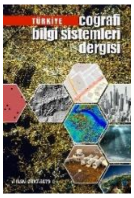
Turkish Journal of Geographic Information Systems
https://dergipark.org.tr/tr/pub/tucbis
e-ISSN 2687-5179



Earthquake-oriented spatial modeling of relational coded geographical attributes

Hande Okurlar*[1], **Metin Altan**[2]

[1]*Eskişehir Technical University, Science Faculty, Department of Physics 26470, Eskişehir-Turkey*
[2]*Eskişehir Technical University, Astrophysics Education and Research Unit, Eskişehir-Turkey*

Keywords
GIS,
Spatial Analysis,
Remote Sensing,
Aviation,
Space

Research Article
Received: 24/07/2023
Revised: 12/09/2023
Accepted: 18/09/2023
Published: 25/12/2023

ABSTRACT

Earthquake is a natural event that threatens living spaces on a global scale, cannot be prevented, but its destructive effect can be reduced by taking precautions. In earthquake-resistant settlement planning, determining the interaction of physical and spatial variables for site components is a primary requirement. The aim of this study is to produce a digital ground quality map that is scaled, rectified, projected and database interactively based on contribution independent of amount through positional recoding and grading methodology. Within the scope of studies towards this goal, ground quality was graded and impact assessment of residential areas in terms of earthquake exposure was carried out. Three-dimensional geographical modeling techniques were used on the digital platform and attribute effects on ground quality were mapped one by one and coded in proportion to their contribution to the result. As a result of field and laboratory studies, the analysis and modeling results on the digital map we produced were compared with the critical settlements and numerical data in the field. The impact risk of the ground was rated and detailed spatially in terms of geographical and geological characteristics. In the final stage, based on the case study, two districts from the Eskişehir-Turkey region were selected and the results of previous projects were detailed to examine the ground quality of the regions. Data of all geographical and geological parameters that contribute to ground quality as field components were graded using GIS modeling techniques and layered on the digital platform again by coding. As a result of this methodological study, a dynamic interactive digital risk map was obtained to check the real condition of buildings in terms of earthquake effects.

1. Introduction

When planning residential areas, detailed analysis of the geographical and geological characteristics of the ground through three-dimensional models created on digital platforms in a laboratory environment is of priority and importance in order to ensure safe settlement and reduce the destructive effect of the earthquake. This stage determines securely that re-structure of workspace design, engineering management and the precaution to be taken before, during and after the construction. At first, in order to detect the seismic condition of the zone, earthquake hazard analysis and engineering geological parameters must be determined (Ayday et al., 2001). The engineering geology applications to be used consist of geology, environment, city and regional planning and architecture. Mapping the data of the ground with different characteristics according to the degree of earthquake danger within these areas is called microzonation. The micro zoning and land use maps of the ground that will be used in detecting the locality which will be opened for settlement play an important role in predicting the hazards in an earthquake.

For spatial analysis and three-dimensional modeling within the framework of topological rules, the coordinates on the digital map and the geographic coordinates in the field should be associated. With GIS (Geographic Information System) techniques which enable gathering, modeling and analyzing geographical data, three-dimensional assessments can be performed and the data sets can be defined volumetrically by means of coordinating three-dimensionally (Bonham-Carter, 1994).

In this study, by two and three-dimensionally modeling the geological engineering parameters obtained from the field and laboratory surveys, their positional relations are revealed and the ground quality distribution is mapped. In order to explain distribution of ground quality characteristics precisely, a model had been constructed considering all related attributes of geographical parameters by CIAPRG (Contribution

---

***Corresponding Author**

*(handeokurlar322@gmail.com) ORCID 0009-0007-0893-6347
(maltan@eskisehir.edu.tr) ORCID 0000-0002-5247-887X

Cite this article

Okurlar, H., & Altan, M. (2023). Earthquake-oriented spatial modeling of relational coded geographical attributes. *Turkey Geographic Information Systems Journal*, *5*(2), 85-91.

Independent of Amount through Positional Recoding and Grading) Methodology.

2. Geographical and geological peculiarity

Two districts called Kurtuluş and Gökmeydan (Eskişehir-Turkey) were designated for as the study area. Study area which is included settlement area is length E-W direction is 1,74 km and N-S direction is 0,62 km and is 785 m above sea level located (Figure 1).

Studied area is located between Eskişehir Fault Zone and North Anatolian Fault Zone. İn addition, this area is located in the second-degree earthquake zone and contains geological units such as new alluvium, old alluvium and rock unit (Nefeslioğlu et al., 2003).

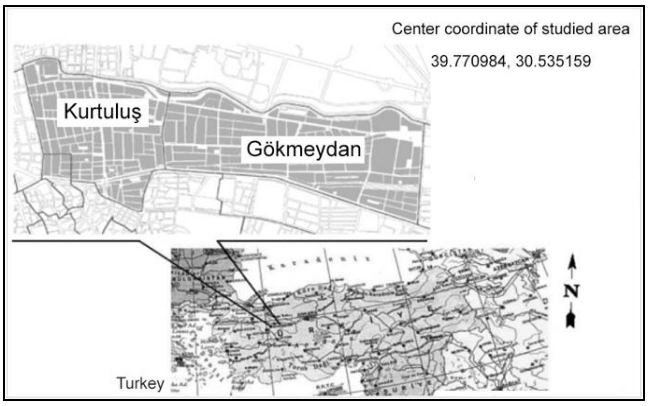


Figure 1. Location map of the study area

In this area, new alluvium ground is at high earthquake risk due to its liquefaction potential. Generally, below this level is silty clay in which silt percentage is higher and thick clay layer. In the lower layers, there is sand level and then below is silty sand. In the lower layers sand percentage increases and gravelly sand starts (Ayday et al., 2001).

3. Methodology and application

3.1. Modeling and mapping methodology

CIAPRG (Contribution Independent of Amount through Positional Recoding and Grading) method stages, in which the analysis and modeling process steps of the interactions of physical and spatial relationships between field components are used, have been effectively applied in our study. The purpose of the CIAPRG Methodology is to define the effect of the relational physical and chemical properties of the components on the 3D digital model and to structure them as map layers in element class format, taking into account the structural relationships between the components. (Altan et al., 2016). In the application phase, the components of the risk distribution to be mapped are first defined. Each of these components contributes to the total risk distribution in different ways in terms of structural, physical and locational aspects. By averaging the contribution of each impact, a distribution of total risk values is created and layered in the digital platform. Each variable that contributes to the risk distribution and each component that constructs that contributor should be structured at a different layer where the locational relationships will be modeled. Each component which contributes to the risk in the area takes a score as the risk contributor. At this stage, the vector based risk distribution map layer is transformed by the grid based map layer. The extent of contribution to the risk is defined by the relative contributions of other components. The contribution of each component depends on its own characteristics. These individual characteristic scores are written at the grid related coordinate and are correlated with their own characteristic information. Hence, it can be included in the calculations using the grid value. The contribution to the risk of each component in the same coordinate is different to that of the other components. The important point here is that each grid value represents the degree of contribution to the risk in the related coordinate. After this, the noted score at each grid is added to the other grid values at the related coordinate. Therefore, the recorded score at the related coordinate and grid will give a changeable result with the correlation of the extent of contribution to the resulting value which denotes the total result. In the last stage, the amount of contribution to the risk distribution was recoded due to its contribution to the risk and its own characteristic. The resulting map is a grid-based, scaled, coordinated, projection-defined and data base interactive digital map. On that map, for each of the coordinates, a grid based examination is possible. The contribution to risk can be examined for every separate coordinate, and therefore, the contribution of the component itself can be obtained as a ratio or the contribution of all the components can be obtained as a total. In this way, the researcher can interpret the results in terms of the different contributions of the components.

3.2. Mapping of individual layer

3.2.1. SCPT (seismic conic penetration test)

In terms of potential effects on accurately modelling and analyzing, it is very important that digitally define the threat of seismic activities to the ground of the settlement with geographical coordinate sensitivity, Kramer (1996). In addition to these related parameters, liquefaction potential is one of the most important risk factors.

The micro zoning and land use maps of the ground must be used for detecting the locality of settlement before will be built for predict studies the hazards in an earthquake. SCPT, which improved for this purpose, is one of the most important geophysics methods that are commonly used for determining the properties of dynamic ground (Campanella et al., 1986; Luna et al., 2000). On the other hand, empirical relations are the most important parameters in the process steps of the CPT (Conic Penetration Test) method (Suzuki et al., 1995). CPT makes it possible to measure constantly the penetration resistance of the ground and enables determining very thin layers that cannot be determined by using other techniques.

3.2.2. Field studies and modeling

A total of 69 different SCPT drilling data were used in the field research carried out with Anadolu University's SCPT device, and a general distribution was obtained by modeling the necessary data from 279 different layers (Ayday et al., 2001). In the context of this study, in terms of digital map layer formats, firmness values (N60) mapped, recoded and graded according to its contribution to the ground quality by CIAPRG methodology steps.

Vs (Shear Wave Velocity) is one of the parameters that are used especially for determining the effects of the earthquake-borne strong ground movement in alluvial grounds (Bozdağ, 2002). In another phase of this study, seismic ground effect was determined by assessing the Vs profile. Modeling and mapping of Vs distribution results, obtained by using effectively the GIS techniques, played an important role in determining earthquake risk. Vs measurements of alluvial ground were taken by SCPT that obtained in the microzonation stage of ground survey studies carried out in the year 2001 by Anadolu University, and rate of Vs change of the ground was modeled (Ayday et al., 2001). In the context of this study, Vs intermediate values distribution map that were calculated and mapped by using seismic records taken from the area was reexamined and Vs values were recoded and graded according to the contribution level to the ground quality of study area.

We included the NEHRP (National Earthquake Hazards Reduction Program) ground classification method, which is used to determine the effects of earthquakes according to ground conditions, at this stage of our study. Determination of ground motion growth standards are obtained by using regional conversions of Vs_{avr} (Average Speed Values of Shear Waves) of discrete grounds in upper levels, (Bauer et al., 2001). NEHRP (1997) soil classification are formed according to these standards and ground is divided into 6 different classes (Table 1). In this classification, value of ground motion growth increases from class A to class F (Street et al., 1997).

Table 1. NEHRP ground classification parameters

Soil Type	General Description	Vs (m/s)
A	Hard Rock	Vs >1500
B	Rock	760<Vs≤1500
C	Hard or stiff soils; most gravels	360<Vs≤760
D	Sand silts and/or stiff/very stiff clays, some gravels. Having average blow counts of 15≤N≤50 or average shear strength of 50kPa≤S≤100kPa	180<Vs≤360
E	Having thickness lower than 3 meters and Pl>20, w≥40% and S_u<25kPasoft clay	Vs <180
F	Needs specific calculations	

Vs_{avr} values were determined for each of SCPT in central Eskişehir and its vicinity by using first and last level reference signals. NEHRP soil classification was done by using regional conversions of obtained Vs_{avr} values (Ayday et al., 2001). For the purpose of explaining the ground behaviors in earthquake ground motion in detail, D soil class interval 180<Vs≤360 m/sn was divided into classes in itself. Class D was divided into intervals of D1: 180<Vs≤240 m/sn, D2: 240<Vs≤300 m/sn and D3: 300<Vs≤360 m/sn, Street (1997). Soil classification of central Eskişehir and its vicinity was done and mapped according to this principle (Tün et al., 2004a, b). Regions having condensation risk in previous NEHRP map, recoded and graded in terms of its effect on ground quality in the context of this study.

Earthquake waves, which have different characteristics in terms of the physical and geological characteristics of the ground of residential areas, were also examined in terms of motion characteristics in this study. Soil's water saturation, classification and granulation, the regions where the ground water levels are close to earth surface and the regions where the thickness of alluvium increased includes very important risks in terms of the buildings that is destroyed by impact of earthquake.

Electrical resistivity applications has been applied in 112 locations at city center by Government Water Department with a depth of nearly 60 m. The geophysical measurements obtained revealed that, the thickness of the alluvium in the studied area varied between 10-25 m, and that the northern east part reached a thickness varying between 10-15 and 15-25 m due to the over-storage of materials carried away by the Porsuk river (Azdiken & Çatalyürekli, 2001). The map of alluvium thickness recoded and graded in terms of its effect on ground quality in the context of this study for using CIAPRG methodology. The high level of Sand and silt proportions in the regions where alluvium thickness increases causes ground saturation. Around the river in the studied region, while towards the north direction thickness of alluvium increases, the deepness lays off from topography and the level of ground water closes to the earth surface (Figure 2).

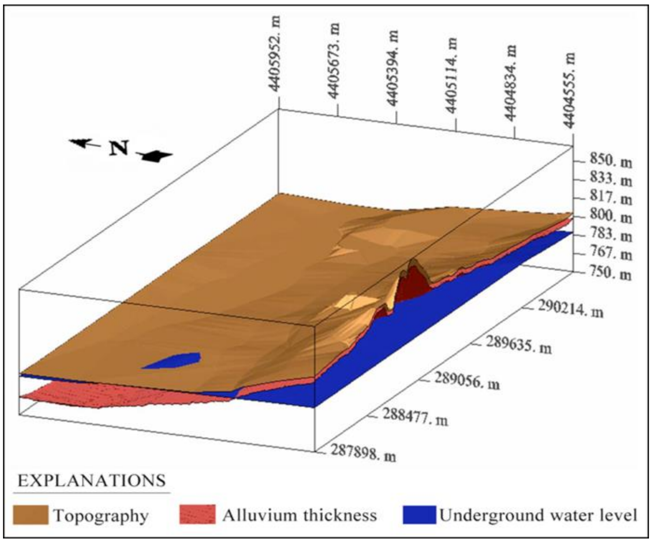


Figure 2. Relationship of topography-thickness of the alluvium-underground water level

According to the closeness of the ground water to the earth of its effect on ground, quality was recoded and graded in this context of the study (Altan et al., 1999).

Ground classification map of studied area was recoded and graded in terms of its effect on ground quality in the context of this study for CIAPRG methodology application. According to model (Tün et al., 2005) which was built by Anadolu University in 2005 and included the whole study area, study area is located where class E is densed and has high growth feature which is lower than 5 m. Volume elements of obtained Vs and saturation potential were modelled in three dimensions for CIAPRG methodology application steps and could be enabled more realistic interpretations compared to two dimensional maps in this context of the study (Figure 3).

In addition to this, in consequence of the analysis on model which was built in context of CIAPRG methodology, volumetric distribution of Vs speed was revealed in the area of 5 m below the surface and the layers where less than 108 m/s values were obtained.

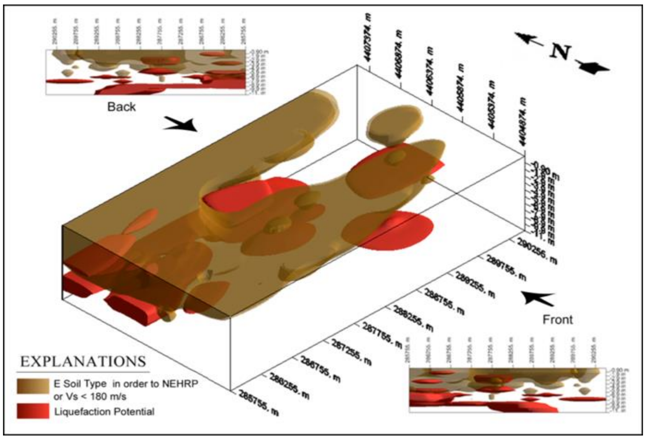


Figure 3. 3D Modeling of Vs-liquefaction potential and liquefactionable ground

According to the model, the layers with high sand and clay percentages are concentrated below 4m depth. For this reason, it is estimated that these overlapping areas will be under the influence of earthquake-borne ground movement double risk factor. The settlements on these areas will be damaged more. The positionally distribution of the liquescent ground could be interpreted based on the three-dimensional volume modeling produced by CIAPRG methodology steps (Figure 3). On these loose grounds, earthquake-borne ground movement magnifying effect and liquefying risk are encountered (Figure 4).

In order to determine the risk of earthquake in settlement areas, all the sources that have seismic activity must be detected and their future potential devastation capabilities must be estimated, Kramer (1996). For this reason, the ground properties must be known and modeled in detail.

The relationship between the resistance of normalized conic end (q_{tl}), friction rate (R_f) and liquefying potential used in CPT studies are important parameters in determining the liquefying potential (Nefeslioğlu et al., 2003).

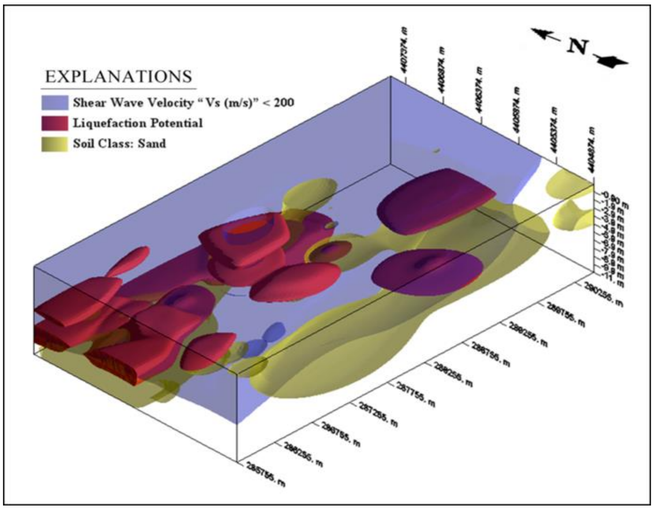


Figure 4. 3D Vs-liquefaction-sand distribution

0.5% R_f equals to approximately 5% fine grain rate and 1% R_f equals to about 10% fine grain rate. Therefore, R_f value can be used for characterization of fine grain rate. The fact that q_{lt} value is less than 15 Mpa and R_f value is less than 1% shows the liquefying potential (Suzuki et al., 1995). The potential of liquefaction was recoded from distribution map for building digital map of layers and graded in accordance with its contribution to the ground quality by CIAPRG methodology steps.

In context of this study, 25 drills and about 80 layers were used for creating a 3D model in terms of CIAPORG methodology applications. The areas where fine grain is lower than 35% and where sand is existent more than 40% yield unfavorable effects in terms of ground quality. It could be defined distribution of the sand (more than 40%) and fine grained (less than 35%) on different volumes of model thanks to CIAPRG methodology steps. Even if couldn't enough drills present on the target part of the study area, as artificially it could be made drills more than available drills on the 3D model at the related coordinates and could be modelling as 3D. While cutting the model volume from any levels horizontally, it could be produced, 2D distribution levels based on GIS applications. In terms of the underground components, thanks to CIAPRG methodology steps, this distributions could re-produced as a 2D map layer. In accordance with the objectives of the study, different 2D layers can be produced and spatial modeling can be made among themselves by based on GIS mentality. (Altan et al., 1999). In context of this study, digital map of the study area has been overlapped to the distribution of risky region layers in the model and these region effects on the ground quality have been recoded and graded by CIAPRG methodology application steps (Figure 5).

Ground types was classified in accordance with Robertson-1986 by modeling the data obtained from scientific research project related the CPT studies carried out by Anadolu University (Ayday et al., 2001). These ground classes have been recoded and graded again in accordance with the level of contribution to the ground quality in the context of this study in terms of CIAPORG methodology steps.

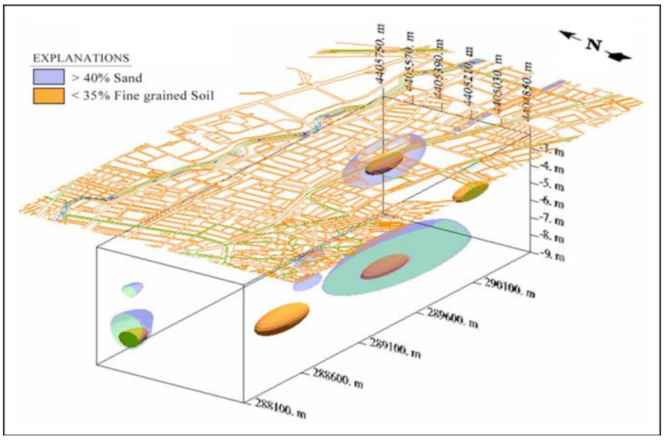


Figure 5. Overlapping 2D and 3D digital maps

The figures, q_{tl} and R_f, obtained from CPT data, exhibits different liquefying characteristics of attribute distributions depending upon the sort of the ground. It has been determined that the workspace includes the 7, 8 and 9 numbered sort of soil. Unified soil classification map have been prepared in accordance with the obtained data and within the scope of this study; the variables in the map graded and recoded in accordance with their effect on the soil quality by CIAPORG methodology.

3.3. Locational analysis and modeling

3.3.1. Spatial analysis with CIAPRG methodology for map layers

In context of this study, digital distribution relationally map layers have been re-produced for each of the contributors exhibited different qualities using analyzed data thanks to CIAPORG methodology steps. Superimposed maps have been used as contributor layers, which were classified and recoded, and the final ground quality distribution map have been generated by using CIAPRG methodology.

The superimpose process in terms of contribution of ground quality as an example for only one grid, located at the same coordinate in each contribution map, is shown in Figure 6. Thanks to the CIAPRG methodology applications, since the reproduced layers with the data obtained from field studies are defined in scaled, coordinated and projected, all areas and volumes examined on the digital map represent the facts in the field. The distribution maps in these layers can be superimposed by coordinated satellite image, and the spatial and volumetric characteristics of the study area can be revealed. This grading of ground quality and the effect assessment of residential areas when exposed to earthquake are exhibited with high resolution in artificial model scaled, rectified and projected.

The virtual model, which was produced from the analysis of the real field data, was re-coded and modeled again in terms of the total ground quality as a percent. These values, which were calculated, recoded and graded for each map, were generated for characterization of ground quality. All layers were overlapped with GIS techniques and effect parameter, re-analyzed, and modelled by CIAPRG methodology steps.

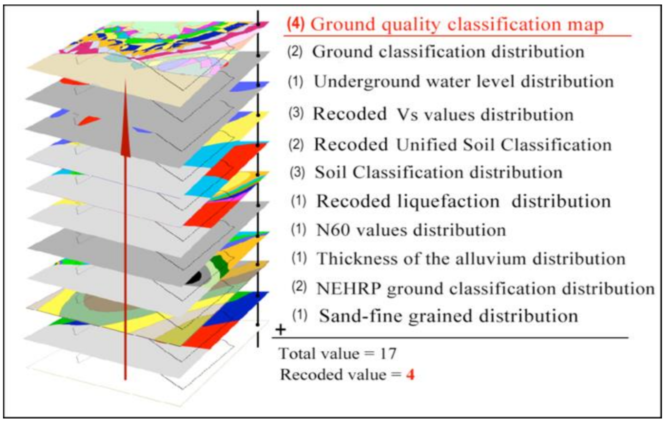


Figure 6. Example showing the superimposed process, in terms of contribution of ground quality, for one grid

Three-dimensional geographical modeling techniques were used in digital platform and the parameters affecting the ground quality are encoded again in the ratio of their contribution to the outcome by mapping one by one (Figure 6).

3.3.2. Determination of the number of storeys of the buildings in the study area

A pilot region consisting of 2 districts was designated for as the study area. The number of the storeys of 2713 buildings in the pilot region, consisting of the districts of Gökmeydan and Kurtuluş, was determined and was linked to relational database. As a part of this study, all the building in the workspace were examined one by one at the whole region and their physical properties was determined and digitized, and their features data was saved to database in terms of CIAPRG methodology steps.

3.3.3. Constitute of ground quality map.

In this study, effect parameter figures (included the ground firmness degree, velocity of shear wave, ground class, alluvium thickness, the approximation of the underground water to the surface, soil, liquefying point, fine grain and sand percentages) was mapped and modelled in 2D and 3D in terms of their contributions to the ground quality. In the wake of micro zoning studies, workspace is divided into 20 categories and the area each category covers is determined in percentages. The 1st ground category is the hardest and 20th ground category is the weakest one, for each variable reduces the quality of the ground (Figure 7, 8).

4. Conclusion

As a result of our field and laboratory studies, a 3D model-based ground quality classification map containing the contribution levels of all considered parameters was produced. This map, exhibits potential risks in terms of ground stability, should be used effectively in local authority's housing efforts and all the physical properties layer by layer should be considered during construction based on CIAPRG modelling.

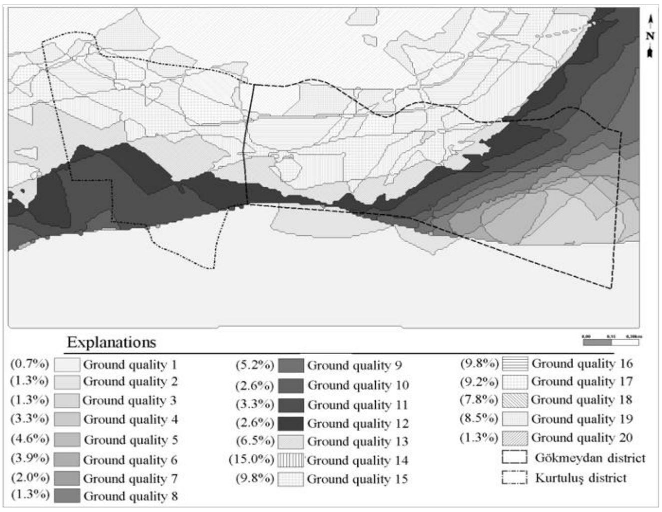
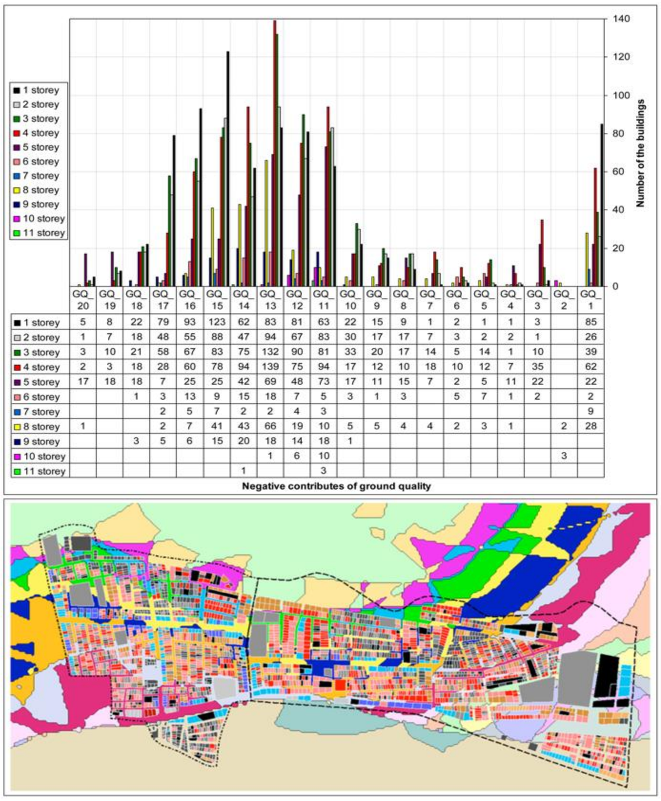


Figure 7. Ground quality classification map

In an attempt to evaluate the present condition of the workspace, in the map, vector polygons for each class was made by using positional modeling techniques and the buildings were determined in accordance with their ground class.



	GQ_20	GQ_19	GQ_18	GQ_17	GQ_16	GQ_15	GQ_14	GQ_13	GQ_12	GQ_11	GQ_10	GQ_9	GQ_8	GQ_7	GQ_6	GQ_5	GQ_4	GQ_3	GQ_2	GQ_1
■ 1 storey	5	8	22	79	93	123	62	83	81	63	22	15	9	1	2	1	1	3		85
□ 2 storey	1	7	18	48	55	88	47	94	67	83	30	17	17	7	3	2	2	1		26
■ 3 storey	3	10	21	58	67	83	75	132	90	81	33	20	17	14	5	14	1	10		39
■ 4 storey	2	3	18	28	60	78	94	139	75	94	17	12	10	18	10	12	7	35		62
■ 5 storey	17	18	18	7	25	25	42	69	48	73	17	11	15	7	2	5	11	22		22
■ 6 storey			1	3	13	9	15	18	7	5	3	1	3		5	7	1	2		2
■ 7 storey				2	5	7	2	2	4	3										9
□ 8 storey	1			2	7	41	43	66	19	10	5	5	4	4	2	3	1		2	28
■ 9 storey			3	5	6	15	20	18	14	18	1									
■ 10 storey								1	6	10									3	
■ 11 storey							1			3										

Figure 8. Overlap digital map of the studied area to model as virtually. (Storey-Ground quality classification relationship)

The distribution of ground classes according to the number of buildings and their height were examined statistically. Thanks to the CIAPRG analysis and modeling process steps, buildings with a selected degree of risk hazard could be found interactively on the database and could be mapped as a separate layer. For instance, using this digital map by CIAPRG steps, it could be separately mapped the buildings belongs to top priority risk like eight-storey with 20-point ground quality, eleven-storey with 14-point ground quality, eleven and ten-storey with 11-point ground quality (Figure 9).

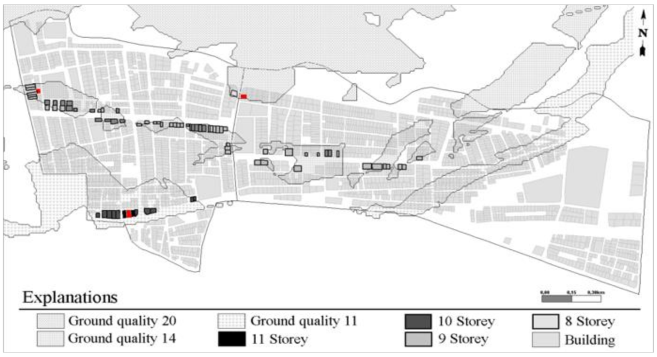


Figure 9. Relationship between risky buildings and ground quality

Figure 10. Relationship between ground quality and storeys

On the same coordinate ground quality and storey height have been gathered together and graded, and a new classification prepared (Figure 10). The map prepared at the end of this classification shows the risk in the settlement in the workspace in a way that involves the contribution of all parameters. Local authorities should be more cautious about buildings at the 8 to 10 graded scores and take necessary precautions in order to reduce risk.

Acknowledgments

This paper was supported by Eskişehir Technical University Scientific Research Projects Commission with project number 1404F204.

Author Contributions

Author1: Conceptualization, methodology, visualization, analysis and modeling. **Author2:** Review, edit, verify.

Statement of Conflicts of Interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

Research and publication ethics were complied with in the study.

References

Altan, M., Ayyıldız, O., Malkoç, S., Yazıcı, B., & Koparal, S. (2016). Mapping of heavy metal contamination characteristics using CIAPRG methodology. *Applied Ecology and Environmental Research*, 14(2), 433–446. http://dx.doi.org/10.15666/aeer/1402_433446

Altan, M., Öztürk, F., Gençler, G., & Ayday, C. (1999, October 18–22.). *Preparation of earthquake risk map of two districts of Eskişehir by using 3-dimensional geographic information systems techniques* [Symposium presentation]. International Conference on Earthquake Hazard and Risk in the Mediterranean Region, Near East University, Cyprus.

Ayday, C., Altan, M., Nefeslioğlu, H., Canıgür, A., Yerel, S. & Tün, M. (2001). *Eskişehir Yerleşim yerinin yerleşim amaçlı jeolojik ve jeoteknik etüd raporu*. Anadolu Üniversitesi, Uydu ve Uzay Bilimleri Araştırma Enstitüsü (in Turkish).

Azdiken, S., & Çatalyürekli, E. (2001*). Eskişehir Odunpazarı Belediyesi Jeofizik rezistivite etüt raporu.* Odunpazarı Belediyesi, Eskişehir (in Turkish).

Bauer, R. A., Kiefer, J., & Hester, N. (2001). Soil amplification maps for estimating earthquake ground motions in the central US. *Engineering Geology,* 62(1-3), 7-17. https://doi.org/10.1016/S0013-7952(01)00045-

Bonham–Carter, G. F. (1994). *Geographic Information Systems for Geoscientists*. Pergamon Press.

Bozdağ, E. (2002). *Estimation of earthquake site effects by array processing of microtremors in Yeşilyurt and Avcılar* (Publication No. 126921) [Master's thesis, Istanbul Technical University]. YÖK National Thesis Center.

Campanella, R. G., Robertson, P. K., & Gillespie, D. (1986). Seismic cone penetration test. *Proceedings of In Situ 86, A Specialty Conference on Use Of In Situ Tests In Geotechnical Engineering,* Blacksburg, Virginia.

Kramer, S. L. (1996). *Geotechnical Earthquake Engineering*. Prentice Hall.

Luna, R., & Jadi, H. (2000). Determination of dynamic soil properties using geophysical and NDT methodologies to transportation facilities and infrastructure. *St. Louis, MO,* 1-15.

Nefeslioğlu, H., Tün, M., Ayday, C., & Göktan, M. (2003). Change detection of structures in the earthquake hazard zoning map of Eskişehir City, Turkey, by using satellite images. *2nd Joint Workshop on Remote Sensing and Data Fusion over Urban Areas, Urban,* Berlin, Germany.

Street, R., Woolery, E., Wang, Z., & Harik, I. E. (1997). Soil classifications for estimating site-dependent response spectra and seismic coefficients for building code provisions in Western Kentucky. *Engineering Geology,* 46(3-4), 331–347. https://doi.org/10.1016/S0013-7952(97)00010-0

Suzuki, Y., Tokimatsu, K., Koyamada, K., Taya, Y., & Kubota, Y. (1995). Field correlation of soil liquefaction based on CPT data. *Proceedings of the International Symposium on Cone Penetration Testing,* 538-588.

Tün, M., Avdan, U., Altan, M., & Ayday, C. (2004, July 12–23). *Determination of characteristic site period and preliminary ground responce analysis according to responce by using GIS*. [Symposium presentation]. XX Congress International Society for Photogrammetry and Remote Sensing, ISPRS, İstanbul, Turkey.

Tün, M., Avdan, U., Altan, M., & Ayday, C. (2005, Mart 23–25.). *SCPT'den elde edilen sıvılaşma potansiyeli ve makaslama dalgası hızı (Vs) haritalarının 3 boyutlu CBS yöntemi kullanılarak karşılaştırılması* [Sempozyum sunumu]. Deprem Sempozyumu Kocaeli, Türkiye (in Turkish).

Tün, M., Avdan, U., Altan, M., Ayday, C., & Azdiken, S. (2004, Aralık 7–10). *Eskişehir yerleşim yerinde SCPT uygulaması ile NEHPR zemin sınıflaması* [Sempozyum sunumu]. Türkiye 16. Uluslararası Jeofizik Kongre ve Sergisi, Ankara, Türkiye (in Turkish).