Implications of GIS and RS Application in Geotechnical Mapping

Geotechnical Engineers study and predict the behavior of soils under natural and unnatural conditions. Their duties include evaluating the stability of slopes, designing excavations and foundations, as well as predicating settlements and developing subsurface cross-sections. Data used by geotechnical engineers is inherently difficult to obtain and analyze. It is not possible to excavate an entire site to determine what types of soil are present and where the stratums change. Geotechnical engineers rely on multiple sources of information to generate conservative predictions about soil interactions with minimal physical access to the soil in question. Because of the numerous sources of information used and the complexity of analyzing the information, a GIS can serve as a useful tool in the geotechnical engineer’s toolbox.

A GIS allows a geotechnical engineer to input field data displayed in CAD, spreadsheets, photos or maps and export it to a visual model to bring all relevant and available data together into a single, less complex database. By presenting all relevant data in an easy to view medium, geotechnical engineers can make better quality decisions more efficiently. A GIS presents an excellent medium to achieve this.

Through research, it is evident that GIS applications in geotechnical engineering practice are emerging. Currently, the two most prevalent applications of GIS within this field are risk analysis and development planning.

Research has proposed that evaluating the potential for failures resulting from earthquakes, landslides, and soil swelling can be improved by implementing a GIS into the analysis. When evaluating the potential for earthquakes, aerial photos can be used to define land use while a GIS can be used to analyze the potential for earthquake and soil liquefaction in relevant land use zones. By overlaying maps with data regarding soil type, groundwater level, tectonic plate fault lines and land use, a map can be developed that indicates communities at high risk for earthquakes. If only point data is available, kriging can be used to interpolate risk throughout larger areas. A similar process can be used to determine the potential risk for other various natural disasters by using different
input data. The implications of this method show promising potential for additional applications and development. Not only can this be used to identify areas currently at risk for natural disasters, but it may also be used to plan future developments to minimize risk potential and reduce costs incurred by overdesigning to accommodate for potential disasters.

The second emerging application of GIS and RS in geotechnical practice is improving the development planning process by utilizing a GIS with RS. Currently, geotechnical aspects of development planning is extremely difficult because in order to obtain accurate and reliable data, comprehensive and expensive site investigations need to be completed. As a way around this, research has proposed using a GIS to improve the amount of data available before performing site investigations, and presenting the available data in an easy to analyze medium. Reviewed case studies show the benefits of using TIN models to showcase soil stratums to evaluate contamination flow. Creating 3D models of soil stratums can be beneficial in many other applications as well. Another use of a GIS to improve project development is to optimize infrastructure placement to reduce external impacts such as impeding traffic flow by overlaying maps. A GIS can also be used to determine the amount of earthwork that needs to be performed and quantify volumes of excavation and fill required. This can improve cost estimation as well as project scheduling. A very interesting method proposed in research is to provide a web-based system that allows users to purchase relevant available information by presenting a map displaying locations of spatial and non-spatial data in certain areas. Unfortunately, this presents a conflict of interest. The amount of information a firm possesses is essential to maintaining a competitive market advantage, and by releasing this information to other firms, they will directly benefit the competition even if they are charging for the information. Another interesting application of GIS in a geotechnical setting is analyzing the quality of a subsurface investigation for a site by combining kriging with generally expected correlations relating investigation quality to various spatial qualities of the investigation. Geotechnical engineers rely heavily on obtained data, and determining the quality of the data is often difficult. By using a GIS, engineers and developers can use an alternative method to determine the quality of the data available to them.
The introduction of GIS and RS to geotechnical applications is relatively new, and is continually developing. Originally, two-dimensional models were the primary application of GIS. In a geotechnical setting, three-dimensional models containing information regarding location and depth of soils are essential. The presented applications of GIS provide significant reason to continue developing three-dimensional models. The complexity and magnitude of subsurface properties require an easy to understand and maintain medium to effectively provide access to pertinent available data. GIS provides a quintessential venue to achieve this. As it becomes more understood, it will certainly become more widely used in geotechnical offices.

The authors present GIS as a new, state of the art tool that is available to geotechnical engineers and highlights its application by reviewing four case studies. The three GIS components that the authors believe should be utilized are: databases, graphic interfaces and data analysis. The first case the authors discuss is an archeological survey where subsurfacial soil conditions were mapped using TIN models to showcase the archaeological potential of the site and to locate the most effective excavation locations. The second case presented a use of a GIS for contaminated land assessment and remediation. A GIS was used to create a TIN model of subsurface soil stratum and to determine the path of contamination found in boreholes and trial pits. In the third case study, a GIS was used to evaluate the foundation design options, calculate volumes for earthwork, and assess slope stability for a proposed large shopping complex in Czech Republic. The fourth case described how a GIS was used to optimize the construction of a retaining wall for a new railway in Hong Kong, while minimizing disruption to traffic in a busy urban area nearby. The authors suggest that the uses in each case prove the merits of GIS application in a geotechnical setting and should thus be a standard tool in the civil engineering workplace.


The authors provide a new approach to assessing the potential for landslides in a given location by utilizing a GIS as a tool for “efficient and effective data capture, storage, management, retrieval, analysis, integration and display”. They discuss the parameters used to quantify landslide probability as being either intrinsic (geological conditions/slope structures) or extrinsic (rainfall/human activities) and by using a GIS, both of these different types of factors can be analyzed simultaneously. The first proposed method is using map overlaying to create landslide mapping units based off of different maps in common locations, which show the inferred or computed degree of landslide hazard. The second proposed method is the application of digital elevation models (DEMs) to estimate slope gradient, analyze hydrological flow paths, provide aspect and shaded relief information and various other uses to estimate landslide probability. The final, and most detailed proposed method is to create a GIS-based model of landslide hazard that combines the previous two methods with various GIS tools to “model geospatial data in an integrative way” to predict landslide potential. The authors discuss how these methods and models can only be validated through time and the overall benefit of using a GIS prediction system over the current practice still remains in question.
The authors present an online application of a GIS in geotechnical engineering that can be used to locate and purchase boreholes of interest, view borelogs and cross sections that are generated online, provide downloadable data in standard format for downstream analysis, and perform geotechnical queries using a geotechnical search engine. The authors explain how beneficial it is for existing geotechnical information to be accessible. They present a 3D GIS that models information such as stratification of soil types, variation of soil properties with depth and other subsurficial parameters. Because GIS was originally developed to deal with 2D planes, the authors had to develop a GIS in which 3D geotechnical information was stored digitally. To do this, the authors integrated GIS with a relational database management system (RDBMS), which allowed for multirow information for a single feature. The developed GIS had three main components: the database, the server-side geotechnical engine (SGE) and the web interface. The database includes both spatial data (town boundaries, roads, buildings etc.) and nonspatial data (borehole info, soil properties etc.) about certain areas. The SGE allows for interaction between the web-interface and the database. The web-interface allows third-party users to go to the website and search for relevant services. The ability to search a database of available 3D subsurficial cross-sections on the Internet is an extremely useful tool to geotechnical engineers.


This paper discusses the advantage of using a software tool called GIS-ASSES to evaluate subsurface site investigation quality. The tool uses ordinary kriging, indicator kriging and applies principals and concepts presented by Tsai (1996) and Tsai and Frost (1996, 1999), which relate investigation quality the effective measurement area of the tool used, spatial correlation, prior knowledge of the site, nature of the contamination, the target object’s characteristics, and noise effects. The tool generates a value of investigation quality to specific locations, which can be used to interpret overall site investigation quality as well as specific locational investigation quality. Analysis is based geostatistical methods, and results are displayed in ways that are easily comprehended. The tool can also be used to measure the effect of varying sampling techniques and additional sampling on overall site investigation quality. This can provide engineers with valuable information allowing them to make decisions more confidently and can also save both engineers and clients money.
Due to the recent increase in demand for slate, the authors propose a new method for evaluating the potential for proposed slate mine locations in Spain to improve the selection of mines with the highest quality slate. The authors’ process includes collecting relevant topographical and geological maps for the areas in question, defining the variables impacting quality of slate, creating a geotechnical quality index for a given rock mass, using ordinary kriging to create geotechnical quality maps, integrated all the previous data into a GIS and ultimately providing the potential for a proposed mine location. The GIS contains topographical and geological data, information on licenses and permits, and other information impacting the mining feasibility of a proposed location. The collection of information can be analyzed simultaneously to quantify the quality of a proposed mine location. Decisions to choose mine locations can now be made based off of all available relevant data in a way that is easier and more effective than previous analytical techniques.


The authors present a GIS-based model that can be used to measure the risk that certain areas have for natural disasters. The authors chose to exemplify the model by showing its effectiveness in the North Antolian Fault Zone, an area with high risk for earthquakes and soil liquefaction. Their method uses a GIS-based model to create a database of seismic microzonation studies for cities with high risks of natural disaster. The Unified Modeling Language was used to model world objects in the computer environment. Aerial photos were evaluated to determine land use and geotechnical investigations and studies were used to create a database of subsurficial soil conditions and groundwater levels. The combined data was integrated into a GIS environment using ArcGIS and potential areas for soil liquefaction were displayed. The method could also be used to measure the potential effect of earthquakes or other natural disasters by simply inputting different failure parameters. The proposed method can be used to reduce or prevent damage resulting from disasters such as earthquakes, landslides and floods.


Swelling of clays occur when dry clay is inundated with water increasing its void ratio and thus increasing its total volume. Swelling clays can cause damage to vital infrastructure such as drinking and wastewater networks, aboveground structures, or irrigation pipes. The author proposes a method of developing a swelling potential map by using a GIS. A digital map of a region is prepared and data obtained from the
investigated area was added to the GIS. Zonation maps were prepared by evaluating the various mechanisms that cause swelling, which indicated high and low risk areas for swelling. These maps can be used in development planning to reduce the risk for future damage due to swelling as well as reduce the initial cost of projects by allowing developers to design in locations with lower risks for swelling soils.