



TeMA

This Special Issue of TeMA - Journal of Land Use, Mobility and Environment, collects twenty-seven contributes of international researchers and technicians in form of scenarios, insights, reasoning and research on the relations between the City and the impacts of Covid-19 pandemic, questioning about the development of a new vision and a general rethinking of the structure and urban organization.



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Special Issue

Covid-19 vs City -20

scenarios, insights, reasoning and research



ISSN 1970-9889
University of Naples Federico II

TeMA

Journal of
Land Use, Mobility and Environment

Special Issue

COVID-19 vs CITY-20 SCENARIOS, INSIGHTS, REASONING AND RESEARCH

Published by

Laboratory of Land Use Mobility and Environment
DICEA - Department of Civil, Architectural and Environmental Engineering
University of Naples "Federico II"

TeMA is realized by CAB - Center for Libraries at "Federico II" University of Naples using Open Journal System

Editor-in-chief: Rocco Papa
print ISSN 1970-9889 | on line ISSN 1970-9870
Licence: Cancelleria del Tribunale di Napoli, n° 6 of 29/01/2008

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Given the short time to produce the volume, the Editorial Board of TeMA Journal carried out the scientific quality audit of the contributions published in this Special Issue.

The cover image is a photo collage of some cities during the Covid-19 pandemic quarantine (March 2020)

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Special Issue

COVID-19 vs CITY-20

SCENARIOS, INSIGHTS, REASONING AND RESEARCH

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Data analysis and mapping for monitoring health risk What has the spread of the Covid-19 pandemic in northern Italy taught us?

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Abstract

The construction of the knowledge framework is a fundamental phase in the territorial governance process and data analyses, together with their mapping using GIS software, provide a fundamental basis for the structuring of a system for making decisions. With reference to the issue of risk management, monitoring of spatial and temporal evolution of the phenomena is equally fundamental.

The aim of the paper is to address these issues in relation to health risk, starting from the pandemic situation that affected northern Italy in the early months of 2020.

The paper presents an ex-post statistical analysis of the ISTAT data on mortality in the Italian provinces, comparing the currently available 2020 data to previous years. A territorial analysis is then presented, using a GIS, regarding the spread of the Covid-19 infection in the 205 municipalities of the province of Brescia. The paper also proposes a comparison with analysis conducted for other territories outside Italy. Finally, a reflection is offered on what we have learned from this pandemic regarding the need to have a monitoring system for phenomena related to health risk, in order to reduce the vulnerability of the health system.

Keywords

Data mapping; Data analysis; Risk; Monitoring; Prevention.

How to cite item in APA format

Tiboni, M., Pezzagno, M., Vetturi D., Alexander C. & Botticini, F. (2020). Data analysis and mapping for monitoring health risk. What has the spread of the Covid-19 pandemic in northern Italy taught us?. *Tema. Journal of Land Use, Mobility and Environment*, 343-360. <http://dx.doi.org/10.6092/1970-9870/6899>

1. Safety in the city

1.1 The importance of planning for reducing and monitoring risk

In the aim of planning and building a safer city, particular importance is given to the prevention and management of risk, both of natural and anthropogenic origin.

Researchers have long acknowledged the centrality of the theme in planning (see among the others Foster, 1980; Varnes, 1984; Tira, 1997; Tiboni, 2007; Fistola, 2011; Zoppi & Lai, 2011; Tira & Zazzi, 2012; La Rosa, et al., 2013), and the specific Covid-19 pandemic situation that hit the whole world in the first months of 2020 requires us to extend our reflection to health risk or, more generally, to any type of risk, not only of natural origin, but also anthropic.

The risk is due to an event that sets off the disaster that occurs in a limited period and/or space, even if the effects may continue over time and spread to affect a larger area than that immediately involved.

The risk level perceived by a society is the discriminating factor for establishing how much that society is prepared to pay to eliminate the phenomenon that determines the risk. This decision is the result of the definition of a maximum risk level considered acceptable, a risk which the society decides not to eliminate because it considers the effects of the event as acceptable.

Risk specialists and experts tend to emphasize the numerical data regarding recurrence, intensity and destructiveness of disasters. This is a purely scientific approach that aims to set out the dynamics of the events and pinpoint possible solutions.

The sociological aspect of the risk, on the other hand, regards politicians and citizens who are unable to distinguish between objects/people and the values attributed to them. This aspect is linked to fear, uncertainty and problems understanding the event.

The concept of risk is often mistakenly confused with that of hazard. Indeed, the hazard is an integral part of the risk, but the two concepts are not synonymous.

The two terms have a precise philological definition:

- Hazard is "a threatening situation which is the source of the risk". For example, a natural phenomenon in general, such as a landslide, heavy rain, a hailstorm or an earthquake;
- Risk is "the product of the probability that the event occurs and the losses that this can generate".

The number of times a physical phenomenon recurs may be studied by analysing the historical data, enabling us to understand how likely a certain zone is subject to the specific event in question.

This information is useful for a technical evaluation of the hazard, but does not indicate the number of people, assets and infrastructures exposed to the event.

For an effective analysis, we need to introduce the concepts of vulnerability and exposure in order to take differences in geography and population density into account.

The generic concept of loss, or better the damage rate, is therefore replaced by:

- Vulnerability (V), understood as the propensity to suffer damage because of a certain event;
- Exposure (E), understood as the quantity and value of the assets (human beings and material assets) present in the area involved by the event.

So, risk should be measured in terms of expected damage, obtained from the combination of the cause (hazard), the system vulnerability and exposure, relative to both the human and economic component:

$$\text{Risk} = f(\text{hazard, exposure, vulnerability}), R=f(H, E, V)$$

Hazard, vulnerability and exposure depend on the intensity (I) of the event and the type (T) of elements at risk:

$$H=f(I), V=f(I, T), E=f(T)$$

The risk function thus takes on its complete form:

$$R=f(I, H, V, T, E)$$

Where:

R=risk

I=intensity of the event (the magnitude of an earthquake, the volume of a landslide);

H=hazard, the probability that a phenomenon of a given intensity (I) takes place within a certain time period and in a certain area;

V=vulnerability, or rather the propensity to suffer damage as a consequence of an event of a certain intensity (I) and on the basis of the type of elements (T) at risk;

T=type of elements potential subject to the effects of disasters (population, material assets, infrastructures);

E=quantity and value of the type of elements (T) at risk.

1.2 Hazard, exposure and vulnerability: some definitions

Starting from literature in the field of urban planning, short reflections on the definitions of the three variables will be presented below, with the aim of extending the widely studied approach to natural risk to the case of health risk (Tira, 1997; Tiboni, 2007; Fistola et al., 2020; Giuliani et al., 2020).

Hazard

Hazard depends on specific parameters based on the characteristics of the phenomenon in question. In the field of regional planning, it always refers to three parameters: intensity, frequency, location.

Different parameters for measuring the intensity are in place for each type of event. It is important to know how often the phenomenon reaches an intensity held to be significant and when an event above the safety threshold may presumably occur.

Exposure

The exposure is a function of the number of people who could potentially be affected by the event and all the economic assets in the area at risk.

If no asset (either human or economic) is exposed to the hazard, there is no risk.

The urban environment is an exposed place, due to the intense presence of people, structures, infrastructures and strategic functions, but the conditions of the subjects at risk may vary greatly in time and space and therefore have a major effect on the system's ability to respond. It is also possible to imagine different levels of exposure: for the single object at risk or for the regional system, where the exposure is also conditioned by spatial distribution and regional hierarchies of towns.

This leads us to deduce that, in risk analysis, exposure is a constantly changing factor, because cities change in form and, more rapidly, in use.

Exposure reflects the concept that the risk increases with the increase in quantity and value of the subjects affected. From this point of view, it is important to identify a method able to associate a value with each exposed element, to be able to establish a safeguarding order. Estimative methods (costs/benefits and risks/benefits analysis) can be applied to material assets, but it is completely unrealistic to quantify the value of human life. In the insurance field, there are some estimative methods based on the investments made by the society in the individual rather than on the presumed income, but none of these analyses can take into account the impact that the loss of a loved one has on his or her family members. Whilst this is emotionally true, effective planning must surely ascribe a value to life? Otherwise you end up with what in economics-speak is called a lexicographic preference ordering - possible outcomes will be ranked first solely on loss of life. Only if two outcomes have the same loss of life would a second factor such as financial loss be considered.

Therefore, human life is the main asset and the most important thing that needs to be protected.

Vulnerability and exposure have various elements in common, which should be borne in mind in order to avoid considering the same variable twice in the risk assessment. The concentration of assets, services and people in a given area, in other words the exposure, is also an indicator of vulnerability, because there is an increased probability of subsystems or fragile elements and a greater number of interdependencies that increase the vulnerability of the system as a whole.

If our goal is to reduce the risk to which a community is exposed, we will have to work to reduce one of the 3 variables that make up the risk (hazard, vulnerability, exposure), or better yet act in parallel on each variable. It is obvious that if there are no hazards (i.e. $H = 0$), there is no risk, and high exposure and vulnerability can generate a high-risk level also with a low hazard level. Hazard is only a part of the risk. In order to know the risk level of a region, it is necessary to know vulnerability, exposure and hazard levels in each point of the region, so that combining the three variables a risk map algebra could be produced (Tiboni & Tira, 1997; Tira et al., 2006; Zoppi & Lai, 2014).

The more the area is unprepared, or the more inadequate the response, the greater the system's vulnerability. This brings us to the importance of a "Mitigation Plan", or rather all the operations devoted to mitigation: the emergency is the manifestation of the vulnerability found in a certain area.

Vulnerability

A structure is vulnerable if it is inclined to suffer damages from a specific event.

Vulnerability is a function of the specific characteristics of the stressed system, but it only enters in play when the cause surpasses a certain severity threshold.

It can be interpreted as that level of severity (understood as a combination of intensity, spatial expansion and frequency in time) beyond which the system is no longer able to withstand the stress without breaking up. If the level is high, the system is not very vulnerable and is even able to withstand very intense events, while if the level is low, the system is very vulnerable and reaches crisis point with even a small amount of stress. The vulnerability analysis therefore involves the evaluation of numerous system/hazard combinations to be subjected to events with different levels of intensity. Evaluating the response of different regional systems is indispensable for creating vulnerability evaluation models.

The concept of "socio-systemic" vulnerability also expresses the possible damage that could occur in a given social system in terms of human, economic and environmental resources, but also the propensity for damage that this system presents in terms of risk or poor response capacity. The vulnerability therefore expresses, in qualitative and quantitative terms, the possibility that the system is struck by any external event in a limited period of time.

It is easy to understand how the socio-economic-environmental system's propensity to damage is substantially linked to two factors:

- the type of "risk" that the system is subject to;
- the system's response capacity (in terms of organization, for example).

In fact, vulnerability is also a function of the community's level of risk awareness, not just of the hazardous agent, but also of the spatial and social distribution of the vulnerability itself and of the material and human resources in place to combat it. Two communities subject to the same risk are not equally vulnerable, inasmuch as some societies have adopted regulations and implemented many projects targeted at risk reduction. Therefore, a society that has adopted a disaster prevention policy will be far less vulnerable than a community that has not put any provisions into place. Many forms of ground usage may increase the level of vulnerability, just like the increase in the complexity of the social system (Greco et al., 2019).

The vulnerability of the physical, social and institutional structure of the area, that is to say how much the physical structures (such as houses built on the basis of anti-seismic criteria, in the event of an earthquake), and the social and institutional structures (for example if there is an organized response structure, and if emergency contingency plans are in place) are prepared to deal with a calamity, determines the risk level. The more the area is unprepared, or the more inadequate the regional response, the greater the system's vulnerability.

2. Health risk: the case study of the Covid-19 pandemic in northern Italy

2.1 Introduction

The definition of risk proposed in the previous section finds plenty of applications in the urban planning field, namely for what concerns natural risk (seismic, hydrogeological, volcanic, ...).

The use of GIS software (Geographic Information System) is consolidated for risk scenarios definitions, particularly for analysis and adaptation to phenomena linked to hydrogeological instability and seismic vulnerability of the land (Campagna & Craglia, 2012; Amato et al., 2015; Campagna, 2016; Martellozzo et al., 2018; Giuliani et al., 2020; Scorza et al., 2020). Furthermore, in recent years, the amount of research aiming to define possible scenarios for the development of urban settlements has increased. Those researches employ GIS capabilities in assessing land resources, namely the ones linked to natural assets and ecosystem services (Arcidiacono & Ronchi, 2019; Campagna, 2016; Manganelli et al., 2016; Martellozzo et al., 2018; Scorza et al., 2020).

The application of methodologies traditionally applied to the analysis of physical risk, to the study of health risk, does not constitute an element of novelty, on the contrary! Already in 1854, the English epidemiologist John Snow had used a tracing system, during a cholera epidemic in London, to trace the source of the infection. However, in recent years the use of GIS software for this type of applications has been limited as recent seismic and flood events, partly related to climate changes too, have imposed other research priorities and today, the use of GIS for urban management and adaptation to health risk is a field that is suitable for numerous experiments.

The aim of this article is therefore to propose a reflection on the importance of applying this same approach to health risk management, reflecting on what happened in the first months of 2020, with the Covid-19 pandemic, in order to draw lessons from it for the future (Murgante et al., 2020).

The ex post analysis can help us to understand what is important to monitor, such as fundamental data for the management of the phenomenon, with reference to the three variables (hazard, exposure and vulnerability) that contribute to the definition of the level of risk.

In this work we propose an analysis of data on the spread of infection and mortality, with a focus on northern Italy, the area most affected by the disease.

To apply the definition of risk to a pandemic, the "exposure" variable will certainly be a function of the population living in the territory affected by the virus. Population will be investigated not only in absolute terms (the number of people residing or present in that territory), but also by studying specific features to which can be linked different characters of vulnerability.

The variable "hazard", essentially morbidity in the epidemiological sense, depends on factors such as the spread of the virus, its contagiousness and virulence. A topic that can be addressed both with epidemiological models specific to the medical sciences and by analysing the available health data. With reference to the case study, the number of infections detected in the area compared to the total population was considered an expression of the hazard.

In relationship to the type of health risk to which people are exposed it is possible to have different individual vulnerability degrees. Those degrees are related to the so-called unchangeable risk factors such as age, gender, ethnicity or genetic aspects and changeable risk factors like nutrition, lifestyle and past illnesses.

This is only one of the aspects that contribute to define vulnerability. Beyond individual vulnerability it is important to study systemic vulnerability too. This aspect depends on how the system (social system, health system, ...) can react when a phenomenon occurs.

To understand the difference between the two components of this variable it is feasible to consider as an example the case of seismic risk: in this case vulnerability is given by both the capability of single structures or buildings to respond to seismic stresses that allows them to remain undamaged until the event reaches a certain threshold (assuming their construction according to anti-earthquake criteria) and how the anthropic system react to the event.

To better understand this second vulnerability aspect it is useful to think at the interruption of a road due to the collapse of a bridge: systemic vulnerability will be lower if the system is able to react identifying temporary solutions that will guarantee the accessibility to the isolated territory (with the creation of a new alternative path or a new temporary structure that can replace the fallen one) in the short and midterm or, in the long term, with more articulate and complex solutions. These solutions can lead to a rearrangement of the previous vulnerable system.

2.2 Data analysis and mapping

For the analysis of the spread of Covid-19 epidemic in Italy and in the northern regions we have considered data coming from different sources:

- data about the daily number of affected people registered by Territorial Health Agencies (ATS) of Brescia province in the period from March 4th 2020 to April 11th 2020, subdivided by day and City of residence;
- data about resident people distribution in Italian Municipalities observed by ISTAT on January 1st 2019 and subdivided into classes of gender and age. This is the last official available datum about resident population in Italy;
- mortality archive registered between January 1st and April 15th related to the five-year period 2015-2019 for all of Italian Municipalities and the update related to the same period for the year 2020 observed by ISTAT for those part of Municipalities who joined the early data collection. Data are available with information related to any cause of death in Italy, distributed by city of residence, ages and day of the year.

If the last two data have an irrefutable validity as they are based on the official information of municipal registries (residing in 2019 and dead until 15.04.2020) the spread of the infection has a very reduced reliability as it is now clear that in the critical period of the emergency, and namely in the Lombardy Region, this figure largely underestimates this phenomenon due to the limited monitoring activities implemented by the regional health authorities.

However, it is possible to consider that datum as a valid form of sampling for understanding the spatial and temporal distribution of the phenomenon. Absolute values don't have the same value. Today there is no official and validate figure about the extension of the phenomenon and the spread of the disease.

Using a desktop GIS software, it was feasible to manage layers containing georeferenced data about the spread of the pandemic. This allows to obtain maps at municipal, provincial and regional scale and heat map that are referred to sequential time thresholds. They show the temporal evolution of the spatial distribution of the pandemic.

This type of map shows the spread of the disease in the territory under consideration.

Although it is now publicly ascertained that the number of official infections in Lombardy, the region most affected in Italy, as well as that of deaths officially associated with the virus, are only the tip of the iceberg, for the small number of diagnoses made, however, it is valid It is worth seeing how this tip of the iceberg has moved over the territory over time, as illustrated in Figures 1 and 2, relating to the province of Brescia.

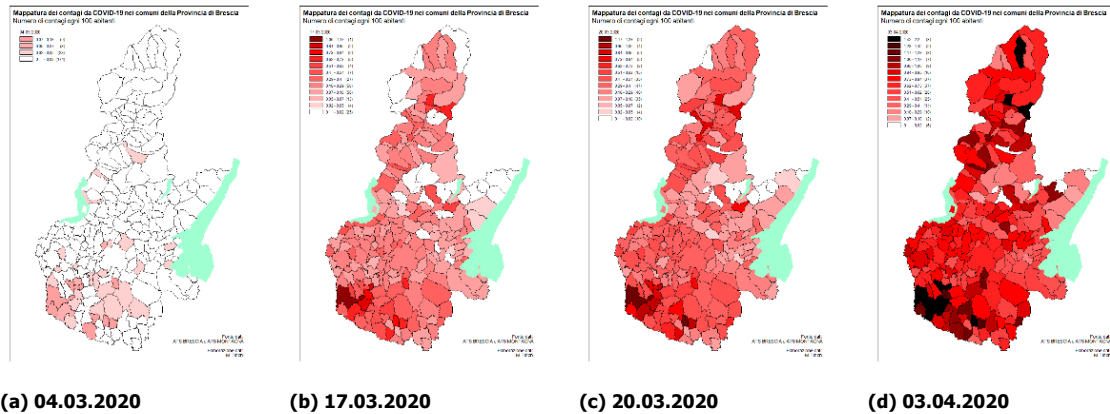


Fig. 1 Brescia province, variation in time and space of the number of positive Covid-19 cases per 100 inhabitants

Why is a detailed mapping of contagions essential? Obviously to identify and isolate the outbreaks, to see how the phenomenon moves on the territory, but also to see what are the effects of the measures put in place. The work could be even more detailed, going down to the street and house number scale. If the infection was identified more precisely, this would allow activating a tracing process, isolating the cases found and their contacts. A model approach to the spread of this type of contagion is precisely that implemented for this same pandemic in other territories such as South Korea and Taiwan. The analysis cannot be addressed only on a large area scale, with data aggregated by province, because the problem must be tackled locally.

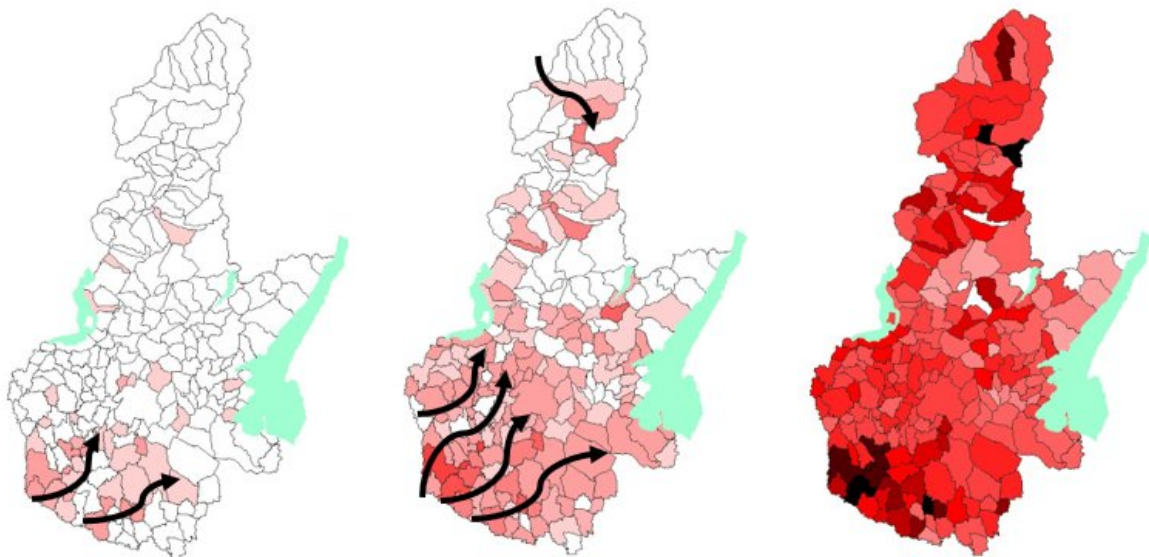


Fig. 2 Possible identification of the routes for spreading the infection through the mapping of cases

On the contrary, the choice to operate by analysing the number of deaths and the comparison with the average of the previous five years, is irrefutable and, however extreme, a quantitative sign of the effects of the pandemic on the population.

As shown in Tab. 1, mortality data for 4,252 Italian municipalities were considered (in red in the map of Figure 3), out of a total of 7,904 and represent 57% of the Italian population. The distribution of the municipalities that participated in the data collection promoted by ISTAT is mainly concentrated in the northern regions that are most affected by the pandemic. For that area the population considered in the mortality analysis represents 69% of the residents while in the centre 56% and in southern Italy 44%.

Region	Resident population on 01.01.2019	Population considered in the analysis					all	percentage of population considered
		Age						
		0 - 24	25-64	65 - 74	75 - 84	over 85		
Abruzzo	1'311'580	161'076	402'080	85'283	61'136	29'432	739'007	56%
Basilicata	562'869	28'243	70'149	13'703	10'013	5'239	127'347	23%
Calabria	1'947'131	167'340	373'156	73'906	49'896	22'329	686'627	35%
Campania	5'801'692	383'393	826'014	153'131	97'684	40'366	1'500'588	26%
Emilia-Romagna	4'459'477	819'895	2'019'952	417'237	326'276	154'389	3'737'749	84%
Friuli-Venezia Giulia	1'215'220	92'096	229'879	53'944	38'912	16'184	431'015	35%
Lazio	5'879'082	275'701	669'287	134'137	89'283	37'125	1'205'533	21%
Liguria	1'550'640	236'131	616'219	149'525	125'516	61'310	1'188'701	77%
Lombardia	10'051'747	1'809'424	4'277'675	854'839	651'271	276'016	7'869'225	78%
Marche	1'525'271	159'245	388'308	84'120	66'178	31'640	729'491	48%
Molise	305'617	35'910	90'080	19'549	13'550	6'997	166'086	54%
Piemonte	4'354'636	555'934	1'362'662	312'145	238'369	105'066	2'574'176	59%
Puglia	4'019'194	572'948	1'309'587	278'307	187'271	79'809	2'427'922	60%
Sardegna	1'639'591	184'735	508'436	106'554	71'125	29'603	900'453	55%
Sicilia	4'999'891	616'999	1'350'038	272'818	180'852	77'256	2'497'963	50%
Toscana	3'729'641	636'515	1'590'919	352'663	272'242	126'404	2'978'743	80%
Trentino-Alto Adige/Südtirol	1'062'940	102'434	222'001	45'250	32'496	15'319	417'500	39%
Umbria	882'015	137'123	336'147	73'071	57'416	27'426	631'183	72%
Valle d'Aosta/Vallée d'Aoste	125'666	24'259	57'820	12'531	9'368	4'118	108'096	86%
Veneto	4'869'591	811'863	1'924'673	394'900	294'883	125'198	3'551'517	73%
Italy	60'293'491	7'811'264	18'625'082	3'887'613	2'873'737	1'271'226	34'468'922	57%

Tab.1 Distribution of the resident population in Italian Regions and in the municipality considered in the mortality analysis

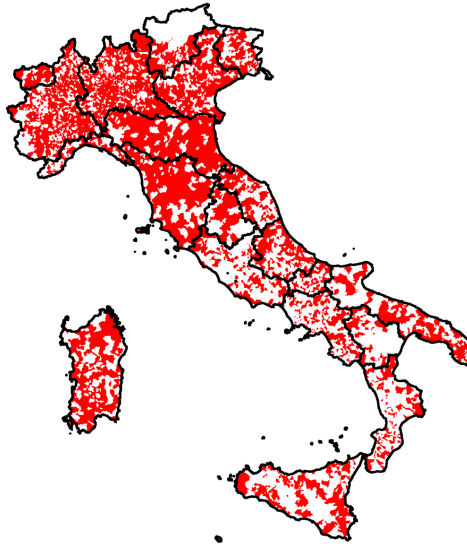


Fig. 3 In red municipalities included in analysis of mortality with data collection promoted by ISTAT

The Tab. 1 also shows the breakdown of the resident population by age group considering five different classes: young people up to 24 years old, working age adult (25-64 years) and elderly population divided into three subclasses (65-74 years, 75- 84 years and over 84 years old).

As shown in Table 2, the number of deaths recorded in Italy in the year 2020 shows significant differences only for some regions and only for some age classes. The Covid-19 epidemic did not affect the different Italian regions in the same way, but it was concentrated in some regions of northern Italy. In this section we will not investigate the reasons for differences in mortality, just identify them.

The analysis was also conducted at the level of the 105 provinces in which the municipalities that participated in the transmission of mortality data to the National Statistics Institute fall, with results superimposable to the considerations that emerged on a regional basis.

Region	Average 2015 - 2019						Number of death (from January 1st to April 15)						Difference 2020 vs. Average 2015-19					
	Age						Age						Age					
	0 - 24	25-64	65 - 74	75 - 84	over 85	all	0 - 24	25-64	65 - 74	75 - 84	over 85	all	0 - 24	25-64	65 - 74	75 - 84	over 85	all
Abruzzo	11	268	331	808	1'374	2'793	6	267	339	807	1'447	2'866	-5	-1	8	-1	73	73
Basilicata	2	47	56	148	253	506	2	46	59	117	244	468	0	-1	3	-31	-9	-38
Calabria	15	255	313	737	1'062	2'381	12	248	349	696	1'098	2'403	-3	-7	36	-41	36	22
Campania	33	631	714	1'520	1'988	4'887	24	593	736	1'370	2'078	4'801	-9	-38	22	-150	90	-86
Emilia-Romagna	58	1'130	1'551	3'843	7'048	13'630	55	1'359	2'051	4'878	8'531	16'874	-3	229	500	1'035	1'483	3'244
Friuli-Venezia Giulia	6	147	221	454	766	1'594	7	135	197	453	796	1'588	1	-12	-24	-1	30	-6
Lazio	20	456	578	1'157	1'746	3'956	12	376	576	1'058	1'736	3'758	-8	-80	-2	-99	-10	-198
Liguria	16	431	629	1'546	2'754	5'376	12	415	727	1'864	3'161	6'179	-4	-16	98	318	407	803
Lombardia	113	2'430	3'225	7'591	11'871	25'230	106	3'187	5'454	13'041	19'102	40'890	-7	757	2'229	5'450	7'231	15'660
Marche	12	212	297	739	1'446	2'706	11	250	365	940	1'787	3'353	-1	38	68	201	341	647
Molise	2	66	78	195	332	673	2	67	71	165	304	609	0	1	-7	-30	-28	-64
Piemonte	40	917	1'308	3'089	5'015	10'369	26	964	1'553	3'710	6'282	12'535	-14	47	245	621	1'267	2'166
Puglia	41	821	1'090	2'387	3'576	7'916	32	816	1'068	2'262	3'766	7'944	-9	-5	-22	-125	190	28
Sardegna	14	382	432	823	1'243	2'895	8	374	429	866	1'368	3'045	-6	-8	-3	43	125	150
Sicilia	57	959	1'261	2'837	3'956	9'072	52	904	1'227	2'472	3'967	8'622	-5	-55	-34	-365	11	-450
Toscana	38	931	1'317	3'141	5'805	11'232	28	883	1'346	3'191	5'974	11'422	-10	-48	29	50	169	190
Trentino-Alto Adige/Südtirol	10	119	157	343	680	1'308	5	120	211	433	957	1'726	-5	1	54	90	277	418
Umbria	7	181	265	633	1'263	2'349	8	167	245	599	1'214	2'233	1	-14	-20	-34	-49	-116
Valle d'Aosta/Vallee d'Aoste	3	39	57	125	192	415	1	33	75	154	267	530	-2	-6	18	29	75	115
Veneto	62	1'096	1'448	3'309	5'652	11'566	35	1'107	1'485	3'663	6'324	12'614	-27	11	37	354	672	1'048
Italy	560	11'520	15'327	35'425	58'022	120'854	444	12'311	18'563	42'739	70'403	144'460	-116	791	3'236	7'314	12'381	23'606

Tab. 2 Number of deaths in period 01.01 – 15.04 for pre Covid-19 period (average 2015-19) and in the year 2020, and difference

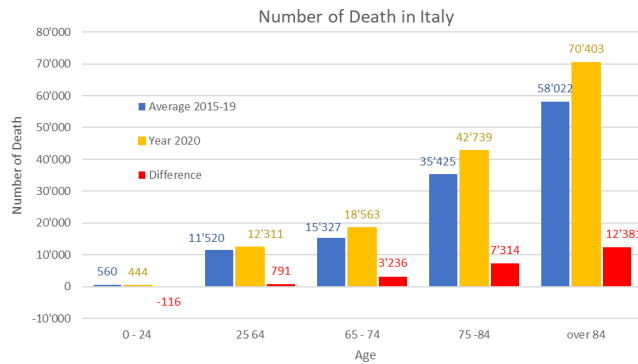


Fig. 4 Number of deaths in period 01.01 – 15.04 for age

It is also possible to give a territorial representation of the same information using thematical maps generated with a GIS software starting from data presented in summary form in Tab. 2 but also available at municipal level. The two Figures 6a and 6b present the distribution of mortality on the national territory in the five years preceding the Covid-19 epidemic (a) and subsequently. Data indicate the number of deaths recorded per 100,000 inhabitants in the period 01.01 - 15.04 of each year, for a total of 105 days observed.

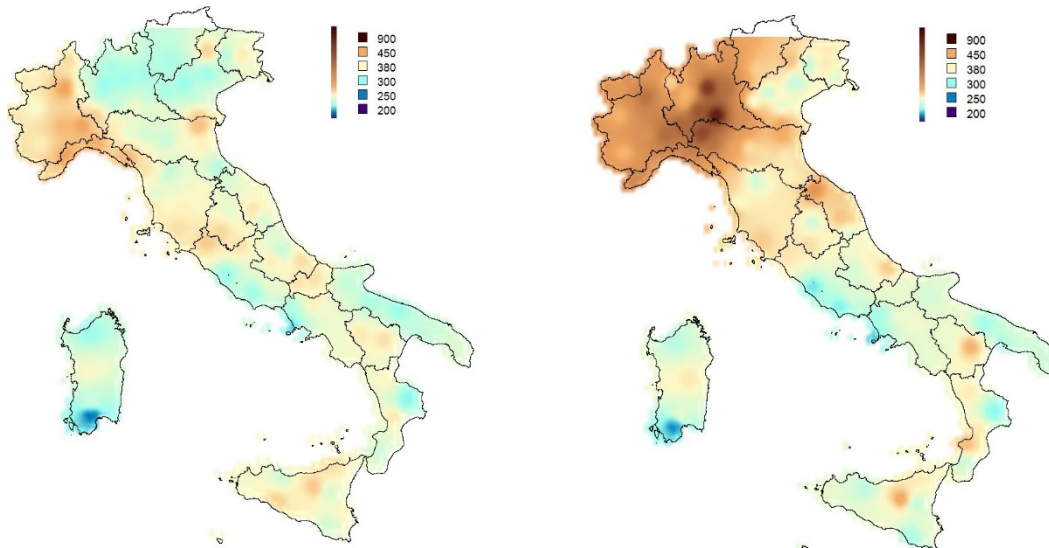


Fig. 5 (a) Deaths per 100,000 inhabitants – Average of years 2015-2019 and (b) Deaths every 100.000 inhabitants – year 2020

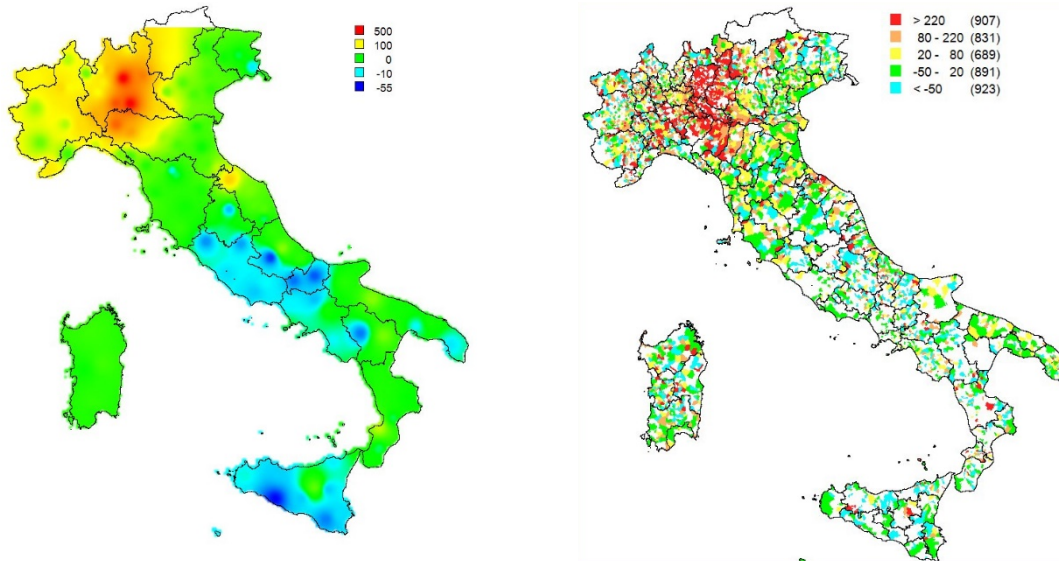


Fig. 6 (a) Variation of deaths per 100,000 inhabitants – year 2020 VS average 2015-2019 and (b) Variation of deaths per 100,000 inhabitants – year 2020 VS average 2015-2019 subdivided for Municipalities

The two figures show the variation in mortality recorded in the same period in the form of a heat map (a) and on a municipal basis (b). The white areas indicate the territories of the municipalities that did not participate in the timely transmission of the mortality data.

Table 3 shows the distribution of mortality by age group and by region.

Region	Mortality Variation - 2020 vs. Average 2015-19											
	[number of death]					[deaths / 100'000 inhabitants]						
	Age					Age						
	0 - 24	25 64	65 - 74	75 -84	over 85	all	0 - 24	25 64	65 - 74	75 -84	over 85	all
Abruzzo	-5	-1	8	-1	73	73	-3.1	-0.3	9.1	-2.0	248.0	9.9
Basilicata	0	-1	3	-31	-9	-38	0.0	-2.0	24.8	-311.6	-164.2	-29.7
Calabria	-3	-7	36	-41	36	22	-1.6	-1.8	49.0	-81.8	162.1	3.2
Campania	-9	-38	22	-150	90	-86	-2.3	-4.6	14.4	-154.0	222.0	-5.7
Emilia-Romagna	-3	229	500	1'035	1'483	3'244	-0.4	11.3	119.9	317.3	960.3	86.8
Friuli-Venezia Giulia	1	-12	-24	-1	30	-6	1.3	-5.1	-44.9	-3.6	184.1	-1.5
Lazio	-8	-80	-2	-99	-10	-198	-2.8	-11.9	-1.3	-110.7	-26.4	-16.4
Liguria	-4	-16	98	318	407	803	-1.8	-2.6	65.8	253.4	663.5	67.6
Lombardia	-7	757	2'229	5'450	7'231	15'660	-0.4	17.7	260.7	836.8	2'619.9	199.0
Marche	-1	38	68	201	341	647	-0.8	9.8	81.1	304.0	1'078.4	88.7
Molise	0	1	-7	-30	-28	-64	0.6	0.7	-35.8	-218.5	-405.9	-38.7
Piemonte	-14	47	245	621	1'267	2'166	-2.6	3.4	78.5	260.7	1'205.7	84.1
Puglia	-9	-5	-22	-125	190	28	-1.5	-0.4	-8.0	-67.0	237.6	1.2
Sardegna	-6	-8	-3	43	125	150	-3.5	-1.5	-3.0	60.5	420.9	16.7
Sicilia	-5	-55	-34	-365	11	-450	-0.8	-4.1	-12.5	-202.0	13.7	-18.0
Toscana	-10	-48	29	50	169	190	-1.5	-3.0	8.2	18.3	133.9	6.4
Trentino-Alto Adige/Südtirol	-5	1	54	90	277	418	-4.9	0.5	119.3	278.2	1'808.2	100.0
Umbria	1	-14	-20	-34	-49	-116	0.6	-4.2	-27.1	-59.2	-177.2	-18.3
Valle d'Aosta/Vallée d'Aoste	-2	-6	18	29	75	115	-8.2	-10.7	143.6	313.8	1'831.0	106.0
Veneto	-27	11	37	354	672	1'048	-3.3	0.6	9.5	120.0	537.1	29.5
Italy	-116	791	3'236	7'314	12'381	23'606	-1.5	4.2	83.2	254.5	973.9	68.5

Tab. 3 Number of deaths in period 01.01 – 15.04 for preCovid period (average 2015-19) and in the year 2020, and difference in age group

A further analysis that has been developed is the one related to the variation of mortality on a municipal basis assuming time as a variable. Fig. 4 shows the overall trend of mortality in Italy and Lombardy and its distribution among the different age groups.

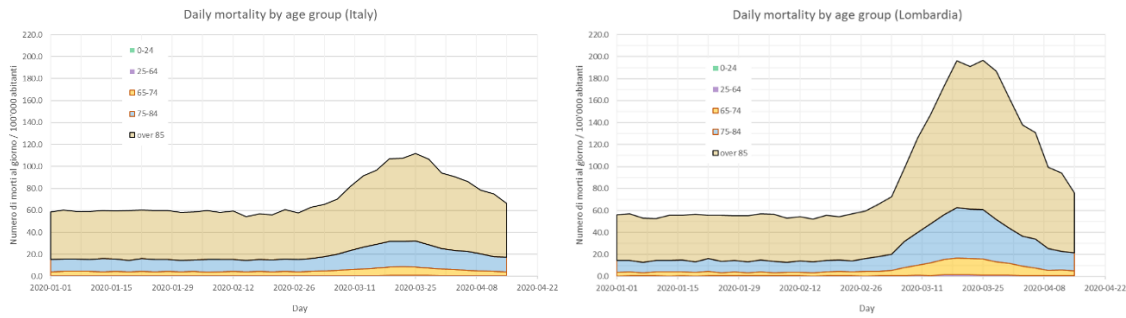


Fig. 7 Time history of daily mortality in Italy (a) and in Lombardy (b) for different age groups

From the analysis of these graphs, some considerations emerge: the age group most affected by the epidemic is that of the oldest population, over 65 years of age and especially for those over 85.

The population groups composed of young (under 25 years old) and adult (25-64 years old) are affected marginally in terms of mortality.

The second consideration regards temporal and spatial aspects: from early March the number of Covid-19 cases in Lombardy was much more notable, implying that the virus had been circulating since at least late February.

The provincial analysis shown in Fig. 5 highlights that the infection started from the province of Lodi (yellow) to first involve Cremona (pink) and Bergamo (dark blue), finally followed by Piacenza (light blue) and Brescia (orange). The province of Milan (green) on the contrary was affected only marginally by the event. The national (red) and regional trends of Lombardy (blue) are reported too and are shown as dotted line.

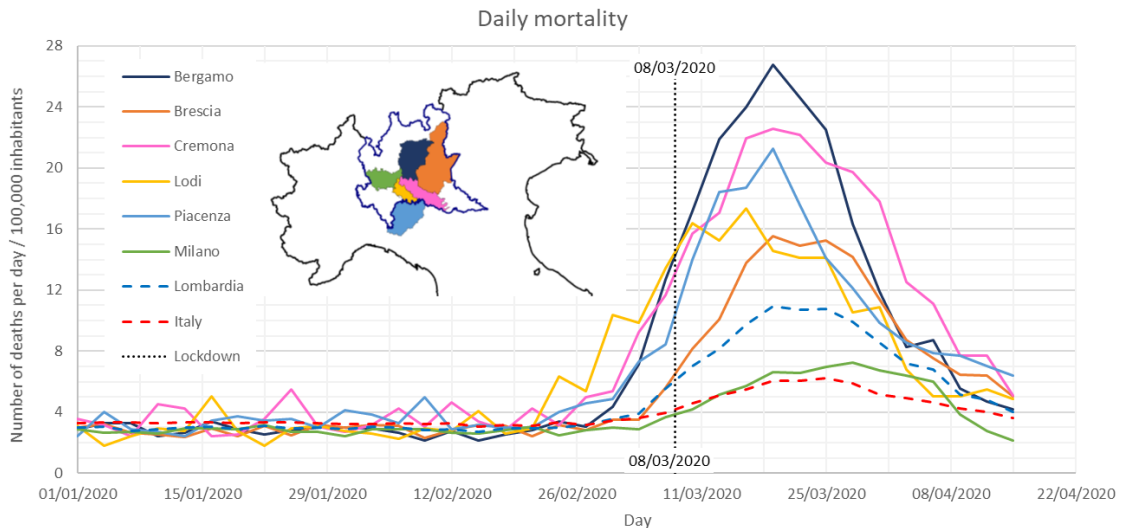


Fig. 8 Time series of daily mortality in various northern Italian provinces

March 8th 2020 is highlighted because it is the day on which the national government announced the lockdown of all of Italy, while restrictive measures were adopted only for Lodi area in the previous days. From this graph it is possible to understand that these measures were adopted only after the disease was already widespread and many deaths had occurred.

Similar considerations can be made at the regional level as shown in Fig. 6. The change in anomalous mortality spread first in the Lombardy region and then continued in Emilia Romagna and Piedmont. The Veneto region did not have a significant variation in mortality, although the first cases of Covid-19 were recorded in that area in the same days in which the cases in the province of Lodi were found.

It is significant to note that the regions of southern Italy, Campania was reported as an example, have had, in relation to the lockdown, a reduction in mortality compared to the ordinary situation.

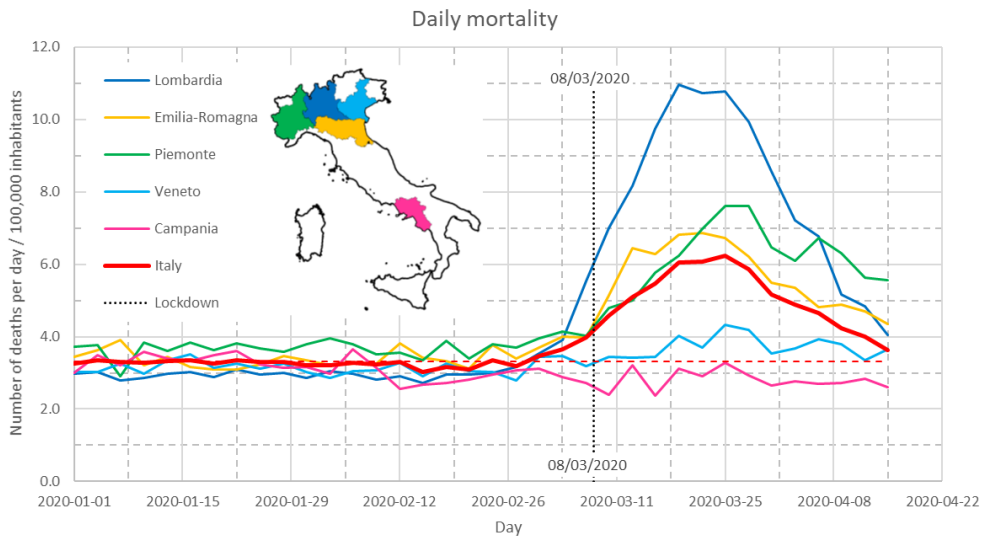


Fig. 9 Time history of daily mortality in some regions of Italy

Finally, the same analyses were performed, based on the data of the individual municipalities, and it was possible to map them.

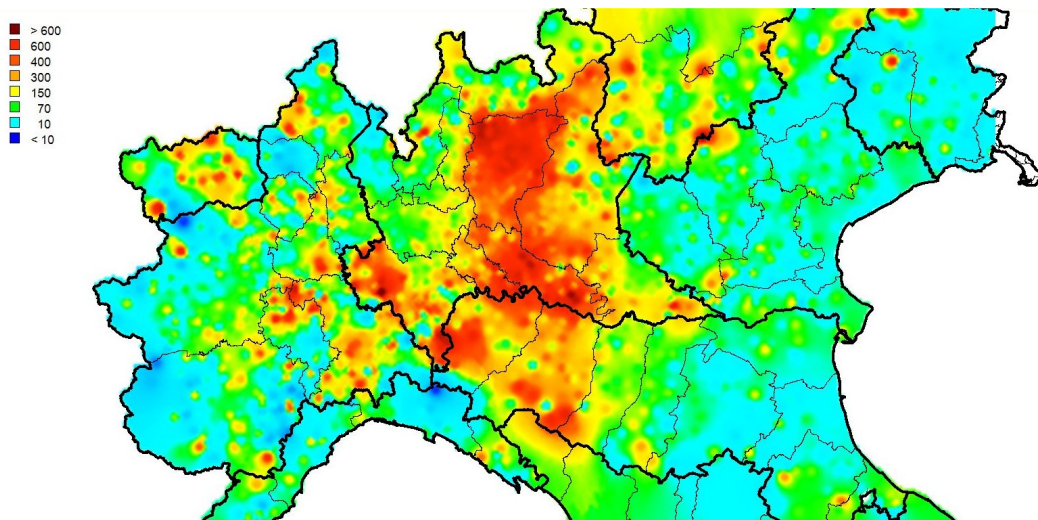


Fig. 10 Deaths variation map 2020 VS average 2015-2019 at municipal level

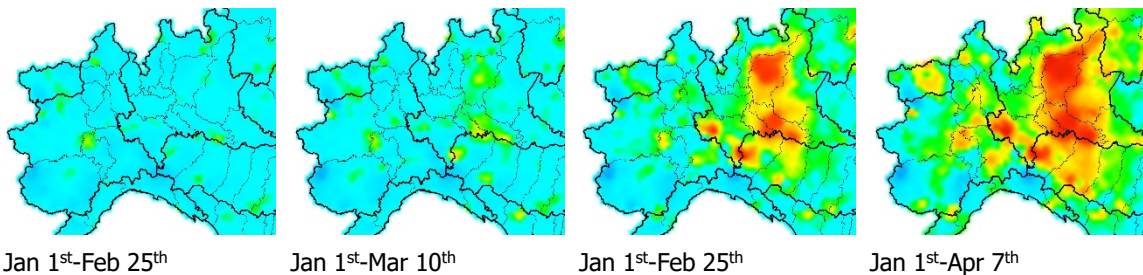


Fig. 11 Deaths variation map 2020 VS average 2015-2019 at municipal level

The maps developed on a provincial scale for the entire national territory show that the area of Bergamo, Lodi, Brescia, Cremona and Piacenza is the one with the highest number of confirmed deaths and with the greatest variation in mortality compared to the previous five-year period.

No further statistical analyzes are presented in this paper about the mortality data presented, however several considerations have been made using the ANOVA variance analysis.

Preliminarily, it was analyzed with a one-way ANOVA analysis if there were no significant variabilities in relation to the 2015-19 mortality data, and if for each province the average deaths in the observation period could be considered constant in the five years considered. This analysis gave a positive result with good significance ($\alpha < 0.05$ for all the provinces considered). The analysis was considered considering the 105-day period divided into 15 weeks. This result made it possible to consider the average mortality of the five-year period as a reference, for each individual province, for mortality variation analysis.

After, a two-way ANOVA variance analysis was conducted to verify whether the variation in mortality observed in 2020 relative to the Covid pandemic was statistically significant different from the variation in mortality for the provinces most affected by the phenomenon (first classification) and in the period following the beginning of the pandemic (second classification). This analysis also gave a positive result.

This kind of analysis was widely implemented to monitor data all over the world. Similar maps and data elaborations have been developed to monitor the level of the disease in England too (Fig. 12).

These maps show the evolution of the phenomena in relations to different parameters assessed with geodata analysis and georeferenced with a desktop GIS software which allows to understand which is the spatial development of the disease.

As it was done for the Italian case, similar analyses were developed for the British case too (Fig.13) in which is explained the outbreak of the virus referred to different scales, such as national or regional (Upper Tier Local Authorities).

The British case study and the Italian ones are similar because they both consider the mortality rate related to the distribution of people because, as it was said by Frank Snowden: "Data for mortality were always more reliable than those for morbidity" (Snowden, 2019).

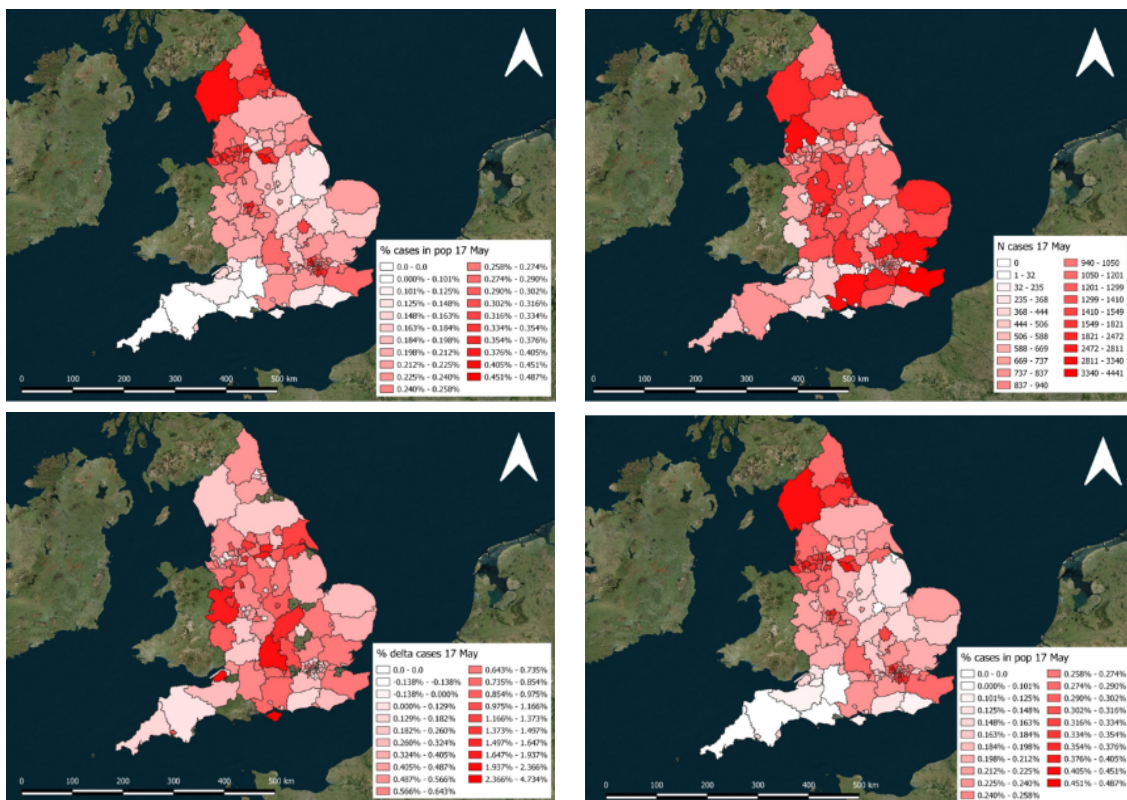


Fig. 12 Example of maps at national level in which different data about the epidemic in England are highlighted.

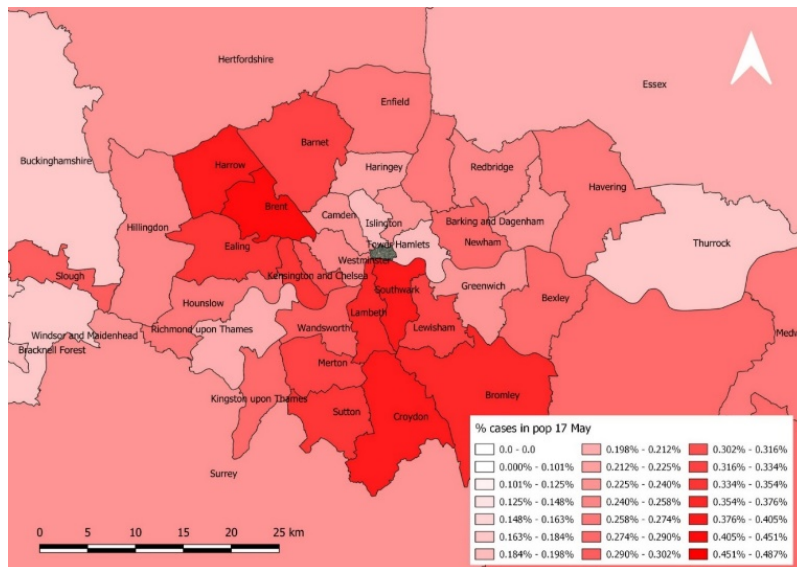


Fig. 13 Example of maps at Upper Tier Local Authority level in England.

2.3 From desktop GIS to dashboards for sharing information and supporting decision-making

The processing of the information layers described above allowed to move to the next step in which the processed data were uploaded on interactive online platforms, with a purpose that could be both communicative and operational (Environmental Systems Resource Institute, 2020a).

Risk communication should not be underestimated. Public administrations, at all levels, often have to manage complex situations linked to environmental health determinants, sometimes in a tense climate. There are many factors that contribute to a rapid aggravation of events. These may also include greater sensitivity to uncertain risks, an unequal distribution of risks and benefits and less trust in institutions and bodies responsible for public health decisions.

This is why it is important to manage information, evidence and communication of possible risks (Environmental Systems Resource Institute, 2020b, 2020c).

The online platforms offer different solutions such as webmaps and dashboards (Fig. 14), in which the georeferenced data are accompanied by a series of interactive and customizable graphs and indicators. Therefore, they are useful to communicate the developed analyses and processed data with possible users. Users that can be both technical analysts employed in the decisions field or common people.

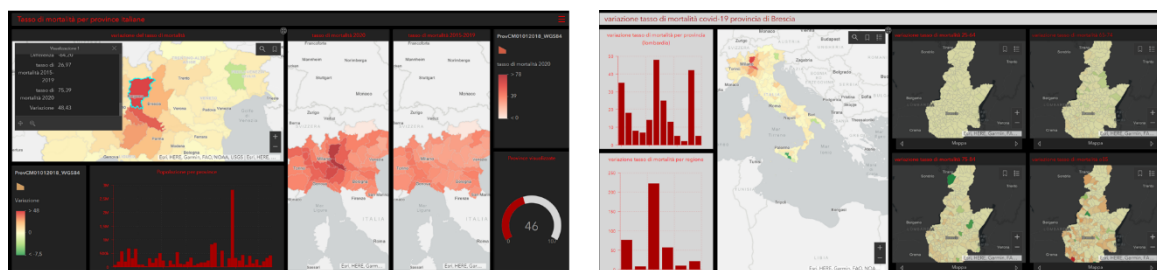


Fig. 14 Example of dashboards with visualization of numerical elaborations and data mapping, in order to highlight the diffusion of the phenomenon at national, provincial, municipal level

This kind of dashboard is highly used worldwide. Thanks to the possibility to customise the interface and add graphs and data they found broad diffusion as a solution to highlight up-to-date data that would help local authorities and residents to make decisions to reduce the impacts of the disease (Geraghty & Lanclos, 2020)

and are an example of how experts in geodata analysis can have an important role in assessing and reducing health risk (Fig. 15).

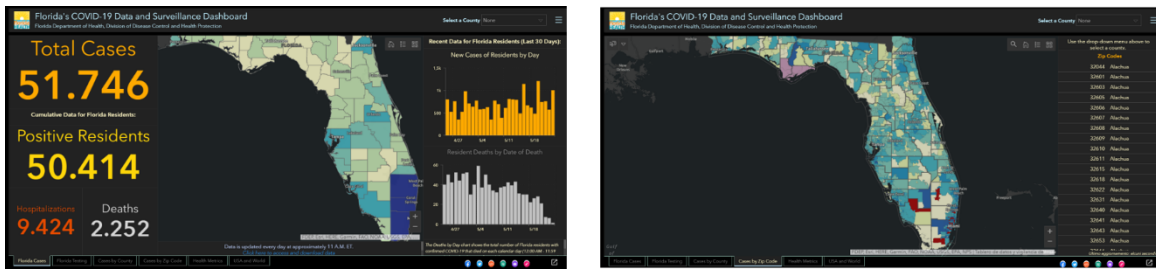


Fig. 15 Example of dashboards developed to monitor the evolution of the epidemic in Florida in which data about the illness have been linked to the ZIP code to obtain the spatial distribution of the virus.

Webmaps and dashboards have the advantage of being able to be interrogated and therefore each object is associated with popups that "explain" the information shown on the map. They also offer the possibility of comparing different cartographies, namely, with the creation of dashboards it is possible to highlight different themes in parallel, thus allowing to immediately observe the variation of the analysed phenomenon in relation to previously fixed parameters.

This type of tool has a double value: on one hand it can be used to provide citizen with information on the phenomenon and its evolution and, on the other side, it can be a grounding point to build a system for the monitoring phase that can provide data to engage the decision-making process at all levels.

For communication purposes, data are shown in aggregate form, without violating the privacy rules (Environmental Systems Resource Institute, 2020a). This, in fact, is a very sensitive issue in the world of online applications, as there is risk of disclosing personal information. However, by showing the overall value by territorial portions, the point references to individual cases are lost and only the general trend for the analysed area is shown.

Different is the case in which the applications are intended for decision makers for the emergency phase in which the aggregate data may not be enough.

3. A lesson for the future: knowing how to provide support for risk management and decision making

What have we learned from this pandemic that has affected one of the most populous areas in Italy?

The need to have a system for monitoring phenomena connected to health risk has certainly emerged, aimed at promptly intervening and implementing procedures to contain the spread of the phenomenon.

We have seen that GIS can be, for this purpose, an important support tool, both from an operational point of view and as a communication and information tool, thanks to the spatial-temporal mapping of data. What everyone sees, after an event has occurred, is nothing more than the consequence of previous actions (or failure to act). In other words, a highly vulnerable area will be struck heavily by a calamity, not because the event is exceptional, but because the area is not sufficiently protected against that eventuality.

We now add that this implies the need to tackle latent emergencies, before they actually arise. The latent emergency concept is fundamental for understanding the "risk mitigation" concept.

If it is understood that an area has some imminent hazards, it is necessary to act in order to reduce the damage. Given that, for example, we cannot prevent earthquakes, all we can do is try to draw as near as possible to $V = 0$ so that we can face on the events without suffering damage.

The three systems to be worked on, with structural and non-structural operations, are:

- the health organization, which expresses the vulnerability of the system;

- the social system, which expresses the social vulnerability; this includes all the measures of a collective nature that can be put in place, such as more careful regional planning;
- the political system, which expresses management (or organizational) vulnerability. In this case, “political” means the ability to equip ourselves, forward thinking in the organization of human resources, precise planning, but also creating public awareness and generating agreement on technical/organizational measures, necessary in order to prevent things from happening, and not after an event has occurred. If the politician/decision-maker ignores the seriousness of the latent phase, the vulnerability of the regional system increases exponentially.

These first studies carried out on the pandemic from Covid-19, with an in-depth study of the Lombardy provinces, show how appropriate and indispensable it is to prepare surveillance, prevention and limitation plans for the disease, in order to modulate the health risk. Diagnostic ability is essential for disease control and surveillance (the topic is discussed in many papers, among others we mention Ascione et al., 2013; Torrisi et al., 2017; Gargiulo et al., 2018).

As with all dangerous situations, what must be assessed is the socially acceptable risk of a present danger.

In the case of the Covid-19 pandemic, the Lombard system has proved in our view extremely vulnerable from a systemic point of view. The management of human health has not been able to contain the spread of the phenomenon, on the one hand by not promptly identifying the first cases of contagion, and then, with the large numbers, not having the adequate structures to deal with the health emergency.

A systemic vulnerability that has dragged individual vulnerability (it is sufficient to think about the age groups most affected), thus amplifying the overall risk. There is certainly also a need to reflect on the general rejection of what was happening. It is surprising that the finding of the virus in a young patient with incurable pneumonia was random and not the result of a monitoring plan that was to be expected.

Western countries are united in their failure to recognize the globalization of disease: if a person can travel from Beijing to Milan in 12 hours, so can a virus!

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Image Sources

Fig.1: Processing of ATS Brescia and ATS Valle Camonica;

Fig.2: Processing of ATS Brescia and ATS Valle Camonica;

Fig.3: Processing of ISTAT data (Deaths 2015-2020, observation period Jan 1st-Apr 15th);

Fig.4: Processing of ISTAT data (Deaths 2015-2020, observation period Jan 1st-Apr 15th);

Fig.5: Processing of ISTAT data (Deaths 2015-2020, observation period Jan 1st-Apr 15th);

Fig.6: Processing of ISTAT data (Deaths 2015-2020, observation period Jan 1st-Apr 15th);

Fig.7: Processing of ISTAT data (Deaths 2015-2020, observation period Jan 1st-Apr 15th);

Fig.8: Processing of ISTAT data (Deaths 2015-2020, observation period Jan 1st-Apr 15th);

Fig.9: Processing of ISTAT data (Deaths 2015-2020, observation period Jan 1st-Apr 15th);

Fig.10: Processing of ISTAT data (Deaths 2015-2020, observation period Jan 1st-Apr 15th);

Fig.11: Processing of ISTAT data (Deaths 2015-2020, observation period Jan 1st-Apr 15th);

Fig.12: Processing of PHE - Public Health England data;

Fig.13: Processing of PHE - Public Health England data;

Fig.14: Processing of ATS Brescia and ISTAT data;

Fig.15: Geraghty & Lanclos, 2020;

Tab.1: Processing of ISTAT data (Deaths 2015-2020, observation period Jan 1st-Apr 15th);

Tab.2: Processing of ISTAT data (Deaths 2015-2020, observation period Jan 1st-Apr 15th);

Tab.3: Processing of ISTAT data (Deaths 2015-2020, observation period Jan 1st-Apr 15th).

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