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RISKS AND VULNERABILITIES UNDER MULTI-HAZARD THREATS IN A PROTECTED AREA OF BUCHAREST, ROMANIA

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ABSTRACT :
Romania and its capital, Bucharest, suffered building collapses, heavy damage and casualties in the 1940 and 1977 Vrancea earthquakes. The paper presents methods for the assessment of urban multi-hazard risks for emergency planning, using affordable tools. The field identification of materials, structural types and physical state of buildings, functional value and seismic vulnerability, for each building class, were considered. The cultural value was scored with 13 criteria and six scaling stages of the Romanian Law of Monuments.
Multi-hazard scenarios in the pilot study protected area have shown that:

- Earthquake damage and casualties can be significant; for the seismic intensity I = VIII, a number of 63 buildings would suffer considerable damage, while for I = VIII½, the damage would affect 165 buildings, mostly low-rise structures. The number of heavy injured persons would be 29 and 64, while live loss will be 59 and 92, respectively, for the considered intensities. The damage would affect safety of living for about 1,809 to 3,061 people. The day-time scenario would reduce exposure and casualties by 50% in houses; however, other people would be exposed in other places, i.e. 10,120 persons in public institutions around, 1,000 clients in commercial places, 1,400 in offices, 800 in schools and 400 in churches.
- The scenario of climatic and hydrologic hazards is dominated by an extreme event of accidental flooding, in which the water cover could be as high as 2.5 m;
- The terrorist blasting scenario, with three hypotheses, according to the explosive quantity, has shown that, as the explosive quantity increases, the impacts would have great potential of damage, injured people and casualties.

In conclusion, the assessment allowed a synthetic mapping of impacts and risks and the identification of potential shelter / security community centers. The risk reduction strategies were structured on emergency and perspective terms, in order to achieve resilience.

KEYWORDS:
multi-hazard scenarios, Romania, Bucharest, earthquake vulnerability, terrorist blasting, casualties, impacts mapping

1. BACKGROUND OF STUDY

1.1. Hazards, risks and resilience vs. community stakeholders in public policies

The first step in emergency management planning is to recognize and evaluate hazards and associated risks. This risk assessment has become a field of rather specialized and sophisticated approaches, while the speed of

urban life and changes usually prevent the timely identification of threats.
Romania and its capital, Bucharest, suffered building collapses, heavy damage and casualties in the 1940 and 1977 Vrancea earthquakes (Balan et al, 1982, Georgescu. and Pomonis, 2008). In the case of Romania, many urban districts have been exposed to natural hazards, and the long-term damage impact is visible, while other parts of them have undergone rather forced changes, governed by political or market pressure. The current urban planning – and even Civil Protection approaches, that relies only on the enforcement of laws and codes – proved to be less efficient, since the community stakeholders do not participate in the risk reduction processes. When threats become realities, communities often loose a part of their heritage, while people suffer alienation when evacuated in other locations and being unable to participate in the recovery of their own neighborhoods. There is a need of a comprehensive view about emerging urban risks (Georgescu et al, 2010).

Resilience is a key-word of recent decades, but tools are still in other hands. The Sendai Framework for Disaster Risk Reduction 2015-2030 (2015), reiterated the states commitment to disaster risk reduction and that the building of resilience to disasters should be addressed with a renewed sense of urgency in the context of sustainable development. The need of integration into policies, plans, programmes and budgets at all levels and of consideration within relevant frameworks was stressed out again. (http://www.wcdrr.org/uploads/...).

In this respect, Italy 2015 TIEMS Conference (https://tiemsic.wordpress.com/international-conference-2015/) addresses important issues, as:

- decision support systems for risk management in the cold and hot phases;
- preparedness and resilience enhancement in growing metropolitan areas, with a due questioning about the "smart cities" pattern;
- system resilience, efficiency, social inclusion, sustainability, risk reduction and mitigation techniques, validation and verification methodologies and tools, human and social aspects in emergency managements.

In this respect, the paper attempts to provide methods for the assessment of urban multi-hazard risks for emergency planning, using affordable technical tools and keeping the community closer to the risk management.

1.2. The patterns of protected area under study and the research to-date

The patterns of the studied area (Figure 1), located in Bucharest, in front of the Romanian Parliament, have been presented elsewhere (Florescu et al, 2014; Georgescu et al, 2014, 2015; Gociman et al, 2014, 2015). This is an example of an area that suffered a huge urban trauma in the 1980's by the total or partial demolition of an urban fabric of more than 450-hectares of the old city, to build the new East-West axis of the city and the new headquarters of several public institutions.

Figure 1 Map of the studied area

The building stock in the area is diverse and dates from different periods. The pre-1950 traditional building stock consists of low-rise brick masonry buildings, with gardens and yards, mixed with some mid-rise masonry and reinforced concrete mansions. The post-1950 buildings consist of mid-rise and high-rise concrete and masonry condominiums. After 1980's, many high-rise buildings have been erected around the areas with low-rise and mid-rise houses remaining after demolition. It is important to note that, after the political changes at the end of 1989, the area was formally declared a protected area; in fact, it is under urban stagnation and decay.

The area was and can be at risk because of earthquakes, floods, extreme climatic events, technological and terrorist explosions, dangerous chemical spilling. For the case of post-earthquake intervention, and much more in the case of multi-hazard impact, it is very difficult to set the target of reconstruction, since the destructured fabric needs special care. As a first attempt of our study (Florescu et al, 2014; Georgescu et al, 2014; Gociman et al, 2014), the cultural value was assessed by using 13 scoring criteria and six scaling stages of the Romanian Law of Monuments. The functional value was evaluated and mapped, as in Figure 2, for the existing building classes.

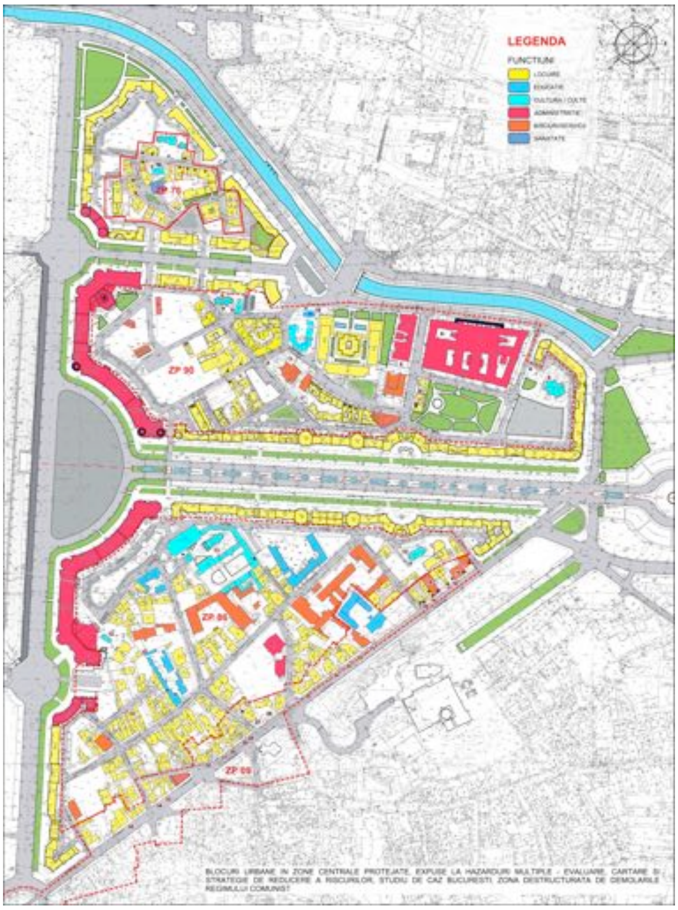

Figure 2 Mapping of the functional value for the study area

To store the attributes of the buildings in the study area, the URBASRISKdb geodatabase was created, based on the past experience (Georgescu et al, 2014). These attributes are used in the multi-criteria, multidisciplinary and multi-hazard 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, with: building identification fields (identification code, address, geographical coordinates), fields regarding the general features of the buildings (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.). It is worth mentioning that, for the vulnerability analyses, specific fields were also included, for the following purposes:

- harmonization with building classification systems, according to the main construction material and to the number of stories, respectively, used in the census records;
- harmonization with building vulnerability classes, adapted and recalibrated, based data on available at INCERC from the 1977 earthquake (Balan et al, 1982, Sandi et al, 2008);
- use of the *Mean Damage Degree*, GA, based on the histograms computed for the above classes, associated with the *Site-Adjusted Damage Degree*, GAMA (Project URBASRISK, 2014).

As a result, a number of about 400 buildings were identified, recorded in the URBASRISKdb geodatabase and mapped, with their associated attributes, using a spatial representation based on ESRI software and data (Figures 3 and 4).

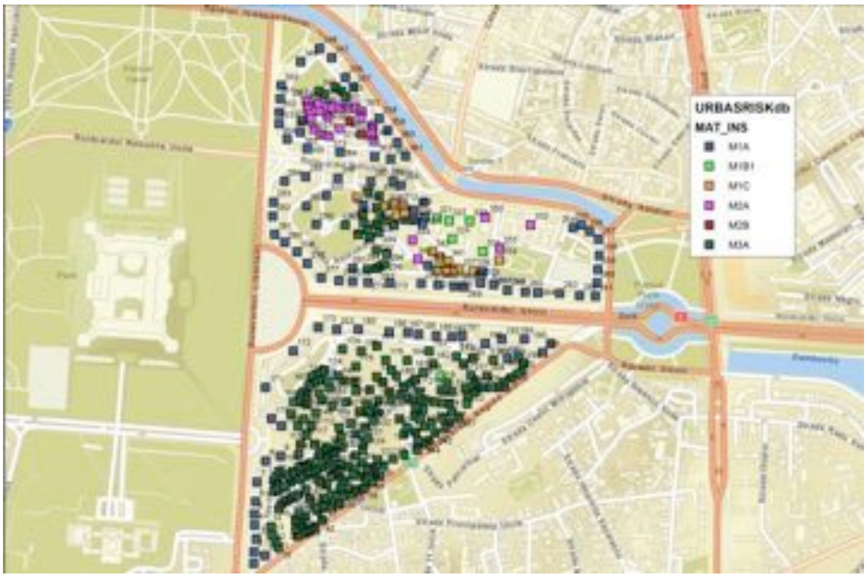

Figure 3 Mapping of material / structural identificators for structural vulnerability, with color codes in the study area. Base map: ESRI, World Street Map (2014). (Project URBASRISK, 2014).

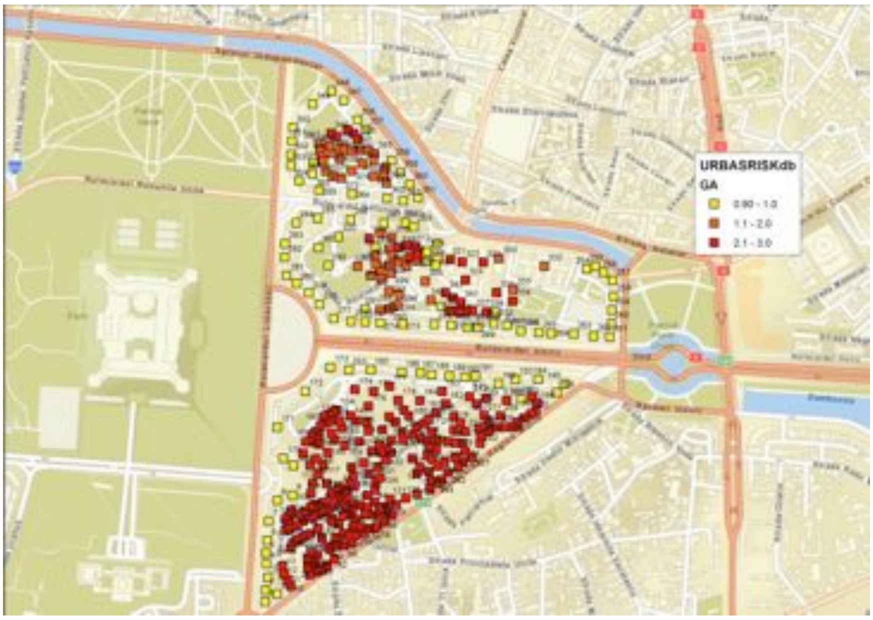

Figure 4 Mapping of structural vulnerability – Damage Degree GA for ranges of values, with color codes in the study area. Base map: ESRI, World Street Map (2014) (Project URBASRISK, 2014).

The base map, i.e. the ESRI *World Street Map* layer, was checked against satellite, aerial and street views, while field visits that were carried on by the members of the team allowed the inspection of buildings to assess their structural vulnerability and, if applicable, the adjusting of the reduction factors required to obtain the Site-Adjusted Damage Degree, GAMA, from the Mean Damage Degree, GA.

2. MULTI-HAZARD THREATS AND IMPACT SCENARIOS IN THE PILOT STUDY PROTECTED AREA

2.1. Natural and man-made hazards

Geological scenario hazards were considered as:

- seismic hazard from intermediate Vrancea source, in two alternatives, as intensity VIII (as in March 4, 1977; Balan et al, 1982: Sandi et al, 2008) and VIII ½ (in order to take into account the cumulative vulnerability);
- local soil hazards, as liquefaction and/or settlements of foundations.

Climatic and hydrologic hazards were considered as:

- snow, snow-storm, urban vortex-tornado, raising water;
- rain and excess water floods;
- flooding from accidents occurring outside the study area, as the breaking of a water control and supply lake dam, under heavy rain, with lack of gates control.

Man-made hazards were considered as:

- explosions with chemical release, under Seveso Directive in the city, reaching the protected area;
- moderate spilling of ammonia gas;
- explosions in the gas network or in houses, or moderate LPG recipients etc;
- terrorist attack on public institutions, with impact upon neighboring communities, a rather new type of hazard, but proven by recent international situations.

Hazard by urban fire: from houses and other buildings, with propagation and combination with other hazards.

2.2. Results of multi-hazard scenarios

For earthquake scenario damage and casualties, the study used specific vulnerability functions for earthquake impact, calibrated and adjusted after Balan et al, 1982; Sandi et al, 2008, and simplified methods and expert opinions for other hazards, under an average occupation ratio per house. When relevant for exposure, some hypotheses of day and night have been used.

As a result of assessments, the number of buildings with significant damage from earthquake was accounted for the alternatives of I=VIII as being around 63 and 165 buildings for I=VIII½, mostly low-rise structures, while heavy injured are 29 and 64 persons, live loss is 59 and 92, respectively, resulting some 1809...3061 evacuated persons from such unsafe buildings, indicating a need of shelter. However, since the number of people from heavy damaged houses is only of some 355...677 and houses have gardens and yards, some shelter can be arranged nearby.

The day-time scenario lead to exposure and casualties reduced by 50% in houses, but it was evaluated an extra exposure of 10.120 persons in public institutions around, and 1.000 clients in commercial places, 1.400 in offices and 800 in schools, while 400 can be in churches. Since such buildings are less vulnerable, there are only 26 light injuries and 1 hospital entry.

According to these results, although the number of heavy damage is not excessive, the scenario for I= VIII½ indicates a need of investigations for safety assessment and possibly a great number of temporary or long-term evacuation for repairs and structural strengthening, this community is protected but already weak and heritage buildings need careful and time-consuming works.

The scenario of climatic and hydrologic hazards is based on the hypothesis of an extreme event of accidental flooding in case of Lake Lacul Morii breaking (Drobot et al, 2007). The water supply lake Lacul Morii, in the Western part of Bucharest, has a concrete dam with a height of 15 m, 7 km of earth dikes, 14.7 millions cubic meters volume and it discharges towards the city Dambovita River Canal that passes near the study area. An early warning can save the community persons, but not the built area.

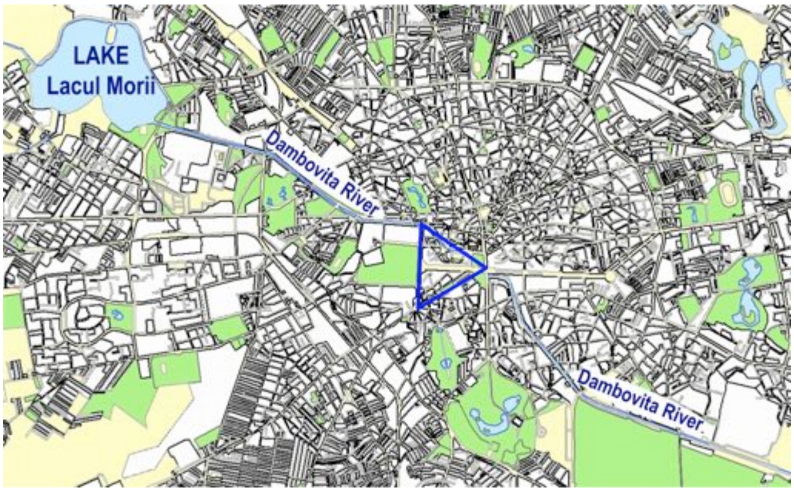

Figure 5 Setting of Lake Lacul Morii and the path towards the study area (marked with a triangle)

The water cover can be as high as 2.5 m and all 2 story houses as well as first 2 stories of condominium would be under water (Figures 5 and 6). Because this scenario is beyond the reaction capacity of the community, and its probability is reduced because of permanent monitoring and water control by gates, it was not further evaluated.

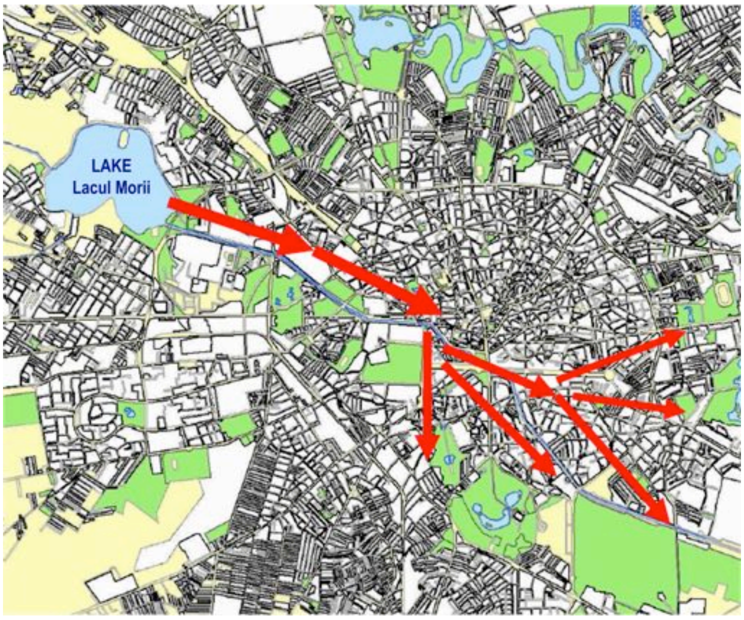

Figure 6 Flooding scenario from Lake Lacul Morii, having impact on study area and beyond

The scenarios for explosions in other places of Bucharest, having impact on the study area, considered the following potential hazards from various tanks with gases or chemicals:

- type BLEVE explosion (Boiling Liquid Expanding Vapor Explosion);
- type UVCE explosion (Unconfined Vapour Cloud Explosion).

In Bucharest, such sources can be in thermal power plants, large storage of toxic gases (ammonia gas NH3, chlorine gas, sulphuric acid) or GPL storages. According to Rufat, 2009, such plants and storages exist in other areas but their nominal release radiuses cannot reach the study area.

The terrorist scenario blasting considered three hypotheses:

- explosive in quantity to be carried by one person (backpack);

- explosive in quantity to be carried by a compact car;
- explosive in quantity to be carried by a urban van.

In this respect, a number of six scenarios were considered, with the said three hypotheses for some particular location of an institution as a target, in each of the two separate sub-zones. The radiuses of impact were evaluated after IABTI - International Association of Bomb Technicians and Investigators, (https://www.iabti.org/). These scenarios considered some particular locations that can be a target; it resulted that such impacts would affect very large and densely inhabited areas of irreparable damage, with fragmentation and debris spreading (Figures 7, 8 and 9).

In figures 7, 8 and 9, the legend is as follows:

- D – radius of demolition impact
- DI – irremediable demolition radius
- DN – non-repairable radius
- DM – minor destruction radius
- DF – minimum protection radius against fragments / debris impact

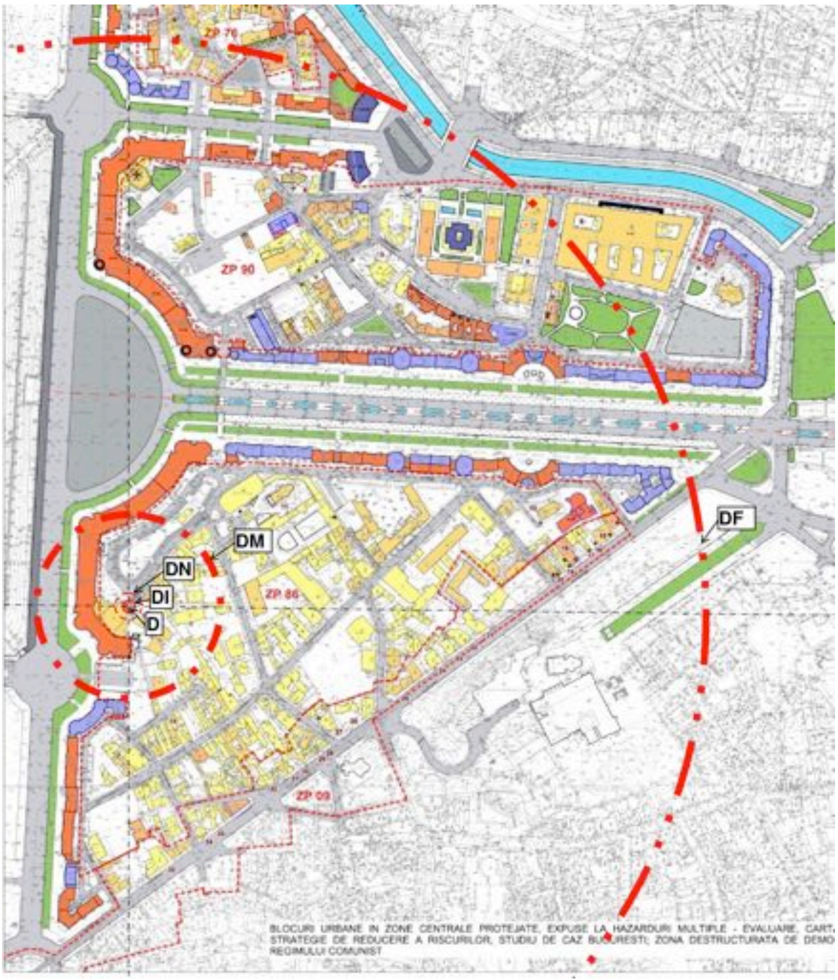

Figure 7 Radiuses of specific zones in a specific location within the study area. Position B – Scenario S 4.4 - case 1 –Explosive in quantity to be carried by one person (backpack).

The results have shown that, as the explosive quantity increases, the impacts would affect very large and densely inhabited areas by irreparable damage, with fragmentation and debris spreading, with great potential of injured and casualties. However, the impacts are more or less nominal, and they depend on the height of existing structures on the blast flow path, as some buildings could provide a shielding effect.

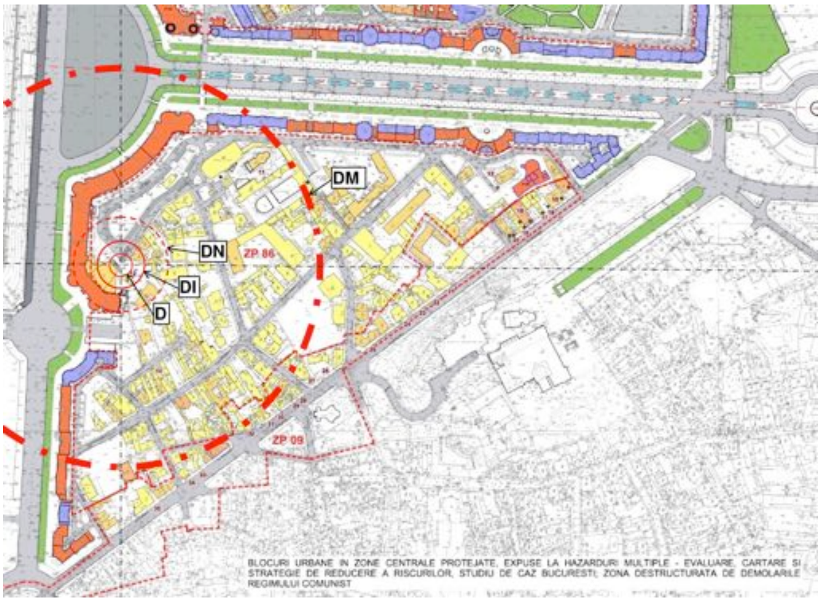

Figure 8 Radiuses of specific zones in a specific location within the study area. Position B – Scenario S 4.4 - case 2 –Explosive in quantity to be carried by a compact car.

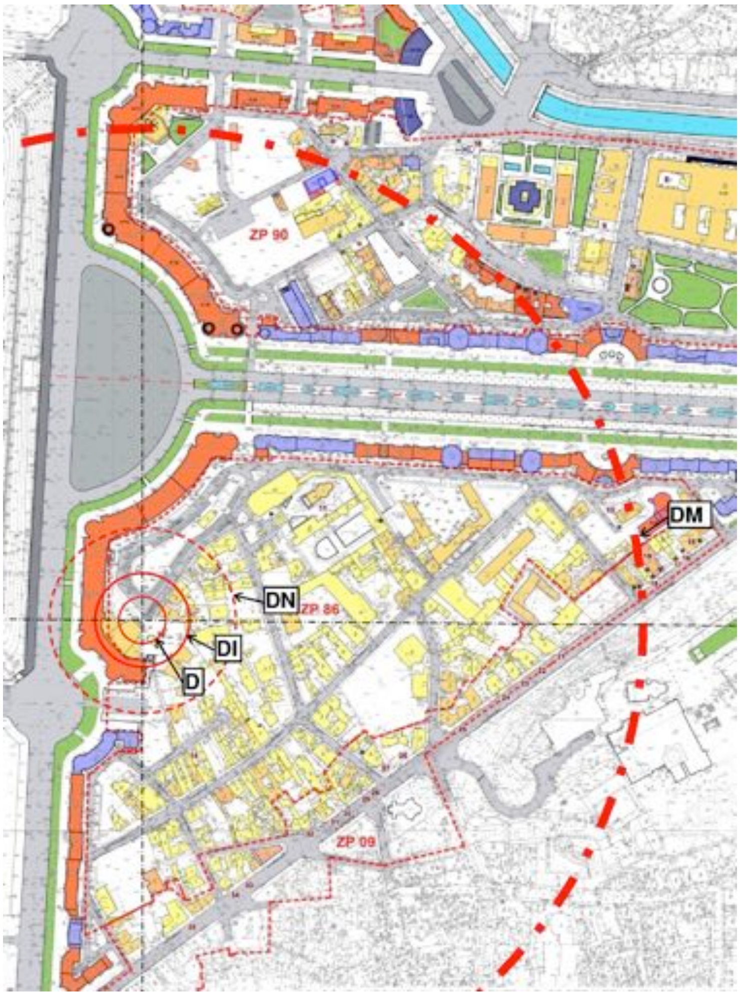

Figure 9 Radiuses of specific zones in a specific location within the study area. Position B – Scenario S 4.4 - case 3 –explosive in quantity to be carried by a urban van.

3. SETTING SHELTERS AND SECURITY CENTERS FUNCTION OF MULTI-HAZARD SCENARIOS

According to the results of scenarios, the need and possibility to create shelters and security centers are as follows:

- for seismic hazard scenarios, considering only the structural impact on buildings, one can create a security center at the nearby "Mihai Eminescu" College;
- for hydrologic hazard, as the flooding is supposed to cover all areas, the refuge and shelter area should be placed in a higher place, for instance near the Academy House / Romanian Parliament;
- for the terrorist scenario and/or other explosions, the impact is rather moderate, thus the security center at "Mihai Eminescu" College or Izvor Park is recommended;
- for extreme climatic hazards, as well as for the damage and lack of function of urban infrastructures, the security center at "Mihai Eminescu" College can play mainly a role of daily feeding and social care, as well as for commnunity information;

4. CONCLUSIONS

The multi-hazard interdisciplinary approach allowed the assessment of the functional value, as well as of the seismic vulnerability, for the existing building classes, with cultural value scored on the six scaling stages of the Romanian Law of Historical Monuments. The approach used affordable engineering methods for structural vulnerability assessment and mapping, in a multi-hazard environment and provided an operative tool for vulnerability assessment, using both past surveys of vulnerability data and inspection of buildings and a number of reduction or amplification factors to obtain the Site-Adjusted Damage Degree, GAMA, based on the Mean Damage Degree, GA. Thus, a mapping of specific building attributes was done, by using the URBASRISKdb geodatabase, census and field data and by creating a basis for urban zonation on disaster protection criteria.

The multi-hazard scenarios used in the assessment were:

- for seismic hazard, Vrancea earthquakes with intensity VIII and VIII ½;
- local soil hazards, liquefaction and/or settlements;
- climatic and hydrologic hazards, as snow, snow-storm, vortex, raising water, rain and flooding;
- man-induced hazards, as explosions with chemical release, gas explosions, terrorist attacks on public institutions and urban fire.

The advantages of the multi-hazard scenarios reside in their ability of providing a comprehensive view of threats and a synthetic mapping of impacts and risks. The assessment allowed the identification of a number of areas for shelter / security centers within the community at risk, at hand for its own citizens. When applied at city scale, the network of security centers could create stable logistics for disaster situations and a poly-nuclear support system in urban development. The risk reduction strategies developed in the framework of the project are structured on emergency and perspective terms, based on the use of structural and non-structural methods and envisaging long-term interventions, as maintenance, improvement and transformation.

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