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A semi-quantitative methodology to evaluate the main local territorial risks and their interactions

E. Pilone*, M. Demichela

Politecnico di Torino, Torino, Italy

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ABSTRACT

The paper presents a semi-quantitative methodology at a local scale, developed to increase the efficacy of Land Use Planning related to the Management of risks, in particular as far as it concerns multiple risks impinging on the same territory (Multi-risks).

At the moment, each risk is managed through a dedicated sectorial plan, having its proper procedures and scale, and the only "meeting point" for these plans – at least in Italy - are the Municipal city plans. The Municipalities have to implement the contents related to the various risks and directly intervene on the territory, but the lack of linkage and coordination between the plans and the authorities in charge often makes the emergency management and LUP less effective towards the achievement of a real safety of territories. In addition, the actual legislative framework does not face the possible consequences of risk interactions.

In this context, the objective was to develop a simple risk pre-screening tool, expressly designed for local planners, able to point out the areas more exposed to risks and risks interactions, in order to better address the distribution of the municipal resources for further studies and interventions. The local planners that, especially in Italy, have a central role for the risk management of the territory, became the central point for the proposed framework, assuming the role of evaluators, and then decision-makers.

A semi-quantitative approach, based on an index scale from 0 to 3 onwards was developed for a direct use from Municipal technicians; the proposed scale is applied to measure both the impact of the risks and risk interaction. The methodology is composed by 4 steps: 1) characterization of the risks; 2) assignation of the ratings to the risks; 3) assessment of binary risk interactions; 4) assessment of the compatibility and planning phase. Each step is accompanied by GIS mapping.

The methodology was tested on two Italian case-studies, two Municipalities affected by multiple types of risks which could interact; the proposed approach demonstrated to be able in identifying and bring multi-risks aspects to the attention of the decision makers, constituting a guide to risk that can be integrated with the existing planning instruments to improve the quality of decisions related to risks.

1. Introduction

The research developed by the authors rose from previous experiences in the field of Major risks and Land Use Planning; in particular, it tried to deal with some difficulties and shortcomings emerged during the drafting of E.R.I.R. plans – Plans for a safe Land Use Planning of the areas around Major risk plants, made in cooperation with some Italian Municipalities.

The need to improve the safety of the Major plants through a detailed planning of their neighborhoods was introduced in Europe by the so-called Seveso II Directive 96/82/EC; each country then adopted different methodologies to harmonize the foreseen urban functions with the possible accidents related to the major risk plants. Italy implemented the European Seveso Directive with the Legislative Decree 334/1999; a dedicated Ministerial decree (D.M. 09/05/2001) was issued to define a method to establish safety distances and bindings around the plants. For this purpose, Italy adopted a hybrid method between the Consequence-based approach and the Risk-based approach employed in other European countries: 4 degrading damage zones, from the inner "high lethality" to the outer "reversible damage" zone, are estimated for each incidental scenario, together with their frequency of occurrence. On the basis of the zone and of the probability, the compatible urban functions are defined.

According to D.M. 09/05/2001, Local authorities (Municipalities) with a Seveso plant are in charge of the identification of the safety distances, through the draft of a dedicated plan called E.R.I.R. -

* Corresponding author.
E-mail address: eleonora.pilone@polito.it (E. Pilone).

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Elaborato per il Rischio di Incidente Rilevante (Technical Document for Major Risk Accidents), that contains analyses and protective provisions for the areas around Major risks plants.

Seveso III Directive, issued in 2012, and adopted in Italy with the Legislative decree 105/2015, did not modify the general framework for Land Use Planning related to major risks plants; however, Italy should have prepared new Guidelines to substitute D.M. 09/05/2001, that until now were not released (Pilone et al., 2017).

As highlighted in Camuncoli et al. (2013) and Demichela et al. (2014), D.M. 09/05/2001 provided detailed indication for the assessment of the compatibility of Seveso plants with the existing urban functions, but the relationship between industries and environmental vulnerabilities was treated in a superficial way. In fact, the Italian legislation only required to evaluate if the environmental damage could be "Relevant" or "Severe", on the basis of the years presumed for the recovery. In addition, neither the European legislation nor the Italian one deal with the possible mutual relationship of Major risks plants and environment: extreme natural events can deeply impact on the industries generating unforeseen consequences.

Despite the several methodologies developed, a specific regulation to analyze NaTech events (Technological hazards triggered by Natural events) was not adopted yet, even if climate change is bringing to an increased exposure of plants and other vulnerable elements to extreme events. The annual Reports released by IPCC on Climate change, and those of the European Environment Agency evidence that in Europe the frequency of flood events, windstorm, heatwaves is constantly growing.

Therefore, Land Use Planning related to Seveso plants should keep into account the mutual influence between industry and environment, assuming a different perspective more related to Multi-risk assessment; but this objective is complicated by the absence of recognized official methodologies for NaTech risk assessment and Multi-risk analysis, and in Italy, by the complex Land Use regulation framework.

In fact, in Italy each risk is managed through separate and dedicated sectorial plans (Galderisi et al., 2008); they are issued by different Planning Authorities and adopt different scales, and different methodologies for risk assessment. The contents of these plans are implemented by the City Plans and Municipal Emergency Plans, drafted by the Municipalities, that are responsible for the direct land management. Therefore, at the moment, the Municipalities are in frontline against Multi-risks, but they have no tools and methodologies to analyze the risks in a systemic way.

On the contrary, the management of risks in a separate way, with different procedures, timings, methodologies, makes it difficult for the Municipalities to have a clear and updated concept of the actual dangers that threaten their territories (in this regard, see Mileu (2018), Galderisi (2014)). As a consequence, the efficacy of risk management responses results affected by delays related to the time required for the drafting and implementation of the instruments, lack of economic / technical resources, etc.

Considering the above-mentioned difficulties, the objective of the research was to develop a new methodology expressly designed for the local scale, able to put together and analyze:

- The main risks on the Municipal territory
- The main environmental and territorial vulnerabilities
- The interaction between the risks and their impact.

The methodology was intended for the direct use by the Municipal technicians, and aimed at working as an all-inclusive "Rapid guide to risks": it immediately highlights the most threatened areas of the territory, in order to address here in-depth studies and interventions, and financial resources.

The application of the methodology implies the development of dedicated GIS maps, that show the overlapping of the different thematic layers (vulnerabilities and risks), identifying the main zones of possible risks interaction.

Since the research started from E.R.I.R. shortcomings and from the lack of specific indications related to the relationship Industry – Natural events, the entire development of the methodology maintained a strong connection with the E.R.I.R. planning procedures, and particularly focused on industrial risk and its implications.

2. State of the art (multi-risk and Na-Tech)

In recent years, a growing attention was dedicated by the scientific community to Multi-risk and NaTech risk assessment: many multi-risk approaches were proposed worldwide and at European level to properly deal with this challenge, with the aim of creating tools and procedures for an integrated risk-analysis. Some authors underlined the crucial role of dedicated land-use practices; Schmidt-Thomé and Klein (2011) considered land-use planning as a "useful tool to protect settlements from hazard impacts", while Cruz et al. (2004) wrote that common land use practices could represent an extremely effective method for reducing the risk of Na-Tech events (i.e., restriction on possible urban functions in high risk areas, relocation of exposed elements, or changes in land use).

According to Garcia-Aristizabal and Marzocchi (2011), the concept of "multi-risk" assumed different connotations, that led to the development of different methodologies for the assessment. The majority of the projects tended to interpret multi-risk as different sources of hazard that threaten the same exposed elements (with or without temporal coincidence); therefore, multi-risk assessment is seen as the assessment of different independent hazards that threat a common area or common exposed elements. More rarely, the projects consider that one hazardous event can trigger other hazardous events (cascade effects); therefore, they concentrate their efforts in trying to define the effects of these triggering, domino, or cascade effects.

- The first type of projects identifies different hazard sources in a given region of interest, and tries to homogenize them during the phase of hazard assessment, in order to make different risks comparable. This 'harmonization' process is generally conducted on the basis of the evaluation of hazards in probabilistic terms; or, more frequently, in a qualitative way, through indexes based on the frequency and / or intensity of the hazards (i.e. projects ESPON, ARMONIA). The final results are generally presented as single hazard maps, layers (in a GIS environment), aggregated maps (overlapping all the maps), and hazard curves (for each hazard), where it is plotted the probability (or return period) against the intensity measure of the hazard. Menoni et al. (2006) criticized the efficacy of this unique "multi-hazard score", stating that emergency managers and urban and regional planners mostly need to understand and face the specific problems provoked by hazards in a given context, trying to verify the expected damage and consequences triggered by natural hazards, also comparing the expenses needed to prevent this or that risk.
- The second methodological multi-risk approach, that considers interactions and/or triggering effects, is a more demanding process because of the complexity in managing the necessary input data, and in constructing the potential hazard 'chains'. Usually, these projects entail a mathematically rigorous approach to multi-risk assessment, aimed at quantitively calculate the probabilities of risk interaction. Even if they apparently seem the most reliable methods, uncertainties and other shortcomings can severely affect them. Some of the major criticalities of the quantitative risk assessment methodologies were punctually highlighted by Garcia-Aristizabal and Marzocchi (2011), like i.e. 1) fragility curves derived by intensity of the hazardous event vs. typology of exposed elements not available for many risks analyzed; 2) difficult definition of a common metric for assessment of loss, and the weighting of the different categories of exposed elements. As a consequence, even when well-structured theoretical frameworks are defined, their application to real cases