

Neo Deterministic Seismic Hazard Approach (NDSHA) for Seismic Response Analyses in Urban Areas: A Case Study from Italian Territory

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Received: July 18, 2025, Accepted: October 15, 2025

Abstract: The Neo-Deterministic Seismic Hazard Assessment (NDSHA) has been applied for nearly three decades to evaluate seismic hazard at both regional and local scales in Italy and internationally. At the local scale, NDSHA is able to integrate geological, seismotectonic, and geotechnical data to generate ground motion scenarios, broadband time histories, and related damage indicators, which serve as input for engineering design. Furthermore, NDSHA is a comprehensive approach to assess the local seismic response (LSR) to be used in microzonation studies. Hereinafter, the NDSHA-based analysis of LSR along a 2D section at the Chieti site (Italy) will be illustrated. While results are broadly consistent with traditional 2D finite element method, NDSHA offers additional insight into subsurface wave field behavior within the simulated domain.

Keywords: NDSHA, Local seismic response, Chieti (Italy), Microzoning, Seismic engineering design.

Introduction

The Neo-Deterministic Seismic Hazard Assessment (NDSHA) in the present study has been used to estimate the local seismic response (LSR) at the Chieti city (Abruzzo Region, Central Italy) through a 2D vertical section traced in Figures 1 and 2. NDSHA uses physically based scenarios of fault mechanisms to generate synthetic signals (that are: Transverse, Radial and Vertical components) propagated from the source to the site (Panza and Bela, 2020; Panza et al., 2022). NDSHA seismic sources are identified through different methods, such as the seismogenic zones (i.e. ZS9 by Meletti et al., 2004 in Italy), the seismogenic nodes, which are identified through the application of the pattern recognition to a morpho-structural analysis (MSZ) of the considered territory and the available active faults information. Compared to the standard probabilistic approach, NDSHA does not provide a

probabilistic estimate of the ground shaking parameter but pursues a credible estimation of seismic scenarios which can affect the target site. Seismic scenarios consist in acceleration, velocity and displacement response spectra on the surface of 1D or 2D vertical sections and the wave fields of Transverse, Radial and Vertical components of the propagated seismic waves.

Table 1, Main features of the seismogenic sources considered in the present study: the acronym ITIS refers to individual source and ITCS refers to composite source.

DISS-ID	ITIS094	ITIS002	ITIS003	ITCS078
Lat/Long (WGS84)	42.21/13.91	41.96/13.61	41.84/13.97	42.44/14.25
Length (km)	12	28	20	27
Width (km)	8	15.5	12.2	24
Min depth (km)	11	1.5	3	8
Max depth (km)	18.5	14.9	12.3	13
Strike (deg)	89	135	144	104
Dip (deg)	70	60	50	25
Rake (deg)	230	270	270	90
Mw	6.0	6.7	6.4	6.8
Past Earthquake	30/12/1456	13/01/1915	*800 B.C-1030 A.D.	3/11/1706

* based on paleo seismological studies

DISS-ID	ITIS015	ITIS131	ITIS132	ITIS027
Lat/Long	42.42/13.26	42.32/13.45	42.27/13.62	42.09/13.88
Length (km)	23.4	14	16.2	20
Width (km)	13.6	9.5	10.5	12.2
Min depth (km)	3	3	0.7	1
Max depth (km)	13.4	9.5	8.7	11.6
Strike (deg)	132	133	127	135
Dip (deg)	50	43	50	60
Rake (deg)	270	275	270	270
Mw	6.5	6.3	6.2	6.4
Latest Earthquake	02/02/1703	06/04/2009	Unknown	Unknown

In this study, the Italian Database of Individual Seismogenic Sources (DISS Working Group, 2025) and Ferrarini et al. (2021) for the composite faults have been used to predict LSR at the free surface in Chieti's city center, throughout the 2D section (Figure 2). Table 1 a, b

shows the main features of the considered faults. Hereinafter, the local seismic response along Chieti's section AA' has been briefly presented. More details can be found in Ricci et al. (2025) and Faraone et al. (2025).

Geological settings of Chieti's territory

The city of Chieti is constituted of an old city and an industrial one. The first is set on a hill (330 m above sea level) which is extended in an SSW-NE direction, with the Pescara River valley on its western bank. The alluvial plain of the Pescara River valley is where the second majority of the contemporary town and business district grew. Chieti's district falls into the Seismic Zone 918, which is characterized by moderate seismicity, with historical seismic events of about 4 M_w and hypocenter depth varying between 12 and 20 km. The main focal mechanism is normal. From a geological point of view, the Chieti's subsurface is constituted of sub-horizontal layers of the Mutignano formation (FMT), which is primarily composed of sandstones with inadequate cementation and over-consolidated clay material, formed the Chieti hill and can be thought of as the region's geologic bedrock. FMT can be categorized into several units, arranged from bottom to top, according to their litho-technical properties (Figure 1). Over the FMT formation, alluvial and eluvial-colluvial deposits outcrop. The physical and dynamic properties used in this study are reported in Figure 2 where the simulated 2D section is presented.

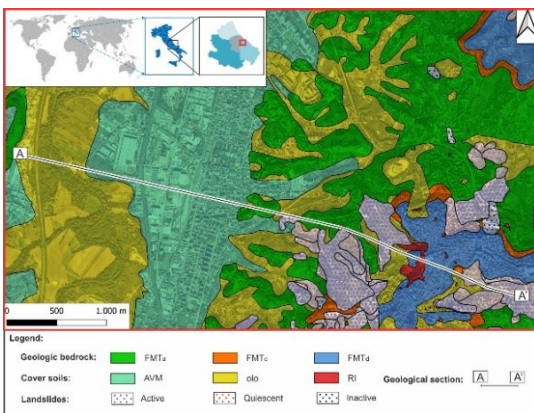


Figure 1, Geological map of Chieti district. FMT= the Mutignano formation: FMT_a= pelitic-sandy association; FMT_c= sandy-pelitic association; FMT_d= sandy-conglomeratic association; AVM= Terraced fluvial and alluvial-fan deposits; olo = Holocene deposits; RI= anthropogenic material.

NDSHA implements a hybrid approach, integrating multimodal summation and the finite difference technique with a viscous-elastic behavior of soils and rocks, effectively models the influence of lateral heterogeneities along seismic wave propagation paths (Fäh et al., 1993).

Local seismic response results

NDSHA approach enables the prediction of LSR by considering the seismic wave propagation from the

source, the directivity of the incoming wavefield towards the surface, its dispersion, refraction, and reflection phenomena.

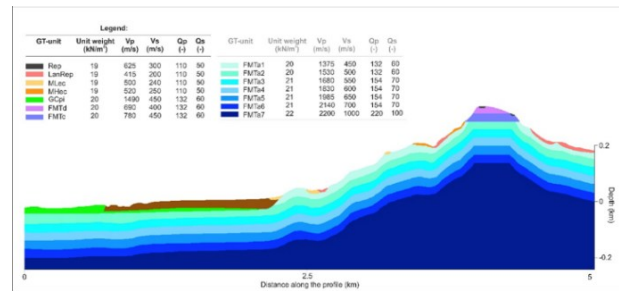


Figure 2, AA' vertical section (Fig. 1) used in this study to carry out 2D numerical simulations of seismic response.

In this study, seismic source ITCS078 produced peak spectral accelerations of about 1g on alluvial deposits and the hill's right flank (Figure 2, brown and orange) at periods 0.2–0.5 s. Amplification Factors (AF) were highest in these areas (1.8 and 1.4), while atop the hill AF reached 1.8 at 2.0 s.

Conclusion

In conclusion, this study provides the first NDSHA-based comprehensive LRS simulation for the Chieti district. Despite limits in representing elastic-plastic soil behavior, NDSHA's ability to account for wavefield directivity, dispersion, refraction, and reflection makes it a promising tool for 2D and 3D LRS-based microzonation in urban areas.

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