ICUR2022
2nd International Conference on Urban Risks
LISBON 23-25 JUNE

Multi-risk mitigation in art cities

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Abstract: This contribution describes a multi-risk mitigation framework for art cities. The workflow considers two different hazard sources i.e., floods and earthquakes. The procedure conceives a coherent path for geospatial data analysis and mapping. The different risks are treated separately and later combined by a unified exposure modelling. The multi-risk is defined in terms of direct economic losses through the Average Annual Loss of the assets. The methodology is applied to a portion of the historical centre of Florence, which is listed a UNESCO World Heritage site because of the integrity, authenticity, and outstanding value. The current state leads to multi-risk losses of the order of 3.15 M€/year. The study provides insights regarding the mutual interactions within the two risks, pointing out the influence of the historical evolution and the urbanization process shaping the multi-risk. The effectiveness of mitigation strategies is then discussed in terms of risk reduction of the historical centre, highlighting the differences within the different hazard sources.

Keywords: multi-risk, multi-vulnerability, art cities, risk management, urban scale

1. Introduction

Art cities represent outstanding values for contemporary societies. Beyond the human actions that may endanger their development, natural risks threaten their preservation. According to the Sendai Framework, the disaster risk reduction passes through the understanding of the risks affecting the assets, hence encouraging the risk assessments of existing contexts (UNDRR, 2015). Multi-risk analysis of urban areas and existing contexts are still scarce, especially for historical cities (Julià & Ferreira 2021). The applications are generally referred to wide territorial areas where the cascading effects of the hazards are accounted (Garcia-Aristizabal et al. 2015). Few contributions are available regarding the art cities, historical realities characterized by high-exposed values and complex urban clusters. In this paper a methodological framework for the multi-risk assessment of art cities is presented. The procedure is applied to the central portion of the historical centre of Florence, a rectangular area characterized by urban aggregates built during the centuries over a Roman layout. The outcomes of the research offer new insights in multi-risk perspectives of how the historical evolution and the architectural features of the urban cluster shape mutually the two risks.

2. Multi-risk workflow

In Fig. 1 the multi-risk workflow is presented. Although the methodological application regards only two risks, the procedure is extendable to *n* risk sources affecting the historical cities. The sources have been treated as independent phenomena from a probabilistic point of view. The three different risk components have been investigated separately. The available probabilistic hazard maps for different return periods have been considered. The vulnerability has been investigated according to methodologies available in literature (Giovinazzi and Lagomarsino 2004, Arrighi et al. 2018). Finally, the exposure of the assets, accounted in terms of economic value represented the unifying layer of the method. The multi-risk efforts have been collected

in terms of spatial correlation analysis and spatial joint probability analysis, then, the multi-risk is defined in terms of average annual loss (AAL). The analysis is finally addressed in resilience perspective, involving the impact of mitigation strategies in terms of economic costs and AALs.

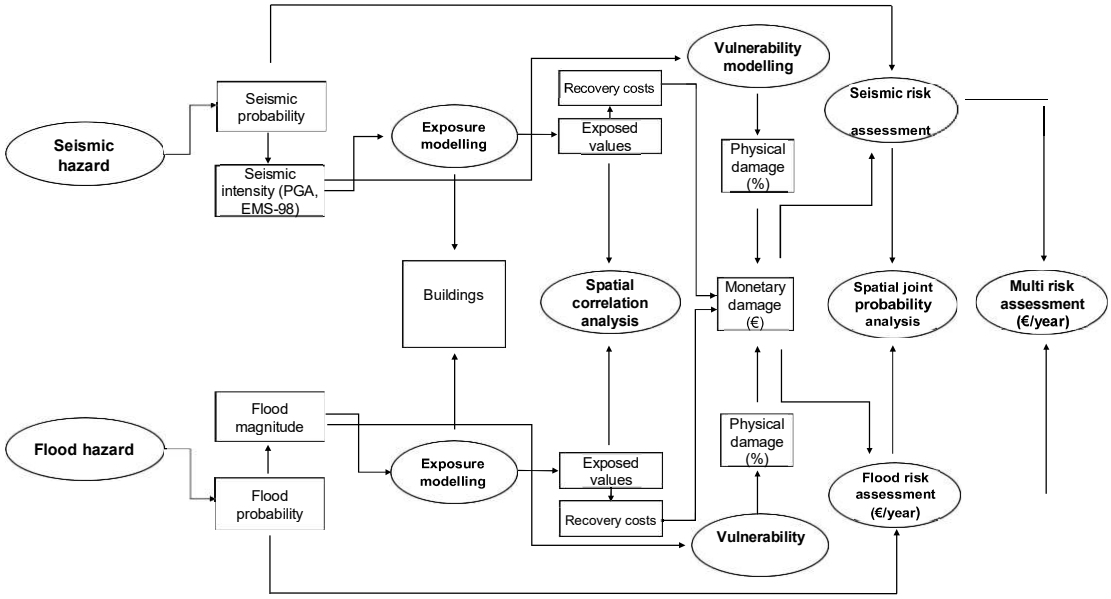


Figure 1 – The multi-risk workflow adopted in the work (adapted from Arrighi et al. 2022).

The workflow took advantage of a building-based GIS database where the information has been collected at the scale of the structural units. Multi-hazard information was assigned to the cartographic building data. Then, the vulnerability of each unit was evaluated through damage models and expert judgement, determining the corresponding physical damage. The integral of the loss-frequency curves has been computed for the single risks in terms of €/year. The flood damage model has been validated on the basis of flood experiences in the Italian contexts; the seismic recovery costs have been validated from the L'Aquila earthquake event (Cosenza et al. 2018). In the procedure the monumental buildings (e.g., churches) have not been considered, due to the exceptionability of the cases in terms of vulnerability and exposure.

3. Application and results

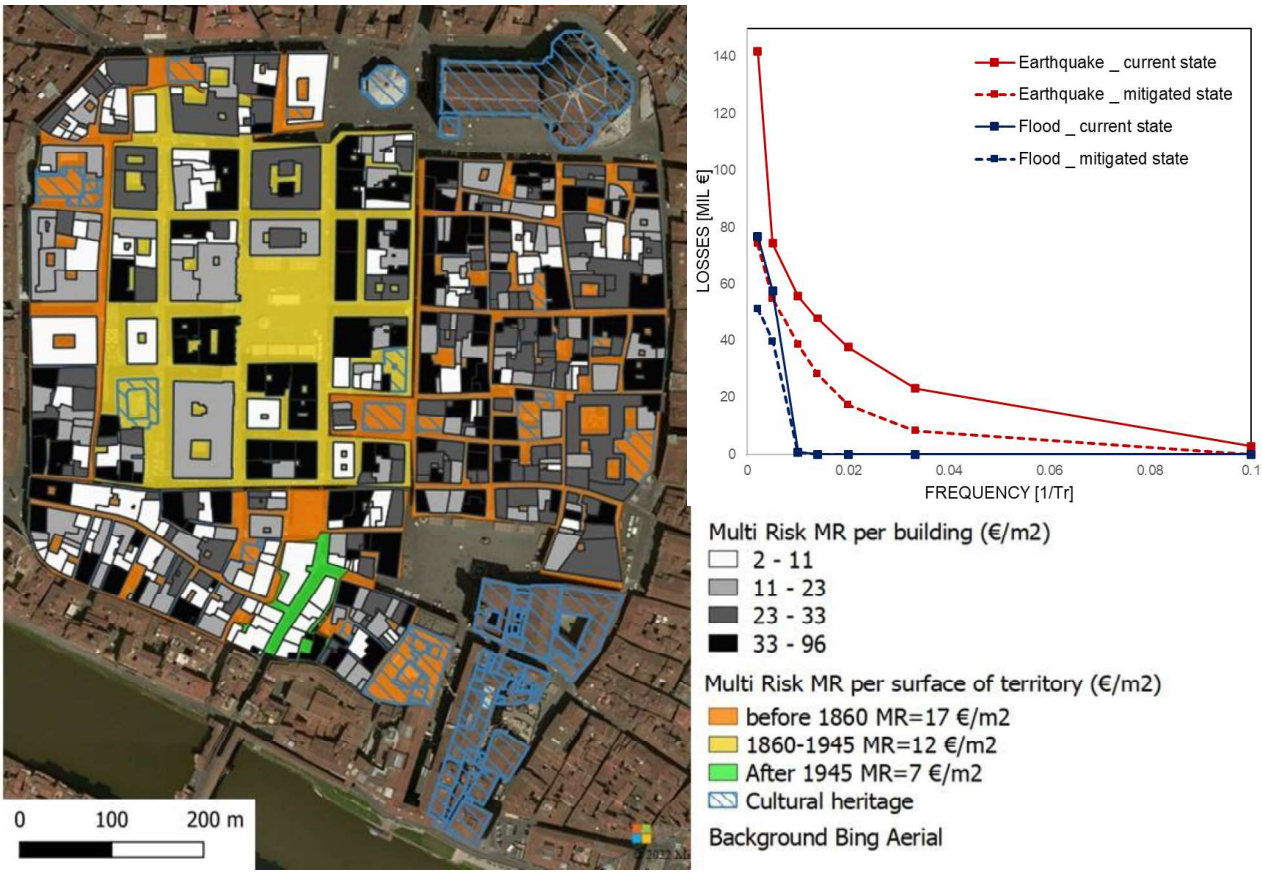
The procedure has been applied to the central portion of the historical centre of Florence (ca. 0.3 km^2). The latter is recognized as UNESCO World Heritage site since 1982 and it is characterized by a urbanized area whose settlements are dated back the Roman age (Arrighi et al. 2022). The urban stock can be divided in three distinct portions: the urban cluster built in the XIX century (1865-1945) after the demolitions of part of the medieval historical centre after the period that Florence become Capital of Italy; the reconstructed stock made by reinforced concrete structures realized after the WWII bombing; the rest of the urbanization, mostly erected in the Medieval period along the centuries.

3.1 Multi-risk analysis: current state

The multi-risk analysis pointed out a significant multi-risk of the assets, of the order of 3.15 M€/year (Fig 2). The latter is mostly driven by the seismic component, which covers over the 80% of the total economic losses. This is ascribable at the exposure of the considered risks; namely, the flood exposure involves the footprint area of the buildings for the basement and the ground floor, while the seismic exposure considers all the levels above the ground. Considering the two risks separately, the flood risk is ruled by the altimetric elevation of the soil, which determines a higher risk in the medieval portion located in the eastern position. The seismic risk results more diffuse along the area. In fact, while the hazard of the area is homogenous,

exposure and vulnerability tend to balance the effects within the different areas. Although the XIX century area has less vulnerable structures (due to structural regularities and workmanlike manners) the high dimensions of the constructions increase their exposure. Yet, the medieval area, because of the more clustered aggregations points out more variable structures with higher vulnerabilities.

Figure 2 – Multi risk for the current state (left panel). Frequency-loss curves for the two hazards for the current and the mitigated state (right panel)



3.1 Multi-risk analysis: mitigation perspectives

An analysis of the possible mitigation strategies has been finally carried out. In terms of the risk reduction, the vulnerability is the component where is possible to intervene. Although prevention measures developed at wider scale would still be beneficial towards the flood risk (e.g., retention basins) in this work only mitigation proposal have been discussed. In a multi-risk perspective, an optimal mitigation strategy would be targeted at reducing simultaneously multiple hazard sources. However, the multi-risk investigation showed how the parameters influencing the different risks are independent and unrelated, except for exposure values. Hence, mitigation scenarios have been simulated for each single hazard. Since the contribution deals with art cities recognized as cultural heritage, the effectiveness of the interventions should be evaluated also in terms of compatibility/reversibility of the proposal. For this reason, punctual and removable solutions have been evaluated for both hazard sources. Considering the seismic risk, the selected strategies have been chosen within local interventions such as punctual strengthening, insertion ofsteel tie rods, connections of the roofs, etc. For the flood risk reduction, waterproofing strategies for the basement have been accounted (installation of backflow valves, flood gates or barriers on the basement's windows). The mitigated scenario was evaluated by modifying the hazard-specific vulnerability models. The results of the risk mitigation highlight a reduction of the direct economic losses to 1.55 M€/year, with 1.2 M€/year given by the earthquake risk and 0.35 M€/year for floods (Table 2).

Table 2 – Multi-hazard scenario losses for different probabilistic scenarios for the current and the mitigated state

	Monetary losses, current state [M€]		Monetary losses, mitigated state [M€]	
Event probability (return period)	Floods [M€]	Earthquake [M€]	Floods [M€]	Earthquake [M€]
High (10-50)	0.00	2.75-37.53	0.00	0-17.21
Medium (75-100)	0-0.73	47.89-55.89	0-0.59	28.03-38.60
Low (200-500)	57.72-76.87	74-47-142.01	39.61-51.41	55-74.29

4. Conclusions

In this work a multi-risk workflow for the assessment of art cities was presented. The methodology considers two different hazard sources statistical independent for both occurrence and effects. The procedure has been applied to a UNESCO World Heritage site, a portion of the city centre of Florence. The outcome of the work points out interesting results. Although the two hazards are uncorrelated the urban stock of the historical city points out multi-risk relations, driven by the urban evolution of the different areas. Further studies will regard the extension of the procedure to the entire city centre, the implementation of the monumental buildings in the assessment as the account of indirect economic costs (e.g., the tourism's economic losses).

Acknowledgments

This work was supported by the Italian Ministry of Education, University and Research within the PRIN funding programme 2015 WELAX9.

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