

## **VULNERABILITY ASSESSMENT AND RISK MANAGEMENT OF LIFELINES, INFRASTRUCTURES AND CRITICAL FACILITIES. THE CASE OF THESSALONIKI' S METROPOLITAN AREA.**

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### **ABSTRACT**

The paper presents an application of a general modular methodology for the vulnerability assessment and seismic risk management of lifelines and infrastructures in Thessaloniki (Greece). A short description is provided of different factors involved like the inventory, the typology, the vulnerability characteristics and the importance (global value) of the elements at risk, as well as the construction of seismic scenarios (seismic hazard), the geotechnical characterization and the detailed site response of the area.. Given the spatial distribution of the characteristics of earthquake motion, loss scenarios for lifelines and transportation systems are produced using inventory data and adequate fragility curves. Herein, examples of estimated earthquake losses for the transportation (port and roadway) and utility (water) systems in Thessaloniki are presented for specific seismic scenarios. Furthermore, the assessment of the “global value” (material and immaterial) is performed in order to classify the importance of each lifeline element in different periods (normal, crisis and recovery) and thus to prioritize in a more efficient way the pre-earthquake retrofitting actions and the post earthquake restoration efforts. Based on the hierarchy of importance of lifeline components, as well as available techniques, man-power, material and equipment, estimates of the restoration process are performed. The previous applications reveal the importance of site specific seismic response analysis (i.e. detailed and advanced microzonation study) and adequate vulnerability and restoration models for the seismic risk management, in order to reduce the expected consequences from different earthquake events.

Keywords: lifelines, vulnerability, seismic scenarios, seismic risk management, Microzonation study

### **INTRODUCTION**

Modern societies are totally relied on a complex network of infrastructures. They are the basic installations and facilities on which the continuance and growth of a community depends. Their variability, the lack of well-validated damage data from strong earthquakes, the definition of damage state and the lack of common guidelines or codes, makes the vulnerability assessment of each particular component and of the network as a whole, a very difficult task. Moreover, taking into account the functional and social vulnerability of lifeline elements through a global value analysis

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lifeline networks can be analyzed as an integrated part of the seismic risk scenario and as a part of the urban system, with human, material and immaterial elements. Thus, a prioritization pre-earthquake retrofiting actions and quantification of the overall importance of different complex and coupled lifeline systems could be made.

Herein a methodology is presented for the seismic risk analysis of infrastructures based on a detailed site response analysis with an application to Thessaloniki's Metropolitan area. The significant influence of the surface geology conditions and topography on ground motion is well known and documented, highlighting the importance of seismic hazard analysis and the role of local soil conditions. Furthermore, adequate loss scenarios are generated taking into consideration the inventory, typology and vulnerability characteristics of the elements at risk, as well as the seismic hazard, geotechnical characterization and site response of the main soil formations for different seismic scenarios. The examples of the vulnerability assessment of different lifeline systems as well as the efficient restoration strategies that presented in this paper are based on the combined consideration of physical and functional/ social vulnerability of different elements at risk.

The work reported in the paper is part of the research project SRM-LIFE (2003-2007) in which several partners from University, Public Authorities, Local Municipalities and Organizations managing/owning lifelines participate.

## METHODOLOGY

The discrete steps of the methodology developed for the vulnerability assessment and seismic risk management of lifelines and infrastructures are illustrated in figure 1. Loss estimates including physical damage, direct and indirect losses, depend on the existing inventory and typology classification of the elements at risk, the vulnerability models to be used and existing interactions between lifeline components. The level of seismic input motion is defined on the basis of a Microzonation study in order to take into account the effects of the seismic soil response and local site effects. Combining the vulnerability assessment with the importance of different elements in pre and post seismic periods, a rigorous disaster management process including mitigation, preparedness, response and recovery actions could be assigned. An important step for the implementation of an "efficient mitigation strategy" includes a simplified or a more advanced reliability analysis of the damaged and the undamaged system in order to estimate the level of the remaining serviceability of the system which is closely connected with the functionality of the community.

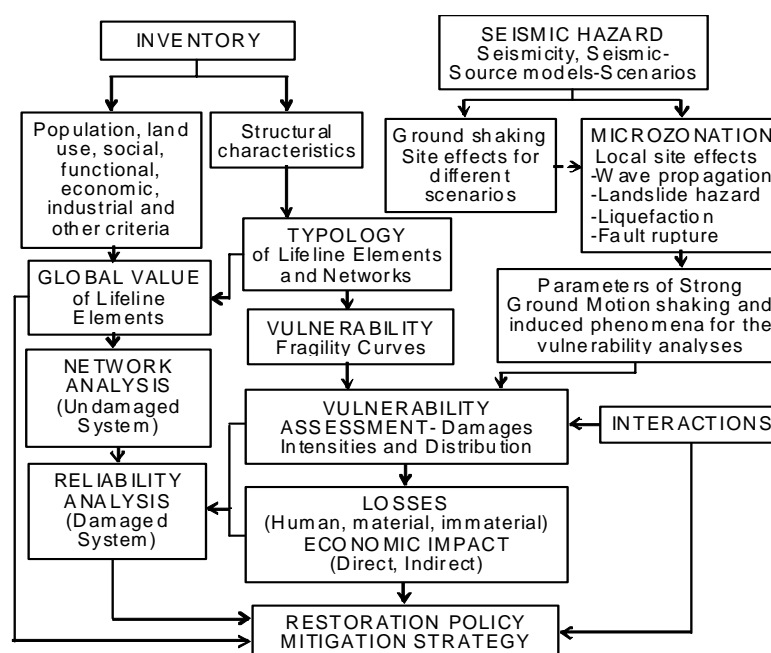


Figure 1. Flowchart of the methodology (Pitilakis et al., 2005).

## SEISMIC SCENARIOS – MICROZONATION STUDY

In Thessaloniki a detailed Microzonation study has been conducted for three different mean return periods  $T_m=100$ , 475 and 1000 years. The study is based on the results of a probabilistic seismic hazard analysis using recently obtained data regarding the seismicity, the corresponding seismic zones and the seismic faults in the greater area (RISKUE, 2001-2004, SRMLIFE, 2003-2007). Site effects are calculated performing a great number of 1D linear equivalent response analyses in order to take into account the influence of geotechnical characteristics and dynamic properties of the main soil formations on expected seismic ground motion. The analysis is performed with five different scaled real accelerograms (representing bed rock conditions) selected according to seismic hazard study.

### Geological and Morphological Setting

Thessaloniki and its suburbs are located along Thermaikos Gulf and have a rather smooth topographical relief. The metropolitan area of Thessaloniki is situated on three (3) main large-scale geology structures, oriented in NW-SE direction. The first formation includes the metamorphic substratum consisting of gneiss, epigneiss, and green schists, which are surficial near the city at the N-NE border of the urban area. These crystalline rocks constitute the bedrock basement beneath the city reaching a depth of 150-300m near the coastline in W-WS direction. The second formation is composed by alluvial deposits mainly of the Neogene period. In this geological structure the red silty clay, series are dominant, covering the bedrock basement beneath the city. Finally, recent deposits consisting of Holocene clay-sand-debris geological materials compose the third surficial unit.

### Seismicity and Tectonics

Thessaloniki is located close to one of the most active seismotectonic zones in Europe (Papazachos et al., 1979). It is a Quaternary formation, tectonically re-activated during the Neocene-Quaternary, in contact with the Jurassic subduction zone of Vardari's ocean under the continental Servomakedonian zone, with nearly vertical normal faults (Mercier, 1968). It is classified as a tectonically active region, with the presence of several active faults. During the Neotectonic period (Lower Neogene and mostly Quaternary period) extensive tectonic submersion zones and sinks have been happened creating the present active normal fault system with an E-W direction.

The city of Thessaloniki has experienced several destructive earthquakes since its foundation. The available historical and instrumental data indicate three discrete periods of high seismic activity near the city (7<sup>th</sup> AD, 15<sup>th</sup> -18<sup>th</sup>, and 20<sup>th</sup> centuries). Despite the "relative accuracy" of the historic earthquakes, referring mostly to the oldest ones and especially to their epicenter geographic position, the earthquakes practically affecting the city occur from Axios', Mygdonia's and Anthemounta's graben zones.

The latest major earthquake registering a magnitude  $M$  of 6.5, struck the city in 1978. Its epicentre was located about 30 km east of the city. It resulted in 50 deaths and severely damaged a significant number of buildings. The public repair cost of the particular residences was of the order of 250 million US dollars (1978). The total economic damage was certainly very high.

### Geotechnical Zonation and Dynamic soil characteristics

Reliable modeling and evaluation of site effects is the key problem in seismic microzonation especially in high seismicity areas, with complex geology and highly heterogeneous soils. Additionally, risk reduction studies require the detailed, spatial distribution of specific parameters (e.g. PGA, PGV, PGD) in a broader area, for different seismic scenarios.

Hence, a detailed model of the surface geology and geotechnical characteristics, for site effect studies, was generated for the city of Thessaloniki. The resulted geotechnical map (Anastasiadis et al., 2001) was based on numerous data provided by geotechnical investigations (boreholes, CPT's, water wells), geophysical surveys (cross holes, down holes, surface seismics), microtremors measurements, classical geotechnical and special soil dynamic tests (resonant column, cyclic triaxial) (Pitilakis et al., 1992,

Pitilakis and Anastasiadis, 1998, Raptakis et al., 1994a, Raptakis et al., 1994b, Raptakis 1995, Apostolidis et al.2004). The thematic GIS maps in figure 2 illustrate the spatial distribution and the thickness of two of the main soil formations. In total nine (9) different soil formations are needed to fully describe the subsoil conditions in the city (Table 1). These maps resulted from the synthesis of all available data and depict the thickness of the A and C soil formations, the depth of the stiff clayey formations (E and F) and the depth of the rock basement (formation G) with respect to the regions where they are predominant. The variation of the thickness and the depth shows a certain irregularity of the subsoil structure beneath the urban area of the city.

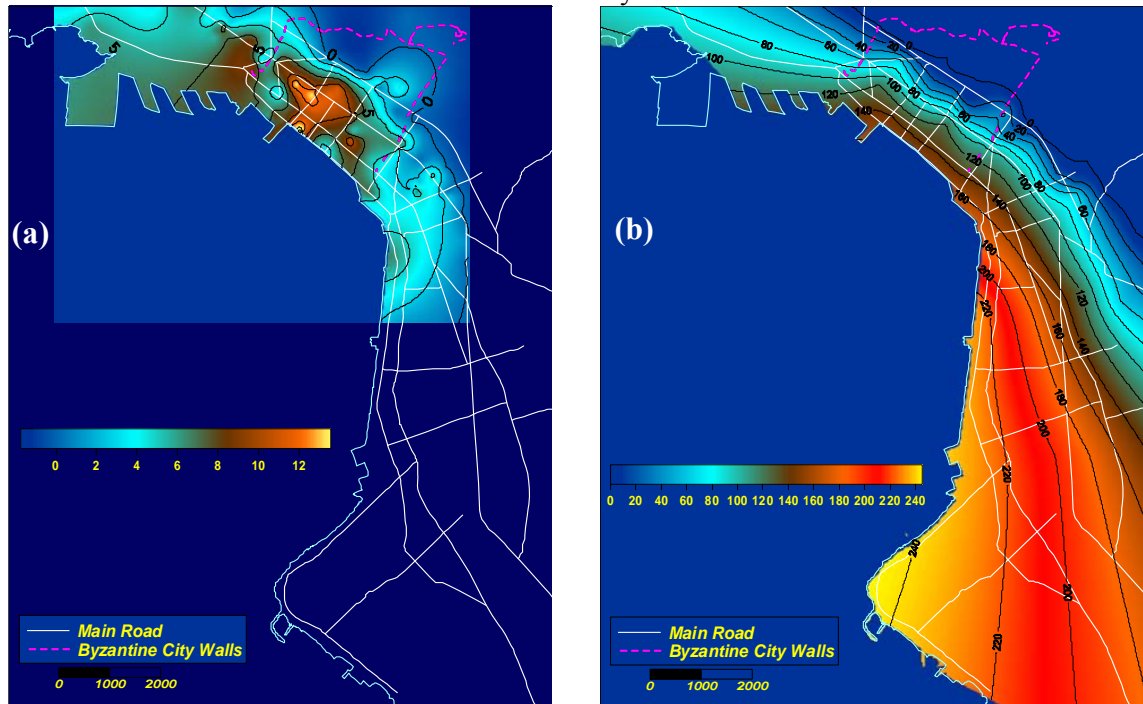
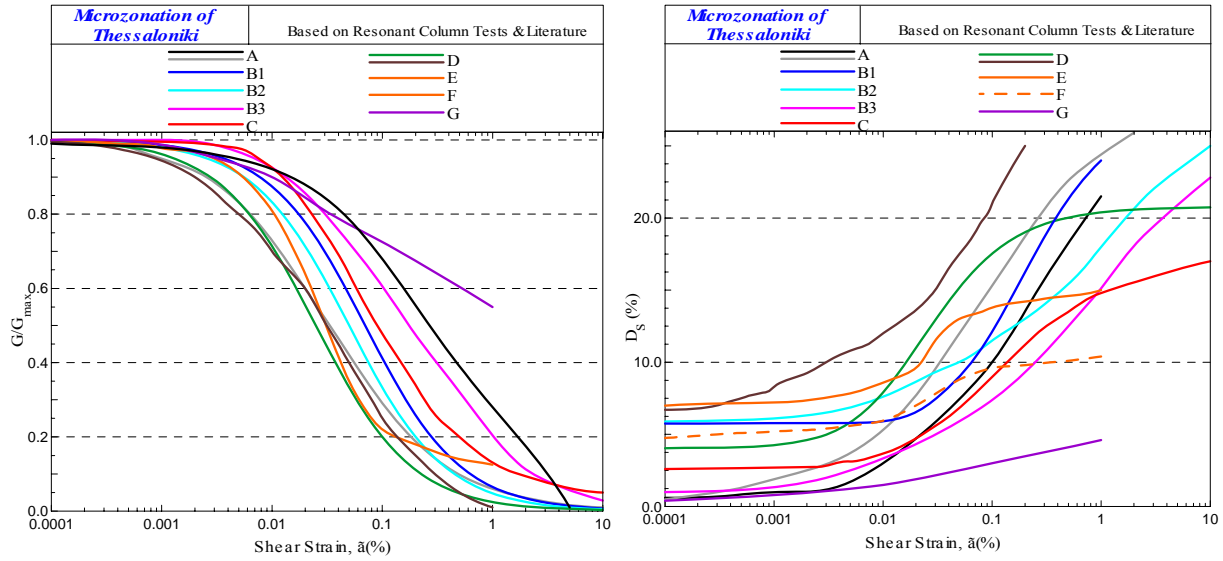


Figure 2. Geotechnical thematic maps for the main soil formations (A, C, E and F and G). a) thickness of formation A (artificial fills); b) top surface of the formation G (bedrock).

Table 1. Dynamic properties of the main soil formations of Thessaloniki urban area. The values in brackets specify the mean values of VS velocities and quality factors QS.

| Formation | Description  | $V_s$<br>(m/s)   | $V_p$<br>(m/s) | $Q_s$         |
|-----------|--|------------------|----------------|---------------|
| (1)       | (2)  | (5)              | (6)            | (7)           |
| <b>A</b>  | Artificial Fills, demolition materials & debris parts  | 200-350 (250)    | 400-1700       | 8-20 (15)     |
| <b>B1</b> | Very Stiff sandy-silty clays to clayey sands, low plasticity   | 300-400 (350)    | 1900           | 15-20 (20)    |
| <b>B2</b> | Soft sandy-silty clays to clayey sands, low to medium plasticity   | 200-300 (250)    | 1800           | 20-25 (20)    |
| <b>B3</b> | Stiff to hard high plasticity clays  | 300-400 (350)    | 1800           | 20-40 (30)    |
| <b>C</b>  | Very soft buy mud and silty sands  | 120-220 (180)    | 1800           | 20-25 (25)    |
| <b>D</b>  | Alluvium deposits, sandy-silty clays to clayey sands-silts, low strength and high compressibility                          | 150-250 (200)    | 1800           | 15-25 (20)    |
| <b>E</b>  | Stiff to hard sandy-silty clays to clayey sands  | 350-700 (600)    | 2000           | 6-30 (30)     |
| <b>F</b>  | Very stiff to hard low to medium plasticity clays to sandy clays, overconsolidated with rubbles and thin layers of gravels | 700-850 (750)    | 3200           | 50-60 (60)    |
| <b>G</b>  | GreenSchists & Gneiss  | 1750-2200 (2000) | 4500           | 180-200 (200) |

Degradation curves of shear modulus  $G/G_0-\gamma$  and damping ratio  $D_s-\gamma$ , determined for all nine-soil formations from an extended laboratory including resonant column and cyclic triaxial tests (Pitilakis et al., 1992, Pitilakis and Anastasiadis, 1998, Anastasiadis, 1994) are depicted in figure 3.



**Figure 3. Average degradation curves of shear modulus  $G/G_0-\gamma$  and damping ratio  $D_s-\gamma$  of the main soil formations of Thessaloniki urban area.**

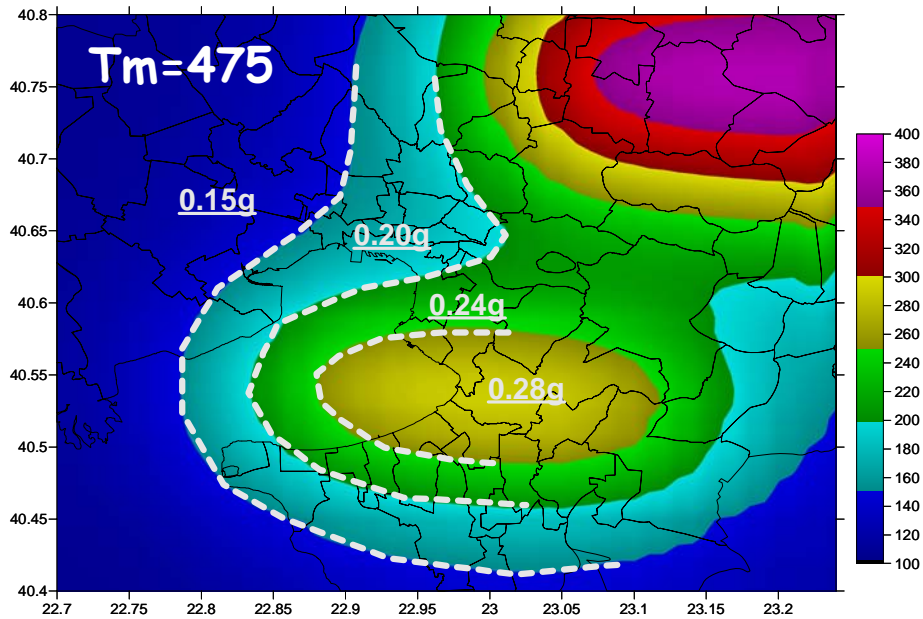
### Site Response Analysis

The geotechnical map together with thematic GIS maps describing the spatial distribution and the thickness of each soil formation combined with detailed 2D design cross sections, were used to develop adequate 1D soil profiles at 520 representative sites in a quadratic grid ranging from 1000m x 1000m to 250m x 250m.

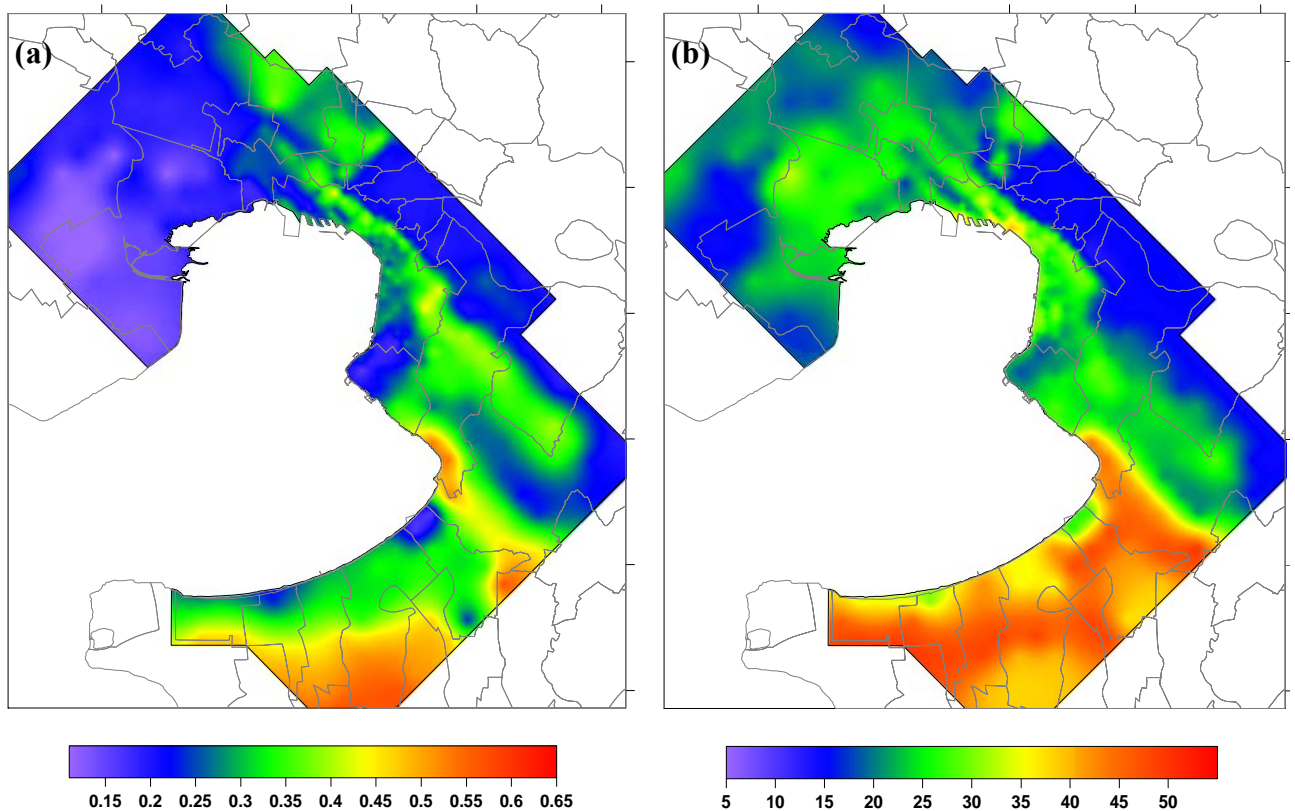
1D-EQL soil response analyses (Schnabel et al., 1972) are conducted using as input motion recorded acceleration time histories of five earthquakes, which were found to have characteristics that cover satisfactorily the intensity and frequency content of the earthquake scenario bedrock motion in the area of Thessaloniki. The recorded input motions were scaled properly according to the seismic hazard results referring at three scenarios (mean recurrence period of 100, 475 and 1000 years) of the urban area and the similarity of the average acceleration response spectrum values with the scenario spectrum on hard soil or outcropping bedrock conditions. Figure 4 depicts representative results in terms of mean PGA(g's) at outcropping bedrock conditions for the area in interest, stemming from seismic hazard analysis for 475 years return period (Papaioannou 2004).

For the earthquake scenario with 10% probability of exceedance in 50 years (mean return period of 475 years), according to the results of probabilistic seismic hazard study, the characteristics of the calculated seismic ground motions at the free surface, in terms of peak acceleration (PGA) and velocity (PGV) are presented in figure 5. It should be mentioned that risk reduction studies require maps with the spatial distribution of strong motion parameters (e.g. PGA, PGV, PGD) in the study area.

In order to account for the liquefaction-induced phenomena, the evaluation of permanent ground horizontal and vertical displacements (lateral displacement, settlements) has been performed for the three scenarios using empirical and analytical procedures (Seed et al., 2003, Youd et al., 2001, EC8, Ishihara and Yoshimine, 1992, Elgamal et al., 2001). Figure 6 illustrates the spatial distribution of permanent ground displacements for the 475 years scenario.

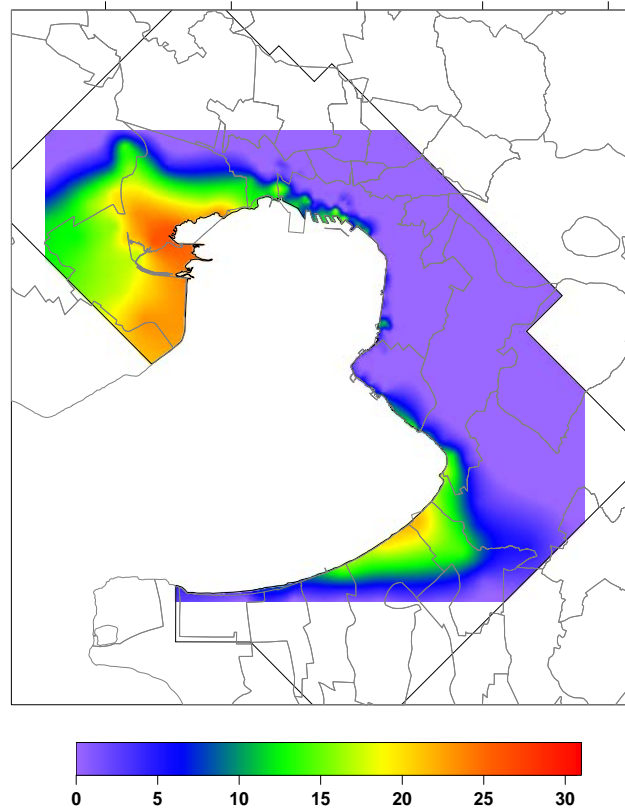


**Figure 4. Representative results in terms of mean PGA(g's) at outcropping bedrock conditions for the area in interest which, stemming from seismic hazard analysis for 475 years return earthquake period (Papaioannou 2004).**



**Figure 5. Distribution of mean peak ground acceleration (PGA: g's) (a) and mean peak ground velocity (PGV: cm/s) (b) obtained by 1D (EQL) analytical approach for the 475 years seismic scenario.**





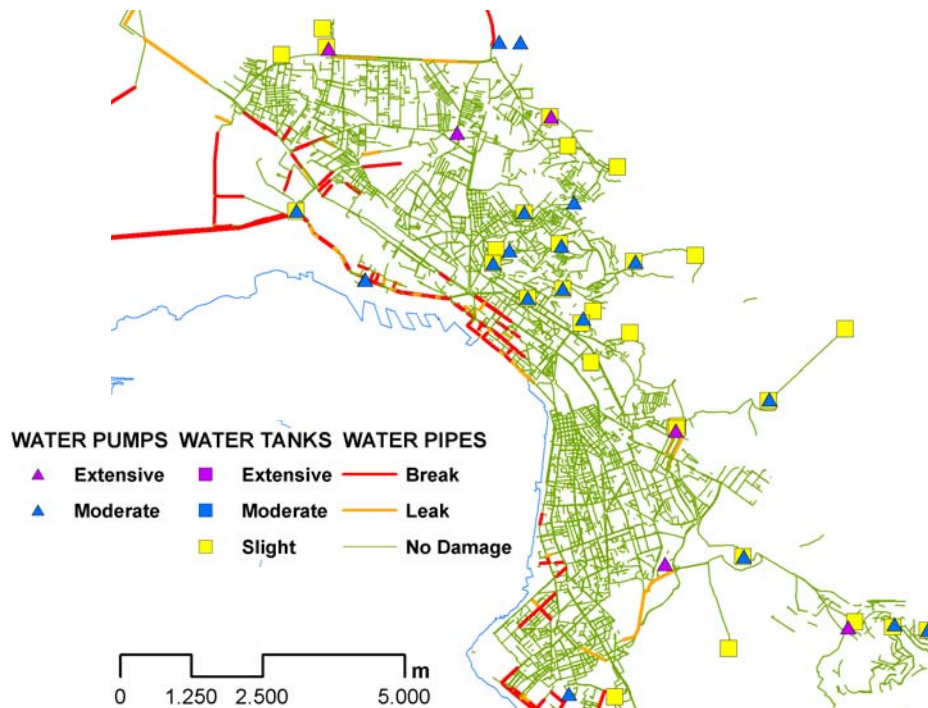
**Figure 6. Distribution of the mean values of “peak” permanent ground displacements (settlements) due to liquefaction -  $\Delta v(\text{cm})$  for the 475 years seismic scenario.**

### **VULNERABILITY ASSESSMENT AND LOSS SCENARIOS**

The assessment of potential earthquake losses is performed for utility systems (potable water, fire-fighting, waste-water, gas, telecommunication, electric power) and transportation systems (roadways, railways, airport, port) as well as for other critical infrastructures in Thessaloniki, based on the results from the Microzonation Study for the three selected scenarios with mean return periods  $T_m=100$ , 475 and 1000 years. Thus, these loss scenarios are constructed on the basis of site specific seismic hazard analysis using available inventory data and adequate fragility curves. In the following some representative examples of vulnerability assessment are given for water, road and port systems.

#### **Water system**

Thessaloniki's potable water system is comprised of about 1351 km of pipes. The current inventory database includes several attributes such as location, diameter, material, age, operating area, supplied tank, type, depth, length, joint type and history of failures. The vulnerability assessment of potable water pipes is based on the estimation of the expected Repair Rate per pipe km (RR/km). Expected damages (leaks and/or breaks) caused by wave propagation are estimated using O' Rourke & Ayala (1993) fragility relation proposed by HAZUS (NIBS, 2004) where the seismic loading is described in terms of peak ground velocity (PGV). The expected damages due to ground failure are assessed based on the Honegger & Eguchi (1992) fragility relation as a function of permanent ground displacements. The above empirical vulnerability functions have been validated and checked with well documented data from recent earthquakes in Lefkas-Greece, 2003, and in Duzce-Turkey, 1999 (Alexoudi, 2005). Appropriate fragility curves for tanks and pumping stations are applied as well according to the structural characteristics of the exposed elements. Figure 7 presents the spatial distribution and the intensity of the estimated damages for the 475 years scenario. The number, the intensity and the location of the damages are related to the spatial distribution of seismic ground motion of the specific scenario as well as the individual characteristics of the examined elements.



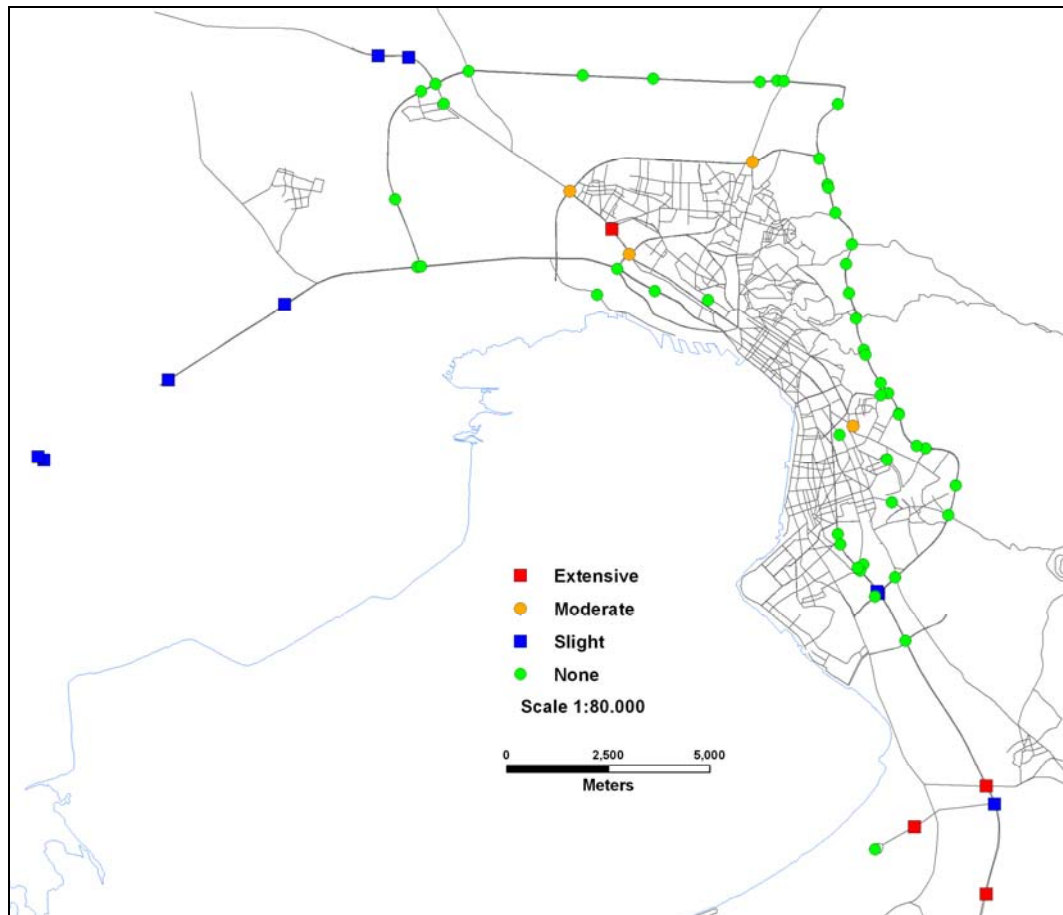
**Figure 7. Vulnerability assessment and damage distribution of Thessaloniki's water system ( $T_m=475$  years).**

### Roadway system

The current inventory for the roadway network in the Metropolitan area of Thessaloniki includes about 600km of roadlines and 80 bridges. The roadway system is rather insufficient, especially in the centre, where the densely built up area creates a complex network, with narrow streets and inadequate parking areas. Roads are classified in freeways, major and secondary arterials, primary and secondary collectives, based on their geometry and functional role in the network. In the other hand, the majority of bridges and viaducts are in the ring road and the main exits of the city, while their classification is based on the number of spans (single or multiple), the seismic code level (low or upgraded), the column bent type (single or multiple) and the span continuity (continuous or simple support). The vulnerability analysis of the network includes the estimation of direct losses such as bridge and road damage due to ground shaking or ground failure and indirect such as street blockades due to debris of collapsed buildings.

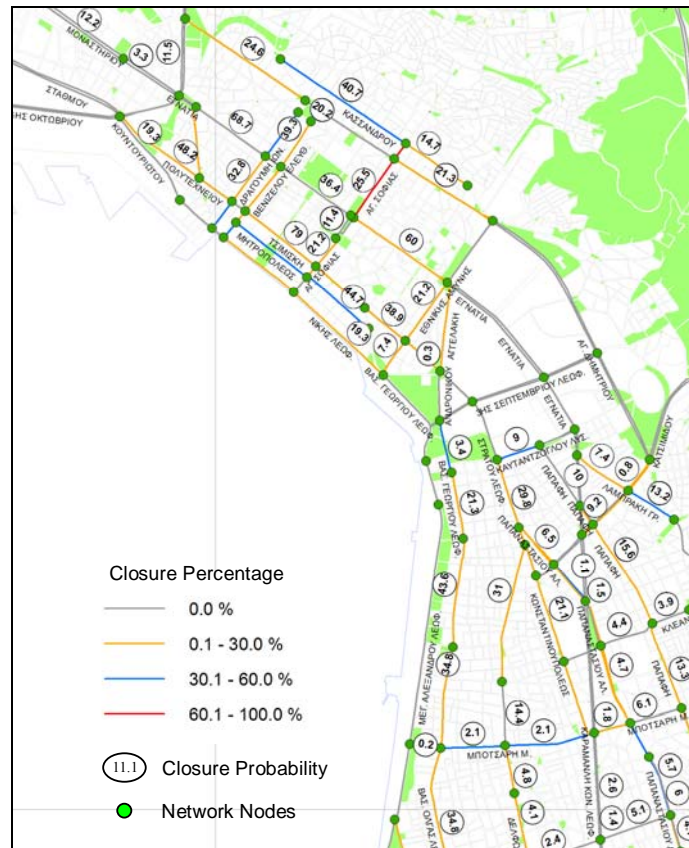
The expected level of damages for bridges is assessed based on the fragility curves that are provided by HAZUS (NIBS, 2004), while the input earthquake hazard scenario is obtained from the Microzonation study and is referred to the mean spectral acceleration at  $T=1.0$ sec. Figure 8 presents the estimated worst probable damage state (i.e. exceeding probability  $>50\%$ ) for each bridge. The application of the fragility model shows that the majority of bridges will respond in a satisfactory way, but there are still few bridges, which are expected to sustain serious damage for the specific seismic hazard scenario. This is due to the higher vulnerability of these bridges (single column, simple support bridges and inadequate seismic design) and the higher values of the expected surface spectral acceleration. The latter is attributed to the local soil conditions and the proximity of the seismic source (ex. southeast part). For instance, in the northwest part of the city the soil is described as deep soft alluvium deposits, sandy-silty clays to clayey sands-silts, with low strength and high compressibility, (category C and D in EC8); thus the seismic motion presents a stronger amplification at longer periods.





**Figure 8. Distribution of damages to roadway bridges of Thessaloniki Metropolitan area (Tm=475 years).**

For the functionality of roads just after the earthquake a correlation between the building's height (i.e. number of storeys) and the width of the induced debris is used, in order to estimate the impact of collapsed buildings. The collapse probability of buildings is estimated based on appropriate fragility models which have been developed for the building types commonly present in Thessaloniki as a function of the peak ground acceleration (Kappos et al 2006, Penelis et al., 2002). However, the experience of past earthquakes in Greece reveals that a percentage of collapses ranging between 10 and 20% can have such form and amount of debris which can result to road closure. The aforementioned probability is assumed to be equal to the occurrence probability of the corresponding debris width and the corresponding road closure. For each road segment (node to node) a total closure probability is derived from the discrete collapse probabilities of the block's façade along the two sides of the road. As an example figure 9 illustrates the probability of closure for the main roads in the central city due to medium height (4-7 storeys) building collapses for the scenario with a mean return period 1000 years. The reduction of the road width ranges from 0 to 100% depending on the distance from the buildings, the width of the road and the induced debris width. The probabilities for the corresponding road closures range from 0 to 80% depending on the concentration of the most vulnerable building type, the length of the road segment and the discrete collapse probabilities. In addition the expected level of damage due to ground failure (i.e. liquefaction) is estimated based on appropriate fragility curves for roads.



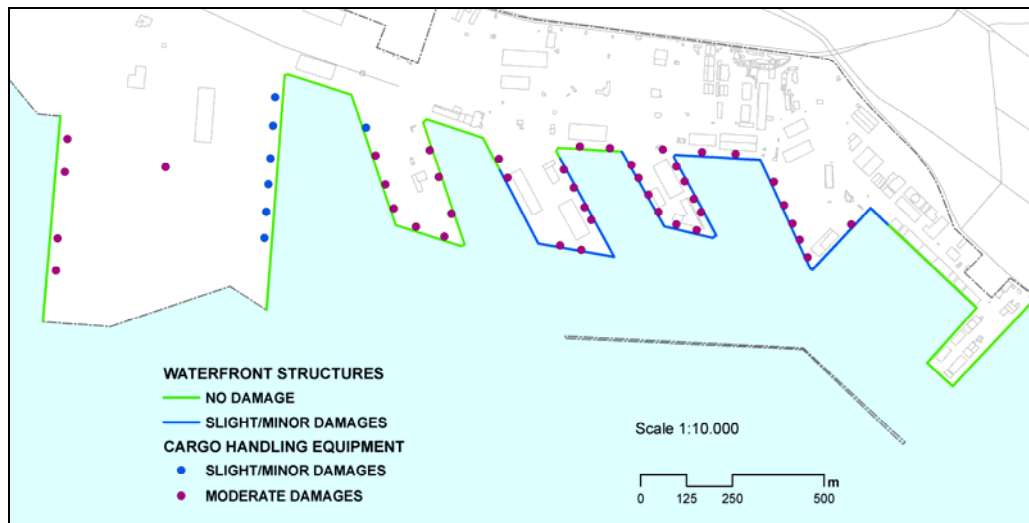
**Figure 9. Sample map with closure probabilities of main roads due to medium building height collapse for the 1000 years scenario.**

### Port system

The port of Thessaloniki covers an area of 1,500,000 m<sup>2</sup> and trades approximately 15,000,000 tons of cargo annually, having a capacity of 200,000 containers and 6 piers with 6,200m length. In collaboration with the port authority (Thessaloniki Port Authority, THPA), various data was collected and implemented in GIS format for the considered elements at risk, including cargo & handling equipment, waterfront structures, electric power (transmission and distribution lines, substations), potable and waste water (pipelines), telecommunication (lines and stations), railway (tracks) and roadway system (roads & bridge) as well as buildings and critical infrastructures. The presence of all the above utilities in a limited area enables the complete application of the methodology for the seismic risk assessment of lifelines and the specification of possible weak points.

The inventory developed for the waterfront structures includes several attributes such as name, location, operational depth (m), year of construction, equipment, material, type, foundation type, maintenance, damages in previous earthquakes and length (m). A validation of the empirical vulnerability functions for waterfront structures has been performed according to data from recent European earthquakes (Lefkas, 2003) (Kakderi et al., 2006). Herein, the vulnerability analysis is performed based on the fragility curves that are provided by HAZUS (NIBS, 2004), while the input earthquake hazard scenarios were obtained from the Microzonation study and are referred to the permanent ground displacements due to liquefaction. For cranes and cargo handling equipment the available inventory data include their type, capacity (t), working range (m), year of construction, source, location, anchorage, type of cargo and energy, alternative energy sources, maintenance and damages in previous earthquakes. The fragility curves that are provided by HAZUS (NIBS, 2004) were also used for their vulnerability assessment, based on the spatial distribution of peak ground acceleration (PGA) and permanent ground displacements due to liquefaction (PGD). Figure 10 presents the estimated worst probable damage state (i.e. exceeding probability >50%) for Thessaloniki's port waterfront structures and cargo handling equipment for the 475 years scenario. In both cases the anticipated damages are attributed to the occurrence of liquefaction induced phenomena

and are related to the spatial distribution of seismic motion and the local soil conditions (loose, saturated, susceptible to liquefaction deposits).



**Figure 10. Distribution of damages to waterfront structures and cargo handling equipment of Thessaloniki's Port ( $T_m=475$  years).**

### GLOBAL VALUE ANALYSIS

The aim of the global value analysis is to identify the main issues of each lifeline network through the ranking of the value of the exposed elements, based on various factors that describe the role of each element in the urban system and system's "weak points". In that way, the global value of each element at risk, is depended not only on its direct specific value or content (physical and human), but also upon its indirect/immaterial value that is represented by the usefulness and relative role in the whole urban system at a specific time. Three periods are identified in respect to the occurrence of an earthquake event: normal period, crisis and recovery. The distribution of lifeline elements "global value" in different periods could be a powerful tool for the prioritization of pre-earthquake retrofitting actions and quantification of the overall importance of different complex and coupled lifeline systems. Several criteria are used such as operational attributes, land use, population influenced, human losses, economic and social weight under normal, crisis and recovery circumstances, identity/radiance, environmental impact and other. Appropriate qualitative or quantitative indicators can then be defined for each period, while relevant measuring units are used for their evaluation and the identification of "main", "important" and "secondary" elements and system's weak points.

An example of the indicators used for the classification of the importance of Thessaloniki's Port cargo handling equipment is provided in table 2. Representative GIS maps illustrating the definition of main, important and secondary elements at risk can also be constructed.

**Table 2. Indicators used for the global value analysis and classification of importance of cargo handling equipment seismic of Thessaloniki's Port.**

| Cargo handling equipment |                   |  | Period |        |          |
|--------------------------|-------------------|--|--------|--------|----------|
| Components               | Indicators        | Description  | Normal | Crisis | Recovery |
| Operation                | 1. Capacity       | Lifting capacity in tons.                                    | •      | •      | •        |
| Operation                | 2. Location       | Location / dock-pier located                                 | •      | •      | •        |
| Operation                | 3. Cargo capacity | Type of cargo that can be handled (conventional, containers) | •      | •      | •        |
| Operation                | 4. Redundancy     | Alternative equipment to cover the activity.                 | -      | •      | •        |

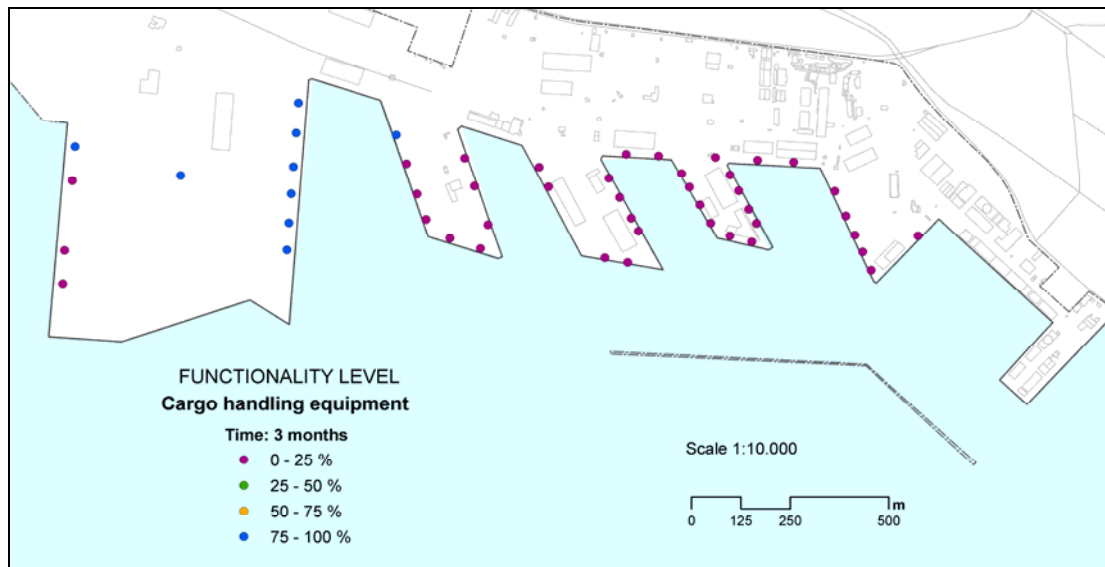
## SEISMIC RISK MANAGEMENT

The pre-earthquake mitigation plans must be based on appropriate prioritization criteria that combine engineering techniques, economic analysis tools and decision-making or political aspects. The identification of “main”, “important” and “secondary” element at risk in “normal” period provides a prioritization according to the importance of the activities, the social and economical values and the daily demand for serviceability. A disaster management plan can enhance the pre-earthquake activities for retrofitting important and critical components in the urban environment and prepare an efficient organization of public services and local authorities for “crisis” period. For the “recovery” period an efficient management plan must minimize the restoration time, the efforts and the cost. In order to achieve reliable estimates of the required time for recovery, restoration curves for every component in each lifeline system should be defined by lifeline companies, local actors in collaboration with lifelines experts using basically qualitative evaluations.

The method applying the “global value” approach uses the classification of lifeline system components into main, important and secondary issues according to their global value. Combining “global value” evaluation and vulnerability assessment and using an “expert opinion” it is possible to estimate priorities to account for the economic and social losses for a specific utility system and a given seismic scenario. Recovery activities could also follow these priorities aiming at efficient seismic risk management procedures. Table 3 summarizes the application of the proposed methodology for the cargo handling equipment of Thessaloniki’s Port. Restoration curves have been defined in collaboration with the port authority, based on available techniques, local experience and expertise. Assuming that there are only two available teams that could work together, the time requested for the full recovery of all damaged equipment for the 475 years scenario reaches the 6 years. Figure 11 illustrates the functionality level of cargo handling equipment 90 days after the seismic event given that the restoration process starts immediately after the earthquake.

**Table 3. Risk analysis matrix showing cargo handling equipment seismic retrofit priorities.**

| Urban Risk/ Seismic hazard  | Priorities               |                          |                          |
|-----------------------------|--------------------------|--------------------------|--------------------------|
|                             | Main                     | Important                | Secondary                |
| Complete/ Extensive damages | 1 <sup>st</sup> priority | 1 <sup>st</sup> priority | 2 <sup>nd</sup> priority |
| Moderate damages            | 1 <sup>st</sup> priority | 2 <sup>nd</sup> priority | 3 <sup>rd</sup> priority |
| Slight/ minor damages       | 1 <sup>st</sup> priority | 2 <sup>nd</sup> priority | 4 <sup>th</sup> priority |



**Figure 11. Functionality percentage of cargo handling equipment of Thessaloniki’s Port in three months time (90 days) after the seismic event ( $T_m=475$  years).**

## CONCLUSIONS

In the present study the application of a general methodology for the vulnerability assessment and seismic risk management of lifelines and infrastructures is presented for the city of Thessaloniki in Greece. Seismic risk scenarios take into consideration the inventory, typology and vulnerability characteristics of different elements at risk, as well as the seismic hazard, geotechnical characterization and site response of the main soil formations for different seismic scenarios. Thus, vulnerability and loss estimates for lifelines and infrastructures are evaluated on the basis of site specific seismic hazard analysis using available inventory data and adequate fragility curves.

Herein, a very short presentation of the site characterization and seismic zonation for the city of Thessaloniki is presented. A detailed Microzonation study has been conducted for three different mean return periods  $T_m=100, 500$  and  $1000$  years. Based on these results, examples of the assessment of potential earthquake losses are presented for the water system, roadway and port system of Thessaloniki.

On the basis of a global value analysis (material and immaterial) of lifeline elements, the classification of their importance in different periods is performed. This leads in a prioritization in a more efficient way of the pre-earthquake retrofitting actions and post earthquake restoration efforts. Pre-earthquake mitigation actions could include upgrading of structural performance of lifeline components, improvement of the network performance, organization of redundant systems, implementation of advanced technologies during earthquake emergency (early warning systems, real time damage estimation etc). Furthermore, efficient disaster management plans aiming at the minimization of the restoration time, the efforts and the cost could be implemented. An example of a global value analysis, determination of priorities and estimation of the recovery time are presented for the cargo handling equipment of Thessaloniki's Port and for the 475 years scenario.

Finally based also on the previous applications, the importance of site specific seismic response analysis (Microzonation study), is revealed for the vulnerability assessment and the definition of efficient mitigation strategies and policies for pre and post earthquake actions in order to reduce the expected consequences from different earthquake events.

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