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An Integrated Approach for Urban Earthquake Vulnerability Analyses

H.S. Düzgün (1), M.S. Yücemen (2), and H.S. Kalaycioglu (3)

(1) Geodetic and Geographic Information Technologies, Middle East Technical University, Ankara, Turkey, (duzgun@metu.edu.tr), (2) Civil Engineering Department, Middle East Technical University, Ankara, Turkey, (yucemen@metu.edu.tr), (3) Sibel Kalaycioglu, Department of Sociology, Middle East Technical University, Ankara, Turkey, (ksibel@metu.edu.tr)

The earthquake risk for an urban area has increased over the years due to the increasing complexities in urban environments. The main reasons are the location of major cities in hazard prone areas, growth in urbanization and population and rising wealth measures. In recent years physical examples of these factors are observed through the growing costs of major disasters in urban areas which have stimulated a demand for in-depth evaluation of possible strategies to manage the large scale damaging effects of earthquakes. Understanding and formulation of urban earthquake risk requires consideration of a wide range of risk aspects, which can be handled by developing an integrated approach. In such an integrated approach, an interdisciplinary view should be incorporated into the risk assessment. Risk assessment for an urban area requires prediction of vulnerabilities related to elements at risk in the urban area and integration of individual vulnerability assessments. However, due to complex nature of an urban environment, estimating vulnerabilities and integrating them necessities development of integrated approaches in which vulnerabilities of social, economical, structural (building stock and infrastructure), cultural and historical heritage are estimated for a given urban area over a given time period.

In this study an integrated urban earthquake vulnerability assessment framework, which considers vulnerability of urban environment in a holistic manner and performs the vulnerability assessment for the smallest administrative unit, namely at neighborhood scale, is proposed. The main motivation behind this approach is the inability to implement existing vulnerability assessment methodologies for countries like Turkey, where the required data are usually missing or inadequate and decision makers seek for prioritization of their limited resources in risk reduction in the administrative districts from which they are responsible. The methodology integrates socio-economical, structural, coastal, ground condition, organizational vulnerabilities, as well as accessibility to critical services within the framework. The proposed framework has the following eight components: Seismic hazard analysis, soil response analysis, tsunami inundation analysis, structural vulnerability analysis, socio-economic vulnerability analysis, accessibility to critical services, GIS-based integrated vulnerability assessment, and visualization of vulnerabilities in 3D virtual city model

The integrated model for various vulnerabilities obtained for the urban area is developed in GIS environment by using individual vulnerability assessments for considered elements at risk and serve for establishing the backbone of the spatial decision support system. The stages followed in the model are: Determination of a common mapping unit for each aspect of urban earthquake vulnerability, formation of a geo-database for the vulnerabilities, evaluation of urban vulnerability based on multi attribute utility theory with various weighting algorithms, mapping of the evaluated integrated earthquake risk in geographic information systems (GIS) in the neighborhood scale. The framework is also applicable to larger geographical mapping scales, for example, the building scale. When illustrating the results in building scale, 3-D visualizations with remote sensing data is used so that decision-makers can easily interpret the outputs.

The proposed vulnerability assessment framework is flexible and can easily be applied to urban environments at various geographical scales with different mapping units. The obtained total vulnerability maps for the urban area provide a baseline for the development of risk reduction strategies for the decision makers. Moreover, as several aspects of elements at risk for an urban area is considered through vulnerability analyses, effect on changes in vulnerability conditions on the total can easily be determined. The developed approach also enables decision makers to monitor temporal and spatial changes in the urban environment due to implementation of risk reduction

strategies.