ENVISIONING RESILIENT CITIES for a POST-PANDEMIC ONE HEALTH FUTURE

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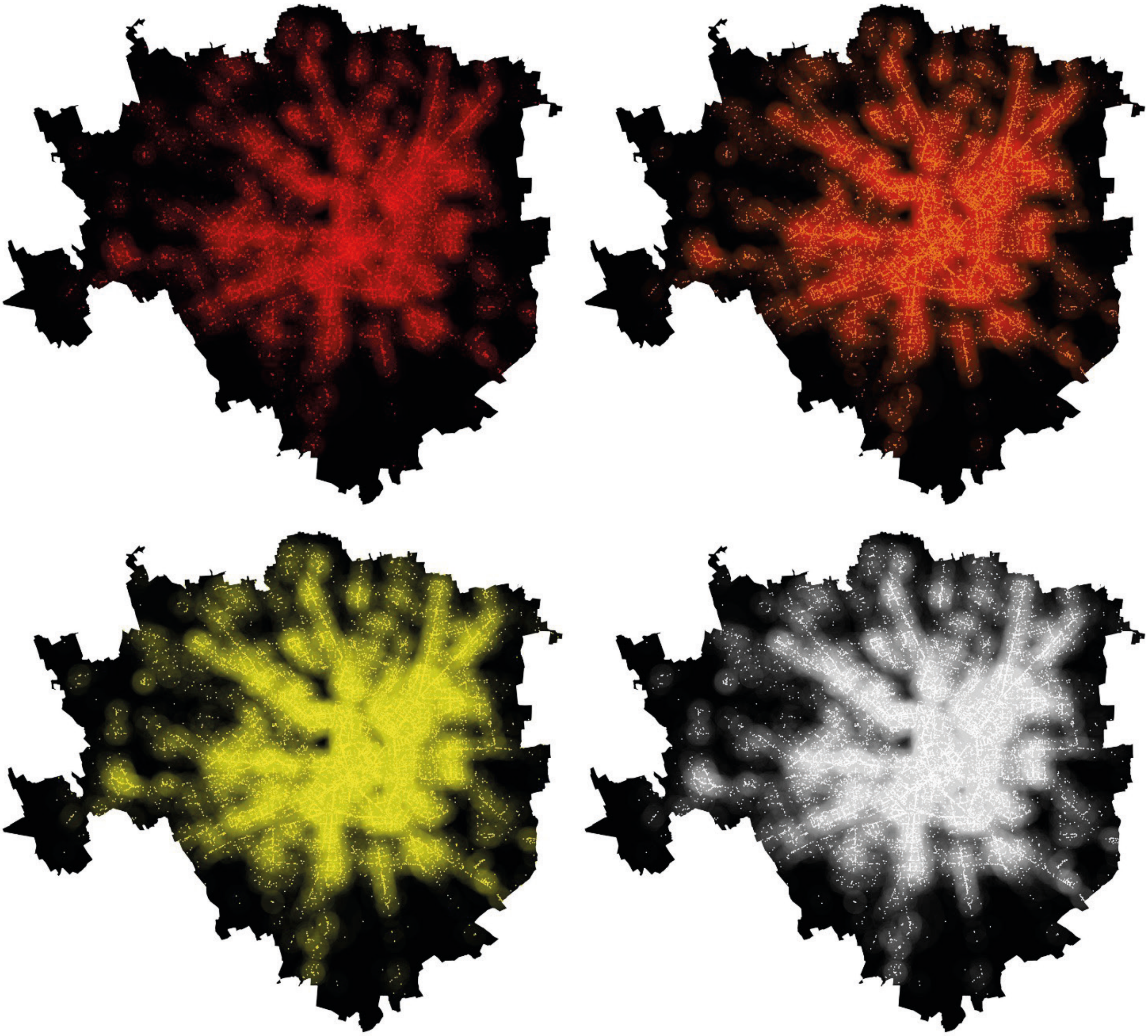

Heatmaps representing the total number of open activities during the colored zones restrictions. Source: author elaboration

[SCh 4] Lessons from the Pandemic: Mapping Urban Resiliency and Robustness

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ABSTRACT

This article contributes to highlight the role of urban form in the debate of urban resilience and robustness using the elements of IMM methodology to read the impact of COVID-19 on urban systems. Milan is used as case study to map how the pandemic restrictions impacted different areas.

1. Introduction

In the last two years COVID-19 hugely impacted people's health and habits on a global scale.
In particular, cities have received a lot of media attention as they have been the scene of over 90% of cases (United Nations 2020). The unusual conditions that urban systems were asked to adapt highlighted the differences between cities and between areas of the same city. The restrictions that have been imposed and the difficulties in carrying out normal daily life and restoring a pre-pandemic condition, pushed many to wonder if COVID would definitely change our cities or even spell their end. In order to answer, it would be necessary to understand how long it will be able to change the way we live our cities. There is not agreement on this front. We cannot predict the emergence of new viruses (Geoghegan and Holmes 2017) and we do not know if this virus will become just one of the endemic viruses of our communities, will be eradicated, or will never disappear (Ryan 2020).

Even without certainty on the evolution of the pandemic we can certainly say that rethinking cities tailored to COVID would be a serious mistake given on one side the unpredictability and variety of potential challenges on the horizon (natural or anthropogenic disasters), and the persistence of many unsolved wicked problems (Rittel and Webber 1973) already characterizing urban settlements worldwide (pollution, poverty, congestion, access to services etc.). In fact, as much as today the pandemic seems to us a top priority, it is good to remember that the World Health Organization (WHO) has also other big challenges to face (WHO 2020) in addition to the major trends underway such as climate change and the loss of biodiversity. The attention of urban studies in the last years shifted from the concept of sustainability to that of resilience (Stumpp 2013) trying to limit sectorial views encouraging a more holistic approach. Even if the research community, and also the civic society, agrees on the fact that cities need to become resilient and robust systems able to adapt to a wide range of changing conditions easily and rapidly, this transition is still not straightforward.

There is no doubt that the pandemic has been a dramatic sanitary event that made even more evident the problems existing since long time in urban contexts. However, it gave the opportunity to look at our cities and habits from different, sometimes unimaginable, perspectives. This article wants to learn from the pandemic how to shape more resilient and robust cities. For doing that, it first reviews the existing literature on these terms and the different facets of their opposite (fragility and vulnerability), identifying a specific position for the discourse on urban form in the dimension of robustness, identifying in the Integrated Modification Methodology (Tadi, Zadeh, and Biraghi 2020) a good framework to work within for trying to evaluate the ability of urban modifications to increase the resilience of a system (section 2). It then reviews how evolved in the literature the debate on how urban structure affects the performances of urban systems, shows how the pandemic put in crisis also rooted practices of urban planning and collects some of the initiatives taken by the most proactive municipalities worldwide to mitigate the impact of the pandemic often taking advantage of this exceptional situation to boost already ongoing plans and projects (section 3). Section 4 presents some experiments conducted by the authors on the case study of Milan, focusing mainly on ground floor activities, investigating how some of the restrictions imposed for the containment of the infections unevenly affected different areas of the city, with proved consequences on the proximity level and potential ones on the infection rate (not proved).The conclusions (section 5) trace different possible research lines both at the theoretical and practical level to verify what hypothesized here based on structural properties, to extend this approach to new experiments and to implement a comprehensive urban resilience assessment framework.

2. Theoretical backgrounds

2.1 Urban resilience and robustness

The concept of resilience has been for the first time introduced by Holling (1973) in ecologic context as "the persistence of relationships within a system" and "the ability of these systems to absorb changes of state variables, driving variables, and parameters, and still persist". Concerning the similarities of the cities and living organisms as both are known to function as a complex system, the concept was later borrowed to urban studies as "urban resilience". According to OECD the "urban resilience" in simple words, can be defined as "the ability to absorb, recover and prepare for future shocks" (OECD 2021).
As noticed in the work of Stumpp (2013), in many cases the transition from sustainability to resilience has been more a change of label than a change of paradigm. Speaking about resilience to climate change (Morecroft et al. 2012; Jabareen 2013) is comparable to studying environmental sustainability but is no more enough. As confirm, there is "a whole spectrum of global environmental changes that interplay with interdependent and rapidly globalizing human societies". Resilience can thus be against a chronic or slow onset stress or compounding long-term stressors. This holds true for resilience in cities when considering sudden crises (natural or man-made) as well as interacting long-term trends (e.g., climate change, biodiversity loss, rapid urbanization, declining public services, increasing violence and growing social exclusion) (Patel and Nosal 2016).

Many authors described resilience in different ways but most of them agree on the need of developing properties as system robustness, redundancy, and rapidity/reactivity (Norris et al. 2008; World Bank 2015). Related to the disaster and addressing its risks, "urban resilience" and the related actions to increase it could be divided to two sets. The first is called "preparedness" and refers to the anticipation of expected and unexpected disasters taking measures to increase the flexibility and adaptive capacity accordingly (Labaka et al. 2019). According to the first part of Urban resilience definition by Klein, Nicholls, and Thomalla (2003), in this stage resilience is defined by "the amount of disturbance a system can absorb while retaining a state similar to the original" this often relates to the robustness and unaffectedness of the city which happens before the shock event (Pirlone and Spadaro 2020).
Robustness in a city comes from being proactive. In other words, it is essential to anticipate the future shock, predict its possible results and prepare for that. A 'robust city' is safe, stable, and unaffected by external and natural shocks, often by means of additional and better technology and physical infrastructure (Meriläinen 2020).
The second part of resilience often related to self-organization, is known to be more reactive. This means that after the shock, regardless of the previous preparedness and its defects which can have led to losses in the system, it is important to act based on the current exact situation and condition to "quickly return to normal" (Pirlone and Spadaro 2020).
According to Meriläinen (2020), the first requires a "top-down" approach while the latter is more related to a "bottom-up" one. Previous studies point out that resilience, as much as the shock itself, is site-specific (Vale and Campanella 2005). Therefore, for a proper definition of resilience in a specific context it is essential to understand how different components of the specific context are functioning together. Because city resilience is a complex, multidisciplinary phenomenon, focusing on a single or small number of contributing factors ultimately results in partial or inaccurate conclusions and misrepresentation of the multiple causes

of the phenomenon (Jabareen 2013). Adaptiveness, which is highly linked with resilience, requires the synergic work of all actors who live or work in a city.

Looking to the opposite terms, having a negative meaning, two terms can mainly be found in the literature: fragility and vulnerability. Fragility is often discussed related to social aspects and is particularly used in the Italian context and for booming cities in developing countries (Muggah 2014). According to Selby and Desouza (2019), fragility is framed as a function of unresolved fractures of social compacts that degrades a city's ability to function over time and stress exacerbates its effects. On the other side, vulnerability is often discussed in environmental issues specifically with specific attention to climate change. According to Salas and Yepes (2018), its most accepted definition is the degree to which a system (entity) is susceptible to, or unable to cope with, adverse effects of environmental threats. More precisely, it is a function of the character, magnitude, and rate of the threat to which a system is exposed, its sensitivity, and its adaptive capacity. In other words, vulnerability has been conceptualized as an entity's susceptibility to harm from exposure to environmental (unavoidable) threats. The advantage of these terms is that they are easier to be measured respect to resilience.

2.2 Assessing urban resilience

It is clear that applying resilience to systems involves identifying how processes are interrelated and can therefore create cascading chains of disruption (vulnerability) and recovery (resilience) (Pirlone and Spadaro 2020). Knowing the importance of identifying the contributing factors in urban resilience, different previous studies have established various sets of categories and sub-categories trying to explain different components of urban resilience. Ostadtaghizadeh et al. (2015), for example, in a systematic review of assessment models for community disaster resilience, summarize ten models that attempt to measure community resilience and suggests that the concept can be understood using five dimensions: 1) social, 2) economic, 3) institutional, 4) physical, and 5) natural.

Measuring urban resilience is important to allow decision makers to address city fragilities and vulnerabilities, and a wide variety of work exists to guide selection of indicators and metrics (Patel and Nosal 2016). An example is the Fragile Cities web portal ("Fragile Cities" 2021) , that collects statistical data for many world cities and use them to compute customized fragility indexes.

However, a key aspect to be deepened is the assessment scale of urban resilience. The city in fact risks being a too broad scope and the indicators used, also to cope with data availability, if on one side can be acceptable for the social, economic, and institutional dimensions, they can hardly be used to guide modifications of the physical and natural ones. To properly investigate the physical dimension, narrowing down the scale of analysis is crucial, intervening on the different sub-systems the city is composed. In this article, the city is considered a dynamic Complex Adaptive System (CAS), generated by the superimposition of a huge number of components connected to each other and organized in subsystems, which are themselves complex adaptive systems. In fact, their arrangement and the architecture of their links define specific unique and provisional physical-formal organizations that we refer to as an urban system. The city, in fact, as a complex system, simultaneously involves many systems, including energy, built structures, water and sewers, food production and distribution chain, waste management, transport, health and biodiversity, but also economic, social, and cultural systems. In this sense, the city can be defined as a system of systems.

The Integrated Modification Methodology (IMM, Tadi, Zadeh, and Biraghi 2020) seems a promising framework to perform this additional step in the assessment of urban resilience. IMM is a model-based approach able to define through an objective qualitative and quantitative representation, the structure of city as a CAS and its performance in a defined time. In IMM, urban diagnostic analyses patterns of problems and the malfunctioning conditions of the system. The identification of the nature of malfunctioning condition by systematic investigation makes possible eventually to quickly recover the system from unpredictable behavior when faced with unexpected perturbations. Its multi-scale nature allows to investigate urban subsystems from the block up to the city scale. The IMM city dismantling into components (Volumes, Voids, Networks and Type of uses) and their integration for the description of more complex urban properties (Key Categories) are here adopted to frame both literature and experiments. The mapping experiments of section 4 refer to the Type of Uses Component and to the Proximity Key Category, that are only a small part of the aspects usually investigated (Porosity, Permeability, Accessibility, Interface, Effectiveness, Diversity).

A combination of this approach with tools like the vulnerability analysis matrix (Jabareen 2013) and decision-making methods in conflicting multi-criteria scenarios (Zionts 1973) could significantly increase the awareness on the preparedness level of urban form in the different contexts. As this study moves from the physical dimension of resilience, the following sections try to show how to ensure robust built environments working in the domain of prevention and uncertainty-oriented planning.

2.3 Robust urban structures

It is now commonly accepted that urban form can have a significant impact on environmental performances and people's quality of life (Jabareen, 2006; Nijkamp and Finco', 2009). The current global scenario sees extremely varied settlement phenomena ranging from the formation of boundless urban agglomerations (mega-cities), mainly in developing countries, to the creation of new cities (new towns) also in Western countries, to cities that contract (shrinking cities) to cope with changed boundary conditions. Considering the great variety of physical, but also economic and social contexts, it is difficult to think of an urban form or a building typology capable of solving all the problems of our cities.Most of the recent literature in urban studies focusing on environmental sustainability deal with the optimisation of urban form according to a specific aspect to improve the overall system performance. This often-created paradoxical situations due to the lack of a systemic and holistic approach (Bettencour 2013) because the optimisation of one component (catalyser) might have negative impacts on others (reactants, Tadi et al. 2020). The switch to the resilience paradigm made this aspect even more evident and the questions that were usually told, immediately obsolete and incorrect.

For example, the property of redundancy, desirable in resilient systems (Norris et al. 2008; World Bank 2015), is incompatible with the optimization processes.

We are still far from a full understanding of how to achieve a robust urban structure but at this stage, the key aspect is identifying the right path to be followed. This path is long, complex and requires holistic methodologies, as the one proposed, to be travelled but is also the only possible one to avoid the mistakes generated by methodological shortcuts. An example can be the evolution of the concept of density, characterized by very contradictory results in the correlation with social, economic, and environmental factors, that was initially condemned to the point of creating urban sprawl, then become in many policies the "panacea for a sustainable life" (Boyko and Cooper 2011), and now attacked again as responsible for the spread of COVID-19. The reasons for this swing of success can be found both in a deterministic planning approach and in the nature of the concept itself, too generic to precisely determine modification of the urban structure. The attention has now swift to the concept of compactness or city of short distances, characterized by a high density of use, short travel distances and associated with a higher quality of life (Schwarz 2010), but again, there is no agreement on its definition and measurement.

Many studies try to find correlations between one or more specific morphological aspect and performance aspects (air and noise pollution, CO_2 emissions, energy consumption etc.) falling in the trap of simple and partial outcomes. The two aspects, structure, and performance, can be independently investigated and morphological aspects deserve more attention and better methods. This can be done only with methodologies able to look at the very local scale to grasp the fine grain differences between urban structures and modifications. The next section contains a collection of critical urban aspects that the recent pandemic highlighted putting in crisis also aspects well routed in the contemporary planning practice

3 COVID stress-test: learnings

3.1 Observable trends

Coronavirus is neither a problem nor a crisis. Coronavirus falls into the category of wicked problems (Rittel and Webber 1973) which, without a global mitigation strategy, will perpetuate the domino effects and feedback loops (OECD 2017). The pandemic has exacerbated problems already present since long time in urban contexts. Similarly, many of the solutions in response to it are processes already underway since some time that have seen a sudden acceleration (teleworking, home deliveries). We start talking about blended city, characterized by an approach both online and offline not only to work but to the way of life (BBC, Chee 2021). As Norman Foster (2021) said: "Every crisis has accelerated and amplified the inevitable". In fact, many polls show that most people don't want to go back to normalcy, made up of travel, office, and large inequalities (Pomeroy and Chainey 2020).

Large European cities have seen an exodus of hundreds of thousands of people, sometimes as much as 10-20% of their population. These inhabitants, mostly temporary, preferred smaller towns more in contact with nature once the need for work ceased. This may create a demand for new or improved local services by emerging a pattern that includes dispersed groups of commercial, cultural, employment and public space offerings that serve dispersed populations (BBC, Kayden 2021). In support of this hypothesis there are the data relating to the resumption of commercial activities after the restrictions imposed, which in the case of Manchester have seen small towns perform better than the city centre (Maginn and Hubbard 2021). Although we are inclined to consider the compact urban structure typical of city centres as more resilient, the current commercial and tertiary offer is oversized and cannot do without mass transport, which has however suffered a 90% reduction in use revenues (MSCI 2021). Until now, public transport has been strongly promoted for its competitiveness in terms of environmental impact with respect to the use of cars (Gutiérrez, Miravet, and Domènech 2020). However, the pandemic has shown that it is preferable to invest in pedestrian and cycling infrastructures, activities that are less vulnerable or more resilient, safe from the point of view of contagion and even more sustainable for the environment and for the mental and physical well-being of people (Capolongo et al. 2020).

The use of public transport has in fact accelerated infections due to the proximity between people, both inside and outside the vehicles, which it inevitably entails, and the restrictions imposed by local governments, although theoretically useful in the initial stages of an epidemic (MUG et al. 2020), are often difficult to respect and therefore not sufficient. Those who had the opportunity have taken refuge in the use of cars and consequently traffic congestion, after the forced decline in times of lockdown, has already regressed, exceeding pre-Covid levels in some cities (BBC, Simons 2021).

With regard to air pollution in relation to the pandemic, two aspects can be identified. The first is that the majority of cases and deaths have been found in those cities where people are exposed to greater air pollution. This is both because the atmospheric particulate matter acts as a transport vector for many chemical and biological contaminants, including viruses (Setti et al. 2020), and because the virus in question attacked the respiratory tract. The other aspect was the evident drop in the concentration of some specific contaminants as a result of the lockdown periods, the closure of production plants and the reduction in travel (Collivignarelli et al. 2020).

Another aspect highlighted by the pandemic is that of inequalities. From India to the United States, we have seen an explosion of cases, especially among the poorest strata of the population, many of whom are forced to live in extreme conditions that favor, if not ensure, the spread of the virus (Albert Henry 2020). It therefore appears evident that it is not density (Carozzi, Provenzano, and Roth 2020; Hamidi, Sabouri, and Ewing 2020) that promotes the spread of the virus, but the lack of density management, i.e., overcrowding and the consequent lack of access to adequate housing, health, education, transport services and sources of water, energy. and public green spaces (Gandhi S 2021). Tadi et al. (2021) presented an example that well represents all these aspects comparing two nearby areas in Istanbul, Şirinevler e Ataköy, showing the relationship between morphological features (and the related socio-economic implications) and the spread of the virus.

3.2 Cities resilient initiatives

What we have learned from the recent pandemic is that large urban centres are now more vulnerable to external shocks and events. However, we know that more collaborative and integrated cities are better prepared to manage these events than those that are not (Costa and Peixoto 2020). Unpredictable events, natural, health, environmental disasters could happen anywhere and at any time and cities, as complex systems, are particularly vulnerable in the face of these events without an adequate resilience capacity. The cases presented in this section are just a limited sample of all the ongoing initiatives currently on the planning tables of municipalities worldwide.

Barcelona can be surely considered as a pioneer municipality as it started already in 2013 to implement strategies for improving its performance. The first step has been the Climatic plan 2013-18 (Ajuntament de Barcelona 2014) that introduced more than 500 Supermanzanas, 400m x 400m super-blocks generated by the aggregation of 9 blocks on a 3 x 3 grid, converting more than the 60% of car space into a mix-use pedestrian one for social interaction. It then Approved an Urban Resilience Plan in 2016 with the goal of becoming a "self-sufficient city composed of productive neighborhoods at human scale and speed, within a hyper-connected metropolitan area with zero emissions" (Ajuntament de Barcelona 2016).

In 2020 The European Investment Bank approved a €95 million loan to help Barcelona complete around 40 projects, with a focus on climate action and social inequalities. Among those there is an extension of the supermanzanas project starting in 2022 aiming to create 21 green streets and squares dedicating to the pedestrians use up to 33.4 hectares (Ajuntament de Barcelona 2020).

Another very active is Paris, guided by its major Anne Hidalgo and her intention to apply the 15 minutes city (Moreno et al. 2021) principles. Car-free transit and pedestrian infrastructures have already been doubled (Sisson 2020) and the plan is to maintain after the pandemic 50km of traffic lane temporarily reserved to cyclists (The Local fr 2021).

London officials began a "Streetspace" project in 2020, creating temporary bike lanes and widening pedestrian zones as commuters tried to avoid the dangers of crowded subways and buses. The project aims to make it easier and safer for people to keep up social distancing, encourage people to walk, cycle or scoot, prevent an increase in car use and enabling deliveries, emergency services and essential vehicle journeys from becoming gridlocked and keep London's air as clean as possible to protect everyone's health and tackle the climate emergency (London Assembly 2020).

From New York arrives the six-feet city (Sadik-Khan and Solomonow 2020; Popescu 2020), a vision of a future cities that respects the recommendations of the epidemiologists enlarging sidewalks and converting car space into pedestrians one for allowing safe, socially distant mobility, crating open-air commercial districts, and making outdoor classrooms and civic activities. In addition, the Transit Tech Lab announced the COVID-19 Response Challenge to adopt new technologies, ranging from air filtration to digital monitoring, to restore confidence in public transportation (BBC, Haot 2021).
Milan started interventions of tactical urbanism already in 2018 with the conversion of car streets and parking into temporary squares that then became permanent after a phase of monitoring. The approach is characterised by minimal non-invasive interventions like painting the ground and positioning urban furniture like benches, pots, and ping-pong tables (fpsshare 2021). During the pandemic, the Piazze Aperte (open squares) project has been launched gathering 65 new proposals for similar interventions around the city (Comune di Milano 2020). In the meanwhile, the municipality also announced a project that foresees the destination of 23 kilometres of road for the exclusive use of cyclists, always following a tactical approach, and the creation of new area with a speed limit of 30km/h (Urban 360 2021). All these initiatives are coherent with the 15 minutes city model that the Major decided to pursue even if an official comprehensive plan has not been implemented yet.
It's not by chance that all these initiatives focus on soft mobility. In fact, municipalities needed to find an alternative to public transportation able to perform well for both pandemic and climate change issues. Intervening on the Network and Void components, modifying the street area, they had freedom of action and the opportunity of enhancing the value of their own property. Working on other components requires more time and agreement with a multitude of actors (Volume) and the modification strategy is not so straightforward (Type of Uses) as the experiments in the next section tries to demonstrate.

4 Milan shops case studies

4.1 Object of the analysis

To make a step towards a fine grain investigation of the resilience/robustness of urban systems it is necessary to look at the local scale, that of neighborhoods, blocks, and single streets, and to map the level of preparedness of the different city components. This article, aware of the more general framework previously outlined, focuses only on the Type of Uses component in the city of Milan during the different phases of the pandemic. More precisely, it wants to show how the "colored zones" restrictions unevenly affected the city.
The purpose of this maps is not to propose any ready-made solution for the displacement of activities in the city nor to move any critic to the restriction measures adopted. They wish instead, to highlight the complexity in downscaling resilience planning and how even consolidated planning practices, result of long-time optimization processes, can generate vulnerable places for this specific kind of risk (the pandemic).
The "colored zones" (Ministero dell'Interno 2020) are a measure imposed by the Italian government in order to fight the spread of COVID and they are characterized by a progressive opening of commercial activities and services following intensity of the pandemic. Even if the guidelines were provided by the Italian Ministry of Interior at a national level, every region and every municipality was allowed to adopt stricter measures. Lombardy region was the most affected one, with the highest number of both total cases and deaths (Google 2021) and also among those adopting more severe measures.
The four zones ranged from red, corresponding to the lockdown periods where only essential functions were left open, to white, where all the shops and restaurant were open but with a limited capacity and the need for the customers of wearing personal protection equipment. A lighter zone (e.g., orange) always allowed the opening of the activities open also in the stricter zone (e.g., red). Table 1 summarizes all the zones and the

[SCh 4] Table 1. Activities allowed to remain open during the colored zones restrictions. Source: author elaboration

Zone	Open activities
Red	food shops, basic necessities, news agencies, tobacconists, pharmacies and Para pharmacies, laundries, hairdressers and barber shops
Orange	all shops, excluded those inside malls on holidays and days before holidays
Yellow	Bars and restaurants with limitations of opening time and capacity
White	All the shops and services

activities that were allowed to open.
The investigation has been articulated in three phases. First, the whole city has been considered showing the impact of the restrictions, in terms of number of open shops, both for the city and for each "Nucleo di Identità Locale" (NIL), 88 neighborhood-like areas in which the city has been divided. Then, a focus on the malls, how they have been affected by the closures and how their partial opening impacted on the surrounding areas has been performed. Finally, areas with a high concentration of essential activities (open during the lockdown) in a limited physical space have been identified using a clustering algorithm highlighting the potential risks of such "hotspots" for the spread of the disease.

4.2 Data sources and processing

Open datasets regarding the commercial activities are often missing, incomplete, divided into many separate and partially overlapping layers. It is the case also for the city of Milan that presents a collection of georeferenced point layers available on the Open Data city portal updated to 2018 (Portale Open Data | Comune di Milano). These data have several limits that required a pre-processing. The actual division does not match the categories of the different colored zones, for many features the attribute table is incomplete, some activities are included in more than one dataset sometimes with a slightly different location (few meters) and some others doesn't even have a valid corresponding geometry as the attributes for the georeferencing are missing.
The OpenStreetMap (OSM) data have the advantage of adopting a unique classification criterion and the relevant attributes (or keys) are available for a good percentage of the geometries (98%) but the total number of features (5'582) is still significantly lower than the authoritative datasets (16'505). For this reason, the data of the Municipality, namely the following layers, have been used:

- ds555_uffici_postali_milano_final (post offices); ds290_economia_botteghe_storiche_2017 (historical shops).
- ds589_grandi-strutture-di-vendita-nel-comune-di-milano_5pzf-etyy_final (large sales structures);
- ds612_negozi-e-locali-storici-georeferenziati-nel-comune_puf6-2m2d_final (historical shops);
- ds690_tabaccai_ordinari_e_speciali (tobacconists);
- economia-artigianato-settore-alimentare_2018_coord (food artisanal shops);
- economia_esercizi_vicinato_sede_fissa (shops);
- economia_media_grande_distribuzione_coord (medium and large distribution);
- economia_panificatori_coord (bakeries);
- economia_parrucchieri_estetisti_centri_abbronzatura_coord (personal services);
- economia_pubblici_esercizi_fuori_piano_2018_coord (bars and restaurants inside other activities);
- economia_pubblici_esercizi_in_piano (bars and restaurants);

Regarding the malls, as no official dataset exists, a new one has been created starting from the OSM shops polygon layer and integrating information from the websites of the different malls and other online sources
The pre-processing consisted in extracting subsets of specific layers and group them according to the zone classification; removing the duplicate geometries after merging the different source layer into a new single one; deleting the features without a corresponding geometry. A new field was added to classify the activities in small, medium, and large sales structures based on the commercial surface. This operation was done to differentiate large sales structures during the phases of the pandemic and to have a simple attribute to be used for scaling the catchment area of the points while doing the heatmaps. All these operations and the following maps and analysis have been done using QGIS 3.16.4.

4.3 Results

Activities

The first aspect that has been investigated is how different areas, characterized by heterogeneous urban structure, were affected by the restrictions imposed. Figure 1 collects a map for every color zone showing a heatmap and the single points concurring in its generation. The heatmap was created by generating a simple round buffer around every point with a radius corresponding to the sale structure size classification (400m; 800m; 1'200m). The buffers were then displayed in the color of the corresponding zone using an opacity of 1% and selecting addition and overlay respectively as layer and feature blending mode. A summary of the data used to construct these maps is reported in Table 2

From these maps it is possible to notice how if one side the city centre maintained a significant number of open activities also during the red zone, it is also the area where in the other maps, especially the yellow and white zones, an overall increase in brightness can be noticed. It is also clear how important commercial systems (north-west axis), visible in the white map, resulted more fragmented in the red one with a final effect of passing from a continuous line to a dotted one.

Also, peripheral areas with a small number of activities in the white zone were significantly affected, almost disappearing from the map in during the red zone. In Figure 2 the NILs are classified according to the ratio between the activities open during the red zone (R) and those open during the white zone (W).
As this metric will be used other times in the article, we'll refer to it as R/W. From this map, also the north-east commercial axis made of Corso Buenos Aires, Via Padova and Viale Monza becomes more evident. In addition to what emerged from Figure 1, it can be noticed that certain areas, in black, had no open activities during the lockdown (Stephenson; Parco dei Navigli; Ronchetto delle Rane).

These areas have less than thousand inhabitants and very low population density values and experienced a desert of function during the harder months of the pandemic with no proximity at all.
Also, larger and more populated areas (Parco Forlanini – Cavriano, 0.15; Maggiore – Musocco – Certosa, 0.24) experienced a closure of more than three fourth of the activities. Interesting is also the case of three recently developed areas as Tre Torri (City Life), Cascina Merlata and Scalo Romana that scored respectively 0.1, 0.25 and 0.28. This highlights that the presence of essential activities is still poor and didn't follow the arrival of new residents in the area. The last thing that can be noticed is how the railway ring often separates areas belonging to different classes.

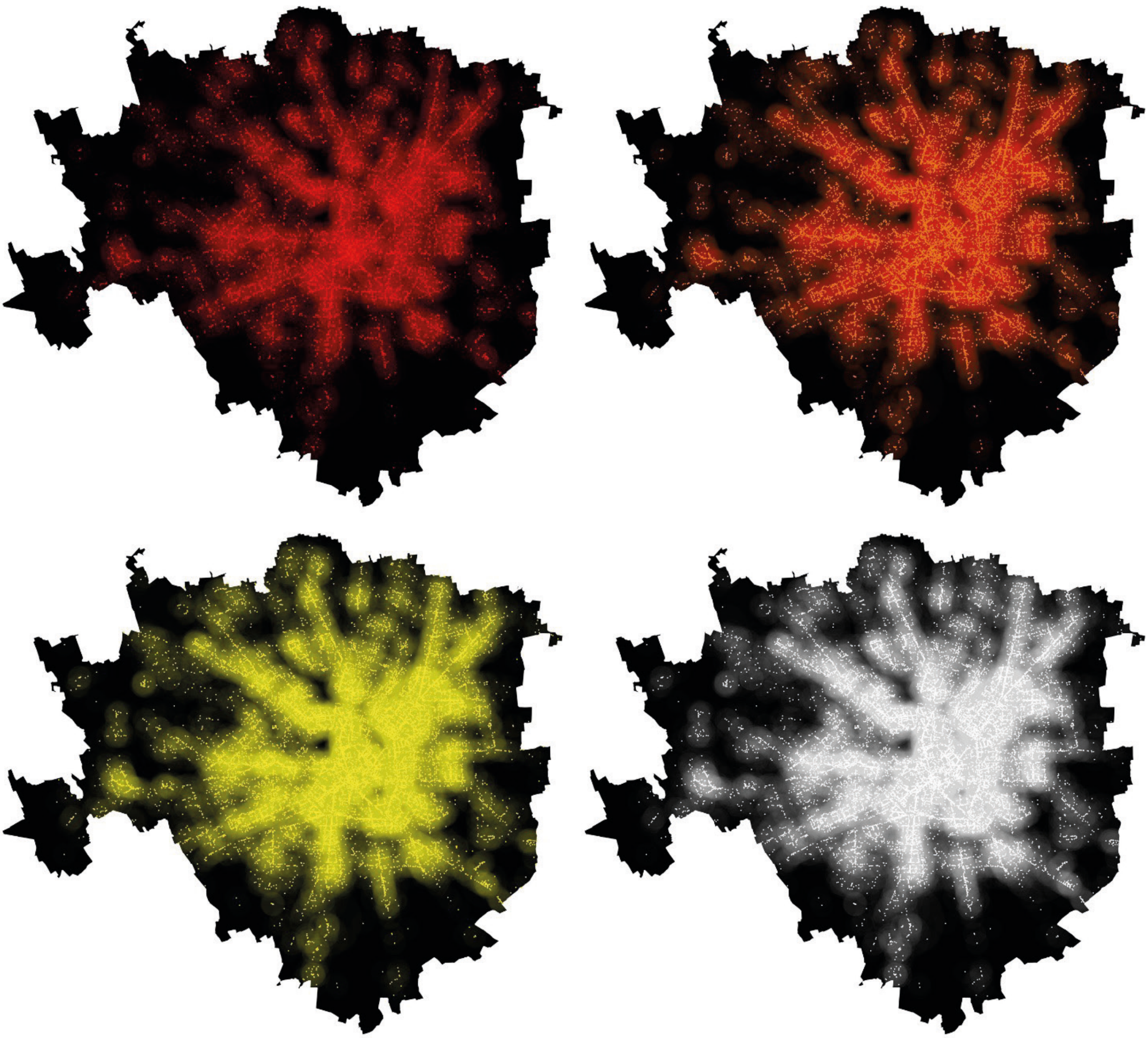
Malls
Passing to the analysis malls, it is necessary to remember that this list doesn't come from any official source, and it is the result of the integration of different online sources. For this reason, there might be other structures in the city at least comparable to those included in this sample. One example is The Oriental Mall, located in Via Paolo Sarpi, excluded because it wasn't possible to get the information about the number and the typology of shops inside it.
Similarly, to what done for the whole city, the activities open during the red zone were compared to those open during the white zone. The reason for looking at malls is that the restrictions imposed forced them, on holidays and days before holidays, to practically be in the red zones for at least 3 days per week even during the orange and yellow ones. In Table 3 the malls and the NILs they belong are compared showing the R, W and R/W value for the sole mall, for the NIL it belongs and for an 1km buffer area around the mall centroid.
This last column has been computed because the NILs consistently vary in size and to also consider those activities nearby the mall but laying in a neighboring NIL.

The Mall column mainly helps us in distinguishing different types of malls and their attractiveness at the city and metropolitan scale. The recently open City Life Shopping District has the lowest value (0.08), that is coherent with its metropolitan echo, while Centro Commerciale Bonola (0.16) has a more local character. Unicenter is a very small sale structure in comparison to the others and mostly contains essential activities in an area characterised by urban sprawl and a relatively low density as Bovisasca NIL. This explains its very high value of R/W (0.75). The NIL column adds details to what presented in Figure 2 and shows the need of overcoming administrative geographical units to perform this analysis. In fact, the range of the values is smoothed in the last column (1km buffer) where, however, interesting differences still emerge. Centro Commerciale PiazzaLodi R/W value (0.45) is significantly higher than that of Centro Commerciale Bonola (0.31). This can be easily explained by the morphology of the surroundings (Figure 3), by the accessibility to the mall, mostly intended for pedestrian in the first case and for cars in the second, and by the size of the mall itself.

[SCh 4] Table 2. Comparison between the total number of features and those with a valid geometry. Source: authors elaboration

Zone	Total number of open activities	Total number of open activities with a valid geometry
Red	8'320	7'744
Orange	16'505	14'037
Yellow	20'381	16'933
White	20'794	17'166

[SCh 4] Figure 1. Heatmaps representing the total number of open activities during the colored zones restrictions. Source: author elaboration



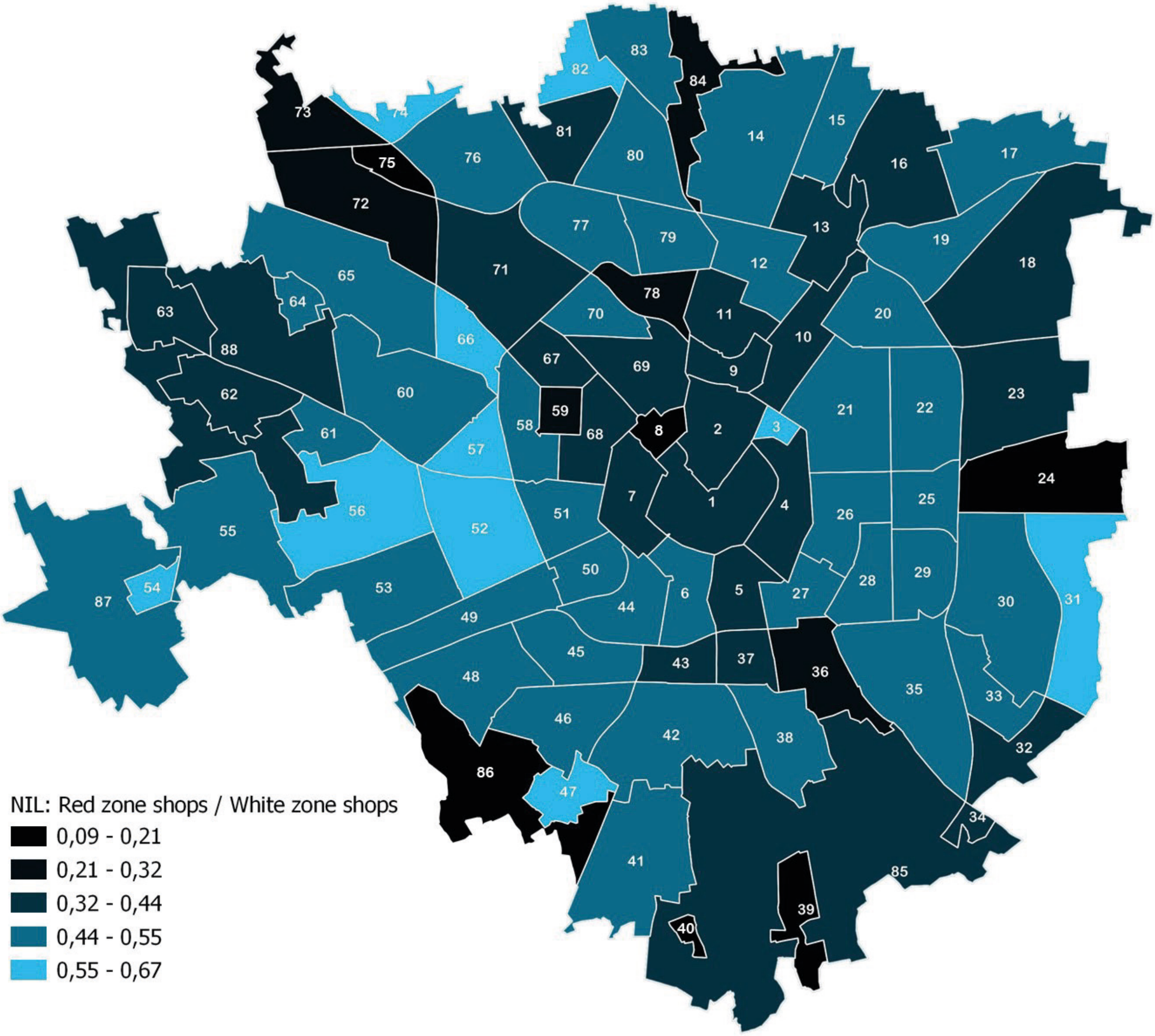
Clusters/Hotspots

The last aspect that has been investigated is the identification of potential hotspots for the spread of the virus. The assumption is based on the direct observation and report (Milano Today 2020) of long queues outside the few open shops during the pandemic (e.g., up to 3 hours for the post office and 40 people for the bakery) generated by the limited number of open activities, by the limited capacity of the activity in order to maintain the safety distance and by the fact that people were not working or in smart mode.

For this reason, those areas characterised by a high concentration of activities always open during the lockdown (red zone) in a limited space have been identified using the DBSCAN clustering algorithm of QGIS testing different maximum distance values (25; 50 and 100m) as input. At 25m, the largest clusters were in Via Marghera (10 activities), Corso San Gottardo (9) and Via Paolo Sarpi (9); at 50m in the area of the former Lazzaretto (41), mainly in Via Panfilo Castaldi, Via Lazzaro Palazzi and Via Lecco, and again in Via Paolo Sarpi (26, with Via Messina and Via Aleardi) and Corso San Gottardo (23); finally, at 100m, in a large area on the south of Piazza Duomo (119), particularly in the blocks around Via Torino, Via Mazzini and Via Orefici, and again in the Lazzaretto (53) and Paolo Sarpi (48) area. Figure 4 compares the three areas that presented clusters at least at two distances showing them at the same scale with a red convex hull grouping the activities concurring in the formation of the cluster on a figure-ground map.

According to the authors, the most representative and potentially risky clusters are those at 25m both for

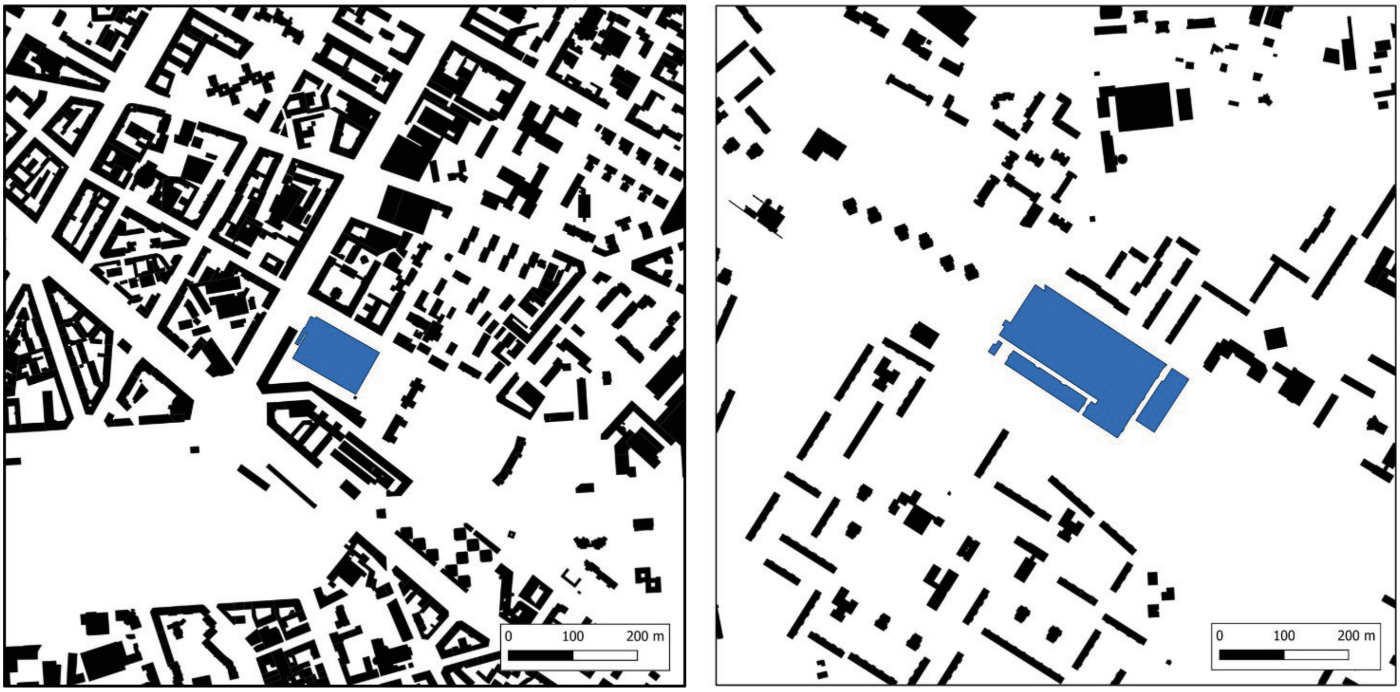
[SCh 4] Figure 2. NILs classification according to the R/W ratio [R = activities open during the red zone (R); W = activities open during the white zone (W)]. Source: author elaboration



[SCh 4] Table 3. Comparison of the Malls in the study and the impact of the restrictions on the number of open activities in the mall, in the NIL and in 1km buffer area. Source: author elaboration

		Mall			NIL			1km buffer		
NIL	**Mall name**	**R**	**W**	**R/W**	**R**	**W**	**R/W**	**R**	**W**	**R/W**
BOVISASCA	Unicenter	6	8	0.75	21	51	0.41	26	72	0.4
VILLAPIZZONE - CAGNOLA - BOLDINASCO	Portello	5	45	0.11	185	501	0.37	196	446	0.41
Q.RE GALLARATESE - Q.RE SAN LEONARDO -	Centro Commerciale Bonola	10	62	0.16	68	178	0.38	40	97	0.31
TRE TORRI	City Life Shopping District	7	92	0.08	12	116	0.1	207	500	0.36
UMBRIA - MOLISE - CALVAIRATE	Centro Commerciale PiazzaLodi	3	30	0.10	117	240	0.49	316	676	0.45
BICOCCA	Bicocca Village	8	48	0.17	45	126	0.36	69	169	0.35
STAZIONE CENTRALE - PONTE SEVESO	Stazione Centrale	9	89	0.10	181	515	0.35	448	1037	0.41
PORTA GARIBALDI - PORTA NUOVA	Stazione Garibaldi	6	22	0.27	95	229	0.41	408	937	0.43

[SCh 4] Figure 3.Ground maps of the context of Piazza Lodi and Bonola malls, highlighted in blue. Source: author elaboration



the closeness of the activities and also because they usually interest a single street. While Via Paolo Sarpi is a pedestrian area, with the whole street width at disposal, Corso San Gottardo is not but luckily it has quite large sidewalks. However, its cluster interests both sides of the street for a length of nearly 100m. Great concentration of people may discourage pedestrians to walk through and, in this case, no alternative path with a similar length could be found. Looking at 50m clusters, in the first two cases we have simply an extension of the 25m ones involving side streets while in the area of Lazzaretto, the upper part of the cluster is generated by a grid of four perpendicular streets with very narrow sidewalks. Finally, clusters at 100m are probably less warning as it's difficult to imagine having great concentration of people in such large areas. However, in a case like Paolo Sarpi, the sole in the whole city where clusters emerged also at shorter distances, this information can be relevant with the area of potential risk becoming significant.

4.4 Discussion

These maps and data show aspects made visible by the pandemic restrictions with the purpose of demonstrating how they significantly modified the normal urban system behaviour. They all highlight potential vulnerabilities of the Type of Uses Component that can be seen as a lack of preparedness to this specific kind of crisis.

This doesn't want to be a critic to the city planning, also given the unpredictability of what happened, nor to paint in a negative light a specific area, that could have had a better performance respect to the one here descripted. Their purpose is to reflect on how each crisis might suffer or benefit from different arrangements of urban components, with implications at a very local or fine grain scale.

Looking at the proposed experiments from a different risk perspective, like that of climate change, interesting things can be noticed. From the first one, we can notice that great concentrations of optional or occasional activities in few areas require people to commute and a certain share of this movement is still polluting and congesting our streets. If malls confirm their negative performance as energy-intensive structures often promoting the use of cars, grouping essential activities in a car-free zone with high accessibility is surely a positive thing.

The complexity of these issues discourages any ready-made and globally acceptable solution while requires a full understanding of urban system structure and performances and the integration of the different dimensions of resilience. Vulnerable structures, unable to effectively perform under different crisis scenarios, can and should be rethought. On the contrary, as seen in the clusters example, a structure that well answers the challenges of climate change, that however surely remains a priority issue respect to COVID, shouldn't be modified every time for the new emergencies.

The laws and the measures temporarily modifying urban structure and consequently its performance should be tailored to the needs of every context, possibly exploiting the advantages of smartly managed cities.

[SCh 4] Figure 4. Areas of potential risk of exposure due to the concentration of open activities during the red zone. Source: author elaboration

5 Conclusions

This article wants to make a step in the direction of defining an operative methodology for assessing urban resilience at the various scales. It assumes IMM methodology as a good theoretical infrastructure to operate in this direction but recognizes the need to delineate a more comprehensive and exhaustive resilience framework. This could be done by creating a matrix-like model showing the implications of any experienced and future risk for cities on the different urban components, identifying those structures, maybe not yet in place, able to perform positively in the widest range of conditions. As resilience is a context-specific property, the outcomes of this model should possibly be weighted according to the risks' probability of occurrence, which varies case by case.

New experiments can also be done to simulate how the restrictions imposed affected the other urban components and explore the emergence of both positive and negative aspects. For example, the presence of private open-air spaces or the proximity to green infrastructures (Porosity KC), the change in transportation offer and demand (Effectiveness KC) or the suspension of mobility restrictions (Permeability KC). These additional studies, as well as the one here presented, would then greatly benefit from a comparison with dynamic performance data (social network, sensors) to understand the reliability of preliminary structural simulations as the one presented.

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