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Local Multi-risk Screening: the Application of a Semi-Quantitative Methodology on an Italian Case-study

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The paper presents a semi-quantitative methodology developed to help Italian local authorities in facing multi-risk aspects inside their Land Use Planning practices. The methodology acts as a pre-screening of natural and industrial risks and their possible interactions, with the aim of better addressing the possible LUP interventions to increase the safety. A quick overview of the methodology is provided, together with a significant Italian case study: a small town affected by both industrial and flood hazard, caused by 'minor elements' not sufficiently analyzed in the sectorial risk plans. The proposed methodology was applied to operate an overall analysis of the risks on the Municipal territory, in order to evidence possible interactions enhancing the dangerousness for the vulnerable elements. The last step of the methodology was to signal further studies and interventions to address critical situations; a dedicated questionnaire was developed to examine in depth the predisposition of industrial plants to cause NaTech events.

1. Introduction

Land Use Planning (LUP) procedures improve and program the use of territories, therefore they have to deal with several types of risks: natural (flood, earthquake, etc.) and anthropic. Each risk is usually managed through its proper sectorial plan, but the multiplication of tools dealing with risks (City plans, Emergency plans, supra-local plans), with different scales and levels, can produce failures in the risk management. In addition, climate change is deeply influencing the expected return times of extreme events. In spite of this increasingly challenging situation, currently no plans and legislation allow to analyse multi-risks in an integrated way; therefore, the consequences of extreme events are rarely examined and traduced in proper actions inside the LUP practices.The lack of integration between risk plans and the non-consideration of risk interactions, summed up to the increasing effects of climate changes, already brought to several disasters (i.e., for Italy, the repeated floods in Geneva, caused by a creek whose dangerousness was well known but not adequately represented in the Municipal emergency plan and City plan, or the Rigopiano hotel tragedy, where an avalanche caused by an earth shake invested an hotel built in an area where constructions should not have been permitted). As far as it concerns Italy, the Municipalities result particularly affected by the problem of an inadequate risk management: even if they are asked to directly intervene on the territory with their City plans, which collect and apply the provisions of the sectorial risk plans, they usually have not the right expertise and financial resources to apply an integrated analysis of risks; they barely deal with emergency, resulting in front line towards any unexpected event.In order to help the Municipalities in dealing with risks in a more efficient way, a semi-quantitative methodology at local scale was settled: it acts as a pre-screening framework for a rapid identification of the areas more exposed to risks and their possible interactions, aiming at better addressing further studies, resources and planning actions. The methodology is here explained through the presentation of an Italian case study: its main tips are briefly summarized in the following Paragraph 2, but an in-depth explanation can be found in a previous CET paper (Pilone et al, 2017).

2. Proposed methodology

The development of the proposed methodology started from a detailed analysis of ERIR, the Plan for the safe LUP around Seveso plants, that in Italy is mandatory for the Municipalities with a Seveso plant inside their

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territory (Camuncoli et al, 2013) (Camuncoli et al, 2012). While ERIR only considers Industrial risk, the objective of the proposed methodology was the identification of the impact of several territorial risks and of their possible interactions; in order to reach this purpose, given the difficulties in the harmonization of different procedures and methods, the probabilistic approach to risks was abandoned in favour of a semi-quantitative rating scale. The scale measures the impact both of risks and risk interactions, going from 0 to 3 onwards:
0 < I ≤ 0.99: Negligible; 1 < I ≤ 1.99: from Low to Moderate; 2 < I ≤ 2.99: from Moderate to High; I ≥ 3 onwards: from High to very high.
The adoption of the scale answered an important objective of the methodology, that means its direct usability by the Municipality technicians. The main steps of the methodology are reported below.

2.1 Risk characterization

The most relevant territorial risks are identified and described on the basis of three Macro-categories, that express peculiar aspects of the risk analyzed and determine its impact:
1) HE Historical and recent events: recurrence of the risk events analyzed;
2) PM Protection measures: protection and preventive measures that could reduce the impact of the risk; this macro-category assumes negative values because it contributes in reducing the impact of the analysed risk.
3) SE Strengthening effects: Local characteristics increasing the risk effects. Intrinsic factors of the risk, sometimes neglected in the sectorial plans, have to be taken into account because they could enhance the final risk impact: i.e., for earthquakes, the quality of the soil; for floods, the section reductions and flow obstructions, for Seveso industries, the quantity and type of substances detained and type of items etc.
The macro-categories are rated in accordance to the local variations of the risk, in compliance with the scale above-mentioned. A dedicated guideline was developed to help the Municipality technicians in this procedure; at the moment, the guide is related to the most diffused risks in Italy and in Europe: industrial, flood and seismic risks (see Pilone et al., 2017).

2.2 Risk interaction

The macro-categories are the basic elements that allow to assess the impact of possible risk interactions, because they accurately describe each risk and its possible impact and therefore can provide an esteem of the interaction effects. However, the Macro-categories have different reliability in terms of available data and capacity to influence the final interaction value, therefore specific weights were introduced to keep into account these aspects: HE - Historical events = 2, SE – Strengthening effects = 1, PM Protection measures = 0,5. The assigned weights were validated through expert judgement.

The interaction value, intended as the impact of one risk on another one, is assessed in accordance to Eq(1). When two risks (R1 and R2) are superimposed, the ratings assigned to their macro-categories HE, SE and PM in that determined point of the territory are summed up through an average sum. To each sum, the specific weight of the macro-category is applied.

$$I = \; [(HE_{R1} + HE_{R2}) * 2 + (SE_{R1} + SE_{R2}) * 1 + (PM_{R1} + PM_{R2}) * 0.5] \; / \; 6 \qquad (1)$$

2.3 Risk compatibility and planning

In order to settle the activities of in-depth studies and ad-hoc interventions, it is necessary to assess the compatibility of interactions and risks with the territorial and environmental vulnerabilities (identified according to the legislation for ERIR, Ministerial Decree 09/05/2001). An alert threshold to evaluate the compatibility was established, adopting a value of 2.5, corresponding to a medium-high impact (see the scale reported in Par. 2). This threshold, validated through experts' judge, works as an alert signal for the Municipalities: if relevant or extreme vulnerable elements are included in areas where the threshold is overcome, they are potentially at risk. Therefore, the Municipality shall conduct further studies and investigations to verify the situation and adopt opportune planning measures.

3. Application on a case study

The proposed methodology was tested and employed on an Italian case study, a little Municipality interested by flood and industrial risks provoked by "minor sources", not adequately considered in the sectorial planning. The aim of the application was to point out possible unforeseen effects of the interactions, providing at the same time a more complete and exhaustive description of the risks on the territory, to improve the quality of the protection measures adopted by the town.The town raises on a flat land crossed by several artificial channels, used in the past for irrigation purposes; during the last 50 years, urbanization and industrialization completely altered the original functioning of the channels, that were abandoned or undergrounded. In 1994, 2000 and 2008, the artificial channels, together with the natural creek in the northern part of the Municipal territory, were responsible of extensive floods; the water height reached 80-100 cm. The flooded areas were mapped in detail by (Regione Piemonte, 1998) and (Provincia di Torino, 2009). In 2016, the new Plan for Flood management (AD.B.Po, 2016) was adopted, to redefine flooded areas and return times in compliance with the EU directive 2007/60/CE; however, it neglected the secondary water network and only reported the areas flooded by the creek. Furthermore, the return times assigned by (AD.B.Po, 2016) to the creek are not completely in line with the recurrence of the flood events in the last 30 years, as demonstrated by (Politecnico di Torino, 2009). In addition to the flood hazard, the town object of study is interested by industrial risk, because of the presence of a Seveso plant, a former plating factory, whose closure in safe conditions could never be proved. ERIR plan was drafted, including in the analysis the so-called Seveso Sub-threshold plants (detaining the 20% of the hazardous sub-stances necessaries to be classified as Under-tier Seveso plant) and all the potential hazardous activities. Thanks to this further investigation, a potential Seveso plant, not signalled by the Authorities in charge, was identified. The hazardous plants are located close to the water network; they were repeatedly interested by flooding, even if there are no testimonies on the consequences of these events. The methodology was applied in these areas of interaction.

3.1 Risk characterization

FLOOD: In order to correctly express the rating assignation, rivers and creeks have to be considered as sum of different portions connoted by homogenous characteristics and behavior. For the case study, the creek was considered as a unique homogenous portion, due to the fact that Politecnico di Torino (2009) identified it as a sub-basin uniformly connoted by small slopes of the riversides and river course. The secondary water network was considered as a unique element too, because of the complexity of the interactions and interdependencies between the canals. Table 1 shows the rating attributed to the macro-categories of the two elements responsible of the municipal flood risk. For the areas interested by medium-low flood hazard according to (AD.B.Po, 2016), HE ratings correspondent to a higher impact (medium = 2) were assigned; in fact, as already evidenced, the return times of the recent flood events were higher than those defined by the flood plan of (AD.B.Po, 2016) .

Table 1: Rating assignation for flood risk

SE		PM	HE
Interaction with other elements	Criticalities of the artefacts, sections	Hydraulic artefacts, levees etc.	Recurrence
Creek			
Possibilities of inverted flow from the creek to the tributaries or upstream	5 critical sections producing hydric insufficiencies were identified in correspondence of bridges	2 areas for flood expansion and a stone riverbank were planned; only the last was realized, after the flood in 2000.	2 zones: Extreme flood hazard Ee (20-50 yrs), Medium-low flood hazard Em (300-500 yrs). Floods in Em more frequent than the assigned Return time, water height 1 m.
3		0	Ee 3 Em2
Secondary water network			
Water intakes cannot be regulated; The creek can feed the channels network during flood events	Reduced slope of soil and canals, scarce maintenance, obstructions, inadequate crossing artefacts; covered portions, diversions.	5 floodway channels were planned to return the exceeding flows to a major river, but no interventions were executed.	No flood buffer zones and return times assigned. Recurrent overflowing in 1994, 2000 e 2008. Water height between 30-80 cm.
3		0	2

INDUSTRY: The ratings for the plants identified were assigned on the basis of a questionnaire compiled by the owners; however, essential information related to case history, storage conditions and preventive and protection measures were missing for all the plants. Google Maps and Google Streetview allowed to verify the presence of items exposed to NaTech risk, waterproof aprons, etc., but no alternative sources of information were available to correctly rate the macro-category HE Historical Events. Table 2 shows the rating assignation to the macro-categories of each industrial plant; a common indicative value was assumed for HE (1.5, corresponding to a low-medium impact), in case the plant had been involved by past flood events.

Table 2: Rating assignation for industrial risk

SE		PM	HE
Items	Substance	General, NaTech, pollution	Recurrence
Plant ‘X’ Seveso			
10 plating basins	(T, N)	The plant did not adopt the recommended measures and was closed. Measures for environmental protection not adopted NATECH: information not available	No information. Plant included in (Em) buffer zone.
3.5 t storage barrels	(T, N)		
Other SE elements: plant closed under unsafe conditions			
3		0	1.5
Plant ‘Z’ potential Seveso			
Tank, 27 t	Phenol (T)	Plant subjected to AIA; Collection system for accidental spills; different drainage lines for rainy and process water; emergency basin. NATECH: Information n.a.	No information on the plant accidents are available. The plant was repeatedly interest by the flooding of the adjacent canal
Tank, 50 t	Formaldehyde 24% (T)		
Tanks, 52 t	(F, N)		
Bags, 22 t	(F)		
Other SE elements: Plant not compliant with Seveso rules			
2.8		-1.8	1.5

3.2 Risk interaction

The risks for the case-study are generated by little lower-tier Seveso plants and low energy flood events, but their interaction could produce unexpected and severe conditions for people and environment, because of the lack of adequate protection and prevention measures. In order to verify possible consequences, Eq(1) was applied to each area where flood areas and plants overlay, through dedicate Binary Interactions tables (Table 3). They report the ratings attributed to the risks in a specific point of the territory (in this case, the areas of plants ‘X’, and ‘Z’, reported in Figure 1) and allow to repeatedly apply Eq(1).

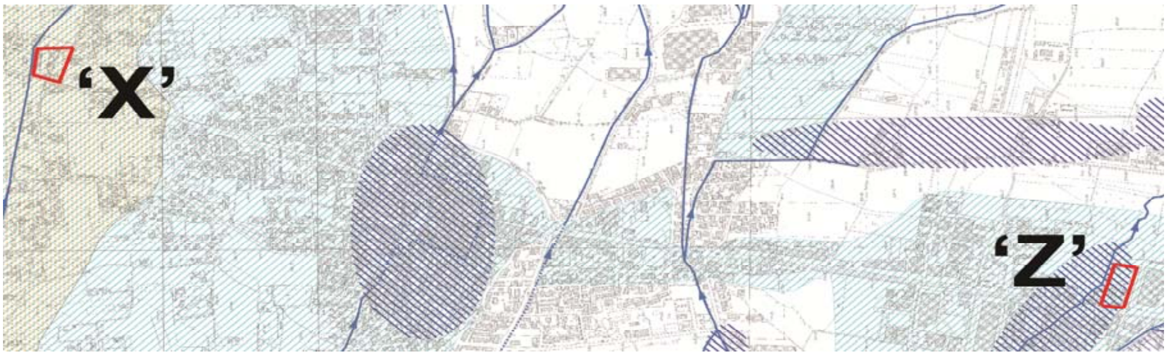

Figure 1: Areas of superimposition of flood risk and industrial risk (Plants X and Z)

Table 3: Interaction tables for the areas of plants ‘X’ and ‘Z’

Plant ‘X’			Flood risk F			Industrial risk I		
			SE	HE	PM	SE	HE	PM
			3	2	0	3	1.5	0
F	SE	3	No interaction				2.17	
	HE	2						
	PM	0						
I	SE	3	No interaction				-	
	HE	1.5						
	PM	0						

Plant ‘Z’			Flood risk F			Industrial risk I		
			SE	HE	PM	SE	HE	PM
			3	2	0	2.8	1.5	-1.8
F	SE	3	No interaction				1.98	
	HE	2						
	PM	0						
I	SE	2.8	No interaction				-	
	HE	1.5						
	PM	-1.8						

3.3 Compatibility assessment

Vulnerable elements were investigated according to the requests of Ministerial Decree 09/05/2001 and regional legislation for ERIR. The major criticalities were found in relation to Environmental vulnerability, because of the scarce depth of the aquifer (0-3 meters) and high quality of the soils for agricultural purposes.
The compatibility was tested in the areas of risk interactions (flood → industry), creating a buffer zone of 500 m. around each plant, in which the values of the Industrial macro-categories and of F/I interaction were projected. The condition of compatibility can be considered satisfied if no A and B vulnerable elements are included in buffer zones where H.E., S.E. or Interaction values are higher than 2.5. The threshold of 2.5. is also adopted for environmental vulnerability, but the specific relation between the threat and the environmental vulnerable element has to be investigated (not all the elements are equally sensitive to risks). The environmental vulnerable elements identified for the case study were sensitive both to Industrial risk and its combined effects with flood. The assessment of territorial and environmental compatibility for each plant is reported in Table 4.

Table 4: Compatibility assessment in the areas of plants 'X' and 'Z'

Territorial compatibility	Environmental compatibility
PLANT 'X'	
No manifest incompatibility because of low people density, but the state of abandon represents a potential threat for the territorial elements, particularly in case of flood events (medium value of interaction). Further analysis should be carried out, in particular to verify the state and filling of the containment basins.	Potential incompatibility due to the presence of environmental elements particularly sensitive to pollution. Flood events, even with low energy, could cause unexpected consequences of spreading and diffusion of pollutants towards the underground water and superficial water. No prevention and protective measures for the environment. An onsite visit is recommended to verify the actual conditions of the plant.
PLANT 'Z'	
Potential incompatibility: two punctual elements classified as B. An in-depth analysis is recommended for: 1) specific activities of the vulnerable elements; 2) storage methods and protection and preventive measures of the substances classified as toxic (H2)	Potential incompatibility: SE = 2.8 overcomes the compatibility threshold; the interaction with flood events, even if connoted by a low-medium value (1.98), could enhance the threat. Further analysis on the possible pollution scenarios and prevention and protective measures against flood should be carried out.

Table 5: Compatibility assessment in the areas of plants 'X' and 'Z'

A. STORAGE CONDITIONS & NA-TECH ITEMS				
1) Storage conditions:				
Substance	Container type	No. of containers & capacity	Position	Containment measures
2) Items vulnerable to NaTech events:				
Underground pipelines, pipelines passing on not-waterproofed soil Description (length, width, substance transported, protection measure)				
Long and slim structures (torches, chimneys, cooling and distillation towers etc.) Description of the structure and its function:				
Open-air water treatment basin / liquid waste storage. Description of the installation and related preventive measures				
B. CASE HISTORY				
3) List of the accidents occurred in the last 20 years that have provoked release of hazardous materials				
Date	Item interested	Accident description		
4) Eventual damages provoked by: flood events, extreme climate events, earthquake.				
Date	Item interested	Accident description		
C. ENVIRONMENTAL ANALYSIS (Provincia di Torino, 2010)				
5) Vulnerability analysis of the conditions of water and soil around their plants:				
Depth and the direction of the phreatic aquifer nearby the plant, in a sector with 30° degrees of amplitude and 3 kilometres of extension, measured from the possible point of release in the direction of the aquifer flow;				
Presence of wells inside the same sector, within an extension of 500 metres				
Presence of drains in superficial creeks or canals.				

3.4 Results and planning step

The application of the methodology to the case study demonstrated that the simultaneous presence of Industrial and Flood risk can produce unexpected interactions, connoted by low-medium impacts (plant 'X' area = 2.17, plant 'Z' area = 1.98), which are reasonably in line with the verified low energy of the flood events (water height between 30-80 cm). The Interaction values do not overcome the alert threshold of 2.5, however the plants analyzed are subjected to a potential incompatibility related to their Industrial macro-category SE. HE received low ratings only as a consequence of the unavailability of data.
The overcoming of the 2.5 threshold signals that further investigations are needed, in order to: 1) confirm or not the incompatibility; 2) plan possible LUP actions, taking into account the actual conditions of the plants and their possible interactions. A detailed questionnaire, reported in Table 5, was proposed by the authors to verify the compatibility for industrial plants: it investigates those aspects of the industrial organization which could have repercussions in terms of dangerousness and NaTech events.

4. Conclusions

The application of the proposed methodology to the case study quickly identified the areas more exposed to risk, returning feasible results in terms of possible risk interaction impact, in line with the initial risk values. The risk pre-screening allows to take into ac-count in an integrate way the risks information contained in the various sectorial plans, and at the same time, the Municipality technicians can employ their direct and enriched knowledge of the Municipal territory. Therefore, the methodology can create an in-creased awareness about risks and a correct risk and LUP management.
Many possible developments and further steps could be carried out: the proposed framework, till now elaborated for 3 risks (Industrial, Flood and seismic), can be extended to more territorial threats and the methodology could be exported to other countries simply adapting the criteria for rating assignation. The authors are currently working on the development of participative practices to facilitate the approach of the technicians to the methodology, and some contacts are in course with Municipalities to directly experiment the proposed approach.

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