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Technological risk mitigation for the resilient cities

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Abstract. The complexity of the urban environment causes a continuous change in the different variables of vulnerability: social, economic and environmental protection, energy, health, water, traffic, climate and security- in connection with sustainable development. Multi-hazard and multi-risk assessment for urban areas, in the context of territorial planning policies, is a priority for increasing the resilience of local communities. Vulnerability, as a factor in risk analysis, can influence the likelihood of negative consequences for man, the environment, and infrastructure. A detailed analysis of the vulnerability indicators in the area of industrial hazard sources can improve the correctness of the decisions in the territorial planning process. The paper presents the analysis of the influence of vulnerability, through the presented factors, in the technological risk assessment of major industrial accidents involving hazardous substances.

Key words: risk assessment, urban resilience, Sendai Framework, disaster management.

1. Introduction

In the context of discussions on improving resilience at the local level, within the cities in the present case, the starting point should focus on the city as a system [1]. As with any system, at the level of any city there are a number of components that are in close connection with each other. Depending on the type of connection, we can state that between these components there is either a relationship of dependence or one of interdependence.

The functionality of a city is determined, as a whole, by the state of the elements that compose it and by the physical and non-physical changes that occur between the respective elements. In the case of dependency relationships, a linkage or connection between two components, through which the state of one infrastructure influences or is correlated to the state of the other [2]. If those elements are connected at multiple points and though a variety of mechanisms, in a way that a bidirectional relationship is created between any

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given pair of elements, we can clearly state that the components are in a state of interdependency. At the city level, there are several types of interdependence: physical, geographic, cyber and logical interdependency. Conceptually, the situation described above is identical to that of critical infrastructures. Practically any element of a city that is essential for the maintenance of vital societal functions, health, safety and security, economic or social well-being of people is a critical infrastructure for that city [3].

The protection of urban critical infrastructures is one of the most frequent topics on the European political agenda and, implicitly, of Romania, being considered a major problem through the security of critical infrastructures associated with urban security and resilience. The resilience of elements in a critical infrastructure system is a major factor determining the reliability of services and commodities provided by the critical infrastructure system to society [4]. The security and resilience of critical urban infrastructures is how they are interrelated so that disruption or disruption of one of the sectors can produce significant negative effects in other sectors and, by effect, cause major damage. The security and resilience of cities is closely linked to sustainable development, being essential objectives to be achieved without being in contradiction with the development of other sectors, including industry [5]. The effects can affect localities, regions or even states and can influence the life and activity of a large number of people, the community being vulnerable in the absence of an efficient management and in the lack of awareness of a new culture of security and urban resilience [6]. As the issue of protecting critical urban infrastructures is of particular importance, affecting vital sectors of the economic-social life and having an impact on both national security and citizen security, it is increasingly accepted today that there is a need to raise the awareness of urban communities in the new culture.

Still, an integrated process of critical infrastructure management, which will improve the resilience of cities, must be largely based on studies on technological risk mitigation, as the chemical sector is a very developed component in many cities. Major accidents involving dangerous chemicals pose a significant threat to humans and the environment. Furthermore such accidents cause huge economic losses and disrupt sustainable growth [7]. As the technological hazards influence spatial development, concrete measures of territorial planning must be identified and implemented in order to reduce the exposure of the various vulnerable elements and subsequently the risk [8,9]. In this context, the UN Office for Disaster Risk Reduction (UNDRR) developed an operational framework of Sendai Framework [10] at local level based on ten essential and independent elements for building and maintaining cities resilience [11]. Those elements, as described in the guidance documents and reports of the UNDRR, are grouped in three major categories (corporate/city governance, integrate planning and response planning) in order to develop consistent city planning and resilience strategy. Also, in order to reduce technological risks, the life cycle engineering of a product must be taken into account by optimizing different stages to balance potential losses [12].

2. Methodology

The foundations of this study were laid by the Romanian national risk assessment project RO-RISK [13], where a large component considered in the analysis was constituted by major industrial accidents involving dangerous substances (SEVESO Accidents). At the national level, a number of 301 establishments that fall within the SEVESO directive provisions were identified. The unitary methodology of risk assessment implies the identification of accident scenarios relevant for each operator and their ranking in order to highlight the relevant scenarios at national level [14]. Within this stage, a number of scenarios were identified based on the experts opinion and some elements calculated using the GIS, taking into account the risk sources, the hazard analyzes and the hazard maps developed. The selected scenarios are considered to have a major impact at national level. For this purpose, the worst case scenarios were used, which provide a suitable analysis grid for identifying and describing the most relevant scenarios. After identifying and describing a number of 40 scenarios, a series of prioritization criteria have been applied to highlight the scenarios that may have a major impact at national level, representative for Romania.

During the process of identifying and selecting the risk areas and related scenarios, relevant data was entered in the PHA (Preliminary Hazard Assessment) software as input data. To analyze the physical effects and consequences of the 40 scenarios selected in the previous phase of the project, the software package SAFETI PhastRisk 6.7 was used. Depending on the properties of the substances and the process conditions, the following datasets were derived: mortality curves, equivalent concentrations, areas of flammability, thermal radiation from fireballs (fireball beams) and distance pressure curves. Thus for the primary hazard types were selected: toxic dispersion, fire, explosion, BLEVE (Boiling Liquid Expanding Vapor Explosion).

During the selection process of the scenarios the following factors were taken into account: type of hazard, substance, affected localities, total affected population, proximity to hazard, economic status, damage caused to infrastructure, recovery time, disruption of supply services, disruption of basic services, frequency. Some of these factors are divided into several components: Distance from residential area, is the site within the locality, distance from protected areas, surface affected, roads, buildings, bridges, energy sector, transport services and fuel supply, water and food, education, health care, telecommunications. Some of the criteria and sub-criteria evaluated are closely related to the critical infrastructures present within a city.

The “population” and the sub-criterion “proximity” were assigned scores using a scale from 1 to 5. The distance between the minimum and maximum values was classified in 5 domains in a linear fashion, and the real values were placed in scale, from which the scores were determined. For the sub-criteria "damage", "disruption of supply services" and "disruption of basic services" was assigned Yes/No. "Yes" means that the value 1 has been assigned to the criterion, while "No" means that the value 0 has been assigned to the criterion. The criterion "Recovery time" was assigned a score using a scale from 1 to 3. Recovery time "days" means that the criterion was assigned the value 1, "months" was assigned value 2 and "more than one year" was assigned the value 3. Usually, the higher the value, the greater the consequences. Each scenario was assigned a value, a score summing up the criteria scores, allowing the identification of the 5 most important scenarios for further evaluation.

As presented in the previous paragraph, not every criterion represents the same impact on the outcome of the scenario. "total population" and sub-criterion "proximity" could have a maximum value 5, "frequency" criterion could have a maximum value of 4, "recovery time" criterion could have a maximum value of 3, while another criterion could have a maximum value of 1. The above was necessary to give priority and to underline certain criteria. The criteria "total population" and "proximity" are the primary determinants of a scenario. "frequency" is the time factor that describes the appearance of the scenario over a long period of time. "recovery time" is the time factor that describes the scenario in a summary form. The sub-criteria "damage", "disruption of supply services" and "disruption of basic services" are best described as side effects of the initial event, therefore they were underweight.

For the most important scenarios it is necessary to carry out a detailed analysis of the vulnerability- as a major component in the risk formula along with the probability and consequences [15]. The vulnerability analysis is based on a set of social, economic and environmental indicators in accordance with the pillars of sustainable development [16].

Seismic effects can increase the risk of major accidents in chemical plants or other SEVESO-type sites. The applied method can estimate seismic failure frequencies specific to several types of storage tanks. The method is based on the convolution of location-specific seismic hazard curves and component dependent fragility curves. The fragility curve is calculated using the probit coefficients of origin in the analysis of the historical data of the earthquake damage.

3. Results

The first results, regarding the spatial distribution of SEVESO operators in relation to the big cities in Romania, show that out of the 301 operators 143 are in the limits or in the immediate vicinity of the cities with more than 50,000 inhabitants (Figure 1).

Following the identification of the scenarios and the application of the methodology, a number of 37 relevant accident scenarios were selected at national level, 84% of them being located within or near a big city.

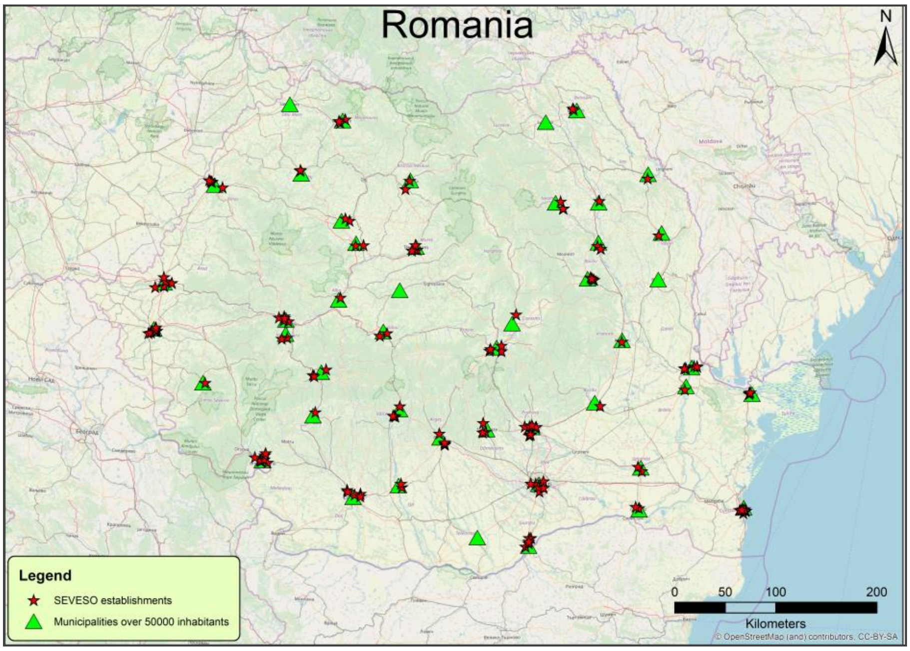

Fig. 1. Spatial distribution of SEVESO operators in relation to the big cities in Romania.

Following the classification of the 37 scenarios, the first five were selected for further analysis. In order to assess the vulnerability a set of sixteen indicators were selected [17]. Vulnerability analysis revealed that there is an average vulnerability for each case.

Since in one of the scenarios there are natural hazards that occur in the area of the SEVESO site, a multirisk analysis was performed. The determination of the seismic failure frequency for a pressurized storage tank was performed for the Râmnicu Vâlcea scenario, using a specific seismic hazard curve (Figure 2). The resulting value is 4.12E-3/year which is significant compared to the frequency of the baseline scenario. The frequency obtained represents a very conservative estimate of the frequency of failure of the chlorine tank triggered by earthquakes.

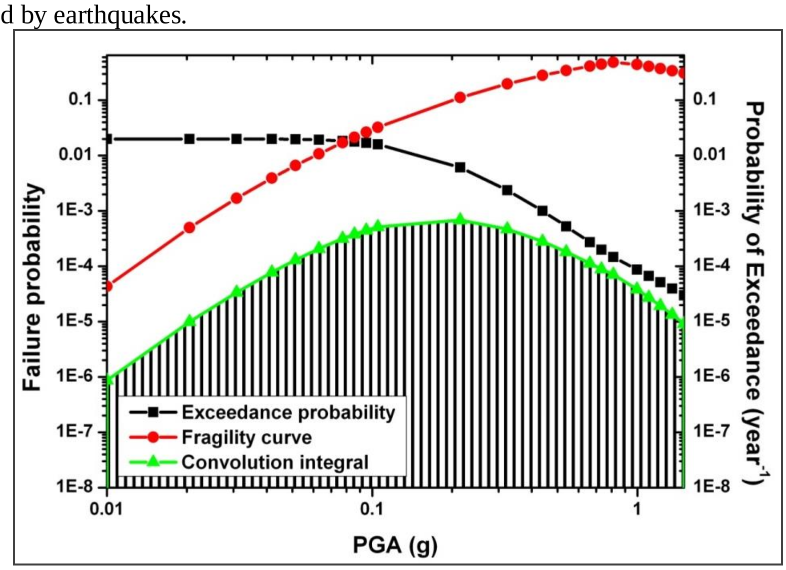

Fig. 2. Multirisk assessment for Râmnicu Vâlcea scenario
(Calculation of the convolution of a pressurized storage tank in the event of a catastrophic rupture using the values of the probability of failure).

4. Conclusions

The fact that in most of the big cities in Romania there are infrastructures that can produce major technological accidents clearly shows that urban resilience is closely linked to technological risks.

The findings of this paper can be useful tools in the planning process of disaster response and in the risk management process in the context of urban planning. The integration of vulnerability indicators offers the possibility of the decision-makers to have access to an overview of the real situation, at the level of the respective city, and to come up with strategic solutions and measures. In this way, the decision makers will be able to determine and evaluate the factors that can contribute to the urban resilience and will be able to compare the perceptions of each actor involved in the consortium for the prevention of the technological risk in urban environments.

In order to have access to integrated, useful and relevant knowledge and information, the need for cross-border partnerships with other cities exposed to the same risks and challenges in terms of urban security and resilience becomes mandatory in the context of globalizing risks to the security and safety of the citizen.

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References

[1] Perdicoulis A., *The city as a system*, SYSTEMS PLANNER, No 16, 1-6, ISSN: 2182-8091, 2013.
[2] Rinaldi S.M., Peerenboom J., *Identifying, understanding, and analyzing critical infrastructure interdependencies*, Control Systems, IEEE. 21. 11 - 25. 10.1109/37.969131, 2002.
[3] Radovici A., Roman E., Török Z., Ozunu A., *A risk assessment study for local critical infrastructures used in hazmat transportation*, STUDIA UBB CHEMIA, LXI, 3, Tom II, 2016, p. 379-389.
[4] Rehak, D., Novotny, P., *Bases for modelling the impacts of the critical infrastructure failure*, **53**, p. 91-96, 10.3303/CET1653016, 2016.
[5] Drebenstedt C., *Responsible mining approach for sustainable development - research concept and solutions*, J. Eng. Sciences and Innovation, **4**, 2, 2019, p. 197 - 218
[6] Bankoff G., Frerks G., Hilhorst D., *Mapping vulnerability: disasters, development, and people*, Earthscan, UK, 2004.
[7] Gheorghiu A.-D., Török Z., Ozunu A., Antonioni G., Cozzani V., *Natech Risk Analysis in the Context of Land Use Planning. Case Study: Petroleum Products Storage Tank Farm Next to a Residential Area.*, Chemical Engineering Transactions, **36**, 2014, p. 439-445.
[8] Thomalla F., Downing T., Spanger-Siegfried T., Han G., Rockström J., *Reducing hazard vulnerability: towards a common approach between disaster risk reduction and climate adaptation*, Overseas Development Institute, Published by Blackwell Publishing, Oxford, UK, **30**, 1, 2006, p. 39–48.
[9] Birkmann J., *Risk and vulnerability indicators at different scales: Applicability, usefulness and policy implications*, Environmental Hazards, **7**, 2007, p. 20–31.
[10] Sendai framework for disaster risk reduction 2015–2030. In: *UN world conference on disaster risk reduction*, 2015 March 14–18, Sendai, Japan. Geneva: United Nations Office for Disaster Risk Reduction; 2015, available at: https://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf, accessed 19.01.2021.
[11] UN office for Disaster Risk Reduction (UNDRR), *The TEN Essentials for Making Cities Resilient- An operational framework of Sendai Framework at local level*,2019, available at: https://www.unisdr.org/campaign/resilientcities/toolkit/article/the-ten-essentials-for-making-cities-resilient, accesed 19.01.2021.
[12] Alecu G., Kappel W., *Technology responsible for sustainable manufacturing*, J. Eng. Sciences and Innovation, **5**, 4, 2020, p. 353-362.
[13] Romanian General Inspectorate for Emergency Situations (GIES), *Methodology for risk assessment and integration of sectoral risk assessments*, 2016, available at: https://www.igsu.ro/documente/RO-RISK/Metodologia%20de%20evaluare%20unitara%20a%20riscurilor%20-%20versiune%20finala.pdf, accessed 20.08.2019.
[14] Romanian General Inspectorate for Emergency Situations (GIES), *National Risk Assessment – RO RISK Country Report*, 2016, available at: https://www.igsu.ro/documente/RO-RISK/Raport_Final_de_tara.pdf, accessed 20.08.2019.
[15] Ozunu A., Senzaconi F., Botezan C., Ştefănescu L., Nour E., Balcu C., *Investigations on natural hazards which trigger technological disasters in Romania*, Nat. Hazards Earth Syst. Sci., 11, doi:10.5194/nhess-11-1319-2011, 2011, p. 1319-1325.
[16] Adger W., Brooks N., Bentham G., Agnew M., Eriksen S., *New indicators of vulnerability and adaptive capacity*, Technical Report 7. Norwich: Tyndall Centre for climate Change Research, 2004.
[17] Ştefănescu L., Botezan C., Crăciun I., *Vulnerability analysis for two accident scenarios at an upper-tier seveso establishment in Romania*, Geographia Technica, **13**, 1, 2018, p. 109-118.