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Resilient urban form addressing pandemic crisis

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Abstract

The pandemic experience of COVID-19 motivated this work, which addresses the need to integrate resilience concept with urban morphology in crisis-time. Indeed, the physical form of cities is relevant in developing their capacity to deal with stressing events and changing conditions. Thus, since citizens' lifestyle will be drastically influenced, the novel Coronavirus pandemic and related global challenges addressing cities and their inhabitants appear both an unexpected and interesting occasion to study the practical role of resilience to deal with pandemic conditions also at urban form level, with long-time perspective. This virus has certainly raised the need to re-discuss the paradigm of planning, designing and managing the city under pressure passing through the concepts of resilience, disturbance absorption and system reorganization. Thus, learning from the first lessons of COVID-19 at the urban and neighbourhood level, this paper provides some practical reflections that can be useful, to both academics, policy-makers and professionals, in identifying resilient urban forms capable to confirm urban properties already in place or to highlight new needs and requirements to deal with this disturbance. In this sense, the present crisis is arising a lot of questions around the urban form properties that may have favoured or limited the current and future spread of the infection, with the final purpose to make cities liveable, healthy and safe again. To reach that, the concept of "resilient urban forms" needs to consider both the physical and nonphysical aspects of the urban built-environment.

In this regard, the effort to "add some words" to this ground-breaking framework on "Resilient Urban Form in time of Pandemic" might contribute to the development of a new research frontier for merging spatial-principles, urban resilience concepts and public health studies, providing both theoretical inputs for further debate and practical ideas to increase urban longevity.

Keyword: *resilience, urban morphology, change, pandemic crisis, transformation*

Introduction

Nowadays cities are growing in number, size, scale and complexity, influencing both their social, economic, institutional profile, and their physical structure. This dynamic condition exposes them to many pressures and different kinds of change. In this contest, the form of cities takes an active role in dealing with new emerging requests, which might be totally or partly different from those they were originally planned and designed for (Marcus and Colding, 2011). Indeed, the capacity of cities to face, adapt to or transform in time of crisis, and thus "to be resilient", will affect the survival and the functioning of the urban system for years. However, today in urban design and morphology studies, resilience is still considered a very innovative concept and is far from being progressively integrated in the discipline and in its operational practice. Therefore, the current emergency-contest of the COVID-19 pandemic experience appears both an unexpected and interesting occasion to define the practical role of resilience in dealing with pandemic conditions also at urban form level (Sharifi and Khavarian-Garmsir, 2020), outlining some practical reflections that can favour the identification of resilient urban forms capable to confirm the efficacy of some urban properties already in place or to highlight new needs and pathways to deal with this stressor. To reach that, it is crucial to find proper answers to the following research question: “How are resilience concept and urban form related in the COVID-19 pandemic contest? Along this crisis, is resilience an endpoint for urban form or rather a property of urban environment?”.

To facilitate this exploration, the present work analyses the diffusion behaviour of COVID-19 within New York City (NYC) neighbourhoods, trying to understand which urban characteristics, considered promising for resilience in literature, have favoured or limited the rise of the disease and thus, how (and if) they contribute to the resilience of the pandemic city. These findings can be useful among academics, policymakers and professionals to advance broader debates on urban longevity, adaptivity and transformability and also to develop a new research frontier on “resilient urban forms in time of pandemic”, where spatial-principles, urban resilience concept and public health studies are integrated.

In terms of structure, the paper starts with a background overview, useful to understand the overall research, describes the methods applied to address the issues, then discusses the results contents, and finally moves to the conclusions, highlighting the main findings of the work and also some limitations.

Background

The growing challenges faced today by cities worldwide point out that they constantly change. In this sense, considering them as “socio-ecological systems” where people and natural-built up environments are interdependent networks (Folke et al., 2010 and Davoudi et al., 2013), introduces an interesting interpretation where cities are viewed as “integrated entities”. In this perspective, their processes and structures interact over time at morphological, ecological and socio-economic levels. Here, the recent “evolutionary” interpretation of resilience, so called “evolutionary resilience” (Davoudi et al., 2012), seems a particularly appropriate ability for cities in need of changing, adapting and transforming in face of strains and stresses, without returning completely to a previous state (Carpenter et al., 2005; Simmie and Martin, 2010 and Davoudi, 2012). In a nutshell, this capacity allows urban systems to survive and succeed in response to uncertainty, adversity and change, re-defining themselves through innovation (Sharifi, 2018).

However, the integration of this concept with urban morphology features is not immediate, as the link between urban science and the adaptive renewal cycle proposed by Holling and Gunderson (2002) is still lacking (Marcus and Colding, 2014). But this traditional image of the physical urban elements (rigid and inflexible) is progressively replaced when thinking about the city-broad reaction to different types of shocks, stressors and unexpected variables, where design and urban form elements get inevitably influenced, adapted or transformed by the new conditions. Sharifi (2019) argues that “resilient urban forms” include qualities that enhance the urban system ability to maintain adequate levels of performance under instable circumstances. In short, urban form interested by any changing experience is based on a double level of analysis: the spatial level and the systemic level, which is less visible than the first one but very dynamic and active too. As a consequence, when addressing more explicitly the crisis experience of COVID-19 within an urban-neighbourhood contest, a better knowledge of the pandemic patterns on the built-environment is needed in order to identify the most effective spatial and systemic features in responding to the virus diffusion. In this regard, this infection experience can offer an excellent opportunity to understand how cities affected by contagions can minimize their impacts through proper resilient spatial attributes, stressing again the "old debate" on the potential urban vulnerabilities to pandemics and infections (Matthew and McDonald, 2006). In this sense, as highlighted by Sharifi and Khavarian-Garmsir (2020), even though several urban forms and design elements can affect the dynamics, the early literature is mainly focusing on density issues and how its levels are (or are not) responsible for the rapid spread of the virus (Hamidi et al., 2020; Boterman, 2020; Lin et al., 2020; Qiu et al., 2020; and Cartenì et al., 2020). The paper broadens this trend and proposes further topic-reflections.

The selection of a case study

In order to tangibly investigate the state of the art in this study-contest, the work focuses on a case-study, corresponding with New York City neighbourhoods, recognized through the 177 ZIP Codes[1]. The first case of Coronavirus disease in New York state was recognised in a laboratory on the 29th of February 2020. After some days (11 March 2020), the World Health Organization (WHO) declared a global pandemic, and cases in New York City (NYC) continued to rise. Thus, being that NYC soon became the US pandemic epicentre, with a transmission degree five times higher than the rest of the country and with some neighbourhoods experiencing more infected and/or fatalities than others, it is interesting to investigate which characteristics of the built-environment have a role in the COVID-19 test positivity and death rate. To date, a growing number of studies is progressively focusing on this topic (Borjas, 2020; Desjardins et al., 2020; Maroko et al., 2020; Nguyen et al., 2020; Sy et al., 2020; Truong and Asare, 2021; Whittle and Diaz-Artiles, 2020, Urban System Lab, 2020), suggesting that physical features, together with socio-economic components, can affect the risk of infection. More specifically, because of the multifaceted interrelationship between space and its socio-economic features, and because of the evident consequences of this relationship on population-health, it became quite immediately clear that in the contest of this pandemic crisis and of this complex case-study, the two features should be considered separately but together. Indeed, a specific study based exclusively on spatial factors of urban environment may appear partial, limited, and not completely related to the real systemic contest. In a nutshell, it is assumed that in order to understand the efficacy and role of the built

[1] ZCTAs represents a reasonable balance between the larger County units (where spatial heterogeneity may get lost), and the smaller census tracts that might be so small that individuals would often use subway stations outside their census track.

environment at urban level (in this case, at neighbourhood level) in dealing with the pandemic crisis and threats, it is necessary to understand also the functioning of the socio-economic dimension as co-participant determinant of the virus circulation.

Therefore, the aim of this work is to identify potential spatial and systemic determinants of the COVID-19 diffusion rate at neighbourhood-level and understand the ability of these factors in tackling the stressor. Through this exercise, it will also become more evident which role resilience concept can cover.

Methodology

In this study, a mixed method research design is adopted, as also evident from the two typologies of data applied. From one side, the research method is based on a desk study that qualitatively explores the current literature on resilient urban forms and on the definition of the so called "urban form properties", suggested from literature. This approach has led to the definition of some spatial and systemic factors that can favour the understanding of resilient urban forms at local level. This qualitative content analysis then, in a second step, will be integrated with the stressor information.

On the other side, quantitative data on tested people, positive COVID-19 cases and victims are collected for 177 Zip Code Tabulation Areas (ZCTA) of New York City (covering 99.9% of the population), directly from the Health Department's COVID-19 GitHub repository, an online data source that contains data on Coronavirus Disease for the whole city. Data have been weekly collected, then monthly grouped through average values, and also thematically grouped (by fatality, positivity and tests topics) through entire average values from March 2020 to March 2021 (yet different timeframes have been produced, since data on tested, positive cases and victims are not available homogenously). When analysing data, "rate" is considered the most effective pandemic representation, also able to relate different typologies of data (physical, socio-economic, etc.). Once that the rates of tested people, positive COVID-19 cases and victims have been collected, then the study develops linear regression analysis to relate each of them to the built-environment features and read any possible direct or indirect associations.

In terms of built-environment components, those spatial and systemic characteristics considered (from literature) to be influent in urban resilience perspective and also in the spread of the disease were collected at ZIP Code scale (Table 1).

After confirming the reliability of proxies-information, they were put in relationship with data about COVID-19 positivity rate (on tested people per ZIP Code from June 2020 to March 2021) and deaths (on the total ZIP Code population, from June 2020 to March 2021), by linear regression analysis (developed through excel and R-software).

Table 1. Physical and systemic features considered in the COVID-19 spread at ZIP Code level.

Feature	Description	Data source
Population density (people/sqm)	Quantity of people per square mile(sqm) in each ZIP Code.	2010 US Census
Household size (average)	Persons per household, obtained by dividing the number of persons in households by the number of households in each ZIP Code.	2010 US Census
Family size (average)	Average number of people in a family per ZIP Code.	2010 US Census
Green areas (% of GA in relation to the total ZIP Code surface)	Gardens, parks and playgrounds, treed plazas and small green areas (parterres, etc.), fields or meadows not destined for agriculture are considered as green areas.	New York City – Official web site
Commuting time (mins)	Average duration of commute to and from work or an educational establishment in each ZIP Code.	ZIP Atlas portal
Public transport use (%)	Percentage of people using public transport regularly (daily base) to move in each ZIP Code.	ZIP Atlas portal
Work from home (%)	Percentage of people working regularly from home in each ZIP Code.	ZIP Atlas portal
Seniors over 65 and 75 (%)	Categories related to the most vulnerable groups in terms of contagion risk, at ZIP Code level.	ZIP Atlas portal
Occupation categories (% employees in each category)	Percentage of employees in 13 occupation categories for each ZIP Code of NYC.	American Community Survey (ACS) - 2018
Income levels (average by ZIP Code)	Average of year-income amounts in each ZIP Code (average in US$)	ZIP Atlas portal

In terms of spatial distribution of positive cases and deaths within the city, complete excel files and updated maps (a sample from the 20th of April 2021) from the Health Department clearly show how different rate values of COVID-19 cases and deaths are miscellaneously occurring within the city by months (Supplementary Materials - Figure S1 and S2). In this way, the merging exercise between data released by the NYC Department of Health with physical and non-physical issues from other sources (see Data Sources in Table 1) produces a broad description of the spatial and socio-economic characteristics that in each ZIP Code impacted more (or less) on the COVID-19 spread. In the further step of results and discussion, a good measure of model's accuracy was the value R^2, the coefficient of determination, that measures the strength of a linear relationship between two variables, with values between -1 and 1.

Results and Discussions

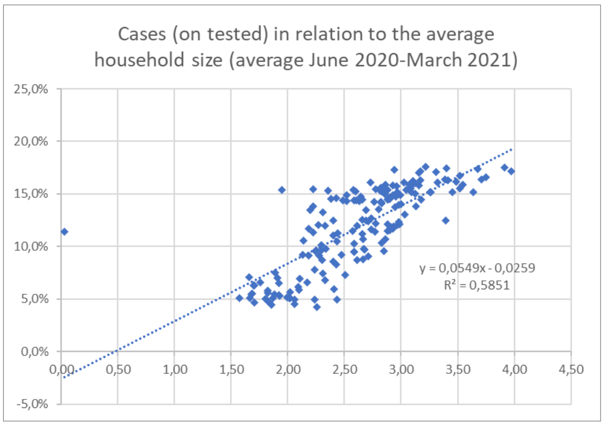
The critical contribution of this work is to identify physical and “non-physical” factors, so called “determinants”, that favoured or limited the COVID-19 diffusion in New York City neighbourhoods by using linear regression analysis, and then to integrate them in the topic of resilient urban forms. The observation of R^2 values for each linear regression analysis is particularly effective to apply spatial modelling methods to read the association between rates of COVID-19 cases/deaths recognised in different neighbourhoods of NYC and neighbourhood- level predictors (Whittle and Diaz-Artiles, 2020).

So firstly, the study outcomes reveal that some housing conditions (household and family size), specific working categories, long commuting time habits and low-income levels have a positive effect on the confirmed COVID-19 rates (on both positive cases and deaths, but especially on the first ones) (Figure 1).

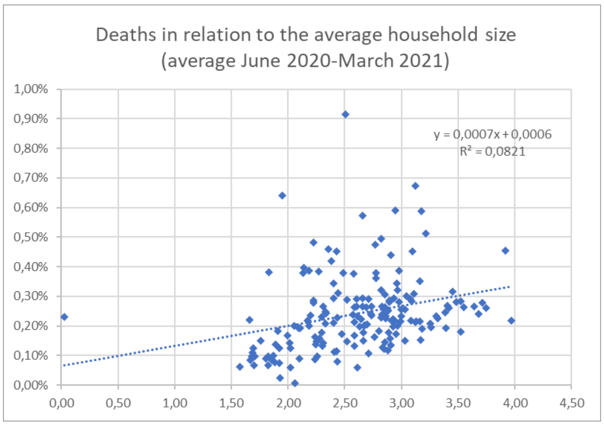
Those neighbourhoods presenting shared family dwellings or large family size (Figures 1.a, 1.b, 1.c, 1.d) (the average value for NYC corresponds with 3,32 members per family, but in some areas this average exceeds 4 - Census, 2010) contribute more easily to the transmission of the virus among residents of a neighbourhood (Cases - on tested- in relation to the average household size with $R^2 = 0,5851$; Cases - on tested - in relation to the average family size with $R^2 = 0,629$).

Poor living conditions in obsolete buildings, distant from essential facilities, especially in low-income neighbourhoods of Bronx, Southern Brooklyn and Western Queens, in congregate living and with multi-generational households, prove to be key contributors in the contagion spread. These permanent conditions hindered communities living there to follow preventive measures of social distancing and to adopt personal protective equipment.

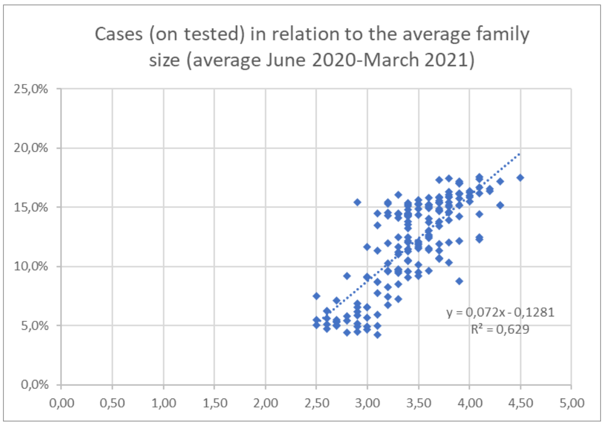
Additionally, employees who kept on working along the pandemic crisis, like healthcare staff, factory and retail employees, and transport workers face higher threats of get infected (Figure 1.e). Not only, because of the NYC structure of the daily urban movement network, human mobility has been substantial for influencing the large-scale spatial transmission of the pandemic (Cases - on tested- in relation to the commuting time (mins) with $R^2 = 0,4443$) (Figures 1.f, 1.g). Despite local data on how the mobility habits changed during the lockdown and restriction periods are not available, it can be said that these data, together with the information on working categories that kept on using public transport regularly during the virus outbreak, underline that crowded public vehicles can cover a key role in increasing the rate of COVID-19 circulation (Lak, 2020). In this sense, commute data from the 2012-2016 CTPP tabulation of the American Community Survey Several show that neighbourhoods in Queens, Brooklyn and Staten Island have the worst values of commute (almost close to an hour) among the US, while most of Manhattan ZIP codes boast averages commute time of just 20 – 30 minutes.


Cases (on tested) in relation to the average household size (average June 2020-March 2021)
y = 0,0549x - 0,0259
R² = 0,5851

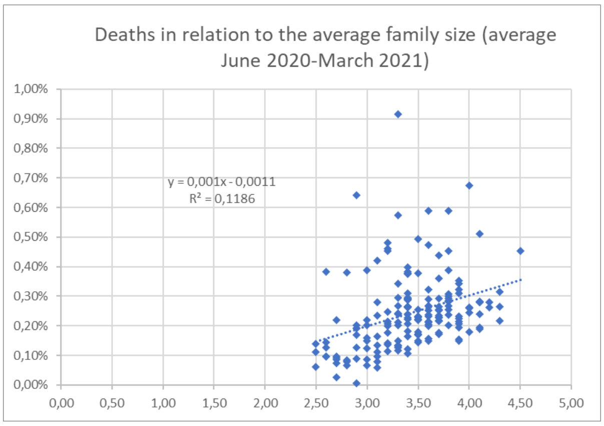
1.a


Deaths in relation to the average household size (average June 2020-March 2021)
y = 0,0007x + 0,0006
R² = 0,0821

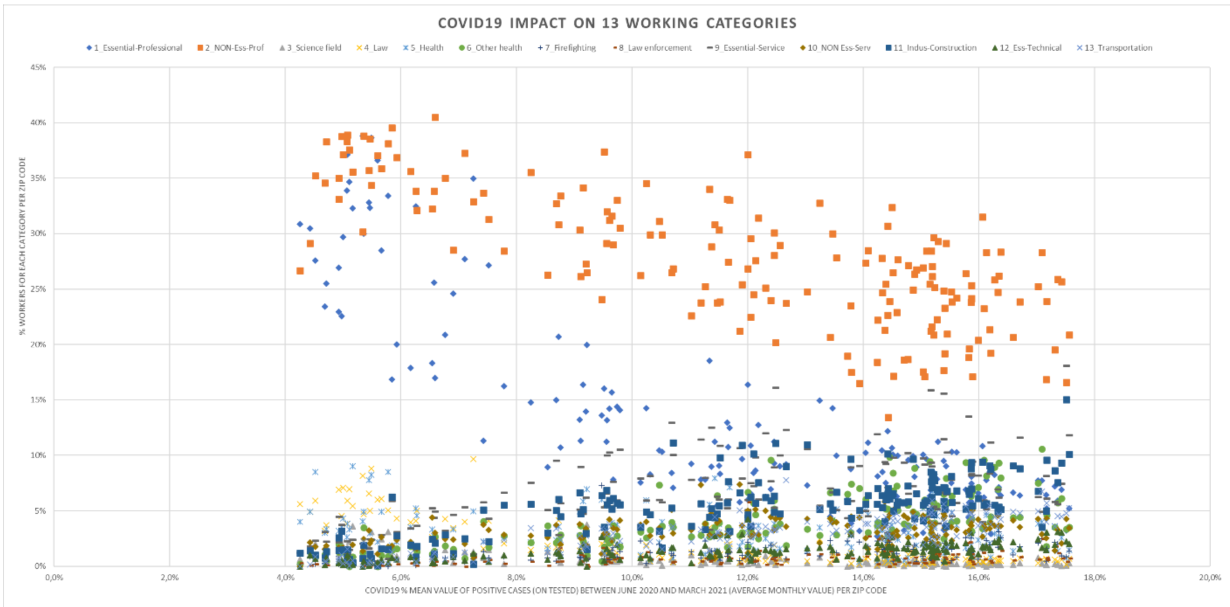
1.b


Cases (on tested) in relation to the average family size (average June 2020-March 2021)
y = 0,072x - 0,1281
R² = 0,629

1.c


Deaths in relation to the average family size (average June 2020-March 2021)
y = 0,001x - 0,0011
R² = 0,1186

1.d


COVID19 IMPACT ON 13 WORKING CATEGORIES
1_Essential-Professional
2_NON-Ess-Prof
3_Science field
4_Law
5_Health
6_Other health
7_Firefighting
8_Law enforcement
9_Essential-Service
10_NON Ess-Serv
11_Indus-Construction
12_Ess-Technical
13_Transportation
% WORKERS FOR EACH CATEGORY PER ZIP CODE
COVID19 % MEAN VALUE OF POSITIVE CASES (ON TESTED) BETWEEN JUNE 2020 AND MARCH 2021 (AVERAGE MONTHLY VALUE) PER ZIP CODE

1.e

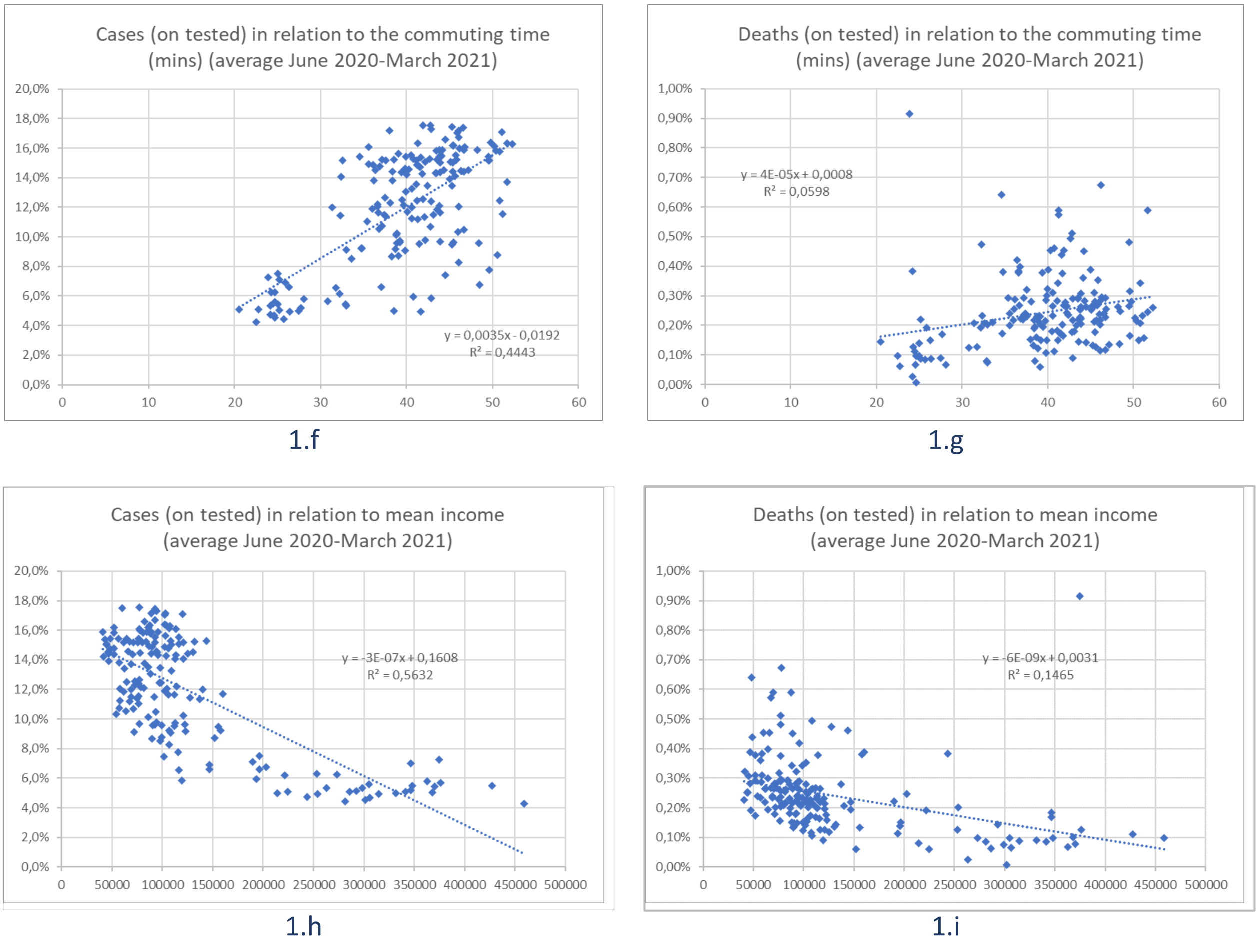


Figure 1. *Graphical representation of the linear regression analysis between COVID-19 impacts (in terms of positive cases of deaths) and (in order): average housing size (1.a, 1.b), average family size (1.c, 1.d), occupations (analysed only in terms of positive cases) (1.e), commuting time (1.f, 1.g) and mean income per ZIP code (1.h, 1.i). Source: Personal elaboration.*

The integration of these habits with COVID-19 data highlights that neighbourhoods with higher commuting patterns have also higher numbers of both COVID-19 cases and, sometimes, of deaths. This information does not reflect the public transport use during the outbreak, but rather provides an idea of "connectedness" or "centrality" levels of a ZIP Code (Moroko et al. 2020).

A strong association was also demonstrated between the median household income at ZIP Code level and virus transmission (Cases - on tested- in relation to the mean income with $R^2 = 0{,}5632$) (Figures 1.h, 1.i), as the more the average on incomes decreases, the more the virus contagion grows, highlighting a greater difficulty in low-classes in accessing to health services, to adopt proper social distancing measures and to get an insurance coverage. Moreover, data highlight that disadvantaged residents usually live in more obsolete residence arrangements, including community housing conditions or shared family dwellings where the transmission moves faster.

Less relevant or clear, on the contrary, is the role played by population density, people working from home, presence of green and seniors on the spread of the contagion (Supplementary materials - Figure S3). Indeed, in line with the contrasting debates on the relationships between COVID-19 and density in literature, results from the NYC ZIP Codes show a progressively lower virus-related positivity and mortality rates in high-density locations. Also in this case, as demonstrated by Boterman (2020), Hamidi et al. (2020) and Lin et al. (2020), density and infection rate are not significantly positively related (Figures S3.a, S3.b).

Another relevant aspect comes from homeworking, an option that has been improved in some job-fields during the pandemic phase (despite data have not yet been updated), thus preventing people from daily commuting and from the formation of crowds (Figures S3.c, S3.d). Accordingly, encouraging people to work from home may not only contain contagions but also contribute to a sort of transformation of the "employment urban landscape" in big cities, like NYC (Whittle and Diaz-Artiles, 2020). In line with Chan et al. (2020), Bai et al. (2020) and Whittle and Diaz-Artiles, (2020), linear regression analyses point also out that population over 65 and 75 does not cover a heavy role in rising the COVID-19 positivity rate, mainly because significant transmission is mostly covered by "*young asymptomatic carriers*" (Whittle and Diaz-Artiles, 2020:11) (Figures S3.g, S3.h, S3.i, S3.l). Less clear but worth of attention is the data on green areas presence, since despite it is quite obvious their key role in allowing citizens to take on outdoor activities also in lockdown conditions and to guarantee social distancing, however there is no clear evidence on its pandemic local benefits on local users (Figures S3.e, S3.f). In fact, because of a lack of tracing-system, it is not possible to clearly connect green areas presence at ZIP Code level with COVID-19 positivity and mortality rates at this scale. The relationship between some features identified in this study and COVID-19 rates suggests that the most vulnerable people and communities in New York City present higher risk of contagion, sometimes resulting also in higher death rates.

This work also contains some limitations. First, the analyses put in relationship different kinds of data: while COVID-19 data are "dynamic", since they evolve through time, the other physical and socio-economic variables are "static", since they take a picture of specific topics (density, commuting time, etc) in a specific moment and are not updated from any databases also considering the pandemic-effects (eg. On mobility patterns, on working from home options, etc.). Second, in New York City, as in many other contemporary cities, unfortunately it was not developed a proper contact-tracing system able to find out where people got the contagion. This fact limited the identification of where people really got infected and made the COVID-19 positivity simply correspond with the ZIP Code of residency. Third, the significant features found should not be considered exhaustive to explain the virus spreads between distinct neighbourhoods. However, this work offers initial useful reflections to read the COVID-19 spatial distribution among ZIP Codes. Fourth, because test-access is not equally distributed within the city, there may be inaccuracies related to COVID-19 testing at neighbourhood level. But in any case, if these imprecisions would be solved, they may probably emphasize what the model already suggests, highlighting then higher COVID-19 rates in those lower-income and more crowded neighbourhoods. Finally, another limitation of this work relates to the temporal dimension analysed. In fact, transformations in urban contests impacting also on urban morphology are usually observed along centuries, not years or few months. Although such study would be a very interesting and precious analysis, under the current contest of COVID-19 it is not possible (yet) to consider the dynamics "concluded", as they are still on-going and data collection is continuously evolving and increasing. That said, the main study outcomes remain unaltered.

Conclusions

The outbreak of COVID-19 in urban settlement has underlined that resilience concept, meant as a property of urban environment, can favour urban form and related functions to cope with this pandemic crisis. From these results, what the several features suggest is that the way their design and dynamics faced the virus-risk has often underlined the need to incorporate resilience and flexibility in the urban form field. Thus, resilient urban form can represent a new approach, able to integrate both spatial and systemic aspects of cities and to implement adaptation and transformation measures for pandemics, but also to other kinds of crisis. Accordingly, recognizing the main gaps at neighbourhood level in facing the virus spread can serve as a guidance in taking some local measures as: improving the living-quality of some community-neighbourhoods; favouring mixed-use local development; proposing alternative public transports (including biking and walking); increasing the presence of green areas equally within the city; planning for better density, redundancy and connectivity standards; and implementing "smart cities" policies and digital infrastructures. Hence, actions to enhance resilience at physical level can bring benefits also at socio-economic level.

Coming back to NYC case study, the findings correspond with previous researches that observe how within low-income communities, living in low-quality contests, the rates of COVID-19 cases and deaths usually increase. Thus, the outcomes of this study can be not only repeated in other contests, but can also drive decision-making processes, governments, and healthcare experts to increase their understandings of the urban vulnerabilities (Truong and Asare, 2020). This means that efforts to work on resilience of spatial and systemic dimensions need also to find good governance and political actors, determined to achieve active leadership and local coordination, together with urban planners and designers, interested in change and adaptation.

Regarding the limitations, it should be recognised that research on topics like urban forms, dynamics and crisis is not wholly definitive, and considering the evolving state of this pandemic, new and different results may arise in the coming months. Thus, more updates and reviews are needed not only to update data where possible, but also to deepen under-studied issues and analyse how COVID-19 is transforming citizens lives.

To conclude, it is worth underlining that this unexpected crisis remarks the necessity to rethink the role of cities and how they are planned. There is reason to hope that local authorities, planners and scientists, mindful of the great impacts of COVID-19 on their cities and citizens (Sharifi and Khavarian-Garmsir, 2020), will be more effective in supporting transformative actions to face not only pandemics but also climate change and other important threats that are pending on cities.

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Supplementary materials

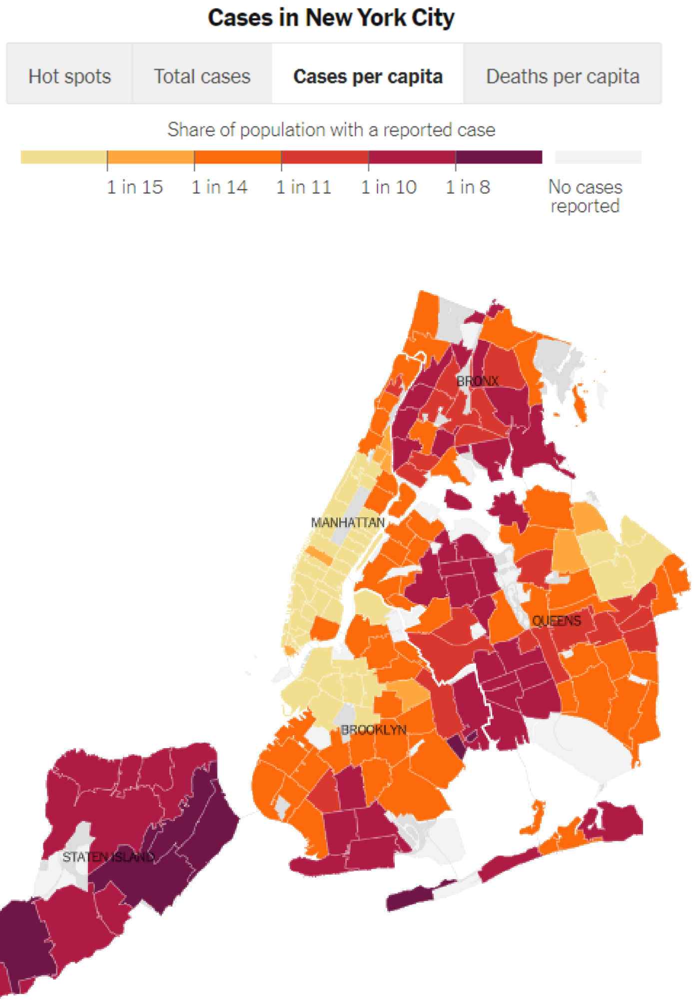


Figure S1. *Geographical distribution of Coronavirus cases by ZIP code in New York City on the 20th of April 2021. Source: New York City Department of Health and Mental Hygiene.*

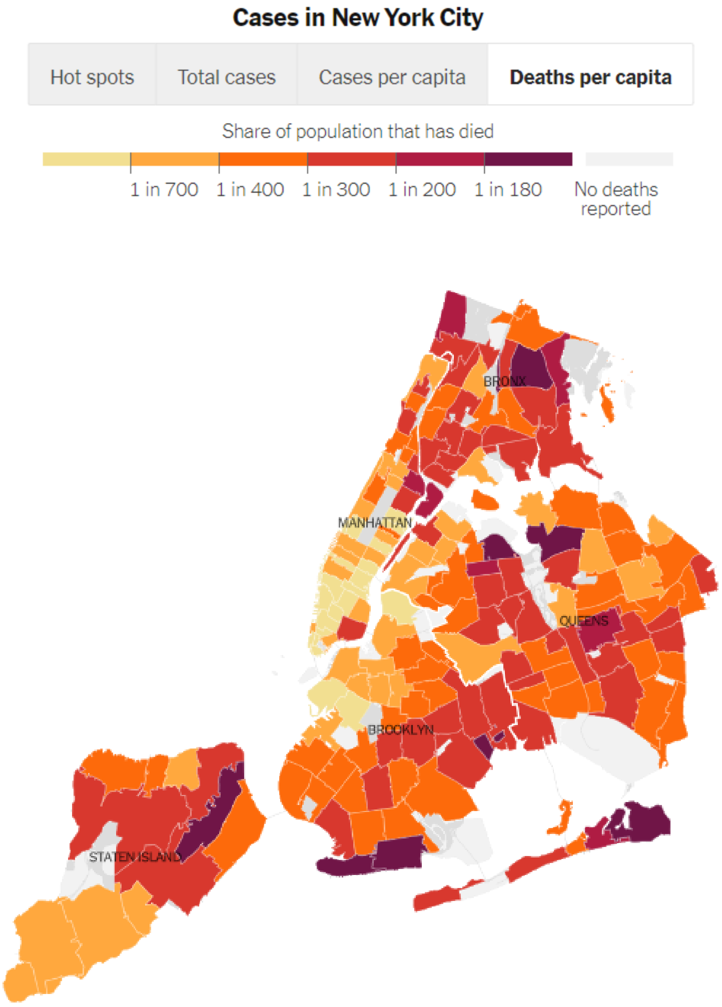
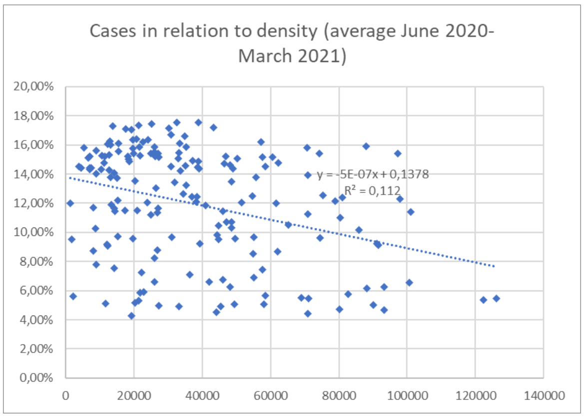


Figure S2. *Geographical distribution of Coronavirus deaths by ZIP code in New York City on the 20th of April 2021. Source: New York City Department of Health and Mental Hygiene.*



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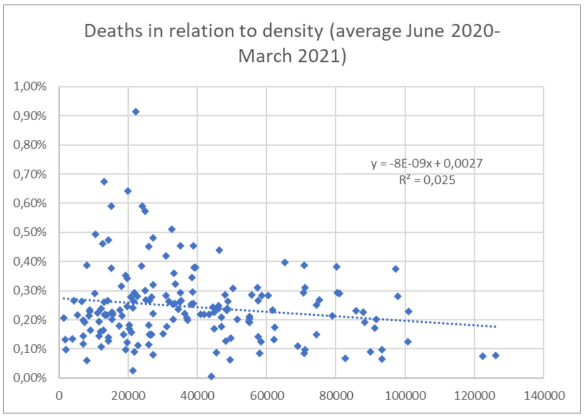

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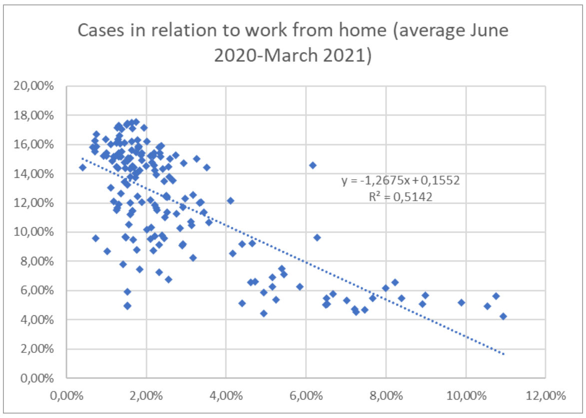

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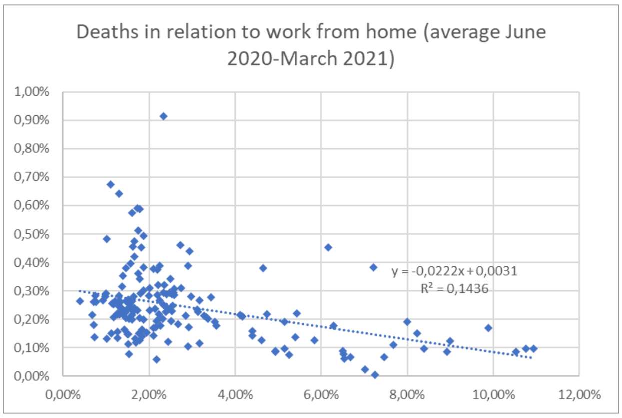

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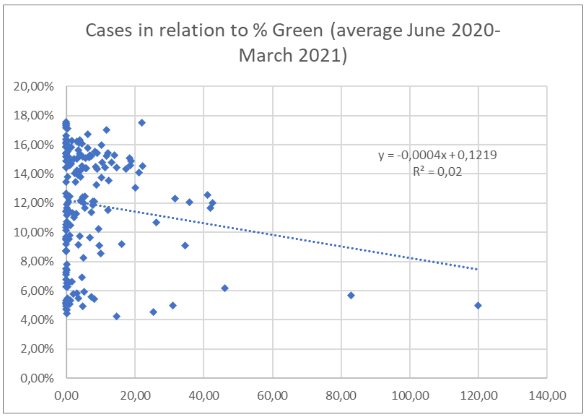

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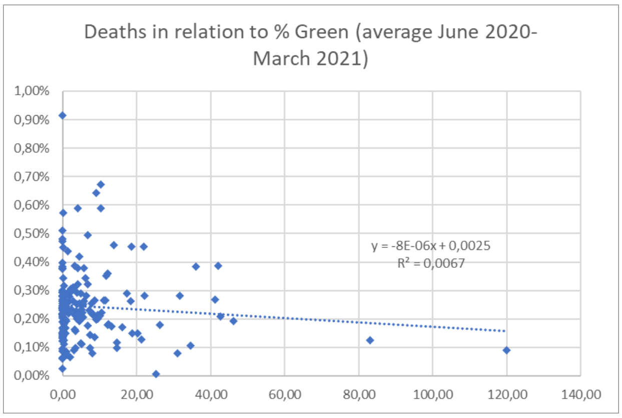

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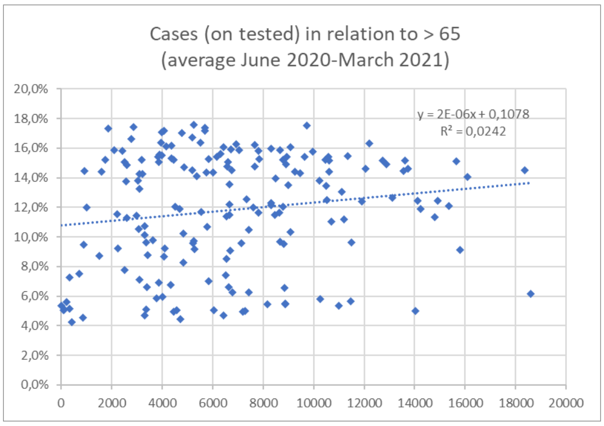

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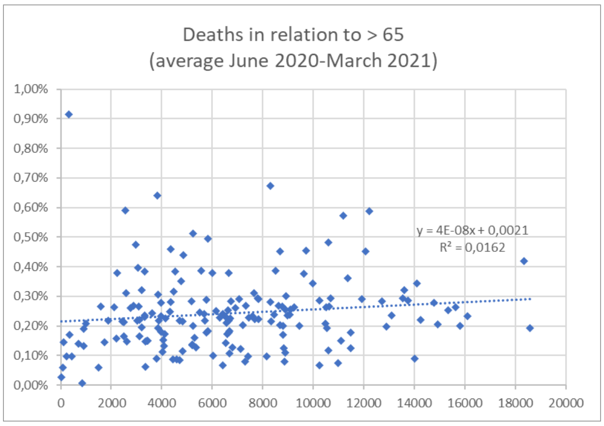

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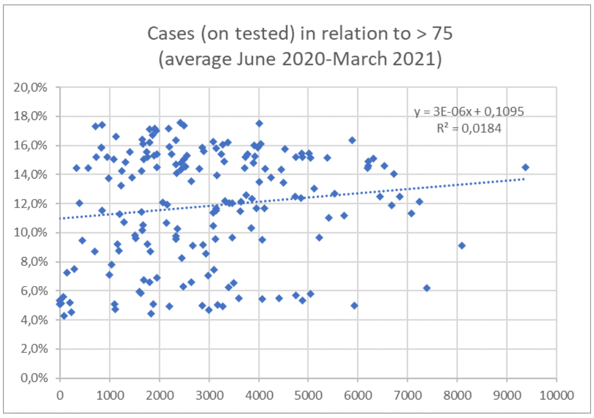

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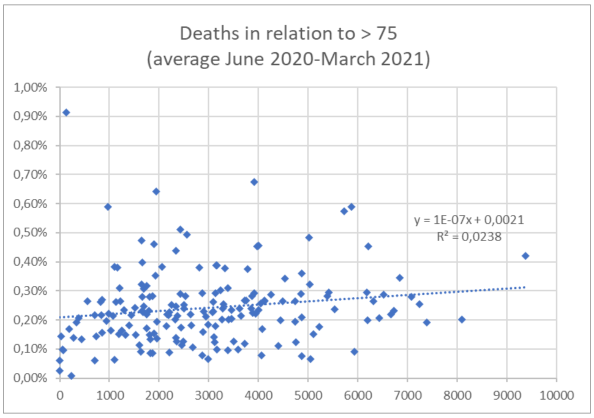

S3.l

Figure S3. *Graphical representation of the linear regression analysis between COVID-19 impacts (in terms of positive cases of deaths) and (in order): density (S3.a, S3.b), people working from home (S3.c, S3.d), green presence (S3.e, S3.f), presence of Seniors > 65 (S3.g, S3.h), presence of Seniors > 75 (S3.i, S3.l). Source: Personal elaboration.*