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CHEMICAL AND RADIOLOGICAL VULNERABILITY ASSESSMENT IN URBAN AREAS

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Cities and towns are faced with various types of threat from the extraordinary events involving chemical and radiological materials as exemplified by major chemical accidents, radiological incidents, fires, explosions, traffic accidents, terrorist attacks, etc. On the other hand, many sensitive or vulnerable assets exist within cities, such as: settlements, infrastructures, hospitals, schools, churches, businesses, government, and others. Besides emergency planning, the land use planning also represents an important tool for prevention or reduction of damages on people and other assets due to unwanted events. This paper considers development of method for inclusion vulnerability assessment in land use planning with objective to assess and limit the consequences in cities of likely accidents involving hazardous materials. We made preliminary assessment of criticality and vulnerability of the assets within Belgrade city area in respect to chemical sites and transportation roads that can be exposed to chemical accidents, or terrorist attacks.

KEY WORDS: chemical, radiological, terrorism, accident, vulnerability, land use planning

INTRODUCTION

Over 60% of European population lives in cities, because they are a driving force of the economic development. On the other hand the cities are faced with many kinds of threats, such as: risk of the chemical accidents, radiological incidents, fires, explosions, traffic accidents, terrorist attacks and others. Such threats within cities, find a target-rich environment due to a complex interacting system of people, buildings, infrastructures (utilities, roads, railroads, ports, airports), hospitals, schools, churches, businesses, government, and military facilities, which all together, define a city's way of life. Many of those assets are incompatible with their surroundings involving hazardous establishments. Accidents as these of Bhopal and Mexico City, and more recently of Enschede and Tolouse, have clearly demonstrated how the consequences of industrial accidents may be severely amplified by the adjacency of hazardous installations and high-density population areas [1]. More over the experience of the war conflicts in the past decade has shown that attacks on chemical facilities produced severe impacts to environment and people [2]. After the tragic events of 11th September 2001, terrorist and criminal acts are now considered credible incidents in the process industries and threat to their surrounding. To-date, the response of both, governments and industry has been to focus on improved physical and cyber security to prevent accidents as well as attacks and the associated consequences [3]. While prevention is clearly preferred, the potential for accident and successful attacks and vulnerability of facilities and cities must be recognized and addressed.

However, methods for vulnerability assessment in respect to accidental or intentional hazardous events, particularly terrorist attacks involving chemical and radiological (CR) materials and various weapons, have not been sufficiently developed. Some methods and guides have been developed for some important assets, as exemplified by: chemical facilities [4], buildings and public areas [5], transportation infrastructure [6], and some others. Although these methods include some spatial aspects, they do not enable inclusion of the results on vulnerability assessment in land use planning.

This paper presents preliminary results of developing a generic methodological framework for analysis of vulnerabilities of specific assets in pair with the chemical and radiological threats. Main steps in this framework include identification of critical assets and vulnerable zones in urban area, and implementation of results in the formulation of mitigation strategies, specifically in the process of land use planning, site selection and spatial arrangement of critical and sensitive assets. Results of a preliminary study of the vulnerability of assets in the vicinity of dangerous establishments within Belgrade city area are presented.

DEFINITIONS

In practice, the terms in risk management context are commonly used in various ways. Therefore, it is useful to define how these terms are used and how they relate to each other. These definitions were derived from material used by the US National Infrastructure Protection Center [7], taking into account some specific characteristics of chemical and radiological risk management.

Risk is the potential for some unwanted event to occur. Risk is a function of the likelihood of

the event occurring and its consequences. The likelihood of the event occurring depends upon threat and vulnerability.

Threat is the capability of an accident on chemical or radiological site, or intention of an adversary to undertake actions that are hazardous to an organization or community's interests. Threat can be intristic, related to factors internal to the system (failure, sabotage), and extrintic related to factors external to system (terrorism and others). Extrinsic threat is a function of the adversary only and the owner or user of the asset cannot typically control it. However, the adversary's intention to exploit his capability may be encouraged by vulnerability in an asset or discouraged by its resilience.

Vulnerability is best understood as any weakness in an asset or community that can provoke accident or can be exploited by an adversary to cause damage to an organization's or community's interests. More precisely, vulnerability is defined as an estimate of the inability of an asset to tolerate impacts over time and space. A **vulnerability assessment** addresses the susceptibility to attack and the broad range of physical-chemical-radiological threats to the security and safety of assets. It provides a basis for an estimation of the probability of realization of adversary threat.

Asset is anything of value (people, natural and built environment, facilities, economic and societal activities). Assets are what a community or organization needs to carry out the mission. The more critical the asset is to a community accomplishing its mission, the greater the effect of its damage or destruction.

Consequences are effects if the threat is carried out against the assets. Consequences of a chemical and radiological event may include deaths, illness; contamination of people, environment and property; economic losses, and psychological impact.

Countermeasures (mitigation measures) are actions or devices that mitigate risk by affecting an asset, threat, or vulnerability.

ROLE OF LAND USE PLANNING (LUP) IN RISK MANAGEMENT

Land use planning (LUP) represents a framework for spatial arrangement of urban structures and functions, as exemplified by housing, job locations, infrastructure, recreation, water, nature and agriculture, etc. Accident and threat control and assets protection objectives have to be balanced with other planning objectives, such as the efficient use of land and resources, and must take into account existing physical, programmatic, and fiscal constraints.

The need of land-use regulations around hazardous installations was one of the factors leading to the revision of Directive 82/501/EEC (the Seveso Directive) [8]. In the resulting Directive 96/82/EC (Seveso II Directive) [9], the European Commission has considered the introduction of land use planning requirements in the vicinity of sites falling under the obligations of the Directive as a necessary measure for the mitigation of consequences of accidents [10]. The recent amendment of the Seveso II Directive, has furthermore stressed the need to develop common guidelines, calling for the development of a common database, to be used in order to assess the compatibility between the establishments and their surroundings [11].

Directive through controls on the siting of new establishments, modifications to existing establishments and new developments such as transport links, locations frequented by the public and residential areas in the vicinity of existing establishments. In the long term, land-use planning strategies shall ensure that **appropriate distances** between hazardous establishments and residential areas, areas of public use and areas of particular natural sensitivity or interest are maintained, so as not to increase the risks to people, as shown in the Fig. 1 [12].

The problem of incompatible land-use planning around hazardous installations seems to exists due to improper implementation of a plan, and interchanging of plan implementation with planning. Such a conclusion stems from a number of suggestions, proposals, models on how to solve existing or potential conflicting situations as illustrated in Fig. 2.

These cases consider the problem of precise land-use planning related to hazardous installations after zoning is already established, i.e., after the general land-use plan is already approved.

Important areas excluded from the scope of the Seveso II Directive include nuclear safety, the transport of dangerous substances and intere-iate temporary storage outside establishments and the transport of dangerous substances by pipelines.

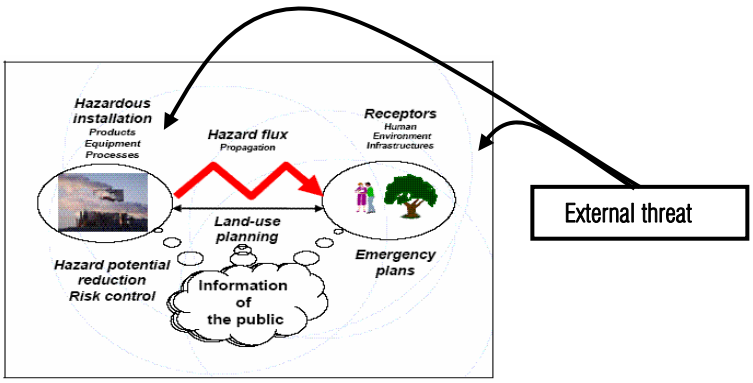

Fig. 1 – Role of land use planning in risk management

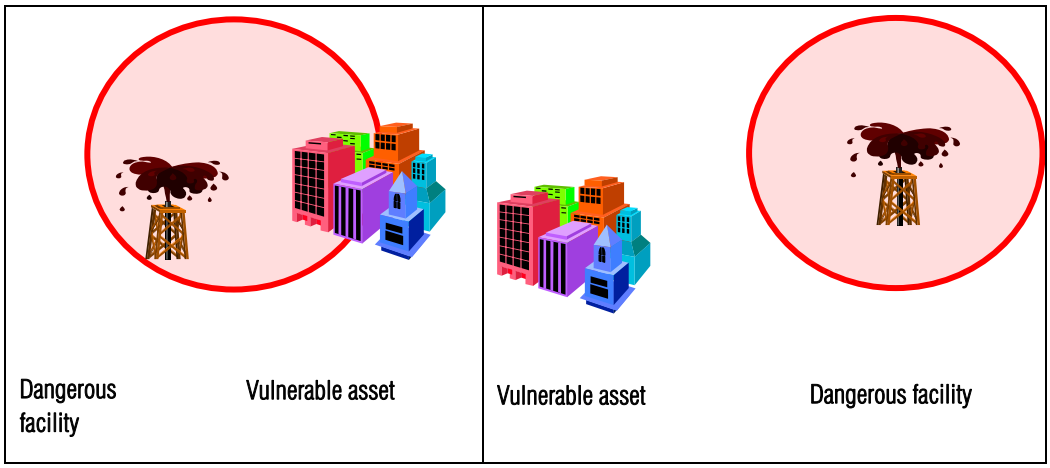

Fig. 2 - Illustration of a common conflicting situation, which occurs due to isolated licensing processes: (a) conflicting situation and b) non conflicting

However, as accidents from various sources and terrorists and other attacks against assets do continue to occur, it is necessary to limit the consequences of such accidents not only for people (safety and health aspects) but also for the environment (environmental aspect). In that respect, the land use planning should include all risks in planning area taking into account vulnerability of valuable assets.

METHODOLOGY

The vulnerability assessment integration in urban planning process typically occurs in two major phases: (I) risk assessment, and (II) planning, as shown in the Figure 3 .

Main steps of the methodology are:

1. Vulnerability screening determines if further risk management is needed. In this step assessor identifies critical asserts and assess the threat in urban area. Identification of critical assets begins with identification of the LUP issues (existing and planned land use pattern, hazardous zones, sensitive zones, buffer zones, infrastructures, etc.), then proceed with creation of an all-inclusive list of critical assets (sites involving CR materials, government establishments, transportation infrastructure and facilities, public places, commercial and financial buildings, cultural and religious buildings, and others). Key indicators for estimation of an asset criticality are: symbolic importance, functional importance, economic value, people count, effectivity of safety management system, time to recover and accesibility. Threat assessment defines the degree of the threats against an asset by evaluating the intent, motivation, tools, weapons and possible tactics of those who may carry them out. The process involves collecting historical data about hostile events and evaluating terorrist group existence, their intent and capability to use CR agents against critical asset. Preliminary vulnerability assessment would be carried out by use of multicriteria analysis (MCA) matrix of pair identified assets

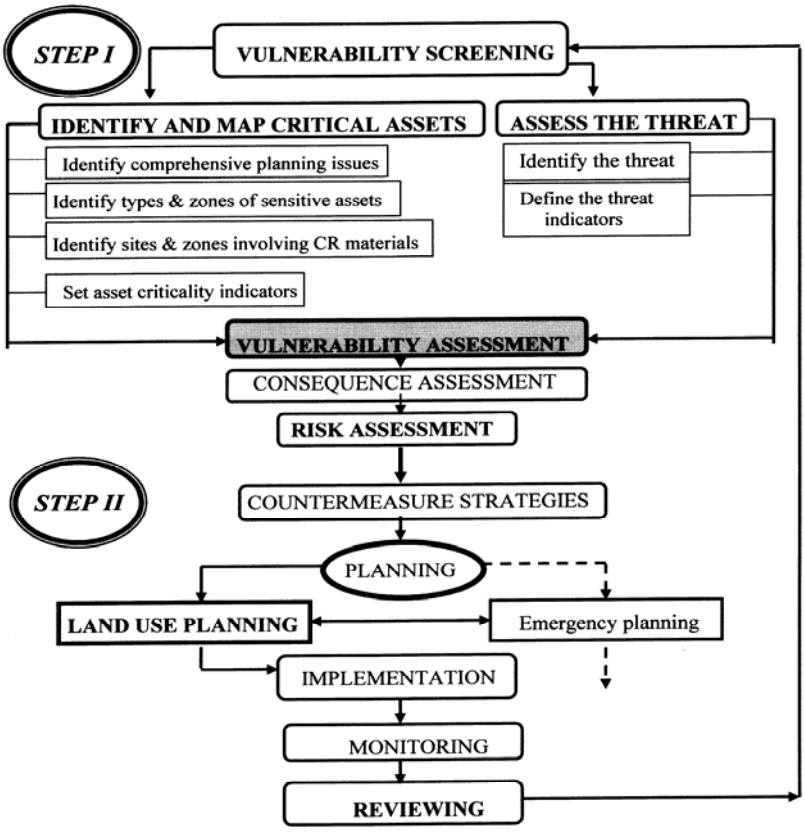

Fig. 3 - Methodology for integration of vulnerability assessment in land use planning

and threats. Criteria for the asset criticality estimation are based on the criticality criteria of each indicator, ranking them from "extremely important" (5) to "less important" (1). Determination of the threat level include relative ranking of threats against each asset on the list, using numerical scale and ranking them from "critical threat" (5) to "negligible threat" (1). After calculating the scores and ranking the critical assets, a screening thresholds would be applied. The selected items form the prioritized critical asset list which should be integrated in the composite city map showing specific geometries that include vulnerable assets as zones, lines and points. The assets having highest priorities would be further assessed to determine detailed threats, vulnerabilities, consequences, risks and countermeasures.

Table 1. – Vulnerability screening (assets criticality analysis) criteria

	Criticality indicator	Criticality criteria	Factor value
1	Functional importance	International	5
		National	4
		Regional	3
		Municipal	2
		Local	1
2	Economic value*	More than 100 mil. USD	5
		50 – 100 mil. USD	4
		10 – 50 mil. USD	3
		2 – 10 mil. USD	2
		Less than 2 mil. USD	1
3	People count in hazardous zone*	More than 1,500	5
		1, 500 – 120	4
		120 – 61	3
		60 – 11	2
		10 – 0	1
4	Ecological sensitivity	Underground water-supply protected zones	5
		Protected natural assets	4
		Valuable agricultural zones – fertile land	3
		Surface waters	2
		Unfertile land	1
5	Type of chemical - radioactive material	Extremely toxic/radioactive	5
		Highly toxic/radioactive	4
		Toxic/radioactive	3
		Highly flammable/explosive	2
		Flammable/explosive	1
6	Quantity of chemical - radioactive material	More than upper threshold value (UTV)	5
		Between UTVand lower threshold value (LTV)	4
		100-50 % LTV	3
		50 – 10 % LTV	2
		Less than 10% of LTV	1
7	Ratio (separation distance/ required safety distance)	Less than 0.1	5
		0.1 – 0.25	4
		0.25 – 0.50	3
		0.50 – 0.75	2
		0.75 – 1.00	1
8	Safety system affectivity	Low	5
		Poor	4
		Moderate	3
		Good	2
		High	1

* Adopted from: Risk Management Guidance for Health, Safety, and Environmental Security under Extraordinary Incidents, American SHRAE, Atalanta, Georgia, 2003

2. Consequence assessment analyses the nature and severity of the adverse effects associated with identified causal factors. This process begins with creation of scenarios that pair identified assets and threats, followed by exposure assessment and estimation of effects on the assets, in particular on people and environment. Consequence assessment includes two estimates: level of possible accident, e.g. geographic scale, and type and intensity of effects.

3. Risk assessment uses qualitative or quantitative analysis to integrate the results of consequence assessments with the estimation of vulnerability e.g. probability that these consequences can occur.

4. Countermeasure strategies, that include: terrorrist attack deterrioration and prevention, improvement of physical security, reducing threat and vulnerability, limiting consequences and remediation of consequences. The most important task for spatial planning is exlusion of further settlement in vulnerable and risky zones.

5. Planning assumes preparing of two main types of plans: land use planning and emergency planning. Inclusion of a range of security and safety measures into comprehensive and local land use planning can contribute to reducing vulnerability and limiting consequences of an extraordinary event occuring. Planning elements are: spatial arrangement of spaces and activities, site selection for particular uses, area development planning including buffer zones in vicinity of hazardous establishments and installations, relocation of hazardous or vulnerable assets, building and structure protective requirements, security measures in infrastructures planning, identification of evacuation routes, determination of implementation rules, etc.

6. Implementation of plan includes conducting planned activities by reponsible authorities and developers according to prescribed rules, phasing and costs.

7. Monitoring includes an evidence of the land use plan implementation and extraordinary events occuring in the space of plan.

8. Reviewing assumes evaluation of implementation planning objectives and tasks and seting up the proposals for further reducing of vulnerabilities of the critical assets.

RESULTS

We carried out a preliminary study of the CR vulnerability of assets within Belgrade city area. At present, there are no recognised specific terrorist threats from use of chemical-radiological materials and weapons. Taking into account that some chemicals and radioactive materials may be particularly attractive targets, as great potentials for greater consequences if released, we identified sites involving these materials in study with the aim to test proposed vulnerability assessment methodology. We carried out procedure of vulnerability screening as the first important step of procedure. A list of 46 sites and facilities involving hazardous materials prepared, and additionally main transportation routes of hazardous materials. On the basis of general vulnerability screening indicators we developed a specific assets criticality indicators and ranking criteria, as shown in the Table 1.

Each establishment was estimated using these indicators and criteria. After calculating the scores and ranking the critical assets, a criticality categorization of the assets was applied, as follows: (1) high, having score 30-40; (2) moderate (20-29); and (3) low (les than 20). We got a list of 14 highly critical establishments that belong to the first category. These establishments are shown in the Fig. 4 together with corresponding hazardous zones, represented by cycles of 500 and 1,000 meters in radius [13]. We made, also, vulnerability screening of the main transportation routes of hazardous materials. Results of the highly critical rail and road routes are shown in the Fig. 5 [14]

The results indicate that most of hazardous zones and transport routes are in conflict with densely populated areas (housing, businesses) and protected underground water sources. Responses to the present weakness of spatial arrangement of sensitive and hazardous assets were set up in the new Belgrade general plan. These include: planed options for sitting of new establishments, reconstruction and relocation of existing establishments, and new rules and conditions for the implementation of plan by application: quantitative risk assessment, safety barriers and zones, safety barriers and corridors on transportation routes, new safety criteria in a building design, monitoring and public participation.

DISCUSION AND CONCLUSION

Despite the great advance in theory and practice of urban planning, there are still many unsolved problems, particularly in respect to the assets security and safety in cities. Existing regulatory framework in the land use planning and building involves consideration of natural and man-made disasters, but do not take into account the threat from intentional attacks on valuable urban assets.

In this study we proposed a methodology for inclusion of the vulnerability assessment procedure in the process of land use planning. By application of this methodology framework urban planning becomes more complex, and also requires huge volume of information. This is the reason for testing only the first step of

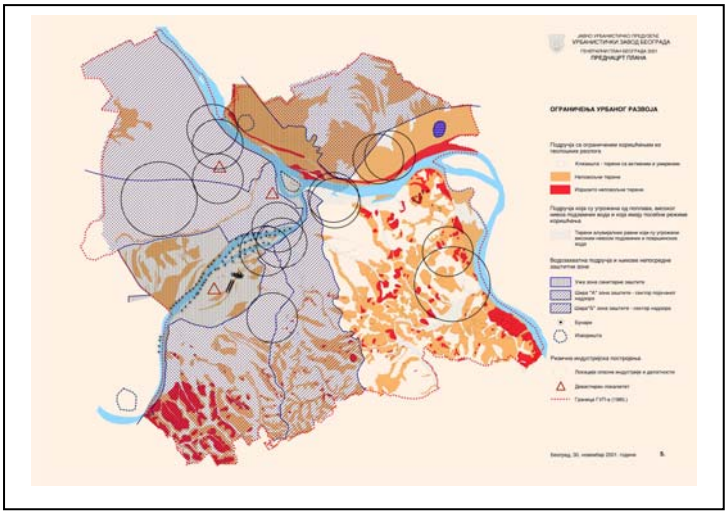

Figure 4 – Hazardous sites and vulnerable zones in Belgrade

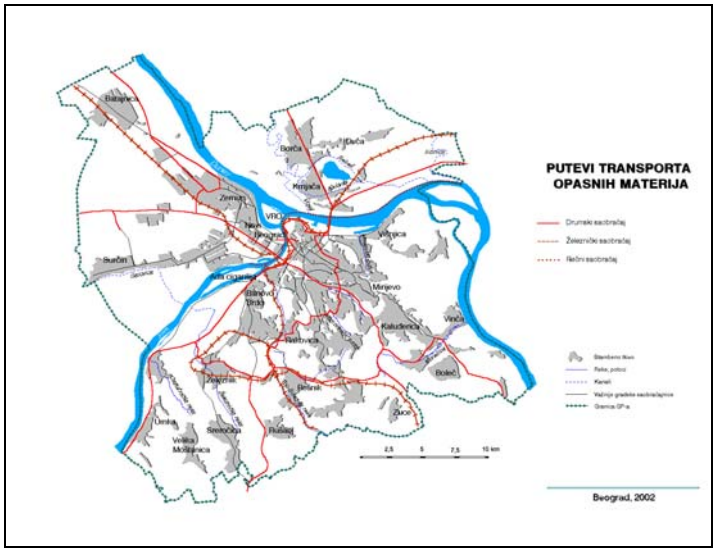

Figure 5 – Road & rail routes for transportation of hazardous materials in Belgrade

methodology, e.g. vulnerability screening of assets in the case of urban area of Belgrade city, based on available data about hazardous establishments, installations and transportation routes and spatial arrangement of the sensitive assets. The results of vulnerability screening show that despite qualitative approach it was possible to identify, estimate and categorize critical assets. This methodology enabled us to prioritise critical assets, for further investigation. However, by using the table of safety distances adopted from Christou&Porter [11], we defined hazardous zones for each of 14 establishments on the list of highly critical assets. After spatial analysis of hazardous zones it was possible to propose mitigation measures that were applied in the General urban plan of Belgrade city.

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