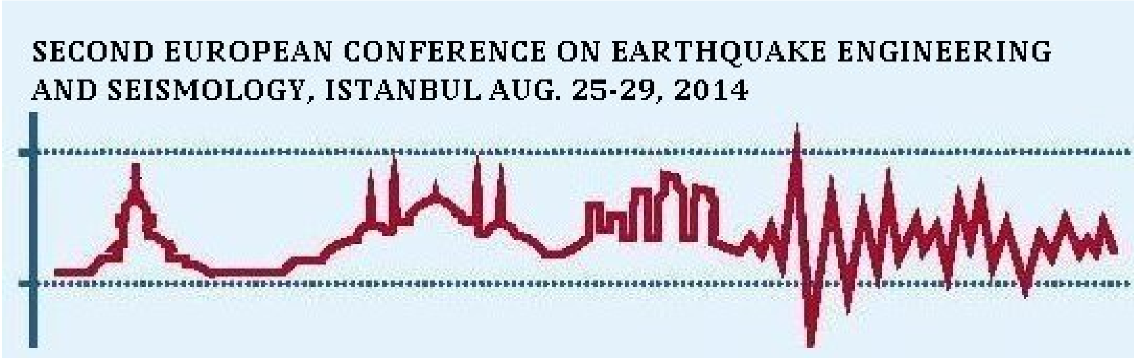

URBAN HERITAGE VALUE AND SEISMIC VULNERABILITY MAPPING: CHALLENGES FOR ENGINEERING AND ARCHITECTURAL ASSESSMENTS. CASE STUDY OF A PROTECTED AREA IN BUCHAREST, ROMANIA

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ABSTRACT

The paper evaluates the urban heritage situation at almost four decades after the Bucharest, March 4, 1977 earthquake disaster, followed by a razing of the present Civic Center area and a large-scale remodeling project. In this context, the first results of the URBASRISK Project (2012) are presented as a contribution to a new multi-hazard paradigm to cope with European urban scale threats, especially in heritage areas, with a case study of a historic zone now designated as protected area. The cultural and utility value was identified and graded on specific scales for further analysis and mapping. For this phase of study some data of 1977 were adjusted to express the vulnerability by the Mean Damage Degree, GA, with a possibility to make corrections after visual inspection. The URBASRISKdb geodatabase was created for storing the attributes of the buildings. The basic source, i.e. the ESRI *World Street Map* layer, was verified against satellite, aerial and street views freely available online from various providers. Given the dynamics of the area, the final version of the map was obtained by also considering information obtained by field visits.

INTRODUCTION

As a result of March 4, 1977 earthquake, 90% of the killed, 67% of the injured, and 70% of 2 billion US Dollars economic losses were in Bucharest. Damage to constructions were of over 69,4% of total,

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while housing was 71,4% of construction losses (Berg et al, 1980; Balan et al, 1982; World Bank, 1978). Unfortunately, although the heavy damage was elsewhere, the 1977 earthquake was used by the communist regime as a pretext for the razing of some urban heritage, followed by a large-scale remodeling project, as in the present huge area of Bucharest Civic Center, with Parliament Palace as a central item. For a while, some part of the area was not built, just because some other priorities existed at frontlines. After the political changes of the 1990's, the fabric of a huge area was left partly as a ghost-town, although private property was regained. In this context, the initial results of the URBASRISK Project (2012) are presented, with a case study of this historic zone of Bucharest, partly demolished three decades ago by and now designated as protected area (Gociman et al, 2012; 2014; URBASRISK Project, www. http://www.uauim.ro/...).

The ongoing project (2012-2016) is presented as a contribution to a new multi-hazard paradigm to cope with European urban scale threats, especially in heritage areas. Our habitat must be treated as an ecosystem (Gociman, 2006), but the protected areas cannot be treated like a usual neighborhood. The dense fabric puts many problems to provide safety and avoid further destructions or marginalization. On the other hand, there is need for community implication against any risk that impinges on the architectural and urban ecosystem. The case of Bucharest was approached, in the past, as a desperate appeal to the entire world (Giurascu, 1989) or as a contemporary parallel with the situation of cities like Paris, Moscow, Berlin and Rome under authoritarian or totalitarian regimes, when the major heritage was in part or wholly affected (Cavalcanti, 1997). The bitter case and success story of the reconstruction of the city of Skopje after the 1963 disaster (Milutinovici, 2001), versus nowadays critical opinions about the lost heritage, was presented elsewhere (Georgescu et al, 2013).The lessons of the earthquake disasters of L'Aquila, Italy (2009), New Zealand (2010 and 2011), Lorca, Murcia, Spain (2011) and Emilia, Italy (2012) are a proof that there is a need to protect heritage both before and after seismic events.

The paper will present the concept and preliminary results of the project, concerning available knowledge from earthquake engineering, architecture and urban planning to be used. On the other hand, any approach depends on available usual and IT tools for assessment and mapping of relevant hazards and exposure of elements for vulnerability assessment and impact scenarios.

METHODOLOGICAL ASPECTS

In its first stage, the research investigated the current situation, in terms of cultural and functional value, that gives the identity dimension and the safety, stability and environment as state value (vulnerability). As final objectives, one takes into account methodologies of setting out territorial intervention multilevel decision-making in direct relationship with the identity and vulnerability value. The evaluation methodology is applied to a pilot area.

The cultural value was assessed by 13 criteria and grading artistic, architectural, urbanistic, functional, structural, technical execution, decorative, furnishing conception, local, religious, ethnical, seniority, historical, political or memorial references (Gociman et al 2014).

The basic earthquake hazard was considered in terms of zoning maps and local site conditions, while any other particular natural or technological hazards have been listed and weighted in terms of their impact.

Concerning the vulnerability assessment, due to the specific of old built stock, detailed analitical approach was not feasible. To be coherent with other partners approaches and their scaling, in this project it was required a one-number description of structural vulnerability. The European approaches of vulnerability evaluation methods used in Mediterranean area since the 1980's have been evaluated (Benedetti, Benzoni and Parisi, 1988; Lagomarsino and Giovinazzi 2006; Guéguen, Michel, LeCorre, 2007, Achs and Adam, 2012; Karacostas et al, 2012). It was concluded that each method is highly dependent on local patterns of heritage buildings and their direct use is not reliable. An attempt to use the rapid visual screening of USA type was considered in terms of principles, but in all cases and countries the vulnerability data from past investigations were predominant.

The Romanian Code P100-3/2008 requires quite a great amount of data and needs much time per building. In order to avoid such conceptual or practical hinderings, it was decided to start from the local data gathered in Bucharest after March 4, 1977 earthquake.

Concerning the mapping methods for built stock and vulnerability, the references of the last decade indicate the satellite applications and GIS systems, with specific databases, as most appropriate (Taubenböck, 2011). Such data allow automated updating of maps when some attributes are changing, as well as specific reports and syntheses. (Craifaleanu et al, 2008).

THE STUDY AREA: BUILDINGS PATTERNS IN TERMS OF PHYSICAL STATE, HERITAGE AND MEMORY VALUE

The study area has the shape of a large triangle, in front of the present Romanian Parliament and near important governmental institutions, being located on (former) Dambovita River drained marshes, with high water table. The local building stock consists mostly of masonry residential houses from 1900's to 1980's and of low- to mid-rise housing blocks erected between 1930 and 1950 (See buildings in Figures 1-9 and maps in Figures 10 and 11).

Figure 1. Left: Belfry of Antim Monastery, major heritage, built at 1715. Right: Sinodal Palace, major heritage, was translated towards the monastery precinct in the 1980's (Photo E. S. Georgescu)

Figure 2. Left: Schitul Maicilor Church, major heritage, that was moved in the 1980's from the demolished precinct to let space for Parliament, and left hidden between new high-rise blocks and old houses. Right: St. Ilie Rahova Church, major heritage, that was translated from the present Blvd. Unirii path and left surrounded and aggressed by neighboring blocks (Photo E. S. Georgescu)

Figure 3. Heritage buildings with residential function near Antim / Str. Justiției, recently rehabilitated (Photo E. S. Georgescu)

In the study area, the multihazard could be represented by earthquakes with or without additional hazards, as: floods or rising damp in walls, snow, strong wind, fire and gas pipes explosions, hazardous substance release from industry, inclusive from terrorism addressed to some institutions. The study area suffered damage in 1940 and 1977 earthquakes and some buildings ranked in seismic risk classes exist. In the 1980's, a courtain of high-rise reinforced concrete blocks have been built along the new broad street fronts, cut over the former urban fabric.

Figure 4. Masonry houses that resisted earthquakes but are now threatened by lack of maintenance, as the ownership situation and financial ability are at stake on Str. Justiției (Photo E. S. Georgescu)

The vulnerability of the area confirms the conclusion of Rashed et al (2003) about the dependence of this factor on human behaviour. Although the aging and decay were natural up to a certain point, the razing policy of the 1980's induced a lack of confidence and less care for maintenance, since the property and the local memory were aggressed. It is also true (Cartier et al, 2012) that in the case of architectural heritage it is difficult to let the market principles work. Indeed, not so far away, the historical core of Lipscani in Bucharest was restored, but without due care for structural vulnerability, which is why, at present, some damage are threatening the tourists.

Figure 5. Detail of the XIX-th century endangered architecture of the Figure 4 building (Photo E. S. Georgescu)

Figure 6. Reinforced concrete and masonry mid-rise residential buildings of the 1930's proving lack of maintenance (Photo E. S. Georgescu)

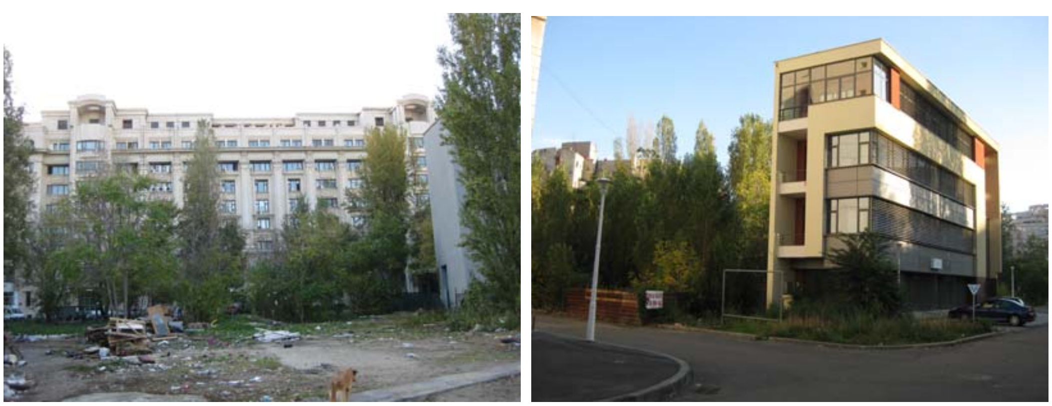

Figure 7. Example of a fully destructured area behind the 1980's high-rise buildings used for ministries and government agencies, with some new buildings and land for sale (Photo E. S. Georgescu)

Figure 8. Left: High-rise buildings of the Civic Center 1980 – 1990 on Blvd. Unirii. Right: the same types of buildings towards Blvd. Libertății (Photo E. S. Georgescu)

Figure 9. Romanian Parliament Palace, the main socio-political and architectural object whose building triggered the razing of the study area (Photo E. S. Georgescu)

THE VULNERABILITY ASSESSMENT

For the existing heritage, protection is recognized as a need for disaster prevention but engineering methods are time consuming and less familiar to officials and practitioners of local authorities. It is known that after 1977 earthquake, a survey of damage distribution was organized in Bucharest under the auspices of the National Council of Science and Technology. More than 18.000 buildings of the City of Bucharest were investigated according to a methodology derived on the basis of the MSK-scale methodology (Balan et al, 1982, Sandi et al 2008).

These latter results were processed additionally, leading to vulnerability functions expressed in terms of conditional damage distributions Thus, the Romanian experience to date and official census use a classification of residential buildings on 7 material types, 6 age periods and 5 height ranges. The specific years of code enforcements lead to some time spans, as before 1945, 1945-1963, 1964-1970, 1971-1977, 1978-1992 and after 1992…2006. A detailing of categories / classes was chosen as in Sandi et al, 2008:

- *M*: material and structural system:
- M_{1a}: RC frames, with incorporation of some RC shear walls;
- M_{1b}: large prefabricated RC panels;
- M_{1c}: buildings of RC frames, with unreinforced infill masonry walls, and buildings of reinforced load-bearing masonry (e.g. small columns and/or RC ring-beams);
- M_2: unreinforced masonry with RC floors;
- M_3: unreinforced masonry with wooden floors;
- M_4: wooden;
- M_5: adobe or other mud-brick or clay houses;

The stock vulnerability data were further on adjusted in the URBASRISK Project, because data of 1977 reflected a state of that period, while the further earthquakes and aging acted for some 35 years; moreover, such data were needed to fit also to other building types. To address vulnerability in the framework of this project (URBASRISK Project, 2012), some adjustment were necessary, mainly:

- adjusting some histograms of 1977 categories / classes to consider effect of subsequent damage;
- introduction of a new category M.1.b.2, to include many precast low-rise and mid-rise buildings, with good behavior in 1977;
- a new category M.1.a. include r. c. buildings designed with post-1977;
- a new histogram for M.1.c pre-1940 high-rise buildings:
- it was chosen the histogram for M.1.b.1. as representative for high-rise buildings r. c. of 1946 – 1977;

It was remarked a reasonable fitting of vulnerability with the mean damage degree GA; this is approximately one unit for categories M.1.b.2 and M.1.a, of two units for M.5….M.2.b and of three units for M.1.c and M.1.b.1; mean standard deviation is about one unit for most categories, except M. 3.a and M. 2.a, where there is a concentration of values in similar ranges, possibly due to traditions embedded in such buildings. Therefore, the vulnerability was expressed by the Mean Damage Degree, GA, with a possibility to make corrections after visual inspection, using the "Damage Degree Adjusted to site - GAMA". Such alterations may increase or decrease the expected damage degree by 0.5...1 degree, until a maximum value of 5.

Table 1. Vulnerability characterisation by damage degree adjusted to site - GAMA using a minimum of field data on physical state.

Material+ Structural system / Adjusters		M.1.a (A_9)	M.1.b.2 (A_8)	M.1.b.1 (A_7)	M.1.c (A6)	M.2.b (A_5)	M.2.a (A_4)	M. 3.b (A_3)	M.3.a (A_2)	M.5 (A_1)
Mean Damage Degree for a given category (GA)		*0.90*	*1.25*	*2.86*	*2.85*	*1.87*	*1.74*	*1.84*	*2.12*	*2.08*
Iregularitaty on vertical		0,21	0,21	0,21	0,19	0,19	0,18	0,16	0,12	0,12
Iregularitaty in plan		0,05	0,05	0,08	0,10	0,12	0,12	0,13	0,18	0,18
Cracks	Horizontal	0,21	0,21	0,21	0,19	0,19	0,15	0,13	0,09	0,09
	Inclined at 45^0	0,16	0,16	0,15	0,14	0,14	0,12	0,11	0,09	0,09
	Vertical	0,11	0,11	0,10	0,10	0,09	0,09	0,08	0,06	0,06
Structural interventions (tirants, buttresses, jacketing, etc)		N/A	N/A	-0,13	-0,12	-0,14	-0,21	-0,21	-0,26	-0,26
Damage extent		0,26	0,26	0,38	0,38	0,40	0,47	0,47	0,53	0,53
Heavy roof		N/A	N/A	N/A	0,02	0,02	0,09	0,13	0,21	0,21
TOTAL adjustments		*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*
Damage Degree Adjusted to site (GAMA)		*1,90*	*2,25*	*3,86*	*3,85*	*2,87*	*2,74*	*2,84*	*3,12*	*3,08*

N/A – adjustment not allowed

THE GEODATABASE AND MAPPING OF SPECIFIC ATTRIBUTES

The URBASRISKdb geodatabase was created for storing the attributes of the buildings in the study area, based on past experience (Craifaleanu et al, 2008).These attributes are used in the multicriterial, multidisciplinary and multihazard analyses within the scope of the project, for statistical and reporting purposes, as well as for spatial representations. The URBASRISKdb structure includes several interrelated data tables, containing either features for general use across all analyses, or features pertaining to separate analysis criteria.

Thus, the geodatabase includes: building identification fields (identification code, address, geographical coordinates), fields regarding general features of the building (number of stories, year of construction, typology, ownership, specific values on a scale for historical heritage building / monument) and fields describing the compliance of the building with various requirements (strength and stability, safety, serviceability, quality of living etc.). For the vulnerability analyses, specific fields were also included, serving for the following purposes:

- harmonization with building classification systems according to the main material used in their construction and to the number of stories, respectively, used by the National Institute for Statistics; this was required for using census results
- harmonization with vulnerability classes established by the studies performed after the March 4, 1977 earthquake
- implementation of the observed vulnerability classes, according to building material type, adapted and recalibrated based on available at INCERC from the 1977 earthquake
- introduction of the mean damage index, GA, based on the histograms computed for the above classes
- introduction of the site-modified damage index, GAMA.

Each record in the URBASRISKdb geodatabase corresponds to a building in the study area. For geographical representation, a simplified approach was used, consisting in using a single point feature for each building. To each feature, the corresponding attributes were associated.

The mapping of actual situation of the buildings in the study area and a database was established from multiple sources. The basic source, i.e. the ESRI *World Street Map* layer, was verified against satellite, aerial and street views freely available online from various providers (Figure 10)

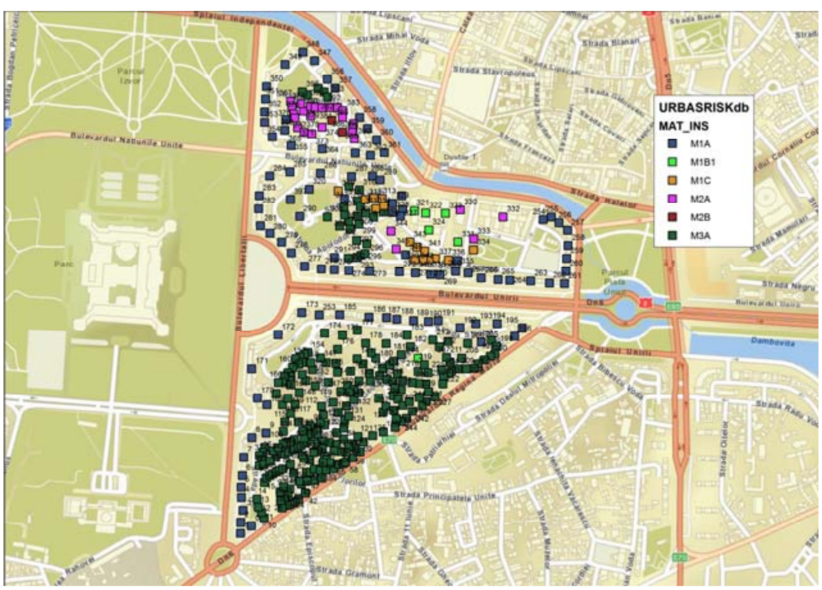

Figure. 10. Mapping of material / structural identificators for structural vulnerability, with color codes in the study area, in front of Parliament Palace (left of figure). ESRI, World Street Map (2014).

Given the dynamics of the area, the final version of the map was obtained by also considering information obtained by field visits. Such visits also allow the inspection of buildings from the point of view of their structural vulnerability and, if applicable, the assessment of the reduction factors required to obtain the site-modified damage index, GAMA, from the mean damage index, GA. It is significant to note here that a large part of the older buildings located in the study area are in a very poor state, due to multiple socio-economical factors and due to their exposure, in the past, to multiple hazards. Using a spatial representation, obtained with ESRI ArcMap software, of the buildings in the URBASRISKdb geodatabase, a number of about 400 buildings were identified and mapped, with with their associated attributes.

The preliminary data have shown that some 60% of the buildings types have the average mean damage degree, a situation that fits the pattern of Vrancea motions that caused a lesser damage to low-rise and stiff masonry houses. This percentage must be considered as orientative, since the visual inspection may increase the assessed damage degree.

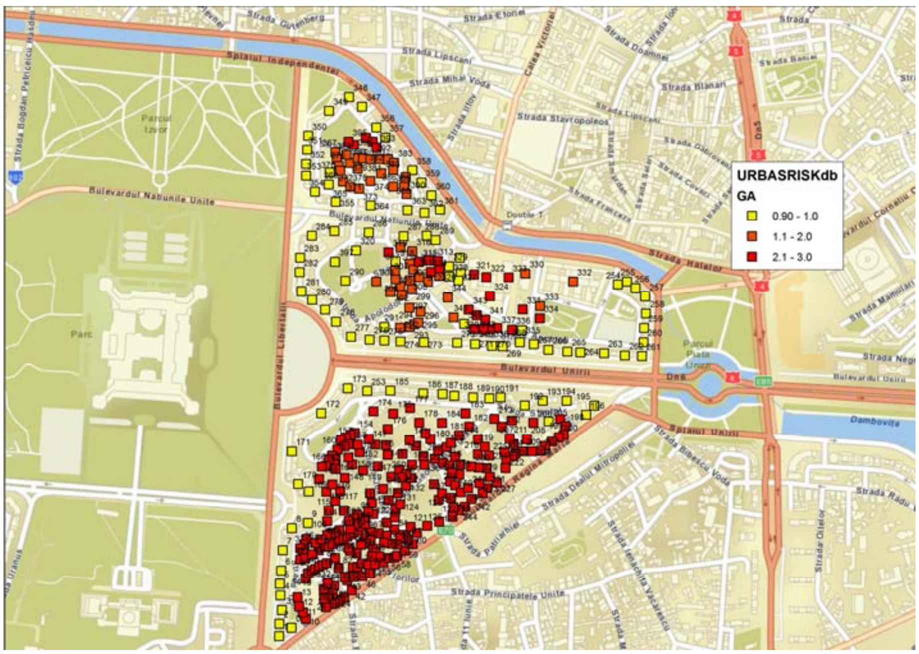

Figure 11. Mapping of structural vulnerability – Damage Degree GA for ranges of values, with color codes in the study area, in front of Parliament Palace (left of figure). ESRI, World Street Map (2014).

CONCLUSIONS

The first phases of the URBASRISK Project allowed to derive a methodological approach and applicative instruments for:

- establishing an investigation and scaling methodology able to answer demands of disciplines as architectural and urban heritage protection, salvage of community memory in conjunction with urban heritage value and functional value, using affordable engineering methods for structural vulnerability assessment and mapping;
- taking into account the multihazard environment of the study area;.
- provide an operative tool for vulnerability assessment, using both past surveys vulnerability data and inspection of buildings for their structural vulnerability and using some reduction or increase factors to obtain the site-modified damage index, GAMA, from the mean damage index, GA;.
- mapping of specific attributes using the URBASRISKdb geodatabase, census and field data..

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