Territorial Resilience towards Healthy and Safety Workplaces

An Analysis of the Enterprises' Exposure to Earthquake and Landslides in Fragile Central Italy

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A healthy working environment is not enough if it is unsafe against natural hazards. The paper is an exposition of the research Re-scale (2020-21), and it focuses on earthquakes and landslides to assess the enterprises' exposure in Central Italy through a spatial analysis of companies' locations and multi-hazard conditions. The goal is twofold: i) to increase risk awareness by disseminating information about hazardous situations in which enterprises operate; ii) to arrange a working method to develop preventive planning that reduces disaster risk and increases the resilience

Introduction

In the 2030 Agenda for Sustainable Development, the United Nations Organization expresses a clear judgment on the current urban development. It is unsustainable from an environmental, economic, social and cultural point of view. In particular, Goal 11 aims to "make cities and communities safe, inclusive, resilient and sustainable", in the awareness that the environment surrounding inhabitants and workers can drastically affect habits and lifestyles. In this perspective, urban planning can promote both healthier behaviours and the safety of living and working environments despite the unpredictability of risks. The business performance is an essential parameter for assessing the sustainability of urban development. Despite this approaching sustainability, it is often pointed out that industries negatively affect the environment due to greenhouse gas emis-

of fragile territories. The study is relevant for recognizing which economic sectors are most exposed to earthquakes and landslides. For each economic sector (e.g., agriculture, manufacturing, commerce, real estate), the analysis highlights the exposure of working capital, human capital, and fixed capital (goods, buildings, and equipment). The analysis method and results can help support decisions in risk management, towards preventive planning: a way of planning that prioritises action to increase the resilience and security of the territory in peacetime, limiting the interruption of economic activities. The latter represents a high stress factor for workers' health.

sions and pollutions produced as well as major industrial accidents. More rarely, it is analysed how the environment, and in particular natural and climatic hazards, influence the production system and its liveliness in the economic system. The paper deepens the research *Re-scale. Multi-scale project for resilient cities and regions. Planning and design guidelines for natural disasters prevention, and adaptive capacity development* developed in 2020-2021 at Politecnico di Milano[1]. The paper investigates the relationship between companies and natural risks, supporting the idea that a workplace that is safe from natural risks helps to support business continuity and improve the well-being of workers and people.

State of the art

The concomitance of risks should not be underestimated in the contemporary era. Epidemiological, technological, and natural hazards that occurred in Europe during the last decades showed an increased vulnerability of built-infrastructures and economy (Caverzan & Solomos, 2014). The health emergency, likewise the climate emergency, is one of the many crises of the Anthropocene, in which people's health has been correlated with the quality of the living and working environment, emphasising the general "systemic unsustainability" of globalisation (Bruyninckx, 2021). However, it should be noted that in some cases health risk (such as Covid-19 pandemic) has been an aggravation of the current territorial fragilities: from socio-economic to environmental ones (De Rossi, 2018; Coppola *et al*., 2021). The well-being of people (inhabitants, tourists, workers) is not measured only in terms of healthy places but also in terms of the safety of domestic, urban and workplace spaces. In particular, health and safety are two goals

increasingly pursued to lessen the political, economic, financial uncertainty (Taleb 2007, 2012) and multifactorial risk (environmental, climatic, territorial, and health). A healthy living and working environments (free of barriers for workers' psycho-physical well-being) is not enough if those spaces are unsafe against natural hazards that can interrupt the economic support to families.

In this perspective, preventive planning against natural hazards can improve people's health, both directly (by creating ecologically sustainable environments) and indirectly (by stimulating the creation of energetically sustainable, more comfortable, safer workplaces). Moreover, the awareness improvement against risk are essential for reducing entrepreneurs/workers' physical and mental stress, who should not have to live with the fear of losing their firms and their jobs. The business continuity contributes to the well-being of workers. For instance, first the Covid-19 pandemic and later the energy crisis due to the Russian-Ukrainian conflicts have generated an unprecedented economic crisis, that is hitting many companies. This crisis is having repercussions on the psycho-physical health of entrepreneurs and workers due to the risk of closure that companies may have to undergo or recover from these shocks (Aa.Vv., 2015).

All business activities involve risks (financial, reputational and image, strategic, technical, and operational), and a company's success (of any sector and size) is based on risk management. Managing risk means limiting business interruption and recovering it when a disaster occurs (Cerullo & Cerullo, 2002). This is why it is important to safeguard both the health of workers in the workplace and the survival of enterprises from the ongoing crises. To safeguard enterprises, all territorial actors should respond in a coordinated manner to foster the development of a 'risk management' culture namely to create a culture of risk-informed decision-making, to transform behaviours and to ultimately increase the resilience of societies and economic systems (Montoli, 2008; Insurance Connect Editorial, 2015). It involves supporting and affirming a systemic and comprehensive approach to risk prevention based on multiple cooperation between public administrations, communities, and businesses (UN, 2015). The goal is not only to respond to emergencies in a timely and effective manner. Instead, to enhance the knowledge of territorial fragility (hazard, vulnerability and exposure) and increase the resilience of businesses.

Exposure reduction should be applied where it is impossible or insufficient to reduce hazard and vulnerability, where events have high destructiveness, high onset rate, low temporal predictability and high spatial predictability (limited and circumscribed geographical area). In the context of hazard-avoidance public policies, aimed at minimising exposure in terms of number of lives (human, animal and plant) and

Vision for a smart management of public buildings stocks
Fig. 1

goods (economic, social and cultural), there are two main approaches. First, acting on 'potential exposure'; in other words, preventing the settlement of new population and new buildings in hazardous areas through regulatory, disincentive, and educational actions. Second, acting on 'existing exposure'; in other words, relocating already settled population/activities and buildings, through incentive and regulatory actions (SMCI, 2017: 113-115).

At this point, the crucial role of preventive planning is evident. Through the regulation of land use and the definition of urban transformation strategies of territories, preventive planning can orient and define intervention priorities as well as stimulate education and awareness through cognitive mapping and following information campaigns. Despite this, in Italy, there is a lack of systematic integration between urban planning and sectorial tools for managing risk. For instance, hydrogeological planning and seismic zoning plan are considered too technical and sectorial (Cremonini & Galderisi, 2007; SMCI, 2017; Gaz, 2019). Preventive planning can play a strategic role in building territorial and enterprises' resilience against natural risks, acting mainly on two sides. On the one hand, by developing spatial analyses that incorporate knowledge of natural hazards and the state of enterprises. The knowledge could be transfer to companies and workers. On the other, by developing urban planning designs that consider the territorial and economic fragilities highlighted by the analyses (Fabietti, 1999; Fior, 2022).

The paper aims to analyse the enterprises' exposure to natural hazards that could occur together or influence each other (Tilloy *et al.*, 2019). The paper considers that the multi-hazard condition is the only future urban planning scenario, and, as planners, we must cope with it. The paper presents the Seismic Crater Area (SCA) in Central Italy and shows the exposure of local firms to earthquakes and landslides. The case study is in severe social and economic distress that must regain the ability to compete in a safe environment to return to job creation and wealth (Marinelli & Domenella, 2020). The research offers a set of data and maps helpful in supporting preventive planning and stimulating firms to invest in building and urban regeneration. In SCA, preventive planning, which considers companies' sector and needs, can better guide the process of risk management. Generally, we are awarded that there will never be the certainty of removing the hazards definitively. Despite this, prevention from natural hazards goes hand in hand with general and sectoral planning choices, both at territorial (regional, provincial or metropolitan) and local scales (Di Lodovico & Iagnemma, 2012; Zublena, 2017). The real issue is not in which tool but how to use knowledge about risks (hazards, vulnerability, and exposure) in the day-to-day practice of territorial governance.

Case study and research methodology

The economic crisis in 2008, the seismic events in 2009, 2016 and 2017 (plus the meteorological event), and finally, the pandemic have compromised the urban framework and infrastructure networks, fragmented communities, de-powered the already fragile local economies in the Seismic Crater Area (SCA) in Central Italy.

The Seismic Crater Area includes 138 municipalities (located in four different Regions) and extends for almost 8,000 sqkm. A predominantly mountainous territory characterizes the area (about half of the municipalities is located 900 meters above sea level), crossed longitudinally by several rivers such as Potenza, Chienti, Tenna, and Tronto. The infrastructure system is limited to few roads that from the coast-highway go up towards the inner lands. The bigger urban areas are located along the border of the SCA, in the plain, such as Fabriano, Macerata and Ascoli Piceno (Marche Region), Teramo (Abruzzo Region), Rieti (Lazio Region), Spoleto (Umbria Region). They are municipalities often industrially linked to the big cities on the coast. At the centre of the study area, in the highest part, several ancient nucleuses such as Norcia and Cascia (Umbria Region), Camerino and Arquata del Tronto (Marche Region), Accumuli and Amatrice (Lazio Region), Montereale and Isola del Gran Sasso d'Italia (Abruzzo Region) stand out. A small urban system develops through picturesque historical centres, landscapes, and environmental systems with very high biodiversity and typical products (lentils, sausages, wine) but poorly accessible by roads and railways on the Apennine ridge.

From a geomorphological perspective, the SCA is identified precisely because of its high vulnerability to earthquakes and landslides. Often, landslides are linked to seismic events (Tondi *et al.*, 2022a, 2022b; Luzi, 2022; Fabbrocino *et al.*, 2022). The territory is characterized by sedimentary rocks deposited in the marine environment during the Pleistocene. The Apennine mountain range is made up of extensive outcrops of limestone, limestone-marly, and limestone-siliceous rocks. Marly-clayey, arenaceous and conglomeratic rocks instead characterize the other bands. Generally, the area is characterized by the presence of intermontane depressions filled with fluvial-lacustrine sediments. The Quaternary uplift subsequently generated intense morphodynamic activity that led to landscape modelling and activating large landslides and deep gravitational deformations. Some showed signs of reactivation during the 2016 seismic sequence.

The SCA has varied economic macro-specializations, as following:

- the Macerata and Fermo district qualified in the footwear sector and excellent at the national level,
- the Fabriano district, with the paper industry and electrical appliances such as Indesit,

Merloni, and Ariston firms;
- the Ascoli district with agro-alimentary specializations;
- the Val Vibrata district in Abruzzo Region specialized in leather goods and clothing;
- and the Rieti and Cittaducale district specialized in highly innovative sectors (for example, the Solsonica company, based here, is a leader in latest-generation photovoltaics).

The research focused on SCA and combined data from different sources. Our analyses used the AIDA database provided by Bureau van Dijk (data updated to March 2021), containing complete company information. For each company we identified both the location of headquarters (registered offices/*sedi legali*) and operative businesses (operating offices/*sedi operative*). This distinction is helpful to understand the different production equipment located in the buildings and, therefore, to assess possible losses by catastrophic events.

For each company, detailed financial statements are available under the IV EEC Directive (in Italy, the European directive has been implemented by Legislative Decree 139/2015). Moreover, a complete description of the activity carried out by each company is present in the AIDA database (according to ATECO[2] 2007 classification). The company's geolocation was done by ESRI ArcMap software, through geocoding operations. Geocoding is the process of transforming a location description, such as a coordinate pair, address, or place name, into a site on the earth's surface. The resulting locations are output as geographic features with attributes that can be used for spatial analysis. The AIDA database is not complete of all the companies operating on the territory. Nevertheless, it allows assessing the exposure of a part of enterprises to natural hazards because we can know their precise location. Up to now, AIDA is the only national database with location descriptions of companies. Other databases have complete quantitative data but only on a municipal basis.

The other databases used in the research were the seismic hazard areas defined by the National Institute of Geophysics and Volcanology (INGV) in 2006 and the landslide hazard areas defined by the Superior Institute for Environmental Protection and Research (ISPRA) in 2017. Both maps result from our reworking in ESRI ArcMap because INGV provides only the point cloud of the seismic hazard (INGV, 2008). We transformed the point shape-file into a polygonal shape-file through a series of spatial conversions. First, transforming the points into a grid of pixels and then convert the raster image into a vector file ready to intersect with the geo-located companies. ISPRA, instead, provides the polygonal shape-file with the landslide hazard areas (ISPRA, 2017). We have distinguished the four hazard thresholds established by the Hydrogeological Plans.

We queried the location of enterprises first with seismic hazard areas and then with landslide hazard areas. Specifically, we subdivided enterprises by their economic sector and developed spatial queries for 20 different businesses, including agriculture, manufacturing, energy, construction, trade, transportation, and real estate. We assessed the exposure of various economic sectors on two seismic hazard thresholds (subdivided into a single threshold for Very High Hazard and four sub-thresholds for High Hazard, based on ground acceleration values). We assessed the enterprises' exposure to four landslide hazard thresholds (P1 Moderate, P2 Medium, P3 High, P4 Very High). In addition, business exposure was analysed by distinguishing the following information: number of locations, number of employees; and analysing circular capital (value of materials and value of products expressed in €) and fixed capital (value of buildings, land, plant, equipment, and other assets held expressed in €).

Results and discussions

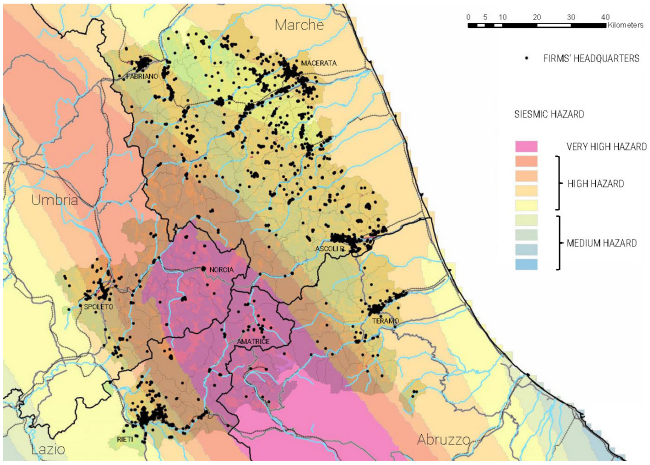
More than 15 thousand headquarters and more than 8 thousand operative offices have been located in the SCA. The headquarters refer to about 77,600 employees, with annual revenue from product sales of about 14.6 billion €. The operative businesses correspond to companies with approximately 61,500 employees, with an annual income from product sales of about € 12.3 billion (fig. 1, 2).

Concerning seismicity, the territory under consideration is classified in zone 1 (Very High hazard) and zone 2 (High hazard) according to the scale defined by INGV through the values of maximum horizontal ground acceleration (ga) in a given period. In particular, it is the probability that the ga is exceeded by 10% in 50 years. In zone 1 there are 3.2% of the headquarters and 3.4% of the operational offices. In zone 2, the others expose 98% of the employees (data referring to headquarters).

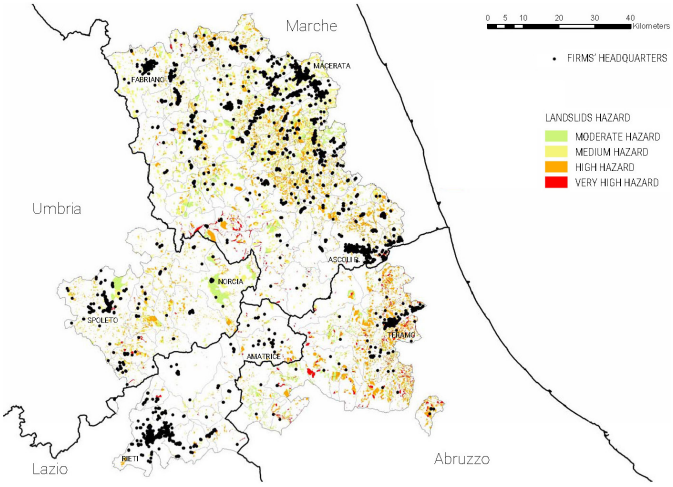
The territories in which a landslide is likely to occur extend over 114 thousand hectares (or 14.3% of the SCA). In the landslide hazard areas fall a total of 1,156 headquarters (equal to 7.6% of the total of the SCA) and 634 operative businesses (equal to 7.6% of the total of the SCA) distributed as follows:

- in Very High hazard area (that is 5.5% of the landslide hazard areas) there are 223 headquarters and 40 operative businesses,
- in High hazard area (that is 42.1% of the landslide hazard areas) there are 97 headquarters and 143 operative businesses,
- in Medium hazard area (that is 29.1% of the landslide hazard areas) there are 578 headquarters and 261 operative businesses,
- in Moderate hazard area (that is 23.2% of the landslide hazard areas), there are 258 headquarters and 190 operative businesses.

In general, the research shows that slightly less than 30% of the companies in areas subject to possible landslides are located in areas



Spatial distribution of enterprises in reference to seismic hazard areas
Fig. 1

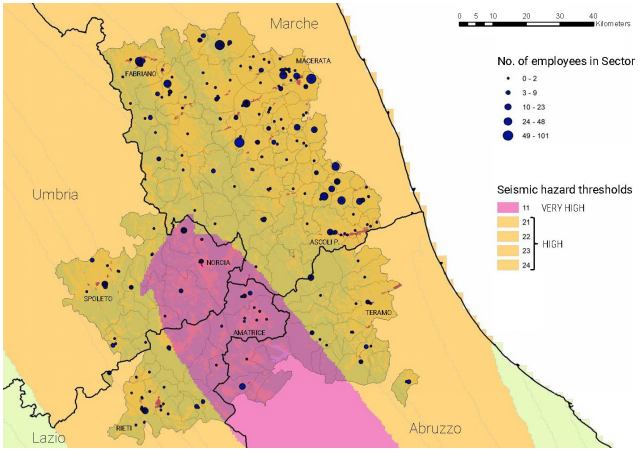


Spatial distribution of enterprises in reference to landslide hazard areas
Fig. 2

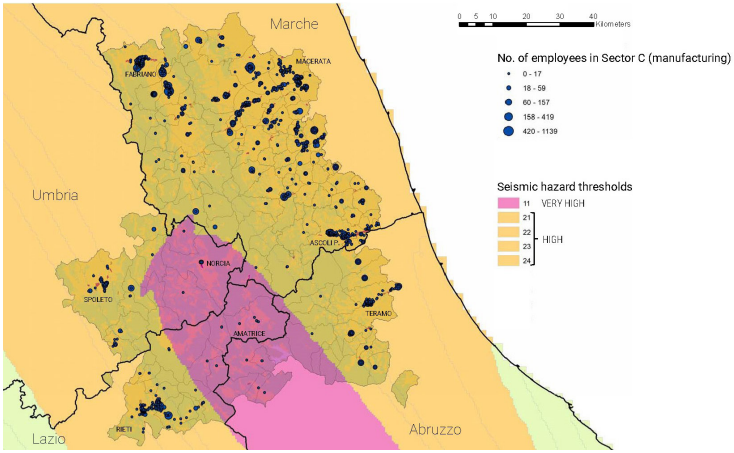
with high or very high hazards, putting at risk more than 6,000 employees if we consider the headquarters (almost 4,000 considering companies by their operative businesses).
The research outcomes are as follows:

- Maps of businesses' exposure (in terms of no. of enterprises and no. of employees exposed) to earthquake and landslide hazards, split by economic sector.
- Charts indicate the overall exposure of companies, employees, and working capital and fixed capital according to each hazard threshold.
- Final tables that, for each economic sector, indicate the exposure of companies, employees, working capital and fixed capital.

Fig. 3 shows the distribution of 418 headquarters in the economic sector ATECO A (agriculture) equal to 2.8% of total headquarters in sector A in the SCA. They have 1,141 employees representing 1.5% of the total number of employees in the SCA.
Fig. 4 shows the distribution of 2,450 headquarters in economic sector ATECO C (manufacturing) equal to 16.2% of total headquar-



Distribution of 418 headquarters in the economic sector ATECO A (agriculture)
Fig. 3



Distribution of 2,450 headquarters in economic sector ATECO C (manufacturing)
Fig. 4

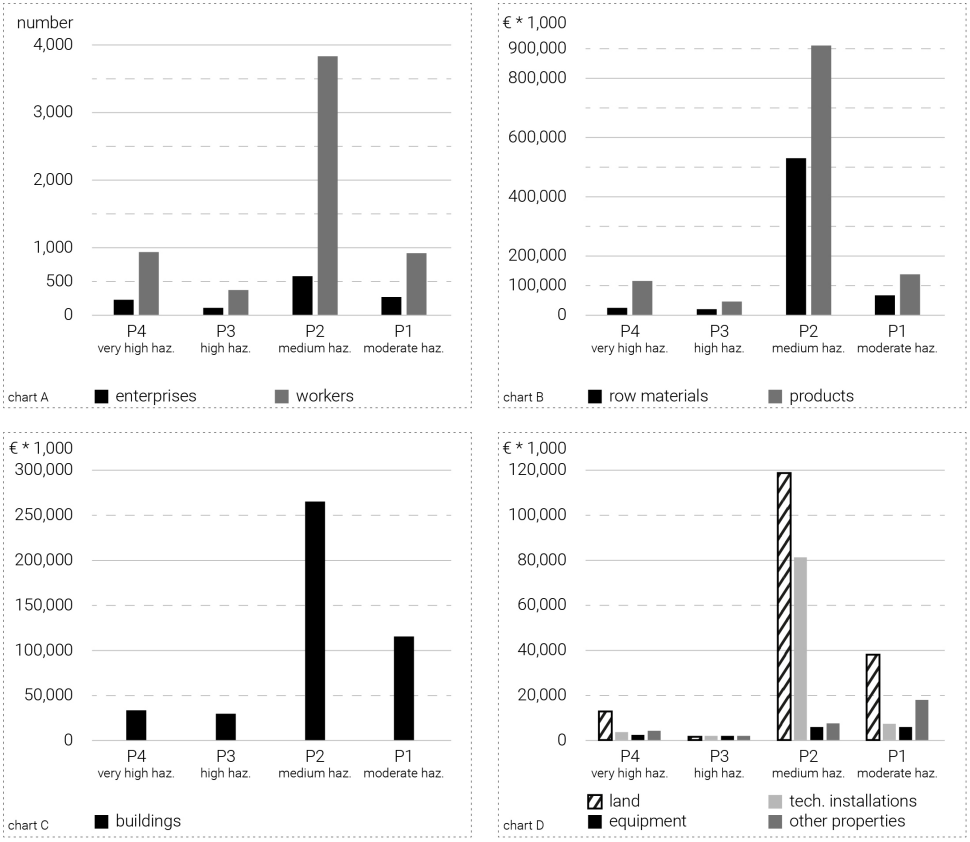
ters in sector C in the SCA. They have 27,543 employees representing 35.5% of total employees in the SCA.

Maps show the differences between economic sectors in terms of distribution of employees. Considering the employees' exposure to the seismic hazards, we can see that the agricultural sector (fig. 3) exposes many people in both lowland and mountainous municipalities (the largest dots are in rural areas along the edges of the SCA, but other dots are in the central territories). On the opposite, the manufacturing sector (fig. 4) exposes many workers in highly accessible areas and municipalities with road and rail networks. The analysis help planning in the emergency phase by identifying, e.g., safe places where people join in case of earthquakes.

The charts (fig. 5) return a reading of enterprises' exposure based on hazard thresholds.

Fig. 5 shows the enterprises' exposure to landslides in Seismic Crater Area considering data on headquarters (March 2021). The graph on the top left (A) shows the number of firms and workers exposed to the four landslides hazard thresholds. The graph on the top right (B) shows the value of working capital (raw materials and products) exposed to the four landslide hazard thresholds. The graph at the bottom left (C) shows the value of the fixed cap-

Enterprises' exposure to landslides in Crater Area (Headquarters in March, 2021)



Enterprises' exposure based on hazard thresholds.
Fig. 5

ital in terms of the value of buildings exposed to the four landslides hazard thresholds. The graph at the bottom right (D) shows the value of fixed capital (different from buildings) exposed to the four landslides hazard thresholds. The simultaneous observation of the four charts highlights that, usually, the headquarters are numerous in the P2 threshold (medium hazard) in terms of the number of companies, workers, fixed and working capital. Despite this, on closer observation, we note that in the P1 threshold (moderate hazard) the number of fixed capital exposed is far greater than the one exposed in the P4 threshold (very high hazard), but looking at the number of workers and the value of the products, the exposure in the thresholds P4 and P1 is almost equivalent.

For example, considering the landslide hazard and the four hazard thresholds (P1 Moderate > P4 Very High), the graphs show the exposed values. Comparing the values exposed in P4 and P1 areas emerges that in P4 area workers are particularly exposed, whereas in P1 area mainly buildings and soils. This analysis is handy for preventive planning, as it shows

HQ	ECONOMIC SECTOR	ENTERPRISES	WORKERS	INCOME	PROFIT	SALARIES	RAW MATERIALS	PRODUCTS	BUILDINGS	LAND	TECH INSTALL.	EQUIPMENTS	OTHERS
A	AGRICOLTURE	5,0%	1,4%	0,8%	-1,0%	0,9%	0,8%	1,1%	4,4%	3,5%	0,6%	0,5%	0,8%
B	EXTRACTION	0,8%	0,2%	0,2%	1,6%	0,2%	0,2%	0,2%	0,2%	0,4%	0,1%	0,0%	0,0%
C	MANIFACTURING	16,1%	26,9%	52,8%	63,2%	33,0%	60,8%	51,7%	35,4%	48,8%	39,0%	14,0%	14,5%
D	ENERGY	1,5%	0,1%	0,5%	0,9%	0,1%	0,5%	0,5%	1,2%	0,0%	4,7%	0,0%	0,0%
E	WATER-SEWAGE	0,5%	7,7%	4,8%	7,3%	11,8%	0,4%	5,2%	12,3%	3,7%	48,6%	15,1%	0,9%
F	CONSTRUCTIONS	16,1%	11,0%	6,6%	12,9%	11,4%	3,5%	6,8%	6,6%	3,9%	1,0%	4,3%	2,9%
G	COMMERCE	20,1%	13,6%	20,9%	1,0%	12,0%	29,3%	20,5%	5,7%	4,9%	1,0%	8,9%	5,6%
H	TRANSPORTATION	3,5%	7,0%	4,0%	-5,2%	8,7%	0,7%	4,4%	16,1%	11,4%	1,1%	44,0%	57,5%
I	LODGING-CATERING	8,7%	9,5%	2,4%	-2,5%	5,3%	1,9%	2,4%	6,1%	9,7%	1,4%	1,6%	11,6%
J	INFORMATION	3,7%	1,8%	1,3%	1,3%	2,0%	0,6%	1,4%	0,7%	0,8%	0,0%	1,3%	0,7%
K	FINANCIAL	1,3%	0,2%	0,3%	14,9%	0,1%	0,0%	0,3%	1,0%	2,7%	0,0%	0,0%	0,3%
L	REAL ESTATE	6,0%	0,8%	0,6%	0,1%	0,8%	0,1%	0,6%	6,8%	6,7%	1,3%	3,7%	2,2%
M	PROFESSIONAL	5,9%	1,3%	1,0%	5,6%	0,9%	0,5%	1,1%	0,8%	0,2%	1,1%	4,4%	0,8%
N	RENTAL	4,5%	6,9%	1,5%	-1,2%	5,3%	0,4%	1,5%	0,5%	0,2%	0,1%	0,4%	1,3%
O	AMMINISTRATION	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
P	SCHOOL	1,0%	0,3%	0,1%	0,1%	0,2%	0,0%	0,1%	0,0%	0,0%	0,0%	0,0%	0,0%
Q	HEALTH	1,7%	7,4%	1,4%	0,6%	5,6%	0,1%	1,4%	1,5%	3,2%	0,0%	1,0%	0,8%
R	ART	2,2%	2,8%	0,5%	0,0%	1,2%	0,1%	0,5%	0,6%	0,0%	0,0%	0,6%	0,0%
S	OTHER SERVICES	1,3%	1,1%	0,3%	0,3%	0,6%	0,2%	0,3%	0,1%	0,0%	0,0%	0,0%	0,0%
U	ONG	0,3%	0,0%	0,0%	-0,1%	0,0%	0,0%	0,0%	0,0%	0,1%	0,0%	0,0%	0,0%

Value of assets for each economic sector exposed to landslide Hazard"

Tab. 1

HQ	ECONOMIC SECTOR	ENTERPRISES	WORKERS	INCOME	PROFIT	SALARIES	RAW MATERIALS	PRODUCTS	BUILDINGS	LAND	TECH INSTALL.	EQUIPMENTS	OTHERS
A	AGRICOLTURE	2,8%	1,5%	1,6%	-0,5%	0,9%	2,3%	1,7%	5,0%	6,0%	2,4%	0,8%	1,7%
B	EXTRACTION	0,3%	0,2%	0,1%	0,2%	0,1%	0,1%	0,1%	0,3%	0,1%	0,0%	0,2%	0,1%
C	MANIFACTURING	16,2%	35,5%	40,6%	40,1%	41,4%	41,5%	40,2%	31,1%	35,5%	33,8%	40,0%	23,1%
D	ENERGY	1,6%	0,4%	0,8%	6,9%	0,5%	0,6%	1,0%	4,4%	2,2%	6,8%	0,8%	2,9%
E	WATER-SEWAGE	0,7%	4,0%	3,5%	3,1%	5,3%	1,4%	3,8%	12,1%	7,5%	36,5%	9,8%	8,1%
F	CONSTRUCTIONS	17,3%	9,7%	8,2%	6,0%	9,3%	4,8%	7,8%	7,6%	4,3%	5,1%	7,6%	7,9%
G	COMMERCE	17,8%	15,0%	26,8%	15,0%	14,6%	38,3%	26,5%	10,6%	16,5%	6,2%	15,3%	15,3%
H	TRANSPORTATION	2,6%	5,0%	3,1%	-0,3%	5,0%	0,9%	3,3%	4,2%	4,1%	0,4%	5,6%	27,9%
I	LODGING-CATERING	6,9%	6,5%	1,7%	-0,6%	2,9%	1,4%	1,7%	2,8%	1,8%	0,3%	2,0%	3,9%
J	INFORMATION	4,6%	3,2%	1,4%	1,2%	3,0%	0,3%	1,4%	1,0%	0,8%	1,5%	0,3%	1,0%
K	FINANCIAL	1,3%	0,3%	0,2%	2,4%	0,3%	0,0%	0,2%	0,3%	0,4%	0,0%	0,0%	0,2%
L	REAL ESTATE	8,9%	0,7%	1,5%	9,4%	0,5%	0,6%	1,5%	13,7%	14,1%	2,1%	0,7%	1,5%
M	PROFESSIONAL	7,1%	3,5%	5,3%	16,6%	5,1%	4,8%	5,3%	3,4%	3,2%	4,0%	14,6%	2,2%
N	RENTAL	4,8%	6,3%	2,9%	1,9%	5,6%	2,5%	3,0%	1,2%	1,4%	0,3%	1,0%	1,7%
O	AMMINISTRATION	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
P	SCHOOL	0,9%	0,5%	0,2%	0,2%	0,3%	0,0%	0,2%	0,1%	0,0%	0,0%	0,0%	0,2%
Q	HEALTH	2,2%	4,3%	1,2%	0,5%	2,9%	0,3%	1,2%	0,9%	1,4%	0,4%	0,6%	1,1%
R	ART	2,5%	2,2%	0,5%	-2,2%	1,5%	0,1%	0,7%	0,8%	0,3%	0,1%	0,3%	0,3%
S	OTHER SERVICES	1,6%	1,3%	0,4%	0,2%	0,7%	0,3%	0,4%	0,5%	0,3%	0,0%	0,3%	0,8%
U	ONG	0,1%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%

Value of assets exposed to the earthquake hazard for each economic sector

Tab. 2

how companies are exposed in different ways. In this case, we are dealing with landslide exposure. It is clear that while the protection of workers can be pursued through safety programs developed by firms, sheltering less real estate from landslide risk means working towards the relocation of businesses to safer areas. Following, we show which economic sectors expose the highest level of fixed capital.

The last part of the research shows the differences between economic sectors exposed to seismic and landslide hazards. The following two tables (tab. 1, 2) represent a summary of the values exposed in relative terms between economic sectors, regardless of the hazard threshold in which the firms are.

Analysing the two risk conditions in the SCA, it emerges that the manufacturing sector (C) is the most fragile to both landslides and earthquakes, exposing the most significant number of businesses, workers, raw materials, products, buildings, land, equipment, and tools. The commercial/trade sector (G) is also particularly affected. While companies,

workers, and raw materials are most exposed to landslides; businesses that generate the most revenue, or hold the most value of raw materials, products, land, and other assets, are further exposed to seismic hazards. Other considerations include the construction sector (F), which exposes many companies to both earthquakes and landslides, but many workers are also exposed to the latter. It is interesting to note that the transportation sector (H) exposes many buildings, equipment, and other goods to landslide risk. This is a crucial detail to know because it can determine new scenarios for urban planning. The interruption of the transport sector can trigger the post-event reconstruction phase. To safeguard the transport system, it could be useful to review the location of nodes and intermodal exchanges while considering the need to efficiently serve a vast and dispersed territory like the case study. Other considerations regard the exposure to earthquakes. Sectors such as real estate (L) as well as exposing many companies put buildings at risk. The water supply and sewage sector (E), on the other hand, exposes mainly technical installations. Finally, the professions sector (architects, medical practices, law firms) (M) exposes the companies that generate the most profit relative to other economic sectors.

The research outputs show that spatial analysis can provide detailed information to policymakers and urban planners. The information about the businesses' exposure is useful for both public and private realm. In one hand, such kind of information influence the spatial governance, on the other hand, it increases companies' awareness on the risks they are hitting. That information can stimulate a fruitful collaboration among the territorial actors who are required to increase the territory and community's resilience by securing workers, buildings, and business continuity. Furthermore, this investigation is useful both in the emergency phase and in the reconstruction phase, increasing the risk management capacity. On the one hand, it indicates the areas with the greatest workers' density; on the other hand, it provides data on type of fixed capital to restore.

It should also be considered that much frequent hazard is – from 1985 to 2019, Italy has been hit by 15 'destructive earthquakes', i.e. with a magnitude greater than 5.5 on the Richter scale –, more the individuals' trust in experts and institutions tends to diminish, paradoxically increasing the likelihood of supporting reconstruction processes by the community (Wachinger *et al.*, 2012). We must take into account that the trust in public authorities, in

crisis and emergency situations, is a key factor in sustaining relief and reconstruction operations. From this perspective, urban planning is crucial to join stakeholders in preventing disasters. Moreover, preventive planning is crucial to manage such king of technical and sectorial information, offering a quantitative and qualitative representation of territorial fragility.

This research is an example of the importance of acquiring knowledge to improve risk management in urban planning. The role of businesses is presented as an antidote to the fragility and vulnerabilities of territories: their business continuity is a precondition for the resilience of settled communities. Analyses such as the one presented show how important it is to know the exposure of economic activities. Because if urban planning aim is to reduce the fragility of territories, it must begin by reducing the exposure of workers and businesses to hazards. However, the various economic sectors differ substantially in their locations and in their capacity to adapt buildings to cope with natural hazards. Thus, geo-spatialisation of businesses, split by economic sector, offers help to planners and decision-makers in the preventive phase. In peacetime, analysis business' exposure could guide strategic planning and design choices.

Concerning spatial analysis, urban planning could improve knowledge about hazards and risks, both in bottom-up and top-down perspectives. First, planning could increases enterprises' awareness about natural hazards that hit the territory they want or would like to operate, offering maps about enterprises' exposure. Second, urban planning could broaden planning authorities' knowledge about companies' needs fostering territorial resilience. Knowing the characteristics of existing companies (location, economic sector in which they operate, supply chains/relationships, fixed and circulating capital) end exposure, would benefit authorities because that could prioritize urban planning programs in line with business fragility.

Concerning the urban planning designs, firstly, land use strategy must influences the business locations, showing the environmental and economic unsustainability of fragile areas, and planning new industrial districts environmentally friendly. Secondly, urban planning must drive non-relocatable businesses to improve the physical performance of their buildings/equipment through architectural/engineered interventions (deepening building codes). At building scale, planning guidelines (for existing productive districts or firms that cannot be moved) can reduce business vulnerability and improving the health of workers and urban life quality through technological solutions. At the same time, preventive planning could act at large scale through nature-based solutions. Knowing the businesses' exposure to natural hazards provides a matrix of valuable information to urban planning recommendations in

line with the fragility of the territory (high soil imperviousness, scarcity of natural areas, unfavourable geo-pedagogical characteristics), as well as with companies' needs (accessibility to amenities, availability of suitable spaces for production, building energy performance).

Final considerations

Analysing the businesses' exposure by economic sectors contributes to increase the effectiveness as well as the efficiency of the spatial governance, in order to provide the decision-makers an instrument to choose in time which buildings/equipment to relocate in terms of location, time and costs. Indeed, relocating existing activities to less dangerous areas is an extreme solution that requires a cost-benefit analysis as well as a careful assessment both from the urban planning point of view (is the target area suitable for business?) and from the social acceptance of this choice. Conversely, decision-makers may decide the order of priority for securing or seismic retrofitting of infrastructure and services based on the inability of companies to relocate them. Relocation is not always feasible, especially for activities that have a vital link with the territory (site dependency) such as tourism, agriculture, water supply. Certainly, as Menoni and Pesaro (2008) suggest, abandonment and resettlement should be considered important parameters to ensure the effectiveness of public spending and the conformity of location decisions with other landscape and natural resource conservation requirements.

Landslides that add up to earthquakes, epidemics that add up to floods, hurricanes that add up to industrial accidents are currently and frequently possible multi-risk situations. The multi-risk condition and the unpredictability of the global economic trend impose a multi-scalar vision and a robust collaborative approach. Everyone (policymaker, inhabitants, and entrepreneurs) could contribute to increase the resilience of communities and people health, reducing business interruption and consequently people's fear. Urban planning involvement in risk management is strategic because it can define preventive policies priorities according to the ecological, environmental, and energy regeneration of productive buildings, improving the quality, healthy, security, and liveability of cities.

The preventive planning could implement community and territorial resilience freeing up spaces for ecological continuity, de-sealing soils, densifying and rationalizing urban functions, modernizing sewage and drainage systems, according to the need to reorganize or protect firms on less fragile areas. In the end, the outcome is people stress reduction during emergency crises and implementing their well-being during peacetime and not only when disaster strikes (Oliva, 2014).

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Note

[1] Marika Fior was the post-doc Research fellow, Paolo Galuzzi was the scientific Supervisor in 2020, and Piergiorgio Vitillo was the scientific Supervisor in 2021. Re-scale was one of the sixteen-research line developed at the DAStU Department of Excellence for the Project Fragilità Territoriali (2018-2022).

[2] The ATECO (ATtività ECOnomiche) classification of economic activities is a type of classification adopted in Italy by the National Institute of Statistics (ISTAT) for economic surveys. It is the Italian translation of the nomenclature of economic activities (NACE) created by Eurostat, adapted by ISTAT to the specific characteristics of the Italian economic system. As of 2020, the ATECO 2007 version, which came into force on 1 January 2008, is in use.