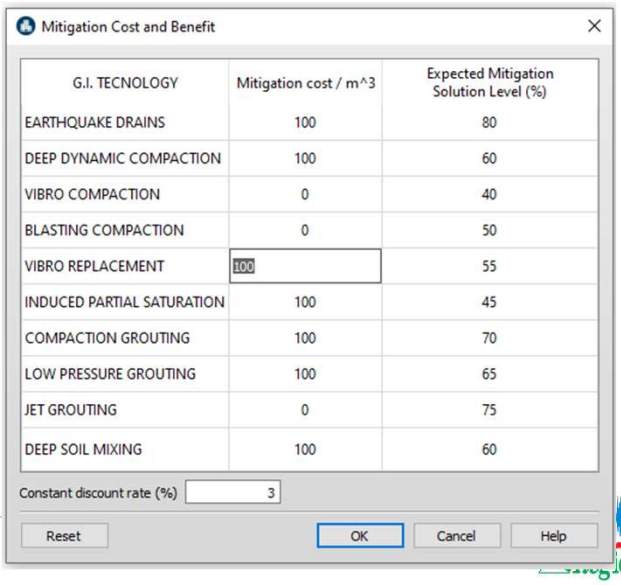
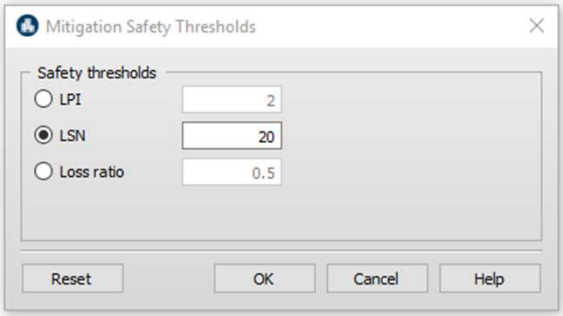
Mitigation Analysis

Mitigation Safety Thresholds / Mitigation Cost and Expected Mitigation Solution Level





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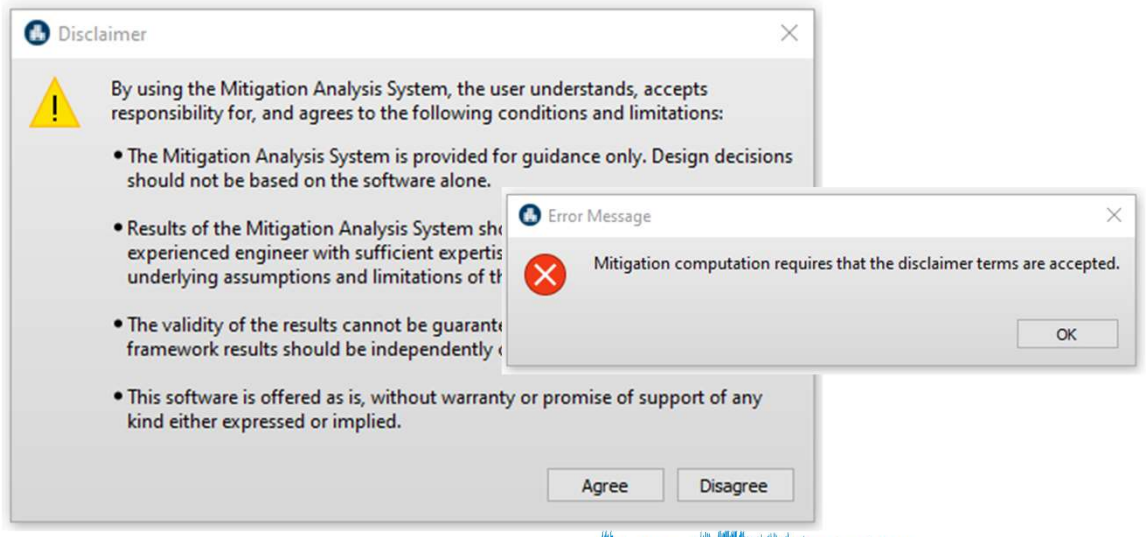
Mitigation Analysis



Mitigation Analysis

Hazard Analysis Output | Risk Analysis Output | Mitigation Analysis Output

Applicationable to Existing Buildings/Infrastructure

ALL | MITIGATION TECHNIQUES APPLICABILITY SCORE | MITIGATION COST | EXPECTED BENEFIT | COST BENEFIT RATIO (CBR)

	Risk Identification	Latitude	Longitude	EARTHQUAKE DRAINS (Score)	DEEP DYNAMIC COMPACTION (Score)	VIBRO COMPACTION (Score)	BLASTING COMPACTION (Score)	VIBRO REPLACEMENT (Score)	INDUCED PARTIAL SATURATION (Score)	COMPACTION GROUTING (Score)	LOW PRESSURE GROUTING (Score)	JET GROUTING (Score)	DEEP SOIL MIXING (Score)	HEIGHEST RANKED G. I. TECHNOLOGY
15	B015	44.803853	11.405559	173	141	192	90	128	236	227	256	209	191	LOW PRESSURE GROUTING
16	B016	44.803192	11.404738	173	141	192	90	128	236	227	256	209	191	LOW PRESSURE GROUTING
17	B017	44.803499	11.405588	173	141	192	90	128	236	227	256	209	191	LOW PRESSURE GROUTING
18	B018	44.804262	11.411034	173	141	192	90	128	236	227	256	209	191	LOW PRESSURE GROUTING
19	B019	44.803789	11.410564	173	141	192	90	128	236	227	256	209	191	LOW PRESSURE GROUTING
20	B020	44.804494	11.410094	173	141	192	90	128	236	227	256	209	191	LOW PRESSURE GROUTING
21	B021	44.804180	11.410419	173	141	192	90	128	236	227	256	209	191	LOW PRESSURE GROUTING
22	B022	44.804892	11.411208	173	141	192	90	128	236	227	256	209	191	LOW PRESSURE GROUTING
23	B023	44.804677	11.411108	173	141	192	90	128	236	227	256	209	191	LOW PRESSURE GROUTING
24	B024	44.804846	11.410874	173	141	192	90	128	236	227	256	209	191	LOW PRESSURE GROUTING
25	B025	44.804519	11.411434	173	141	192	90	128	236	227	256	209	191	LOW PRESSURE GROUTING

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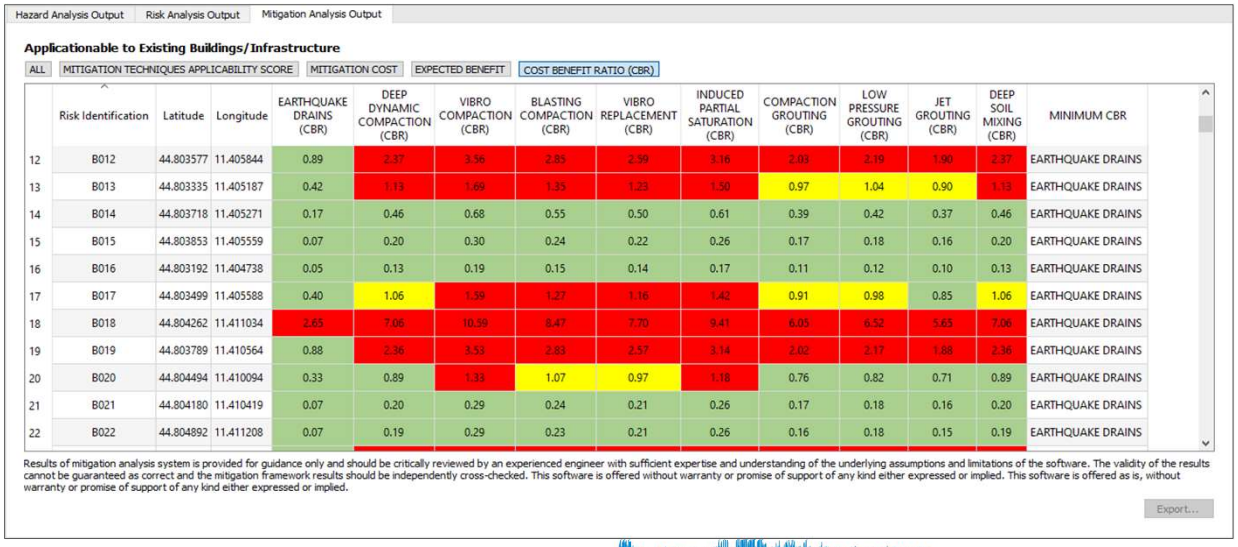
Export...

Cost-Benefit Analysis



Hazard Analysis Output | Risk Analysis Output | Mitigation Analysis Output

Applicationable to Existing Buildings/Infrastructure

ALL | MITIGATION TECHNIQUES APPLICABILITY SCORE | MITIGATION COST | EXPECTED BENEFIT | COST BENEFIT RATIO (CBR)

	Risk Identification	Latitude	Longitude	EARTHQUAKE DRAINS (CBR)	DEEP DYNAMIC COMPACTION (CBR)	VIBRO COMPACTION (CBR)	BLASTING COMPACTION (CBR)	VIBRO REPLACEMENT (CBR)	INDUCED PARTIAL SATURATION (CBR)	COMPACTION GROUTING (CBR)	LOW PRESSURE GROUTING (CBR)	JET GROUTING (CBR)	DEEP SOIL MIXING (CBR)	MINIMUM CBR
12	B012	44.803577	11.405844	0.89	2.37	3.56	2.85	2.59	3.16	2.03	2.19	1.90	2.37	EARTHQUAKE DRAINS
13	B013	44.803335	11.405187	0.42	1.13	1.69	1.35	1.23	1.50	0.97	1.04	0.90	1.13	EARTHQUAKE DRAINS
14	B014	44.803718	11.405271	0.17	0.46	0.68	0.55	0.50	0.61	0.39	0.42	0.37	0.46	EARTHQUAKE DRAINS
15	B015	44.803853	11.405559	0.07	0.20	0.30	0.24	0.22	0.26	0.17	0.18	0.16	0.20	EARTHQUAKE DRAINS
16	B016	44.803192	11.404738	0.05	0.13	0.19	0.15	0.14	0.17	0.11	0.12	0.10	0.13	EARTHQUAKE DRAINS
17	B017	44.803499	11.405588	0.40	1.06	1.59	1.27	1.16	1.42	0.91	0.98	0.85	1.06	EARTHQUAKE DRAINS
18	B018	44.804262	11.411034	2.65	7.06	10.59	8.47	7.70	9.41	6.05	6.52	5.65	7.06	EARTHQUAKE DRAINS
19	B019	44.803789	11.410564	0.88	2.36	3.53	2.83	2.57	3.14	2.02	2.17	1.88	2.36	EARTHQUAKE DRAINS
20	B020	44.804494	11.410094	0.33	0.89	1.33	1.07	0.97	1.18	0.76	0.82	0.71	0.89	EARTHQUAKE DRAINS
21	B021	44.804180	11.410419	0.07	0.20	0.29	0.24	0.21	0.26	0.17	0.18	0.16	0.20	EARTHQUAKE DRAINS
22	B022	44.804892	11.411208	0.07	0.19	0.29	0.23	0.21	0.26	0.16	0.18	0.15	0.19	EARTHQUAKE DRAINS

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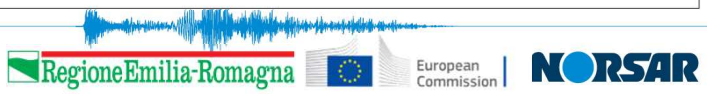
Export...



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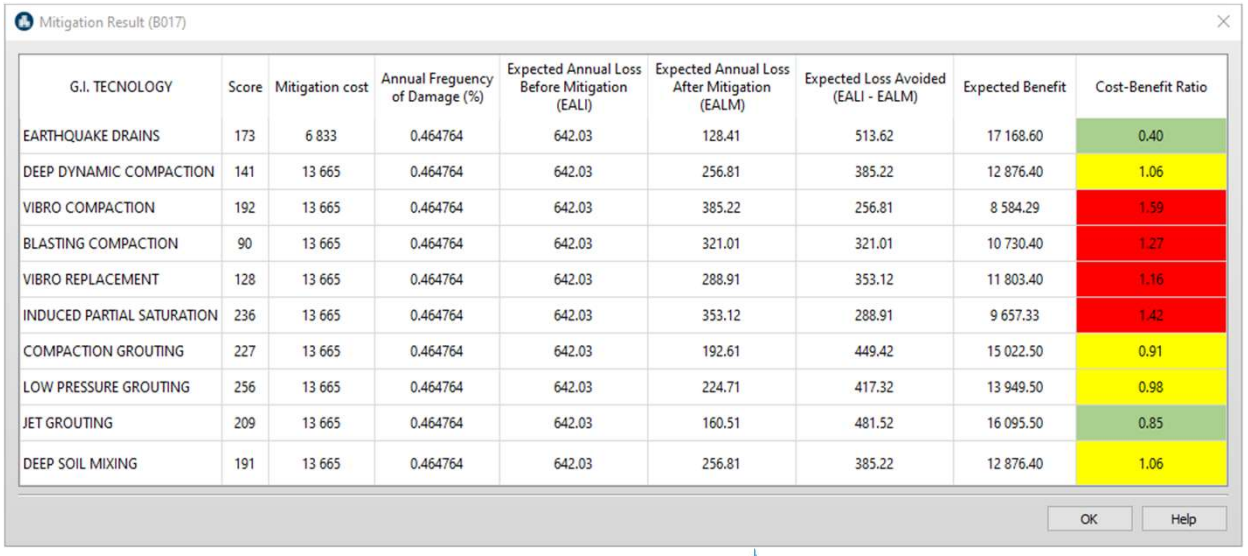
Cost-Benefit Analysis



Mitigation Result (B017)

G.I. TECNOLOGY	Score	Mitigation cost	Annual Freguency of Damage (%)	Expected Annual Loss Before Mitigation (EALI)	Expected Annual Loss After Mitigation (EALM)	Expected Loss Avoided (EALI - EALM)	Expected Benefit	Cost-Benefit Ratio
EARTHQUAKE DRAINS	173	6 833	0.464764	642.03	128.41	513.62	17 168.60	0.40
DEEP DYNAMIC COMPACTION	141	13 665	0.464764	642.03	256.81	385.22	12 876.40	1.06
VIBRO COMPACTION	192	13 665	0.464764	642.03	385.22	256.81	8 584.29	1.59
BLASTING COMPACTION	90	13 665	0.464764	642.03	321.01	321.01	10 730.40	1.27
VIBRO REPLACEMENT	128	13 665	0.464764	642.03	288.91	353.12	11 803.40	1.16
INDUCED PARTIAL SATURATION	236	13 665	0.464764	642.03	353.12	288.91	9 657.33	1.42
COMPACTION GROUTING	227	13 665	0.464764	642.03	192.61	449.42	15 022.50	0.91
LOW PRESSURE GROUTING	256	13 665	0.464764	642.03	224.71	417.32	13 949.50	0.98
JET GROUTING	209	13 665	0.464764	642.03	160.51	481.52	16 095.50	0.85
DEEP SOIL MIXING	191	13 665	0.464764	642.03	256.81	385.22	12 876.40	1.06

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