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COVID-19 as an accelerator of spatial (in)justices: a global comparative project

Supervisors

prof.ssa Francesca Governa (Politecnico di Torino)
prof. Pierre Alain Croset (Politecnico di Milano)
prof. Serge Salat (Urban Morphology Institute)
prof. Luigi Buzzacchi (Politecnico di Torino)
prof.ssa Marianna Nigra (Politecnico di Torino)

Candidate

Emanuele Sciuva

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"*Let your mind start a journey thru a strange new world. Leave all thoughts of the world you knew before. Let your soul take you where you long to be…Close your eyes let your spirit start to soar, and you'll live as you've never lived before*" – Erich Fromm

Abstract

Around the end of 2019, in Wuhan, Hubei Province, China, the first confirmed cases of COVID-19 were identified, and from then on, the world we were used to knowing changed globally. The pandemic had and will have enormous economic, social, and structural impacts, and the consequences are yet to be defined. It is precisely these unanswered questions that capture the interest of many researchers in various research fields. Besides the focus on medical studies, a relevant share of research connected the dynamics of the pandemic to cities and how they responded, bringing back the debate on their potential vulnerabilities. Indeed, the outbreak has drawn significant global attention to how starkly differentiated the spread was across different neighbourhoods. This phenomenon triggers questions regarding the conditions of "the urban" even before the pandemic kicked in. It is no longer solely a matter of who was most affected, but also where. The thesis, partly developed at the Urban Morphology and Complex Systems Institute, aims to research the uneven impact COVID-19 has had on different cities (New York City, London, Rome, and Sao Paulo) at a spatially granular level. It attempts to understand if spatial features (including distance to urban infrastructure and lack of facilities) have directly or indirectly exposed the less advantaged part of the population to the outbreak. Specifically, the approach, in unity with the claims of Jennifer Robinson, was to compare cities that are to a greater or lesser extent different, to shed light on general and shared processes, as well as divergences and singularities. Whereas most studies have focused on density as the main contributor to the spread of the pandemic, with inconclusive results, the thesis aims at "complexify" the discourse around the socio-spatial "determinants" of the pandemic, providing a more multifaceted picture of the factors influencing the spread or mortality of the outbreak. Methodologically, this dissertation proposes a hybrid approach: quantitative - statistical inference via Ordinary Least Squares (OLS) and Geographically Weighted (GWR) regression models - and spatial analytics (GIS), and qualitative (to link the different case studies). The analysis was structured in four distinct steps: a first qualitative spatial analysis of the pandemic's spread and mortality patterns tracked across time. Then, a set of regression models was used, to analyse the correlation with different components. Model, I investigate the link between COVID-19 and health disparities (in the form of the Social Vulnerability Index). Model II ties the pandemic to spatial indicators. Finally, model III adds to the study' complexity by establishing a comprehensive framework. The thesis displays relevant findings concerning the role of urban infrastructure and facilities during the pandemic, both in terms of spread and mortality. It also brings forward results pertaining to the outbreak's evolution over time in terms of spatial patterns. Finally, it provides a critical outtake on density and the role it might have had during the pandemic.

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1. Introduction

Never waste a good crisis. Long before Rahm Emanuel took up that term during the great 2008 recession, Sir Winston Churchill was first accredited as saying, "Never let a good crisis go to waste". He said it at the end of the world war in the mid-1940s. What he meant by this was that a crisis can be an opportunity to do things we did not think we could do before or to rethink the very way in which we came to understand them in the first place.

Around the end of 2019, in Wuhan, Hubei Province, China, the first confirmed cases of COVID-19 were identified, and from then on, the world we were used to experiencing daily changed globally. The pandemic had and will have enormous economic, social and structural impacts, and the consequences are yet to be defined. It is precisely these unanswered questions capturing the interest of many researchers in a variety of research fields. Besides the focus on medical studies, a great interest has been recorded in studies connecting the dynamics of the pandemic to the cities and how they responded, bringing back the debate on their potential vulnerabilities. Shafiri & Khavarian-Garmsir (2020) reported that the number of studies linking the effects of the pandemic to the spatial dimension of cities is still scarce. Moreover, they called for further research in the future urban planning and governance strategy, informed by studies showing the potential long-term shifts and analysing how cities were hit by the pandemic, unveiling hidden patterns and correlations.

Therefore, the dissertation aims to show that the effects of the pandemic have not been homogeneous throughout cities; instead, they have been more severe in urban units which feature long-standing spatial inequalities. The scale of the phenomenon, defined by the Oxford dictionary as "*a disease that spreads over a whole country or the whole world*", suggests looking at this event at a global scale. However, it is pivotal to link this global event to singular and contextual realities, identified as the cities, although at the centre of a broader debate on the optimal unit of analysis (Brenner and Schmid, 2015). It is in this spirit that the research is framed within the debate of comparative urban studies. In congruence with Robinson's (2016) formulation, the thesis proposes a comparative tactic by creating and enriching a virtual field of conceptualisation by bringing together different singularities and cases, which share the same problem, in this case, the pandemic. The thesis aims to place different cities across the globe into conversation and deepen our understanding of the pandemic and long-standing issues characterising cities. The "virginity" of COVID-19 as a global phenomenon provides excellent material to understand how planetary dynamics are "absorbed" by contextual realities.

This work is structured in seven chapters. The current chapter is an introduction to the work and explains the structure of the dissertation. The second part of the thesis will provide a literature review on comparative urban studies. The chapter will first introduce the current debate in critical urban studies, framing the two leading academic positions: those supporting planetary urbanisation and those working on post-colonial urban studies. The field of comparative urban studies is then introduced, tracing its evolution over time, and defining the framework proposed by Robinson (2011; 2014; 2016), which will guide and support the logic of this study.

The third chapter will provide a literature review on spatial justice. Firstly, the evolution and origin of the concept will be analysed, starting from the initial definition of "social justice" by John Rawls (1971) to the ramification of the concept into different fields and epistemological frameworks. For the sake of this thesis, the lens of focus will be placed upon the spatial dimension of justice, which originated from the work of Henri Lefebvre and was then later developed and further conceptualised by scholars like David Harvey and Edward Soja. Lastly, the chapter will discuss the possibility to introduce spatial justice within a global comparative project.

The fourth chapter defines the aim, objective, research questions and methodology. This work hypothesises that COVID-19 dynamics have had uneven consequences throughout the city, accelerating long-lasting spatial structural issues and possibly unveiling new emerging spatial inequalities. Furthermore, the proposal is that the pandemic will have to inform how we plan and the future strategies for urban governance, encompassing the lessons learnt from the events that affected the world in the last year and a half. The chapter also elaborates on the methodological approach and methods. In line with Yin (2018), the case study methodology is chosen for this thesis's sake. Four case studies belonging to different parts of the world and having different historical and contextual backgrounds are selected and disaggregated at a granular spatial scale for the analysis. The method applied consists of constructing multiple multilinear regression models (OLS and GWR) to estimate the relationship between several spatial independent variables linked to urban infrastructure and facilities, and a single dependent variable related to the pandemic, in this case, the case and death rates. The variables are constructed according to the literature review and previous works. The spatial scale was defined according to the availability of data on COVID-19 and concerning future urban governance and planning. The case studies and relative results are then compared qualitatively to avoid introducing statistical biases due to differences in datasets and Modifiable Area Unit Problem (MAUP). Finally, the chapter presents the different models employed and describes the different variables and the data sources.

The fifth chapter displays the results. It is divided into four main parts, which correspond to different analytical steps. The first one aims at analysing the distribution of the spread and mortality of the pandemic qualitatively. The outbreak is also tracked in time, thus evaluating the differences in trend over different periods. Following this section, three main analytical models are employed to analyse the pandemic about a set of independent variables. Model I studies the relationship between COVID-19 and health inequalities (in the form of the Social Vulnerability Index). Model II correlates the pandemic to the spatial indicators. Finally, model III complexifies the analysis by creating a comprehensive framework.

The sixth chapter discusses the results obtained in the different steps of the dissertation, ranging from the outcome of the regression model to the first qualitatively analysis of spatial spread and mortality. The results of the various case studies are drawn together in a comparative gesture let convergences and divergences emerge. The chapter builds upon the results of the analysis to identify patterns, relationships and differences. This part of the work aims to critically analyse the outcome and use the results to formulate levers for future urban governance and urban planning. The last chapter of the thesis gathers the conclusions of this work.

2. The pandemic in a world of cities

2.1 COVID-19 disclosed: state of the art and gaps

Around the end of 2019, in Wuhan, Hubei Province, China, the first confirmed cases of COVID-19 were identified, and from then on, the world we were used to experience daily changed, globally. In the past year, the scientific community has constantly been working to unravel the consequences of the pandemic in a myriad of research fields. Although it has not been the first pandemic in human history, limited literature was produced concerning the spread of the pandemics in cities prior COVID-19 (Matthew and McDonald, 2006). A major effort was carried out to shed lights on the factors favouring the diffusion of the virus and the impact it had on every aspect of our life. Key to this research is the work produced concerning the diffusion of the virus in cities, being physical areas of higher concentration of population and economic activities.

The main research themes so far in this sense have been, as shown by Sharifi and Khavarian-Garmsir (2020): environmental quality, socio-economic impacts, management and governance and transportation and urban design. The environmental aspect, specifically, has shown the most significant number of contributions, with studies covering sub-themes such as air quality impacts, environmental features connected to the diffusion of the virus and the study of urban water treatment. Conversely, other fields are still relatively understudied. The following sub-chapters define a framework of the several works contributing to the study of the connections between the city and the spread of the pandemic, in all its aspects.

2.1.1 State of the art

As mentioned above, the literature so far has been divided in four main themes: environmental quality, socio-economic impacts, management and governance and transportation and urban design. This chapter provides an overview of these studies, ultimately showing the current gaps which will be addressed in the following part.

Environmental-oriented studies focused mostly on three themes: air quality, environmental factors and urban water cycle (Sharifi & Khavarian-Garmsir, 2020). The outbreak of the pandemic forced many countries around the world to enforce partial or total lockdowns. As a result, urban air quality has significantly increased over the corresponding timeframe (Kerimray et. al., 2020). Studies evidenced that the lockdown measure produced a drop in $PM_{2.5}$, PM_{10}, CO, NO_2, SO_2 and O_3. The level of these substances in the air content were compared with either the period prior the outbreak if the virus or comparing the figures with the corresponding periods in past years. In most cases, the reduction of pollutants like NO_2 and CO was connected to the restrictions of the transportation sector (Baldasano, 2020). These trends have been experienced worldwide, although not homogeneously. Whereas for countries belonging to the so called "Global South" such as Brazil, China and India the transportation restrictions showed considerable benefits concerning the reduction in air pollution (Sharma et. al., 2020) other cities, like New York, have not reported similar improvements (Zangari et. al., 2020). Results concerning the reduction of $PM_{2.5}$ and PM_{10} are instead more heterogenous. This is linked to the variety of sources contributing to the emissions of such pollutants, where transportation is not the primary cause (Berman and

Ebisu, 2020). Heating, for example, has been found to be a major element of PM release. In Northeast China, where an increase in PM particles has been recorded, domestic heating, as well as industrial activities, have been identified as the main source of contribution (Nichol et. al., 2020). These findings suggest that transportation restrictions are not sufficient to address air quality problems, but other sectors, and related activities, have to be taken into account when it comes to future policy making. More importantly, several studies found a correlation between air quality and COVID-19 mortality rate (Xu et. al., 2020; Yao et. al., 2020). For instance, studies carried out on northern Italian regions, featuring higher pollution rates, have shown higher diffusion rates of the virus (Cartenì et. al, 2020). Further research is needed in understanding the role of metereological conditions, as the studies produced so far display conflicting results, especially when it comes to the outdoor environment, being the city the main scale of observation. For instance, Lin et. al. (2020) found a positive correlation between lower temperatures and COVID-19 transmission across 20 different Chinese provinces. However, in different contexts, such as Brazil, Prata et. al. (2020) demonstrated that each increase of 1°C corresponded to a decrease of 4,8951% in number of daily confirmed cases of COVID-19. Contrary to these results, several studies argue that there is no correlation between metereological features and the spread of the pandemic. (for instance, Jahangiri et. al., 2020). Other metereological parameters have been analysed in relation to the spread of the virus in cities, however, the different outcomes are mostly conflicting (for instance, Xu et. al. 2020; Lin et. al., 2020). Overall, it is still unclear how environmental parameters are correlated to COVID-19 transmission because of the myriad of contextual variances intrinsic to each case study analysed in the literature. This difficulty to find specific patterns is also reflected in the different findings previously displayed, with conflicting results and disagreement concerning positive or negative correlations.

Turning to the social impacts, the focus of the research so far has mostly been oriented to the negative impacts of the pandemic. However, there are also studies demonstrating the socially positive activities that the crisis activated. A significant number of works has focused on the dynamics of the pandemic in relation to long-standing structural inequalities within cities. Some studies, particularly, have analysed the current events in connection to similar events of the past. From an historical point of view, pandemics have affected cities unevenly, hitting severely minorities and inhabitant verging in poor conditions (Duggal, 2020). This is due to prior conditions of economic difficulty and limited access to services (Wade, 2020). The COVID-19 pandemic made re-emerge this sedimented issues, providing new insights, or drawing attention to long-standing issues within cities (Kihato and Landau, 2020). Several works have been published demonstrating that the vulnerable groups have been hit the most worldwide. The studies range from the effects in New York City, where Wade (2020) notice how the death rate is higher amongst Black and Latino people, compared to Whites. This being partly due to the limited access to healthcare during the pandemic. In some parts of the "Global South", informal urban settlements (the so called "slums") have been object of interest, due to high density, lack of access to basic infrastructures and to the higher exposure to COVID-19 (Biswas, 2020). The spread of the virus was found to be more difficult to contain within slums, due to the impossibility to effectively enforce lockdowns and quarantine actions (Wasdani and Prasad, 2020). Whereas mostly of the studies have focused on the correlation between socio-economic indicators and the spread of the virus, the relationship between the spatial features of cities and the dynamics of the pandemic is still relatively understudied, especially when it comes to injustices reflected in the spatial dimension of the urban (here used as synonym of city, although debatable). The work of this thesis takes this as a primary field of exploration. These findings, nevertheless, should not be overlooked by institutional bodies and future policy making, as the more vulnerable categories will also need to be included and prioritized along with mechanisms of economic growth. (Sharifi and Khavarian-Garmsir, 2020; Wade, 2020).

Other studies, instead, analysed the impact of COVID-19 on the social life of communities, demonstrating the increase of social tensions and decreased sense of community. However, some works also evidences the positive effects of the pandemic in terms of social activities and positive examples of enhanced cohesiveness. The enforcement of lockdowns worldwide has triggered self-centric behaviour, which have been reported in a myriad of situations globally (Biswas, 2020). For instance, in some North American cities, citizens of higher classes fled their residence and ignored border closure to spend their quarantine in secondary homes (Leonard, 2020). However, in contrast to this, in some other cases the sense of community has been strengthened by the pandemic, as documented by Thoi (2020). Similarly, Cattivelli and Rusciano (2020) have reported the enhancement of volunteering programs in Naples to involve the local community to cope with food demand and local needs. Overall, the pandemic has exposed long-standing inequalities within cities, and, governmental bodies will have to consider these issues and "exploit" this crisis to rethink policy making and create inclusive future planning, besides the need to cope with the severe economic setback.

From an urban economic point of view, the effect of COVID-19 has been globally dramatic. It is still early to estimate the overall effects, as the pandemic is still ongoing. However, the impact is multi-layered, complex and has to be estimated across different scales. From the early studies published, it emerges that crisis has significantly impacted on city tax revenues, citizens' income, tourism and hospitality, small and medium retail, urban food supply chain and worsened the condition of migrant workers (Sharifi and Khavarian-Garmsir, 2020). Quite expectedly, a finding of early studies was that cities having a non-diversified economic structure suffered the most. For instance, cities relying on tourism have been hit hard by the travel restrictions imposed by the pandemic (Earl and Vietnam, 2020). Among other works, Rutynskyi and Kushniruk (2020) calculated that the restrictions caused between 40 and 60% decrease in the number of tourists in Lviv (Ukraine). Furthermore, the study conducted by Napierala et. al. (2020) demonstrated that cities relying on international tourism suffered more compared to cities relying on domestic tourism. Other works explored the uneven economic effect of the pandemic within cities, identifying some social groups that have been more affected compared to others. Within this framework, Qian and Fan (2020) suggest that the effects of the pandemic have not been homogeneous and affected almost everyone regardless of their socio-economic background. More importantly, they argue that not only the pandemic might have intensified existing inequalities, but rather, it might have favoured the emergence of new kind of disparities. Their study, carried out within the Chinese context, takes as reference factors like income, education, family status and the membership to the Communist party as main elements determining citizens' exposure to financial difficulties. Similar arguments are presented by Cretan and Light (2020) in Romania and Krzysztofik et. al (2020) in Poland. These "new" or "old" inequalities, however, are context-specific and shaped by local and global dynamics. It is therefore necessary to widen the lens and look at the emergent or sedimented disparities as bound nor to solely local actions or global influence, but rather by the relationship between the two. Finally, the need for self-sufficiency and economic diversification was particularly stressed in several papers. Among other aspects of the economy, the transformation of the supply chain has received significant attention (Batty, 2020). Pulighe and Lupia (2020) argue that the urban food supply chain, particularly, has been highly affected by the travel restriction during the pandemic. Thus, the paradigmatic shift towards urban farming movements and local production of food is expected to be boosted in the following years. According to Batty (2020) the local supply chain, and the implications deriving from it, will play a significant role in the definition of the "New Normal".

Turning to studies centred on governance, the role of local, city-based institution in addressing socio-economic challenges has been increasingly emphasised. Several works demonstrated that integrated urban governance encompassing long-term strategies, prevention plans and adequate investments in primary services and infrastructures, along with the proper coordination of activities and stakeholders involved, produced more effective responses to the spread of the pandemic (Shammi et. al., 2020). Moreover, the effective response to the outbreak allowed cities to focus also on the formulation of strategies aimed at protecting the categories at higher risk of exposure (Duggal, 2020). Vietnam, for instance, has been recognized as a country able to flatten the curve of contagions rapidly, but also for economically supporting the most vulnerable population (Thoi, 2020). Terms like "adaptation", "resilience" and "mitigation" were adopted also prior the pandemic in relation to the disruptions connected to climate change. Therefore, it is not surprising that after this event, their usage has been amplified. Conversely, the absence of integrated urban governance and emergency plans, has led many countries to struggle in the containment of the virus. The lack of coordination and the inability to enhance basic services and infrastructures has had dramatic consequences at every scale of observation (for instance, Bangladesh, Shammi et. al. 2020). The disconnection among different stakeholders, and the fragmentation of urban governance has been problematic not only in developing countries but also in USA and Australia. In fact, the conflictual relationship and hierarchy of interests characterising different coexisting governmental bodies has resulted in limited success in the containment of the virus (Connolly et. al., 2020; Steele, 2020). Whereas top-down management through a multi-layered system is pivotal for coordination purposes, local governance has a pivotal role in the implementation of effective and timely actions. Australia, for instance, characterised by fragmented urban governance, has struggled to contain the outbreak of the virus. Local governments, indeed, took actions to cope with the outbreak, however, due to the lack of coordination, their actions different and were conceived according to different hierarchy of interest (Steele, 2020). Conversely, countries like China or Vietnam, characterised by top-down and state-centric governance, effectively coordinated activities across provinces and regions, together with bottom-up and community-based initiatives at the city-scale. These arguments suggest the possibility of a greater state involvement in local urban governance (Hesse and Rafferty, 2020). However, the empowerment of community-based initiatives is also crucial in case top-down management fails to respond effectively (Duggal, 2020).

On a different note, many studies focused on the effect of the pandemic in boosting the adoption of smart solutions to solve major societal issues (Kummitha, 2020). Within the context of the "smart city", even prior the outbreak ICT technologies were increasingly enmeshed with urban life to enhance productivity, efficiency, and monitoring (Chen at. al., 2020). The literature produced in this sense so far, has gathered insights about how technologies, ICT and big data analytics have been used to monitor, control and effectively intervene during the pandemic. The example of Newcastle showed how data gathered prior the outbreak was used to trace mobility patterns, changes in habits and societal behaviours

(James et. al., 2020). In some cases, like in the Chinese context, technologies have been adopted to avoid physical contact, by employing drones for the delivery of commercial supplies during the lockdown (Chen et. al., 2020). More importantly, smart solutions have allowed the timely identification of infected individuals, thus enabling effective containment strategies. However, depending on the specific context, these initiatives have been approached differently, according to (Kummitha, 2020) these can be divided in "techno-driven", "human-driven" and "combined". Whereas Kummitha suggests that China (among other countries) adopted a mostly techno-driven approach, western countries leaned towards a human-driven one. The former has demonstrated to be more effective during the outbreak, optimally coordinating and informing the different stakeholders involved. The latter, instead, relying on the capacity of individuals to self-correct, has resulted from time to time as ineffective. The employment of technologies has, however, initiated concerns regarding data protection and privacy. Conversely, a human-driven approach has the benefit to empower citizens to solve sedimented or emerging issues. Kummitha argues that a combination of both approaches can lead to optimal results and a proper balance, as shown by South Korea during the outbreak.

Finally, a significant number of studies have explored the effects of the pandemic on transportation and urban design, and viceversa. Transportation, being directly linked with intra- and inter-urban population movement, has been considered as a crucial element in the spread of the virus, and this was proved in previous outbreaks (Connolly et. al., 2020). In the Italian context, Cartenì et. al. (2020) has demonstrated that the number of certified infections during the pandemic was linked with the number of trips made within the prior 21 days. Hence, the first restrictions enforced by governments was to limit mobility (Ai et. al., 2020). This has resulted in an overall decrease of social travels in several contexts worldwide, as reported by several studies (e.g., Aloi et. al., 2020; Bucsky, 2020). Several studies analysed the effectiveness of such restrictions in limiting the spread of the pandemic. Most of the results confirmed indeed the efficacy of the restrictions in UK (Hadjidemetriou et. al., 2020) and in China (Tian et. al. 2020). However, also the timely enforcement of such restrictions affected the effective containment of the outbreak. Several studies, instead, focused on the different transmission rates in relation to various transportation modes. Zhang et. al. (2020) demonstrated the high correlation between air flights and train transportation departing from Wuhan, with the number of confirmed COVID-19 cases in the destination cities. Texeira and Lopes (2020) explored the effects of the pandemic on the different urban transportation systems of New York. They found that whereas the public transit (in this case subway) has experienced a greater decrease of users compared to bike-sharing, 90% and 71% respectively. Similarly, Bucsky (2020) found that cycling and bike-sharing experienced the lowest decrease in demand in Budapest, while transit experienced the highest. These findings prove the higher resilience of certain transportation modes compared to others. Other studies revealed the possible long-term behavioural changes in terms of mobility of the population. On the one hand, the positive effect of the outbreak is that there could be in the next future a preference for walking and biking, both being healthy practices (De Vos, 2020). On the other hand, the pandemic might cause negative attitudes toward public transit and mass mobility modes, thus favouring individual modes of transportation, cars included (Kunzmann, 2020).

The spatial dimension of the city, at multiple scales, has been relatively understudied in relation to the spread of the pandemic. Existing literature has mostly focused on density, whereas other elements are relatively unexplored (Sharifi and Khavarian-Garmsir, 2020). This, indeed, represents one of the main fields of exploration for the dissertation, as it will become clear in the next chapters. The outbreak has questioned the advisability for the development and compact urban forms. The initial assumption was that cities featuring high density in terms of population and belonging to a network of connection with other cities could become soon intense centres of contagion. Nevertheless, so far, the studies show conflicting results concerning the correlation between the spread of the virus and density. For instance, Hamidi et. al. (2020) found that there was no connection between the mortality rate caused by COVID-19 and the density of over 900 US metropolitan counties. Instead, they found higher rates of mortality in sprawled areas rather than densely inhabited urban clusters. In congruence with Hamidi et. al., Boterman (2020) and Lin et. al. (2020) confirmed similar results in the Netherlands and China, respectively. Contrarily, some scholars found a positive correlation between density and contagion rate. For instance, Ren et. al. (2020) found that the spread of the virus was higher in densely populated areas of Beijing and Guangzhou. Likewise, Cartenì et. al. (2020), observed higher transmission rates in Italian regions with higher density. The term "density" by itself can be characterised in many different ways, as debated in the literature. Therefore, the results obtained might be also biased by different frameworks of characterisation of the variable. Nevertheless, it is reasonable to argue that the spread of the virus can be linked to densely populated areas, among other reasons, because of the difficulty to enforce social distancing actions and avoid overcrowding. Notably, the inconclusive results presented are in congruence with previous studies that tried to link density to the spread of other diseases (Connolly et. al., 2020). Hence, density alone cannot be utilised to predict the spread of infectious diseases, as other factors need to be included in the analysis. Among these other variables, connectivity and city size have been object of investigation in the literature. Studies conducted in Wuhan (China), have shown that connectivity was the primary factor affecting the spread of COVID-19 at the beginning of the pandemic (Lin et. al., 2020). In congruence with this finding, Hamidi et. al. (2020) observed the primary role covered by connectivity in the transmission of the pandemic in the US. Regarding city size, Stier et. al. (2020) found it to be positively connected to the spread of the virus, although more research is needed to confirm this hypothesis.

2.1.2 Gaps

The sub-chapter presented above provided a picture of the studies exploring associations between cities (which is the unit of analysis of this thesis) and the dynamics of the pandemic. Whereas much work was carried out in certain categories, others are still relatively understudied. More specifically, the socio-spatial dimension of cities has been only partly explored, mostly using "traditional" parameters and indicators. A significant number of scholars has shown how the pandemic hit the most vulnerable part of the society. However, it is still unclear how injustices, in their spatial form (Soja, 2013), have contributed to the heterogeneous effects of the pandemic. Moreover, there is limited research putting in "dialogue" different cities, realities and contexts which have "absorbed" a shared global phenomenon. This approach, belonging to the stream of comparative urban studies, has been repurposed in the last years by Jennifer Robinson (2016), who is arguing for a comparative tactic whose aim is to create and enrich a virtual field of conceptualisation by bringing together different singularities and cases, which share the same problem, in this case, the pandemic. The approach will be revised in the next chapter, justifying the applicability of such approach in this context.

The goal of this research, therefore, is to “complexify” the discourse around the socio-spatial dimension of cities, in relation to the pandemic, and to connect findings across radically different realities, thus questioning and empowering difference, rather than rejecting it. Notwithstanding, the findings in literature so far are precious and crucial to have a base to start with, although it seems evident that there is still much to learn about either cities and the pandemic. This explorative research aims at setting the ground for an empirical comparative exercise, carried out via a hybrid quantitative-qualitative approach. Far from the intent to state absolute truths or certainties, the spirit of this study is to raise awareness about underlying issues of the research that too often are “mechanically” bypassed, and to foster the debate around the socio-spatial “determinants” of the pandemic within cities.

2.2 The comparative gesture in a pandemic world

The current chapter frames the discourse around comparative urban studies. Firstly, it introduces the contemporary debate of the “Global” and the “local” parallel to the apparent dichotomy between the “General” and the “Singular”. Secondly, the philosophical debate concerning the abstract and the concrete will be evidenced. Thirdly, the evolution of comparative urbanism will be traced in its main steps, drawing particular attention to the claims of Robinson and the epistemological framework she proposes for new theorisation. Finally, the last sub-chapter relates the proposal by Robinson to the thesis and its object of investigation.

2.2.1 Global v local – General v singular

It is a period of intense debate in the field of urban studies. Following the dramatic wave of urban restructuring that has spread all over the world since the 1980s, three macro trends linked to the nature of the city have consolidated over time, according to Brenner and Schmid (2015):

- The formation of new geographies of heterogeneous spatial development at different scales
- The urban, in its limited concept of “city”, has become multi-layered, polymorphic and not bound to a physical unit.
- The processes of capitalist urbanisation have been subjected to deep and rapid changes, rendering the national-developmentalist model of territorial regulation obsolete.

In the attempt to understand these ongoing transformations, the field of urban studies has experienced intellectual fragmentation. In fact, the divide in the understanding of the urban is fundamentally epistemological, not linked to methodology or research paradigm. The debate, therefore, is to understand the urban and develop a contemporary critical urban theory. The different takes on these issues are well summarised by Derickson (2015). The author of the article aimed at expanding on the two main strands of urban theory which have emerged in the midst of the “urban age” to understanding life in cities. Derickson identifies the key concepts and differences characterising these two intellectual positions. Moreover, the author investigates the political and geographical genealogies, and accounts for their political and epistemological implications. The two divergent approaches are named by Derickson as "Urbanization 1" and "Urbanization 2". This distinction derives from the original work of Chakrabarty who distinguished between "History 1" and "History 2".

On the one hand, "Urbanization 1" focus on the paradigm of planetary urbanization, implying the entire urbanization of society. This idea can be traced back to the work of Henri Lefebvre who, in 1970 in "The Urban Revolution" argued for a soon to be "complete urbanization of society". The focus on planetary urbanization leads also to paradigmatic shifts in the study of cities. In fact, quoting Derickson (2015) "*cities – bounded, territorialized agglomerations – are no longer the proper empirical or theoretical object of urban inquiry; such territorial conceits are not so relevant in the age of planetary urbanization*". The statement represent the position of authors like, among others, Brenner and Schmid (2014) and Madden (2012). Within this theoretical framework, urbanization has encompassed the original distinction between the "city" and the "countryside", shifting the focus on the processes though which planetary life can be gauged. Therefore, the set of political strategies and possibilities are based on empirical measurement carried out on large-scale observations (Harvey, 1996). This last posture is at the centre of the critics against Urbanization 1, and it is also epistemologically divergent from the posits of Urbanization 2. As pointed out by Gidwani (2004), the main issues connected to the definition of policies based on global trends is the missing accounting for *difference.*

On the other hand, Urbanization 2 features a more diverse set of theories and implications, bound together by a common refusal for Eurocentrism. The focus for this second approach is to raise questions about the context-specific urban theory, leading to an interest for the local over the global. Therefore, Urbanization 2 aims at producing knowledge about cities and inform policies based on local dynamics and which accounts for minorities. Thus, the role of externalities and the influence of capitalist urbanization is not part of the picture. Scholars are, quoting Derisckson (2015) "*more interested in the ways in which the lived experience of difference, marginalization or subalterneity are productive of subjectivities, and how those various subjectivities might coalesce in ways that undermine and disrupt ways of knowing, governing, and being that reproduce a given power structure*". This approach, being so diverse in its nature, leads also to heterogeneous questions which, as a consequence, need specific heuristic tools to be answered. The stark distinction between Urbanization 1 and 2 lies in the geographical and social scale of knowledge production.

Although divergent, the two positions share common ground. In fact, they both refuse the "universalistic" claims of the "urban age" paradigm (Brenner and Schmid, 2015), characterised by several metanarrative which stem from it, such as: urban triumphalism, techno-scientific urbanism, urban sustainability and megacities. Brenner and Schmid are particularly critical toward this universal view of the urban. However, the reason why these ideologies have found ground to popularise, is also linked to the current intellectual fragmentation in the field of urban studies, which is hindering the production of solid, convincing alternatives. They also stress the need for any critical social theory (included urban theory) to be based on epistemological reflexivity, implying the constant revisability of categories and methods. It is precisely the willingness to reinvent the epistemology of the urban that unites post-colonial scholars and planetary urbanisation researchers, although diverging in terms of approach. The major conflicting point is the object of investigation, whereas the former privilege the city as terrain for urban research (e.g. Roy, 2016), the latter focus on the dynamics of urbanisation which are continuously reshaping the urban.

Within this framework, Robinson (2011) calls for the need to adopt a comparative approach to build theory of contemporary urbanisation. The proposal by Robinson aims at supporting theorisation, where conceptualisation can be regarded as starting anywhere, from any singularity, but it always emerges through the establishment of relationships and the identification of differences between other related instances. Therefore, her claims do not discard either the importance of local and contextual analysis of cities, or the relevance of global phenomena shaping the urban. In the following sub-chapter, her position and proposal will be discussed and inserted in a broad debate of comparative urbanism, which has its roots back in time.

2.2.2 Evolution of comparative urban studies

Robinson (2011) states that "*Cities exist in a world of cities and thus routinely invite a comparative gesture in urban theorizing*". Nevertheless, the field of urban studies has been biased in its analytical framework by clustering cities into, for instance, developed and developing, capitalist and socialist, thus hindering the potential for research across these categories. However, as "globalisation" has acquired increasing importance in the definition of urban phenomena in the last decade, also the interest in drawing comparison across different cities has gained traction. In fact, the recognition of "flows" linking together different cities in a network of communication has represented a crucial point of analysis. Hence, the field of urban studies is experiencing both a revival and restructuring of comparative research (Robinson, 2002, 2006, 2011; McFarlane, 2010; Ward, 2008). Scholars are increasingly engaging in comparisons encompassing a variety of urban contexts to build theoretical insights (e.g. McCann and Ward, 2011; Roy and Ong, 2011). The future challenge will be for researchers to think and theorise cities, therefore, the implementation of new approaches and methods will be crucial to gauge the diversity of urban experiences in the contemporary world. Notwithstanding, there has been limited comparative research stretching across the division between the "Global North" and "Global South", or developed and developing cities (Robinson, 2011). This chapter retraces the historical evolution of comparative urbanism, in order to contextualise intrinsic biases that are still hindering the implementation of wide-ranging comparative methods across pre-defined categories. Moreover, later in this section, a clear framework of current comparative approaches will be defined, thus inserting the position of this work within a wider debate.

Historically speaking, the interest in comparative research can be arguably traced back to the 1940s and 1950s, when the coincidence of extended empirical testing in the paradigm of social ecology and, particularly, Louis Wirth's evaluation of the "urban way of life" and the rise in the field of anthropological research into cities in poorer contexts led to a great deal of comparison (e.g. Wirth, 1964; Mitchell, 1968). In the years that followed, comparative urban studies continued to draw attention, both as a result of previous anthropological/social studies, and also because of the strong engagement of Weberian and Marxists scholars comparing the experiences of social and capitalist contexts as a source of reflection for comparative studies (e.g. Harloe, 1981; Pickvance, 1986). However, the wake of *developmentalism* restrained epistemologically the field of comparative research, limiting the potential for comparisons stretching beyond the limits of poorer or wealthier cities, until the publication of more cross-cutting works inspired by the advent of globalisation (e.g. Walton, 1981; Harloe, 1981; Castells, 1983; Pickvance, 1986; Brenner, 2001, 2003). In this regard, Robinson (2011) observes that "*The intertwining of modernity and development in urban theory, then, has established a landscape in which assumptions about the incommensurability of wealthier and poorer cities are taken for granted, and reproduced it through separate literatures that find few grounds for careful and mutual comparative reflection*". This, reinforced by strict methodologies for comparative urban analysis, has caused the confinement of comparisons among cities assumed to share commonalities. Moreover, another critic to contemporary comparative urbanism, is the universalisation of knowledge which accounts solely for developed cities, even if utilised to describe all cities. This claim is resonant with the calls of post-colonial scholars to localise and contextualise knowledge through broader comparativism (e.g. Chakrabarty, 2000; Connell, 2007). As a result, the field of comparative urban studies has been widened in order to encompass the diversity of experiences in relation to global processes. Among other authors, Tilly's (1984) "encompassing" or McMichael's (1990) "incorporating" comparisons represent a step in that direction.

Building on this insights, Jennifer Robinson proposes an approach able to foster and reinvent a truly global comparative urbanism which is not limited to cities featuring similar characteristics (economically, historically, politically or physically) but that instead encompass radically different cities (McFarlane and Robinson, 2012). Hence, the figure of "difference" is interrogated and make it operative in comparative urbanism. In this perspective, it becomes crucial to identify the ground onto which differences can be placed into analytical relationship. Jacobs (2012) observes that a "third" term of comparison, defined by the author as the "*patterns" for "understanding connection and even causality*", has to be introduced to relate case studies to one another. In the urban geographic field this has too often been structured by the casual and methodologically unchecked assumption that it is impossible to compare poorer and wealthier cities, or those of very various political contexts and city's dimension, thus precluding the possibility to create connections across radically different case studies (Kantor and Savitch, 2005). Therefore, the aim of Robinson is to build up a robust comparative methodology that can encompass the diversity of the contemporary world of cities, and that can overcome the intrinsic biases and limitations which were considered in the past to be incommensurable. This approach would allow to move beyond many ethnocentric assumptions sedimented un urban theory (Pickvance, 1986) and would stimulate the creation of new comparative imaginaries.

2.2.3 "Thinking cities through elsewhere"

The title of this subchapter is borrowed from Robinson's article published in 2016 entitled "Thinking cities through elsewhere: Comparative tactics for a more global urban studies". In this part, a general framework of current strategies for comparison will be constructed, thus facilitating the placement of this thesis within a broader spectrum of approaches.

As mentioned above, the current scarcity of comparative research linking together radically different case studies is based upon the hypothesis that urban experiences in many cases differ too greatly from criteria for a co-investigation. This implies formally that few aspects of urban life are common in these diverse contexts, and that the causal processes that shape cities differ to such an extent that comparative analysis will not be fruitful (Robinson, 2011). However, considering the widespread claim that there are few shared characteristics to explore across certain types of cities would be difficult to support as a general claim in increasing assertions of convergence and linkages across urban experiences in a globalized world, from globalizing formal or informal economic networks to transnational networks of design, policy, and governance (e.g. Marcuse and van Kempen, 2000). The assumption would then be that cities from many different contexts can easily be considered together in the light of an adequate intellectual definition and scope for a comparative research project. Brenner (2001) examines diverse comparative approaches in urban studies in some detail. Similarly, Robinson (2011) provides a picture of the main approaches to comparative urbanism, as shown by Table 1. The current strategies, which are going to be examined below, can be subdivided in "individualising", "encompassing" and "variation-finding".

	Comparative strategy	Causality assumption
Cannot compare	None	Plural and incommensurable
Individualizing	Implicit Any city Case studies not always comparative Or theory building	Historical and specific
Universalizing	Most similar or most different	Search for a general rule
Encompassing	Involvement in common systemic processes; often assumption of convergence as basis for comparison	Universal but potentially differentiated processes of incorporation into impact of system
Variation-finding	Most similar: explain systematic variations within broadly similar contexts on basis of variables held constant or changing	Universal
	Most different	Either: search for universal causality across different contexts based on similar outcomes or pluralist causalities (Pickvance, 1986)

Table 1 - From Robinson (2011). Following Charles Tilly's (1984) assessment of different approaches to comparative research, and Neil Brenner's (2001) application to the urban scale, while also drawing from Lijphart (1971) and Pickvance (1986)

Among the most important and common methods for comparison in urban studies is the 'individualising' or detailed case study comparison. In this context the researcher seeks to explicitly or implicitly (normally qualitatively) compare the distinctive results of a single city (or more than one) with other case studies, thus confirming (or denying) hypotheses of causal processes and results generated by the analysed object. Lijphart (1971) suggests that the case study strategy can eventually be relatively unproductive for social science studies, unless specifically involving theorisation. However, he claims that it is an important component of a broad spectrum of comparative methods. It was particularly productive in the field of urban studies to bring the experiences of various cities into close conversation with each other, stimulating the reflection on existing theories, raising questions about one case study by addressing associated dynamics belonging to different contexts or pointing out limitations or biases in existing assumptions (e.g. de Boeck and Plissart, 2014). Although criticised by a number of scholars (e.g. Brenner and Schmid, 2015; Davis, 2006), the analytical unity of the city has the potential to generate hypotheses (Lijphart, 1971), which can consequently contribute significantly to theory building. Nevertheless, the analysis of the outcomes and causal processes is inevitably linked to contextual specificities and to a variety of processes and actions. In this regard, it is possible to identify phenomena and dynamics, shared by various cities, although configured differently. Otherwise, it is possible to observe processes extending across more than one city, leading to connections, circulations and flows among different entities (Robinson, 2011). Hence, it is pivotal to account for these dynamics, especially in a context of a globalised world, by considering the multifaceted links to causality, informed by the complex spatial features of cities.

The 'encompassing' method (Tilly, 1984), in which the different cases are assumed to be part of a general systemic process such as capitalism or globalization, is a second strategy that has been of primary importance in the field of urban studies for the last couple of decades. In this approach, the different case studies are considered as units belonging to a broader systematic framework, which affects the singular entities. McMichael (1990) expose and expand this approach in relation to world-systems theory. However, to fully exploit the potential of this approach, we should move past the simplistic focus on global cities and extend the analysis to the various connections and transnational processes that shape modern urban life (Smith, 2001; Simone, 2004). Moreover, as strongly supported by Robinson (2002), it would be more fruitful to overcome the incommensurability of convergence as the systematic ground of comparison between different instances. In fact, this attitude constraints the project of a truly international comparative project (Sassen, 2002). The major shortcoming of encompassing approaches is that they tend to frame the comparison outside of its historical specificity, either by prioritizing the "whole" over the "parts" and placing the latter as only subordinate to the former, or by building an abstract theoretical framework. Conversely, the proposal of an "incorporating comparison" by McMichael (1990) redraws the role of the units and the whole, defining them as historically and mutually constitutive rather than establishing the primacy of one over the other.

Finally, a last current strategy for comparative studies lies in the "variation-finding" potential. According to Robinson (2011) "*In principle they do not require the selection of cities based on their place within any encompassing system or their relevance to overarching a priori analytical categories for meaningful comparison*". Nevertheless, so far, variation-finding approaches are extremely selective with the case studies chosen to be object of investigation. There is still a significant reliance on pre-defined categories for the selection of instances, and there is still dependence on convergence for effective comparativism. In Table 1, following (Pickvance, 1986), Robinson (2011) identifies two main strands of variation-finding application. On the one hand, there is a great majority of scholars adopting this strategy by employing similar case studies for comparative purposes. On the other hand, a limited number of works employ case studies featuring radically different characteristics. The latter, has considerable potential for the widening of current comparative tactics and to expand the project of comparative urban studies to a global scale. According to Lijphart

(1971), the basic methodological challenge of finding qualitative variations is to have few cases and numerous variables. Most researchers' response to this challenge significantly reinforced the trend of urban studies only to compare similar urban experiences. The hypothesis is that you can more readily control the likely sources of variation by working with relatively similar contexts. Furthermore, variation-finding research strongly relies on existing theory to identify suitable variables and case studies (Denters and Mossberger, 2006). Considering the argument of Jennifer Robinson for a broader comparativism within urban studies, this fact represents a major downside of the method. This methodological procedure presents two problems concerning a more international approach to urban studies:

- Firstly, there is a high dependence between existing theory and hypothesis formation. The reliance of this approach on pre-defined, universalised and at times parochial knowledge is often biased by observations derived from local contexts and claimed as general (Pierre, 2005; Connell, 2007)
- A second and significant methodological problem originates from the formal process of isolating independent variables. Since cases are selected based on their suitability for testing hypotheses, researchers tend to isolate the hypothesized causal parameters of complex and dynamic cities by selecting cities with many common background characteristics (Pierre, 2005). These prevention measures hinder scholars from learning about different local dynamics in a number of cities. These selection criteria continue to define causal variables at the level of territorial units, usually national or local. This approach at the very least distracts from interconnections and globalizing dynamics in view of the discussion of an inclusive comparison, which may well also be important for explaining local results (Kantor and Savitch, 2005). We must also, more importantly, question the relevance of national comparisons and the hypothesis that the urban territorial unit is the appropriate body for comparative urban research.

This methodology, although used productively in the USA, has created concerns once employed and extended to far-reaching comparisons with Europe. In fact, this approach was questioned about the stretching of concepts and the excessive reliance on abstract theorising, due to the apparent divergences between the different contexts (Denters and Mossberger, 2006). Conventionally, it is claimed that extending propositions to abstract analysis undermines the ability to structure specific testing hypotheses and introduces too many features that vary across contexts so that explicit variables are effectively controlled. On the one hand, Kantor and Savitch (2005) sustain that it is reasonable to assume that the investigation should be contained in advanced liberal democracies, since they share significant characteristics as well as common interests in the world economy. The underlying assumption, in this case, is the fact that it is appropriate to restrict comparative urban studies according to wealth, political system or to similar national contexts. On the other hand, Pickvance (1986) proposes a more suggestive contribution which shows the value of comparing 'most different' cases studies. He suggests that comparative urban studies would benefit by acknowledging diversity and moving away from ethnocentrism. Usually, most different cases can be compared where similar results could help one investigate the common characteristics that caused them, since much else is different and therefore unlikely to explain the common result (Lijphart, 1971). Pickvance (1986), instead, highlights the more radical potential and possibility to move away from the assumption that the same causal processes are being compared. He argues that similar outcome can have quite different causes, drawing attention to assumptions of plural causality, implying that similar outcomes can also originate from different causes. This 'relativist' model of multiple causality is rarely regarded by researchers and remains subordinate to comparative research that focuses on universal causality assumptions. Instead of assuming that the comparison of different cities by itself is difficult, he reminds us that there are serious flaws in the conventional assumptions concerning the comparative methods and that, in reality, there is a lot to be learned across apparently highly different urban contexts. Overall, Pickvance (1986) reminds us that "*awareness of diversity through comparative studies forces one to bring theoretical assumptions into the open*". This has the potential to expand the reach of current comparative studies and to enhance the construction of a more international comparativism.

2.2.4 Comparative urban studies: urban as a "virtual" field for theorisation

This sub-chapter digs into the philosophical debate behind theorisation and the intrinsic challenges that previous and current scholars are facing to construct a solid and consistent methodology to cope with the increasing need of international theory-building. This part stresses the different intellectual positions defining what theory is, and how it is supposed to be formulated. The debate dates back to several decades ago, but it is still central in the contemporary urban discourse.

As extensively discussed in the previous paragraphs, if a conceptual engagement is to exist with the cities of the "twenty first century," it must take place on a radically different footing. New findings and possibilities to reframe taken-for-granted assumptions can emerge from many different sources such as cities, regions, pathways, phenomena, practices and so on. Moreover, a number of theoretical innovations have been proposed during the last decade, thus supporting a more global dimension of urban studies in the era of globalisation (e.g. Ward, 2010; Brenner and Schmid, 2014; Simone, 2011; Jacobs, 2012; Roy and Ong, 2011). Nevertheless, the urban dimension offers both challenges and opportunities to theorisation. Any endeavour to conceptualise the urban in a "world of cities" quickly puts bits of knowledge acquired in one setting in relation to a variety of urban instances. While this is just a specific issue of the wider challenge of creating ideas through specific perceptions across various settings, it acquires a certain explicitness when it comes to the spatiality of the urban, this latter being characterised by multi-level, interconnected and complex urban phenomena (Robinson, 2016). In general, rather than debating a 'case' or a particular experience, the possibility to say anything more comprehensive about urban dynamics, cycles and processes lies in understanding, according to Robinson (2016):

- The relationship between singularities and wider phenomena involving plural instances
- How far concepts can stretch and how reliable they can be
- The methodological conventions which allow the interrelation between different instances, which permit theory-building

The points above are the key components of comparative imagination, working with and questioning concepts in a variety of cases. In order for us to understand and talk about the nature of the urban (in its multiplicity and complexity), Robinson (2011) proposes to put specific cases (outcomes, processes, experiences) into conversations with the others. When thinking comparatively, the differentiation of results can be shown, the different (or shared) processes forming a specific urban outcome can be seen and theory can be developed from other instances or cases. Comparative imagination can be beneficial to theorisation, but comparative methods need to be adapted to support a more global urban analysis project, including a considerable reconfiguration of ontological bases of comparison (Robinson, 2016). In general, the state of the case itself must be rethought with respect to wider empirical processes shaping specific outcomes and the possibility of informing concepts, which is an important ambition in comparative studies.

The conceptual challenges involved in working through specific observations to create concepts that can communicate beyond a single case are involved in the reformulation of comparative methods. Major questions arise concerning the nature of abstraction and to what extent concepts and reality converge (Goonewardena et al, 2008). In this regard, different modes of abstraction in Marxist thinking and in Lefebvre's space and urban analyses, which he used as a method (1968 [1996]) for his detailed explanation of dialectical materialism), have played a significant role in the shaping of this tradition in urban and geographic studies. The different, although connected, modes of abstraction they propose are also highly influential for comparative urbanism, and the way cases are treated. In their propositions, the abstraction process is linked to the creation of a more general "concrete-in-thought" – in contrast to "abstraction-in-practice" (Robinson, 2016). Lefebvre (2009), under the influence of Marx's "Grundrisse", points out that "*the concrete is the concrete because it is the synthesis of several determinations, multiplicity made one*". Abstractions, on the other hand, are unilateral dimensions. Therefore, according to Lefebvre, "*the whole needs to be recuperated through moving from the abstract to the concrete*" (p. 75). This discourse brings forward the issue of "totality". From a Marxist point of view, this "totality" can be untangled by either decrypting the relationship between multi-lateral features of a commodity (for instance, use value and exchange value), or by analysing the whole as composed by interconnected concept of production, consumption, distribution and exchange which are mutually dependent and cannot be thought without one another (Marx, 1993). Therefore, according to Marx, the generalisation of concepts like labour, or production, have limited critical utility, for the historical and contextual specificity is not acknowledged. Hence, Marx rejects the "abstraction-in-practice" and move towards an approach based on "concrete abstraction" of labour as exchange value under capitalism. Moreover, Marx, in the "Grundrisse", examines the constraints of beginning analysing with empty abstractions (Osborne, 2004), dependent on the observational aggregate of any one instance. He suggests, instead, to consider it more as a rich complexity, a "concrete totality" (Marx, 1993). His suggestion, influenced by Hegel, is to consider a simple abstraction as the aggregation of a plurality of determinations, moving increasingly from complex to simpler concepts. Differently, Lefebvre (2009) interprets the abstraction as an abbreviation of the concrete, in his own words "*Categories and concepts are elaborations of the actual content, abbreviations of the infinite mass of particularities of concrete existence*" (p. 92). Moreover, Lefebvre proposes an "open totality", envisioning theorisation which confronts itself with the specific historical and contextual content. In contemporary times, this means to deal with sedimented eurocentrism (Spivak, 1988) and to provide a plurality of starting points of theorisation, in line with post-colonial scholarship claims. Robinson's (2016) positions is in line with the Marxist idea of a "concrete totality" featuring multiplicity, partiality and openness, characterised by complexity of relations. She also argues that as we approach the concrete totality of multiple relationship, we are also drawn to the definition of singularities. This "tension" between universal dynamics and singular outcomes are at the core of comparative studies, as already discussed in previous paragraphs. Shared features, indeed, provide the opportunity to reflect on various phenomena and their effects on local realities to produce conceptual insight (Wacquant, 2008). By comparing the results, we will naturally learn about the particular characteristics of each singularity (Tilly, 1984), but we can also compare and analyse the (local) intervening processes that affect the given outcome and learn more about the broader overall processes. Following the establishment of the globalisation paradigm, we might move past the global-local dichotomy and explore the array of flows, connections, processes which offer an alternative exploration filed to understand the relationship between singularities and elsewhere (Massey, 2005). In this context, Robinson (2016) draws attention to the limits of considering localities only as "hybridised" outcomes of wider processes or as examples of general concepts. Instead, she argues that "*If cases are considered to be singularities they can be seen as distinctive outcomes on their own terms, not already interpreted as specific instances of a wider process, or a universal category. They would be opened up for conceptualisation through a wider array of available interpretations, related cases or emergent concepts*". From this ontological position, she then proposed to reformulate comparative urban studies, to enhance revisability and put at the centre of theorisation any case, any city or any urban outcome.

The reformatting of comparison, therefore, can find directions in the contemporary nature of the urban world, characterised by high interconnections between cities and repetitive urban outcomes, even if simultaneously distinctive (King, 2004; Jacobs, 2006). As Jane Jacobs (2012) demonstrates, the global/local dichotomy is eliminated in favour of addressing the specific interrelated processes which create results. Thus, the "general" elements for comparative analysis would be distributed across multiple cases as well as many differentiations of urban outcomes. When thinking of both interconnections and differences, a multitude of cities and urban results are then placed in the same analytical framework and provide fruitful grounds for methodological experiments (Robinson, 2016). Nevertheless, cities are not only made by Jane Jacobs' broader interconnections and assemblies, but also, as Simone (2011) suggests, by active partnerships, practices, imaginations, alliances and a heterogeneous stitching of opportunities in and across cities. The description of the urban above finds resonance in Deleuze's (1994) "*Difference and Repetition*", which lead us to envision an urban "virtual" able to create a myriad of singular outcomes, repeated and yet different. This framework would ensure the inclusion of all urban outcomes and cities into a common analytical field, thus drawing attention to difference and the necessity to insert singularities into a wider, global conversation (Robinson, 2016). Conceptualisation, therefore, can be thought as starting anywhere, with any singularity, and yet arising through building links to other related cases and identifying differentiations. On this basis, Jennifer Robinson suggests that urban comparisons might be thought of as "genetic," by tracing the interconnections of repeated, related but distinctive urban outcomes as the foundation for comparison, or as "generative," where variation between shared features can be used to generate conceptual insights supported by the various interconnected and sometimes disconnected theoretical conversations that have occurred globally. Hence, the case study, whether envisioned as a process, a city or form, when placed into a truly diverse and global conversation with other cases, can significantly contribute to the development of global urban studies.

3. Spatial Justice through the lens of comparative urbanism

The concept of justice was, and still is, widely debated. The work of Harvey and Lefebvre has advanced our understanding of injustice and the process through which this is implemented systematically. However, nowadays, we find ourselves in the position to deal with a multiplicity of agents, issues of planetary urbanisation and struggles for the right to the city, which must deal with complex mechanisms of appropriation, as the relationships of productions have evolved and are still evolving at a higher pace compared to the past. Firstly, this chapter aims to depict the framework concerning the debate around "justice", emphasising the so-called "spatial turn" and its implications for scholarship. Secondly, comparative urbanism is proposed as a viable methodology to investigate spatial (in)justices as there is a growing need for methods able to stretch across differences in scale and social context.

3.1 What do we mean by justice?

From a legal perspective, justice is intended as the fair judgement of whether an individual is innocent or guilty under the law, followed by the debate of determining the proper punishment for the related wrongdoing. This view is mainly connected to the individual level and usually involves a particular case or event. More relevant to this work is the meaning and attributes of justice within a social order. Despite it being connected to the legal system, this conceptualisation of justice goes beyond laws and regulations, reaching out to principles of democracy and the rights of individuals belonging to a particular social class. To some extent, social justice is often a normative exercise, a rational pursuit of what should be and therefore what should be fought for. Complete justice, though, is unattainable, such as full equality. This realisation turns our focus on the production of injustices and their integration into the social order. A mixture of normative, scientific, and critical theorisation of injustice is directly linked to citizenship, democracy, and human rights. At this point, justice could be investigated through the lens of several intellectual positions and considering different cultural backgrounds. As mentioned earlier, I will focus here mainly on the Western perspective. The origin of the concept, and consequent debate, dates back to ancient Greece and passed through the French revolution events. However, for the sake of this paper, the « virtual » beginning of the debate on justice will start from the propositions of Rawls and the theorisations that followed.

With the 1971 publication of "A Theory of Justice" by the critical legal scholar John Rawls, the evolution of a comprehensive liberal democratic justice theory came as a major milestone. Since then, Rawls has been the focus of almost all discussions and disputes over the nature of justice and liberal democracy. The critical response that followed his work played an essential role in encouraging the development of geographical justice theories in particular. Rawls introduced a theory of distributive justice that was meant to be universally applicable, regardless of space and time, similar to natural law. This fundamentally a-spatial and historical conception of justice is linked primarily to uncompromising egalitarian ideals and a fair distribution of valuable goods, such as freedom, opportunity and wealth. Justice is ideally achieved when the prospects of the least fortunate, as Rawls describes them, are as high as they can be (under certain circumstances) and when the more advantaged contribute to fulfilling the expectations of the least advantaged, considering the existence of a democratic order. The pursuit of an ideal condition is at the heart of the liberal democratic conception of social justice. A significant flaw of this theoretical construct lies in the complete a-dimensionality given to the distribution of inequalities, where the stratification of the social structure, dictated by income rather than notions of class, is the only framework adopted. Time and space as contributors to the creation of inequalities are not challenged, nor are they envisaged in how distributional inequalities change from any given temporal (and spatial) point to another. His theories were also considered to lack in the investigation of the structural processes producing inequalities, which will, on the other hand, be at the core of the work of David Harvey.

Notably, the work of Iris Marion Young, a political philosopher and critical thinker, in her "Justice and the Politics of Difference" (1990), is in line with this critique. She called for the contextualisation of justice in appropriate historical, institutional and geographical ways. She suggested moving away from the abstraction of distribution as a product and focusing more on the structural processes causing inequalities. Moreover, she pointed out the importance of shifting the focus from equality to the respect of differences and plurality, also as a critique of the traditional conceptualisation of communities as homogeneous entities. This last criticism, which gains significant traction also in contemporary studies, implies that society should not be considered a collection of confined communities, for this idea not only tends to disregard internal divergences, but it also draws attention away from significant forms of oppression caused by racial, gender, class and other sources of injustice occurring within communities' boundaries. Whereas Young was rarely explicitly spatial in her early work, the development of a theory of spatial justice, including liberal and radical formulation of the notions of territorial justice (Harvey, 1973), environmental justice and right to the city (Lefebvre, 1968), was addressed with her arguments. Young herself, in her later papers, helped "spatialise" justice concepts.

3.1.1 The 1960s and the Spatiality of Justice

Although the specific spatial reference was generally lost in literature, the city's role remained acknowledged in what was described as urban-industrial capitalism (Soja, 2013). The widespread urban crises of the 1960s brought to the surface the inequalities and unfair geographies that in the previous era of mass suburbanisation and metropolitan growth had become so profoundly integrated into urban life. In an effort to understand these riotous conditions, three interwoven streams of innovative thinking about the spatial dimension of justice. One focused explicitly on spatial justice, defining a more balanced dialectic between spatial and social causality. The explicit use of the term spatial justice was limited in the literature, and it was not as influential as the other two streams. The only relevant publication found was the one by the South African geographer G.H. Pirie, who primarily worked within the context of apartheid and published in 1983 an article entitled "On Spatial Justice". Another intellectual direction was the one undertaken by David Harvey and his "Social Justice and the city", published in 1973. In this ground-breaking book, Harvey, starting from the idea of territorial justice, moved in two directions: firstly, he constructed a liberal formulation based on geographical studies of inequality and social welfare, and secondly, he took a more radical path across Marxist geography towards critical studies on the urbanisation of injustice. Finally, Henri Lefebvre's redefinition of space (1974), along with the ideas about the right to the city (1968), contributed significantly to the emergence of new approaches to the study of inequalities across a variety of fields.

3.2 David Harvey's Liberal and Socialist formulations

The term territorial justice was firstly coined in 1968 by Bleddyn Davies in his book "Social needs and Resources in Local Services". Davies introduced a new normative approach for planners at the local and regional scale, as well as for government action, that not only reflects population size but also satisfies real social needs by allocating public services and related investments across different territorial units. Nonetheless, the conceptualisation of territorial justice was not expanded any further until David Harvey's work, to whom I shall now turn.

In his "Social Justice and the City" (1973), Harvey significantly advances the understanding of the city and its inherent inequalities. The book is composed of three parts: Liberal formulations, Socialist formulations and Synthesis. In the first part, Harvey critically reshaped the theory of justice proposed by Rawls, shifting the attention from the outcomes to the processes through which they are produced and reproduced. He argued that the attainment of justice was an inherently geographical problem, a challenge to "*design a form of spatial organisation which maximises the prospects of the least fortunate region*" (110). Harvey himself recognised the work of Davies, and from there, he started to develop principles of social justice applicable to geography. In the first of these principles, he argues that the needs of the population and the organisation of space and allocation of resources should ultimately meet. Territorial or regional distribution of resources is more fair, according to Harvey, if the locational and spatial pattern of public and privately owned investment produces positive (socially beneficial) spill over or multiplier effect, and if particular attention is provided to environmental and social issues. Such an approach guides the search for justice to the positive impact of the urban economy, similar to the right to the city idea, and on fundamental matters of environmental justice and social democracy. Harvey pushed liberal egalitarian theories of justice to their progressive limits in many ways, creatively and in a profound manner, plunging it into the social and spatial causes of territorial inequality. The dynamics of urban development and the impact on income distribution were one of his most ground-breaking and insightful arguments. Harvey argued audaciously that a redistributive approach to real-life income tends towards the rich by the everyday workings of an urban system, from housing, labour and land markets to retailers, developers, bankers and planners strategy. Harvey's empirically-based critique of Rawls revealed that inequalities arise from an intrinsic unjust process operating at the urban level. He noted the need for massive social intervention to turn these unequal social and spatial trends around. But Harvey was increasingly pessimistic about the probability of redirecting grassroots political and social actions and institutional policies toward the city's relatively poor populations and areas. Taking these ultraliberal forms to their limits, Harvey's search for social justice in the city turned to Marx.

In his "socialist formulation", instead, Harvey scrutinised the discourse on urban social justice through the lens of Marxism, a move that later influenced the birth of a distinctive field in Marxist geography (Soja, 2013). According to Marx, distributive justice was only a way to redirect the attention from issues embedded in capitalist society to elsewhere. He argued that all distributive inequalities fundamentally stem from capitalism itself. Not surprisingly, Harvey is in line with this argument, as he states that "*programmes which seek to alter distribution without altering the capitalist market structure within which income and wealth are generated and distributed are doomed to failure*" (110). The only way to achieve justice, however defined, is by altering the social relationships of production characterising capitalism development. One of the most dividing arguments, arguably at the core of the divergence between Lefebvre and Harvey, is that whereas social or class relationships transform space, social relationships are not shaped by spatial processes, as assumed by the supporters of spatial justice. That is possibly one of the reasons why the specific term "spatial justice" is never used throughout the book, and, despite the acknowledgement of the spatial dimension, space is embedded in terms like "territorial justice" or "urbanisation of injustice". More importantly, Harvey shed light on how powerful capitalist social forces deliberately shape space. These geographies are created to satisfy the needs of those promoting the social processes (capitalists in Harvey's formulation), along with their inherent inequalities and unfairness. Moreover, according to Harvey, the geographies produced over a specific point in time may become obsolete in the future when circumstances and needs have been transformed. This argument will be then be exemplified in later writings by the concept of "spatial fix", to which we shall return later. This spatial-temporal tension implies that urban development is not only significantly shaped by capitalism that creates unjust geographies, but also the geographies produced shape capitalist development, in some instances sustaining and boosting growth and in some cases imprisoning the process of capital accumulation. Due to the relative fixity of built shapes and socially constructed geographies, the version in this socio-spatial dialectic that is mutually formative is even more complex. Therefore, the inability of the built environment to adapt (at a higher or lower pace) to the needs of capitalist development is crucial. This "spatial fix" can be interpreted as a step towards the theories of Lefebvre, where the spatial dimension does indeed play a significant role in shaping capitalist forces of accumulation. Despite his initial rigidity in ruling out space as an active force, Harvey demonstrated greater flexibility in his later writings, although he was cautious in recognising explicit spatial causality. We will return to this later.

3.3 The spatial turn

The role of Michel Foucault, and Henri Lefebvre particularly, occupies a central position in discourses of spatial justice. Lefebvre's critical analysis of space departs from all previous notions of spatiality (except for Heidegger perhaps) and provides us with some of the most insightful observations concerning the production of space (1974) of the capitalist economy and what came to be called "the right to the city" (1968). Both spatial justice and the right to the city concept are so interwoven in their current use that it is difficult to discern them.

The publication of his book "The right to the city" (1968) stems from the explosive context of urban riots in Paris in the 1960s. As originally formulated by Lefebvre and not in its contemporary surrogates, this powerful concept sought to redefine the urban foundations to achieve justice, democracy, and civil rights. Like Harvey's "liberal formulations", Lefebvre believed that the normal functioning of everyday urban life creates unequal power relations, which manifest in the unequal and unfair distribution of social resources throughout the city. The struggle to reclaim the city's multiple rights was determined by the demand for greater access to social force and valued resources for most disadvantaged and unfair geographies. Therefore, from a liberal egalitarian perspective, the objective is to have greater control over the shaping forces of urban spatiality, claiming back the democratic power from the elitarian class. Although less spatially explicit, a similar argument was proposed by Harvey (2008) when he called for greater control over the surplus product of urbanisation. The reappropriation of space claimed by Lefebvre challenged the "*bureaucratic society of managed consumption*" (108), which infiltrated all aspects of urban life. This bureaucratic society and related planning and policy operations did not solely affect the city; instead, he argued, they extended their influence on every aspect necessary to the state and the market. It is from this observation that stems the argument of planetary urbanisation, which is part of the current debate on what the urban is and should be conceptualised in critical theory (e.g. Brenner and Schmid, 2015). In this sense, the right to the city extends well beyond the boundary of urban clusters (here used as a synonym of the city), but it ranges from the forests and the desert to rural areas and the countryside.

The major shift that occurred with the theorisations of Lefebvre is fundamentally ontological: his notions, arguably, derive from the implicit axiomatic assumption that human beings are not only social and temporal beings but also spatial. This was a central argument in his "The production of space" (1974). Lefebvre's thought about the right of the city was driven by his idea that space matters much more than most scholars ever thought. Given the pivotal role of socio-historical analysis in Marxist thought, it was hard to understand and accept these ideas of the generative power of urban space for most Marxists and social scientists. For Lefebvre, furthermore, an even stronger spatial argument, expressed in several publications, including "The Urban Revolution" (1970), is the crucial role that space has in sparking revolutionary social change as a vital political response to contrast capitalists' efforts to create geographies suited to their fundamental interests through the reproduction of social relations of production. That is to say, producing space and, in particular, urban space has been crucial to capitalism's survival since, at least, the mid-19th century, cities worldwide were explosive and frustrated by the social-spatial injustices at work. In his book "The survival of capitalism" (1976), he makes this argument clear: "*Capitalism has found itself able to attenuate (if not resolve) its internal contradictions for a century, and consequently, in the hundred years since the writing of Capital, it has succeeded in achieving "growth." We cannot calculate at what price, but we do know the means: by occupying space, by producing a space"* (1976, 21). This radical position was the initial cause of divergence between Harvey and Lefebvre, as Harvey himself admits in his concluding remarks of the "Social Justice and the City". Their arguments overlap and even coincide to some extent; however, the active (and fundamental) role of space in the production and reproduction of capitalism was certainly the cause of disagreement between the two. Nonetheless, as briefly mentioned earlier, in his later works, Harvey came closer to Lefebvre's argument by introducing the notion of the "spatial fix", or else, the constant struggle of capitalism over the urban, over the static and soon-to-be-obsolete built environment in a variable market. Notwithstanding, Harvey still favours the determinative impact of social forces such as capital accumulation, whilst Lefebvre insisted that social and spatial causality need to be more dialectically balanced. As Soja (2013) notes, this seems to be a minor difference, but it is not indeed. The use of the term "spatial" or "space", when coupled with the study of inequalities, is therefore not accessory but expresses a much deeper and multifaceted meaning behind it, the object of a far-reaching debate which has been here scrutinised. While conceptualising perceived, conceived and lived space (1974), Lefebvre departs from the notion of space as a mere container, an abstraction, an empty background, as it moves to the definition of spatiality as charged with practical social and political meaning. Space can offer benefits and opportunities, empower, emancipate, entertain and delight. It can also restrict chance, oppress, imprison, subjugate and reduce possibilities. Geographical or spatial aspects can be just and unfair, produced through simultaneously social and spatial processes, and subjective and objective concrete, real and creative processes. That is to say: geographies are consequences rather than just the background to the projection or reflection of our social life.

Ontologically speaking, this implies that, as previously mentioned, we are not only temporal and social beings but also, and more importantly for this argument, spatial. With all its embedded inequalities and privileges, we produce space in much the same way we produce our histories. Consequently, space can also be a scenario of conflict, as the multitude of actors involved in its transformation have different political intentions, different social purposes and, fundamentally, different ethical principles guiding actions.

Together with the right to the city, Lefebvre also developed the right to difference, the right to differ as a way to challenge processes of homogenisation, fragmentation, and segregation imposed from political entities, the market or any other subject fostering mass consumerism. In this specific aspect, arguably, the claims of Young seem to be recalled, although not explicitly mentioned. For Lefebvre, urban citizens, because of their urban residence, have a specific spatial right: to participate openly and fairly in all processes which produce urban space, to access the advantages of urban life, in particular in the highly valued centre (or centres) and not to be affected by any form of spatial segregation or confinement.

3.4 Contemporary notions

The notion of socially created spatial justice and injustice was almost incomprehensible for those thinking of space only as a physical form and an abstract container. Neo-Marxist intellectuals, like Harvey and Castells, acknowledged Lefebvre's urban achievements, although criticising some aspects. During the 1990s, this "spatial" perspective remained underexplored, and more traditional forms of geographical thinking remained in place. Nowadays, however, the work of Lefebvre has been reconsidered in geography and, with the spatial turn in many other disciplines, the spatial perspective has gained considerable traction.

Today, the majority of the growing literature on the right to the city refers to the original idea of Lefebvre. However, the concept of a critical spatial interpretative perspective is usually very little envisioned. The right to the city seems in many cases to be nothing more than another way of talking about human rights or merely a generic reference to the urgency for more democratic planning and policy-making, while the notion of consequential geographies is partly or wholly ignored (Soja, 2013). Nevertheless, two leading "schools" of scholarship (at least for what concerns the western context) are emerging and engaging critically with the right to city idea. One stems from the work of geographers and planners at UCLA. Among the most influential figures is Edward Soja, who was arguably one of the major supporters of spatial justice, as amply demonstrated by his book "Seeking Spatial Justice" (2013). We shall return to him in a moment. The other "stream" stems from the work of David Harvey, now based in New York, and his research on the urban condition concerning capitalism. One of the most relevant scholars linked to this stream is Don Mitchell, who wrote "The Right to the city: Social Justice and the Fight for Public Space" (2003) and also worked on the struggles of migrant workers in California over the use of public space, freedom of speech and housing accessibility. He advanced our understanding of territorial justice (or urbanisation of injustice, staying in line with Harvey's vocabulary) and the efforts to reclaim the right to the city in ways that cope with the limitations of both Harvey and Lefebvre. Although his Marxist flexibility, Mitchell still avoids explicitly discussing spatial processes and the effects on social dynamics, while, on the other hand, the influence of social processes over the spatial form is still prioritised, similarly to the approach of Peter Marcuse.

The writings of three geographers-planners linked to UCLA, Neil Brenner, Mustafa Dikec and Mark Purcell, are inspired in part by Harvey but more open to Lefebvre's assertive spatiality and the need to create a new "hopeful" space between revolutionary radicalism and liberal egalitarianism. All three have written fundamental analyses of the writings of Lefebvre, in particular concerning the right to the city.

Dikec (2001) published a more comprehensive and explicit discussion on the notion of spatial justice. Specifically, he distinguished between the "spatiality of injustice" and the "injustice of spatiality", the former describing how inequalities are embedded in space, the latter, instead, being the mechanisms through which injustice is perpetuated through space. Dikec anticipates the growing connection between the search for spatial justice and the struggle over the right to the city. He emphasised the need to create new urban spatial sensibilities and a contemporary ideological discourse that will activate the fight for spatial justice informed by the right to the city and the right to differ. Neil Brenner, instead, has become a leading scholar in state restructuring studies, social production of scale and spatial theory. His work is influenced by Lefebvre, as it can be seen, among other things, from his theorisation of planetary urbanisation (e.g. Brenner, 2014). Finally, Purcell has connected the debates on the right to the city to the contemporary discussion of seeking spatial justice, especially in his book "Recapturing Democracy: Neoliberalization and the Struggle for Alternative Urban Futures" (2008). The right to the city is not only regarded as the right to appropriation, participation and difference but more generally as a right to space and to live in space. The challenge is to fight the oppressive effects of capitalism, and especially its neoliberal variants, but there are also a variety of agents and targets which widen the scope of political action to include what is described as the production of the discrimination and unfair geographies of many different types (gender, race, environment etc.). This plurality recalls the arguments presented by Young (1990), where economic exploitation is only one part of a broader set of cultural and social discriminations. The class-centred struggle of Lefebvre and Harvey is not rejected but expanded to respond to the diversified and cross-sectional demands for justice in the contemporary world. The implied need to build diverse coalitions and networked social movements beyond the past's narrow and often essential canals are vital for the challenges of searching for spatial justice. The last argument sustained by Purcell (2008), which is noteworthy, is the role that space can have in "*unite diverse and particularised struggles into larger and more powerful movements*" (also Soja, 2013 p. 109). Space, therefore, is seen as a potentially integrative medium for bringing diversity together, providing a shared identity, a common goal, the hope we can change things for the better.

Before turning to the last chapter of the paper, I would like to dwell for a moment on the insights and concluding remarks of Edward Soja in his "Seeking Spatial Justice" (2013). In this book, after the description and analysis of the evolution of the concept of spatial justice, he displays the achievement of UCLA and how, during the years, university researchers and local labour and community organisations have worked closely to restore new and innovative coalitions in Los Angeles and to contribute further to urban and regional theory. In his concluding remarks, while dwelling on the possible future evolution of spatial justice, he wrote, "*Driving the spatial turn still further will be currently emerging ideas about the importance of urbanisation, regionalism, and the interconnectivity of geographical scales from the global to the local*" (193). He also points out the need to move away from the monolithic creation of narrow social movements, emphasising the necessity for more cross-cutting coalitions. In this regard, he argues that "*such coalition-building to achieve spatial justice and the right to the city should not be confined to city dwellers, whether implicitly or explicitly. These coalitions must seek to mobilise and organise across geographical scales and to learn from comparable experiences in other countries, regions, cities, neighbourhoods, and households*" (199). Based on these suggestions, I will now move to the proposal for an alternative methodology to expand our current understanding of spatial justice and the right to the city.

3.5 Spatial Justice and the comparative gesture

The claims of Soja are very much in line with the current debates on urban restructuring and all the implications linked to it. The world today is not the same as the one Harvey and Lefebvre used to live in, as well as it will most likely not be the same in the future. Nowadays, we find ourselves in the position to deal with a multiplicity of agents, issues of planetary urbanisation and struggles for the right to the city, which has to deal with complex mechanisms of appropriation, as the relationships of productions have evolved and are still evolving at a higher pace compared to the past. The current debate on the nature of the urban and its epistemological implications have been scrutinised in paragraph 2.2.1, where the positions of planetary urbanisation and post-colonial scholarship have been framed in relation to one another. Significant questions are arising are: Can theorising spatial justice be a possible scope for comparative research? How can comparative studies contribute to expanding our understanding of spatial justice? Which tactics should we apply to produce robust empirical observations? Finally, what is the impact that such observations can have in policy-making and urban planning? This last chapter of the paper will try to stimulate the discussion upon these questions and, hopefully, to make other scholars interrogate the potential of comparative research in analysing inequalities worldwide.

3.5.1 Theorising spatial justice through comparative urbanism

The debate on the urban is vital to guide us through this process. We live in a world where, arguably, heterogeneity is at its peak. The dichotomy between global and local has become obsolete, and cities worldwide need to be interpreted accounting for both their local reality and external dynamics. Fifty years have passed since the riots in Paris, yet, we are experiencing daily revolts worldwide, ranging from Poland to Colombia, from the USA to Myanmar. These events are, very often, caused by existing (or perceived) inequalities in society, and generally, we are not fully aware of how to tackle them or even to fully grasp their nature. Soja claims that we need to transcend geographical scales and learn from comparable experiences, whether these stem from other countries, regions, cities or neighbourhoods.

In such a scenario, can comparative research help us in advancing our understanding of spatial justice? Possibly. Diversity should no longer be considered an obstacle but rather a source of interrogation. Placing different realities in a comparative project can enrich our understanding of diverse local contexts and simultaneously shed light on generalities, systematic flaws, shared struggles, and processes. What is then to be placed at the centre of this comparative gesture? I might argue it is the socio-spatial dialectic linked to the production of inequalities. Any endeavour to conceptualise this dialectic in a "world of cities" quickly puts bits of knowledge acquired in one setting in relation to various urban instances. While this is just a specific issue of the broader challenge of creating ideas through distinct perceptions across various settings, it acquires explicitness when it comes to the spatiality of the urban, this latter being characterised by multi-level, interconnected and complex urban phenomena (Robinson, 2016). The arguments of Robinson have been already thoroughly explained in chapter 2.2; therefore, I will not dwell any further on her insights. What strategies are we supposed to adopt in order to put in relation singularities and generalities? How are we supposed to relate differences to one another? Each strategy – namely, individualising, encompassing, and variation-finding - has its share of critique and praise. It is still early to claim the primacy of a tactic over the others, although the variation-finding approach seems to hold potential. This being said: what impact can the observations deriving from these strategies have? Arguably, they can raise awareness about the urban condition, create coalitions stretching across scales, and claime the right to the city. Using differences to examine convergences and divergences, we can expand our understanding of spatial justice and inform policy-making and urban planning about the socio-spatial dialectic shaping the urban, the stakeholders involved and their related influence.

The field of comparative research holds great potential in expanding our understanding of urban phenomena. Spatial justice, so far (to the knowledge of the author), has never been theorised in a truly global comparative project, nor it has been discussed by relating diverse instances across the world. Studies of this kind, especially when it comes to spatial inequalities, are still in their infancy. This paper intended to stimulate a growing interest in placing (in)justice at the centre of comparative projects that aim to theorise spatial inequalities by learning from difference.

Although promising, there are still gaps and aspects that need further research. One of the major potential issues is the selection of variables, particularly if we are to apply variation-finding strategies. As mentioned earlier, there is still a reliance on existing theory to identify suitable parameters; this is especially true for spatial inequalities, for whom variables in literature are relatively scarce. Therefore, a first helpful step could be the increase in studies determining appropriate variables (either quantitative or qualitative), which can, on the one hand, be grounded in the literature of spatial justice, and, on the other hand, be inserted within the current debates on the urban. The present paper gives a contribution also from this point of view. Furthermore, there are also methodological challenges to overcome, namely, the need to be acquainted with the conditions generating inequalities for each singularity, which requires a thorough investigation of local specificities and relating them to generalities and other instances. In these terms, the author would encourage the active collaboration among scholars across the globe, from South to North, West to East, experts on local processes,, and scholars researching general trends and processes. This, arguably, can be the key to filling the gaps and coping with the challenges that are in place and that are yet to come.

4. Research aim, design, methodology and methods

4.1 Aims and research questions

The previous chapters laid out the scholarship on spatial injustices, COVID-19 and its connection to cities. Now, we shall turn to the aim of this dissertation, which find its place at the centre of three distinct "spheres": health, COVID-19, and spatial inequalities (Fig. 1). The outbreak, indeed, has drawn significant global attention to cities, and the particularly urban dimension of the crisis, and how starkly differentiated the spread was across different neighbourhoods. This phenomenon triggers questions regarding the conditions of "the urban" even before the pandemic kicked in. It is no longer solely a matter of *who* was mostly affected, but also *where*.

The author, therefore, argues that applying a "spatial lens" to the study of the pandemic can be beneficial to expand the current understanding of the pandemics and, furthermore, to question several spatial aspects of cities which might be linked to the spread and mortality of the virus, either directly or indirectly. Specifically, this thesis proposes a spatially granular analysis, at the neighbourhood level, to deeply analyse inequalities at the day-to-day scale, or proximate to it. Moreover, in congruence with the previous chapter, a comparative gesture among different realities undergoing the same situation, can be beneficial to dig into the spatial features of cities that, presumably, were and are still, linked to the outbreak.

Therefore, the research questions that drove this study were: why are neighbourhoods within a city affected differently by the pandemic? This, as a result, generated a set of sub-questions, such as: Is there any spatial feature, or dynamic, correlated with this phenomenon? To what extent? Did different cities experience similar or different patterns? To what extent do they diverge or converge?

A comprehensive and thorough analysis of all these aspects is out of the reach of this study. However, creating a framework to draw together different instances and realities is a contribution that could significantly enhance the study of the pandemic, of cities and processes shaping the "urban". This thesis is therefore a first explorative approach which attempts at undertaking the research questions listed above by adopting a spatial, comparative perspective. The hypothesis is that COVID-19 functioned as an accelerator of pre-existing spatial inequalities, which, as a result, exposed the most vulnerable part of the population to the pandemic, either by contributing to the creation of prior health inequalities, or as supported by recent scholarship, during the outbreak itself. Expanding upon this last point, certain spatial aspect of cities, like access to resources, facilities, and infrastructures, has been proved to be linked to greater health risks (Enright and Ward, 2021). The absence of certain infrastructures and facilities, for instance, renders a share of population more vulnerable to hazards, or, to the development of unhealthy habits, which, on the long, run, might severely affect one's health condition (Forsyth et. al., 2017).

Given these premises, we shall now turn to the methodology and methods adopted for the study, which draws inspiration from the literature on comparative urbanism and, on the other hand, adapts to the specific limits and challenges imposed by the creation of a comparative project, at a granular scale, ranging across different realities, while attempting to answer the driving research questions discussed above.

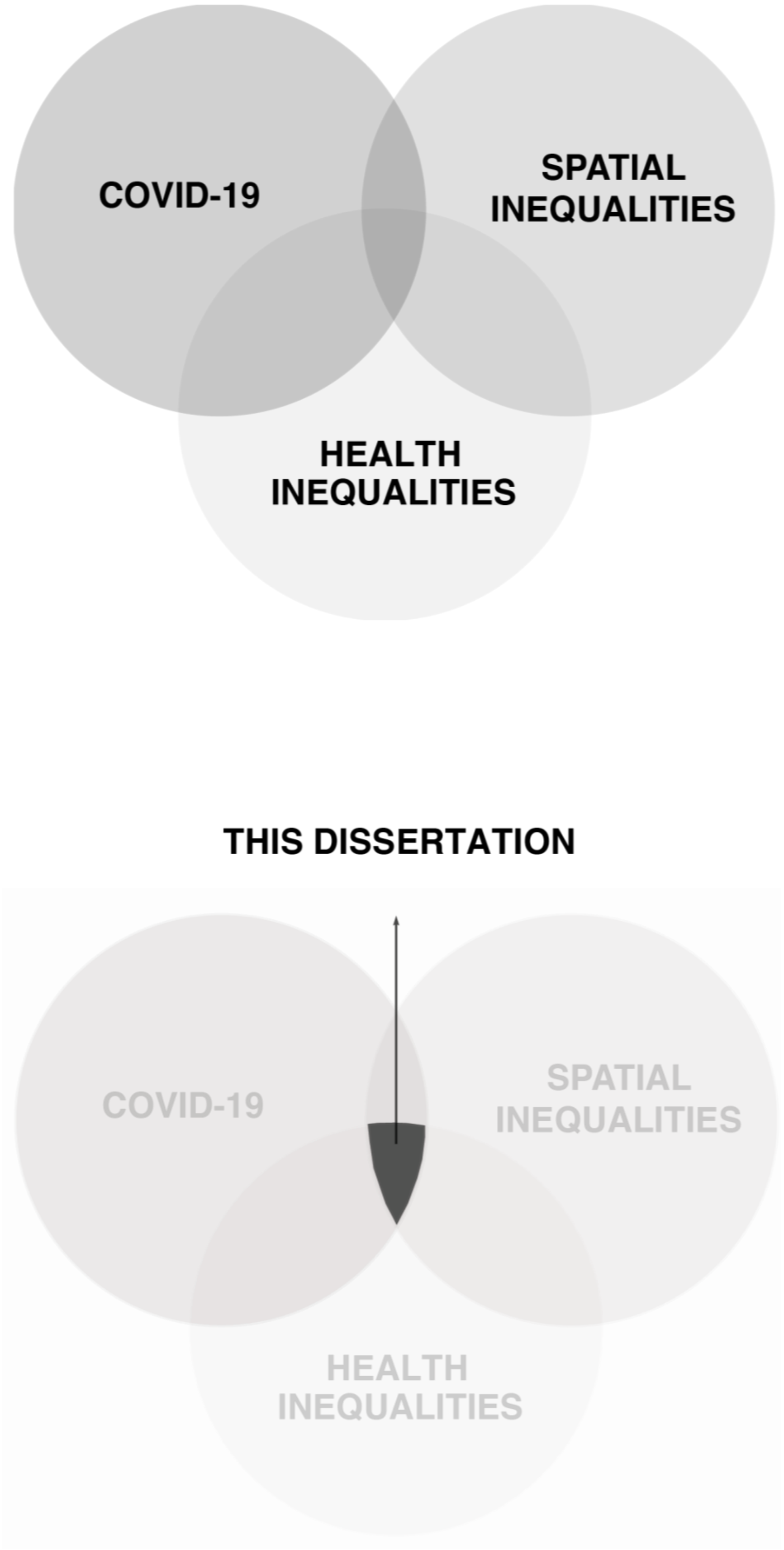


Figure 1 - Dissertation's position

4.2 Methodology and methods

The case study method was chosen as the methodology for this work. There are several reasons for choosing this strategy. According to Yin (2018), it is a methodology that allows for the exploration of contemporary phenomena within their context, especially when their boundaries are unclear. The way the individual case studies are treated, instead, will be explained shortly. According to the previous literature review on comparative projects, there were several strategies among which it was possible to choose, either encompassing, individualising or else. This study, however, had to face several challenges concerning the retrieval of data, and then, how "comparable" this data was. Particularly, the MAUP (Modifiable Area Unit Problem) (Wong, 2004) posed significant challenges in the development of a purely quantitative approach where all instances were drawn together in a purely mechanical way, since the spatial unit of reference for the case studies was not equal in terms of area and scale of aggregation, thus introducing a possible statistical bias in the interpretation of the results. For this reason, the proposed methodology is the case study approach, where the different cases are analysed quantitatively, at the individual level, and then, the comparison of results and insights across the different cities is drawn qualitatively. This hybrid approach allowed to maintain rigour *within* cities and simultaneously create connections and links *between* cities. This framework, therefore, is expected to be also applicable in the analysis of other case studies, enhancing, eventually, the collaboration amongst different scholars all around the word by having a shared system which brings together diversity in terms of instances, contexts and backgrounds

To investigate how urban infrastructure (UI) fragmentation and health inequalities affects the spread and mortality of COVID-19 in the different case studies, it is proposed by the author to estimate a series of spatial regression models centred on variables of health and UIs, which will be extensively explained in the next chapter. The goal, as mentioned in the first chapter is to "complexify" the discourse around the socio-spatial "determinants" of the pandemic, providing a more multifaceted picture of the factors influencing the spread or mortality of the outbreak.

To do so, the author employed two different regression models, namely, the Generalised Linear Regression (GLR) and the Geographically Weighted Regression (GWR). The former is used to generate predictions or model a dependent variable in terms of its relationship to a set of explanatory variables. This tool can be used to fit models that are continuous (OLS, used in this research), binary (logistic), or count (Poisson). In the social sciences, regression analysis may be the most widely used statistic. Regression is a technique used to assess the relationship between two or more feature attributes. Identifying and measuring relationships allows you to gain a better understanding of what's going on in a location, predict where something is likely to occur, or investigate why things happen where they do. GLR generates a model of the variable or process being studied or predicted that can be used to examine and quantify relationships between features (ESRI, 2021a). Despite its benefits, the OLS does not account for the "spatiality" of data, meaning that it is not able to encompass in the analysis the influence of spatial autocorrelation on the results. This issue, namely, the spatial lag, might be relevant when it comes to the analysis of cities and, in this case, of the pandemic, where spatial clusters and proximity might play a crucial role. For this reason, the author employed a second regression model, which is expected, at least partly, to compensate for this drawback and provide more reliable results. Both models will be performed, and the results will be compared for each step of the analysis, which will be described in a few paragraphs.

The shortcoming of the model described above, however, is that it is not a spatial tool, therefore, the "spatial lag" issue is not addressed. To cope with this problem, the author decided to check the robustness of the OLS by comparing the results with the ones obtained from a Geographically Weighted Regression model (Fotheringham et. al., 2003), one of the spatial regression algorithms used in geography and other fields.

By fitting a regression equation to every feature in the dataset, GWR evaluates a local model of the variable or process you are seeking to understand or forecast. The dependent and explanatory variables of the features in the neighbourhood of each target feature are incorporated by GWR into these independent equations. A neighbourhood (also known as a bandwidth) is the distance band or number of neighbours utilized in each local regression equation, and it is the most crucial parameter to consider when using Geographically Weighted Regression as it influences the degree of smoothing in the model. The shape and size of the analysed neighbourhoods are determined by the values entered for the Neighbourhood Type and Neighbourhood Selection Method parameters. The Number of Neighbours or Distance Band parameters can be used to determine the Neighbourhood Type. When Distance Band is employed, the size of each neighbourhood in the study area remains constant, resulting in more features per neighbourhood when features are abundant and less features per neighbourhood where features are sparse. The Neighbourhood Selection Method parameter specifies how the neighbourhood's size is calculated (the actual distance or number of neighbours used). The neighbourhood chosen by either the Golden search or Manual intervals options, is always based on minimizing the Akaike Information Criterion value (AICc). In this study, the Golden Search option is chosen, where the tool determines the best values for the Distance band or Number of neighbours parameters based on the golden section search method. It first determines the maximum and minimum distances and then tests the AICc at increasing distances between them (ESRI, 2021b). In this study, the neighbourhood type chosen is "Distance band", the size is defined by the golden search method. A Gaussian local weighting system is used.

The main model employed, therefore, is the FCR, which ensures more stability of results and conducts a validation process through which the "best" outcome is shown. Moreover, the machine learning approach allows to have a model that learns from the data that has been used. Nevertheless, the use of the two models (GWR and FCR) and the comparison of the respective results, allows to check on the robustness of the findings.

4.3 Research design

We shall now turn to the design of the research, encompassing the definition and selection of the case studies, the rationale behind the specific indicators used to represent health, urban infrastructures, and COVID-19, including their theoretical backbone, and the explanation of the different steps and models that have been created to carry out the analyses.

4.3.1 Case studies selection and rationale

As discussed in the chapter about comparative urbanism, there has been in the past a strong bias concerning the "incommensurability" of certain comparisons. The field of urban studies has been biased in its analytical framework by clustering cities into, for instance, developed and developing, capitalist and socialist, thus hindering the potential for research across these categories (Robinson, 2011). For this reason, in an attempt to overcome these limits, the scope of this project was to select case studies as diverse as possible, encompassing different cultural, social and spatial features. Initially, a wide set of cities was selected as "potential candidates" for this study, spanning across different continents and displaying, to a greater or lesser degree, spatial inequalities. However, the author would like to stress that spatial inequalities were not applied as a "filter" for the selection of case studies. Rather, the main and only characteristic taken into account was to create a set of cities belonging to different realities. As the initial research for instances proceeded, it was soon clear that the main hindering aspect was the availability of data concerning COVID-19 at a reasonably granular scale, and the possibility to retrieve the data via openly accessible platforms. In fact, whereas most of the cities do have datasets concerning the spread and mortality of the pandemic at the borough scale, only a handful provide data at a greater level of detail, and even fewer render this data open access. At the end of this first research, four case studies were selected:

- London (United Kingdom)
- New York City (United States of America)
- Rome (Italy)
- Sao Paulo (Brazil)

The cities above, indeed, have rather different backgrounds and display diverse cultural, social, and spatial characteristics. Moreover, well organised data concerning the spread and mortality of COVID-19 over time, with a disaggregation that, to different extents, came proximate to the neighbourhood scale, although the average area of the reference units was not equal for all cities, from this the issue of the MAUP discussed above and the need for an "hybrid" methodology. This analysis, therefore, spans across three continents, making the study the whole more important, as it affects not only a single reality, as most of the punctual research does, but accounts for the condition of million and millions of people, who have shared similar (or different) struggles not limited to the pandemic only. To the best of the author's knowledge, this is the first research to use spatial regression modelling to investigate the relationship between the spatial arrangement of urban infrastructures and facilities, and COVID-19 disparities at the neighbourhood (or proximate to it) level in a comparative global project. A thorough description of the datasets and indicators, for each case study, will follow in the next sub-chapter.

4.3.2 Indicators selection and data description

As already discussed, this dissertation finds its place between COVID-19, health inequalities, and spatial (in)justices. Hence, the indicators selected had to represent, or be used as proxies for, each of the categories just mentioned. A comprehensive table with all data sources is provided at the end of the chapter.

1) COVID-19

For the purpose of this study, the author chose to focus on both COVID-19 case and death rates as the spread of the virus and the severity of the infection might display different results across the different case studies. In all instances, the "case rates" and "death rates", which are the number of cases and deaths per 100,000 residents, have been used to map and analyse the pandemic. These represent more comparable statistics for the purpose of this dissertation, as different units across the cities, having diverse population size, can be comparatively analysed.

The data for London was obtained from the PHE (Public Health England) website and organized by Middle Layer Super Output Areas (MSOAs), which are defined by the ONS (Office for National Statistics) as "*a geographic hierarchy designed to improve the reporting of small area statistics in England and Wales*". MSOAs are made up of groups of contiguous Lower Layer Super Output Areas. The minimum population is 5000, while the average population is 7200. The Organisation Data Service publishes files created by the ONS on their behalf that link Postcodes to the Middle Layer Super Output Area. Output Areas (OA) were made up for census purposes, and to provide yearly census estimates at the lowest geographical scale (ONS, 2021). The time span of the data concerning the pandemic is from the 29th of March 2020 until the 25th of July 2021. The data was retrieved in form of total incidence (tot. number of cases per MSOA) and normalised per 100k inhabitant dividing by the population estimates of the ONS in 2019 and then multiplied by 100.000. Moreover, the number of cases has also been disaggregated according to the month of occurrence, to spatially track the spread of the pandemics over time.

For NYC, the data was retrieved from the NYC DOHMH (NYC Department of Health and Mental Hygiene) GitHub open folder and organised according to MODZCTAs (Modified Zip Code Tabulation Areas) which was a spatial scale defined for the optimal calculation of rates across the city of New York. This was the lowest geographical scale, to the author's knowledge, the data concerning the pandemic was collected and rendered openly available. The time span is from the 29th of February 2020 until the 24th of July 2021. The data was already retrieved in form of rate, calculated using interpolated intercensal population estimates updated in 2020. Population estimates were updated on November 9, 2020, to reflect annual population estimates for all New Yorkers as of July 1, 2019. These estimates are prior to the COVID-19 outbreak, and therefore, do not represent any changes to NYC's population because of COVID-related migration. Moreover, the number of cases was also already disaggregated according to the month of occurrence.

COVID-19 data for Rome was provided by the DEP Lazio (Department of Epidemiology of the Regional Health Service - Lazio) already disaggregated according to the *Zone Urbanistiche* (ZUB) scale. In this case, however, the data was not openly available, and it has been provided upon official request to the DEP. The time span is from the 1st of March 2020 until the 29th of July 2021. The data was already retrieved in form of rate, calculated using population estimates updated in 2020 provided by ISTAT (The Italian National Institute of Statistics) and are prior to the COVID-19 outbreak. Also in this case, the incidence was provided for each month of occurrence.

The data concerning the pandemic in Sao Paulo, instead, was organised differently. It was retrieved from the TABNET, an online platform created by the Municipality of Sao Paulo, an application developed by DATASUS that allows tabulations by crossing several variables according to the user's interest. The databases are updated periodically. Since the subject involves COVID-19 (Severe Acute Respiratory Syndrome, Influenza Syndrome, and Deaths) weekly the notified cases are geocoded and made available with the analysis units requested by the applicant. The data concerning COVID-19 was classified according to three different systems: E-SUS-VE Flu Syndrome (GS), Severe Acute Respiratory Syndrome (SRAG) and Deaths. For the scope of this dissertation, the first was taken to account for the spread of the pandemic in terms of cases, and the deaths were considered to account for the gravity of it. This was done to maintain homogeneity across different case studies, although not quantitatively compared, and to avoid the overlapping of GS and SRAG. In fact, unfortunately, Brazil has not a unique ID number, and duplicates are found based on full name and mother's name, which are not available. Therefore, there is a possibility of overlapping, because a person can take the test, be positive, and be notified through E-SUS-VE, then, lately requiring hospitalization, a second notification can happen. Moreover, besides the avoidance of this issue, the study does not consider the hospitalisation rates, as deaths are already a proxy for the gravity of the spread. The data was already disaggregated according to the Administrative Districts (*Distritos Administrativos*) scale. The time span is from the 1st of March 2020 until the 27th of July 2021. The data was retrieved in form of absolute incidence; the rate was calculated using population estimates updated in 2015, provided by *Fundação SEADE* (*The Fundação Sistema Estadual de Análise de Dados*). There were estimates also for the year 2020, however, after consultation with a member of SEADE, the data was found to account for the impact of COVID-19. Therefore, to avoid any sort of issues of endogeneity, the previous estimates were used. Also for Sao Paulo, case and death rates were also already disaggregated according to the month of occurrence.

2) Health: Social Vulnerability Index (SVI)

The scholarship studies produced in the past year and a half suggests that there is still uncertainty regarding the elements that contribute to the spread and mortality of COVID-19. The heterogenous impact of the pandemic has been investigated in relation to socio-demographics inequalities (Choi and Unwin, 2020; Lamb et al., 2021; Millett et al., 2020), and the presence of prior clinical conditions, which, according to some studies, have favoured the uneven distribution of cases and deaths across cities. (Centers for Disease Control, 2020). More specifically, data from the WHO shows that elderlies (age >65 y.o.) and those living in nursing homes particularly, are more vulnerable to the virus. Moreover, individuals presenting prior medical conditions, such as chronic diseases, have been proved to be more at risk.

The data concerning the pre-existing conditions, was not possible to retrieve for all case studies. Therefore, only an index accounting for socio-demographic variables, connected to health, was considered, and applied to the different case studies. In this regard, the SVI (Social Vulnerability Index) is a well-known measure in health research, particularly in medical emergencies and disease mitigation planning (Flanagan et al., 2018). According to the CDC, social vulnerability refers to "*the extent to which certain social conditions, such as high poverty, crowded housing, or a community's minority status, may affect the community's ability to prevent suffering and financial loss in the event of a disaster*" (Centre for Disease Control and Prevention, 2020). The social determinants of health inequalities were also thoroughly investigated by Marmot (2005). The index was also used by Kawlra and

Sakamoto (2021) for their study on NYC concerning health and social inequalities in relation to spatial indicators. To test the robustness of the index across the different case studies, and to monitor the information content of it, the SVI was also correlated with another indicator namely, the Life Expectancy (LE), which has been linked in literature to health and social inequalities (Wood et. al.,2006; Bleich et. al., 2012). Although this parameter was not provided for Rome (at the geographical scale of interest), for the other three case studies, the Person's correlation models between the two indices displayed moderate to strong negative correlations, with R values ranging from -0.6 to -0.97. This indicates that the two are indeed correlated and contain similar information, the sign is negative as, logically, the less vulnerable an area is, the greater the life expectancy, theoretically, is going to be. Therefore, using exclusively the SVI was considered to suffice for the purpose of this work, although there would have been room for a parameter accounting for prior medical conditions. Whereas for NYC the index was already constructed, for the other case studies, instead, the index was not always provided, or existing, thus requiring the build up of the index starting from its basic variables and indicators, as it will be explained below.

In the case of London, to the author's knowledge, there was not an already constructed SVI. A similar index, referred to as "Climate Just data", is used to identify which areas may be harmed the most by climate change. It seeks to "*raise awareness about how social vulnerability, combined with exposure to hazards such as flooding and heat, can result in uneven impacts in different neighbourhoods, resulting in climate disadvantage*" (Climate Just, 2020). Therefore, whereas some variables and indicators used to construct the index do overlap with the SVI, others, for example the vicinity to the ground in case of flood, where more tailored for environmental hazards vulnerability. The author decided instead to construct the SVI by retrieving similar variables to those used by the CDC and by applying the same methodology they proposed for the construction of the index; for further information about the methodology, the author readdress the reader to the CDC publication (Centre for Disease Control and Prevention, 2020). The singular variables and indicators were taken from the 2011 Census. Whenever possible, the variables have been taken as close to the CDC's as possible, also to maintain homogeneity across case studies. Other variables, instead, were conceptually close to it and represented similar proxies. Some, instead, were not possible to retrieve. The specific variables taken to construct the SVI were:

- % Unemployed out of economically active population
- Total Mean Annual Income per Household (£)
- % Population with no High School Diploma
- % Population >65
- % Population <15
- % Population with a disability (day-to-day activities limited a lot)
- % Lone parents with dependent children
- % Overcrowded Households (bedrooms)
- % Households with no car

The proportion of overcrowded households in each MSOA was calculated using 2011 Census data, which classifies households in England by occupancy rating based on the number of bedrooms in the household, as also did by Daras et. al. (2021). The data was already provided at the MSOS level, therefore, no transformation of scale occurred.

For NYC, as mentioned before, the SVI was already constructed and rendered openly available by the CDC. The author obtained the 2018 SVI data for NYC at the census tract level. The SVI is based on 15 different census estimated variables and determines the relative vulnerability of each census tract in the United States. Each variable is categorized into one of four themes: socioeconomic status (below poverty, unemployed, income, no high school diploma), household composition and disability (aged 65 or older, 17 or younger, older than age 5 with a disability, single parent households), minority status and language (minority, speaks English 'less than well'), housing and transportation (multi-unit structures, mobile homes, crowding, no vehicle, group quarters). To obtain the index for each MODZCTA, the author averaged the SVI scores of census tracts that intersected each zip code, through the aid of GIS.

For Rome, the SVI was already constructed and named "*Indicatore di vulnerabilità sociale e materiale*". At the hearing held on 24 January 2017 by President Giorgio Alleva before the Parliamentary Commission of Inquiry into the security conditions and the state of decay of cities and their suburbs, ISTAT undertook to extend the analysis relating to the sub-municipal areas of the municipalities of Rome and Milan to the other 12 capital municipalities of the metropolitan cities and to expand the battery of indicators proposed at that time. For Rome, therefore, the index was already available in the previous studies. The SVI was constructed to express with a single value several aspects of social and material vulnerability of a territory. The index is constructed through the combination of seven elementary indicators describing the main "material" and "social" dimensions of vulnerability. The main dimensions that have been considered, based on the factors that can most determine a condition of vulnerability, are the following: the level of education, family structures, housing conditions, participation in the labour market and economic conditions. The selection of elementary indicators was guided by the need to identify indicators with a good degree of validity (e.g., capable of effectively representing the main dimensions of meaning), among the variables made available by the census survey. The specific indicators selected were:

- % Population 25 - 64 years of age, illiterate, and literate without educational qualifications
- % Households with 6 or more members
- % Young (parent's age below 35 years) or adult (parent's age between 35 and 64 years) single-parent families on the total number of families
- % Households with potential welfare hardship indicating the share of households composed only of elderly people (65 and over) with at least one member over 80 years old.
- % Population in crowded conditions as the percentage ratio between the population living in: 1) dwellings with a surface area of less than 40 m^2 and more than 4 occupants 2) in 40-59 m^2 and more than 5 occupants 3) in 60-79 m^2 and more than 6

occupants, and 59 m^2 and more than 5 occupants, 4) 60-79 m^2 and more than 6 occupants, and the total population living in occupied dwellings.

- incidence of young people outside the labour market and training
- % Households in potential economic struggle

For further information about the methodology and the construction of the index, the author would suggest the reader to visit ISTAT (2011). The final values were already provided at the ZUB level for Rome; hence, no spatial transformation of data was required. The parameter is, nonetheless, missing for some areas. The index, as constructed by ISTAT, was thought to be suitable for the purpose of this research, as the variables and indicators used are close to the ones utilised by the CDC for NYC.

For Sao Paulo, *Fundação SEADE* created an index called "*Índice Paulista de Vulnerabilidade Social*" (Fundação SEADE, 2010), which translating would be equivalent to the SVI. Nevertheless, the specific variables and indicators used to construct it differ, to some extents from the ones used for New York. For this reason, the author, also to seek homogeneity among the different case studies, used the "*dados abertos*" platform to retrieve the singular variables and indicators that were close to the ones used to construct the index for the other case studies, again, following the identical methodology proposed by the CDC. The variables used for Sao Paulo were:

- Illiteracy rate of the population aged 25 and over
- % Population aged 25 and over who have completed high school
- % Of poor population
- Average per capita income
- Unemployment rate for the population aged 18 and over
- % Population living in households with density greater than 2 people per bedroom
- % Mothers who are heads of households, without complete primary education and with at least one child under 15 years of age, out of the total number of mothers who are heads of households
- % People in households vulnerable to poverty and dependent on the elderly
- % population <17
- % population >65

3)Spatial inequalities: Urban infrastructure, facilities, and resources

The author, inspired by the approach of Kawlra and Sakamoto (2021), developed a set of metrics along four critical pandemic response and care sectors to determine how inequalities in the availability and access to critical urban infrastructure (UI) and facilities influence COVID-19 case and death rates, either directly or indirectly, in the four case studies. The four metrics identified were: 1) Healthcare, (2) Food accessibility, (3) Mobility, and (4) Open space. A total of six different UI variables were identified: publicly accessible green areas, hospitals, pharmacies, supermarkets, streets intersections and bicycle routes. The author calculated the density of, and distance to, each of the first four UI variables, thus creating a more detailed picture of the effect of UI on COVID-19 spatial spread and mortality. Density is defined as the number of UI features per 100.000 inhabitants, except for the green areas, whose density was considered as square meters of green areas per inhabitant. Distance is defined as the average locational distance to UI features in each zip (Henriksen et al., 2008). For the intersections and the bicycle routes, only the density was considered, respectively in the form of number of intersections per square kilometres and kilometres over square kilometres. The proximity to UI and facilities, instead, was calculated using the 'Euclidean distance,' or the straight-line distance calculated from the centroid of each census tract to the centroid of the nearest UI feature, then, the average was calculated for each unit of reference. The basic datasets and geolocation of UI were retrieved from institutional websites, whenever possible, and from GeoFabrik in the form of SHP formats.

For London, the geolocation of the hospitals was retrieved from the NHS (National Health Service). The location of publicly accessible green areas was taken from the official open access “London Datastore” in the form of area features (.shp), the centroids were then calculated by the “Feature to point” function of the GIS software. The geographical position of pharmacies, supermarkets, and the street network (used to calculate the density of intersections) was retrieved from GeoFabrik. Finally, the data concerning cycling infrastructures was taken from the TFL (Transport for London) data storage, which included both bicycle paths and routes. The statistical boundaries, namely the MSOAs and LSOAs (used as equivalent other case studies’ census tracts), were available at the London Datastore platform.

Turning to NYC, the geolocation of the hospitals was retrieved from the NYC Open Data website, as well as the location of publicly accessible green areas, in the form of point and area features (.shp) respectively. The centroids, for the latter, were then calculated by the “Feature to point” function of the GIS software, as did for London. The geographical position of pharmacies and supermarkets was retrieved from GeoFabrik. Finally, the data concerning cycling infrastructures and the street network was taken again from NYC Open Data. Also the statistical boundaries, namely the CTs (Census Tracts) and MODZCTAs, were retrieved from there.

The data concerning Rome was provided by similar institutional channels. The geolocation of the hospitals was retrieved from the *Roma Capitale* Open Data website, as well as the location of publicly accessible green areas, in the form of point and area features (.shp) respectively. The centroids, for the latter, once again, were then calculated by the “Feature to point” function of the GIS software. The geographical position of pharmacies and supermarkets was retrieved from GeoFabrik as well as the street network dataset. The statistical boundaries of the CTs and ZUBs (Zone Urbanistiche), were retrieved from the *Roma Capitale* platform. Finally, the data concerning cycling infrastructures was taken from the website of *Roma Mobilità*.

Ultimately, for Sao Paulo, hospitals’ geo location was retrieved from the Geo SEADE. The location of publicly accessible green areas was, instead, retrieved from the *Prefeitura de Sao Paulo (Gestao Urbana)* in the form of areas features (.shp). The centroids were calculated in the same fashion as the other case studies. The geographical position of pharmacies and supermarkets was retrieved from GeoFabrik as well as the street network dataset. The statistical boundaries, CTs (Census Tracts) and *Distritos Administrativos*, were retrieved again from the *Prefeitura de Sao Paulo*, the former from the *dados abertos*, and the latter from GeoSampa. Finally, the data concerning cycling infrastructures was taken from the website of the *Companhia de Engenharia de Tráfego* (CET).

A detailed table containing all data sources and related information is provided in Appendix A. For sake of clarity, the tables have been divided according to the specific case study. For the COVID-19 related data in Rome, however, as mentioned before, there is no online source, as the data was provided upon official request to the DEP of *Regione Lazio*.

4.3.3 Structure of the analysis: stages and models' definition

The analysis was articulated in several "steps", thus allowing a comprehensive analysis of several aspects linking the three fields touched by this research. A fist stage was to analyse the single variable(s) connected to the pandemic: the death and case rates. This first "exercise" represented a purely descriptive spatial analysis of the pandemic across the different case studies, drawing comparisons *within* and *between* cities solely in a qualitative fashion. This first attempt is intended to get acquainted with the spatial spread and mortality of the pandemic in the different contexts that have been selected. It is an opportunity to dig deeper into the patterns of the outbreak and to let divergences and convergences emerge at different levels. In this case, differently from what analysed in the following steps, the variables were tracked also throughout the entire time range, which depended on the availability of data at the time of retrieval, as detailed in the previous paragraphs. This variant opened several observations not only concerning the overall impact of COVID-19, both in terms of spread and lethality, but also in terms of evolution over time of what has been described as a dynamic phenomenon, which, as a result, might change over time, in this case from a spatial perspective.

Once this "preliminary" analyses are sorted, the research moves to the construction and evaluation of the mutual relationship between the spatial and health inequalities, and the pandemic, this latter considered solely through the overall case and death rates. In this phase, as mentioned in the first chapters, the author attempts at complexifying the socio-spatial analysis encompassing the cities and the pandemic. This is carried out by employing three different regression models, all following the methods described in the first paragraph of this chapter. In the spirit of building upon previous studies, the population density, widely used in literature at present to study the pandemic, is inserted as a control variable in the last model (Model III).

MODEL I: The first model estimates the predictive power of the SVI, constructed upon socio-economic variables, in forecasting the COVID-19 spread and mortality. It is, therefore, tested twice: firstly, with the case rates and then with death rates. To determine the robustness of the SVI, the index was correlated with the Life Expectancy of three cities, resulting in a moderate to strong correlation (R values ranging from 0.6 to 0.97), thus confirming the suitability of the SVI as a proxy for the health condition of communities, in relation to social determinants.

MODEL II: The second model, instead, brings together the spatial indicators with the outbreak's variables. In this case, the aim of the analysis is to verify the predictive power that the spatial indicators alone have in relation to the pandemic. Also in this case, the indicators are tested twice: once with the spread and once with mortality data.

MODEL III: Finally, a last model builds-up on the previous two by producing a comprehensive analysis which attempts at complexifying the traditional socio-spatial analyses that have, for the great majority, been carried out in literature so far when studying the pandemic and the cities. It is argued that splitting up the different variables can only produce a partial explanation of the phenomenon, and, possibly, a more organic analysis can help improve the performance of the socio-economic and spatial indicators when taken up individually. Certainly, this research does not attempt at giving any absolute claim over the *causes* of the pandemic. Instead, it aims at exploring a more multifaceted picture of what happened, and to critically address the explanatory role that urban infrastructure and facilities can have in understanding the pandemic. There are several limits to the type of indicators used and the analyses that have been carried out. Potentially, there is a myriad of directions this study could be improved and/or expanded. All these aspects will be thoroughly address in the last chapter of this research.

This "incremental" strategy of analysis is used to depict, step by step, the components that seem to show greater influence and predictive power when it comes to the analysis of the pandemic in cities. The goal, as already stated, is not to provide absolute truths or *causal* parameters; rather, it is to show that by widening the concept attributed to socio-spatial phenomena, we might get a bit closer to the understanding of what happened.

5. Case studies analysis and results: COVID-19, health and spatial (in)justices

The analysis will follow the path that has been traced in the previous paragraph. Firstly, with the descriptive spatial analysis of the patterns of COVID-19, over time, and overall, both in terms of diffusion and lethality. The analysis and results of the three models described before will follow. For sake of clarity, as the analysis moves from one part to another, the research will be organised according to the individual cities following this order: London, NYC, Rome, and Sao Paulo. The comparison of the results, particularly crucial for this research, and the discussion of the findings will be part of the sixth chapter.

5.1 COVID-19 and spatial patterns

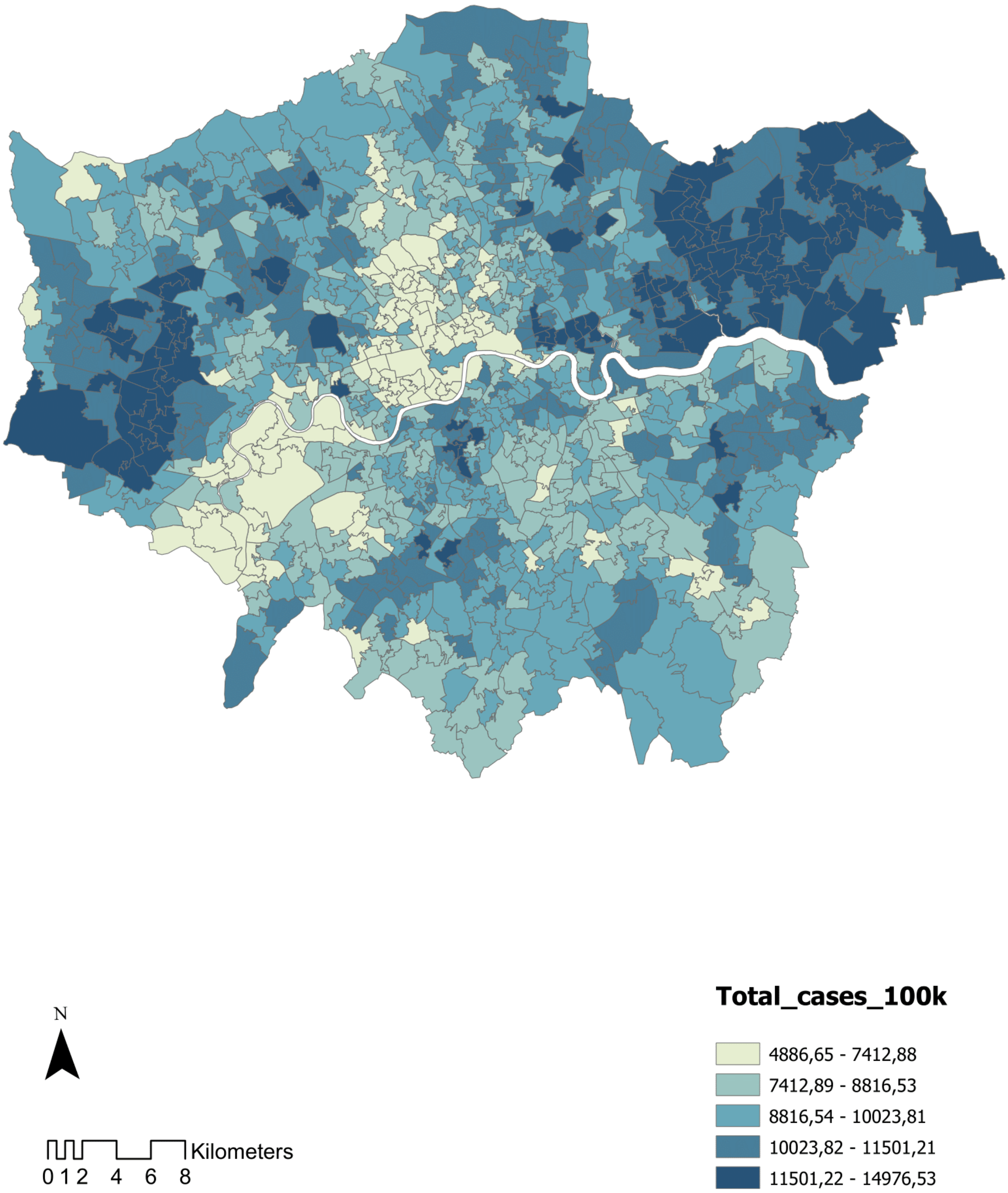
There are several observations that can be done just by visually describing the spatial pattern of COVID-19. This first spatial descriptive analysis aims at observing the distribution of the cases and deaths within the city, throughout time. It is an initial exercise that does not link immediately the characteristics of the spread to possible correlated factors. Each city was analysed in terms of:

- Total cases (normalised)
- Total deaths (normalised)
- Spatial patterns of the pandemic, once again, in terms of spread and mortality, throughout time (also in this case the data for each month was normalised).

The unevenness of the pandemic, or patterns of diffusion constitute by their own a potential source of questioning for further research, especially when placed (in this case qualitatively) in relation with other instances across the globe and within the cities. Moreover, the pandemic, as a dynamic phenomenon, has hit cities differently across time, and this is also reflected on the spatial patterns that can be observed from the maps that will follow. Periods of intense spread of the virus have been named "waves", which are approximately coincident for most of the case studies employed in this research, although the specific dates will be detailed later. A graduated colour map, effective to visualise how the pandemic spread sequentially, was used to highlight the differences in spread an mortality across the units of the case studies. The colour have been maintained coherent throughout the thesis in order to distinguish deaths and cases.

COVID-19 was and is a highly contagious virus which, however, has low mortality rate, as widely proved by a myriad of studies. This is also reflected on the data retrieved for the case studies. Nevertheless, it is of interest to track the spatial patterns of incidence in terms of deaths, to identify the areas mostly affected overall, over time, and compare them with the patterns of cases. Convergences and divergences can be seen as triggers to foster explorative research on socio-spatial correlated determinants, or else. One last note, regarding the maps, is that they were plotted using a "natural break" system, defined by ESRI (2021c) as "*Class breaks are created in a way that best groups similar values together and maximizes the differences between classes. The features are divided into classes whose boundaries are set where there are relatively big differences in the data values*".

Figure 2 - Total cases by MSOA, London



5.1.1 London

1) Total cases

It is possible to notice from Fig. 2 how the virus has spread heterogeneously. The area around Central London, including Westminster, Chelsea, Kensington, have registered the lowest number of cases. Similarly, Camden, which confines with Westminster on the northern side, and Richmond Upon Thames, which is geographically located along the river, on the western side of Westminster, have registered a low number of cases within the time frame considered. On the other hand, the areas which accounted for the highest number of cases were in Eastern and Western London. Specifically, the areas of Barking and Dagenham, Newham, Havering, and Redbridge registered the highest number of cases. A similar impact was seen in West London, where Brent, Ealing, Southern Hillingdon, and Hounslow have accounted for high normalised figures. The Southern areas of London, namely Bromley, Croydon, and Sutton, although accounting for significant figures in terms of cases, lie below the incidence in Eastern and Western London, but above the impact registered in Central London. A similar trend can be observed in North London, where Harrow, Barnet, North Hillingdon, and North Enfield have median figures. It is noteworthy to point out the change in rate as the river Thames is crossed. In East London the MSOAs located northern to the river present higher cases, compared to the output areas on the other side of the river. On the north side the trend changes as we move from Tower Hamlets to Central London, where there is a stark drop in cases. On the south side, instead, the figures per MSOA are maintained stable along the river, until Richmond Upon Thames, where the incidence of COVID-19 decreases, although gradually.

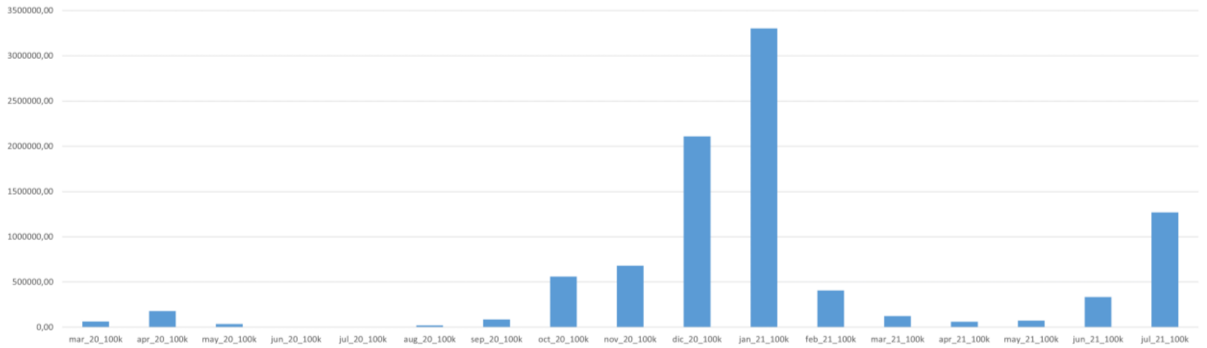


Figure 3 - Bar chart COVID-19 cases in London

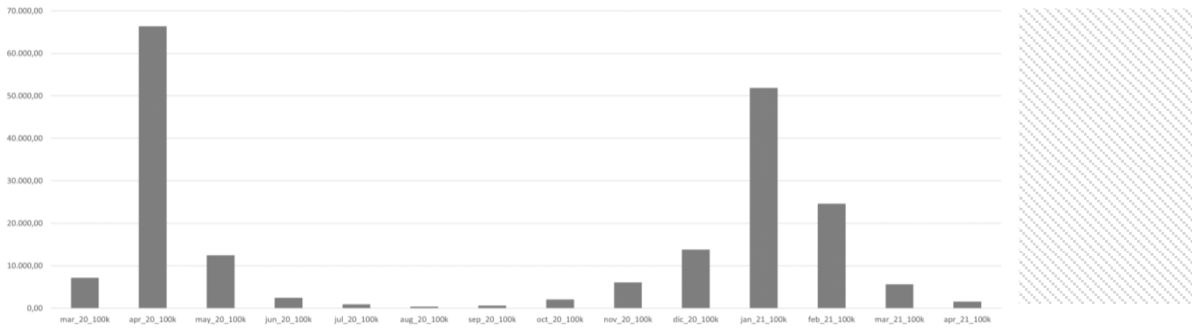


Figure 4 - Bar chart COVID-19 deaths in London

2) Spread over time

Looking at the graph of incidence over time (Fig. 5 to 21), we can roughly define three distinct waves. The first one, although minimal, from March to April 2020. The second started in September 2020, picked in January 2021, and decreased in February 2021. The last wave, up to the date of retrieval of the data, begun in June 2021 and was still growing in July 2021.

Starting from March 2020, although only a few days were monitored, it is possible to see how the areas which were mostly affected in the overall counting, like East or West London (except the area around the border with North London), did not account for a great number of cases at first. In fact, looking at the maps, it is possible to see how initially the central area hosted a greater number of cases, in particular the South-East area of London, such as Southwark and Lambeth. Also, the North-West, namely Brent, Barnet, and Ealing, accounted for a significant number of cases. Compared to the overall counting, the spread in March seems to be more homogeneous. However, contrarily to what can be asserted from the final counting's map, where areas of aggregated MSOAs could be classified under the same impact-class, the disaggregation for March shows a greater heterogeneity, and more and more units, although being proximate to each other, accounted for a greater divide in number of cases. From April 2020, whereas the spread in some of the central areas of London started to decrease, like in the areas of Kensington and Chelsea or Westminster, others, like Hammersmith and Fulham, for instance, showed an increase in cases. East and West London's registered cases grew. In general, it is possible to observe how the spread was pushed also outwards, while simultaneously, the central areas showed decreasing figures, although not homogeneously. This trend is even more evident in May, where, despite the general drop in cases registered (from 180.225,72 to 37.041,24), the external areas accounted for most cases, proportionally speaking, as it can be observed from the maps. These patterns could be suggestive for future research, to question why certain locational continuity or discontinuity happened and why their relationship changed over time. It is beyond the scope of this dissertation to investigate the evolution of the pandemic throughout the entire time spectrum; however, future studies could be centred on this particular "side" of the story.

June, July, and August present lower overall rate figures (2.331, 4.315 and 21.002 respectively), even if it rose over time, particularly in August when the figure quintupled. During June and July, most areas presented little if no cases. However, some hotspots could be observed (e.g., Hackney), which draw attention to specific granular units within the entire city. Why did some specific areas present a significant number of cases, whereas most of the city was "untouched"? What specific reasons can be correlated to this trend? These are just some of the questions that are worth investigating and that, possibly, can lead to expand our understanding of the pandemic and cities. From this perspective, a granular, punctual observation could tell us more about the urban, in a "Ananya Roy" fashion. In August, some patterns can be observed. Firstly, the number of registered cases rose in central London. Secondly, East, West and North London, previously presenting low case rate, start to show increasing figures. South London, on the other hand, present lower registered cases. The rising trend of August 2020 continued also in September (from 21.002 to 86.603). Here again the central part of London experienced an increase in cases rate. The spread is highly scattered, but, contrarily to the beginning of the first wave, West and East London were affected the most. South and North London, which were proportionally more impacted in the first wave, are less affected in the second wave.

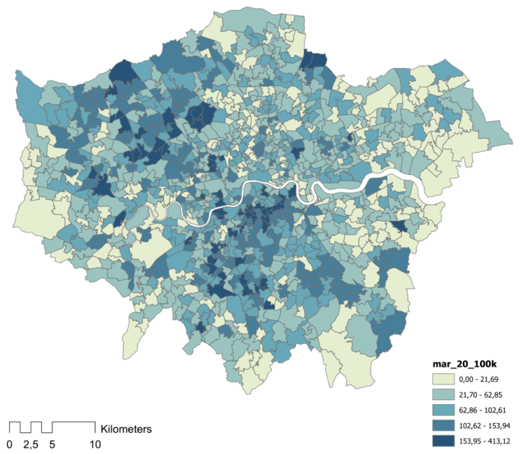


Figure 5 - Spread, March 2020, London by MSOA

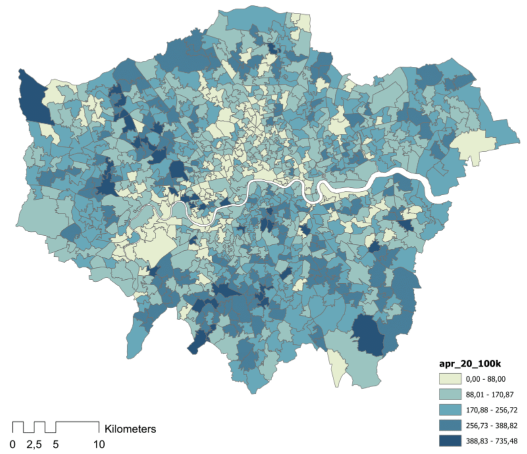


Figure 6 - Spread, April 2020, London by MSOA

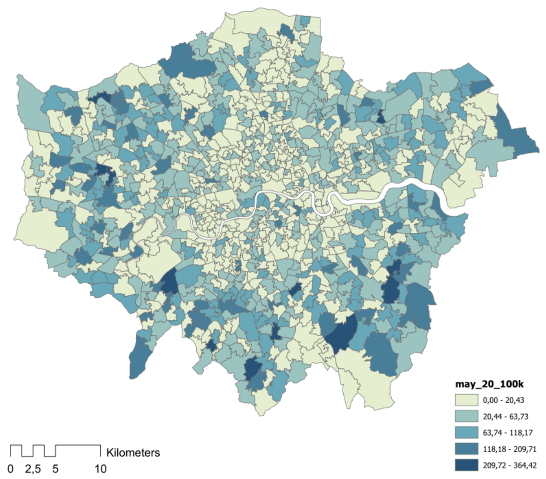


Figure 7 - Spread, May 2020, London by MSOA

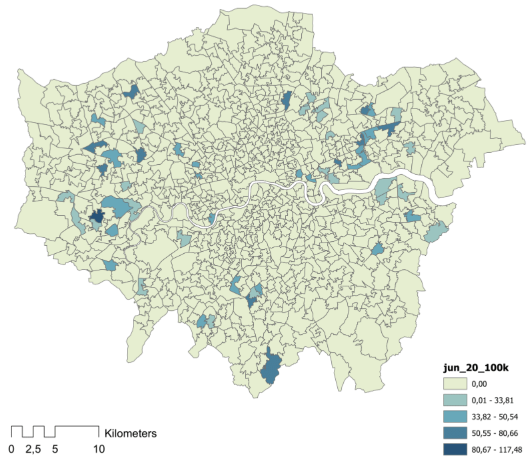


Figure 8 - Spread, June 2020, London by MSOA

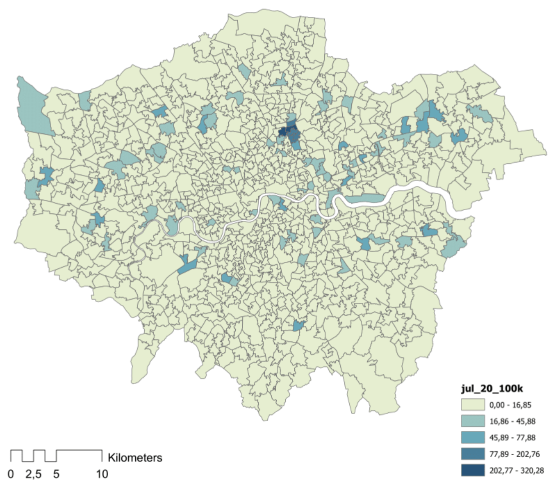


Figure 9 - Spread, July 2020, London by MSOA

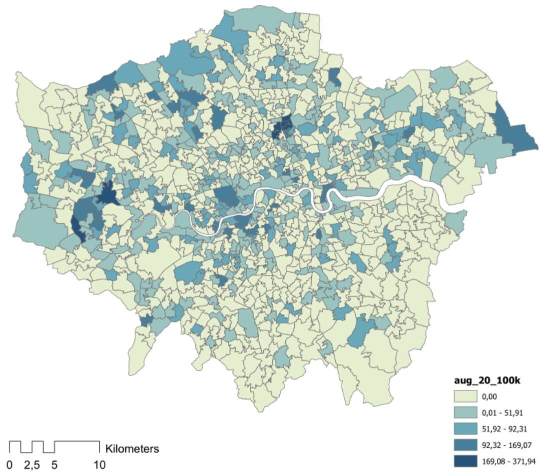


Figure 10 - Spread, August 2020, London by MSOA

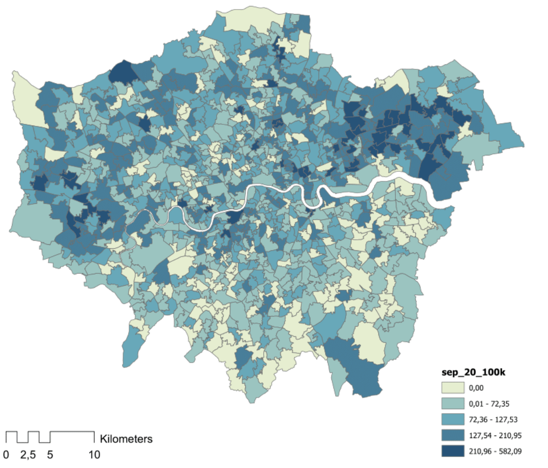


Figure 11 - Spread, September 2020, London by MSOA

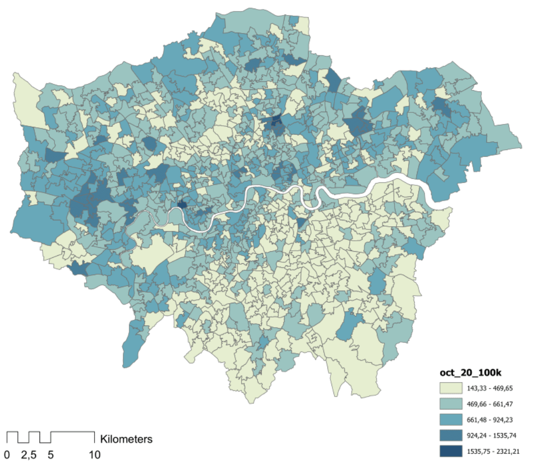


Figure 12 - Spread, October 2020, London by MSOA

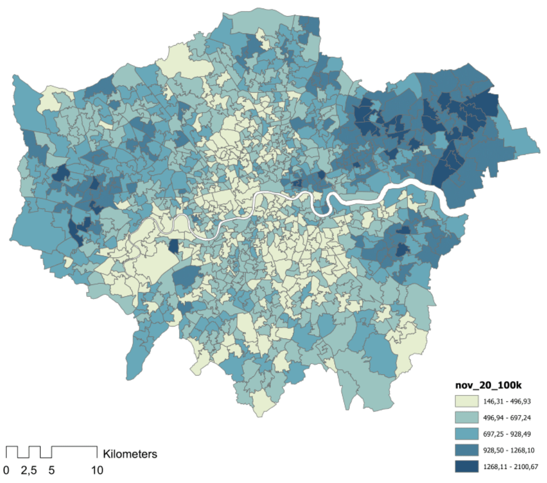


Figure 13 - Spread, November 2020, London by MSOA

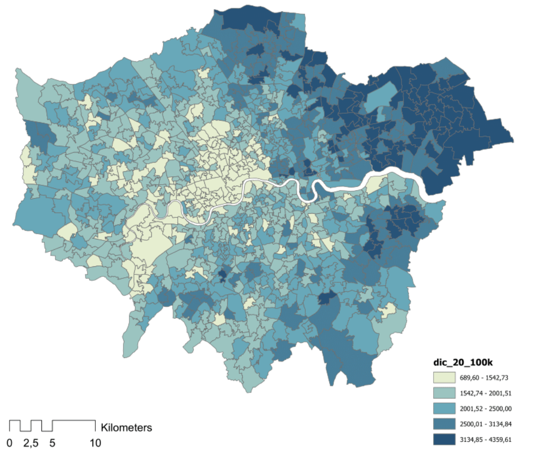


Figure 14 - Spread, December 2020, London by MSOA

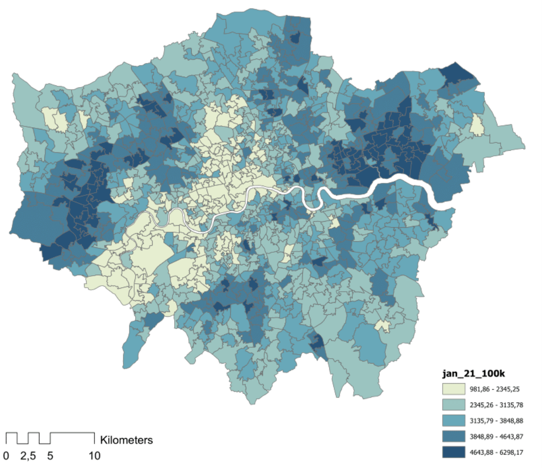


Figure 15 - Spread, January 2020, London by MSOA

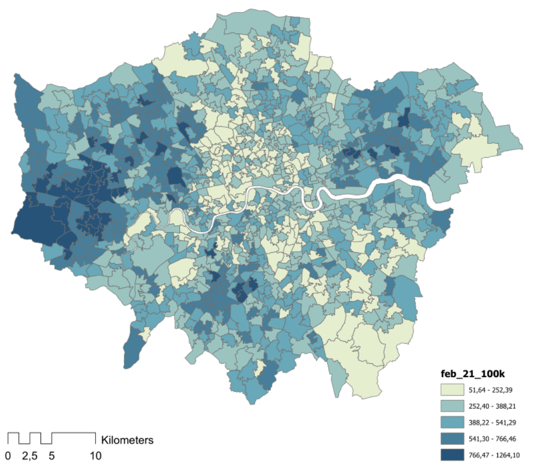


Figure 16 - Spread, February 2020, London by MSOA

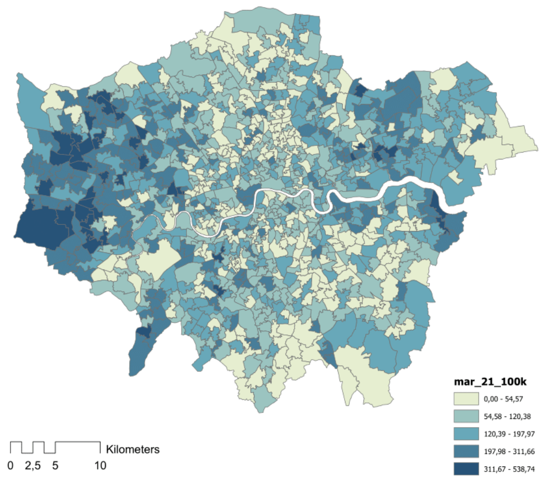


Figure 17 - Spread, March 2021, London by MSOA

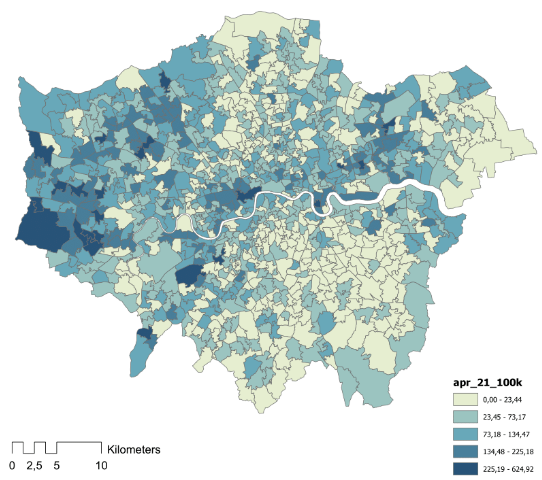


Figure 18 - Spread, April 2021, London by MSOA

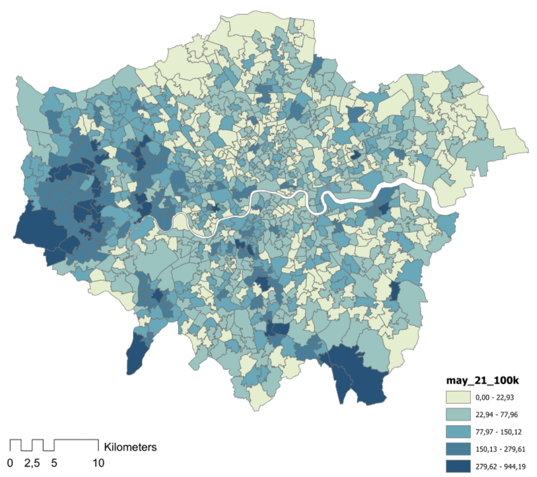


Figure 19 - Spread, May 2021, London by MSOA

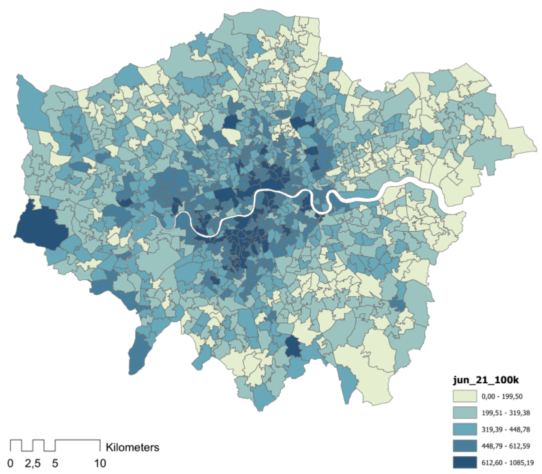


Figure 20 - Spread, June 2021, London by MSOA

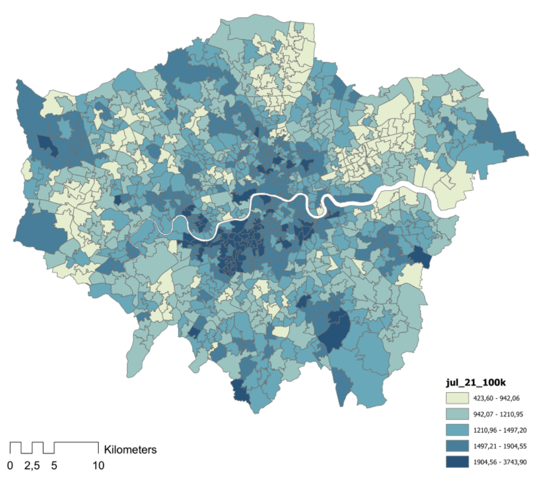


Figure 21 - Spread, July 2021, London by MSOA

By observing the map of August, September, and October (Fig. 10 to 12), it is possible to determine how the proportions of the case rate is roughly the same, indicating a persistent pattern throughout time, although gradually exacerbated, with significant growth in East and West London. From this descriptive visual analysis, it appears the spread is roughly reversed, compared to the first wave (from South-North to West-East spread), although both seem to suggest the beginning of the spread from the centre. The three-month period from November to January (included) was the most impactful, as shown by the overall case rates (680.399,28, 2.110.128,19 and 3.301.524,56 respectively). The rate grew for almost all MSOAs except a few exceptions (e.g., Merton, MSOA E02000692). In this case, conversely to what was observed during the summer period, it might be potentially revealing to explore the reasons why specific units have shown a decreasing trend. In contrast, the entire city experienced significant growth. Besides this, there are other patterns to observe during the second wave. Firstly, throughout the period, Central London had a lower rate than the rest of the city proportionally, particularly in Camden, Westminster, Kensington, and Chelsea. Also, Richmond Upon Thames, although part of West London but proximate to Central London, had lower figures. Secondly, by looking closely at the maps, it is possible to observe how the spread initially affected East London more than other areas. It also spread to South, West and finally North, in an almost clockwise direction. From February to March 2021, there was a decreasing trend in the overall rate, stabilising in April and May. Also, in this case, West, East and part of South London showed proportionally more significant figures, and, geographically speaking, the cluster of infections remained stable over time, although gradually declining. The differences (and similarities) in the spatial spread of the virus between the first and the second wave might be a potential source of investigation for many researchers in various fields, as many different factors might have contributed to the shift in arrangement and diffusion of cases.

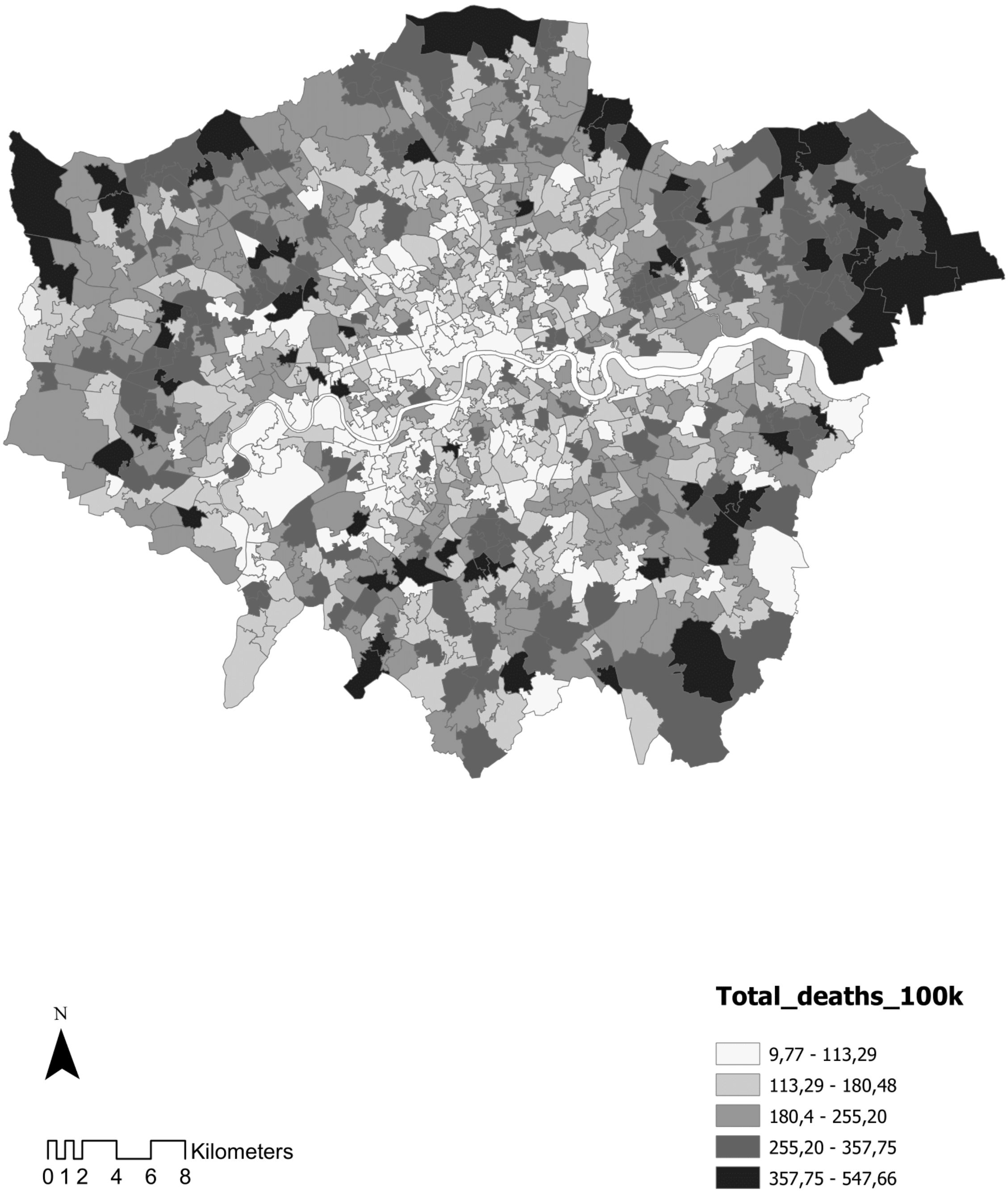
The last wave, although just partial, suggest significant insights. The start of the spread from Central London seems to be confirmed in this third wave, even more clearly, as it can be seen from the map, where there is a pick of cases in basically all the central areas, while the outward proportionally accounts for lower rates.

1) Total deaths

On a general note, looking at the graphs of overall cases and deaths rate (Fig. 3 and 4), it is striking how, although the much lower number of contagions during the "first wave" compared to the others, the death rate was the highest recorded, indicating a shift in the ratio death rate/case rate.

When considering the total mortality of the pandemic in London, it is possible to see from the map (Fig. 22) how central areas accounted for lower rates than the external units. Therefore, as in the previous analysis, the distribution is heterogeneous. There is also, roughly, a similar distribution of both case and death rates, although it seems more scattered in the case of the latter. The areas at the border of Greater London have been the ones registering higher death rates. Richmond Upon Thames, Kensington and Chelsea, City of London and Westminster have lower figures (as observed in the previous analysis). Finally, compared to the spread, the mortality seems to be more evenly distributed (although there is still apparent heterogeneity). The transition from low rates to high rates is more gradual, besides some scattered inconsistency among several units.

Figure 22 - Total deaths by MSOA, London



3) Mortality over time

In March, the external MSOAs presented the highest figures, especially the North-West and East. In general, the death rate is seemingly scattered across the city, with a more significant inconsistency between different areas. In April, despite the overall mortality growth (from 7.089,72 to 66.336,82), the patterns identified above are still relevant. There was an increase in mortality in the central areas, like Camden, Hammersmith and Fulham, and Kensington and Chelsea. Also, in the extreme North, and South there was a rise in lethality. The North-West area of London seems to be critical both in terms of cases and mortality. In general, the divide between “central areas” and “external areas” is less clear, as the death rate is distributed more homogeneously in this phase than in previous analyses.

June, July, and August present lower overall rate figures (2.397, 893, 319 respectively). Similarly to what was observed in the spread of the cases, it is possible to notice how the death counts, in this phase, is primarily concentrated in a few areas, despite most of the city being “untouched”. Once again, these areas are quite homogeneously scattered across the city. Therefore, this trend is relevant for both the spread of the pandemic and its lethality. Analysing these punctual “anomalies” could potentially lead to significant insights on either the outbreak or the correlated determinants, if any. Starting from September, instead, the overall death rate began to grow again. From September to February, some patterns can be identified. Firstly, contrary to the spread trend, there is an outward-inward tendency, meaning that the central areas are affected only later, compared to the external ones. Secondly, although generally the mortality seems to be roughly homogeneously distributed in this phase, East London stands out at least in September, October, and December, as the area with the highest rate. Therefore, in this case, one specific part of the city was affected more than others. During the same time frame, the central areas of London accounted for lower comparatively figures. January and February of the new year were the most impacted (13.755 and 51.812 death every 100.000 inhabitants, respectively). As mentioned earlier, in this period also Central London had areas with relevant rates. Nevertheless, East London and its sub-units were still showing high mortality rates. Notably, the distribution seems to be again scattered and more homogeneous, as it occurred for the previous phase. This trend is even exacerbated in February when the proportional distribution of death rates in the maps suggests a more even situation across the city despite the general pick of deaths.

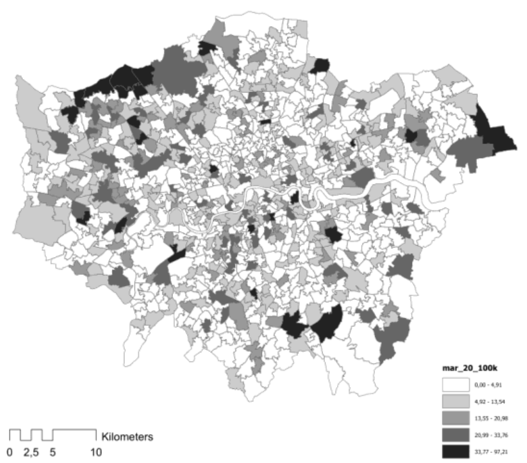


Figure 23 - Deaths, March 2020, London by MSOA

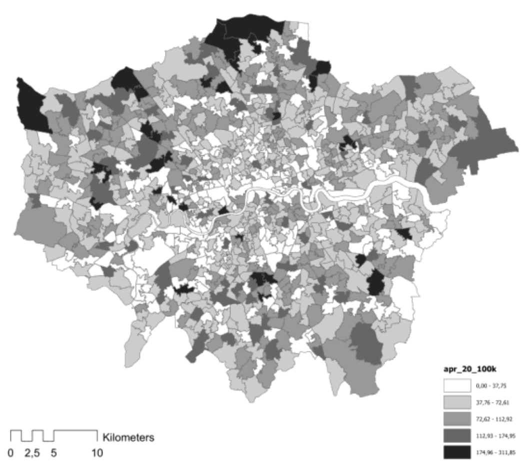


Figure 24 - Deaths, April 2020, London by MSOA

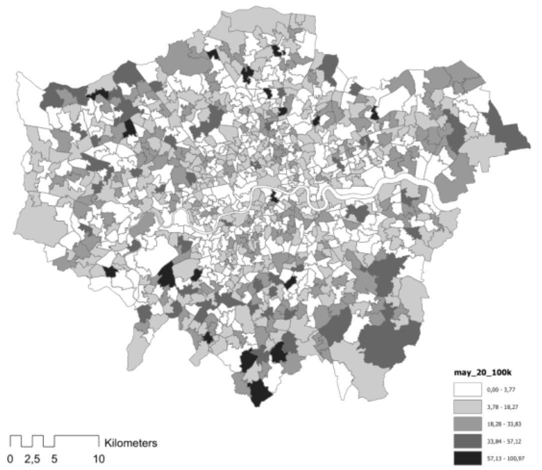


Figure 25 - Deaths, May 2020, London by MSOA

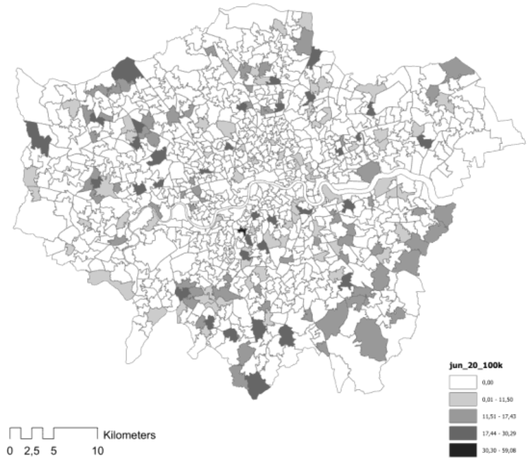


Figure 26 - Deaths, June 2020, London by MSOA

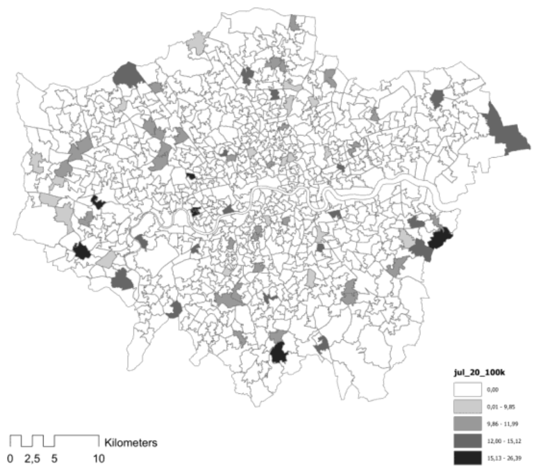


Figure 27 - Deaths, July 2020, London by MSOA

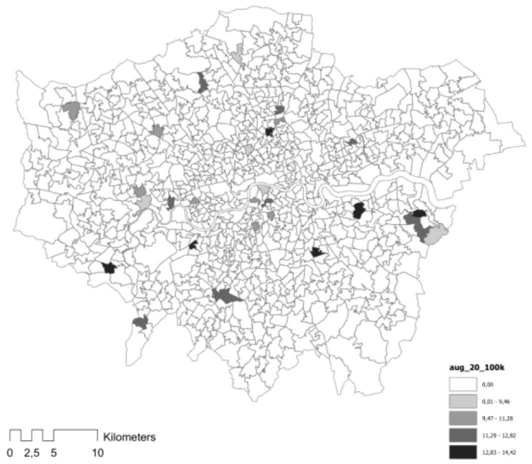


Figure 28 - Deaths, August 2020, London by MSOA

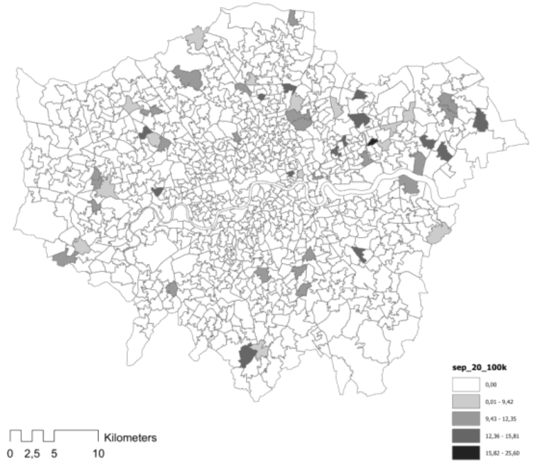


Figure 29 - Deaths, September 2020, London by MSOA

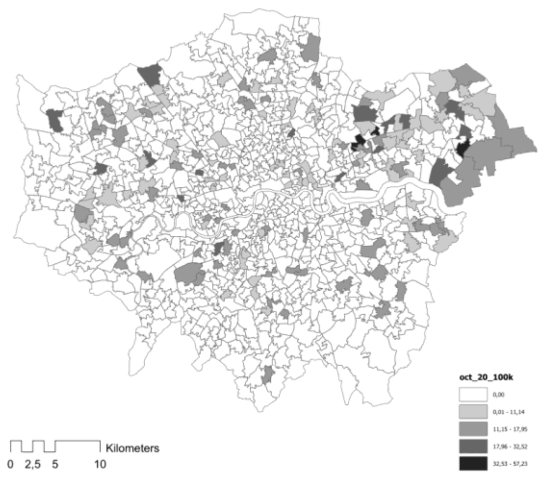


Figure 30 - Deaths, October 2020, London by MSOA

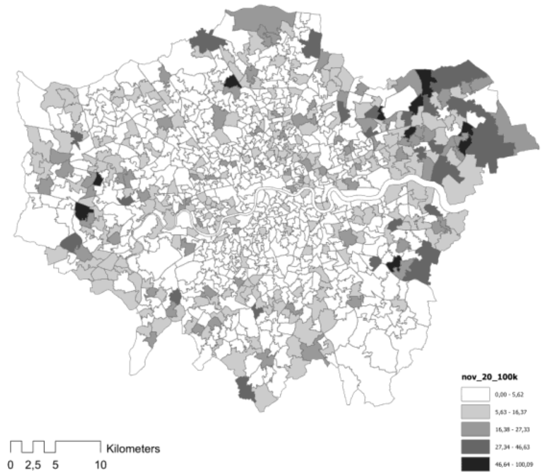


Figure 31 - Deaths, November 2020, London by MSOA

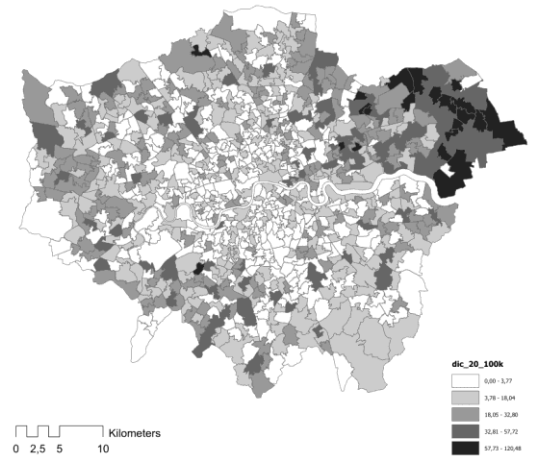


Figure 32 - Deaths, December 2020, London by MSOA

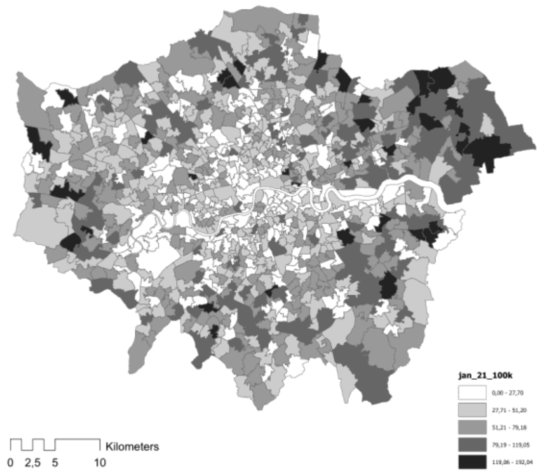


Figure 33 - Deaths, January 2021, London by MSOA

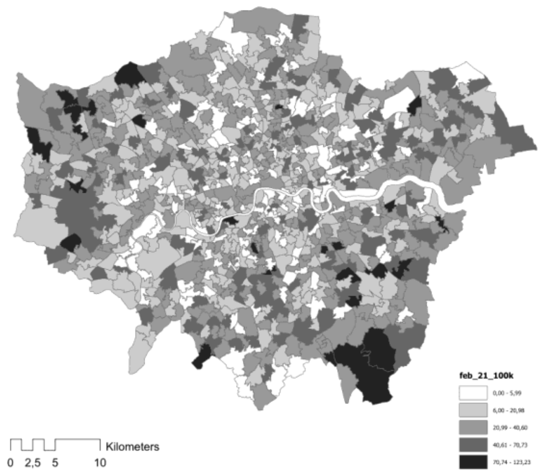


Figure 34 - Deaths, February 2021, London by MSOA

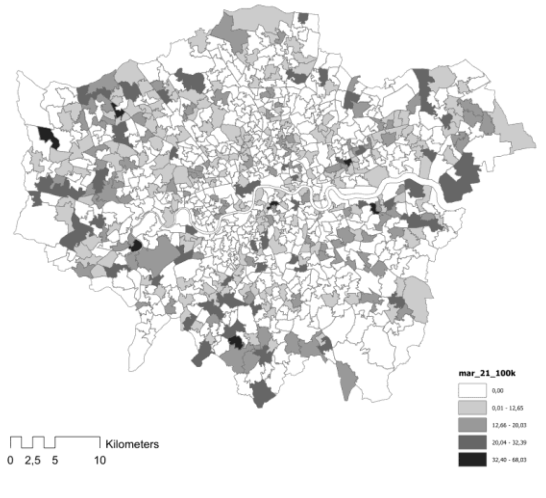


Figure 35 - Deaths, March 2021, London by MSOA

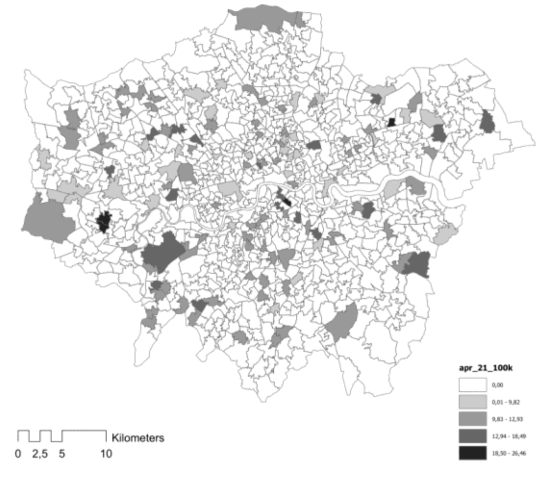


Figure 36 - Deaths, April 2021, London by MSOA

5.1.2 New York City

1) Total cases

The map displaying the total case rates (Fig. 39), has important suggestions to investigate. Firstly, as it happened in London, the spread was not homogeneous, meaning that the city had not been hit evenly. The areas of State Island, for instance, have accounted for a great number of cases, proportionally speaking. Similarly, almost all areas in the Bronx registered a high rate, as well as Queens, where, except some areas such as Bayside and Douglaston, the rates are high, although more diversified compared to the Bronx or Staten Island. Contrarily, all areas encompassed between Harlem and the Financial district showed significantly lower figures, with a few exceptions, namely, the area of Stuy Town, and Midtown West. However, despite this homogeneous trend in Manhattan, the financial district, at the extreme South tip, accounted for a notable rate, although being proximate to low-rate areas. Brooklyn, amongst all others, is the area that shows the greatest heterogeneity in terms of cases. Whereas the MODZCTAs closer to Manhattan accounted for lower rates, for instance Brooklyn Heights or Park Slope, some others, especially those facing Staten Island or located south (e.g., Coney Island), had higher rates.

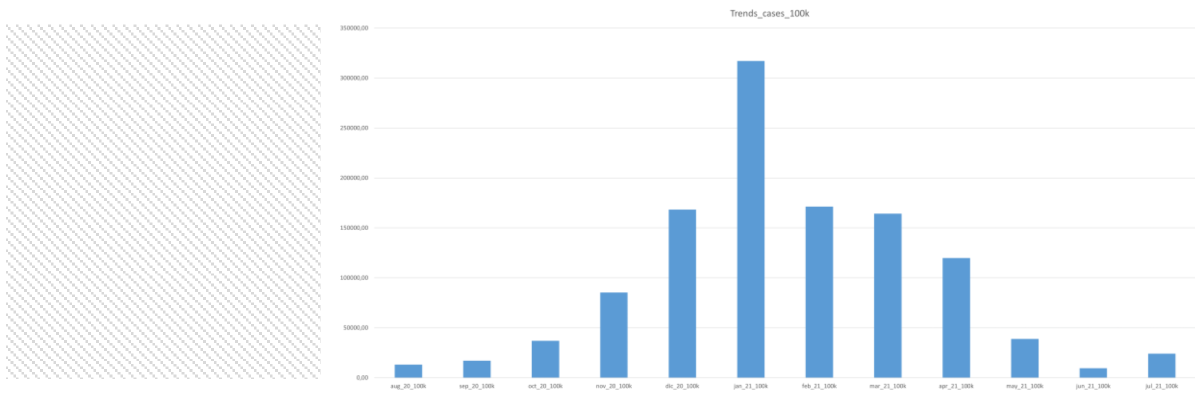


Figure 37 - Bar chart COVID-19 cases in NYC

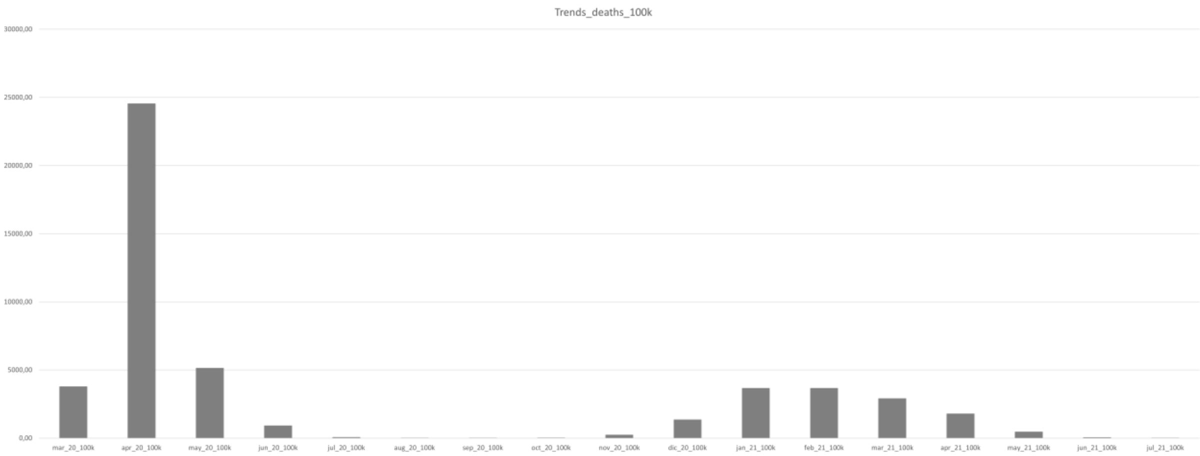
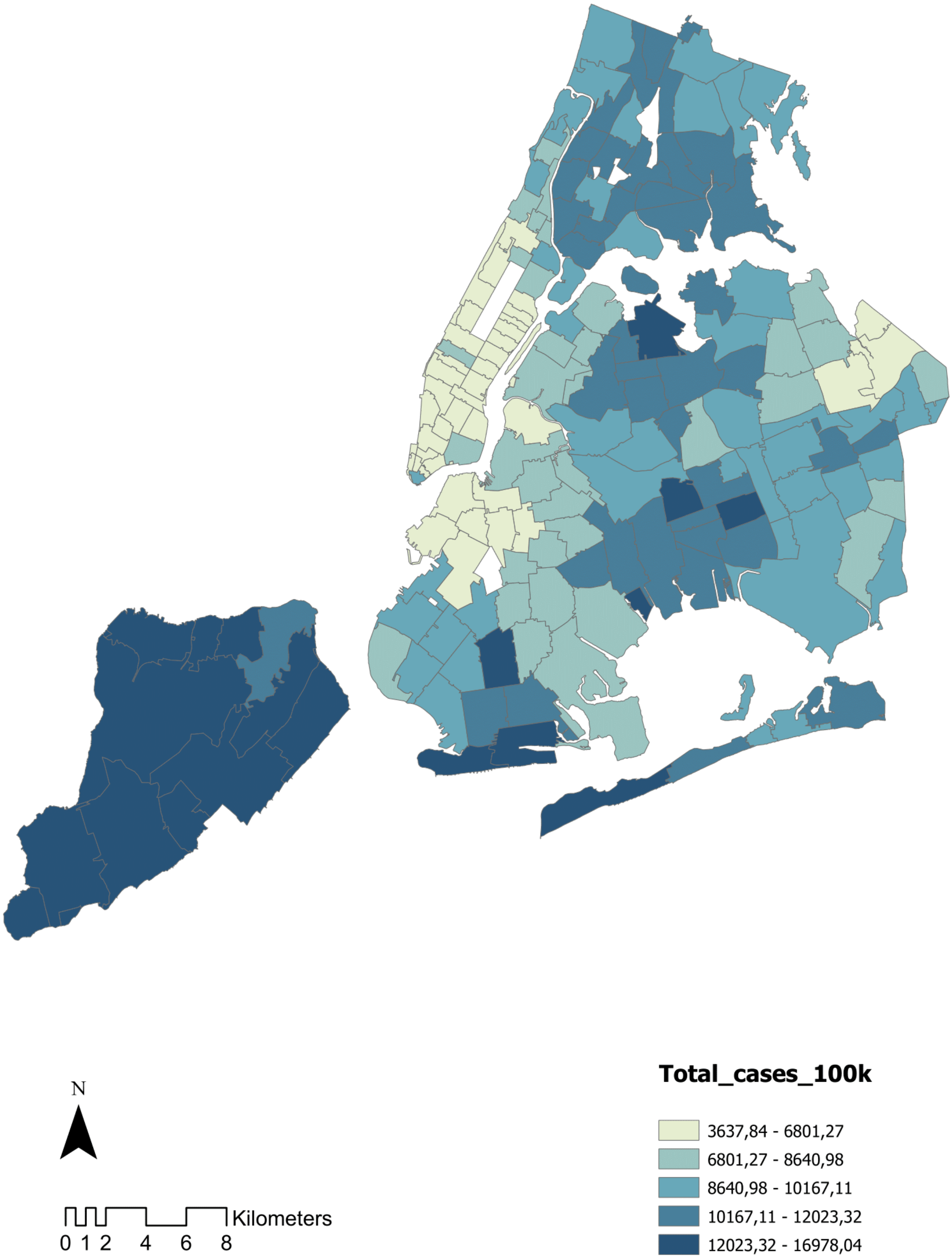


Figure 38 - Bar chart COVID-19 cases in NYC

Figure 39 - Total cases by MODZCTA, NYC



2) Spread over time

Unfortunately, as mentioned in the data description chapter, compared to the other cities analysed, the data concerning the first wave, indicatively between March and May, is not available to the public as of today. Therefore, no considerations can be done on that specific period. The other two "waves" are, nevertheless, visible and can be interpreted in spatial terms.

The data available starts from August 2020, which coincides, approximately, with the beginning of the second wave. Once again, there are several spatial observations that can be put forward, while also comparing with the overall rate, previously investigated. Firstly, Manhattan is internally more diversified, especially when compared to the total spread. In fact, whereas in the latter the rate was seemingly homogeneously distributed, in August the MODZCTAs presented quite diverse figures, particularly in Lower and Upper West and East Side. A common pattern, repeated both in the overall rate and the disaggregation in August, is that certain areas are more affected than others. This is the case for the Bronx (particularly West and South), Staten Island (apart from Tottenville, which, on the other hand accounted for lower rate), the southern part of Brooklyn, such as Bay Ridge or Gravesend, and the western and southern part of Queens, namely, Breezy point or Hamilton beach, among others.

In September the overall rate of cases increased, however, the distribution across the city showed a different pattern, as well as some similarities. The entire island of Manhattan, indeed, shows a quasi-homogeneous distribution of rates, a trend that was already in motion in the previous month, although Upper Manhattan was still more affected. The eastern part of Queens (e.g., Douglaston) and the northern eastern part of Brooklyn (e.g., Brooklyn Heights) had lower figures, besides a few exceptions such as Hillcrest and Kew Gardens, whereas the western part has comparatively higher rates. Staten Island, South Brooklyn and South Queens were still proportionally more affected. However, instead of a homogeneous, high rate, in the Rockaway peninsula, we can observe stark differences in registered normalised cases, although their geographical proximity. It is true, nevertheless, that in this case the MODZCTAs cover an extensive area, thus rendering harder the recognition of the actual "proximity" of the cases during the period. In other words, given the level of aggregation of MODZCTAs and considering the unknown actual distribution of the population in the area, it is more challenging to identify where the actual clusters were located, and if the cases were eventually scattered or concentrated, thus questioning whether geographical vicinity played a role or not. Still, it is worth exploring these stark divides in rates. October and November showed similar patterns, despite the overall, progressive, growth of cases.

In December and January, we can still observe an overall increase in cases, however, with a different distribution, one that is seemingly congruent with the overall incidence, analysed at the beginning. In fact, whereas Manhattan (except for Upper Manhattan) has proportionally lower rates, besides the area of Stuy Town and the BD (Business District), some other parts of the city, previously identified as the most affected, can now be more neatly recognised. Namely, the Bronx, Staten Island, the entire Queens, and South Brooklyn. There is therefore a trend in place: at the beginning of the wave the cases are more evenly spread, whereas it tends to segregate as the pandemic progress. A constant feature is that some areas, already mentioned, regardless of the specific timeframe of observation, are always proportionally more affected than the rest of the city.

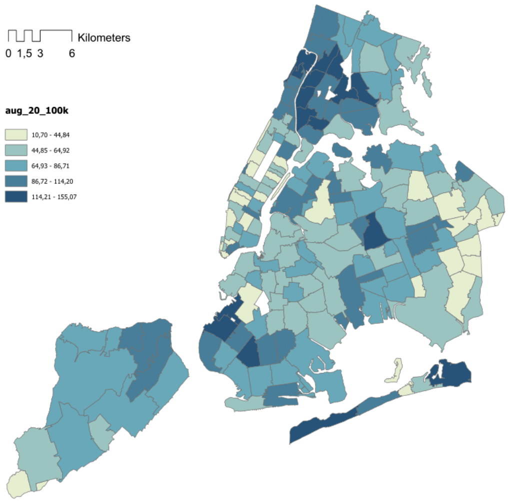


Figure 40 - Spread, August 2020, NYC by MODZCTA

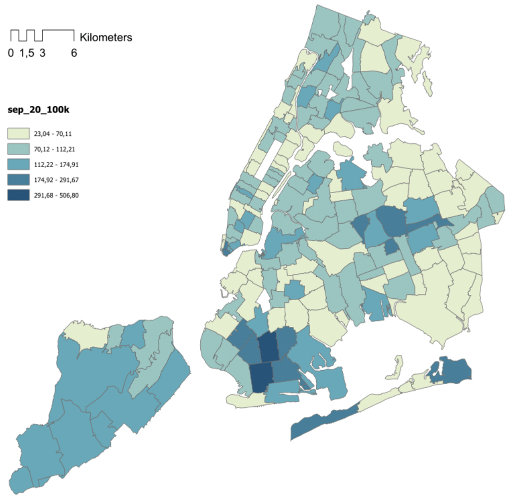


Figure 41 - Spread, September 2020, NYC by MODZCTA

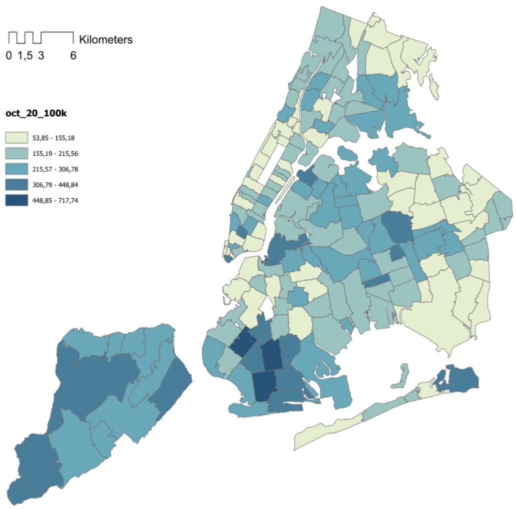


Figure 42 - Spread, October 2020, NYC by MODZCTA

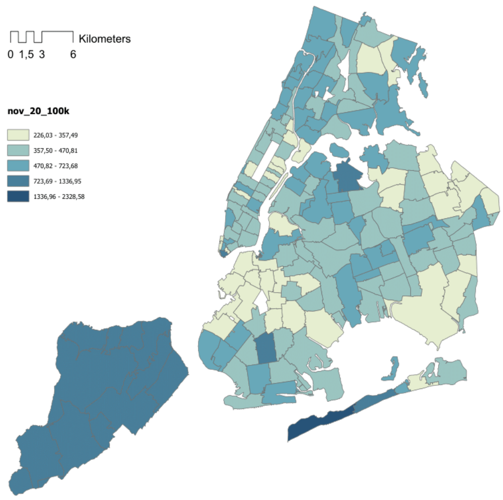


Figure 43 - Spread, November 2020, NYC by MODZCTA

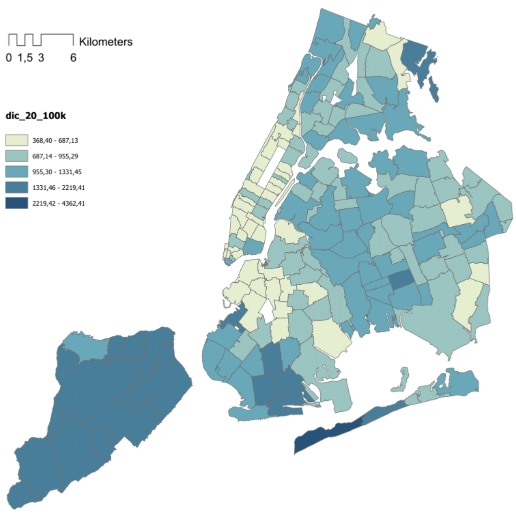


Figure 44 - Spread, December 2020, NYC by MODZCTA

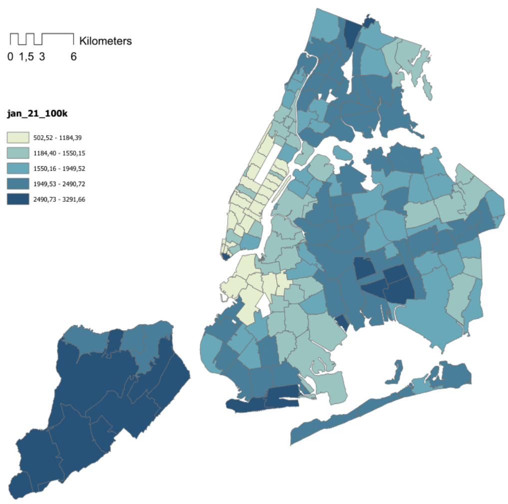


Figure 45 - Spread, January 2021, NYC by MODZCTA

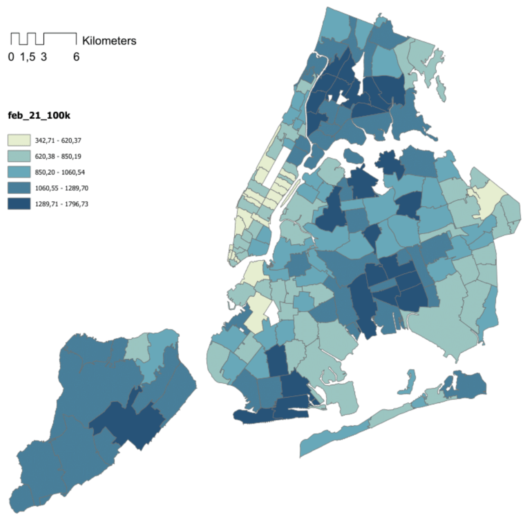


Figure 46 - Spread, February 2021, NYC by MODZCTA

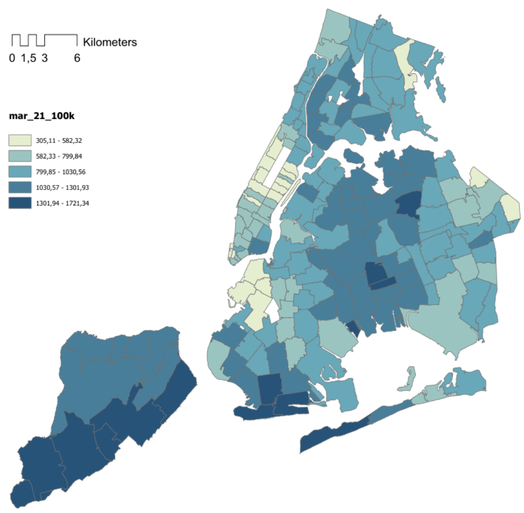


Figure 47 - Spread, March 2021, NYC by MODZCTA

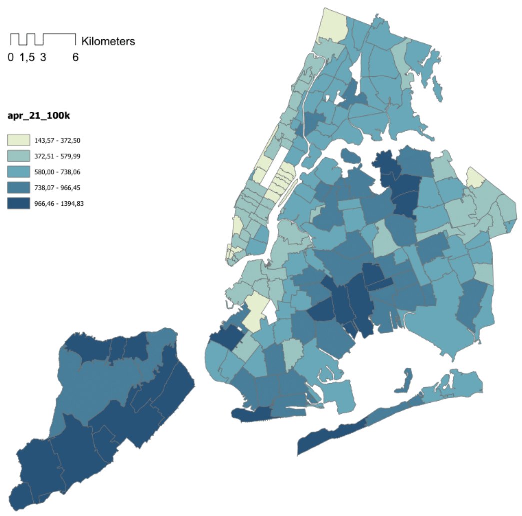


Figure 48 - Spread, April 2021, NYC by MODZCTA

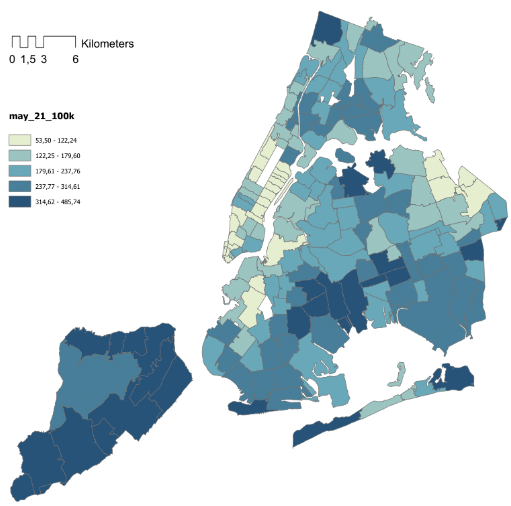


Figure 49 - Spread, May 2021, NYC by MODZCTA

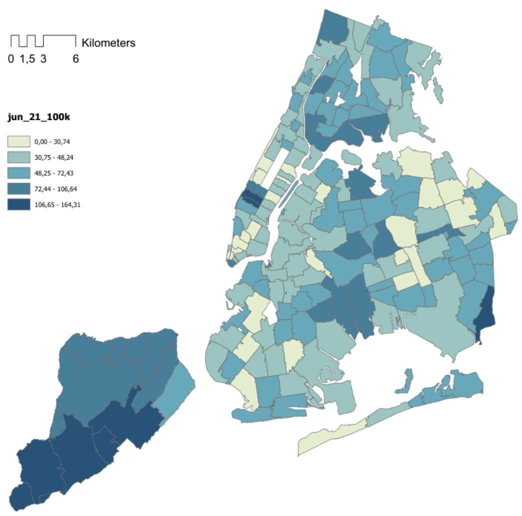


Figure 50 - Spread, June 2021, NYC by MODZCTA

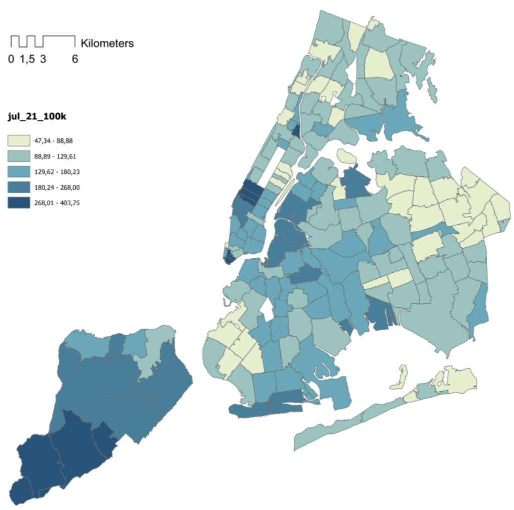


Figure 51 - Spread, July 2021, NYC by MODZCTA

On the other hand, as we observe February, March and April 2021, periods within which the rates were declining, we see that the rates tend to be more even in the island of Manhattan. In other words, whereas initially the Bronx and Upper Manhattan, for instance, displayed much higher rates compared to the rest of the island, from February to April (included), the proportions are seemingly rebalanced. During the same period, the other Boroughs like Queens, Brooklyn, and Staten Island, were comparatively more hit. In June, which also represent the valley, as shown from the graph (Fig. 37), this homogeneity is seemingly reached across the entire city, except for Staten Island.

Looking at the spread in July, which is the beginning of the third wave, we observe rates and overall growth. Interestingly, it is possible to see how Lower Manhattan was amongst the most affected areas, while notoriously more vulnerable areas, like the Bronx or Queens, showed lower figures. Therefore, contrarily to what happened at the beginning of the second wave, the "centre" of the city seems to account for proportionally more cases than other areas of the city (besides Staten Island).

Once again, as observed in London, there seem to be different distribution patterns as the analysis is moved from wave to wave. In fact, by analysing the two (in this case), it is possible to see how the same areas do not show consistent patterns, or at least not wholly, from the former to the latter. This phenomenon would require further investigation, with, perhaps, the creation of specific indicators to "track" the response of the pandemic-related data to particular variables and indicators over time.

3) Total deaths

On a general note, the death rate was the highest recorded in the "first wave" compared to the others. Unfortunately, it is not possible to compare the ratio death rate/case rate, as there is no data concerning the spread of the pandemic during the first wave.

The map displaying the total death rates (Fig. 52) is almost identical to the map of total case rates. This trend was also noticed in London, although for the British capital, the overlaying was less coincident. In NYC, instead, we can observe a remarkably similar distribution of normalised cases and deaths, both characterised by heterogeneity. This similarity was also proved by a Pearson's correlation model, where an R-value of 0.61 was found between the total spread and mortality of COVID-19, as we shall see later.

4) Mortality over time

In terms of mortality, the first wave was experienced between March and June 2020 (it picked in April and then decreased going onwards). From March to May, we can observe a consistent pattern of distribution, where only Lower Manhattan was slightly less affected. The rest of the city shows a relatively homogeneous trend. It is also possible to see, in this phase, greater discontinuity from area to area, with significant divides, especially in March and May, whereas April features a more even pattern. In general, it is more difficult to recognise a clear heterogeneous trend at the whole city level, although there was a more significant number of hotspots in the Bronx, Staten Island, and the southern part of Brooklyn. In June, when death rates were significantly lower, it is possible to observe how the distribution differs from the earlier months. Whereas most areas registered low rates, the

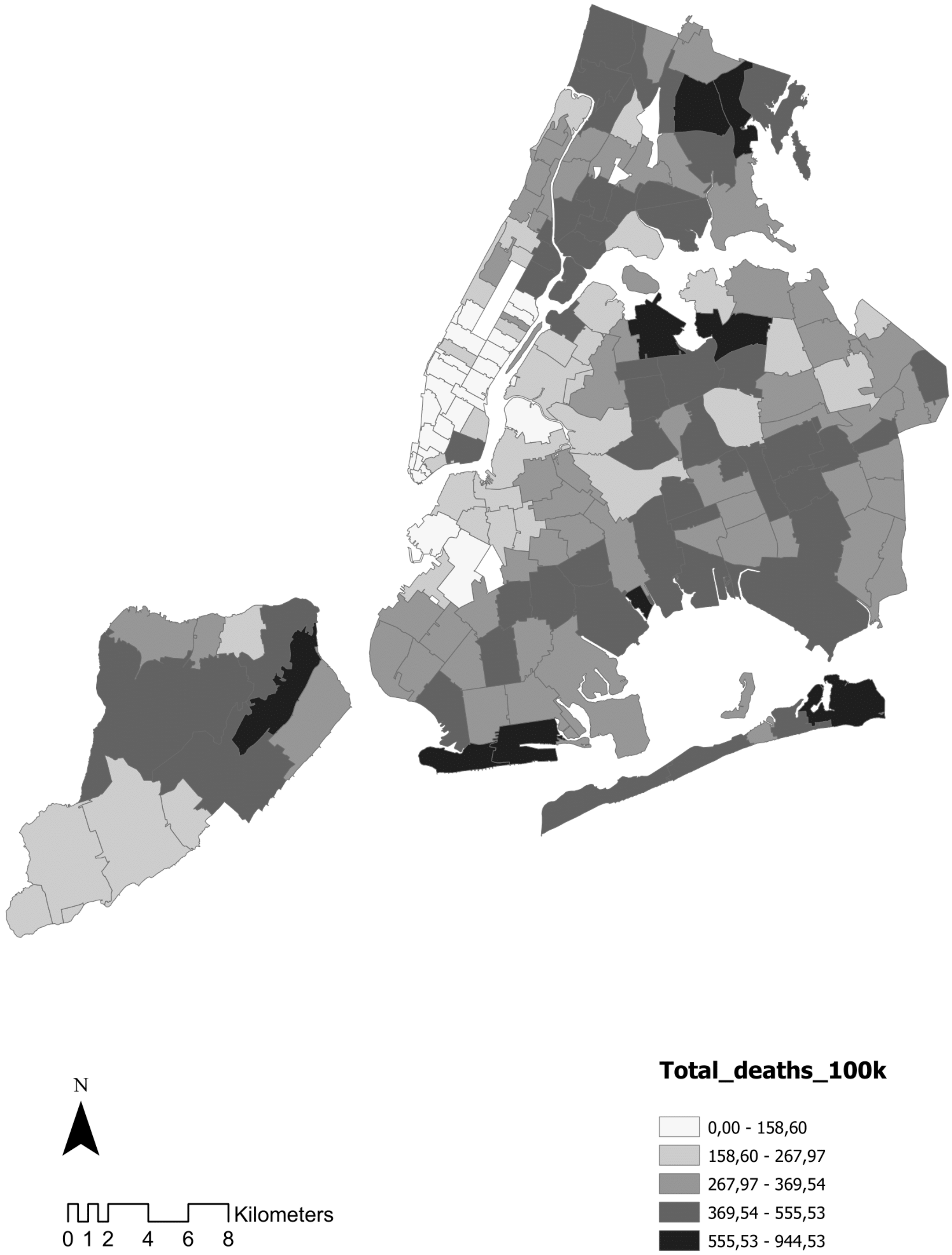
Bronx, almost entirely, accounted for greater figures and Brooklyn, although comparatively less.

There was a plateau from July to October (included), with rates close to zero across the entire city. However, as observed in London, despite the general flat situation, some hotspots are worth investigating. Specific areas (e.g., Midwood) where a greater number of deaths was registered. These "exceptions" or "singularities" should call for attention and foster the investigation of the reasons behind this divergence.

In the second wave, we can observe a trend that was also encountered in London. As we keep the progressive counting of death rates in the seven months of this wave, it is possible to see how, at first, the "external" areas primarily account for deaths. Then, gradually, this spread started to move also to more "central" areas, as it occurred in March, where most areas across the city registered deaths. This "outwards-inwards" movement, as just mentioned, was also noticed in London. This pattern is also coupled with a gradual homogenisation of MODZCTAs, meaning that, whereas at the beginning, there is quite evident segregation in death counts, as the months went on, the mortality started to set more evenly on the territory, like in February or March 2021. As soon as the overall counting starts to decrease, the rates start to be again heterogeneous, with higher rates in what has been observed to be vulnerable areas (e.g., the Bronx, Queens).

In this case, the distribution patterns, from wave to wave, seem to be alike. In fact, by analysing each wave independently, it is possible to observe similar trends and distributions of mortality across the city. In London, for instance, the pattern of mortality did not differ evidently as well, although some changes, from wave to wave, could be noticed and, therefore, questioned.

Figure 52 - Total deaths by MODZCTA, NYC



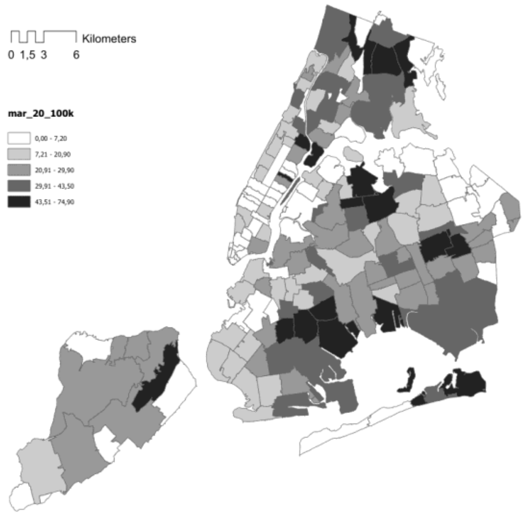


Figure 53 - Deaths, March 2020, NYC by MODZCTA

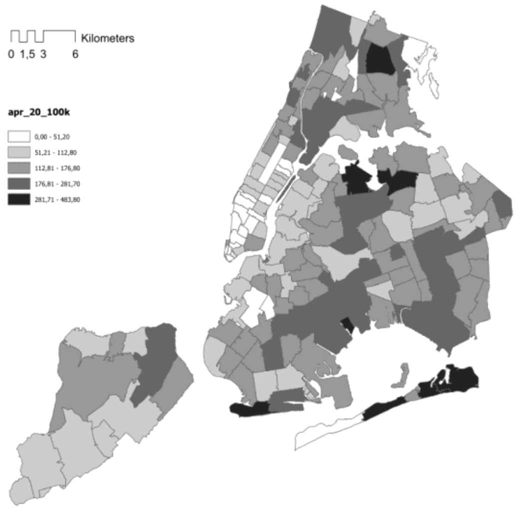


Figure 54 - Deaths, April 2020, NYC by MODZCTA

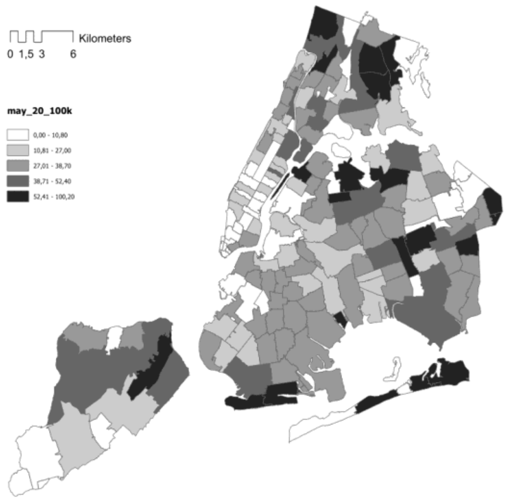


Figure 55 - Deaths, May 2020, NYC by MODZCTA

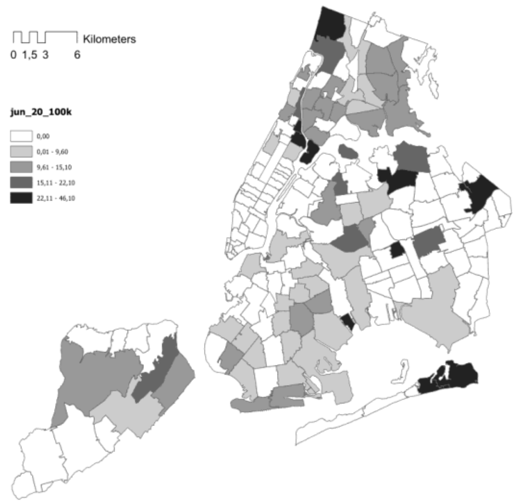


Figure 56 - Deaths, June 2020, NYC by MODZCTA

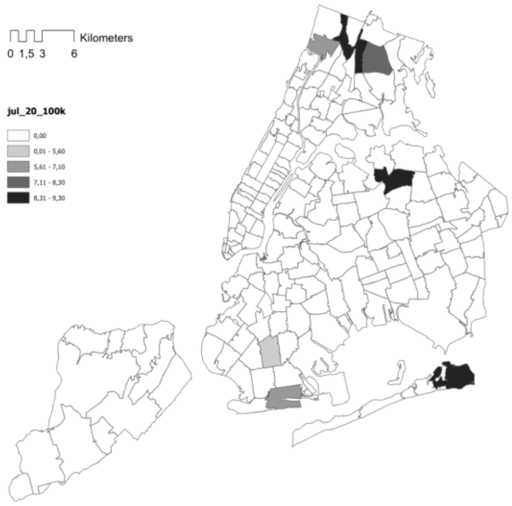


Figure 57 - Deaths, July 2020, NYC by MODZCTA

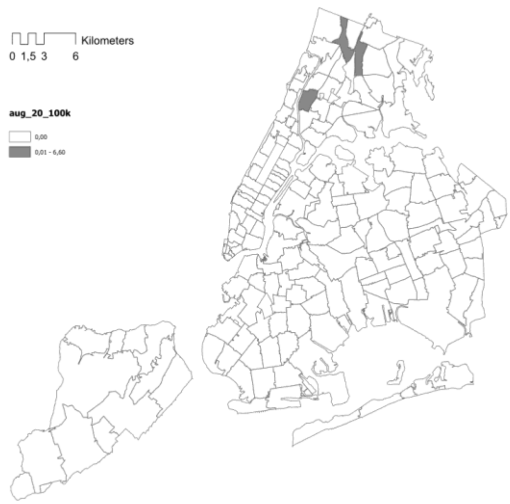


Figure 58 - Deaths, August 2020, NYC by MODZCTA

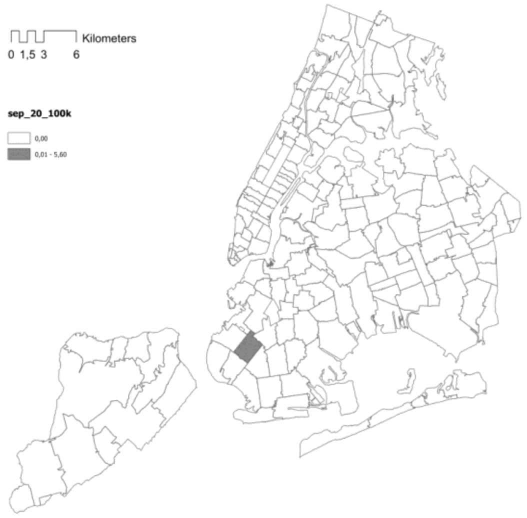


Figure 59 - Deaths, September 2020, NYC by MODZCTA

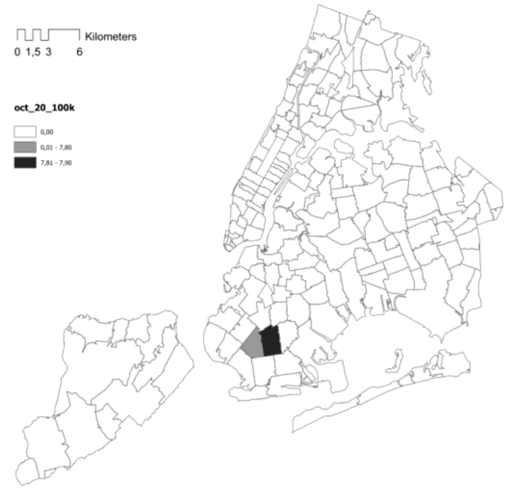


Figure 60 - Deaths, October 2020, NYC by MODZCTA

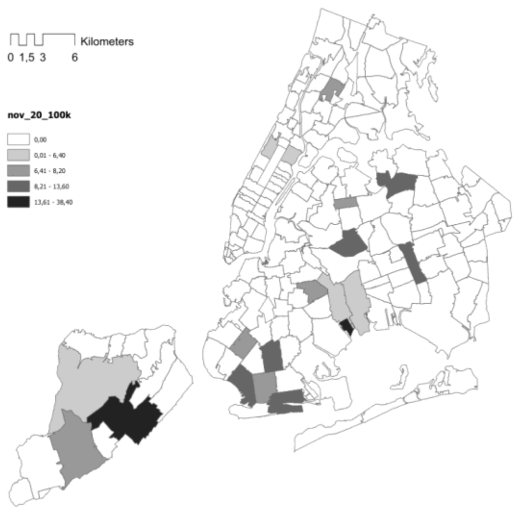


Figure 61 - Deaths, November 2020, NYC by MODZCTA

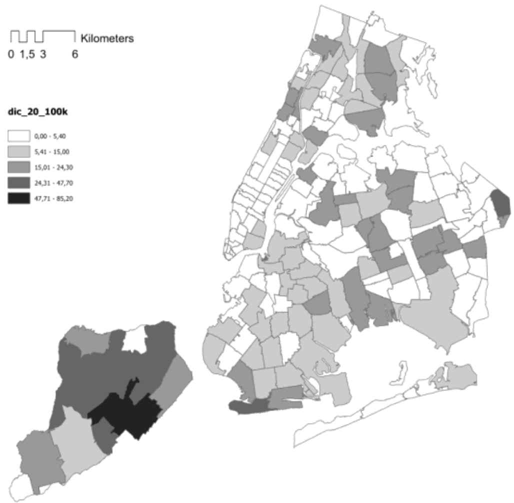


Figure 62 - Deaths, December 2020, NYC by MODZCTA

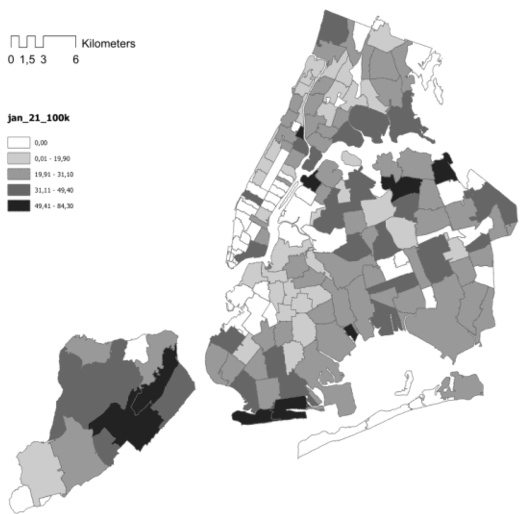


Figure 63 - Deaths, January 2021, NYC by MODZCTA

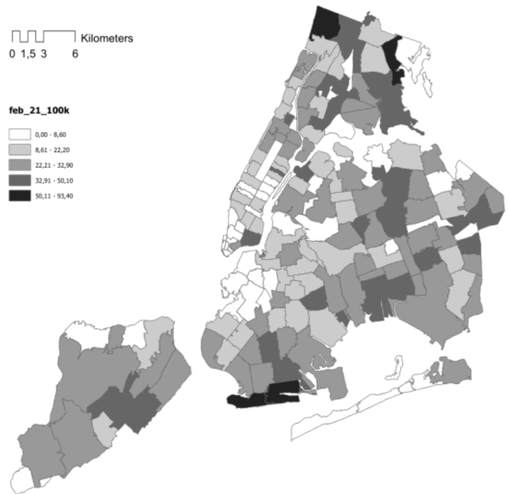


Figure 64 - Deaths, February 2021, NYC by MODZCTA

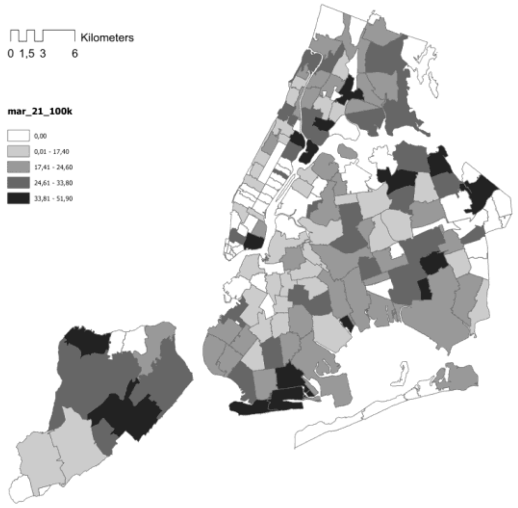


Figure 65 - Deaths, March 2021, NYC by MODZCTA

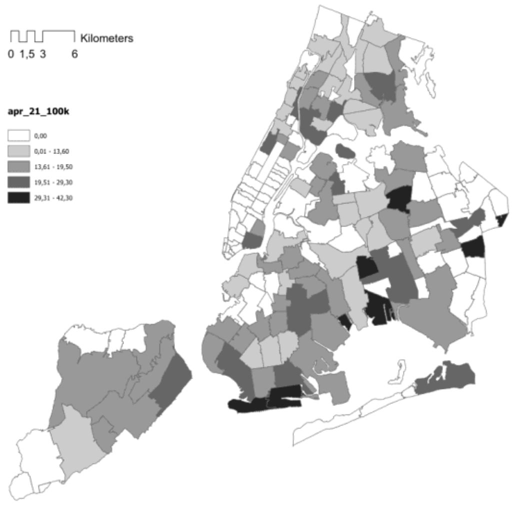


Figure 66 - Deaths, April 2021, NYC by MODZCTA

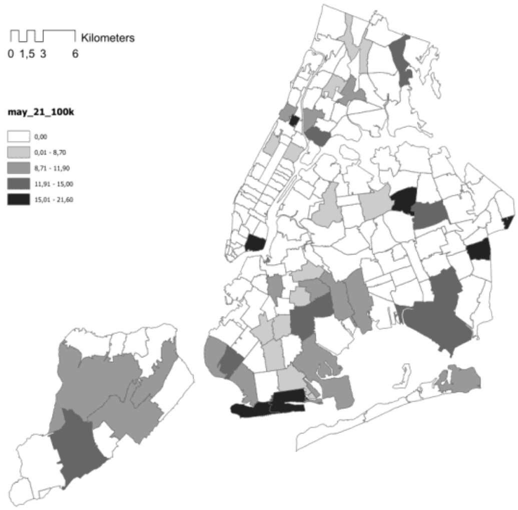


Figure 67 - Deaths, May 2021, NYC by MODZCTA

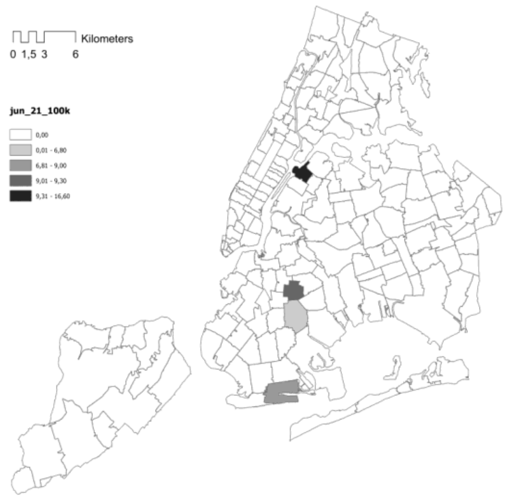


Figure 68 - Deaths, June 2021, NYC by MODZCTA

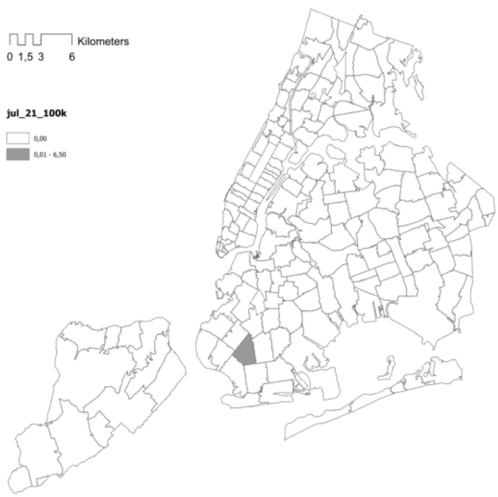
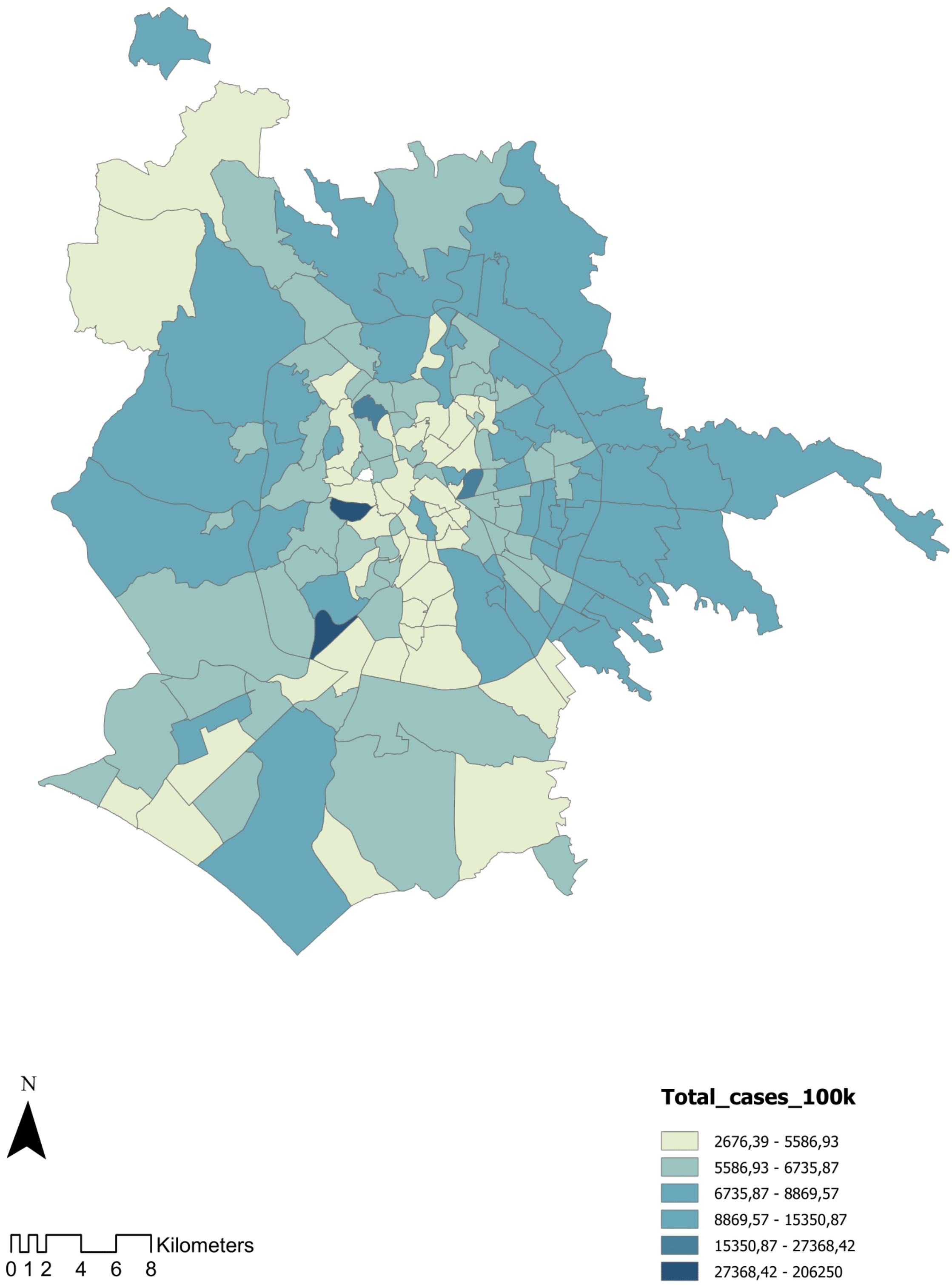


Figure 69 - Deaths, July 2021, NYC by MODZCTA

Figure 70 - Total cases by ZUB, Rome



5.1.3 Rome

1) Total cases

As observed for London and New York, also in Rome, the distribution of the spread is heterogeneous. Rome, specifically, is characterised by an "inner" part, inscribed within a circle, also known as "*Grande Raccordo Anulare*" (GRA), and an "outer" part, located outside. However, this distinction seems to be not so significant, at least for what concern this analysis, as we can see how, along the "ring" there is a certain continuity in terms of rates, besides a very few exceptions (e.g., the divide between *Appia Antica Nord and Sud*). The inner part of Rome shows a quite diversified scattering of rates, although, in general, it was less affected, especially when compared to the outer part. It is also possible to notice that there is a few ZUBs with a very high rate, namely, *Tor di Valle* and *Villa Pamphili.* The ZUBs lying outside the GRA show, altogether, higher rates and a certain consistency between proximate areas. The southern part, however, shows comparatively lower figures, as well as a few ZUBs in the northern side like *Cesano* and *S. Maria di Galeria.*

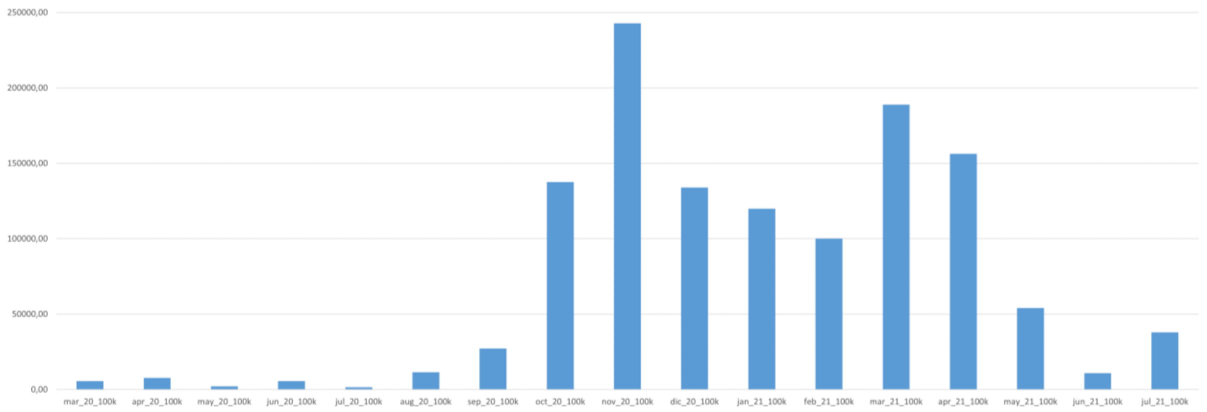


Figure 71 - Bar chart COVID-19 cases in Rome

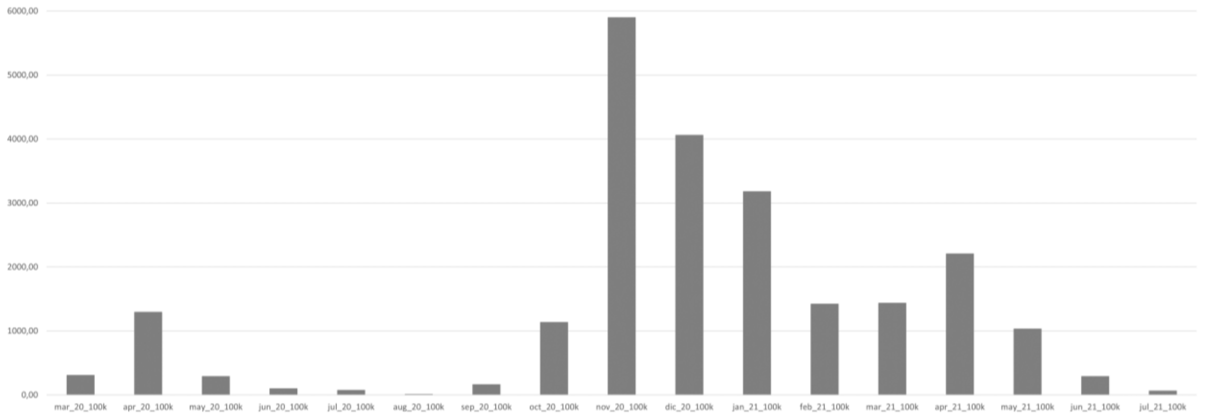


Figure 72 - Bar chart COVID-19 deaths in Rome

2) Spread over time

Starting from March 2020, we observe a higher concentration of cases within the GRA, despite many scattered ZUBs with relatively low figures. The eastern and western parts were also significantly impacted. The southern and northern areas of the municipality of Rome, instead, were comparatively less hit. It is still possible to notice between many contiguous regions at the border of the GRA, despite the infrastructural divide. For example, this was not the case for London, where the natural separation marked by river Thames coincided with a stark divide in case rates. In April, the spread also affected the previously only marginally hit areas, making an exception for the southern areas, which remained proportionally less impacted. We can still see a great deal of heterogeneity within the GRA, with ZUBs accounting for the highest rates (e.g., *Foro Italico* or *Villa Pamphili*). Conversely, other areas are minimally affected. In May, the overall rate decreased (from 7778,34 to 2174,51), and the distribution of cases also varied compared to previous months. In fact, we observe a reduction in rates of many areas within the GRA, although the pattern is maintained rather heterogeneous. Similarly, most of the external ZUBs showed a decreasing trend, except for the eastern part, where areas like *Torre Angela* or *Tor Vergata* maintained a seemingly stable trend, although the rates did show a minimal decline.

It is worth noting that, possibly in divergence with other case studies previously analysed via this "spatially descriptive" approach, in Rome, we observe several zones characterised by dramatically fluctuating figures within the space of a few months and in contrast with the trend of the surrounding areas. One example, among others, is the ZUB "*Villa Pamphili*" (16x). If further investigated, this trend might shed light on specific flows connecting spatially proximate or non-proximate areas and expand our understanding of the pandemic.

After steady growth in June, the rates decreased again in July. In the former, we observe how one specific ZUB, *Villa Pamphili*, accounts for almost the totality of the overall rate (4210, 53 out of 5531,29). It is of interest to explore the reasons behind this singularity. In July, despite the overall decline, the rates were seemingly more distributed within the GRA, which also accounted for proportionally more cases than external areas. Nevertheless, some zones outside the GRA also accounted for significant rates in July, especially in the eastern and northern sides. In general, it was possible to observe more evenness in the distribution of cases across the municipality in the first wave.

In August, the trend is consistent with the one analysed in July, with a prevalence of cases within the GRA. Nevertheless, more external areas started to account for growing figures. In the months that followed, specifically from September 2020 to May 2021, despite the dramatic growth of cases across the entire city, there was a very consistent pattern in the distribution of cases. In fact, it is possible to assert that the whole municipality and its sub-areas were affected evenly, to a greater or lesser extent, throughout the period. Moreover, we can observe that the ZUB of *Tor di Valle* accounted for the highest figures, constantly, over most of the timeframe of interest. This homogeneity in distribution, maintained for a relatively long period, differs from the observations gathered from the previous case studies of London and NYC. In fact, whereas for the two, the evenness in spatial distribution was maintained temporarily, or over short periods, in Rome, the pattern is maintained quite consistent for some months. In June, which represents the valley for the second wave, the spread is more heterogeneous, with a prevalence of rates within the GRA, although there were still external areas significantly affected.

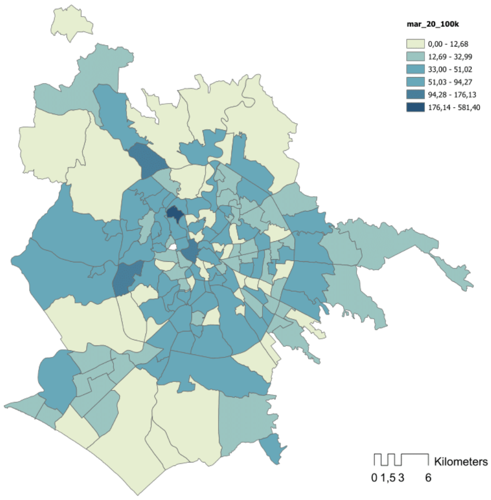


Figure 73 - Spread, March 2020, Roma by ZUB

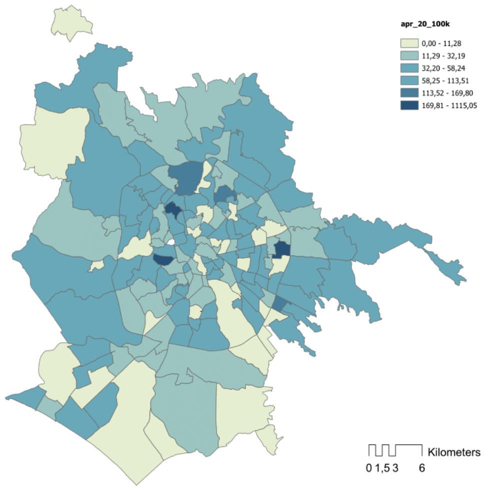


Figure 74 - Spread, April 2020, Roma by ZUB

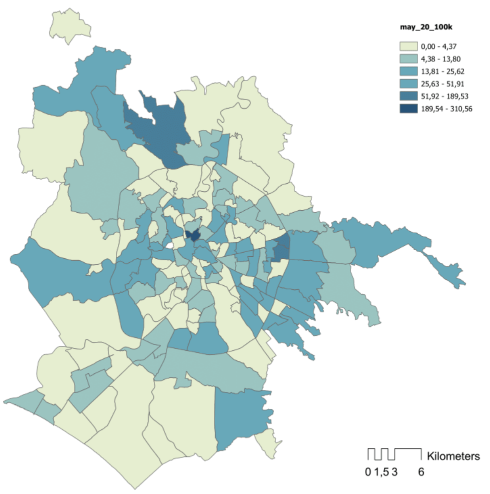


Figure 75 - Spread, May 2020, Roma by ZUB

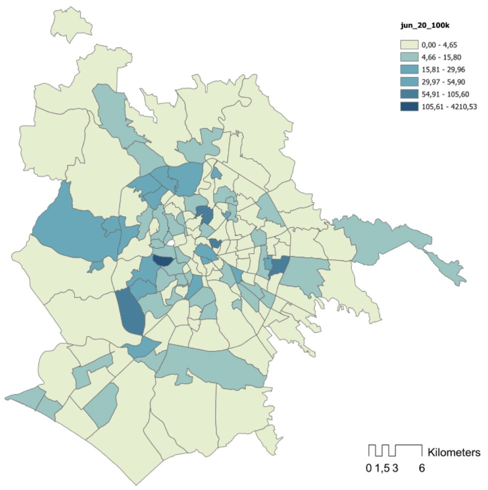


Figure 76 - Spread, June 2020, Roma by ZUB

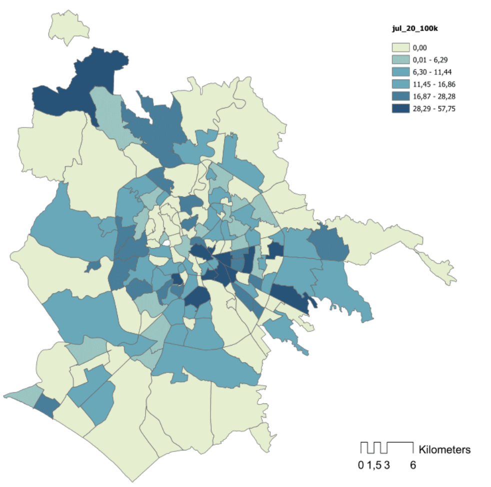


Figure 77 - Spread, July 2020, Roma by ZUB

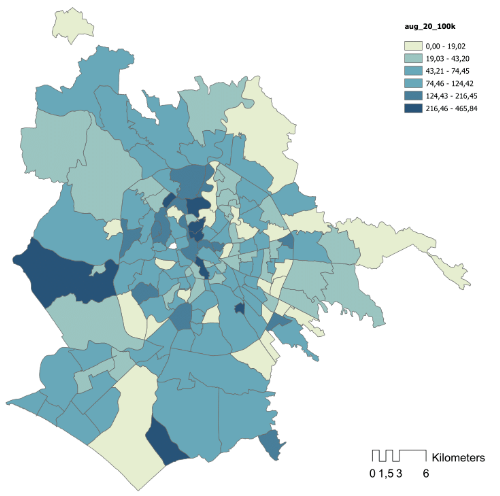


Figure 78 - Spread, August 2020, Roma by ZUB

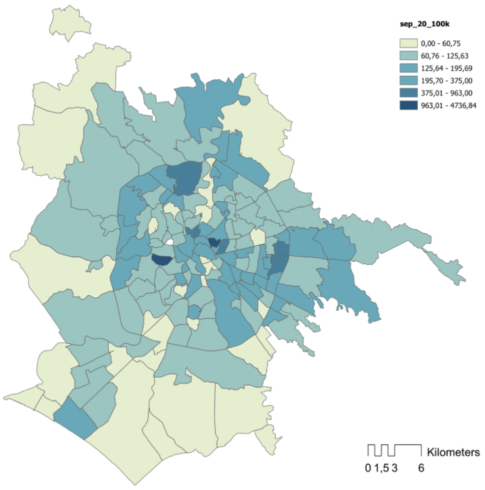


Figure 79 - Spread, September 2020, Roma by ZUB

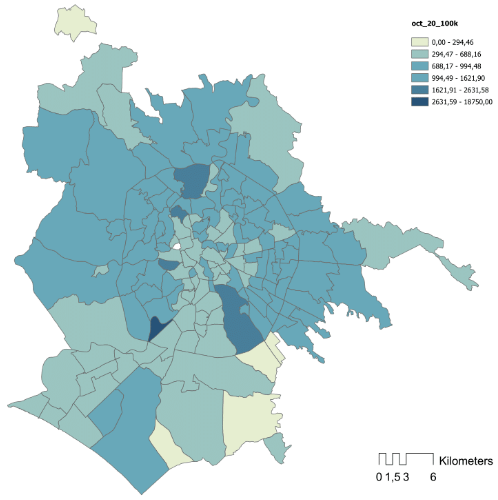


Figure 80 - Spread, October 2020, Roma by ZUB

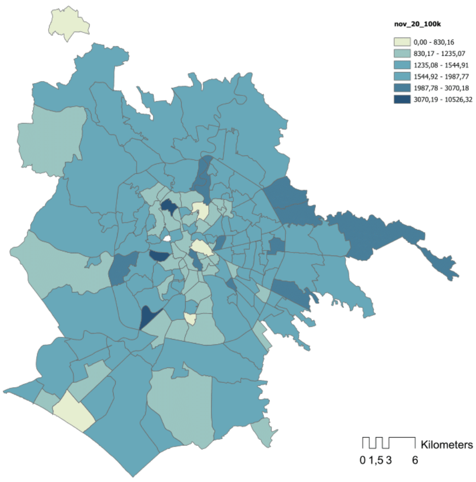


Figure 81 - Spread, November 2020, Roma by ZUB

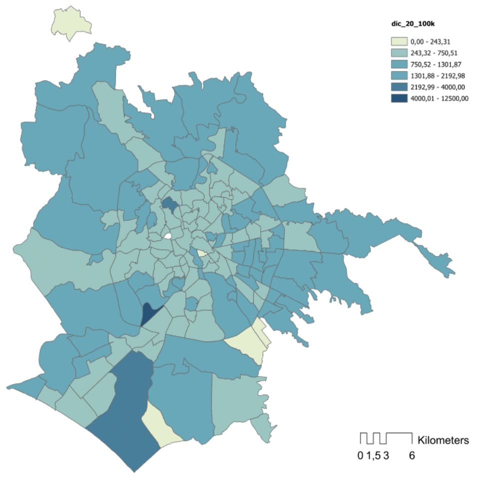


Figure 82 - Spread, December 2020, Roma by ZUB

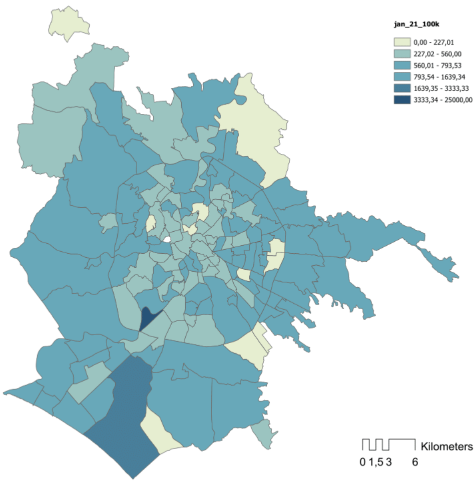


Figure 83 - Spread, January 2021, Roma by ZUB

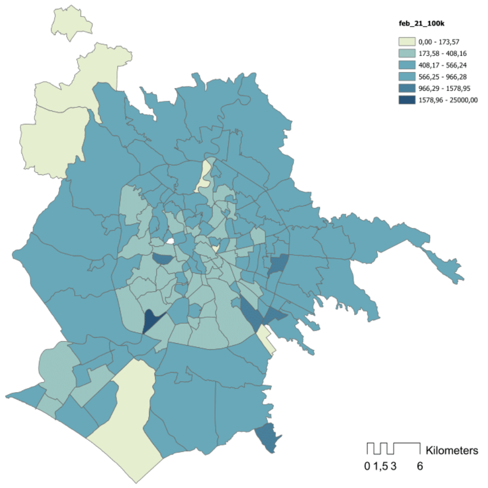


Figure 84 - Spread, February 2021, Roma by ZUB

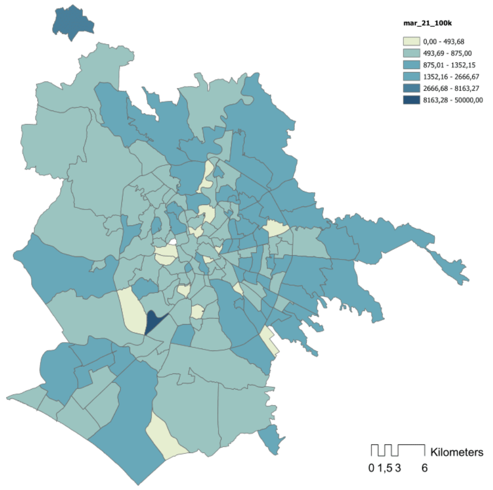


Figure 85 - Spread, March 2021, Roma by ZUB

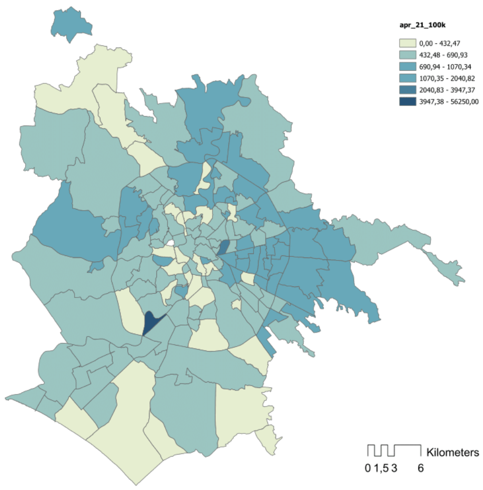


Figure 86 - Spread, April 2021, Roma by ZUB

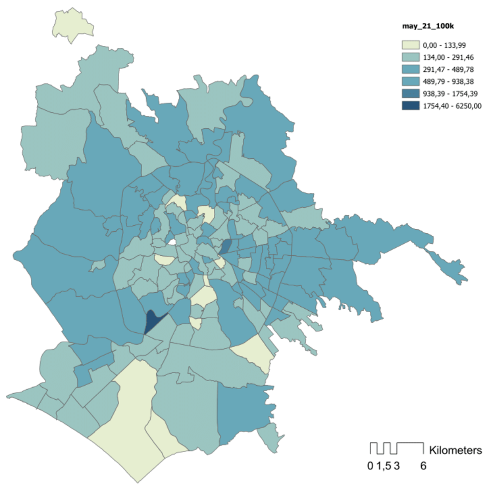


Figure 87 - Spread, May 2021, Roma by ZUB

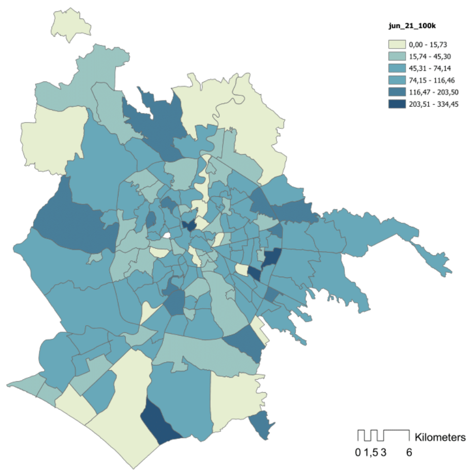


Figure 88 - Spread, June 2021, Roma by ZUB

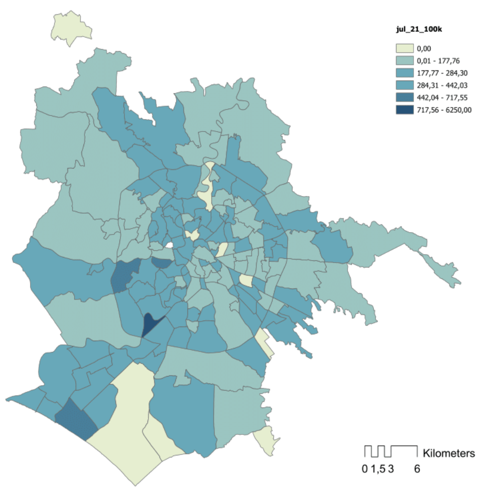
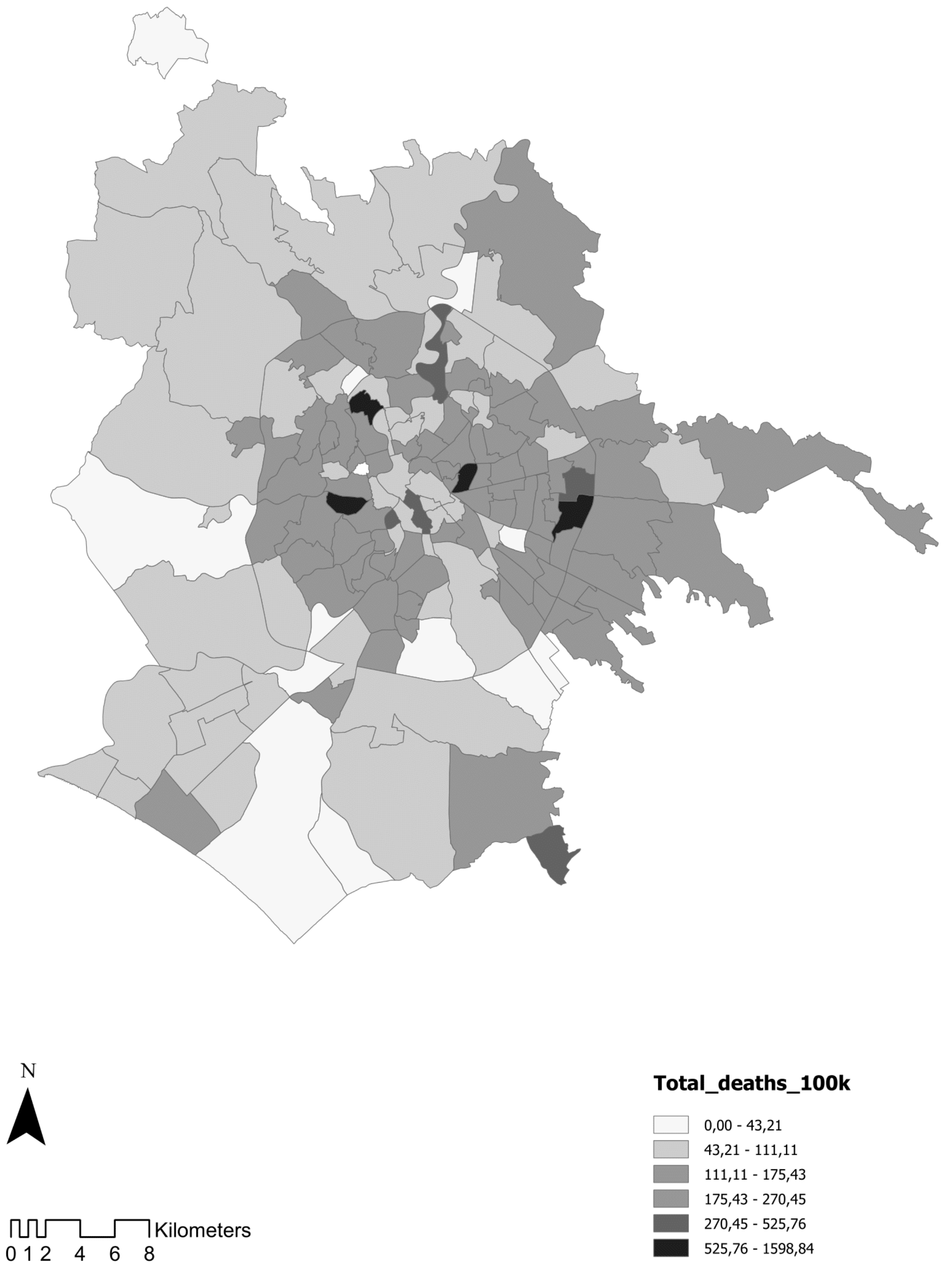


Figure 89 - Spread, July 2021, Roma by ZUB

Figure 90 - Total deaths by ZUB, Rome



3) Total deaths

By observing the total death rates map, it is possible to notice how the pattern differs from what was observed for the case rates. In fact, while the areas within the GRA were comparatively less affected for the latter, we now see that they are the ones accounting for the highest death rates. The highest figures are indeed displayed by *Villa Pamphili, Foro Italico, Verano* and *Casetta Mistica*, all located within the GRA, though the last is at the border. There are similar spatial patterns as well: for instance, the eastern part of the municipality, encompassing *Torre Angela* and *Tor Vergata*, among others, was significantly impacted both in terms of cases and deaths. The northern, western, and southern areas were instead proportionally less. This dissimilarity was not observed in the previous two case studies, at least not to this extent. Also, by correlating the spread with the lethality of the pandemic in Rome, the R-value obtained is 0.04, indicating that the two phenomena do not present any significant correlation. On the other hand, for London and NYC, the values found were, respectively, 0.47 and 0.61.

4) Mortality over time

We observe a higher concentration of deaths within the GRA during the first wave, while the external areas have been less affected. Nonetheless, some ZUBs displayed high rates, especially in the eastern part of the municipality and some northern regions, such as *S. Cornelia* and *Labaro*. In general, the spread of the deaths was relatively scattered, and there seemed to be no clear pattern besides the higher concentration in the inner part of Rome.

Whereas in August, the death rates came close to zero, significant growth was experienced from September to November. By analysing the trend, starting from August, the spread moves from east to the centre and then expands to the northern and western regions. Again, we observe a proportional higher concentration of cases within the GRA, particularly in September, as displayed by the map (Fig. 97). The map shows a somewhat even distribution across the city in November, with significant peaks in central areas such as *Villa Pamphili* and *Verano*. From December 2020 to February 2021, there was a consistent decline in death rates. The spread was maintained seemingly homogeneous throughout the municipality, although some changes in distribution occurred, especially in the outer areas, where significant changes took place from month to month. There seems to be no specific pattern consolidating over time. However, it is possible to observe how, from February to March 2021, when the death rates remained stable, a shift of prevalence of rates occurred from the southern part to the easter part of Rome, which encompassed areas belonging to both the inner and outer part of the GRA. In April, instead, further growth of cases was detected. In this case, once more, it is noticeable how the spread was relatively homogenous. From May to July, the figures decreased significantly, and, as a result, the spatial spread gradually reduced.

Also in Rome, we observe different patterns as the waves are analysed independently. The same areas display diverse impacts across time. Therefore, as it happened in NYC and London, the spatial trends are not repeated from period to period for the case rates. Instead, there seem to be differences in the way the spread has been taken place, not only overall but also considering the different pandemic stages.

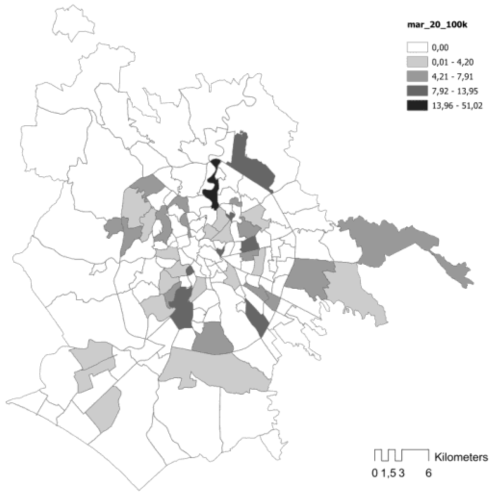


Figure 91 - Deaths, March 2020, Roma by ZUB

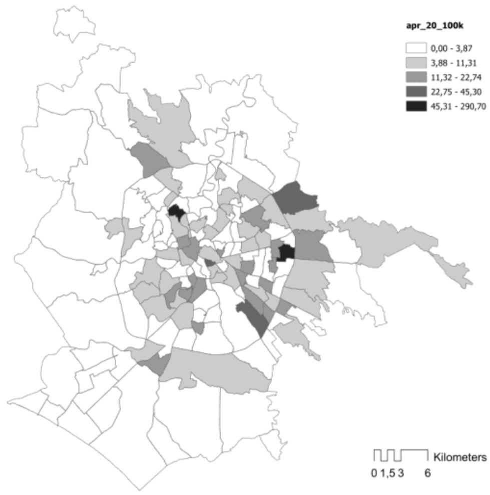


Figure 92 - Deaths, April 2020, Roma by ZUB

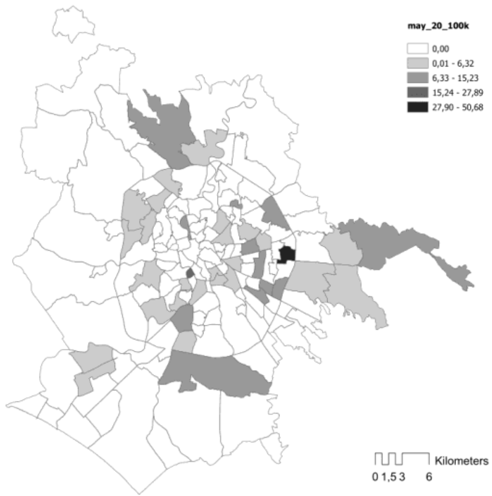


Figure 93 - Deaths, May 2020, Roma by ZUB

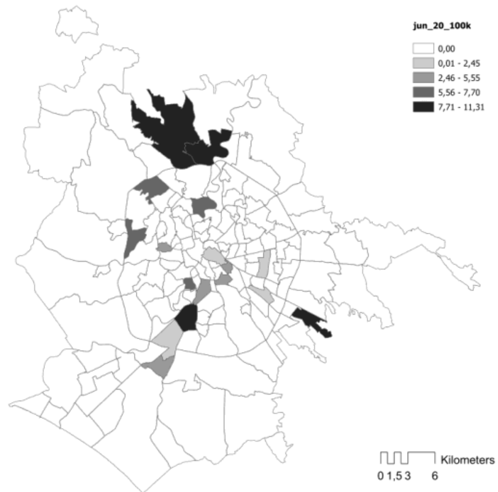


Figure 94 - Deaths, June 2020, Roma by ZUB

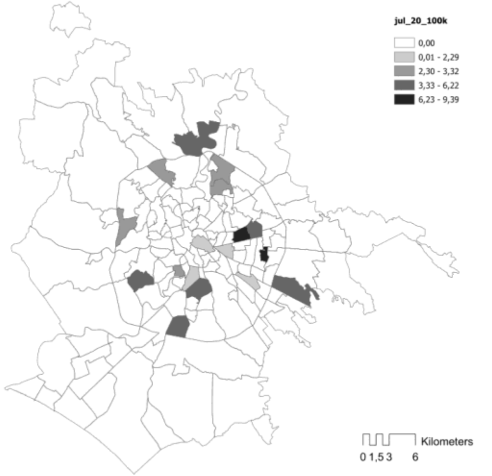


Figure 95 - Deaths, July 2020, Roma by ZUB

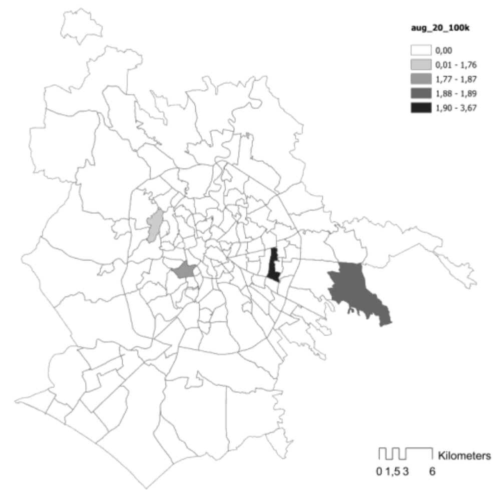


Figure 96 - Deaths, August 2020, Roma by ZUB

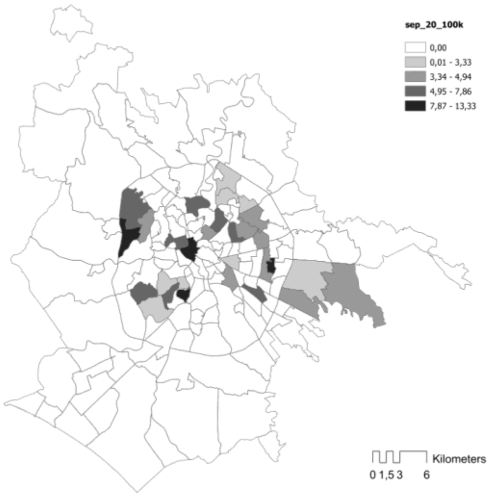


Figure 97 - Deaths, September 2020, Roma by ZUB

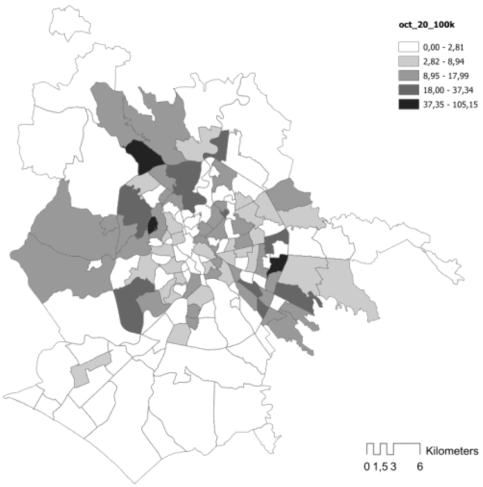


Figure 98 - Deaths, October 2020, Roma by ZUB

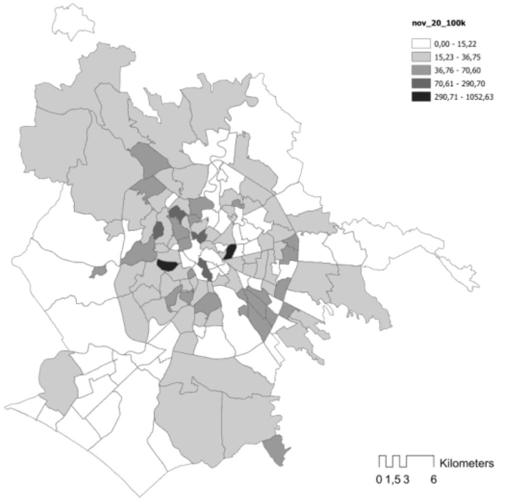


Figure 99 - Deaths, November 2020, Roma by ZUB

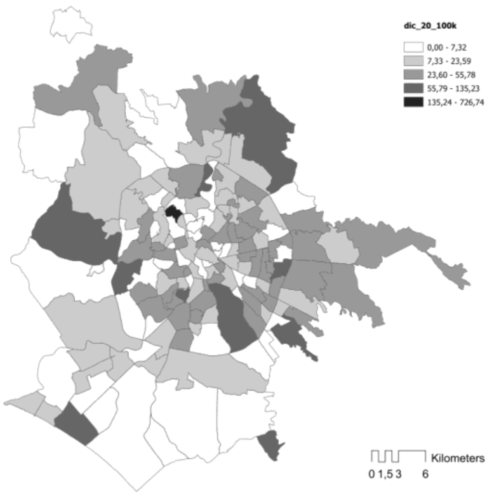


Figure 100 - Deaths, December 2020, Roma by ZUB

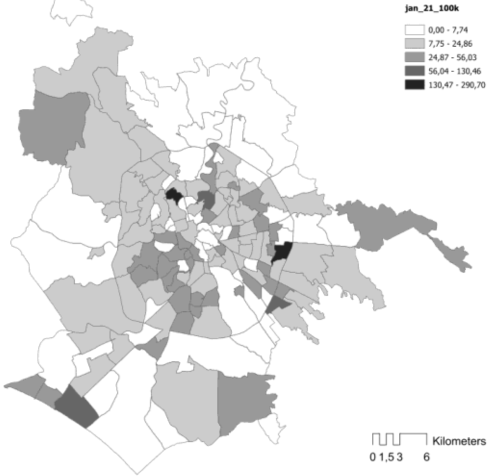


Figure 101 - Deaths, January 2021, Roma by ZUB

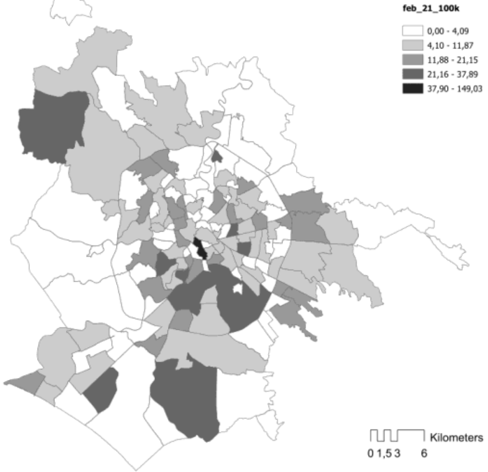


Figure 102 - Deaths, February 2021, Roma by ZUB

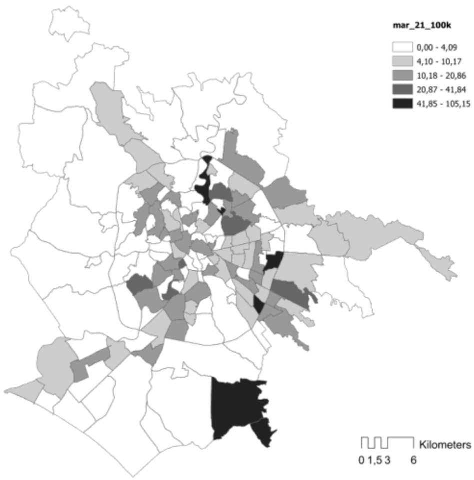


Figure 103 - Deaths, March 2021, Roma by ZUB

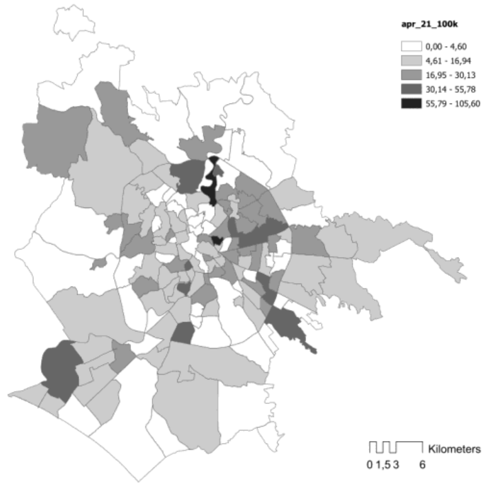


Figure 104 - Deaths, April 2021, Roma by ZUB

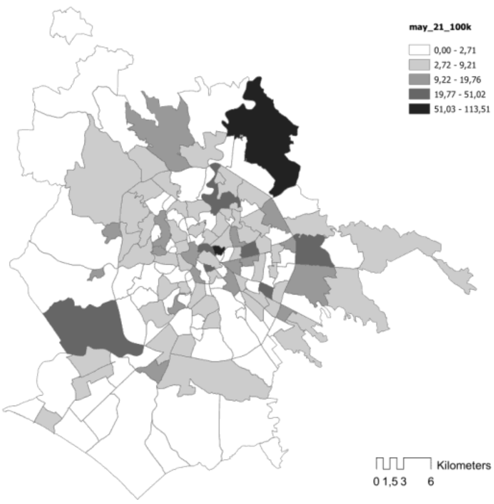


Figure 105 - Deaths, May 2021, Roma by ZUB

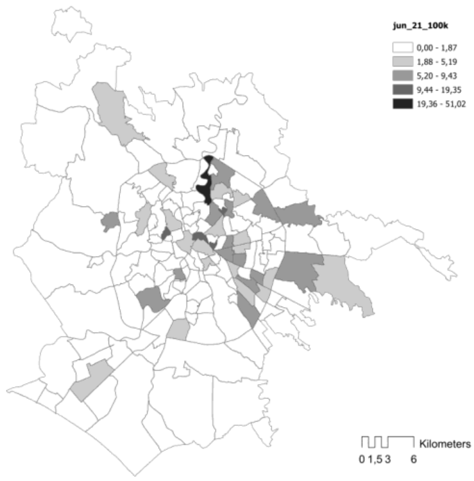


Figure 106 - Deaths, June 2021, Roma by ZUB

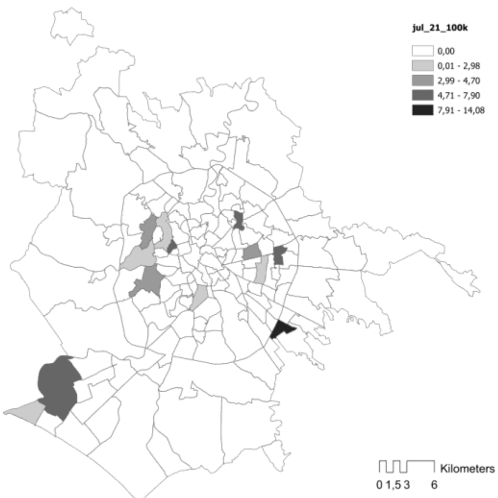
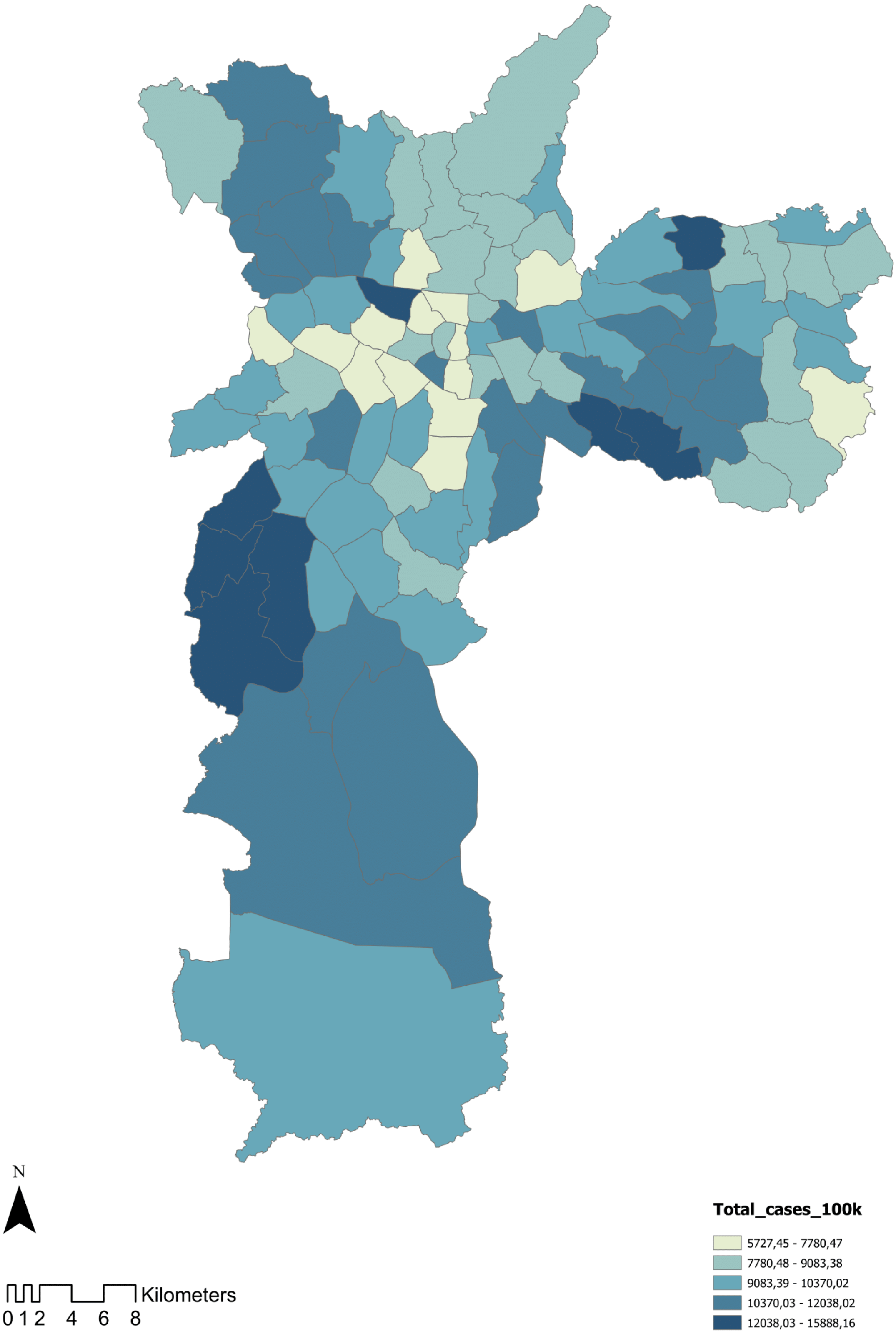


Figure 107 - Deaths, July 2021, Roma by ZUB

Figure 108 - Total cases by *Distrito Administrativo*, Sao Paulo



5.1.4 Sao Paulo

1) Total cases

A first general note is that different from what was seen in the other case studies, in Sao Paulo, there were no actual "waves". In fact, as shown by the graph, the spread was relatively consistent throughout the entire period, although fluctuating, with alternate periods of growth and decline.

As it occurred in the previous cities analysed, also in this case, the overall case rates are distributed heterogeneously across the city. It is also possible to observe how the central area, which encompasses the historical ad extended centre, was comparatively less affected. As we move outwards, we see a growth of rates, although not everywhere. The areas that were affected the most are geographically located south and east, specifically in *Campao Redondo*, *Campo Lindo, Sao Lucas* and *Sapopemba*. Also the district of *Barra Funda* was significantly affected despite its proximity to zones that were less hit overall.

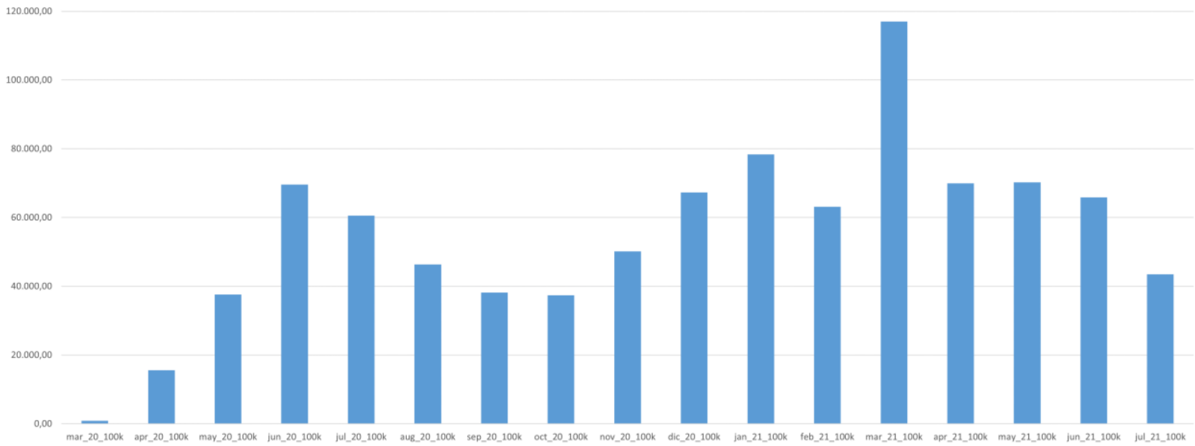


Figure 109 - Bar chart COVID-19 cases (E-SUS-VE) in Sao Paulo

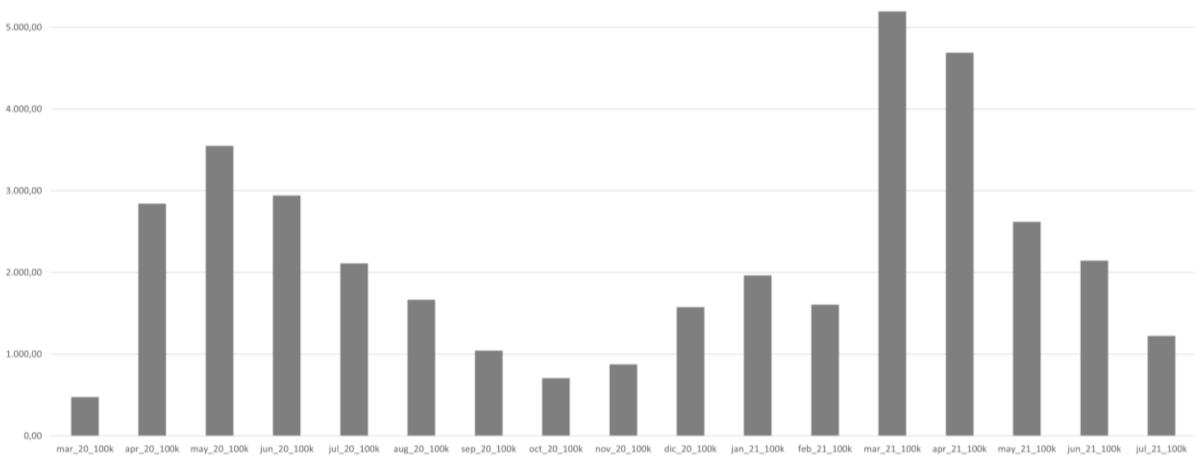


Figure 110 - Bar chart COVID-19 deaths in Sao Paulo

2) Spread over time

When turning to the study of the spatial spread of the pandemic over time, it is possible to point out several patterns which are of interest also in comparative terms with other cities. From March to June, a period characterised by the overall growth of cases, the spread seems to start from the centre and spread outwards, as it happened for NYC and London. We can notice how at the beginning of the period the central areas were the ones most affected. In contrast, in June, the proportional impact across the city was higher in the outer regions, with some exceptions, such as *Marsilac*, located deep south in the municipality of Sao Paulo. In this first phase, the areas mainly affected were found in the southwest (*JD Angela, Sao Luis and Capao Redondo*) and the eastern zone, like *Sapopemba* and *Arcanduva*, among other proximate areas.

From July to October, the general trend was declining, although never reaching zero-like figures. It is possible to observe how the pattern and distribution of cases remained relatively stable during this period, with a few variations. Therefore, whereas the centre was comparatively less hit, the external areas suffered the most, especially those geographically located in the southwestern and eastern districts. However, while approaching October, we observe a gradual "rebalancing" of distribution towards homogeneity.

The period between November and January was characterised by an overall increase of cases citywide. The patterns we observe in this stage differ from the past one to some extent. For instance, it is possible to notice how the extreme south areas, previously showing low relative rates, are now heavily impacted by the pandemic. This diversity of impact within the span of four months represents a point of interest to foster further exploration of the matter and its socio-spatial components. There was once again a progressive redistribution of the cases from month to month; initially, the central areas were almost equally affected, whereas, at the end of the period, they were comparatively accounting for lower figures. This is even more evident in February when the overall rates declined from 78.333,93 to 63.152,29.

In March 2021, however, there was the absolute peak of cases citywide. The heterogeneity in the spatial distribution of cases, in this case, is quite striking. The entire south of Sao Paulo was heavily impacted, as well as the northwest and the eastern districts. The central areas, conversely, had proportionally much lower values, except for Bela Vista.

From April to July, the general trend was declining. Nevertheless, the pattern observed for March was maintained rather constant throughout the following two months, with apparent disparities in rates between the central areas and the rest of the municipality, especially the entire south. Conversely, June and July displayed a trend observed in previous decreasing phases, namely, the move towards redistributing the rates in a more homogenous fashion. This is clearer when looking at the map of July, where almost all districts show almost equal values.

As observed for the previous case studies, it is relevant how the same areas show somewhat different impacts when analysed in different periods of "intensity" of the pandemic. What are the reasons behind these changes? What components are possibly connected to it? How can they be traced over time? These are just some of the questions that need addressing, although not provided by this study.

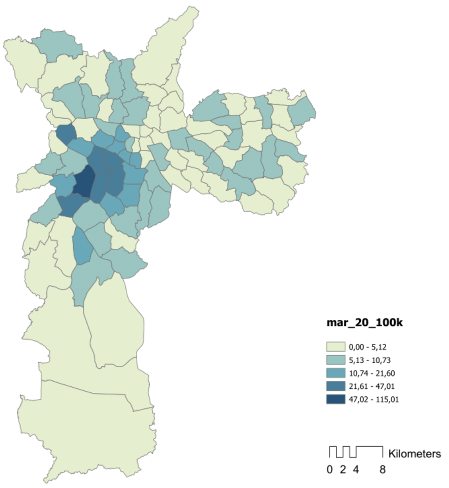


Figure 111 - Spread, March 2020, Sao Paulo by DA

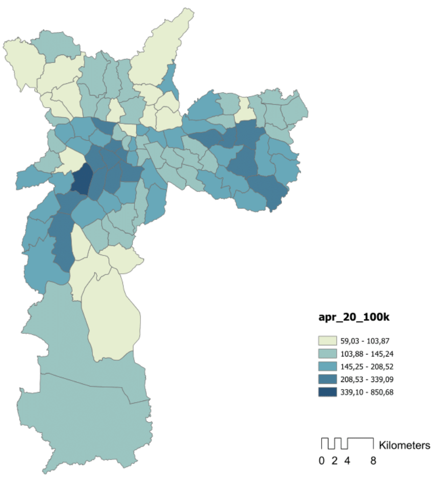


Figure 112 - Spread, April 2020, Sao Paulo by DA

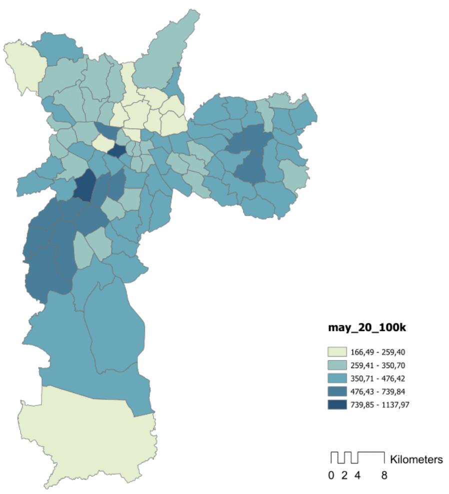


Figure 113 - Spread, May 2020, Sao Paulo by DA

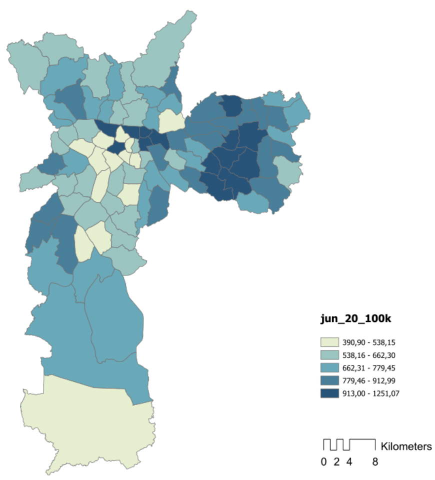


Figure 114 - Spread, June 2020, Sao Paulo by DA

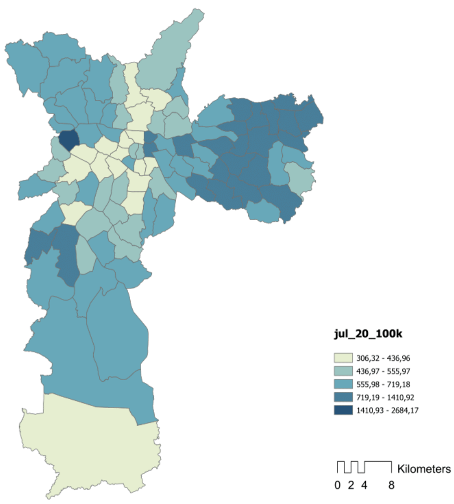


Figure 115 - Spread, July 2020, Roma by ZUB

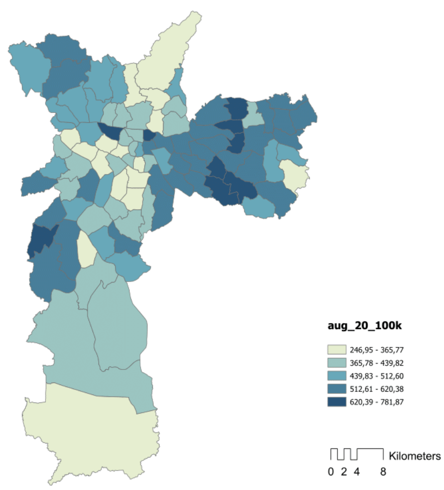


Figure 116 - Spread, August 2020, Sao Paulo by DA

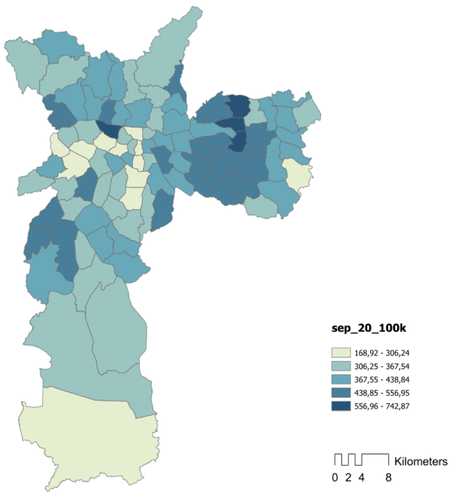


Figure 117 - Spread, September 2020, Sao Paulo by DA

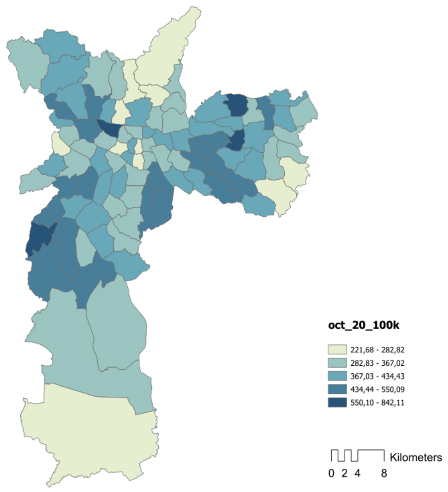


Figure 118 - Spread, October 2020, Sao Paulo by DA

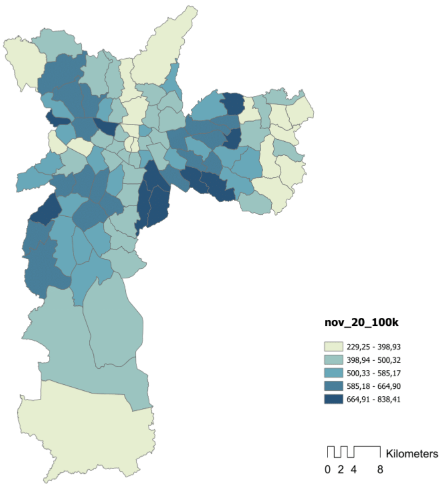


Figure 119 - Spread, November 2020, Sao Paulo by DA

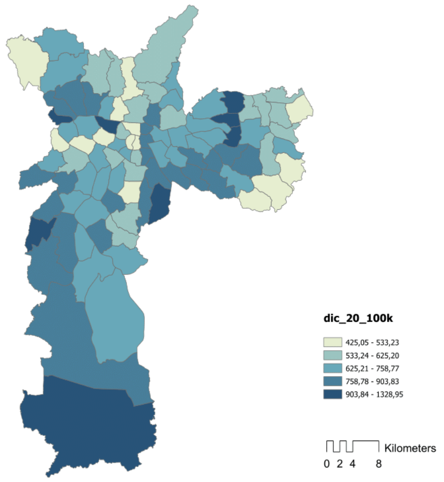


Figure 120 - Spread, December 2020, Sao Paulo by DA

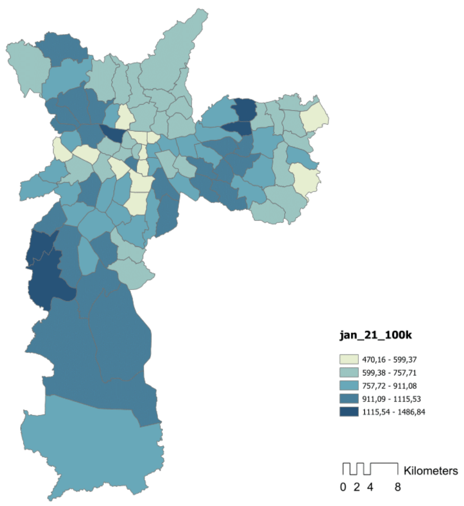


Figure 121 - Spread, January 2021, Sao Paulo by DA

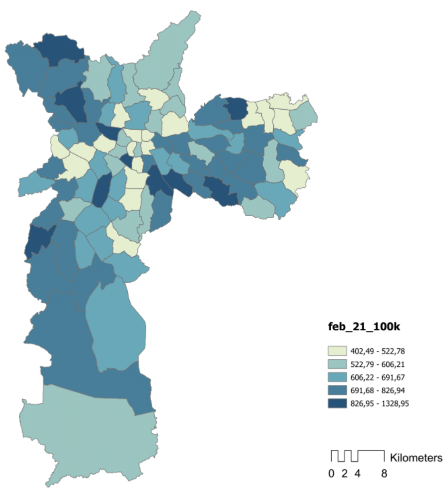


Figure 122 - Spread, February 2021, Sao Paulo by DA

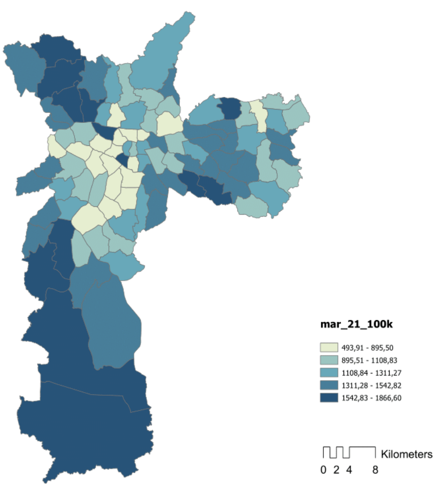


Figure 123 - Spread, March 2021, Sao Paulo by DA

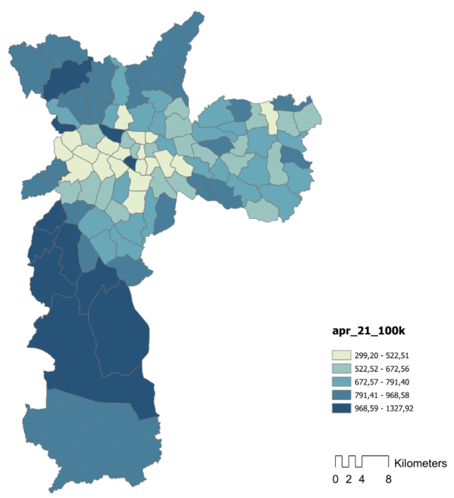


Figure 124 - Spread, April 2021, Sao Paulo by DA

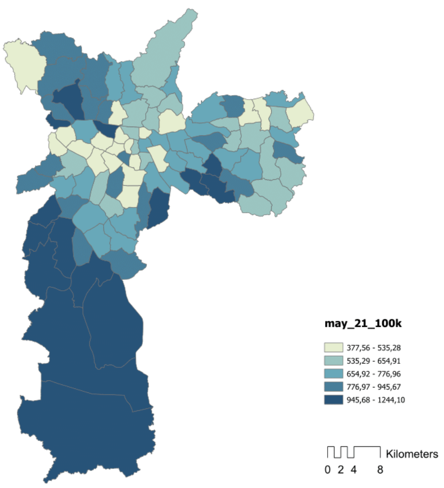


Figure 125 - Spread, May 2021, Sao Paulo by DA

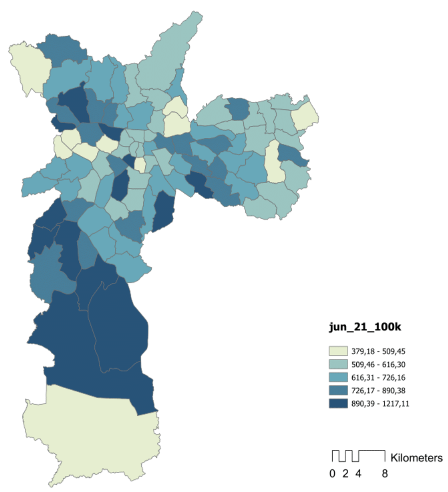


Figure 126 - Spread, June 2021, Sao Paulo by DA

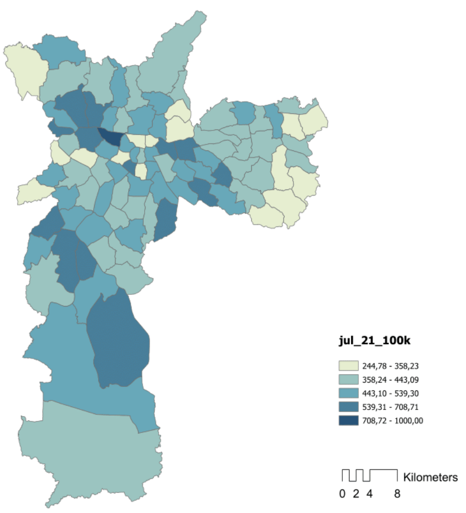


Figure 127 - Spread, July 2021, Sao Paulo by DA

3) Total deaths

By scrutinising the map of the overall death rates, it is possible to notice how the distributive spatial pattern differs significantly from the cases. Indeed, the entire south was comparatively less affected than the rest of the city, while the spread was the highest. Also, the central areas show significant figures, while the "centre" had a much lower number of contagions. Instead, a similar trend is the incidence in the eastern part of the municipality, heavily impacted both in terms of spread and mortality. The divide between the spread and the mortality was also observed in London, but more strikingly in Rome, where there seemed to be no correspondences visually. The correlation, in the case of Rome, gave an R-value of 0.04. For Sao Paulo, the result is slightly higher (0.13), although still indicating a very low correlation.

4) Mortality over time

From March to May 2020, the overall deaths-related figure grew, from 471,25 to 3.545,28. There was a higher prevalence of mortality within the central areas (except for the historical centre, at least in March) and more generally on the entire northern districts. However, whereas at the beginning, the southern part of Sao Paulo was relatively less impacted, in April and May, the mortality rose also in those areas. In April, while most of the deaths were concentrated in the northern part of the municipality, the southern tip, *Marsilac*, accounted for a very high death rate, despite being geographically distant from the hotspots.

The period included between June and October was characterised by a general decrease in mortality, from 2.938,56 to 702,56. Despite this general trend, the patterns displayed over time change significantly. In June and July, there was a distribution similar to what was seen in May, with a greater concentration of cases in the central and northern districts, although the eastern part gradually accounts for comparatively higher death rates, while, simultaneously, the rates within the centre diminish. In August, September, and October, However, we see somewhat discontinuous patterns. In fact, in the beginning, the number of districts accounting for significant mortality rates were quite scattered across the municipality, with peaks reached in eastern, central, and southern areas. In September, however, the central and east regions showed more significant figures than the rest of the city. The southern zones, notably, displayed lower rates. In October, the distribution is once more different, as it is possible to observe an almost even situation on the entire territory.

The period between November 2020 and January 2021, instead, featured once again growing deaths rates overall. The trend over these three months is relatively stable. The central and eastern areas showed higher mortality rates, while the rest of the city was comparatively less affected (made exception for *Marsilac*). Before the absolute peak reached in March 2021, there was a period of overall decrease in February, when the distribution of deaths across the city was seemingly homogeneous, despite the northern and central parts still being more affected. In the following month, however, it is possible to recognise entire clusters of districts with very high mortality, especially in the central, northern, and eastern areas. In contrast, again, the southern districts showed proportionally lower rates. From April to July, the overall rates declined significantly. It is possible to observe a gradual reduction of death rates within the centre in the first two months. However, the surrounding districts, both northern and eastern, were still considerably affected.

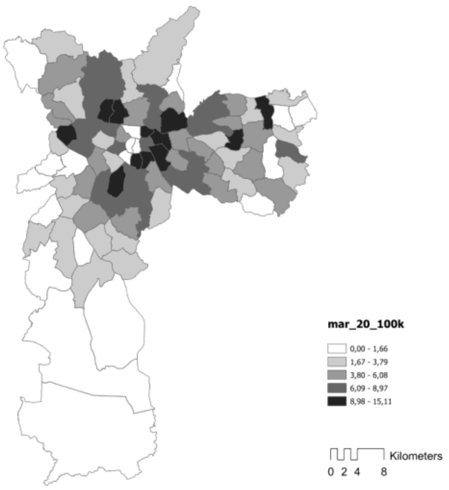


Figure 128 - Deaths, March 2020, Sao Paulo by DA

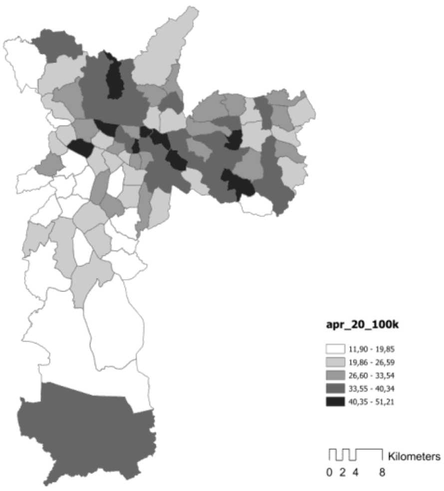


Figure 129 - Deaths, April 2020, Sao Paulo by DA

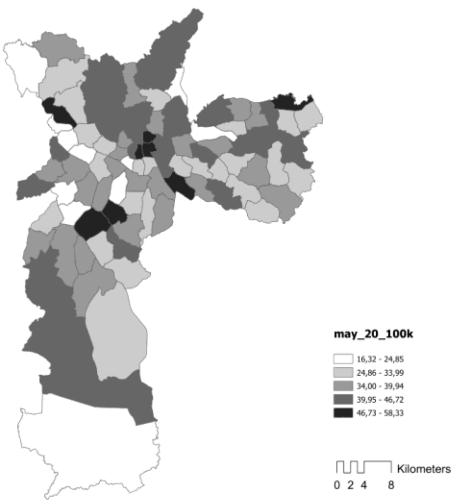


Figure 130 - Deaths, May 2020, Sao Paulo by DA

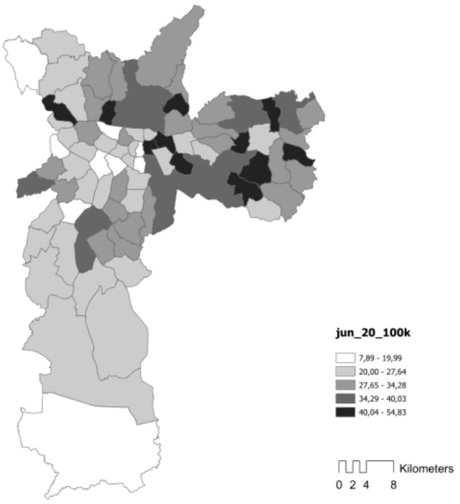


Figure 131 - Deaths, June 2020, Sao Paulo by DA

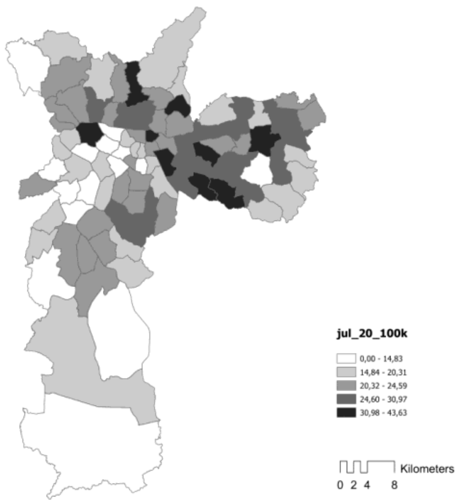


Figure 132 - Deaths, July 2020, Sao Paulo by DA

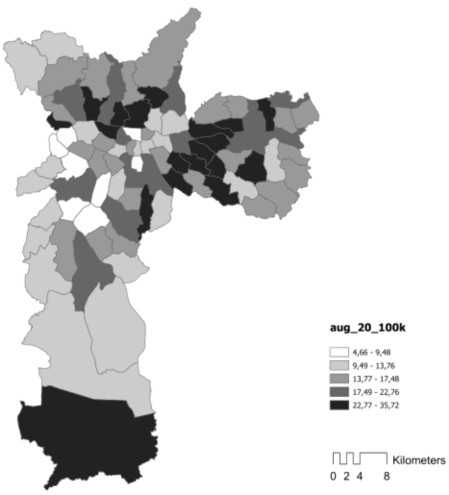


Figure 133 - Deaths, August 2020, Sao Paulo by DA

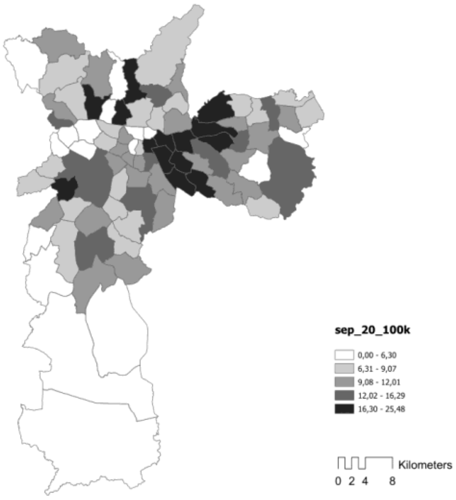


Figure 134 - Deaths, September 2020, Sao Paulo by DA

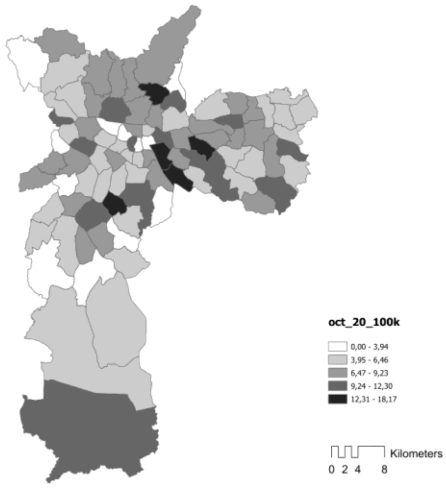


Figure 135 - Deaths, October 2020, Sao Paulo by DA

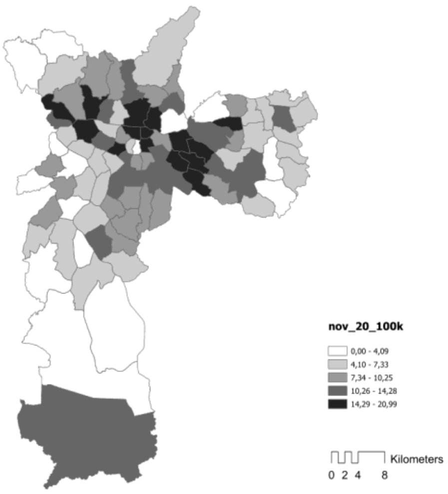


Figure 136 - Deaths, November 2020, Sao Paulo by DA

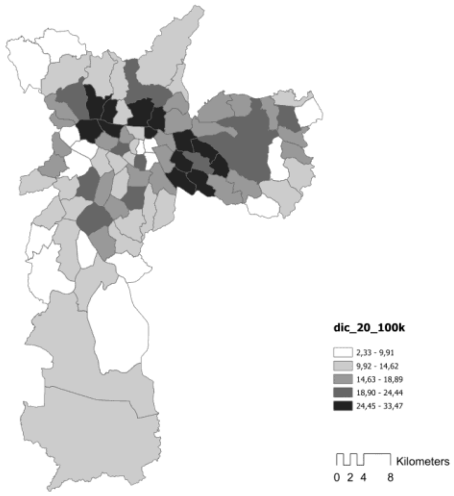


Figure 137 - Deaths, December 2020, Sao Paulo by DA

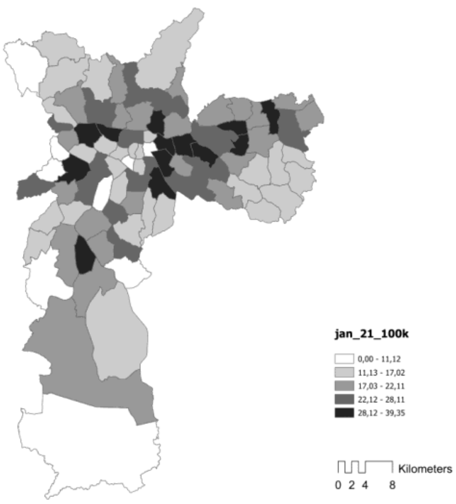


Figure 138 - Deaths, January 2021, Sao Paulo by DA

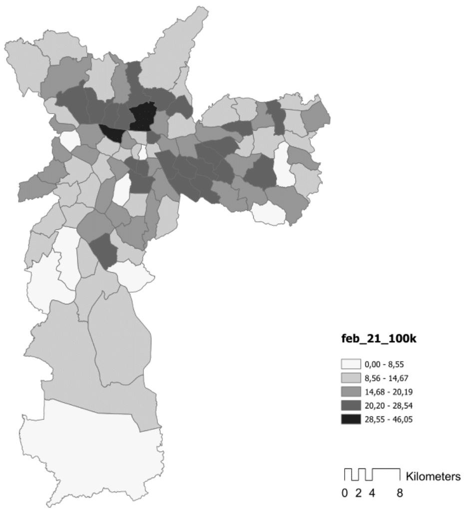


Figure 139 - Deaths, February 2021, Sao Paulo by DA

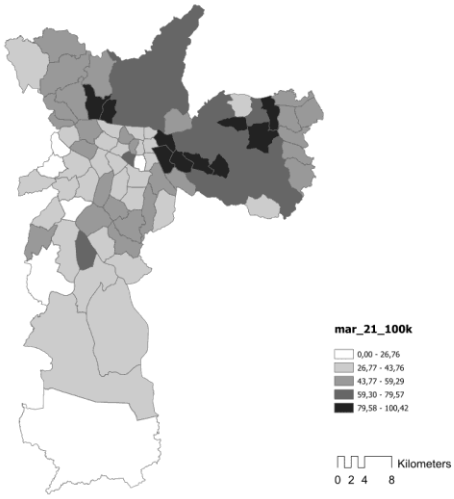


Figure 140 - Deaths, March 2021, Sao Paulo by DA

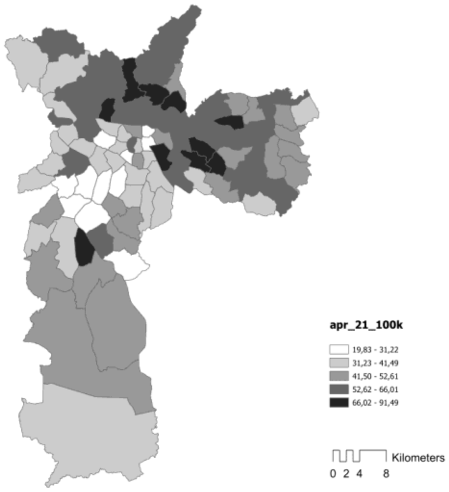


Figure 141 - Deaths, April 2021, Sao Paulo by DA

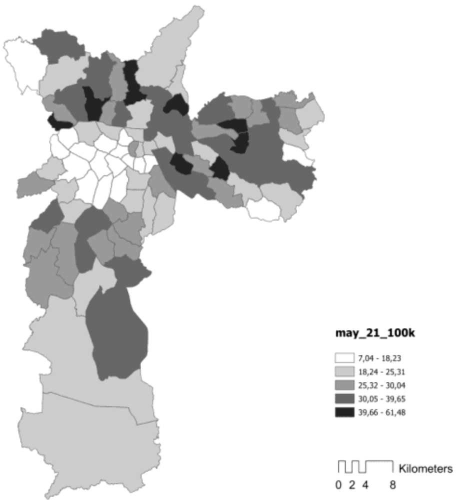


Figure 142 - Deaths, May 2021, Sao Paulo by DA

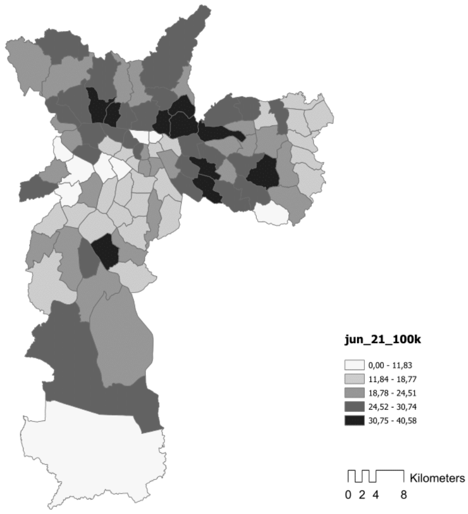


Figure 143 - Deaths, June 2021, Sao Paulo by DA

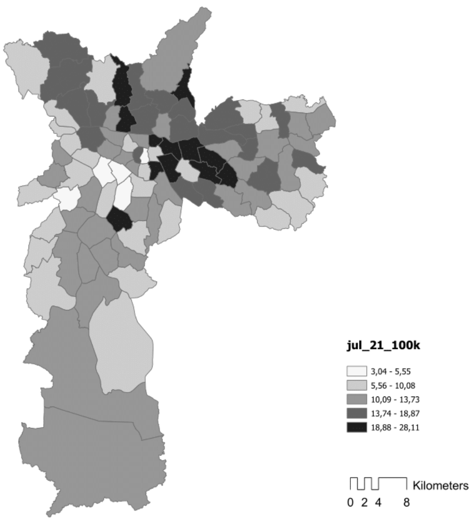


Figure 144 - Deaths, July 2021, Sao Paulo by DA

5.2 Model I: SVI and COVID-19

The first model relates the SVI with the spread and mortality of COVID-19. The variables used to construct the index and the methodology used has been described in the third chapter. Once again, the main models employed are the OLS and the GWR, the latter has been used to encompass in the analysis the variability of results by considering a geographically weighted approach. For each city, the following elements will be provided:

- A table showing the correlation matrix
- Map showing how the index maps the vulnerability of communities across the city
- Table showing the results of the regression models (OLS and GWR): the table lists different parameters, such as the Adjusted R^2, the standardised coefficient (β), the Moran's Index (I) of the residuals, the p-value, and the Akaike Information Criterion (AICc).
- Map showing the distribution of residuals according to the GWR and OLS models

5.2.1 London

In London, the correlation matrix (Table 2) displays some important results. When correlating the SVI with the total cases and deaths the values obtained are, respectively, 0.51 and 0.28. Whereas the second only shows a weak correlation, the former seems moderately correlated. We also observe a moderate correlation between the spread of cases and deaths (R= 0.47). This confirms what was observed in the previous "visual" analysis of the spatial impact of the pandemic, where similar patterns between cases and deaths rates were observed, although not entirely coincident.

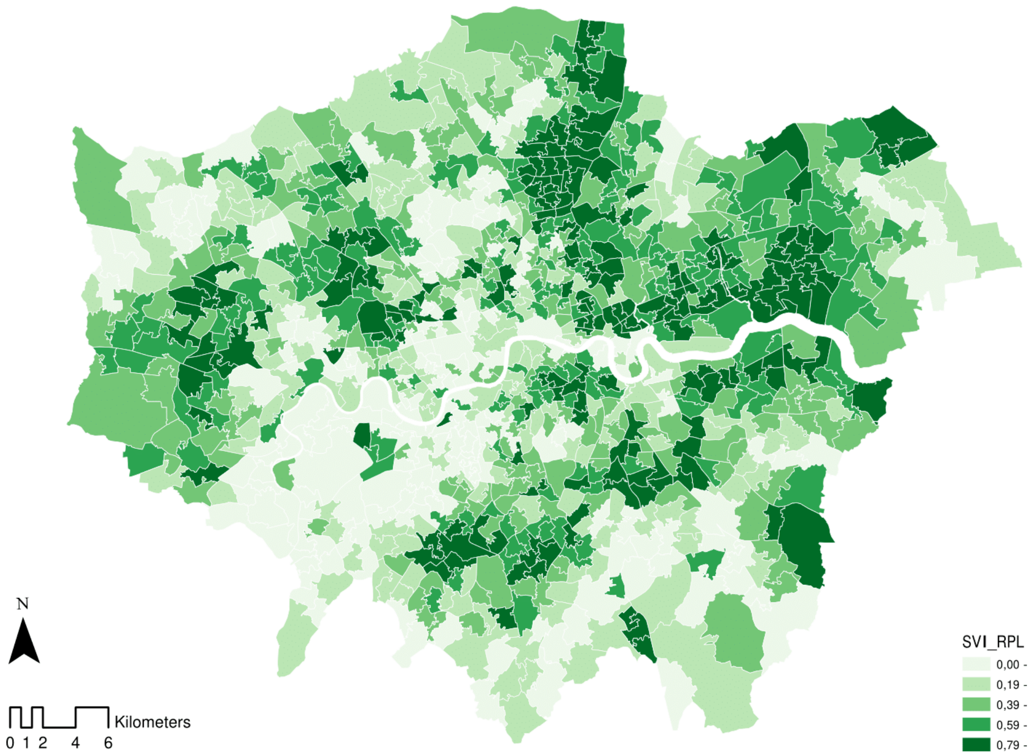
Table 2 - Correlation matrix SVI and COVID-19 in London

	SVI	*Total cases*	*Total deaths*
SVI	1		
Total cases	0,51	1	
Total deaths	0,28	0,47	1

All figures had a corresponding α value lower than 0.05.

From Fig. 145, we observe the MSOAs that, according to the SVI, are more vulnerable, in this case, to health problems. It is possible to see how there are some areas that overlap with the spread of the pandemic (e.g., East London). However, as demonstrated by the correlation matrix and the value obtained, other units do not reflect the same pattern. When compared to the distribution of deaths, instead, the coincidence is diminished (as observed from the correlation).

Figure 145 - SVI by MSOA, London



Turning to the regression models, we can observe quite significant results. As shown by Tab. 3. Firstly, it is possible to notice how SVI performs better compared to the OLS when analysed through the GWR model. However, in general, it seems that the SVI, taken alone, is not sufficient to provide significant prediction concerning the pandemic, nor in terms of cases or deaths. Nevertheless, the value obtained through the GWR (0.39) can indicate a partial explanatory power of the index. The difference between cases and deaths is similar for both models (0.14 difference for the OLS and 0.19 for the GWR). Notably, the Moran's Indices obtained via the GWR are lower, indicating the improvement in decreasing spatial autocorrelation, although the values are still high, suggesting that some variables might be missing. Fig. 146 to 149 show the distribution of the standard residuals produced by both regression models where the values for the violet areas are under predicted. In contrast, the green areas are over predicted.

Table 3 - Regressions results SVI and COVID-19 in London

Model	*OLS* R^2	*OLS* *I*	*OLS* *p-value*	*OLS* *β*	*OLS* *AICc*	*GWR* R^2	*GWR* *I*	*GWR* *AICc*
SVI - Cases	0,26	0,537*	0,0000	0,508	17140,24	0,39	0,45*	16937,84
SVI - Deaths	0,08	0,273*	0,0000	0,285	11636,17	0,20	0,17*	11501,37

** Statistically significant p-value (p < 0,05)*

Figure 146 - SVI – Cases Std. Residuals by MSOA (OLS), London

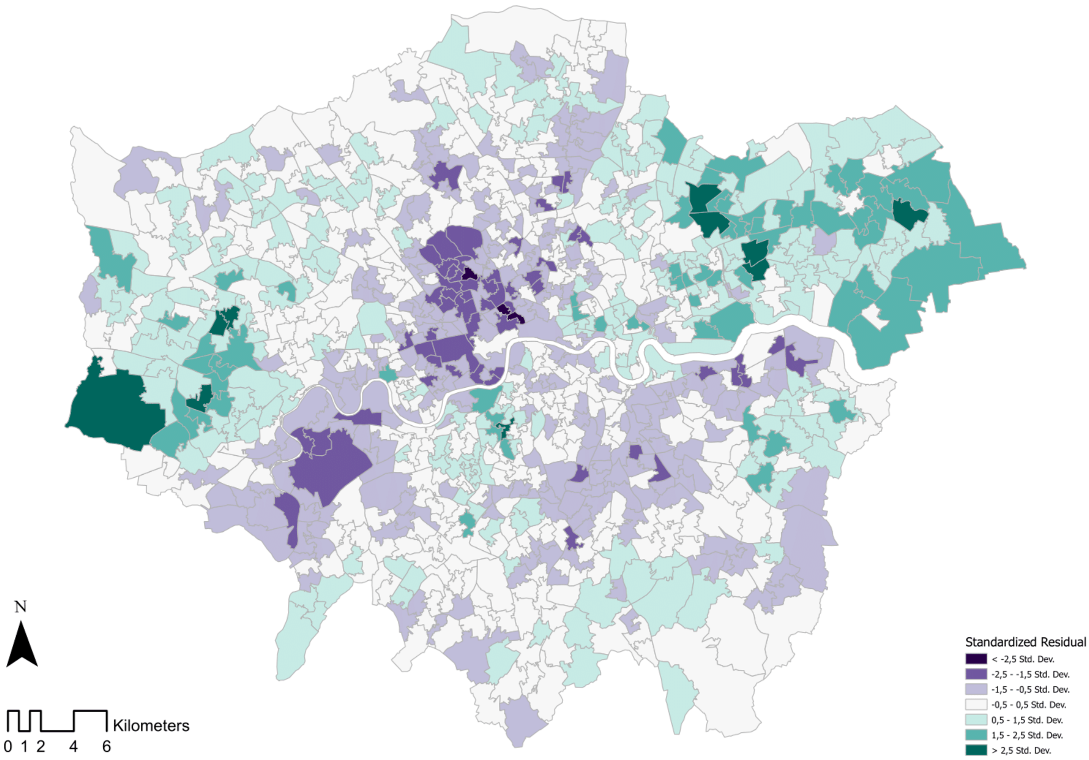


Figure 147 - SVI – Cases Std. Residuals by MSOA (GWR), London

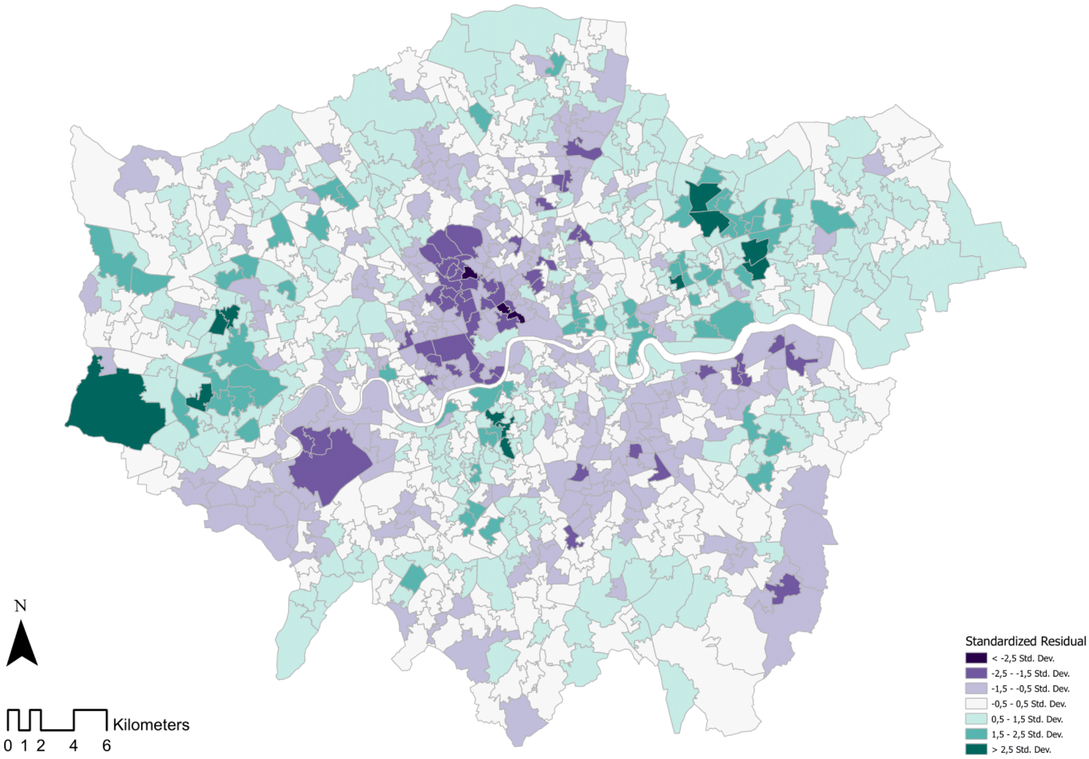


Figure 148 - SVI – Deaths Std. Residuals by MSOA (OLS), London

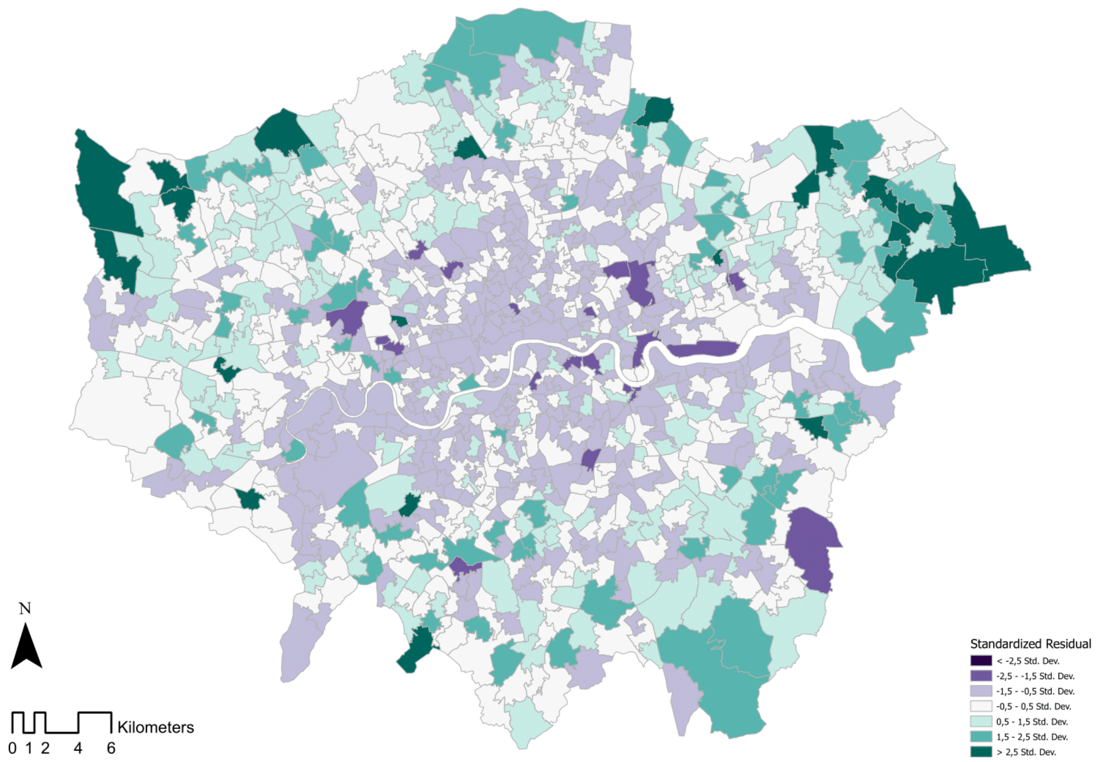
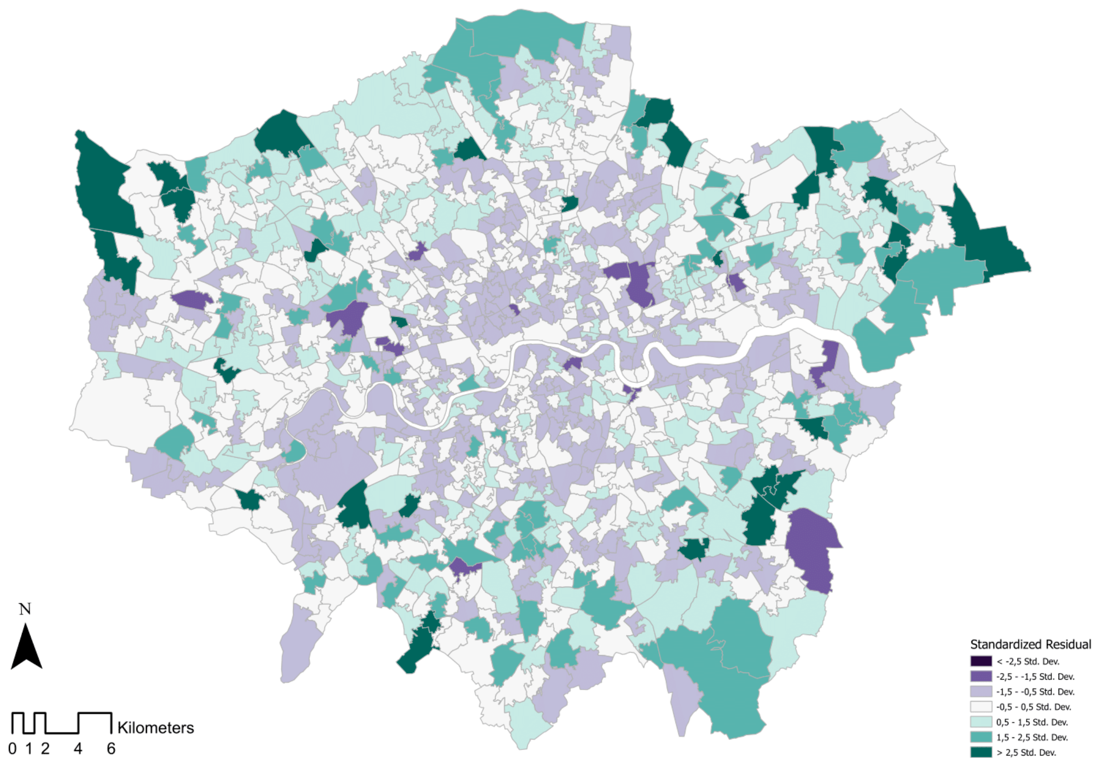


Figure 149 - SVI – Deaths Std. Residuals by MSOA (GWR), London



5.2.2 New York City

In NYC, the correlation matrix below (Table 4) displays results that overlap and differ, to some extent, from the ones found for London. When correlating the SVI with the total cases and deaths, the values obtained are, respectively, 0.43 and 0.60. As observed in London, there are moderate correlation values for both the spread and the mortality (although in London the correlation with deaths was lower). Moreover, the cases and deaths are correlated (R-value 0.61), thus confirming what was observed in the first qualitative spatial description of the pandemic. London's value also indicated a moderate correlation between the two sides of the pandemic (0,47).

Table 4 - Correlation matrix SVI and COVID-19 in NYC

	SVI	*Total cases*	*Total deaths*
SVI	1		
Total cases	0,43*	1	
Total deaths	0,60*	0,61*	1

** Statistically significant p-value (p < 0,05).*

From Fig. 154, we observe the MODZCTAs that, according to the SVI, are more vulnerable to health problems. It is possible to see how some areas overlap with the spread of the pandemic (e.g., the Bronx). However, as demonstrated by the correlation matrix and the value obtained, other units do not reflect the same pattern, such as in Staten Island.

Turning to the regression models, instead, Table 5. shows that the SVI, when analysed through the GWR model, presents better results, although contained. However, in general, as observed in London, it seems that the SVI, taken alone, is not sufficient to provide significant prediction concerning the pandemic, nor in terms of cases or deaths. However, we notice that the index seems to have higher predictive power for mortality in this case. The value obtained via the GWR (0.39) can be indicative of partial explanatory power. The gap between cases and deaths is similar for both models (0.17 difference for the OLS and 0.14 for the GWR). Once again, the Moran's Indices are closer to zero when using the GWR, as shown in Fig. 151 and 153, where it is possible to notice a reduction in clusters compared to the OLS. As for London, it is still high enough to suggest the further investigation of spatial variables.

Table 5 - Regressions results SVI and COVID-19 in NYC

Model	*OLS* R^2	*OLS* *I*	*OLS* *p-value*	*OLS* *β*	*OLS* *AICc*	*GWR* R^2	*GWR* *I*	*GWR* *AICc*
SVI - Cases	0,18	0,70*	0,0000	0,43	3247,86	0,23	0,68*	3235,57
SVI - Deaths	0,35	0,31*	0,0000	0,60	2193,43	0,37	0,29*	2189,63

** Statistically significant p-value (p < 0,05)*

Figure 150 - SVI – Cases Std. Residuals by MODZCTA (OLS), NYC

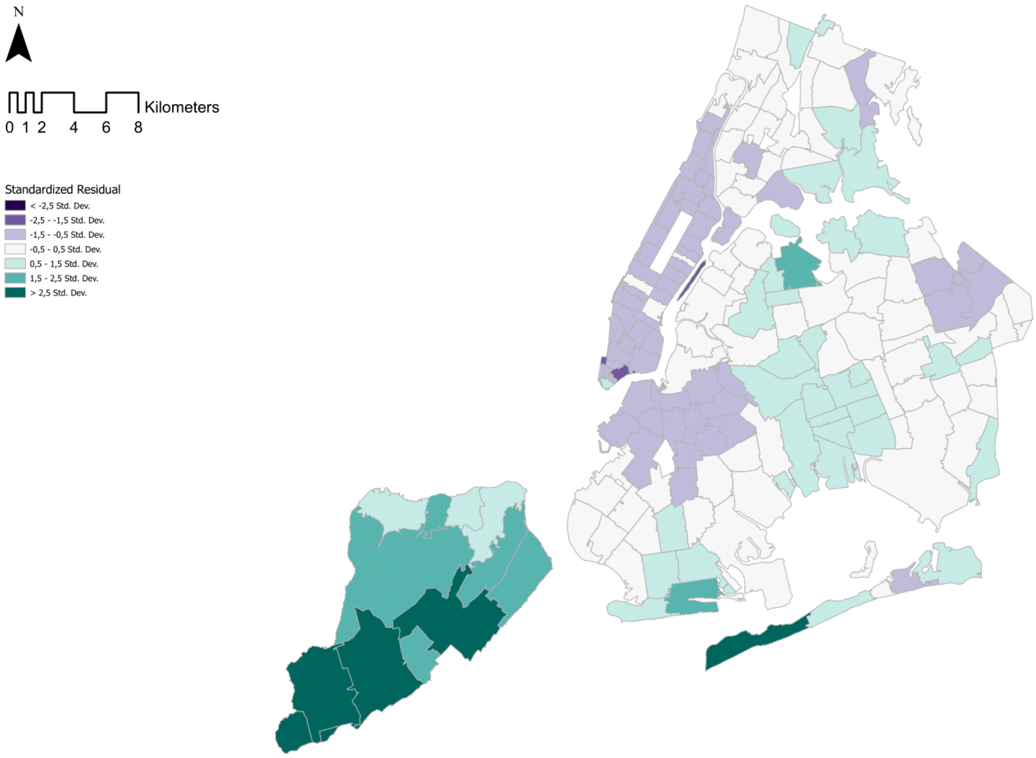


Figure 151 - SVI – Cases Std. Residuals by MODZCTA (GWR), NYC

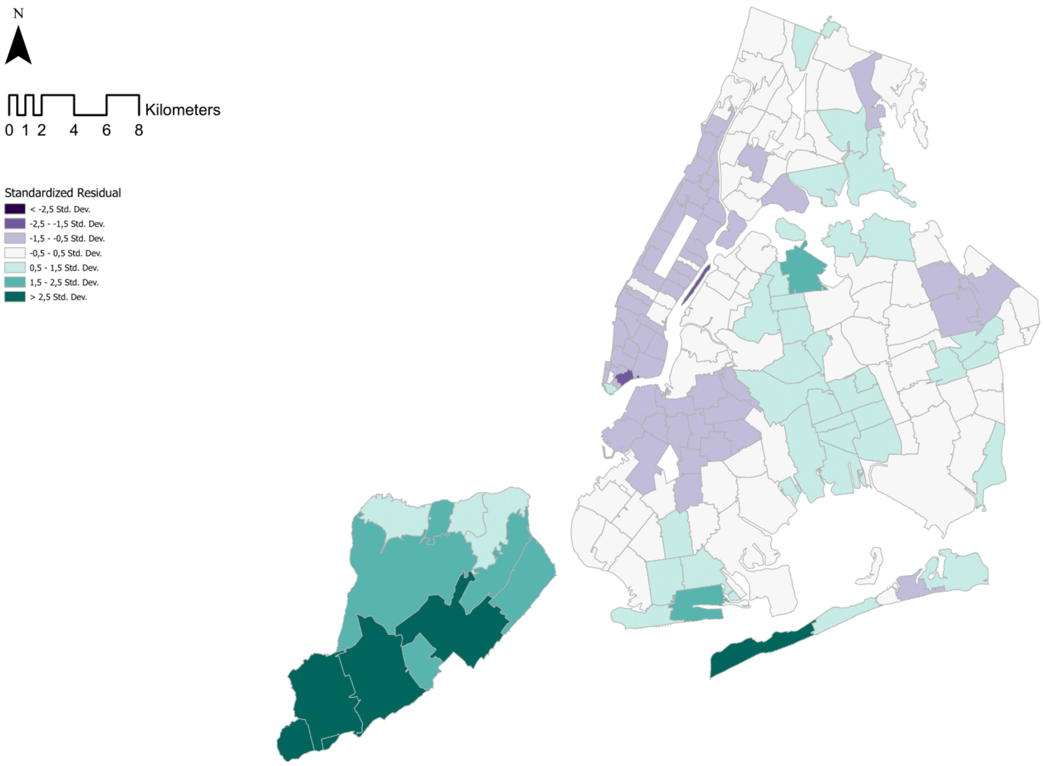


Figure 152 - SVI – Deaths Std. Residuals by MODZCTA (OLS), NYC

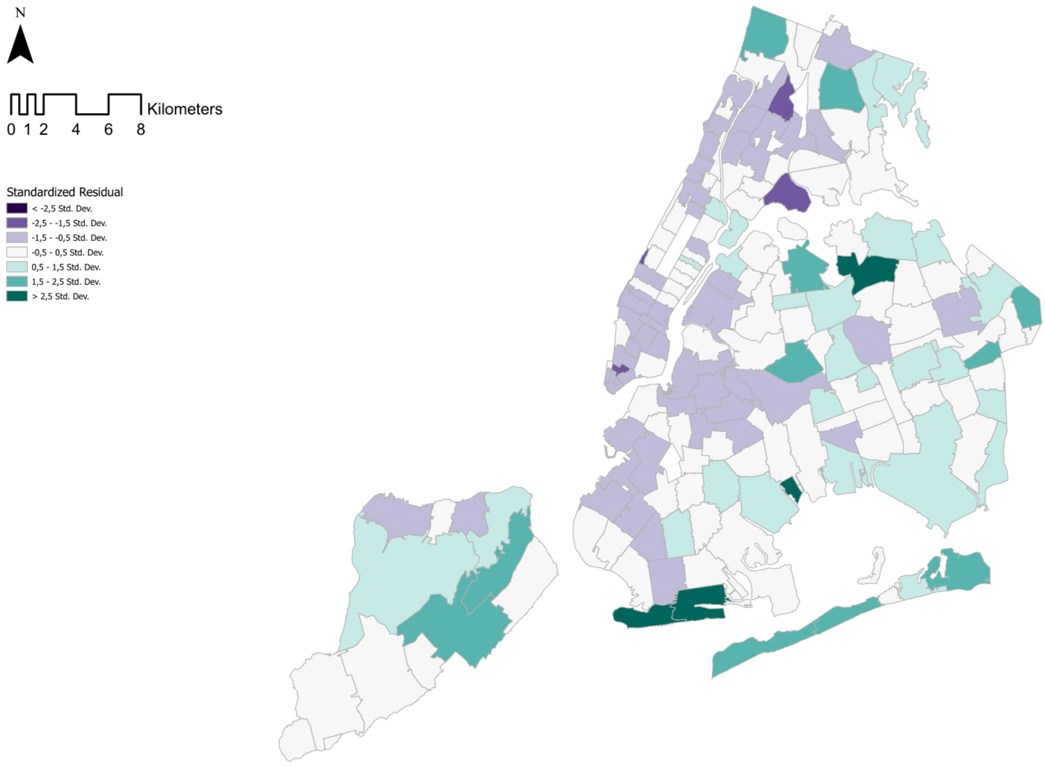


Figure 153 - SVI – Deaths Std. Residuals by MODZCTA (GWR), NYC

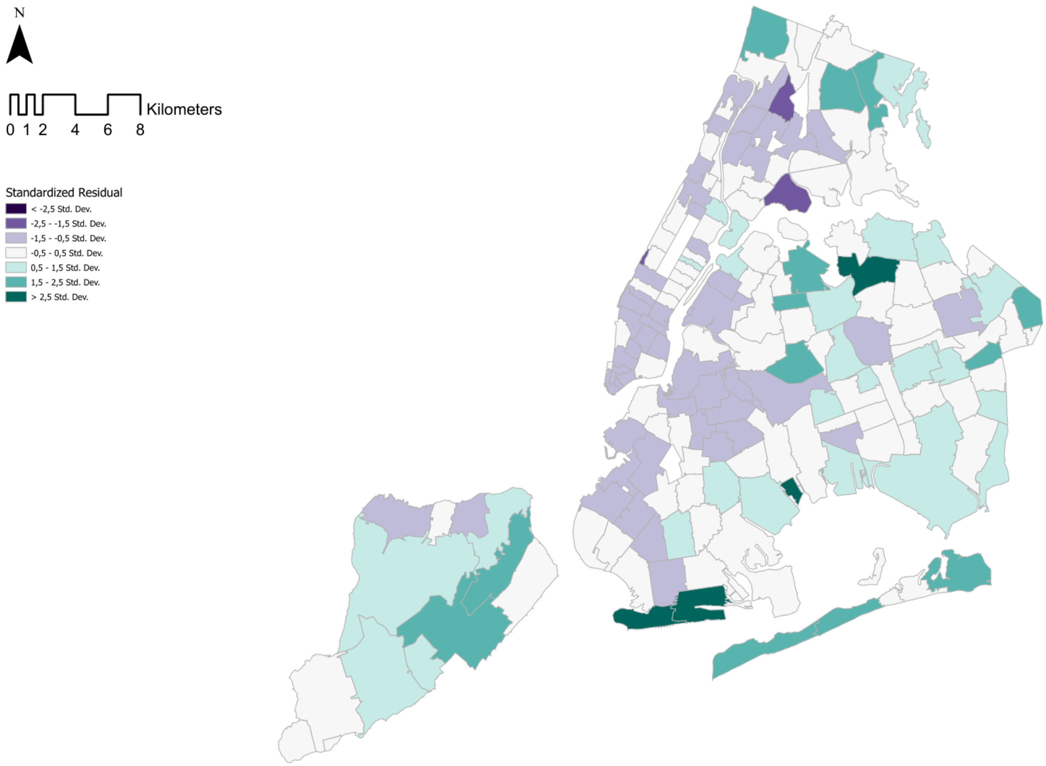
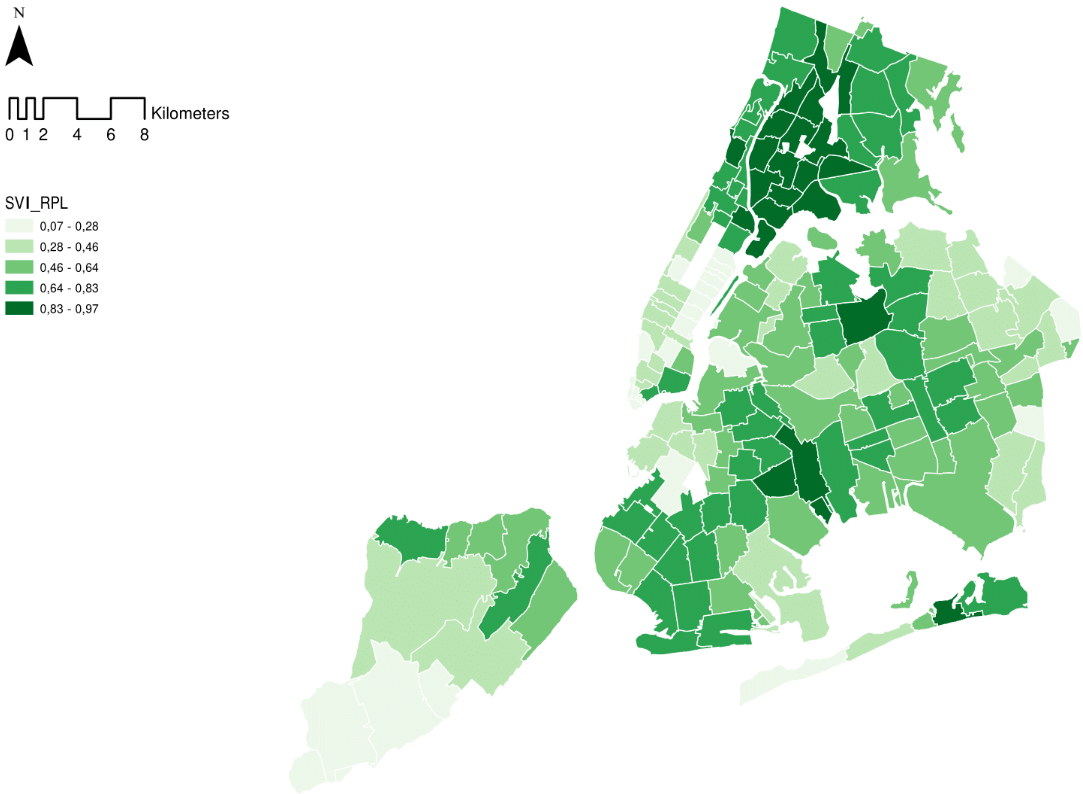


Figure 154 - SVI by MODZCTA, NYC



5.2.3 Rome

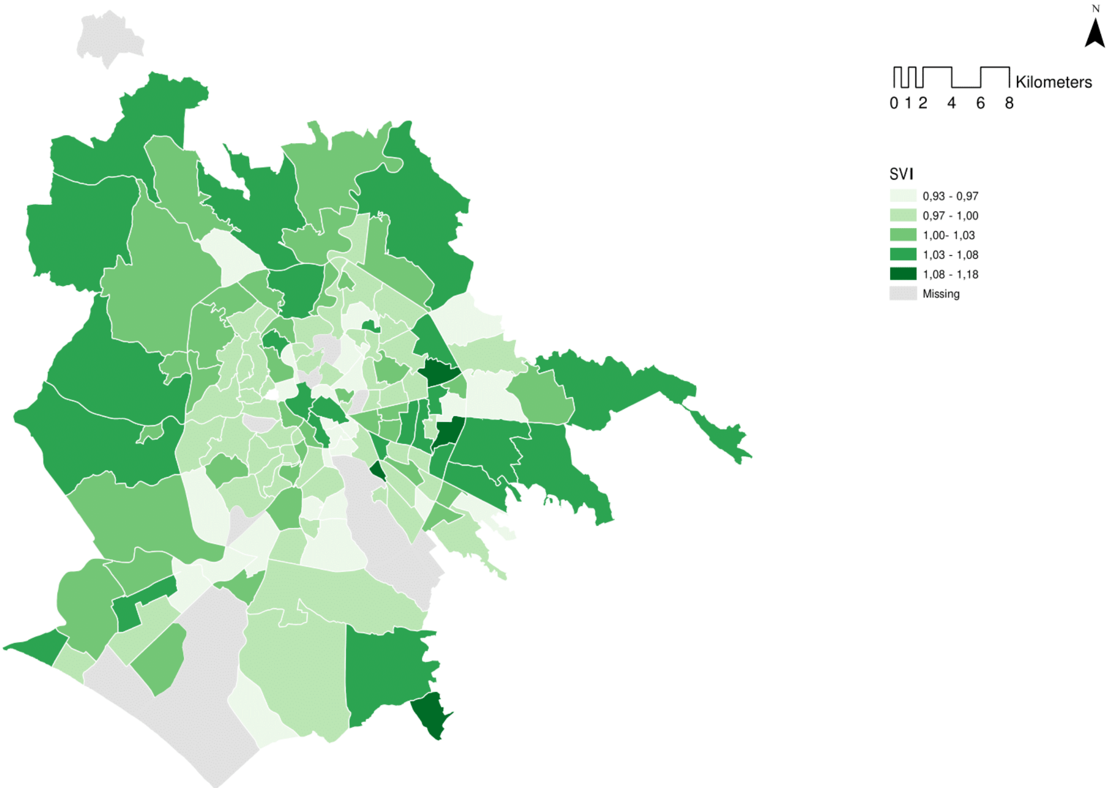
Below (Table 6), it is possible to observe the main results of the correlation matrix for Rome. When correlating the SVI with the total cases and deaths, the values obtained are, respectively, 0.29 and 0.15. Thus, there is a low correlation between the index and the pandemic's spread and mortality in this case. Differently from what was seen in London and NYC, where the cases and deaths were, to some extent, correlated, here the coefficient is proximate to 0 (0.04), indicating a non-correlation. It confirms what was observed in the previous "visual" analysis of the spatial impact of the pandemic, where the patterns for the two sides of the pandemic were pointed out to be non-congruent and with minimal overlapping in terms of distribution across the city.

Table 6 - Correlation matrix SVI and COVID-19 in Rome

	SVI	*Total cases*	*Total deaths*
SVI	1		
Total cases	0,29*	1	
Total deaths	0,15*	0,04*	1

** Statistically significant p-value (p < 0,05)*

Figure 155 - SVI by ZUB, Rome



From Fig. 155, we observe the mapping of vulnerability, at the ZUB level, according to the SVI. Although some areas are missing due to a lack of data, it is possible to observe a greater consistency with the distribution of cases, even though limited. Compared to the distribution of deaths, the coincidence is almost vanished (as observed from the correlation). Turning to the regression models, as shown by Tab. 7. Firstly, it is possible to notice how the SVI performs almost equally as far as the R^2 and the I are concerned when analysed through the GWR or the OLS model. In general, it seems that the SVI, taken alone, is not sufficient to provide significant prediction concerning the pandemic, nor in terms of cases or deaths, as was the case for London and NYC. Moran's Index is closer to 0 for both models, primarily when SVI is used to predict mortality, where the value indicates no spatial autocorrelation. In contrast, for the model of the cases, the spatial issue is still partly unaddressed.

Table 7 - Regressions results SVI and COVID-19 in Rome

Model	*OLS* R^2	*OLS* *I*	*OLS* *p-value*	*OLS* *β*	*OLS* *AICc*	*GWR* R^2	*GWR* *I*	*GWR* *AICc*
SVI - Cases	0,08	0,13*	0,0004	0,2820	2533,49	0,10	0,12*	2530,98
SVI - Deaths	0,02	0,02	0,0722	0,1264	1834,51	0,01	0,02	1834,69

* *Statistically significant p-value (p < 0,05)*

Figure 156 - SVI – Cases, Std. Residuals by ZUB (OLS), Rome

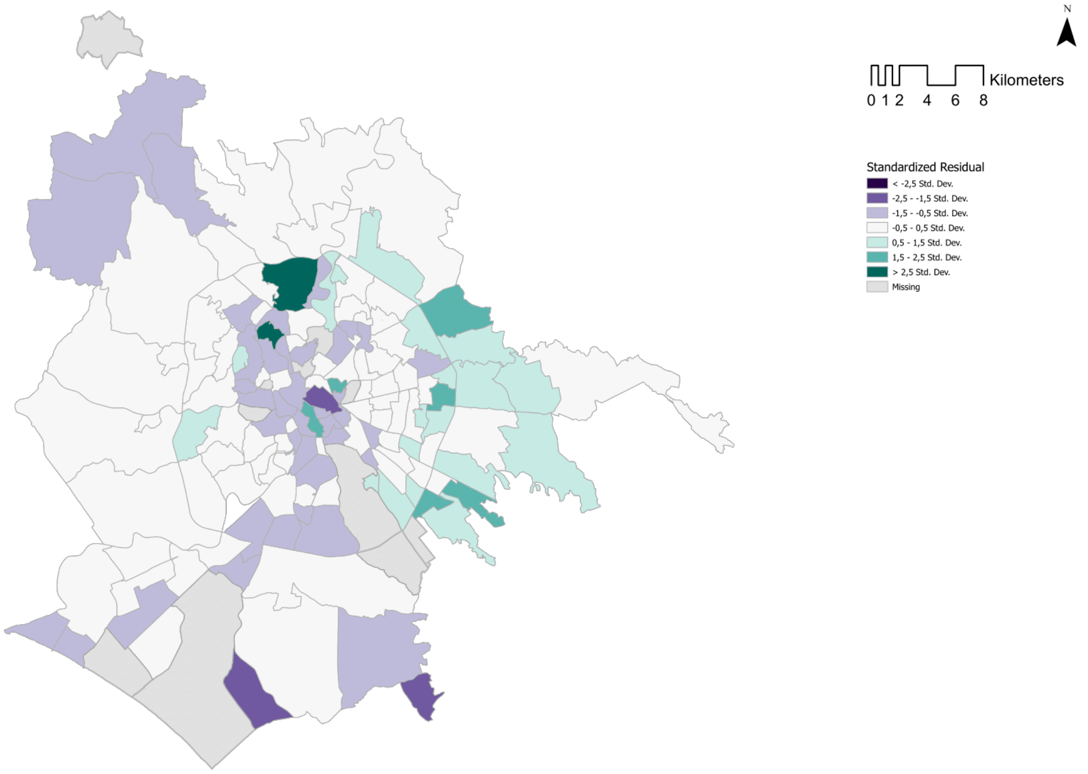


Figure 157 - SVI – Cases, Std. Residuals by ZUB (GWR), Rome

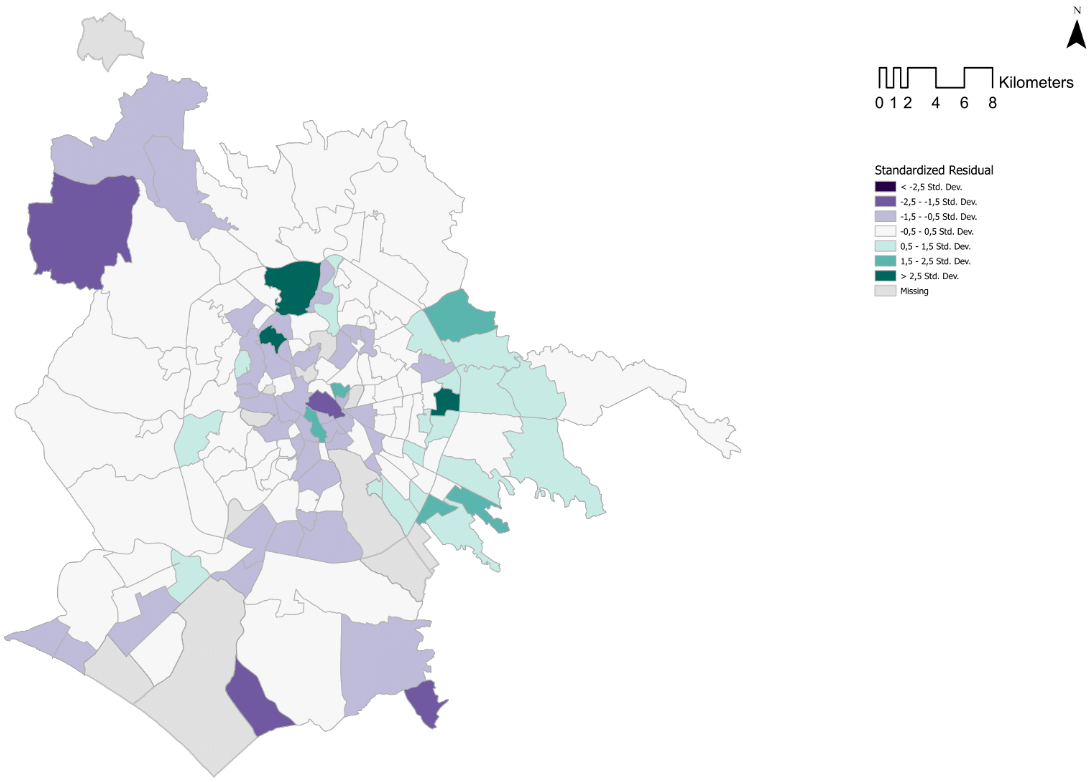


Figure 158 - SVI – Deaths, Std. Residuals by ZUB (OLS), Rome

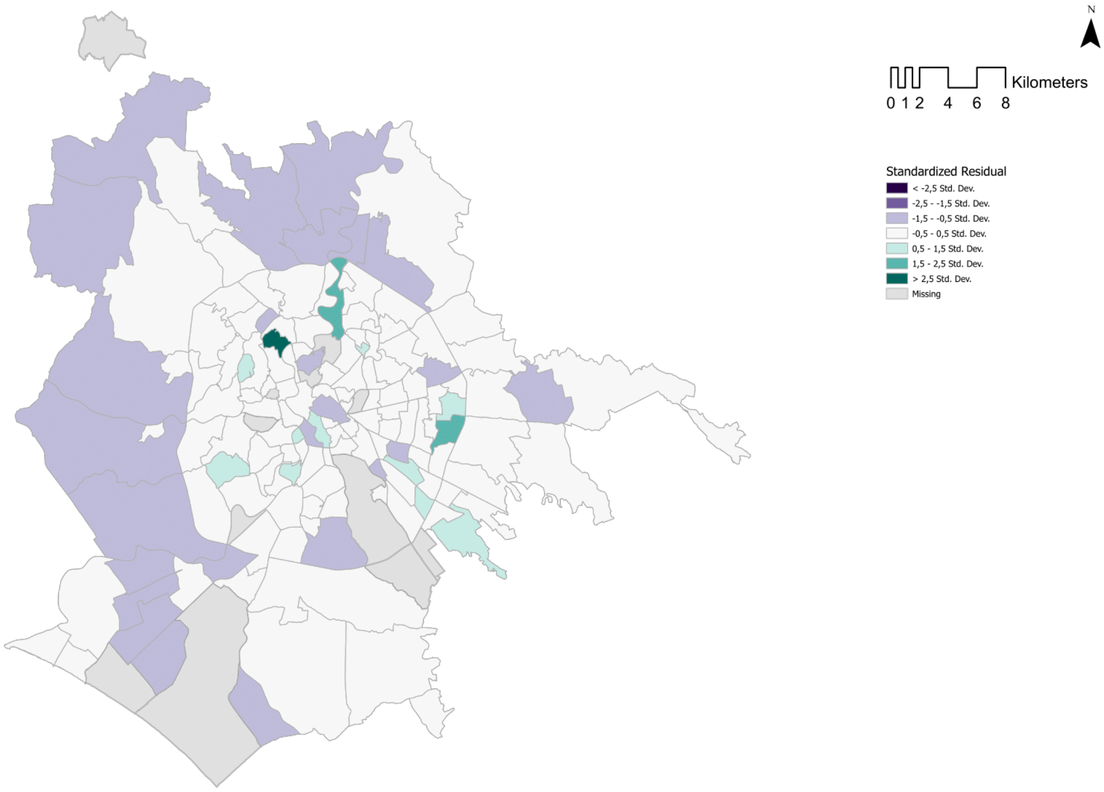
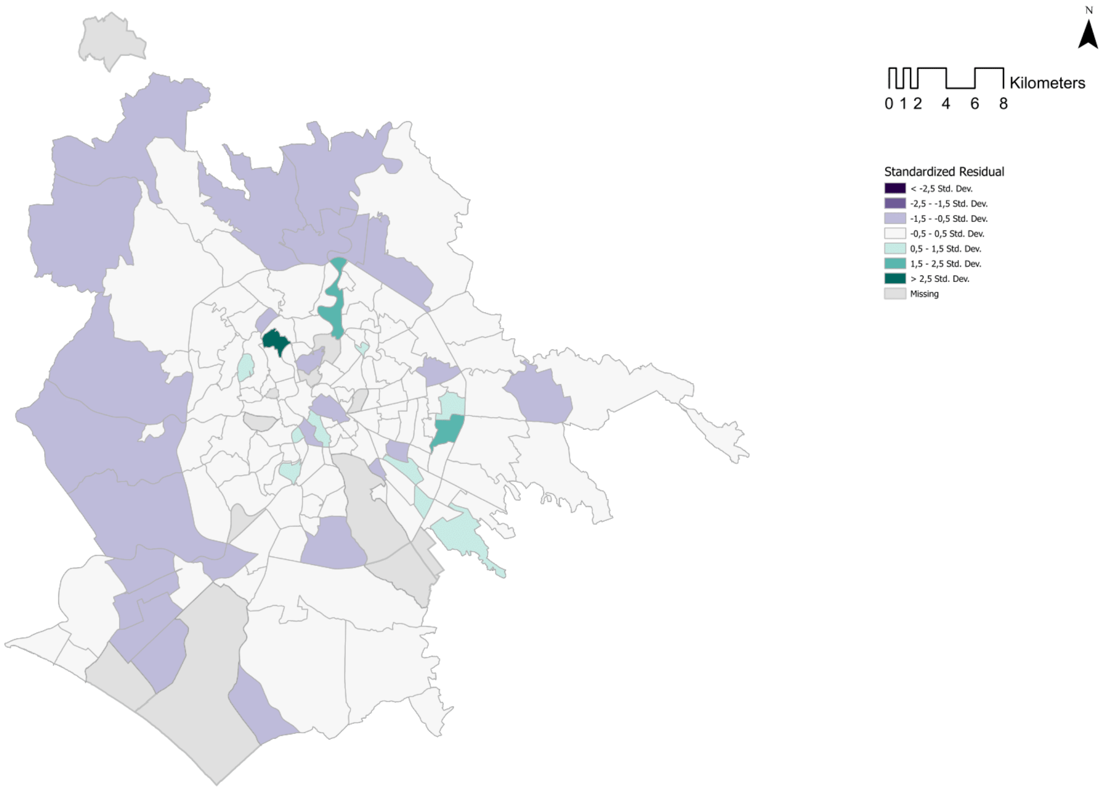


Figure 159 - SVI – Deaths, Std. Residuals by ZUB (GWR), Rome



5.2.4 Sao Paulo

In Sao Paulo, the correlation matrix below (Table 8) displays similar results to the ones obtained for Rome. Again, there is a low correlation with the total cases and deaths, as shown by the coefficients, 0.24 and -0.10, respectively. However, unlike previous observations, we see a negative correlation with mortality, opening to crucial interpretations and questions. As observed in Rome, also, in this case, there is little correlation between cases and deaths distribution, thus confirming what was observed in the first qualitative spatial description of the pandemic, where two different patterns were noticed.

Table 8 - Correlation matrix SVI and COVID-19 in Sao Paulo

	SVI	*Total cases*	*Total deaths*
SVI	1		
Total cases	0,24*	1	
Total deaths	-0,10	0,13	1

** Statistically significant p-value (p < 0,05)*

From Fig. 164, we observe the *Distritos* that, according to the SVI, are more vulnerable to health problems. It is possible to see how there are some areas that overlap with the spread of the pandemic (such as the eastern districts). However, as demonstrated by the correlation matrix and the value obtained, other units do not reflect the same pattern, especially when it comes to the analysis of deaths.

Turning to the regression models, instead, Table 9. shows that the SVI, when analysed through the GWR or the OLS model, presents almost equal results, as in Rome. Again, as observed in the previous case studies, it seems that the SVI, taken alone, is not sufficient to provide significant predictions concerning the pandemic. The R^2 values obtained (all ranging from 0.00 to 0.09) are too low as predictors. The differential between cases and deaths is similar for both models (0.05 difference for the OLS and 0.02 for the GWR). Notably, Moran's Indices are all closer to zero, with the GWR's slightly lower. Whereas for the cases, there is randomness, for the deaths, there is still clustering. Fig. 160 to 163 show the distribution of the standard residuals produced by both regression models.

Table 9 - Regressions results SVI and COVID-19 in Sao Paulo

Model	*OLS R^2*	*OLS I*	*OLS p-value*	*OLS β*	*OLS AICc*	*GWR R^2*	*GWR I*	*GWR AICc*
SVI - Cases	0,05	0,10*	0,0177	0,2415	1707,39	0,05	0,09*	1706,46
SVI - Deaths	0,00	0,37*	0,3137	-0,1039	1133,76	0,03	0,34*	1129,99

** Statistically significant p-value (p < 0,05)*

Figure 160 - SVI – Cases, Std. Residuals by Distrito (OLS), Sao Paulo

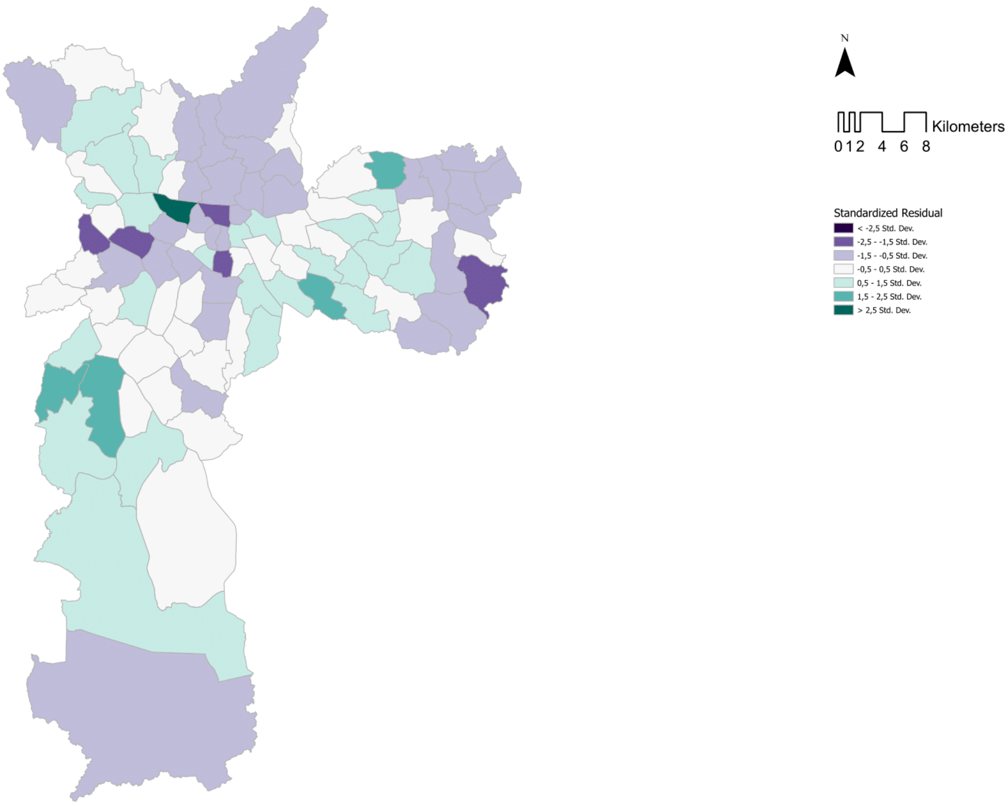


Figure 161 - SVI – Cases, Std. Residuals by Distrito (GWR), Sao Paulo

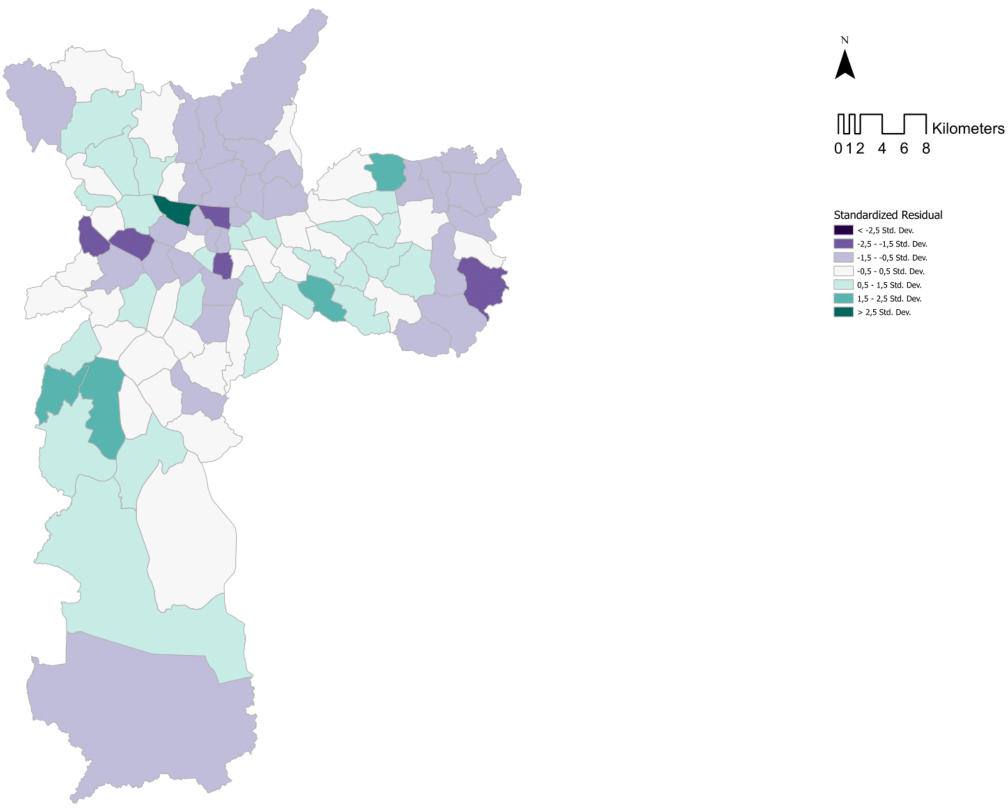


Figure 162 - SVI – Deaths, Std. Residuals by Distrito (OLS), Sao Paulo

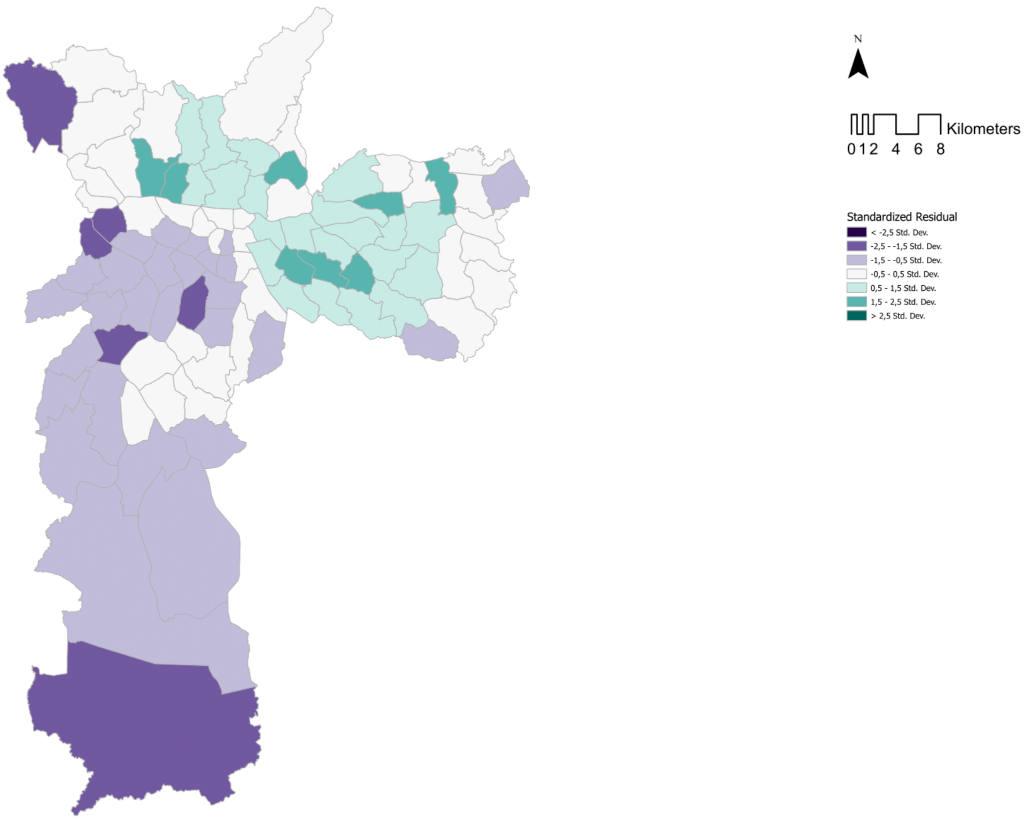


Figure 163 - SVI – Deaths, Std. Residuals by Distrito (GWR), Sao Paulo

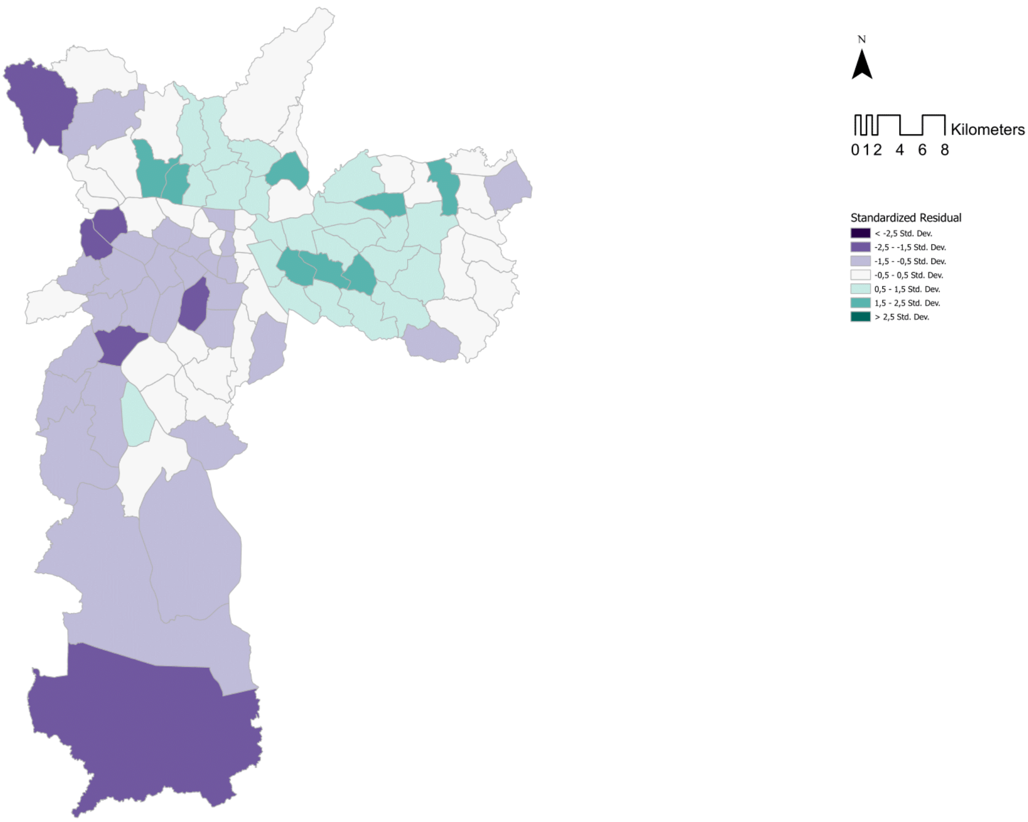
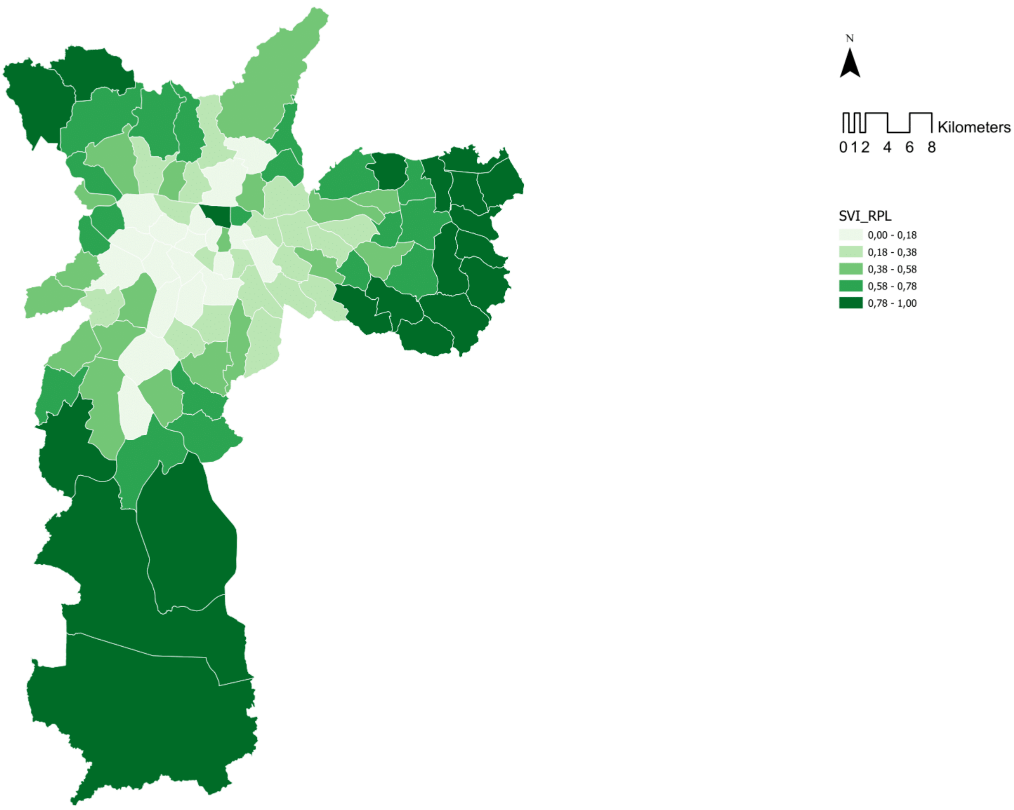


Figure 164 - SVI by Distrito, Sao Paulo



5.2.5 Model I: Wrap-up

This first model has shown already relevant results. Firstly, the GWR, in general, performs better than the OLS, and it helps reduce the level of spatial autocorrelation, especially in London and NYC. Also, in all case studies, the SVI has proved insufficient to predict either the spread or mortality, at least not when taken alone. Despite the encouraging results in NYC and London, with higher values than Rome and Sao Paulo, most cases and deaths are still unexplained. Arguably, there is still a part of the story missing, a set of variables that can help widen the predictive power of the models and simultaneously reduce the level of spatial autocorrelation that was obtained. Interestingly, some results deserve noting. Firstly, whereas for London, Rome and Sao Paulo, the SVI seems to perform better when analysing the cases, in NYC, the regression on the deaths gives better results, both in terms of R^2 and coefficient. Secondly, in Sao Paulo, the coefficient when analysing the virus's mortality is negative, contrary to all the other case studies.

Hence, we shall now turn to the second model (Model II), where a set of spatial indicators, which have been previously presented and detailed, will be used to study the pandemic. This next model is not meant to be an attempt to "split" the different dimensions of the city concerning the pandemic. Instead, the whole process is carried out in such a way to prove the opposite: we need to complexify the socio-spatial discourse around the pandemic. The division in different sub-models cannot provide sufficiently significant results, as shown by the first model described in this chapter.

5.3 Model II: COVID-19 and spatial indicators

As briefly mentioned before, this second model relates a set of spatial indicators linked to distance and density of urban infrastructure and facilities, with the spread and mortality of COVID-19. The variables used to construct the indicators and the methodology used has been described in the third chapter. Once again, the main models employed are the OLS and the GWR; the latter has been used to analyse the variability of results by considering a geographically weighted approach. For each city, the following elements will be provided:

- A table showing the correlation matrix
- Maps showing density and distance to urban infrastructure and facilities
- Table showing the results of the regression models (OLS and GWR): the table lists the same parameters used before (R^2, β, AICc, Moran's *I,* and p-value*),* with the addition of the Variance Inflation Factor (VIF) to measure the possible redundancy
- Map showing the distribution of residuals according to the GWR and OLS models

5.3.1 London

In London, the correlation matrix (Table 10) displays some critical results. In general, it is possible to observe how there are not exceedingly strong correlations among the different indicators. There are only a few having a moderately strong correlation, as the indicators of proximity, with values ranging from 0.35 to 0.57, thus meaning that they might not have the same information content. Turning instead to the correlation between the spread and mortality of COVID-19 and the indicators, again, we observe no significantly strong correlations, with a range of values oscillating between -0.34 and 0.37. Another remarkable result is the relationship between cycling and intersection density and the proximities; it is possible to assert, from the results, that, as a general trend, the greater the distance to facilities, the lower the density of both infrastructures.

Table 10 - Correlation matrix spatial indicators and COVID-19 in London

	Variables	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
1	GREEN_DEN	**1,00**											
2	CYCLE_DEN	**-0,12***	**1,00**										
3	INT_DEN	**-0,28***	**0,54***	**1,00**									
4	HOSP_DEN	**0,11***	0,06	**0,12***	**1,00**								
5	SPRMKT_DEN	**-0,08***	**0,08***	**0,20***	0,03	**1,00**							
6	PHARMA_DEN	-0,02	**0,08***	**0,29***	**0,16***	**0,41***	**1,00**						
7	HOSP_DIST	**0,22***	**-0,23***	**-0,30***	**-0,31***	**-0,09***	**-0,15***	**1,00**					
8	PHARMA_DIST	**0,23***	**-0,25***	**-0,36***	-0,03	**-0,17***	**-0,32***	**0,35***	**1,00**				
9	GREEN_DIST	**0,31***	**-0,44***	**-0,60***	-0,01	**-0,15***	**-0,16***	**0,31***	**0,45***	**1,00**			
10	SPRMKT_DIST	**0,39***	**-0,27***	**-0,37***	0,02	**-0,33***	**-0,21***	**0,41***	**0,57***	**0,53***	**1,00**		
11	TOTAL CASES	-0,03	**-0,07***	**-0,22***	**-0,13***	**-0,07***	**-0,15***	**0,28***	**0,20***	**0,19***	**0,10***	**1,00**	
12	TOTAL DEATHS	**0,16***	**-0,25***	**-0,34***	-0,02	**-0,12***	**-0,12***	**0,26***	**0,26***	**0,37***	**0,29***	**0,47***	**1,00**

** Statistically significant p-value (p < 0,05)*

Figure 165 - Green areas per inhabitant (m^2/inh) by MSOA, London

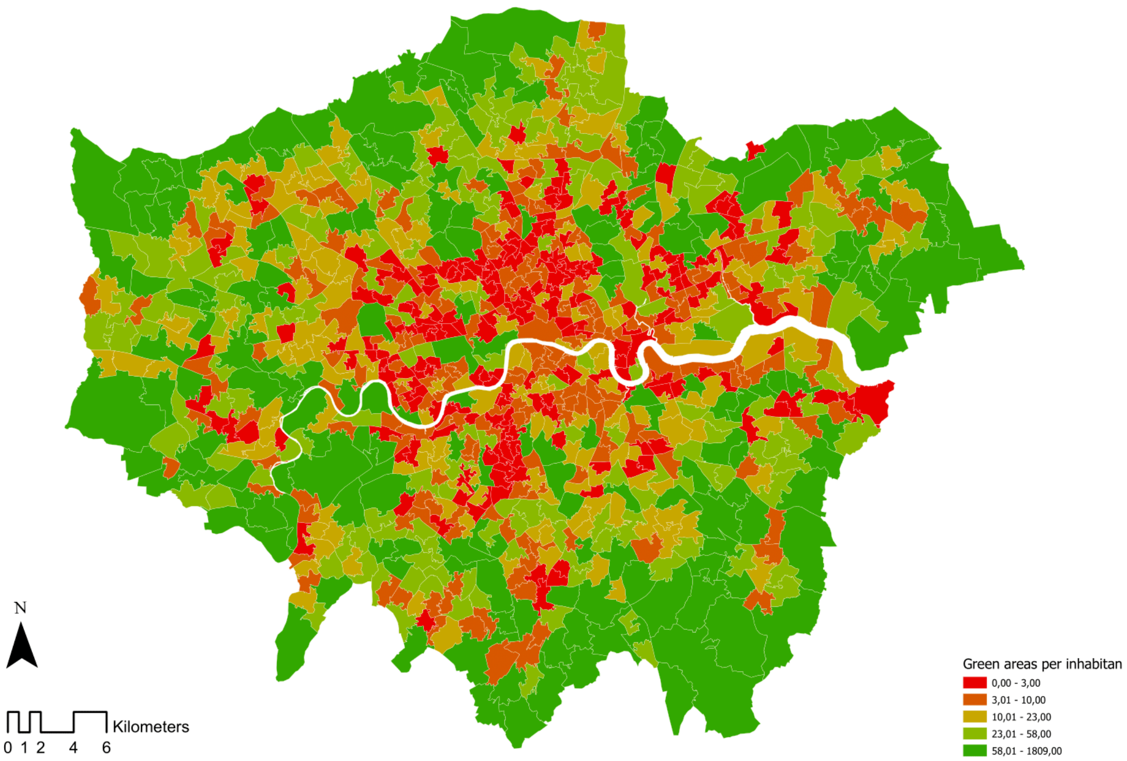


Figure 166 - Bicycle routes and paths density (km/km^2) by MSOA, London

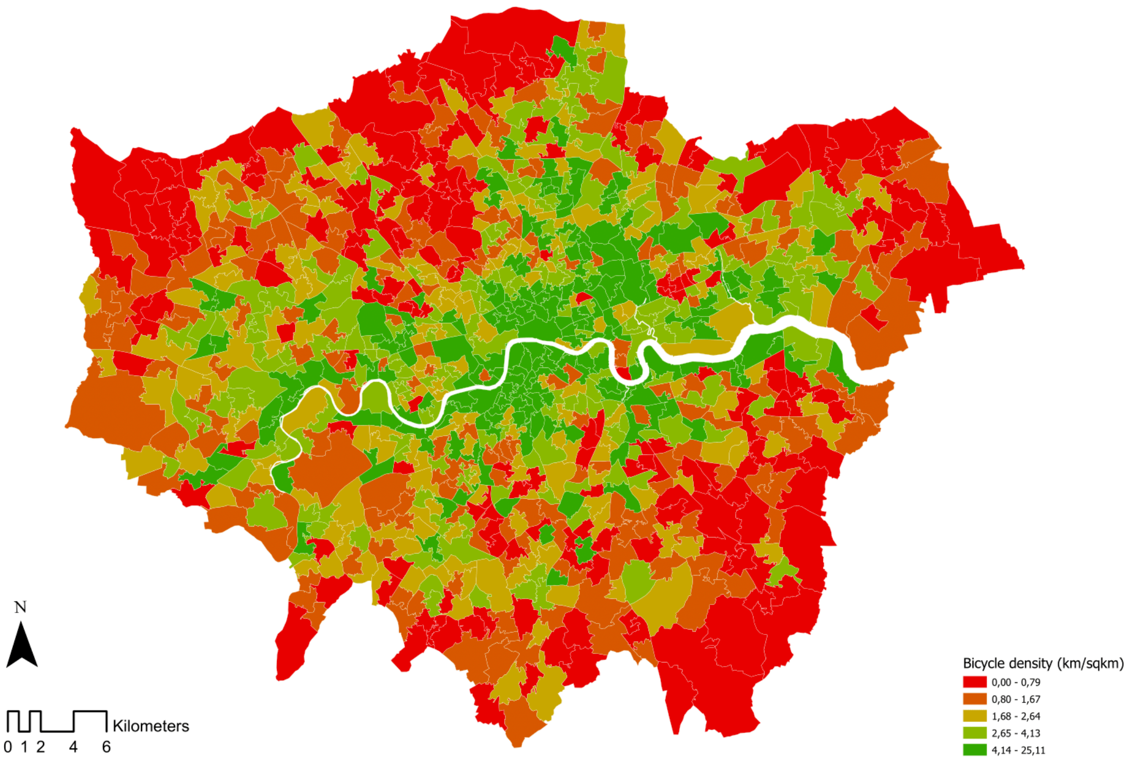


Figure 167 - Street's intersection density (int/ km^2) by MSOA, London

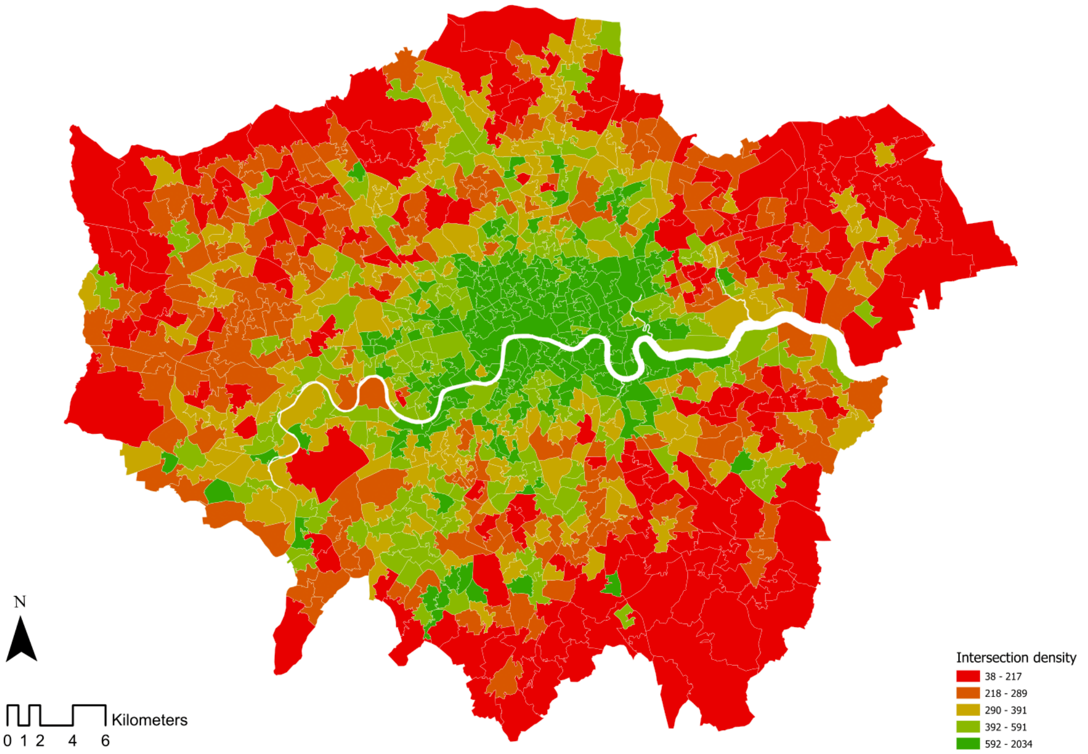


Figure 168 - Hospital density (per 100.000 inhabitants) by MSOA, London

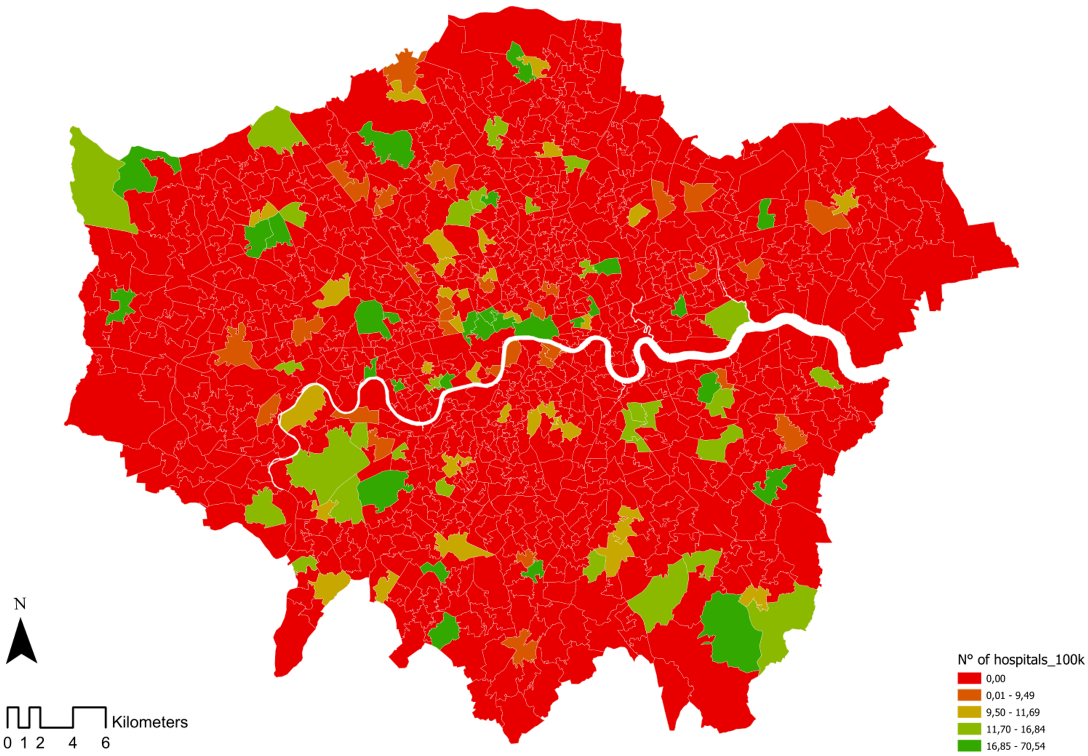


Figure 169 - Supermarket density (per 100.000 inhabitants) by MSOA, London

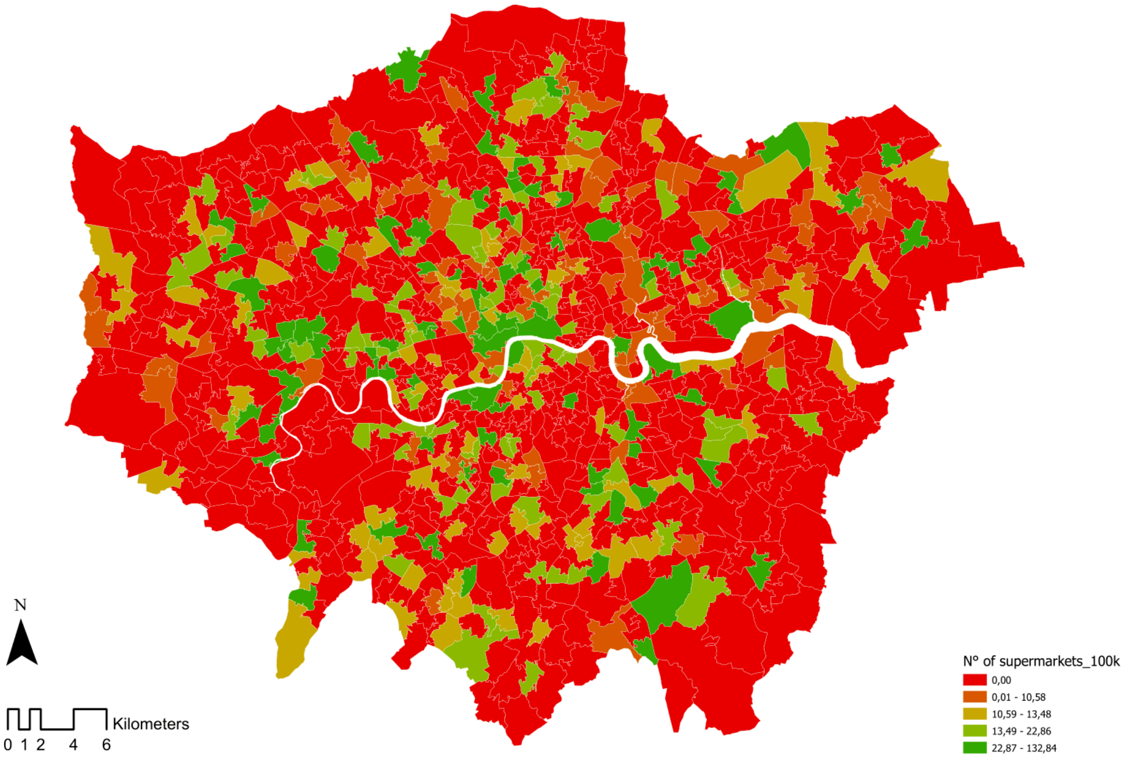


Figure 170 - Pharmacy density (per 100.000 inhabitants) by MSOA, London

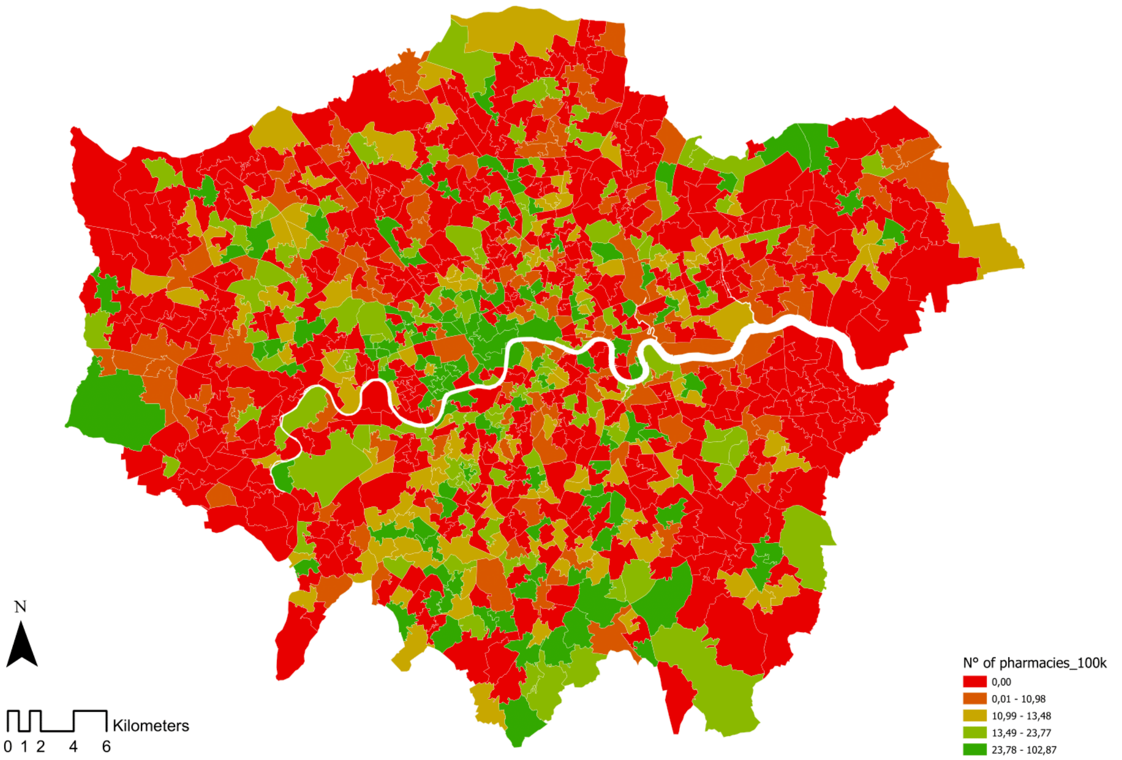


Figure 171 - Mean distance to the closest hospital (m) by MSOA, London

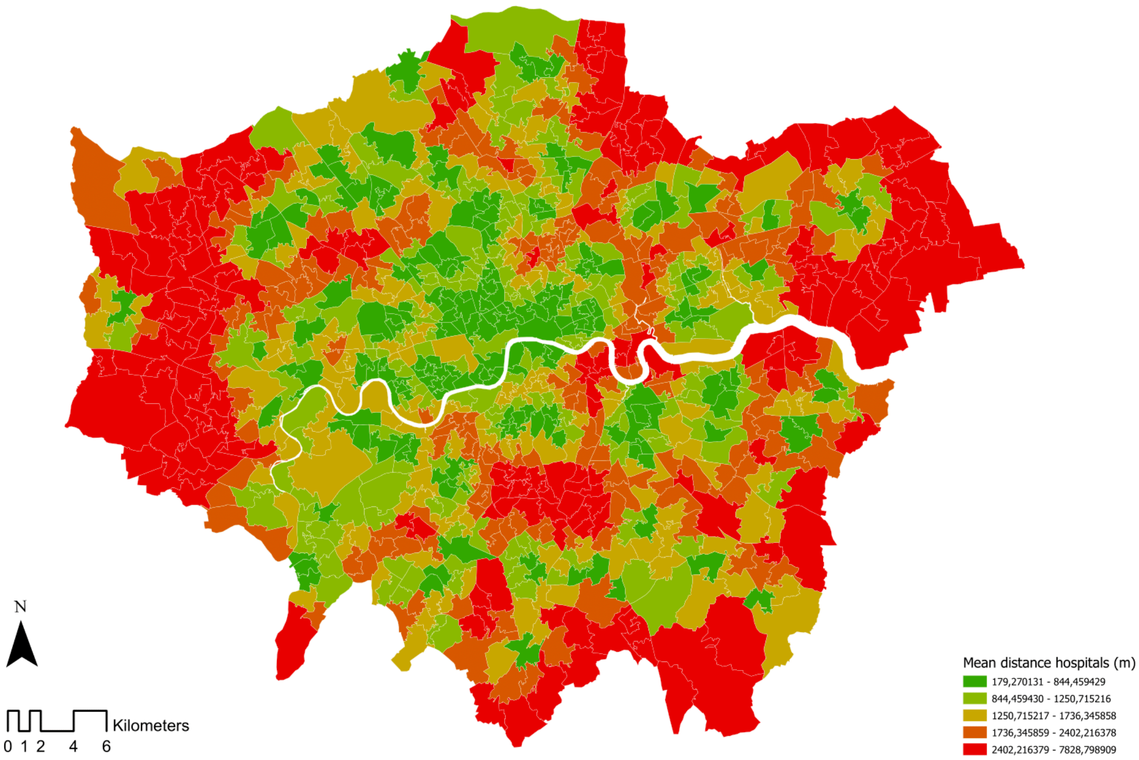


Figure 172 - Mean distance to the closest pharmacy (m) by MSOA, London

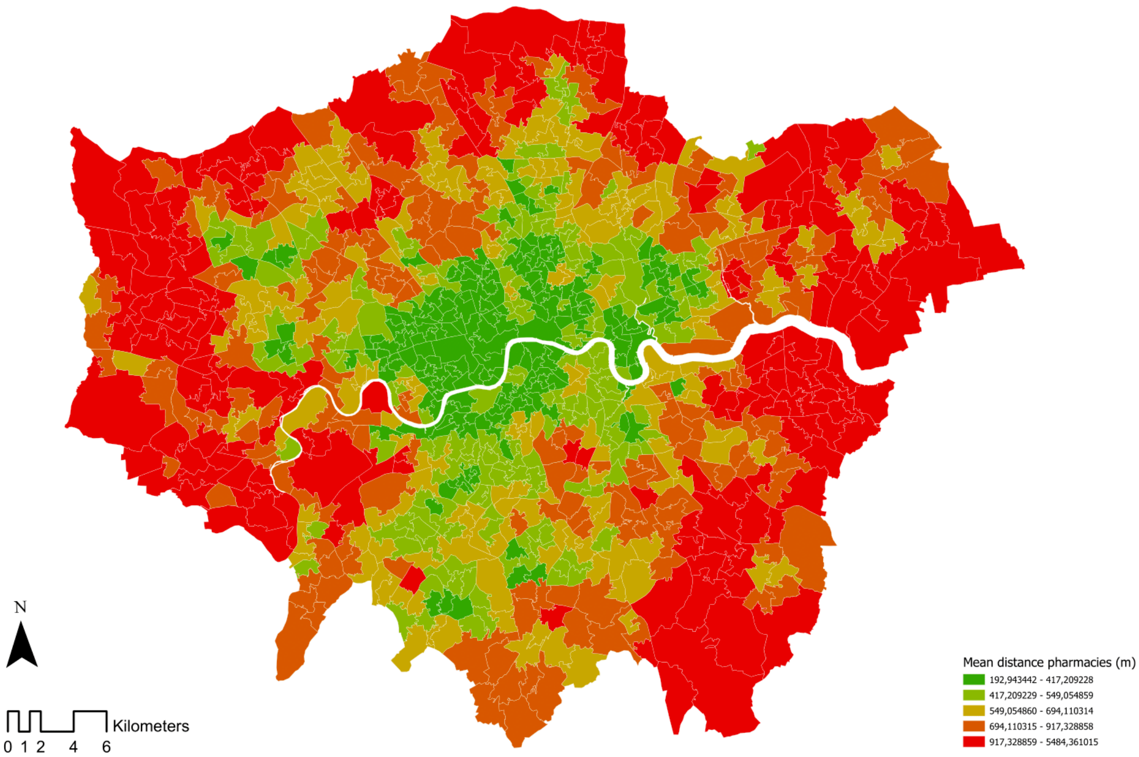


Figure 173 - Mean distance to the closest publicly accessible green area (m), by MSOA, London

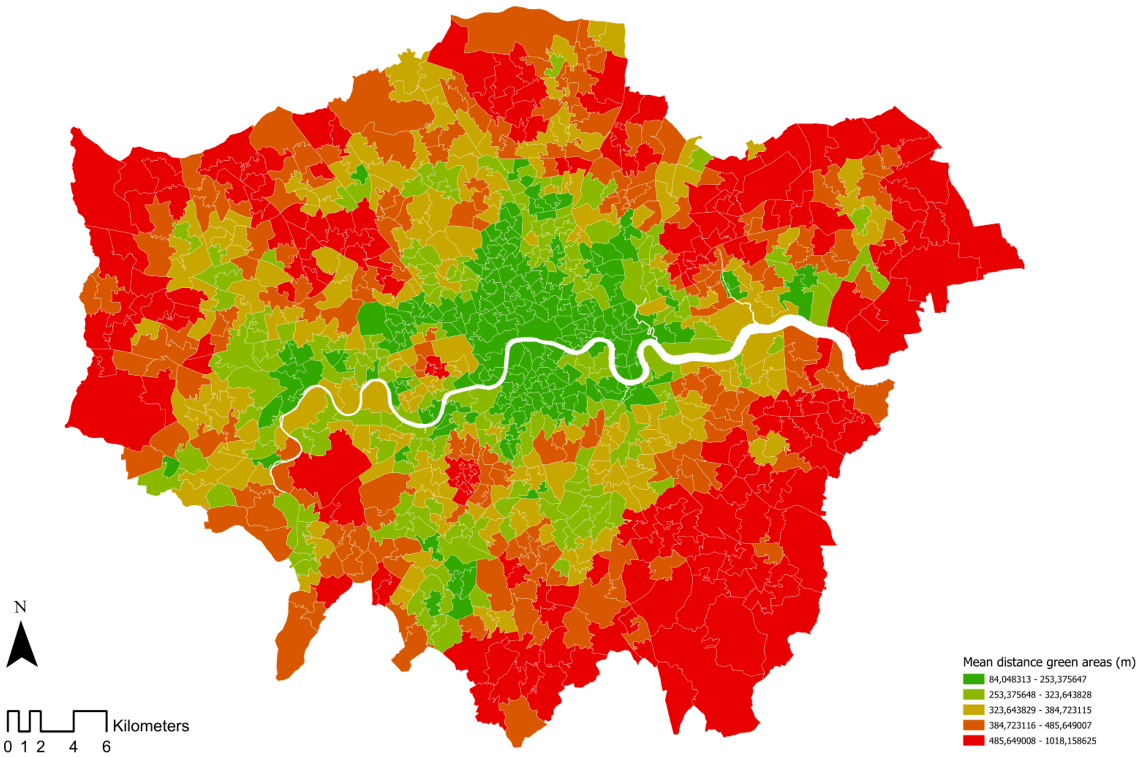
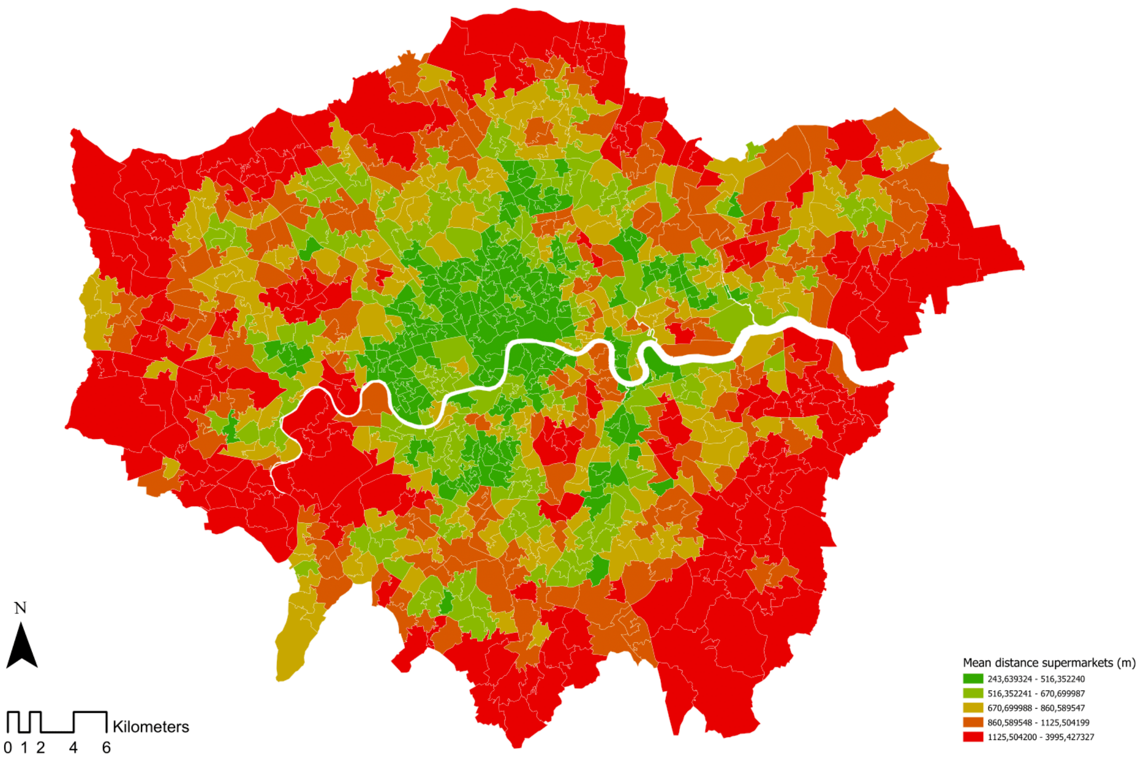


Figure 174 - Mean distance to the closest supermarket (m) by MSOA, London



Tab. 11. below displays the results of the regressions. Starting from the regression on the cases, it is possible to notice how the GWR performs better in terms of R^2 and Moran's *I*. The indicators are statistically significant except for the ones describing the density of facilities. This fact, however, might be linked to the very nature of the phenomenon that has been studied (namely, the inequalities, hence, the more significant variability in values) and the fact that there is a "limited" number of units that show values greater than 0 (as it happens for the hospitals). This fact is also reflected in the coefficients, where it is possible to notice how the distance to hospitals, pharmacies and green areas have the strongest coefficients. Regarding mortality (Tab. 12), instead, several indicators have higher p-values. However, some variables have higher coefficients, such as distance to green areas and hospitals (0,19 and 0,13 respectively). The GWR helps reduce spatial autocorrelation.

Table 11 - Regressions results for spatial indicators and COVID-19 cases in London

Variables	*OLS R^2*	*OLS I*	*OLS p-value*	*OLS β*	*OLS VIF*	*OLS AICc*	*GWR R^2*	*GWR I*	*GWR AICc*
GREEN_DEN	0,13	0,5*	0,0000	-0,13219	1,27	17302,87	0,31	0,39*	17083,3
CYCLE_DEN			0,0048	0,102703	1,49				
INT_DEN			0,0003	-0,15588	2,07				
HOSP_DEN			0,5825	-0,01791	1,19				
SPRMKT_DEN			0,5686	-0,01963	1,33				
PHARMA_DEN			0,2258	-0,04271	1,4				
HOSP_DIST			0,0000	0,242579	1,43				
PHARMA_DIST			0,0051	0,10917	1,71				
GREEN_DIST			0,0094	0,109135	1,99				
SPRMKT_DIST			0,0139	-0,10764	2,16				

Table 12 - Regressions results for spatial indicators and COVID-19 deaths in London

Variables	*OLS R^2*	*OLS I*	*OLS p-value*	*OLS β*	*OLS VIF*	*OLS AICc*	*GWR R^2*	*GWR I*	*GWR AICc*
GREEN_DEN	0,18	0,13*	0,9811	0,000769	1,27	11534,06	0,24	0,07*	11466,23
CYCLE_DEN			0,2124	-0,04407	1,49				
INT_DEN			0,0014	-0,13339	2,07				
HOSP_DEN			0,1682	0,043655	1,19				
SPRMKT_DEN			0,3318	-0,03249	1,33				
PHARMA_DEN			0,9882	0,000505	1,4				
HOSP_DIST			0,0002	0,128324	1,43				
PHARMA_DIST			0,1637	0,052795	1,71				
GREEN_DIST			0,0000	0,187716	1,99				
SPRMKT_DIST			0,4186	0,034397	2,16				

* *Statistically significant p-value ($p < 0,05$)*

Figure 175 - Spatial indicators – Cases, Std. Residuals by MSOA (OLS), London

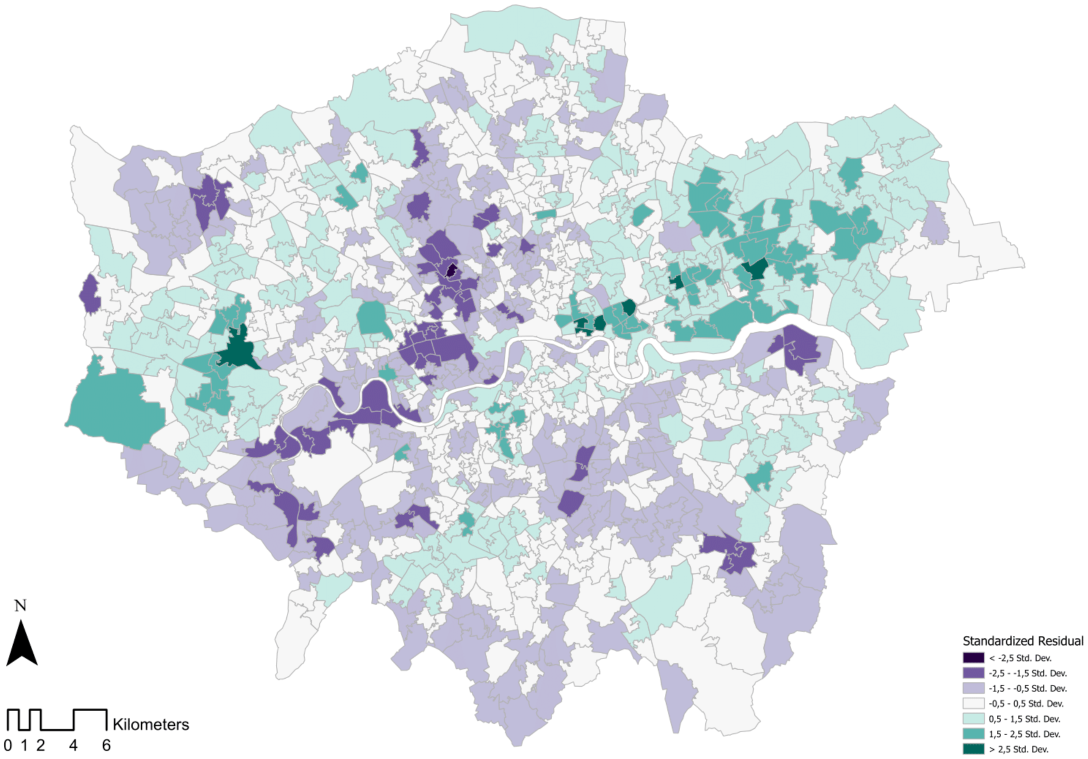


Figure 176 - Spatial indicators – Cases, Std. Residuals by MSOA (GWR), London

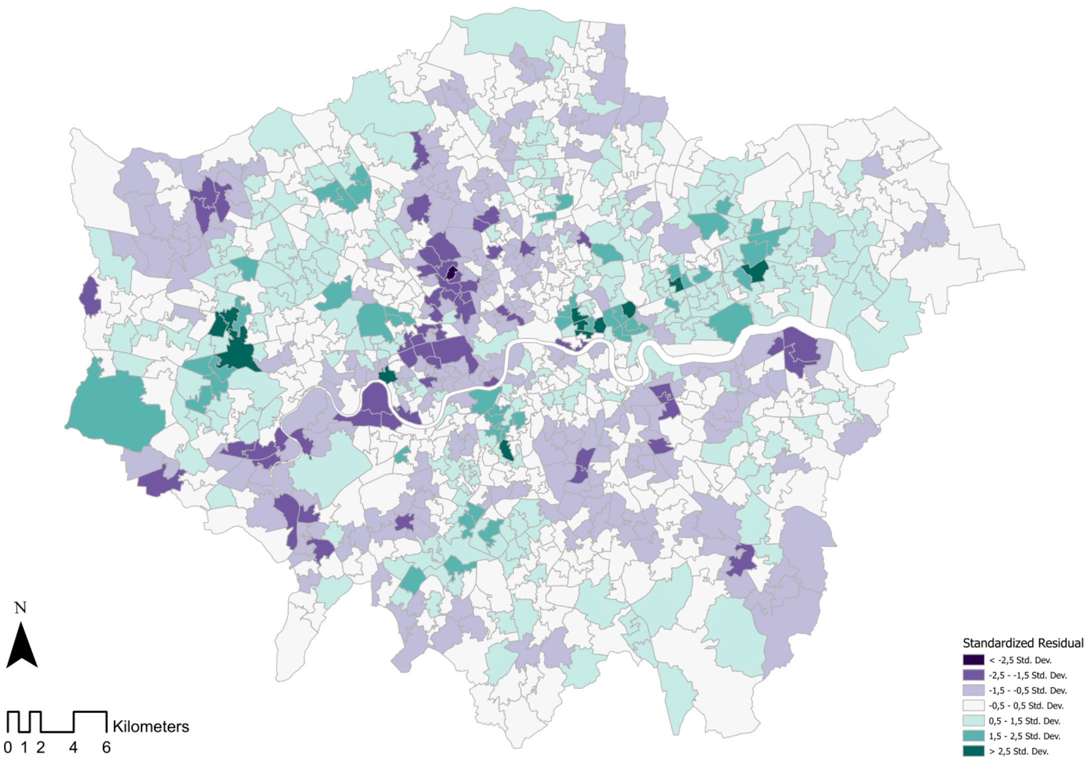


Figure 177 - Spatial indicators – Deaths, Std. Residuals by MSOA (OLS), London

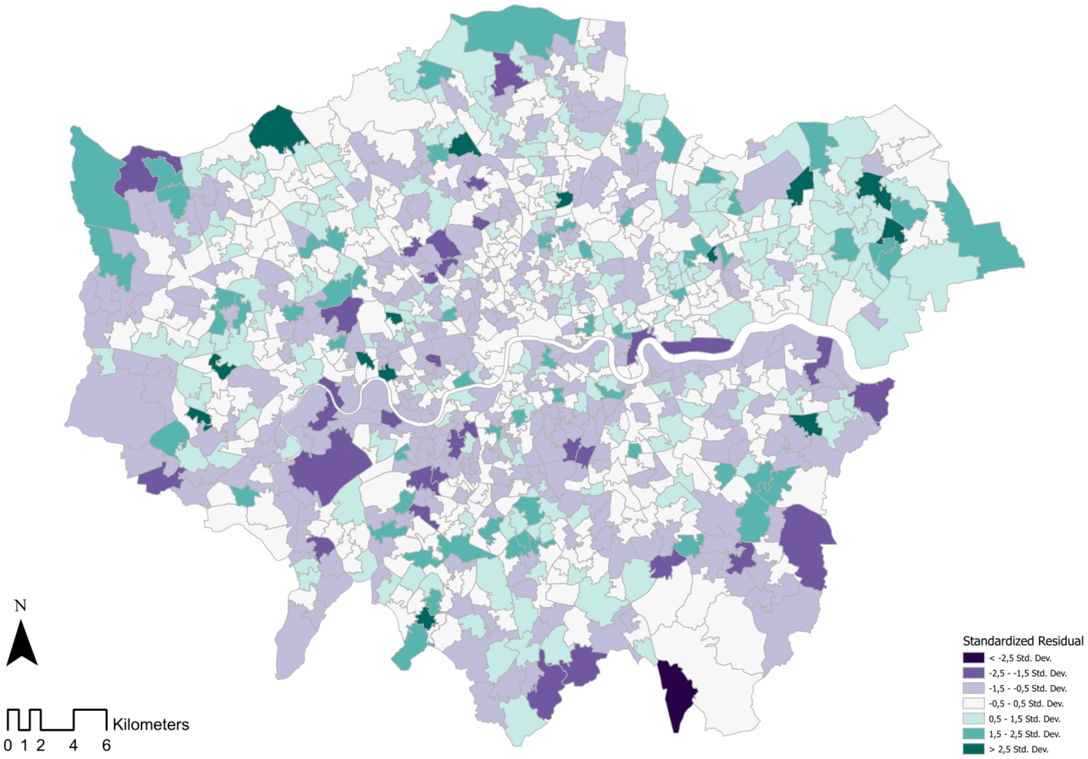
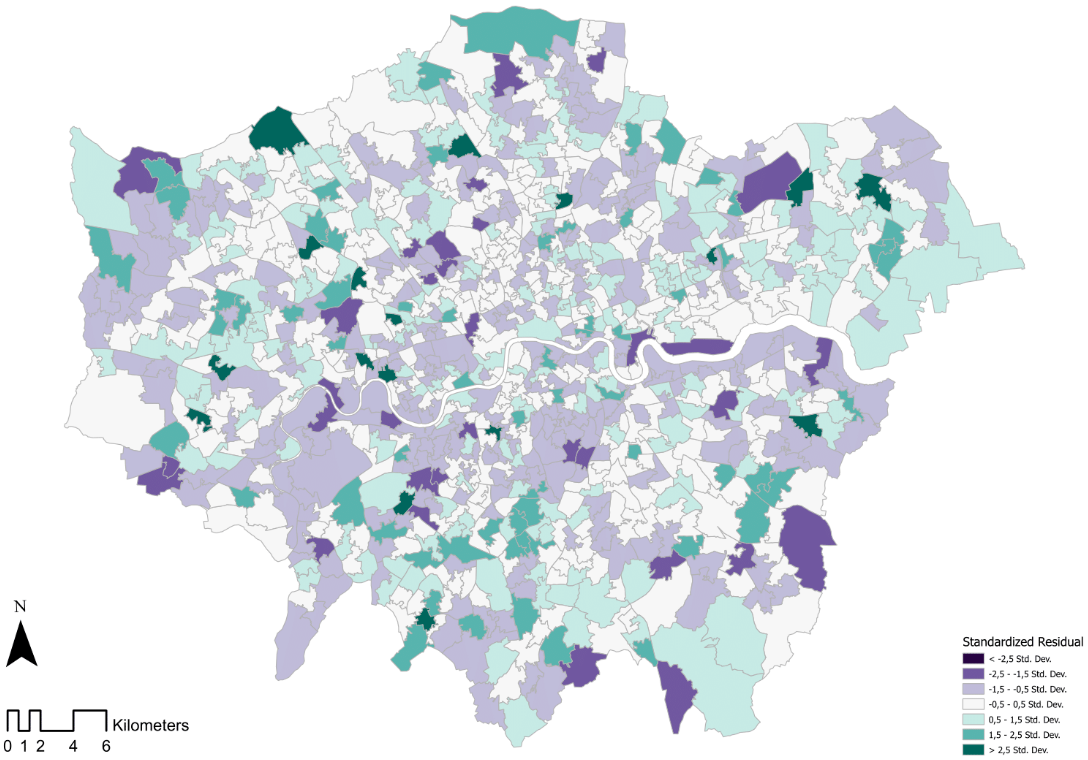


Figure 178 - Spatial indicators – Deaths, Std. Residuals by MSOA (GWR), London



5.3.2 New York City

In NYC, the correlation matrix below (Tab. 13) displays results that overlap and differ, to some extent, from the ones found for London. Also in this case, in general, it is possible to observe how there are not exceedingly strong correlations among the different indicators, with only a few having a moderately strong correlation (besides the distance to pharmacies and green areas, R-value 0.77). As it occurred in London, the indicators of proximity display the highest positive correlations, with values ranging between 0.41 and 0.54, thus indicating a moderately strong correlation. Turning instead to the correlation between the spread and mortality of COVID-19 and the indicators, we observe no exceedingly strong correlations, with a range of values oscillating between -0.59 and 0.55. As a general comment, the results obtained through these correlations are very similar to those obtained for London, showing similar performances of the different indicators concerning the pandemic.

Table 13 - Correlation matrix SVI and COVID-19 in NYC

	Variables	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
1	GREEN_INH	**1**											
2	CYCLE_DEN	-0,089	**1**										
3	INT_DEN	**-0,18***	**0,48***	**1**									
4	HOSP_DEN	-0,04	**0,23***	0,13*	**1**								
5	SPRMKT_DEN	0,09	**0,45***	**0,20***	-0,04	**1**							
6	PHARMA_DEN	0,06	**0,42***	**0,43***	0,01	**0,46***	**1**						
7	HOSP_DIST	0,14	**-0,54***	**-0,30***	**-0,29***	**-0,20***	**-0,26***	**1**					
8	PHARMA_DIST	0,10	**-0,50***	**-0,31***	-0,05	**-0,33***	**-0,41***	**0,55***	**1**				
9	GREEN_DIST	**0,29***	**-0,59***	**-0,52***	-0,03	**-0,25***	**-0,29***	**0,52***	**0,47***	**1**			
10	SPRMKT_DIST	0,10	**-0,54***	**-0,32***	-0,04	**-0,45***	**-0,40***	**0,60***	**0,77***	**0,49***	**1**		
11	TOTAL CASES	0,04	**-0,59***	**-0,26***	-0,10	**-0,40***	**-0,36***	**0,41***	**0,55***	**0,42***	**0,53***	**1**	
12	TOTAL DEATHS	0,05	**-0,41***	**-0,25***	0,04	**-0,41***	**-0,39***	**0,18***	**0,40***	**0,29***	**0,30***	**0,61***	**1**

** Statistically significant p-value (p < 0,05).*

From Fig. 179 to 188, we observe how the indicators map the city by MODZCTA. From the regression on the cases (Tab. 14), it is possible to notice how the GWR performs better in terms of R^2 and Moran's I. Some indicators have higher p-values, due probably to variance in some cases and to lack of data in some units, as discussed for London. Regarding the coefficients, it is possible to notice how some variables have significant figures, such as bicycle paths density and distance to pharmacies (-0,37 and 0,25 respectively). The other indicators have coefficients ranging from -0,10 to 0,10. Overall, the model shows a significant predictive power (0,42 and 0,47, for OLS and GWR, respectively), showing higher values compared to the sole use of the SVI. Nevertheless, as it occurred in the previous model, it is not sufficient. It seems to be a partial view, an incomplete vision. Also the VIFs are below 7.5, thus indicating that there is no redundancy in the variables used. Although the GWR model helps decrease spatial autocorrelation, there is still some effect on the standardised residuals, as proved by Moran's Index I, again suggesting that a part of the story is missing.

Table 14 - Regressions results for spatial indicators and COVID-19 cases in NYC

Variables	OLS R^2	OLS I	OLS p-value	OLS β	OLS VIF	OLS AICc	GWR R^2	GWR I	GWR AICc
GREEN_DEN	0,42	0,44*	0,8430	-0,01221	1,16	3195,72	0,47	0,38*	3179,79
CYCLE_DEN			0,0000	-0,37457	2,33				
INT_DEN			0,1968	0,095718	1,66				
HOSP_DEN			0,7960	-0,01644	1,23				
SPRMKT_DEN			0,1776	-0,09859	1,62				
PHARMA_DEN			0,5275	-0,04629	1,63				
HOSP_DIST			0,8525	-0,01552	2,12				
PHARMA_DIST			0,0065	0,258639	2,69				
GREEN_DIST			0,4191	0,068488	2,18				
SPRMKT_DIST			0,4957	0,07013	3,22				

** Statistically significant p-value (p < 0,05)*

Table 15 - Regressions results for spatial indicators and COVID-19 deaths in NYC

Variables	OLS R2	OLS I	OLS p-value	OLS β	OLS VIF	OLS AICc	GWR R2	GWR I	GWR AICc
GREEN_DEN	0,29	0,15*	0,3678	0,061807	1,16	2221,47	0,29	0,14*	2221,37
CYCLE_DEN			0,0195	-0,22898	2,33				
INT_DEN			0,9418	0,005997	1,66				
HOSP_DEN			0,2968	0,073868	1,23				
SPRMKT_DEN			0,0028	-0,24551	1,62				
PHARMA_DEN			0,0597	-0,15402	1,63				
HOSP_DIST			0,3425	-0,08818	2,12				
PHARMA_DIST			0,0006	0,364707	2,69				
GREEN_DIST			0,7483	0,030187	2,18				
SPRMKT_DIST			0,0334	-0,24475	3,22				

** Statistically significant p-value (p < 0,05)*

Tab. 15, instead, show the results of the regression encompassing the spatial indicators and the mortality of the pandemic. Also in this case, we find higher p-values. The overall performance of the model is lower compared to the one predicting the spread. In this case, the GWR does not help improve the model significantly, while it had a more significant impact on the previous model. Nevertheless, some variables are showing a relevant coefficient, namely, the distance to pharmacies (0,36), distance to supermarkets (-0,24), bicycle paths density (-0,23), supermarkets density (-0,25) and pharmacies density (-0,15). The role of supermarkets could be dual, on the one hand, the distance to these facilities can foster the development of unhealthy eating habits; on the other hand, being supermarkets possibly crowded centres, they might have had a role in the spread of the pandemic, although this is only one of many hypotheses.

Figure 179 - Green areas per inhabitant (m^2/inh) by MODZCTA, NYC

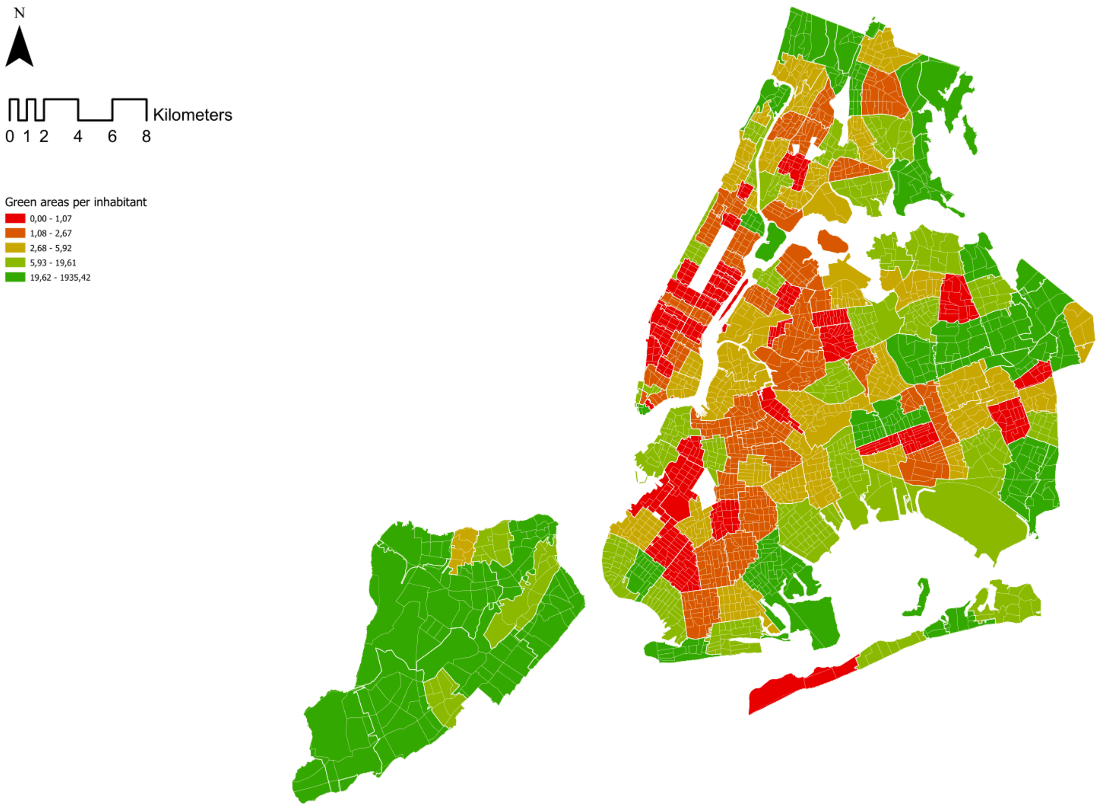


Figure 180 - Bicycle paths density (km/km^2) by MODZCTA, NYC

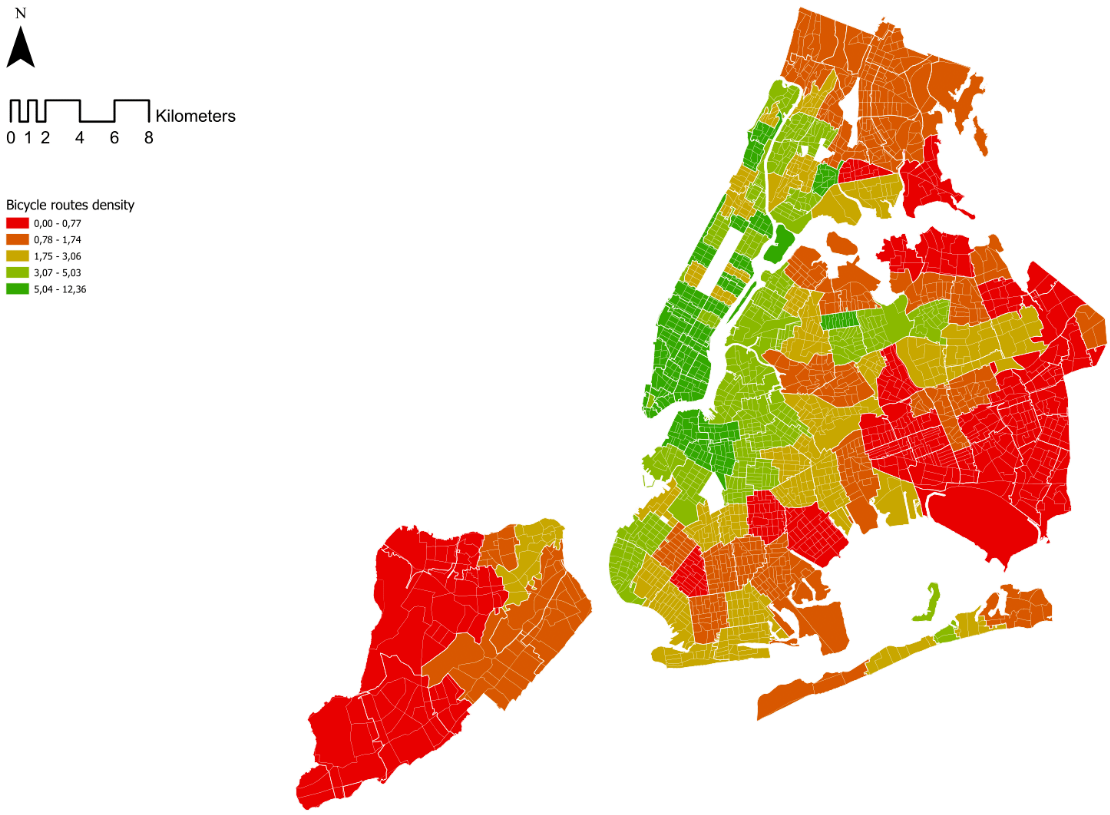


Figure 181 - Street's intersection density (int/ km^2) by MODZCTA, NYC

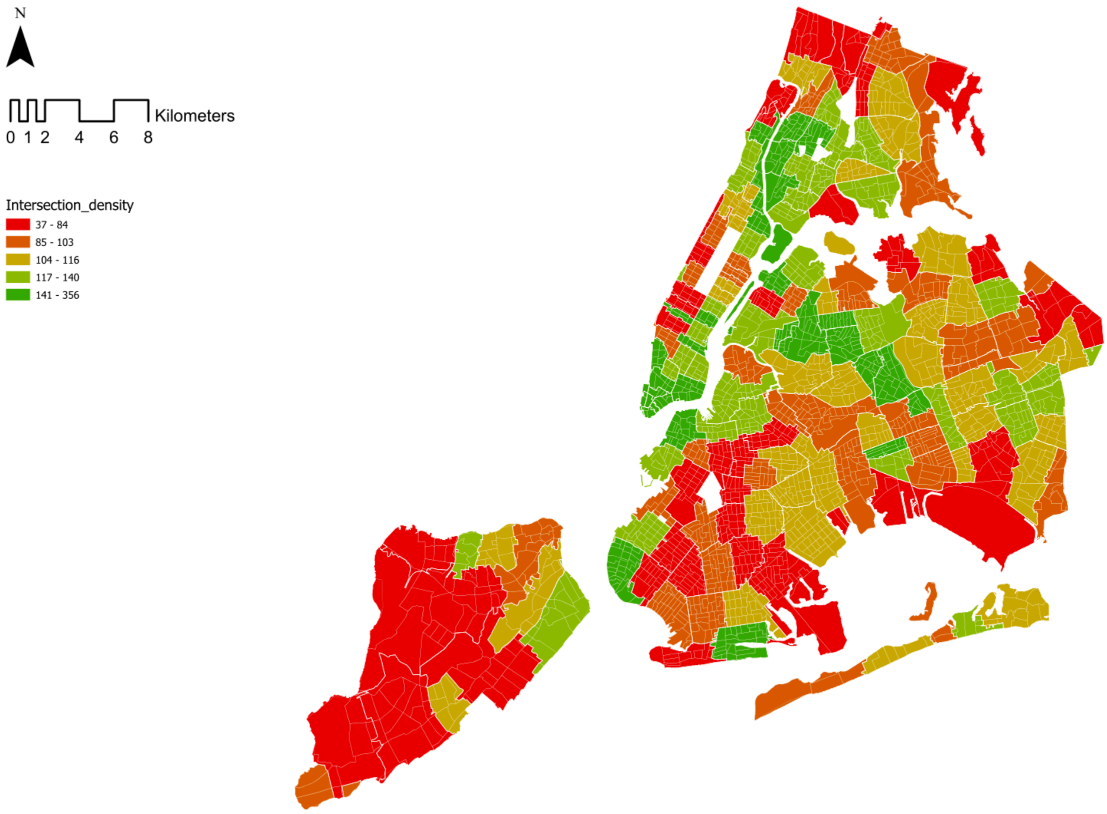


Figure 182 - Hospital density (per 100.000 inhabitants) by MODZCTA, NYC

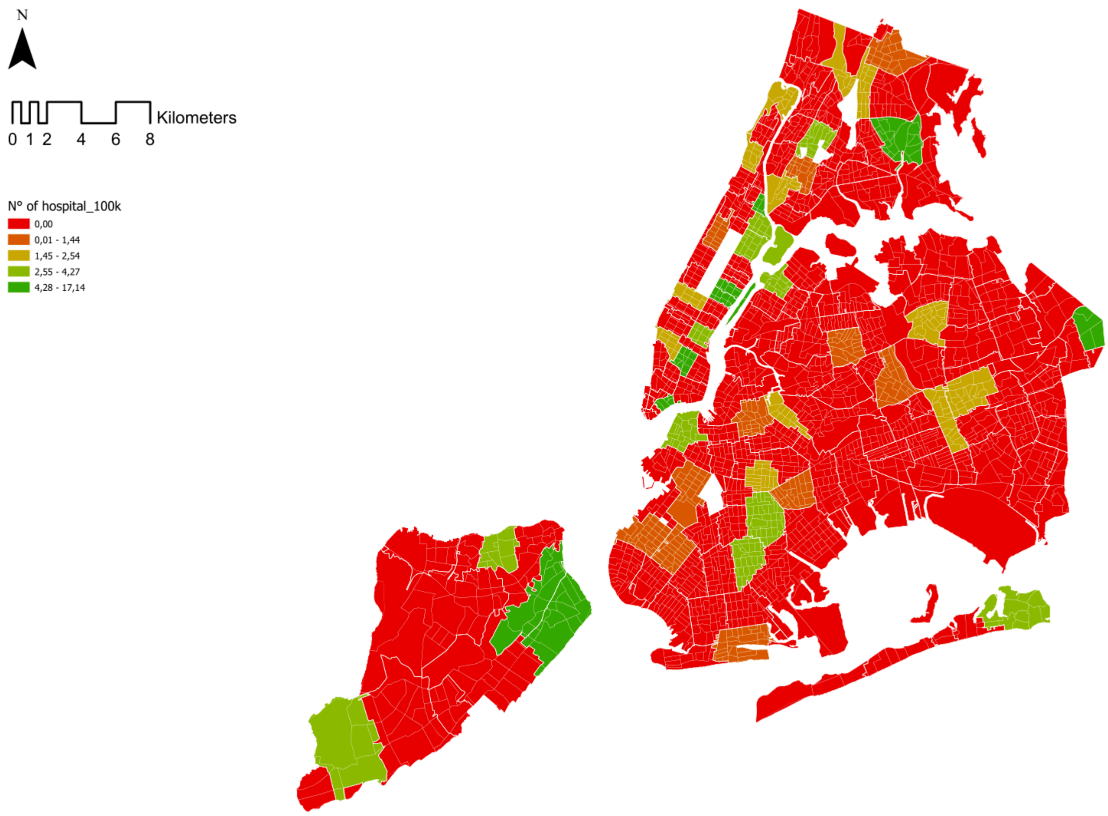


Figure 183 - Supermarket density (per 100.000 inhabitants) by MODZCTA, NYC

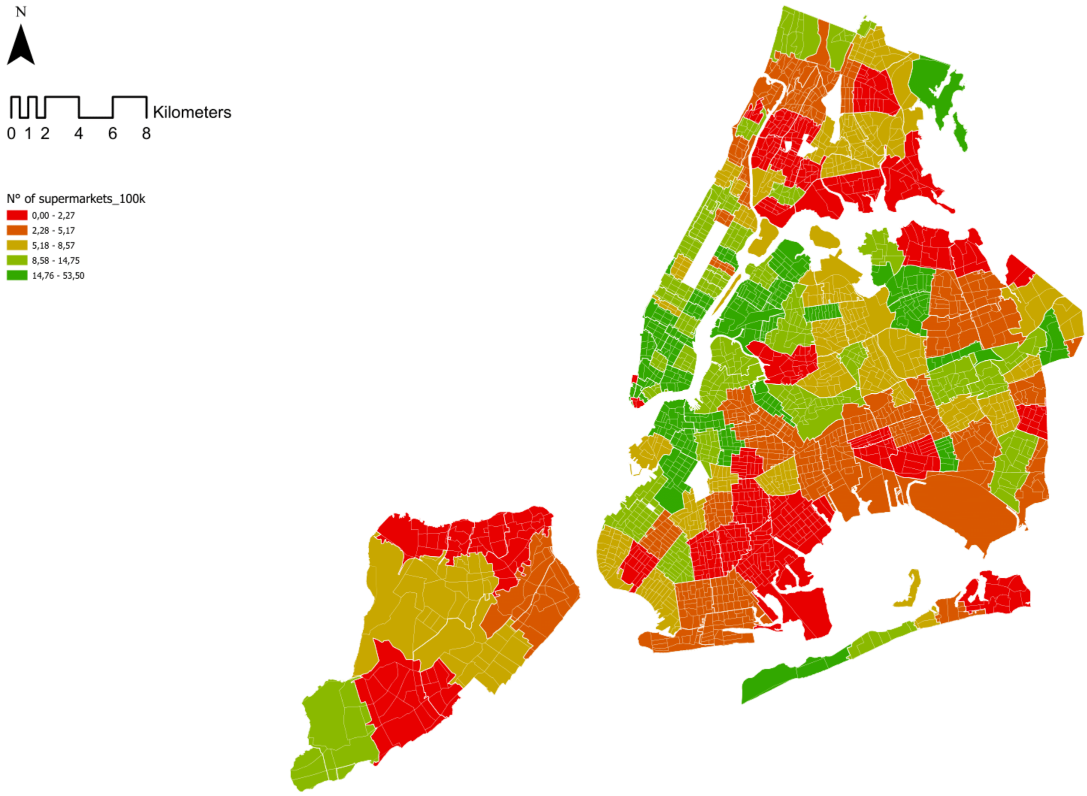


Figure 184 - Pharmacy density (per 100.000 inhabitants) by MODCTA, NYC

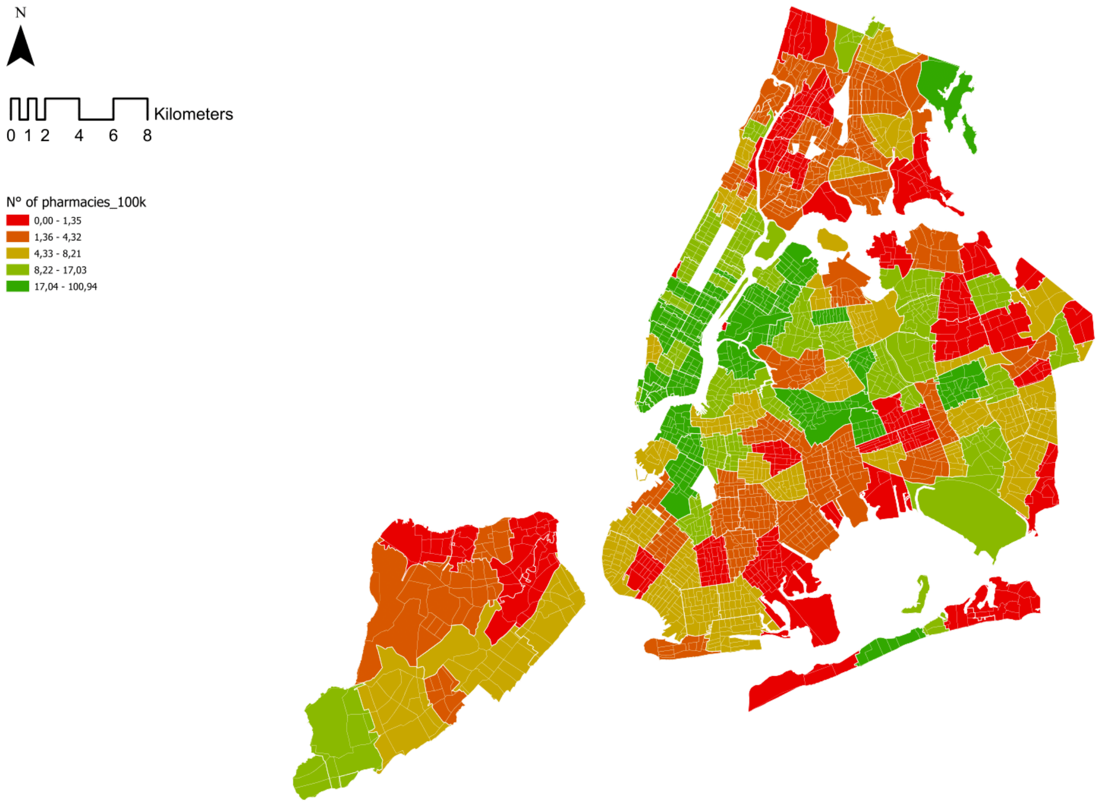


Figure 185 - Mean distance to the closest hospital (m) by MODZCTA, NYC

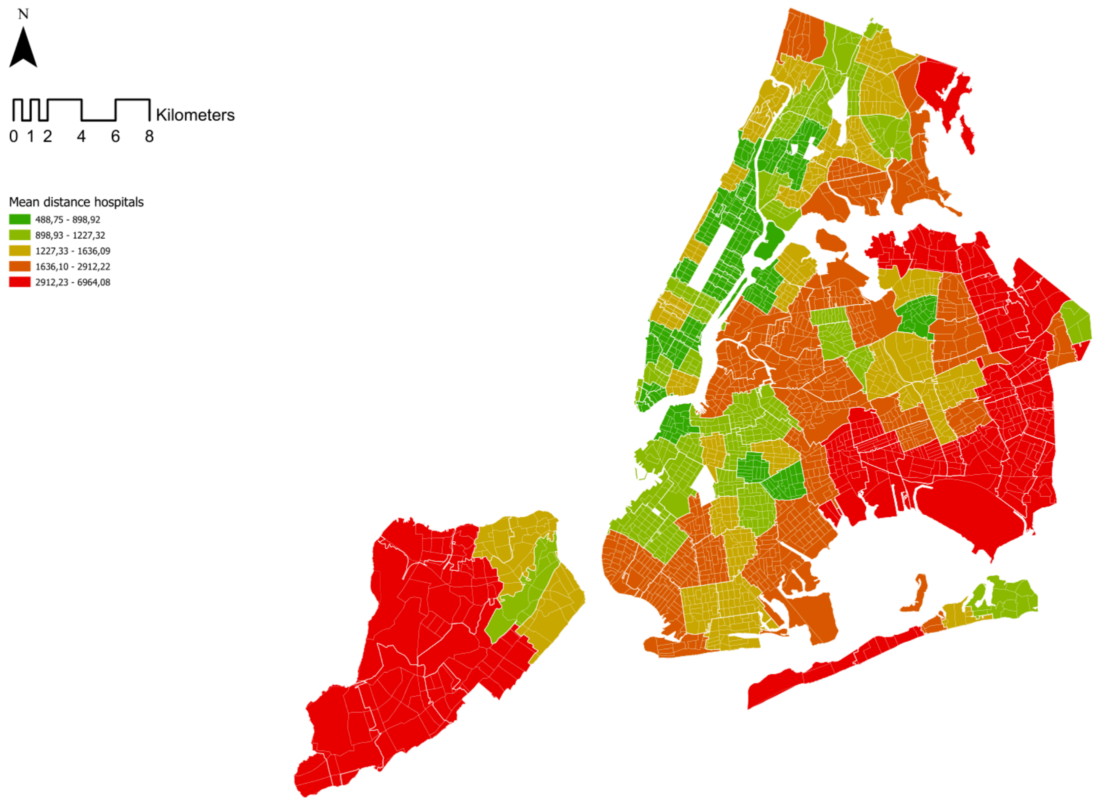


Figure 186 - Mean distance to the closest pharmacy (m) by MODZCTA, NYC

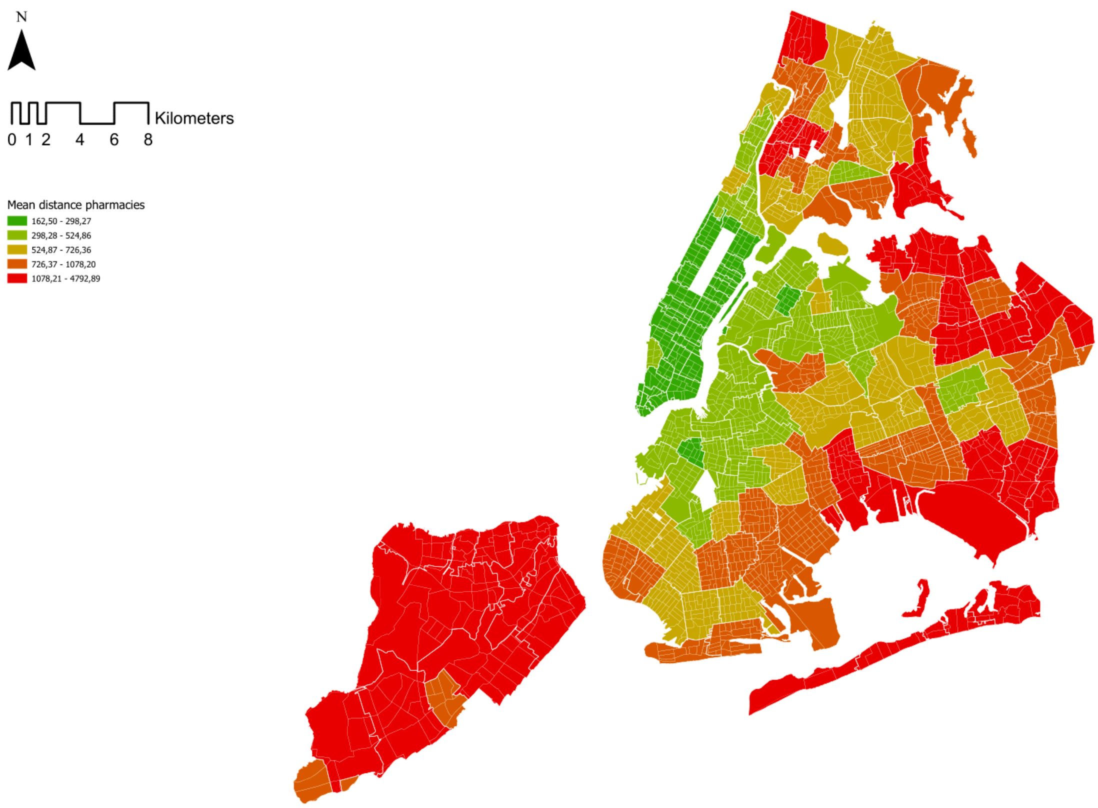


Figure 187 - Mean distance to the closest publicly accessible green area (m), by MODZCTA, NYC

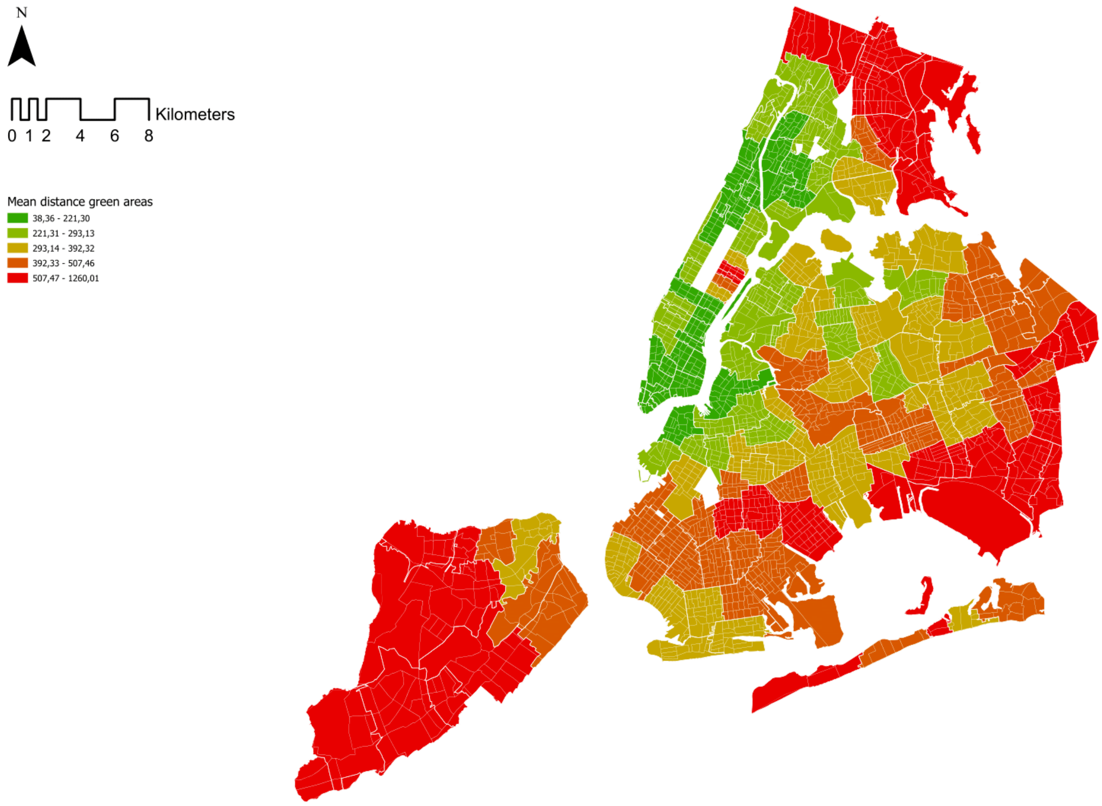


Figure 188 - Mean distance to the closest supermarket (m) by MODZCTA, NYC

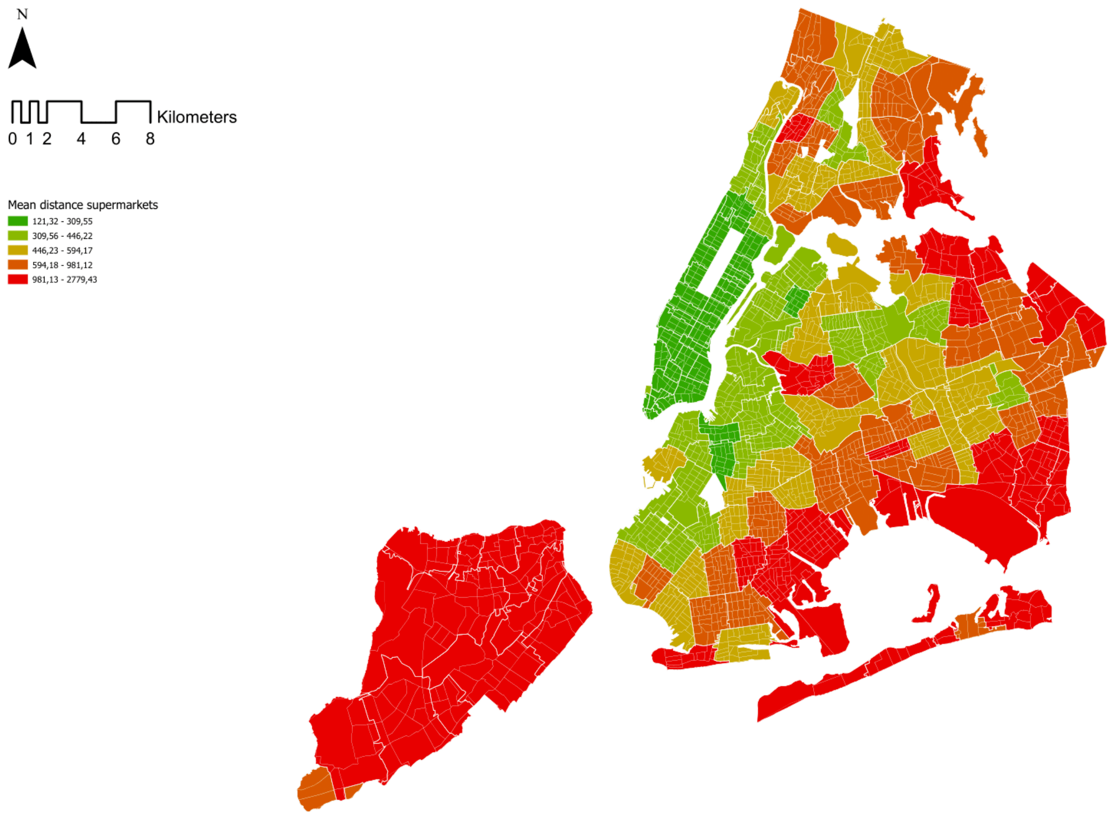


Figure 189 - Spatial indicators – Cases, Std. Residuals by MODZCTA (OLS), NYC

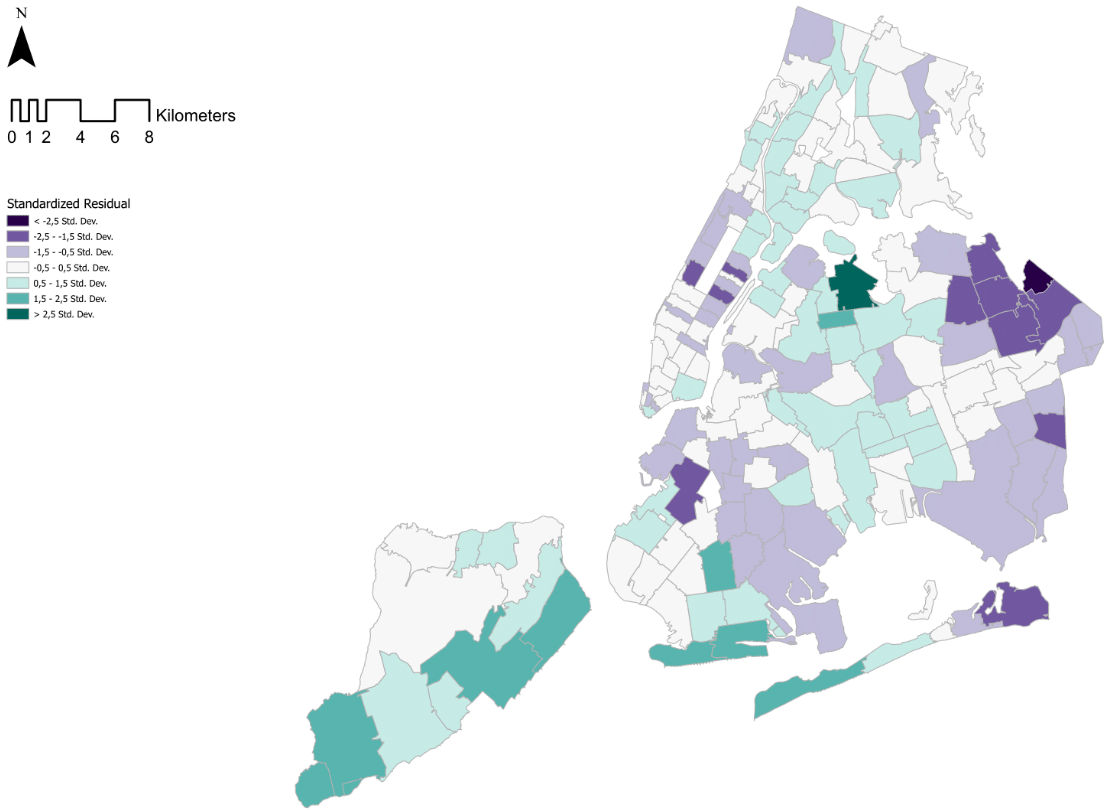


Figure 190 - Spatial indicators – Cases, Std. Residuals by MODZCTA (GWR), NYC

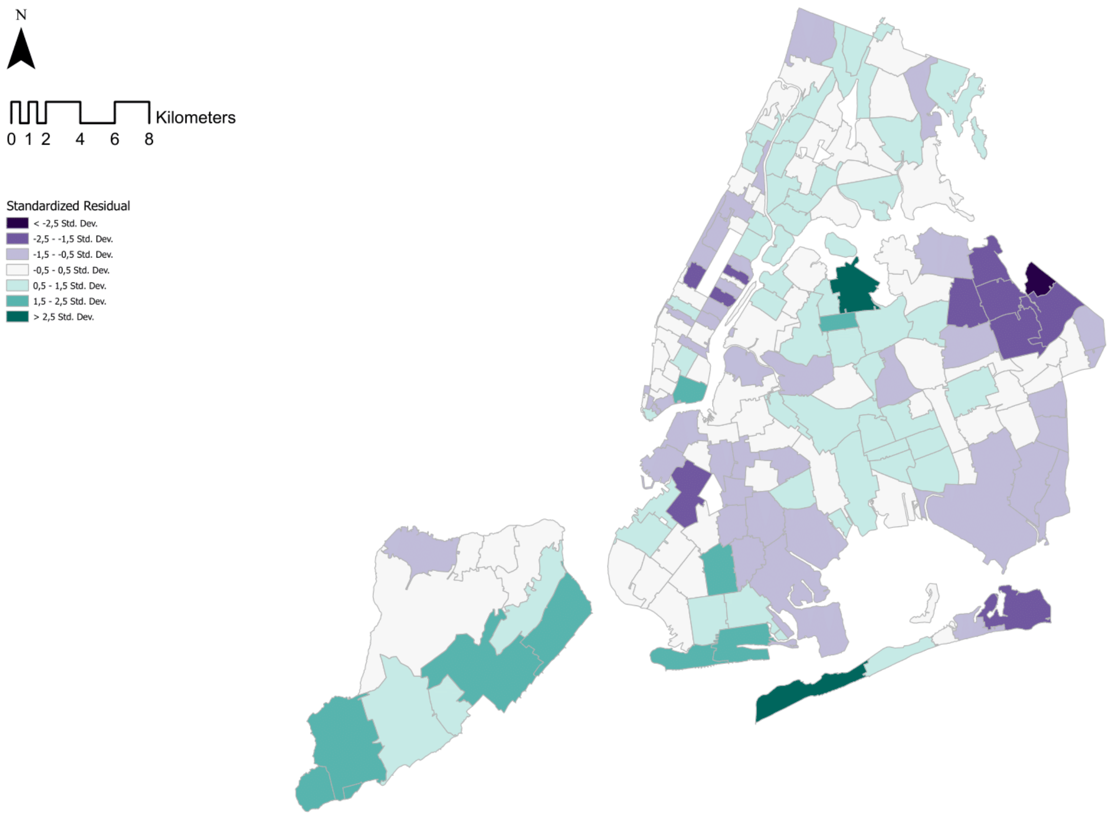


Figure 191 - Spatial indicators – Deaths, Std. Residuals by MODZCTA (OLS), NYC

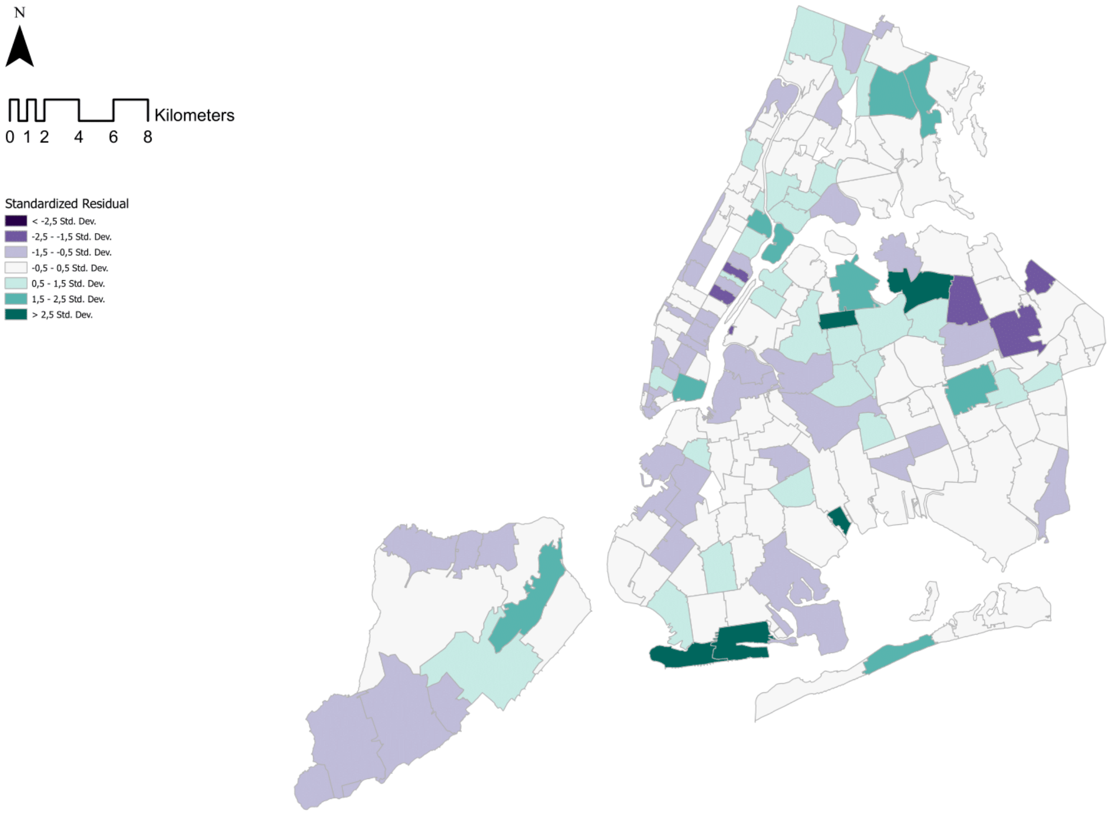
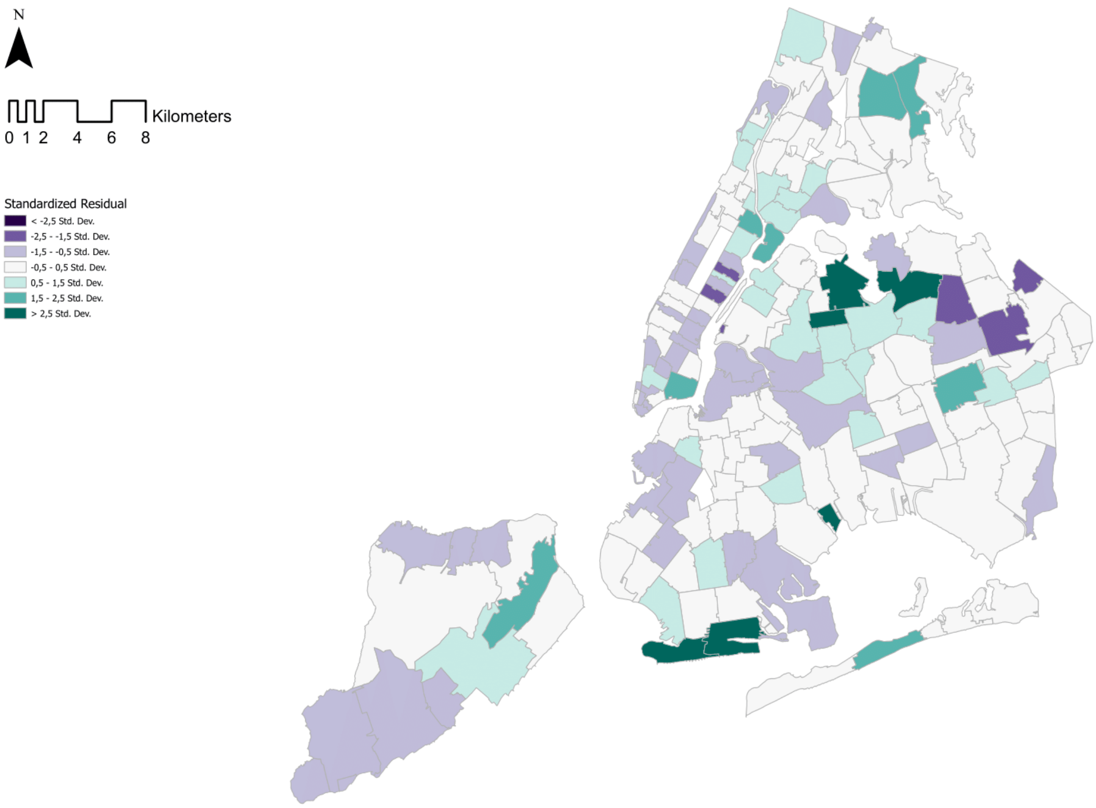


Figure 192 - Spatial indicators – Deaths, Std. Residuals by MODZCTA (GWR), NYC



5.3.3 Rome

Tab. 16 below displays the results of the correlation matrix for Rome. In this case, differently from what was observed for London and NYC, there are strong correlations among several indicators. Specifically, the indicators of proximity display the highest positive correlations, with values ranging between 0.72 and 0.91. This connection was also found in the previous case studies, although the correlation was only moderately strong, whereas the relationship is exacerbated in this case. Turning instead to the correlation between the spread and mortality of COVID-19 and the indicators, similarly to London, we observe no exceedingly strong correlations, except for the density of green areas and hospitals (values of 0.59 and 0.68, respectively). As a general comment, the results obtained through these correlations do not significantly differ from what was found in London or NYC. The main divergence is the strong positive correlations binding the indicators of proximity. Even in the two former case studies, the R-values showed a moderately strong correlation. For Rome, however, this correlation is even stronger.

Table 16 - Correlation matrix spatial indicators and COVID-19 in Rome

	Variables	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
1	GREEN_DEN	**1**											
2	CYCLE_DEN	0,03	**1**										
3	INT_DEN	-0,03	**0,35***	**1**									
4	HOSP_DEN	**0,47***	-0,02	**0,30***	**1**								
5	SPRMKT_DEN	-0,11	**0,19***	**0,49***	-0,02	**1**							
6	PHARMA_DEN	-0,08	**0,20***	**0,59***	0,01	**0,77***	**1**						
7	HOSP_DIST	-0,08	**-0,30***	**-0,52***	-0,16	**-0,33***	**-0,36***	**1**					
8	PHARMA_DIST	-0,06	**-0,30***	**-0,48***	-0,08	**-0,38***	**-0,43***	**0,72***	**1**				
9	GREEN_DIST	-0,08	**-0,25***	**-0,39***	-0,07	**-0,23***	**-0,27***	**0,74***	**0,85***	**1**			
10	SPRMKT_DIST	-0,07	**-0,24***	**-0,39***	-0,06	**-0,36***	**-0,34***	**0,72***	**0,92***	**0,91***	**1**		
11	TOTAL CASES	**0,49***	-0,08	**-0,18***	**0,56***	**-0,27***	**-0,27***	0,06	0,02	-0,10	-0,04	**1**	
12	TOTAL DEATHS	**0,59***	0,10	0,07	**0,68***	-0,09	-0,05	-0,10	-0,07	-0,08	-0,05	**0,70***	**1**

** Statistically significant p-value (p < 0,05).*

From the regression on the cases (Tab. 17), it is possible to notice both models perform very poorly, as indicated by the value of the R^2 (negative sign). As expected, high VIF values are obtained for the indicators of proximity to pharmacies, green areas, and supermarkets (9.16, 7.60 and 11.81, respectively). This is indicative of redundancy among these variables. As shown by Moran's Indices (-0,01 for both), spatial autocorrelation does not affect the models. Despite the poor performance of the models, however, there are some variables with significant coefficients, such as distance to supermarkets (-0,20), to green areas (0,19), and density of bicycle paths (0,17). Hence, even though the model does not perform well, there are variables that might be significantly linked to the pandemic. The other variables show coefficients ranging from -0,12 to 0,06. The higher p-values obtained, in the author's view, are symptomatic of greater variance across the different ZUBs, thus suggesting unevenness in the distribution of values, which, however, are intrinsic in the phenomenon of inequalities.

Table 17 - Regressions results for spatial indicators and COVID-19 cases in Rome

Variables	OLS R^2	OLS I	OLS p-value	OLS β	OLS VIF	OLS AICc	GWR R^2	GWR I	GWR AICc
GREEN_DEN			0,9146	-0,01011	1,34				
CYCLE_DEN			0,0912	0,167196	1,47				
INT_DEN			0,38	-0,09138	1,63				
HOSP_DEN			0,5027	0,057733	1,12				
SPRMKT_DEN	-0,01	-0,01	0,3882	-0,1222	3,02	3462	-0,02	-0,01	3462,33
PHARMA_DEN			0,8788	-0,02202	3,16				
HOSP_DIST			0,8215	-0,03239	3,12				
PHARMA_DIST			0,9414	-0,01806	9,16				
GREEN_DIST			0,3917	0,192246	7,60				
SPRMKT_DIST			0,4723	-0,20095	11,81				

Table 18 - Regressions results for spatial indicators and COVID-19 deaths in Rome

Variables	OLS R^2	OLS I	OLS p-value	OLS β	OLS VIF	OLS AICc	GWR R^2	GWR I	GWR AICc
GREEN_DEN			0,0000	0,46099	1,34				
CYCLE_DEN			0,9828	0,001479	1,47				
INT_DEN			0,0372	0,152537	1,63				
HOSP_DEN			0,0000	0,480288	1,12				
SPRMKT_DEN	0,50	-0,01	0,6914	-0,03926	3,02	1932,23	0,50	-0,02	1932,20
PHARMA_DEN			0,5067	-0,0671	3,16				
HOSP_DIST			0,5960	0,053253	3,12				
PHARMA_DIST			0,6371	-0,08116	9,16				
GREEN_DIST			0,3866	-0,13587	7,60				
SPRMKT_DIST			0,4759	0,139343	11,81				

** Statistically significant p-value (p < 0,05)*

Tab. 18, instead, show the results of the regression encompassing the spatial indicators and the mortality of the pandemic, with different insights. Also in this case we find higher p-values. The model's overall performance is significantly higher than the one predicting the spread (0,50). The GWR does not help improve the model significantly, as occurred for the previous model. Some variables show a significant coefficient, namely, the density of green areas (0,46) and hospitals (0,48). Intersection density, distance to supermarkets and distance to green spaces oscillate between -0,14 and 0,15. Once again, we find that the last three variables of the tables are significantly correlated, thus raising the issue of collinearity and instability of the model, as indicated by the Variance Inflation Factor. Also for this model, the results should not be affected by spatial autocorrelation, as shown by Moran's Indices for both the OLS and GWR. In the following pages, Fig. 193 to 202 show how the indicators map the city. Fig. 203 to 206, instead, map the residuals.

Figure 193 - Green areas per inhabitant (m^2/inh) by ZUB, Rome

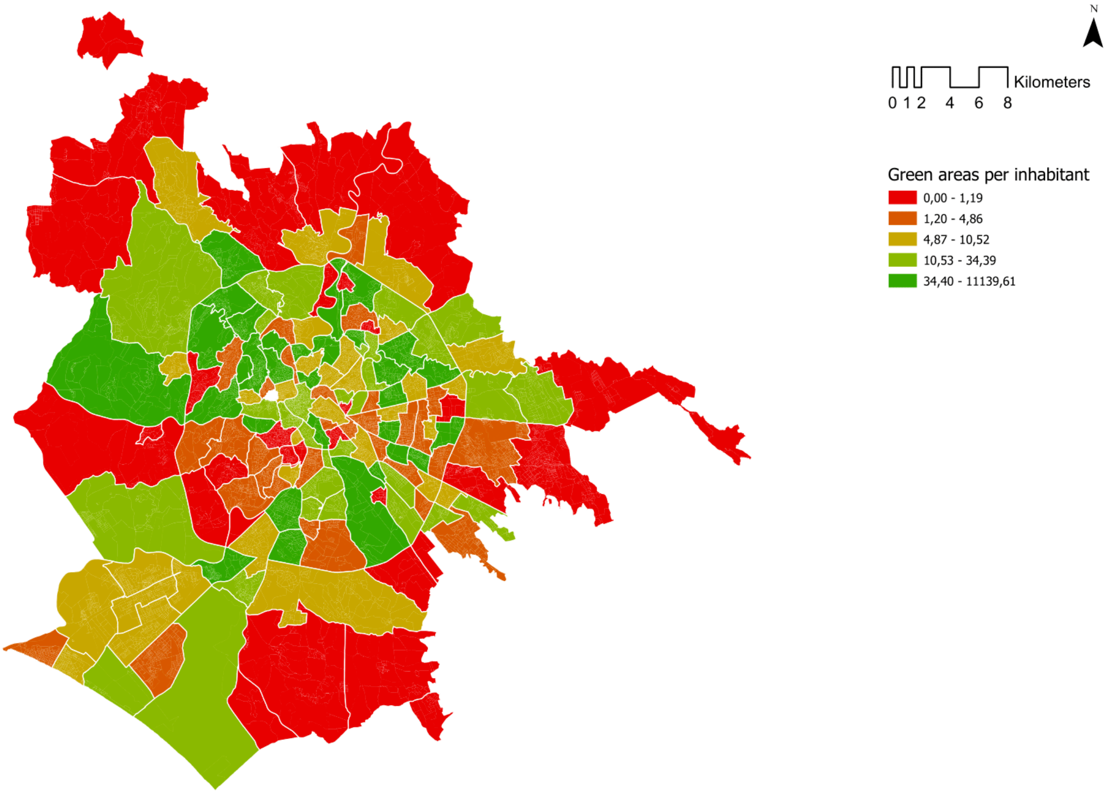


Figure 194 - Bicycle paths density (km/km^2) by ZUB, Rome

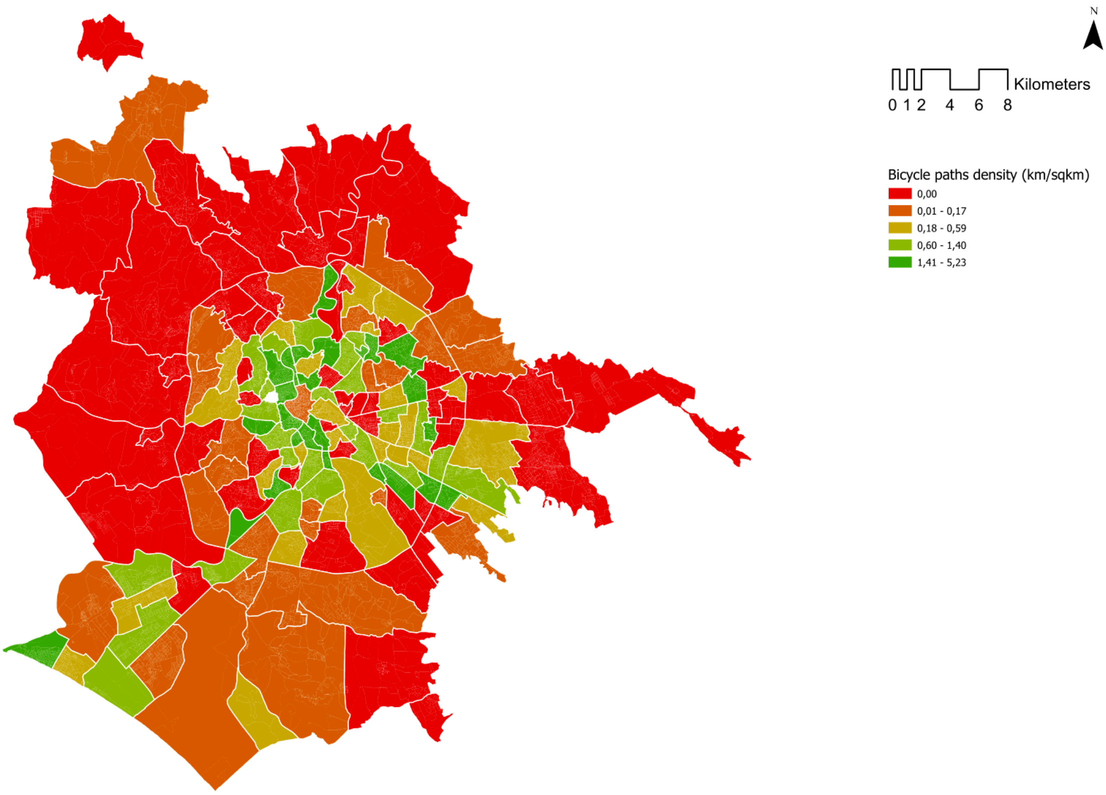


Figure 195 - Street's intersection density (int/ km^2) by ZUB, Rome

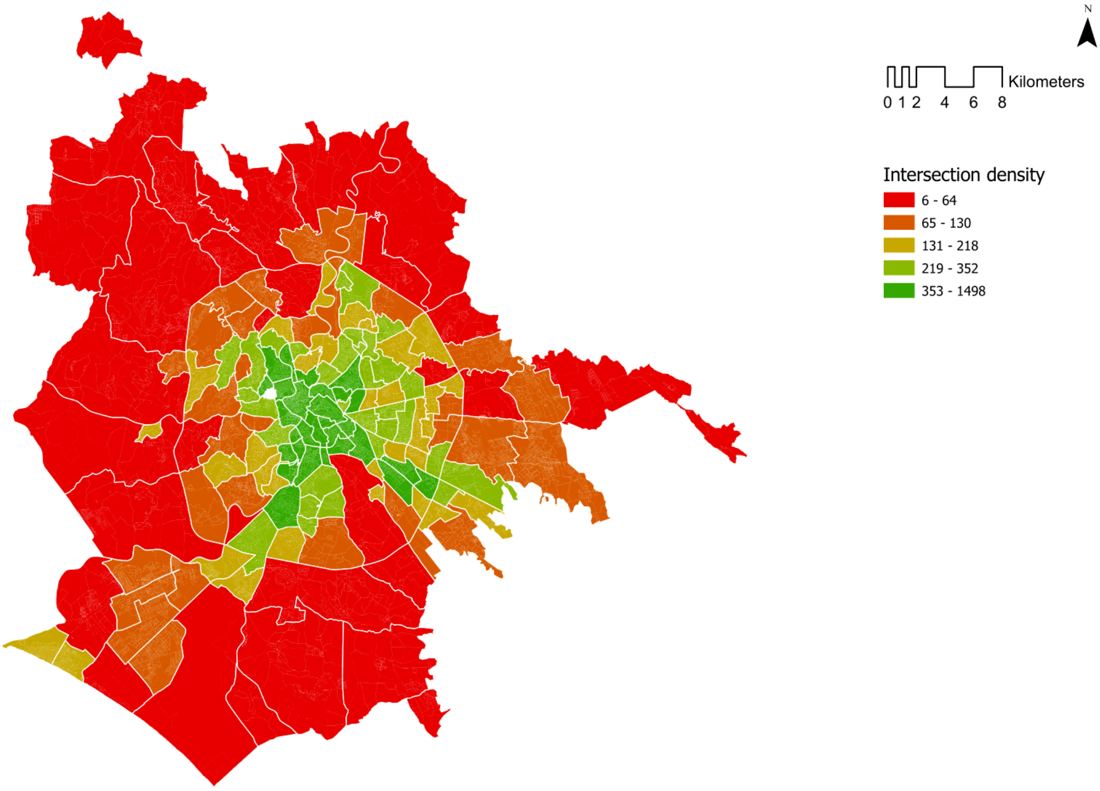


Figure 196 - Hospital density (per 100.000 inhabitants) by ZUB, Rome

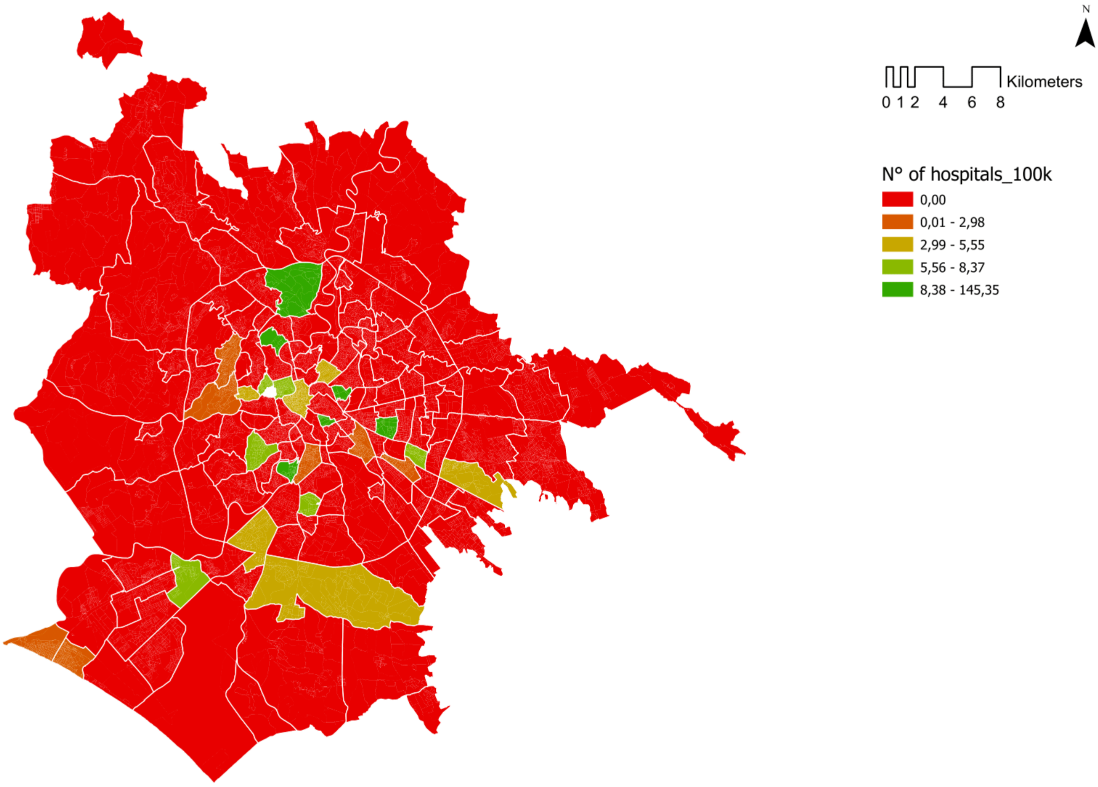


Figure 197 - Supermarket density (per 100.000 inhabitants) by ZUB, Rome

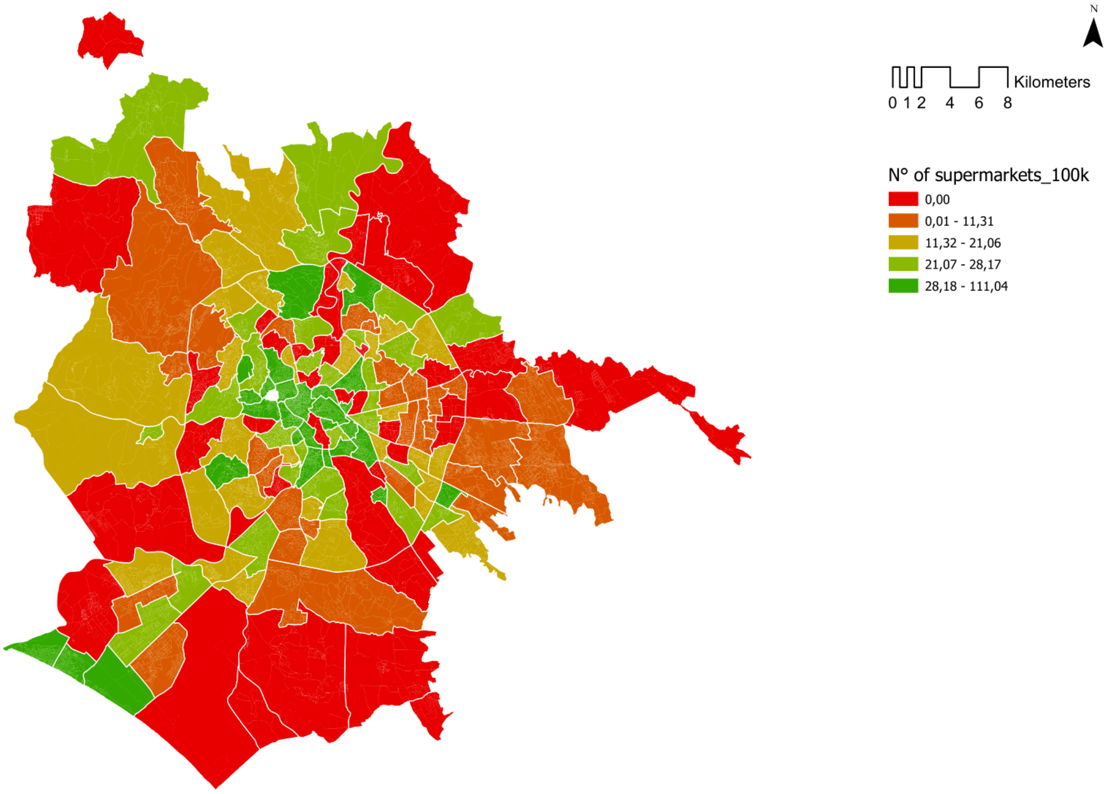


Figure 198 - Pharmacy density (per 100.000 inhabitants) by ZUB, Rome

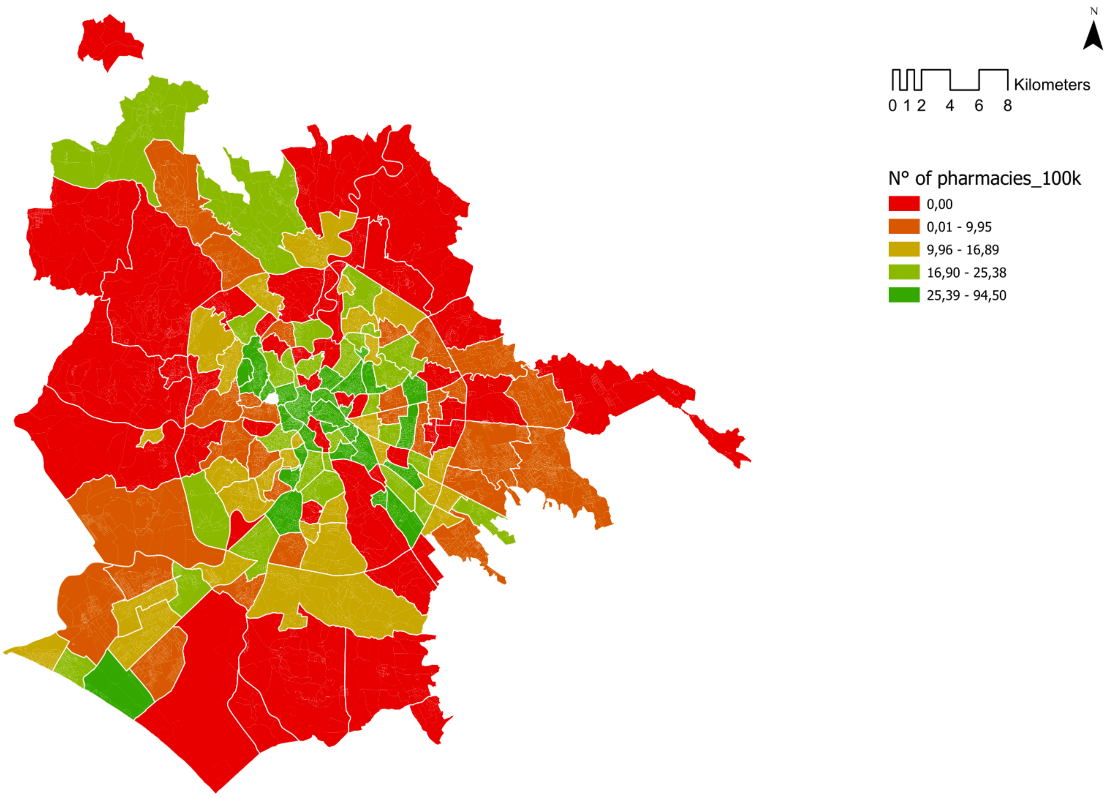


Figure 199 - Mean distance to the closest hospital (m) by ZUB, Rome

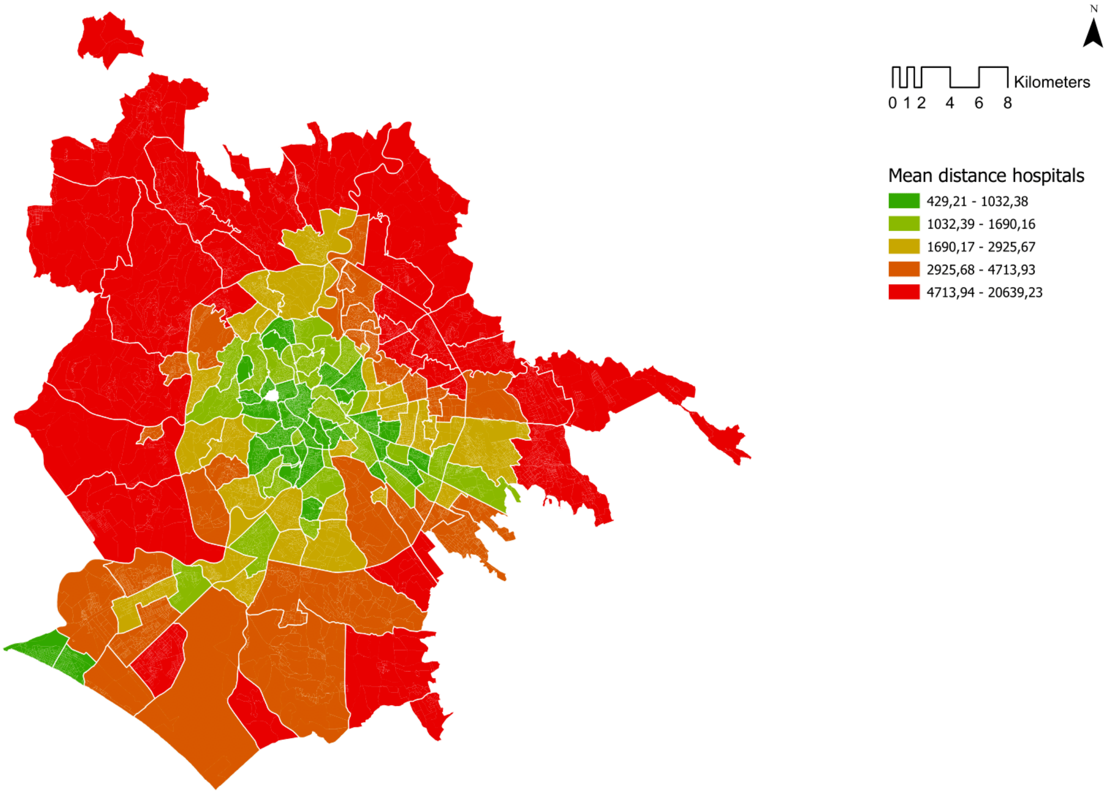


Figure 200 - Mean distance to the closest pharmacy (m) by ZUB, Rome

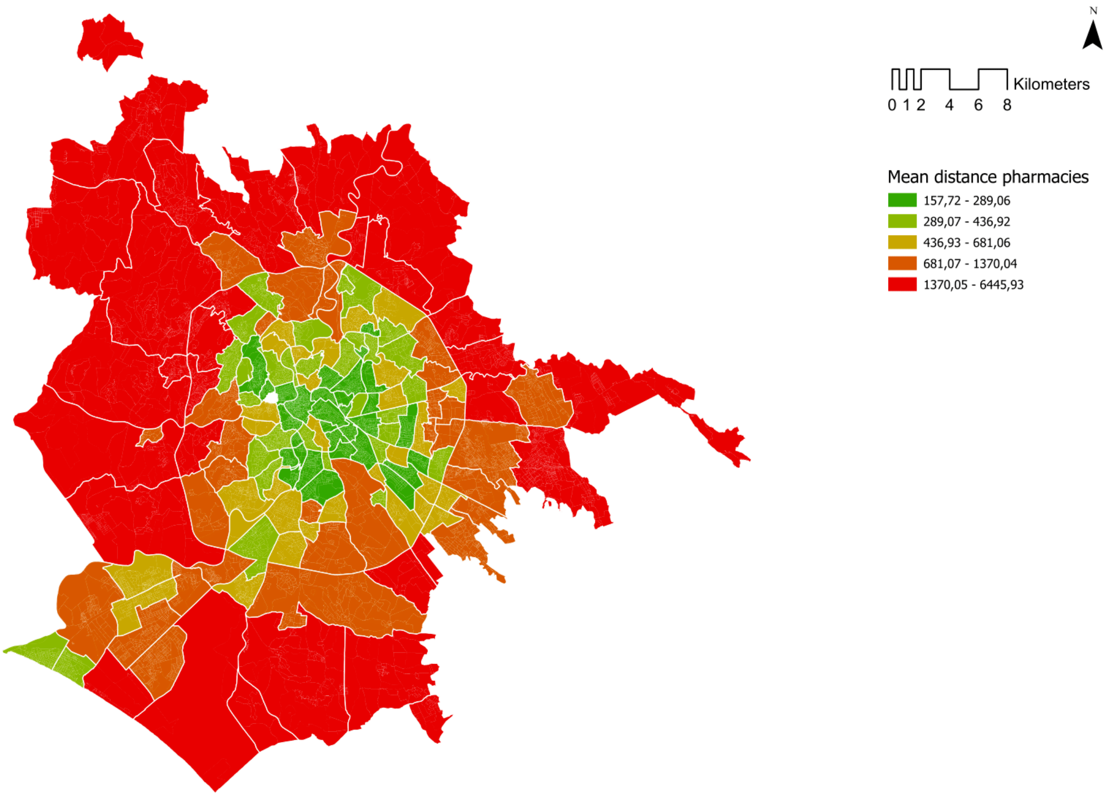


Figure 201 - Mean distance to the closest publicly accessible green area (m), by ZUB, Rome

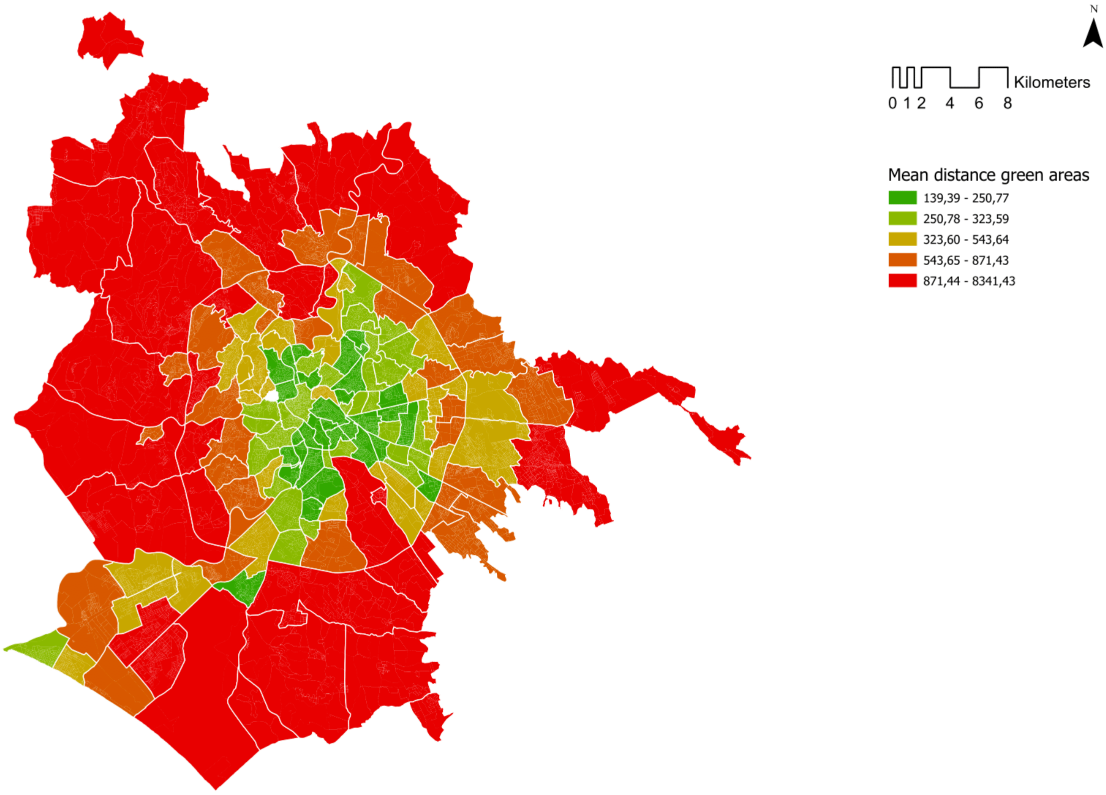


Figure 202 - Mean distance to the closest supermarket (m) by ZUB, Rome

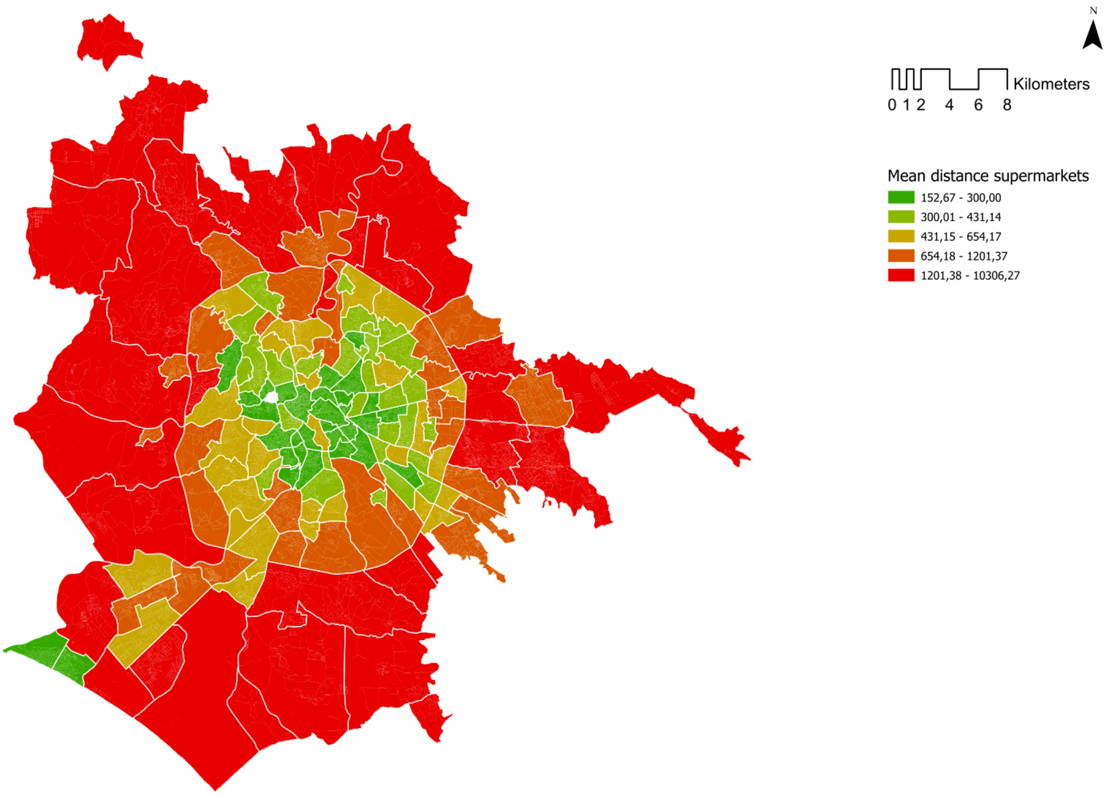


Figure 203 - Spatial indicators – Cases, Std. Residuals by ZUB (OLS), Rome

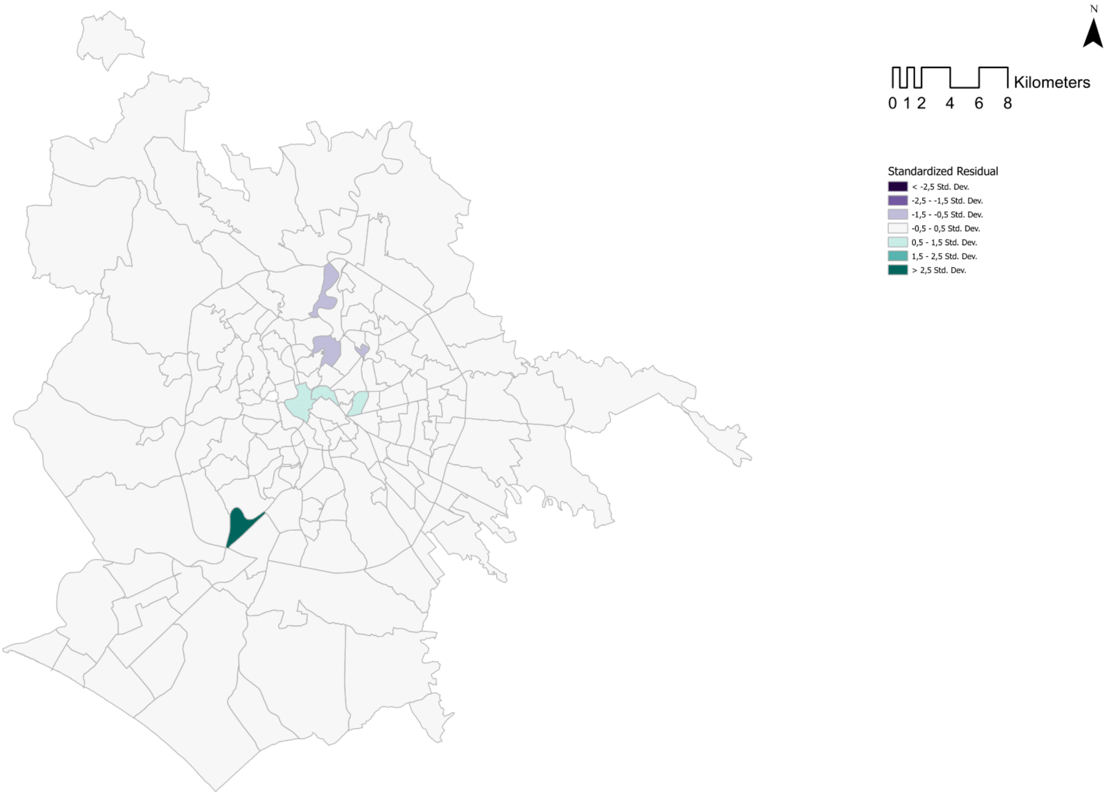


Figure 204 - Spatial indicators – Cases, Std. Residuals by ZUB (GWR), Rome

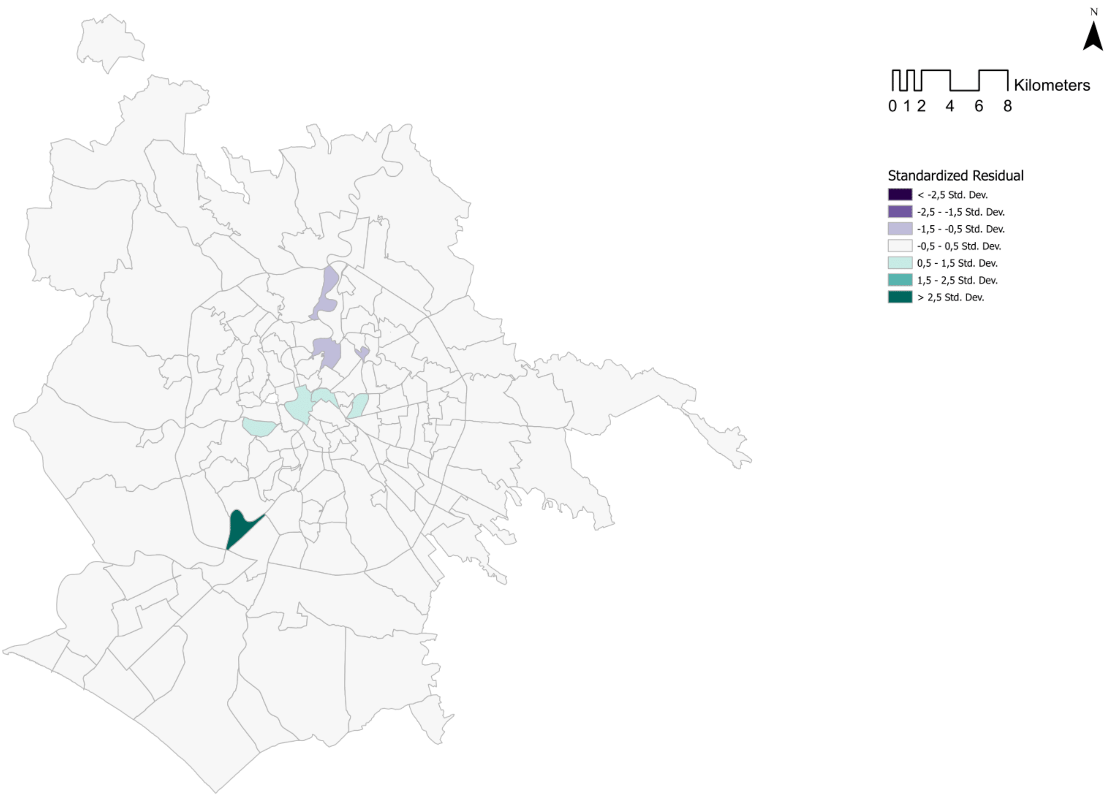


Figure 205 - Spatial indicators – Deaths, Std. Residuals by ZUB (OLS), Rome

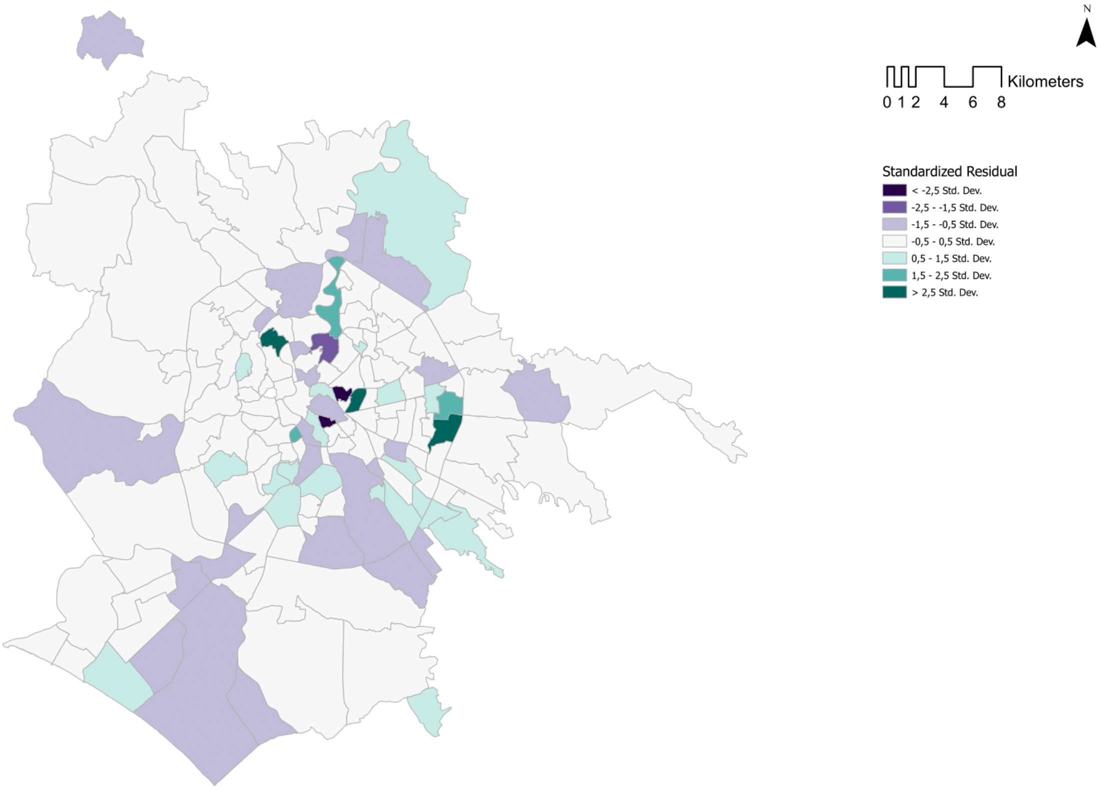
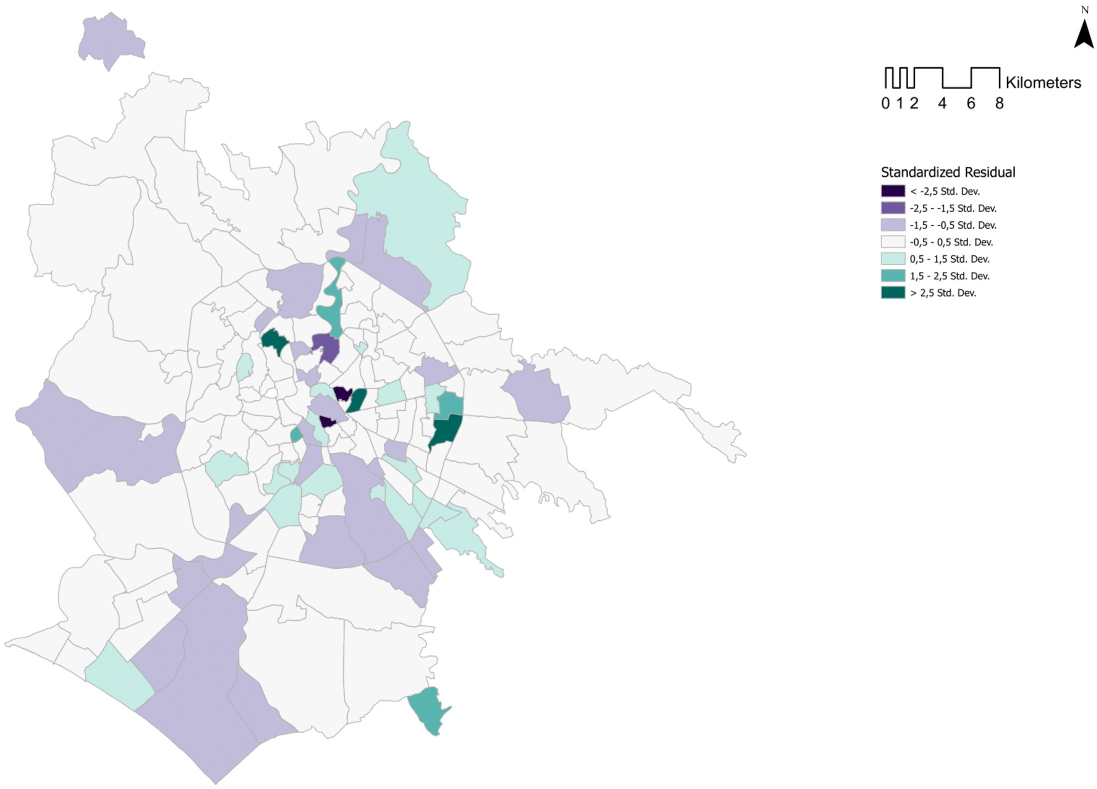


Figure 206 - Spatial indicators – Deaths, Std. Residuals by ZUB (GWR), Rome



5.3.4 Sao Paulo

Tab. 19 below displays the results of the correlation matrix for Sao Paulo. Differently from what was observed for London and NYC, and similar to what was obtained in Rome, there are strong correlations among several indicators. Specifically, the indicators of proximity display the highest positive correlations, with values ranging between 0.37 and 0.89. This connection was also found in the previous case studies, although the correlation was only moderately strong, whereas in this case the relationship is much stronger, as it happened for Rome. Turning instead to the correlation between the spread and mortality of COVID-19 and the indicators, similarly to London, NYC, and Rome, we observe no exceedingly strong correlations, with R values ranging between -0.28 and 0.27. As a general comment, the results obtained through these correlations do not significantly differ from what was seen in the other case studies. The main divergence is the strong positive correlations binding the indicators of proximity. Sao Paulo, from this perspective, is closer to Rome.

Table 19 - Correlation matrix spatial indicators and COVID-19 in Rome

	Variables	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
1	GREEN_DEN	**1**											
2	CYCLE_DEN	-0,19	**1**										
3	INT_DEN	**-0,40***	**0,23***	**1**									
4	HOSP_DEN	-0,10	**0,37***	-0,09	**1**								
5	SPRMKT_DEN	-0,12	**0,61***	0,14	**0,47***	**1**							
6	PHARMA_DEN	-0,10	**0,53***	0,13	**0,46***	**0,85***	**1**						
7	HOSP_DIST	**0,78***	**-0,44***	**-0,49***	**-0,41***	**-0,38***	**-0,36***	**1**					
8	PHARMA_DIST	**0,89***	**-0,38***	**-0,48***	**-0,24***	**-0,28***	**-0,27***	**0,89***	**1**				
9	GREEN_DIST	**0,60***	-0,02	**-0,28***	-0,02	-0,01	0,00	**0,40***	**0,50***	**1**			
10	SPRMKT_DIST	**0,77***	**-0,48***	**-0,45***	**-0,32***	**-0,44***	**-0,36***	**0,86***	**0,89***	**0,37***	**1**		
11	TOTAL CASES	0,00	**-0,26***	-0,05	-0,09	**-0,23***	**-0,38***	0,11	0,10	-0,04	0,13	**1**	
12	TOTAL DEATHS	**-0,25***	0,02	**0,27***	-0,13	-0,13	-0,19	**-0,24***	**-0,28***	0,00	**-0,24***	0,13	**1**

** Statistically significant p-value (p < 0,05).*

From the regression on the cases (Tab. 20), it is possible to notice both models do not have significant predictive power, as indicated by the value of the R^2. As expected, high VIF values are obtained for the indicators of proximity to pharmacies, hospitals, and supermarkets (13,08, 7,15 and 6,85 respectively), although the last two show values lower than 7,5. Spatial autocorrelation does not significantly affect the cases' regressions, as shown by Moran's Indices (around 0,10 for both). At the same time, the models predicting the mortality of the pandemic show higher values (0,29 for the OLS and 0,26 for the GWR). Despite the poor performance of the models, however, there are some variables with significant coefficients, such as the density of supermarkets (0,44) and pharmacies (-0,67). Other indicators, such as density of green areas, bicycle paths, hospitals, and distance to supermarkets, range from -0,15 to 0,17. Hence, even though the model does not perform exceedingly well, some variables might be linked significantly with the spread of the pandemic.

Table 20 - Regressions results for spatial indicators and COVID-19 cases in Sao Paulo

Variables	*OLS R^2*	*OLS I*	*OLS p-value*	*OLS β*	*OLS VIF*	*OLS AICc*	*GWR R^2*	*GWR I*	*GWR AICc*
GREEN_DEN			0,5428	-0,15362	6,78				
CYCLE_DEN			0,1919	-0,17498	1,89				
INT_DEN			0,7498	0,038615	1,56				
HOSP_DEN			0,4186	0,105233	1,79				
SPRMKT_DEN	0,11	0,10*	0,0358	0,444924	4,67	1712,25	0,13	0,09*	1709,63
PHARMA_DEN			0,0005	-0,67756	3,8				
HOSP_DIST			0,8316	-0,05508	7,15				
PHARMA_DIST			0,8998	0,044044	13,08				
GREEN_DIST			0,9979	0,000323	1,65				
SPRMKT_DIST			0,4937	0,173769	6,85				

)

Table 21 - Regressions results for spatial indicators and COVID-19 deaths in Sao Paulo

Variables	*OLS R2*	*OLS I*	*OLS p-value*	*OLS β*	*OLS VIF*	*OLS AICc*	*GWR R2*	*GWR I*	*GWR AICc*
GREEN_DEN			0,8655	0,041982	6,78				
CYCLE_DEN			0,9280	-0,01185	1,89				
INT_DEN			0,1960	0,154688	1,56				
HOSP_DEN			0,3571	-0,11791	1,79				
SPRMKT_DEN	0,14	0,29*	0,9119	0,022767	4,67	1130,72	0,15	0,26*	1129,30
PHARMA_DEN			0,0971	-0,31058	3,8				
HOSP_DIST			0,6872	-0,10261	7,15				
PHARMA_DIST			0,3584	-0,31704	13,08				
GREEN_DIST			0,0452	0,248269	1,65				
SPRMKT_DIST			0,7648	-0,07462	6,85				

** Statistically significant p-value ($p < 0,05$)*

Tab. 21, instead, shows the regression results encompassing the spatial indicators and the mortality of the pandemic. Also in this case we find higher p-values. The model's overall performance is slightly higher than the one predicting the spread (0,14 for the OLS and 0,15 for the GWR). The GWR does not help improve the model significantly, as occurred for the previous model. Some variables show a significant coefficient, namely, the density of pharmacies (-0,31), distance to pharmacies (-0,31) and green areas (0,25). The other variables have figures fluctuating between -0,11 and 0,15. Once again, we find that the distance to pharmacies has a high VIF value, thus raising the issue of collinearity and instability of the model. Finally, both models are affected by higher spatial autocorrelation, as shown by Moran's Indices for both the OLS and GWR (0,29 and 0,26). In the following pages, Fig. 207 to 215 show how the indicators map the city. Fig. 217 to 220, instead, map the residuals.

Figure 207 - Green areas per inhabitant (m^2/inh) by *Distrito*, Sao Paulo

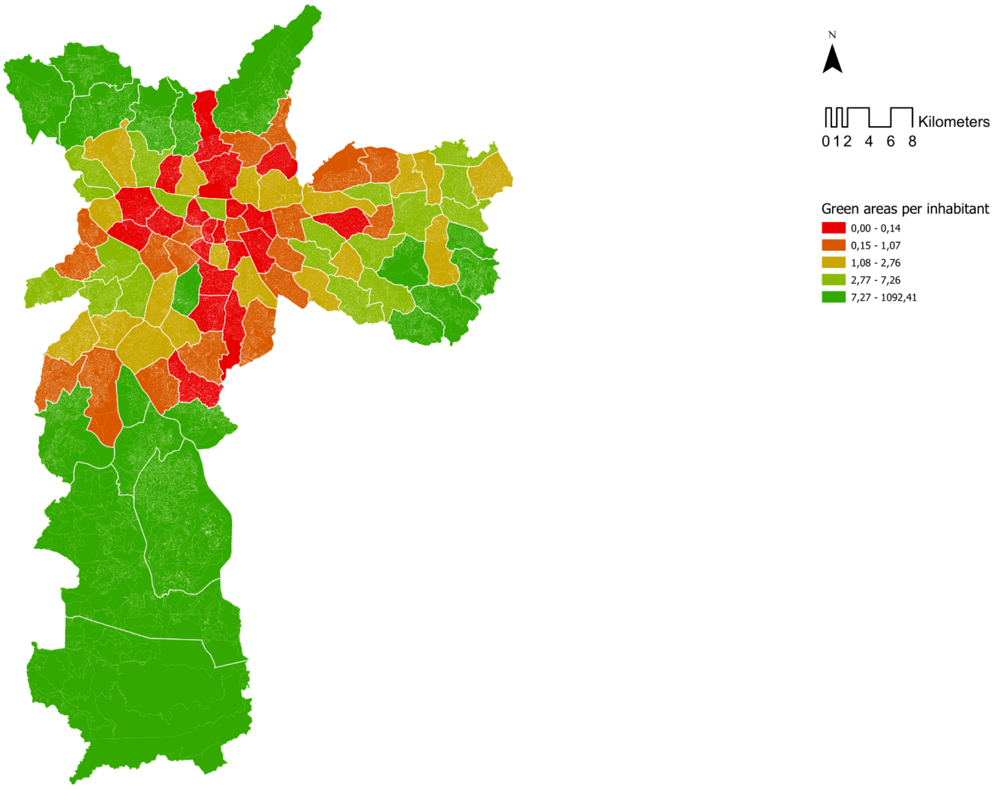


Figure 208 - Bicycle paths density (km/km^2) by *Distrito*, Sao Paulo

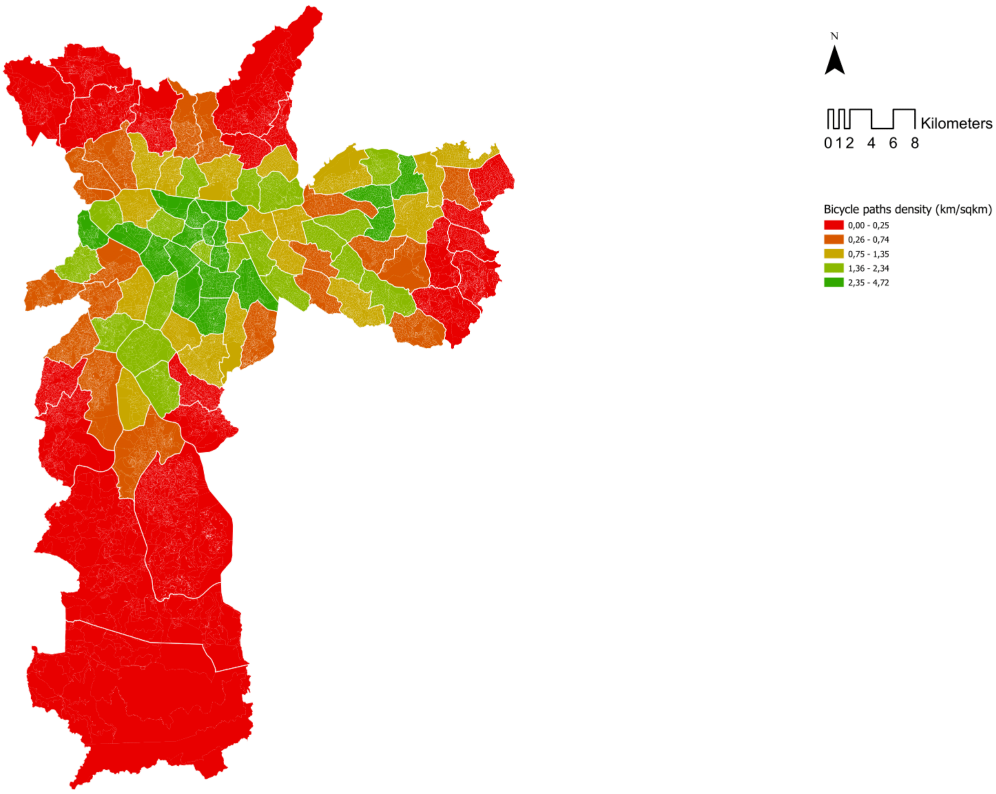


Figure 209 - Street's intersection density (int/ km^2) by *Distrito*, Sao Paulo

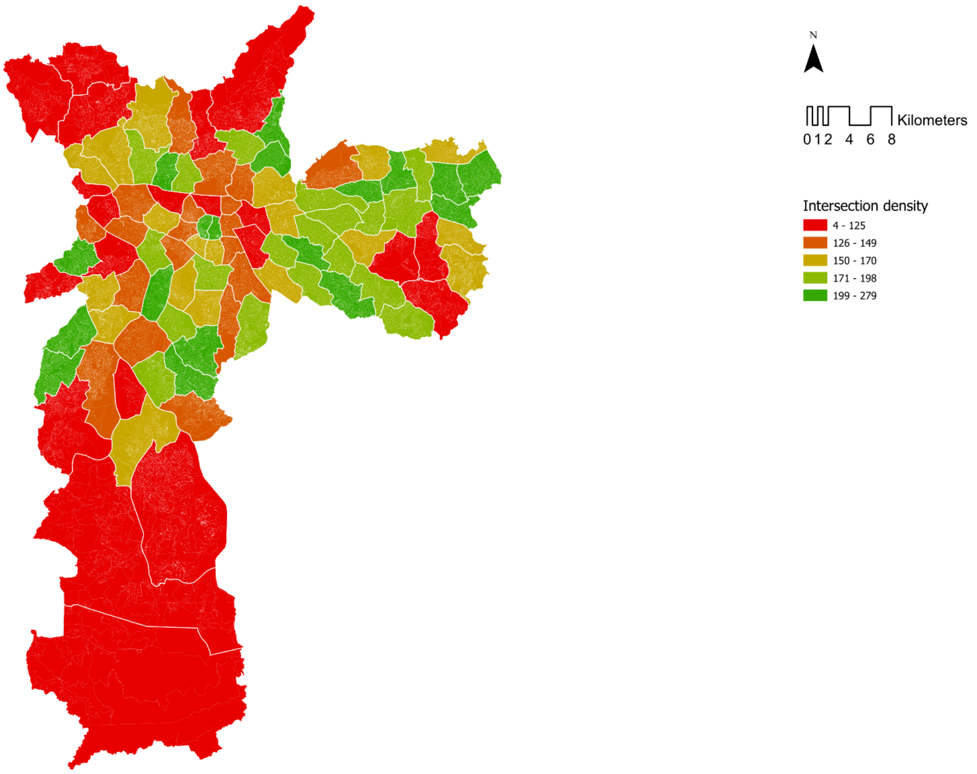


Figure 210 - Hospital density (per 100.000 inhabitants) by *Distrito*, Sao Paulo

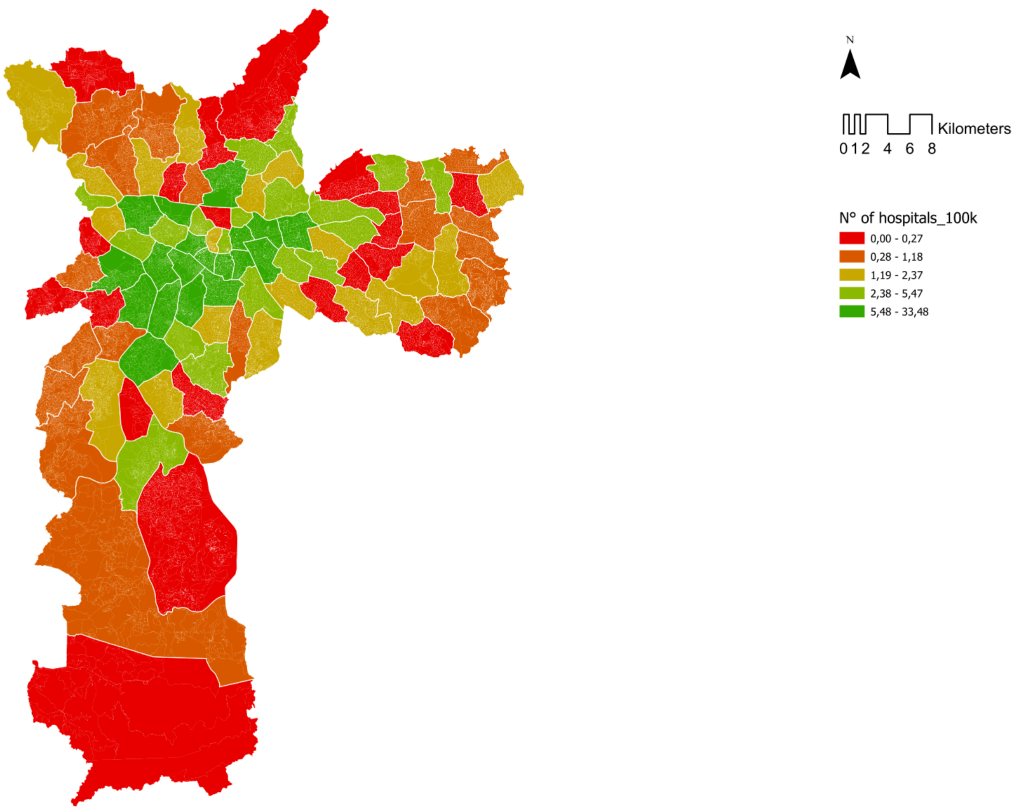


Figure 211 - Supermarket density (per 100.000 inhabitants) by *Distrito*, Sao Paulo

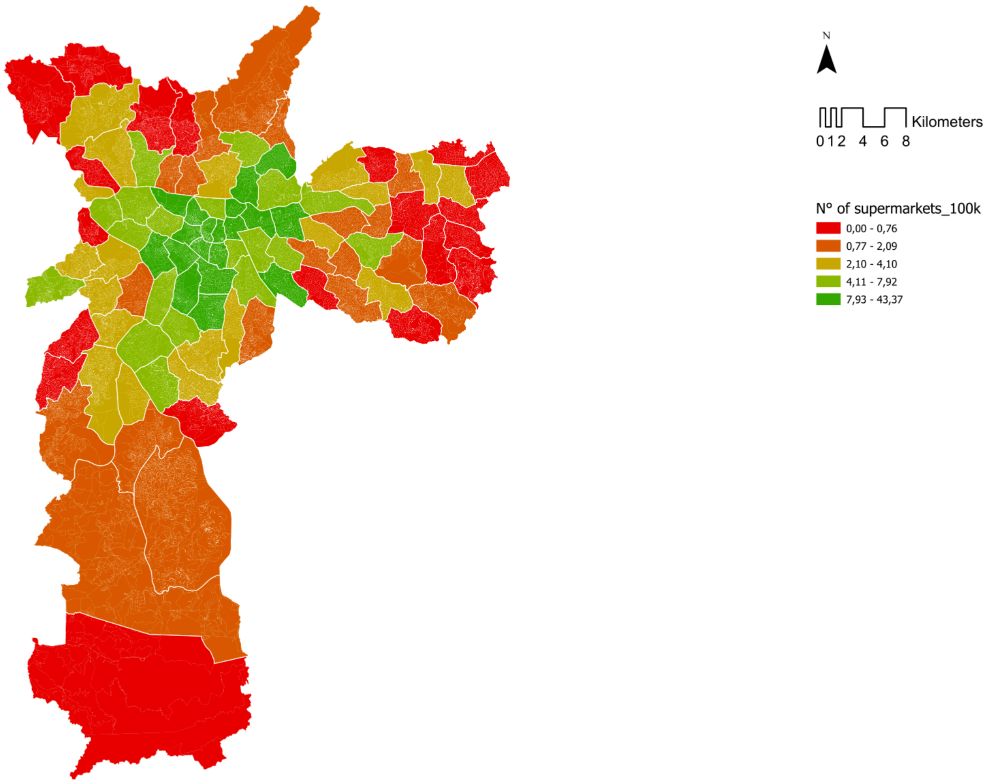


Figure 212 - Pharmacy density (per 100.000 inhabitants) by *Distrito*, Sao Paulo

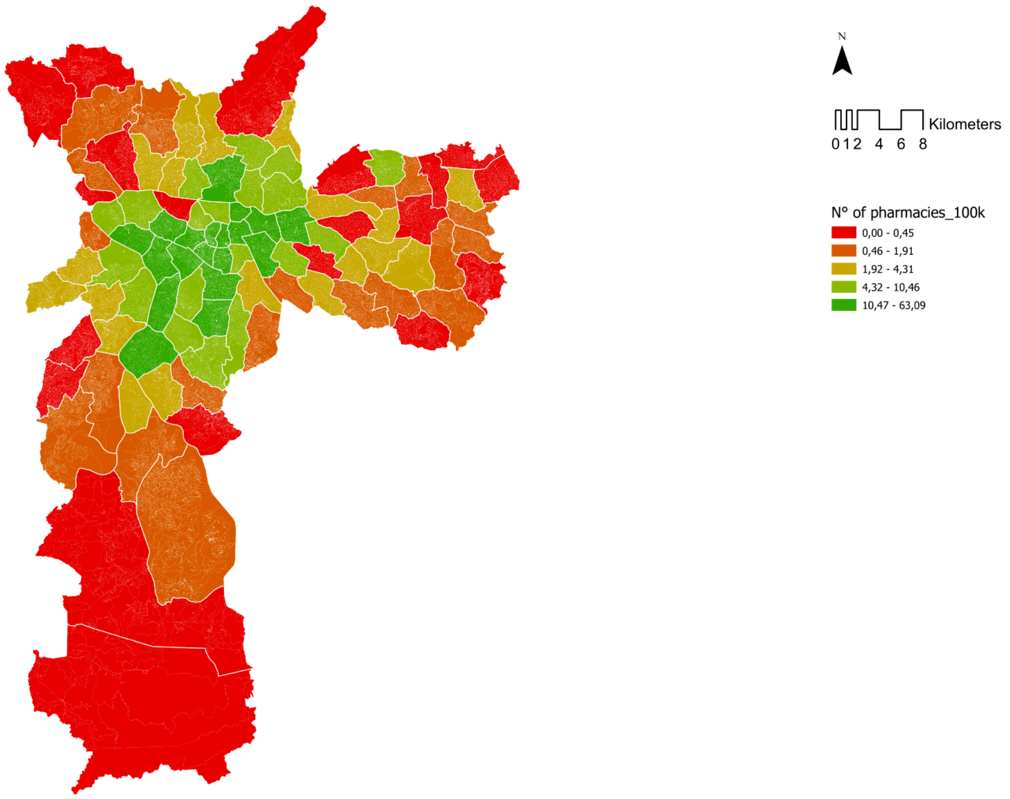


Figure 213 - Mean distance to the closest hospital (m) by *Distrito*, Sao Paulo

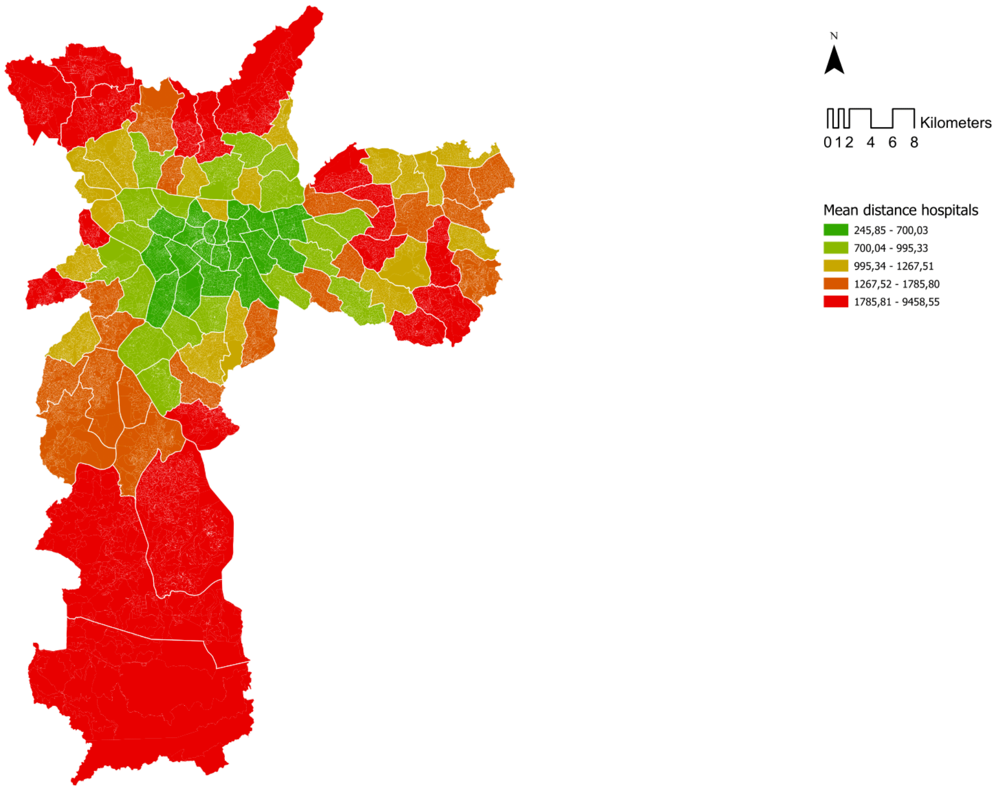


Figure 214 - Mean distance to the closest pharmacy (m) by *Distrito*, Sao Paulo

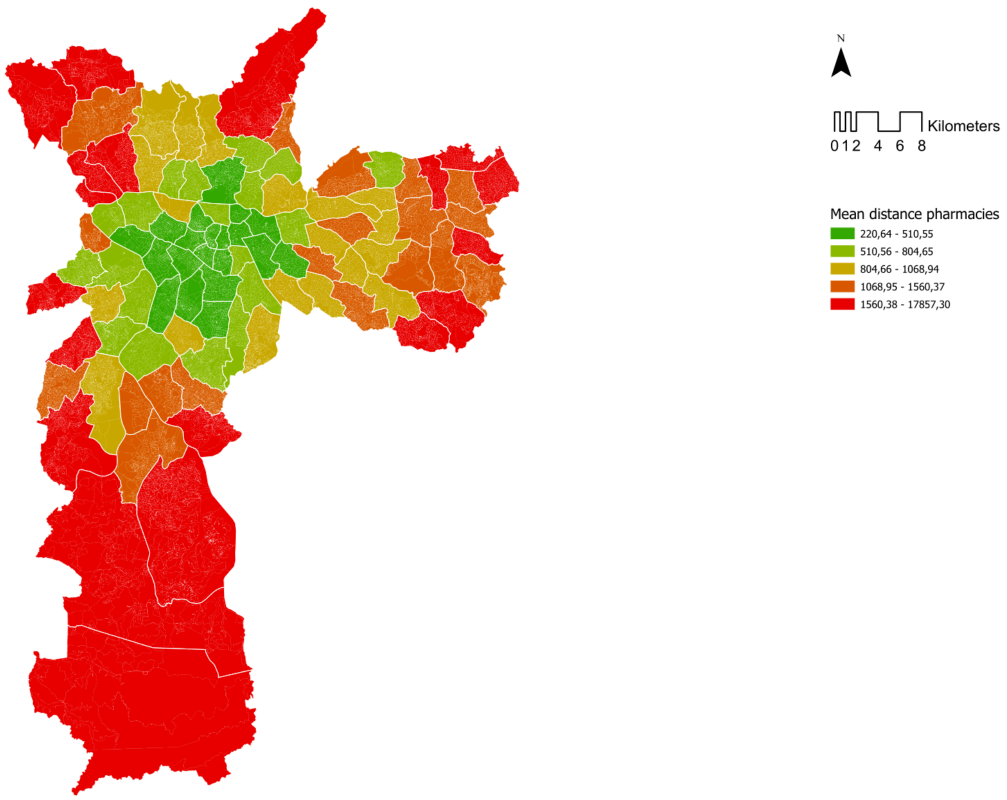


Figure 215 - Mean distance to the closest publicly accessible green area (m), by *Distrito*, Sao Paulo

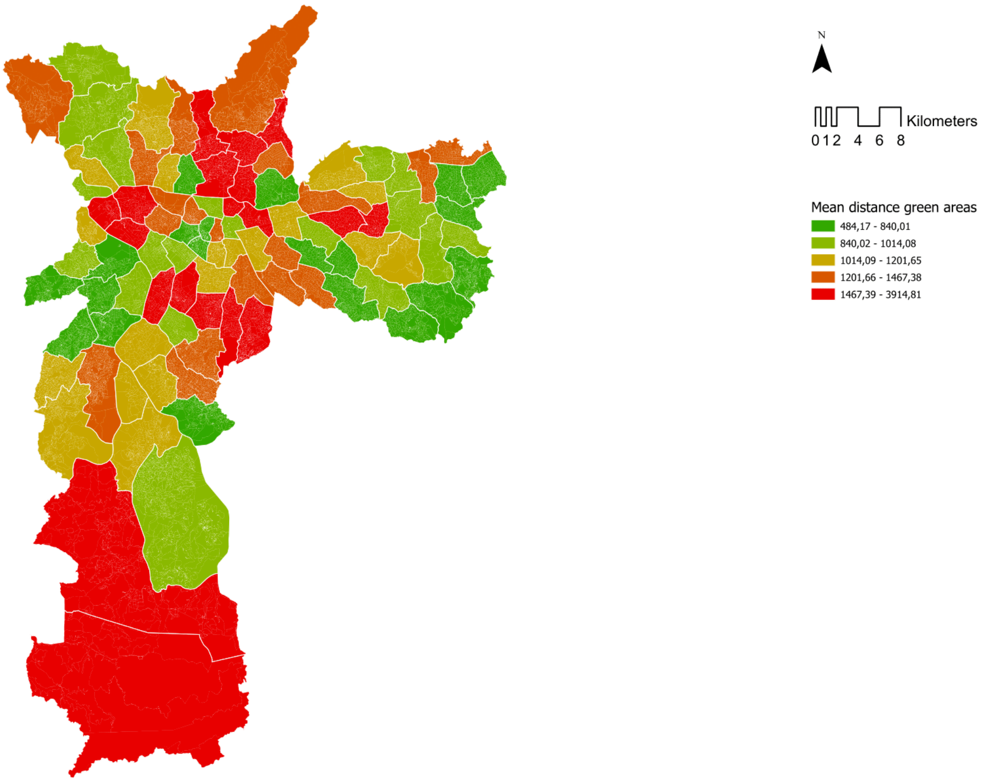


Figure 216 - Mean distance to the closest supermarket (m) by *Distrito*, Sao Paulo

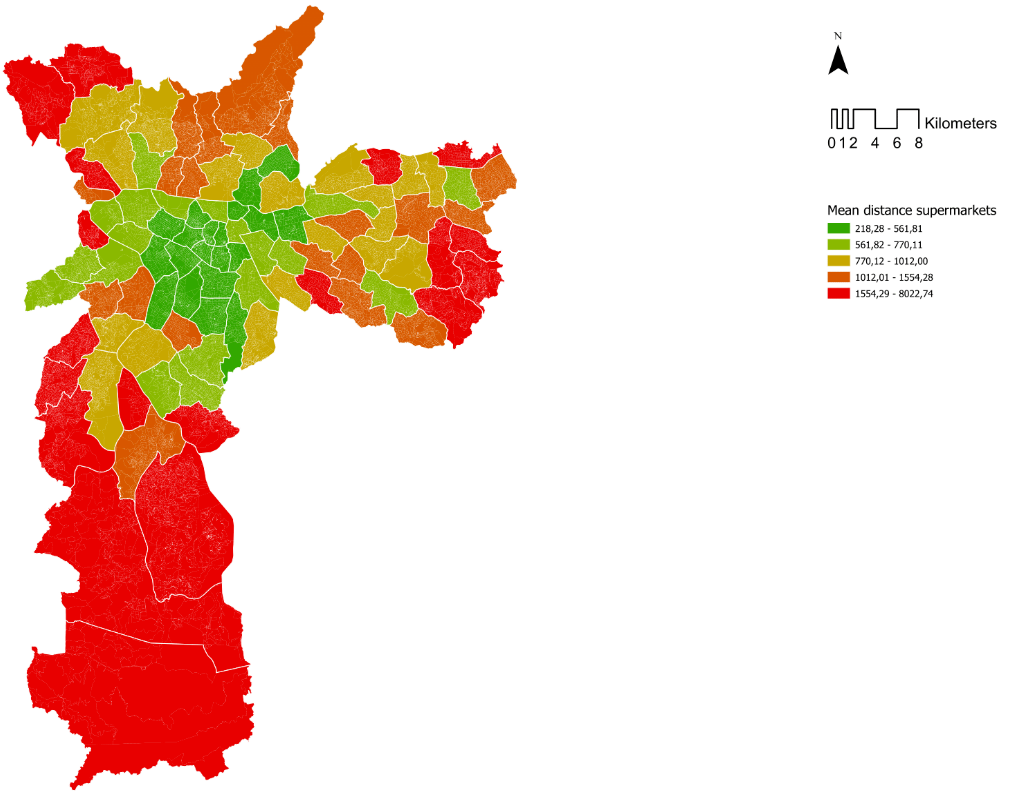


Figure 217 - Spatial indicators – Cases, Std. Residuals by *Distrito* (OLS), Sao Paulo

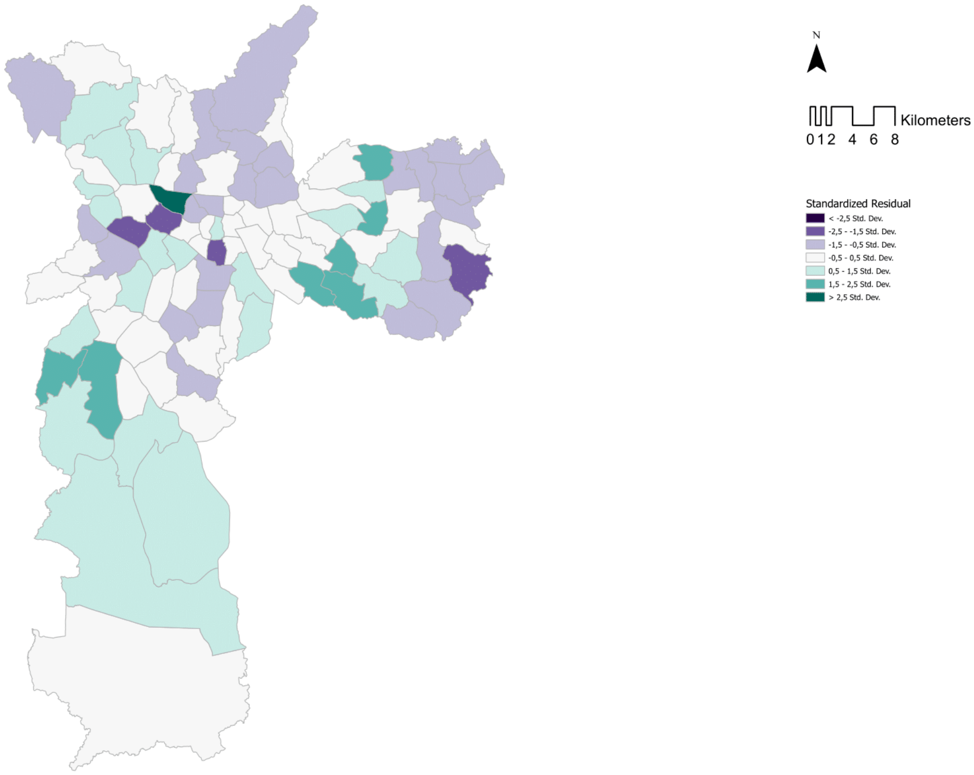


Figure 218 - Spatial indicators – Cases, Std. Residuals by *Distrito* (GWR), Sao Paulo

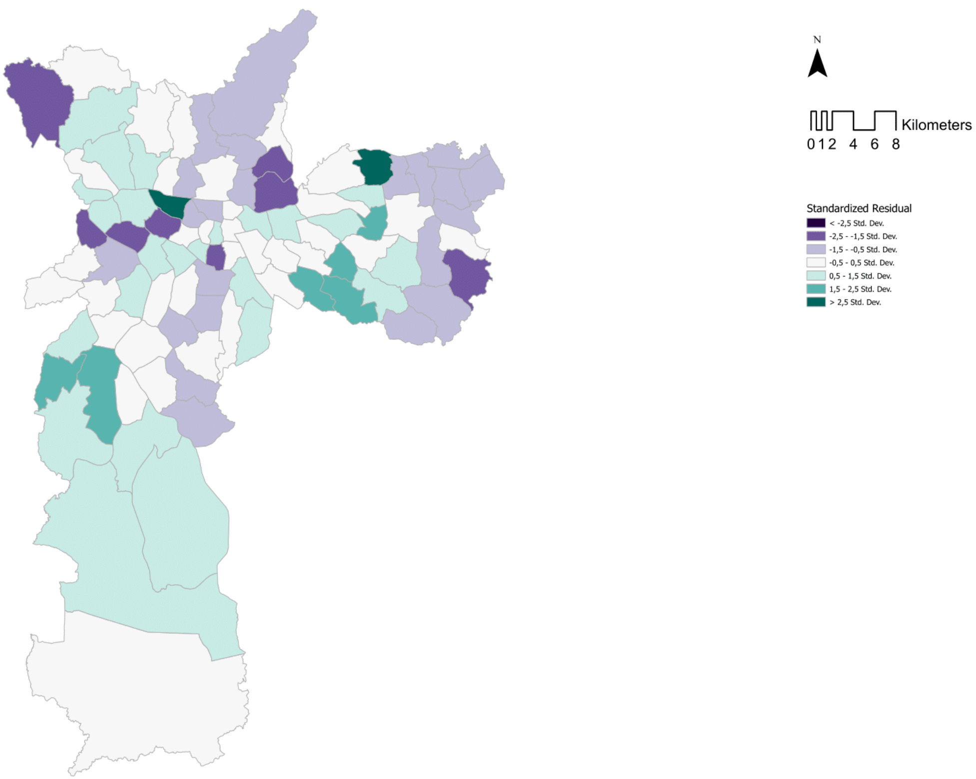


Figure 219 - Spatial indicators – Deaths, Std. Residuals by *Distrito* (OLS), Sao Paulo

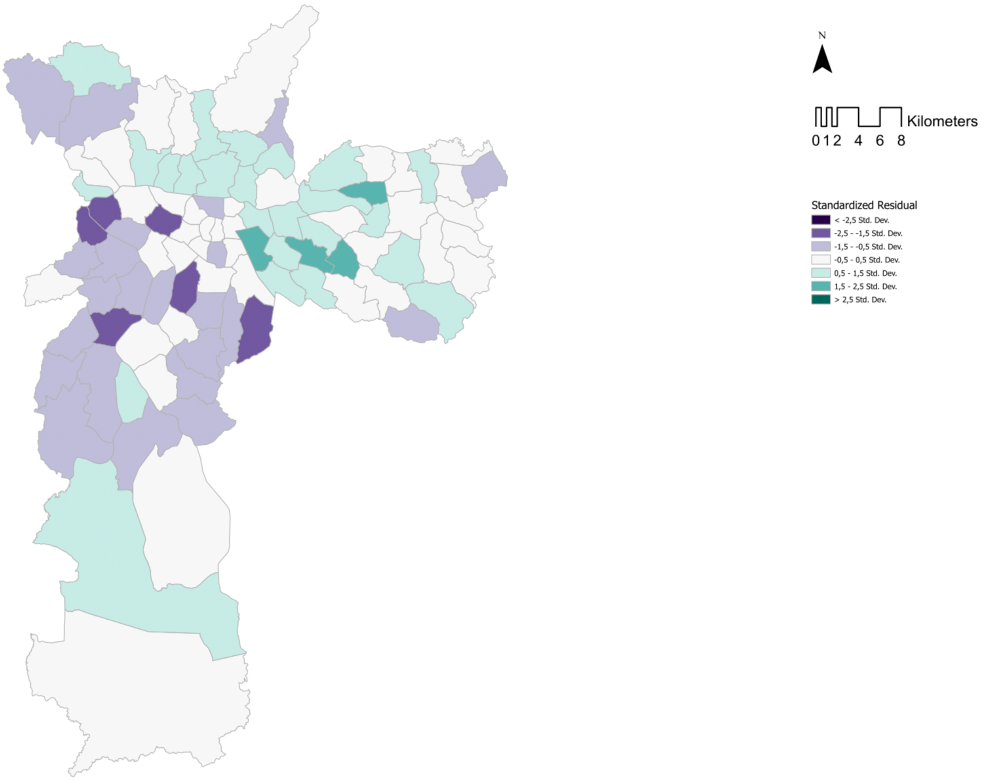
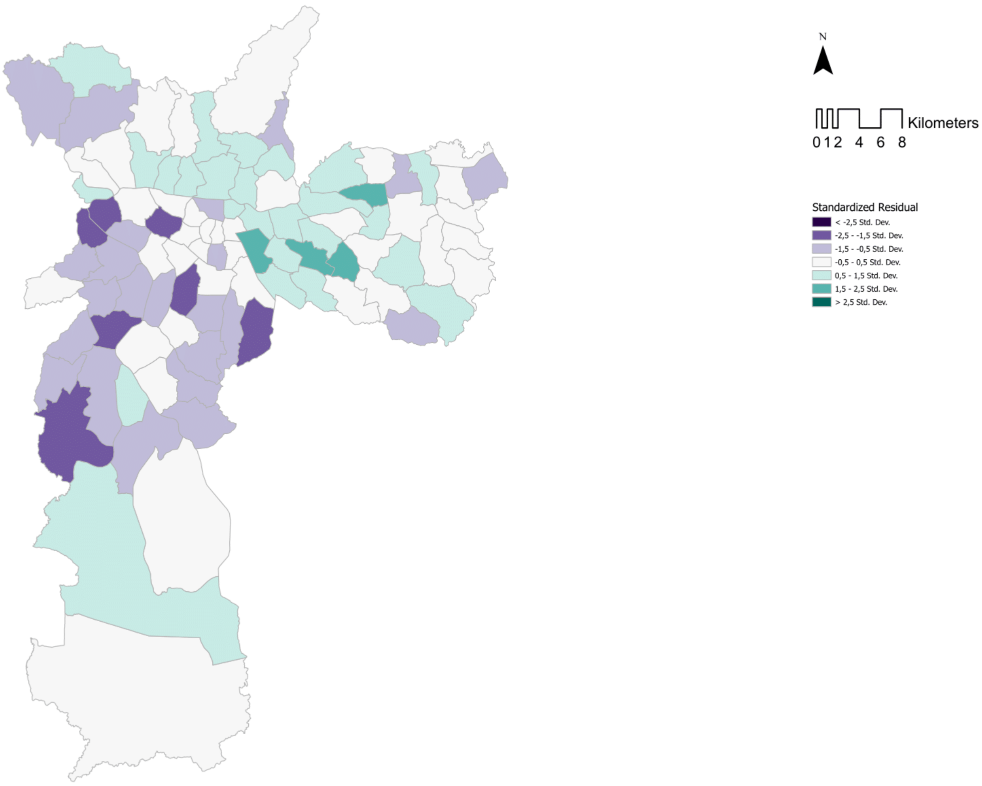


Figure 220 - Spatial indicators – Deaths, Std. Residuals by *Distrito* (GWR), Sao Paulo



5.3.5 Model II: Wrap-up

This second model has shown relevant results. As for the first model, the spatial indicators alone seem to provide only a part of the story, important but still partial, despite some significant R^2 values and coefficients. The GWR, in general, does not seem to show significant improvement compared to the results provided by the OLS. In London, the results are moderately significant, with some relevant coefficients and a discrete performance of the models, although the R^2 values were not exceedingly high. Similar results were obtained in Sao Paulo, where some variables had higher coefficients (such as density and distance to pharmacies). However, in this case, the overall predictive power of the models was slightly lower compared to London. Instead, in New York City, the models performed well, and the outputs were promising in terms of coefficients and R^2's.

In Rome, we observe a distinct set of results. Whereas for the regression on mortality the model performs moderately well (R^2 = 0,50), with many relevant coefficients amongst the variables, the regression on the spread, instead, produced poor results, although a couple of variables did show meaningful coefficients. The results, however, reflect the different patterns that have been observed in the first descriptive analysis and later in the models. In Rome, for example, it was clear since the beginning that the patterns of spread and mortality were not coincident at all. This, of course, is reflected on the regressions, where, for instance, in Model II, the variables fit reasonably well the analysis of the deaths, but not the cases. This discourse also applies to NYC. In fact, during the first analyses, it was noticed how the two patterns had similar traces and high correlations. As a result, the regressions seem to perform meaningfully in both cases. Notwithstanding, it is interesting to verify, drawing comparisons across case studies, why, for example, the spatial indicators perform well when analysing deaths in one city, while in other instances, it is more fit for the analysis of the spread. This, however, is left for the last chapter of this thesis.

Another feature that has been noticed in Model II is that for Rome and Sao Paulo, the indicators of proximity are strongly correlated with each other. This implies that as soon as the distance to one facility increases, the proximity to other facilities decreases. This fact has important implications and worth further investigation. Instead, in NYC and London, this correlation was only partial and not as strong as in the other case studies.

Also, greater p-values were features in all case studies. This fact has been already commented on in the different analyses of this chapter. However, once again, the author would like to point out that in some cases, the higher p-values are due to many units having 0-value (as it occurred for some indicators of densities). In other instances, instead, it was due to great variance in the dataset. Greater variance, however, is likely to be implicit in the study of inequalities. The extent to which variance is manifested is another side of the story.

Finally, several indicators have shown varying values. For instance, the distance to supermarkets has featured negative values across some case studies, as well as the density of green areas, while having positive coefficients in some others. These divergences and differences are essential to expand the understanding of socio-spatial dynamics and the pandemic. They seem to call for a plural perspective and localised actions. We shall return to this later.

5.4 Model III: Complexifying the socio-spatial dimension

The third and last model (Model III) attempts to complexify the socio-spatial dimension of the analysis by placing together the elements that have been analysed independently so far. Moreover, as mentioned, the population density will be added as a control variable. This addition reinforces the idea that this study builds upon previous research, where most of the analyses have focused on density concerning the pandemic, bringing conflicting results. In this case, it is also an opportunity to evaluate the "weight" that density has when inserted in a complexified framework of analysis, encompassing other socio-spatial indicators. For each city, the following elements will be provided:

- A table showing the correlation matrix
- Table showing the results of the regression models (OLS and GWR): the table lists the same parameters used before (R^2, β, AICc, Moran's *I,* p-value and VIFs*)*
- Map showing the distribution of residuals according to the GWR and OLS models
- Hotspots on the residuals
- Final comparative diagrams of the coefficients for each model (I, II, III)
- Summary table containing the main outputs of all models (I, II, III)

5.4.1 London

Besides the already discussed results, the correlation matrix (Tab. 22) shows the correlations between population density, the SVI and the rest of the indicators. The SVI has not a high correlation with any of the variables. On the other hand, population density displays stronger correlations with the indicators of proximity (range -0,55 to 0,57).

Table 22 - Correlation matrix Model III, London

	Variables	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
1	SVI	**1**													
2	POP_DEN	**0,18**	**1**												
3	GREEN_DEN	**-0,13**	**-0,43**	**1**											
4	CYCLE_DEN	**0,11**	**0,32**	**-0,12**	**1**										
5	INT_DEN	**0,06**	**0,57**	**-0,28**	**0,54**	**1**									
6	HOSP_DEN	**-0,08**	-0,05	**0,11**	0,06	**0,12**	**1**								
7	SPRMKT_DEN	-0,05	0,04	**-0,08**	**0,08**	**0,20**	0,03	**1**							
8	PHARMA_DEN	**-0,10**	**0,08**	-0,02	**0,08**	**0,29**	**0,16**	**0,41**	**1**						
9	HOSP_DIST	**0,08**	**-0,38**	**0,22**	**-0,23**	**-0,30**	**-0,31**	**-0,09**	**-0,15**	**1**					
10	PHARMA_DIST	0,04	**-0,46**	**0,23**	**-0,25**	**-0,36**	-0,03	**-0,17**	**-0,32**	**0,35**	**1**				
11	GREEN_DIST	**-0,07**	**-0,55**	**0,31**	**-0,44**	**-0,60**	-0,01	**-0,15**	**-0,16**	**0,31**	**0,45**	**1**			
12	SPRMKT_DIST	-0,05	**-0,52**	**0,39**	**-0,27**	**-0,37**	0,02	**-0,33**	**-0,21**	**0,41**	**0,57**	**0,53**	**1**		
13	TOTAL CASES	**0,51**	**-0,12**	-0,03	**-0,07**	**-0,22**	**-0,13**	**-0,07**	**-0,15**	**0,28**	**0,20**	**0,19**	**0,10**	**1**	
14	TOTAL DEATHS	**0,28**	**-0,30**	**0,16**	**-0,25**	**-0,34**	-0,02	**-0,12**	**-0,12**	**0,26**	**0,26**	**0,37**	**0,29**	**0,47**	**1**

Values in bold statistically significant p-value ($p < 0,05$).

Tab. 23 shows the results of the regressions concerning the spread of the pandemic. It is possible to notice how the model's overall performance (R^2) is improved compared to Model I and II. In this case, the GWR helps increase the predictive power of the models (+0.12 and +0.07). Looking at the coefficients, it is clear that the SVI has a greater figure (0,50) compared to the other indicators. Population density has a β close to 0. Tab. 24, which lists the outcomes of the regressions concerning mortality, shows similar trends. The overall R^2 obtained through the OLS and the GWR is 0,28 and 0,35, respectively. The SVI has the highest coefficient (0,33), and population density, differently from what was observed in the spread analysis, is more correlated (-0,10). Whereas the regressions on the spread are still affected by spatial autocorrelation, the ones involving deaths have I values close to 0. Hence, the former might be missing some critical variables to explain the pandemic.

Table 23 - Regressions' results, cases, Model III, London

Variables	*OLS R^2*	*OLS I*	*OLS p-value*	*OLS β*	*OLS VIF*	*OLS AICc*	*GWR R^2*	*GWR I*	*GWR AICc*
SVI	0,36	0,45*	0,0000	0,496905	1,1	17006,08	0,48	0,35*	16821,78
POP_DEN			0,1524	-0,05521	2,28				
GREEN_DEN			0,0061	-0,08096	1,33				
CYCLE_DEN			0,1621	0,044015	1,51				
INT_DEN			0,0001	-0,1511	2,4				
HOSP_DEN			0,5813	-0,01558	1,22				
SPRMKT_DEN			0,9285	0,002687	1,37				
PHARMA_DEN			0,6200	-0,01513	1,42				
HOSP_DIST			0,0000	0,166777	1,51				
PHARMA_DIST			0,1070	0,054955	1,77				
GREEN_DIST			0,0026	0,109793	2,02				
SPRMKT_DIST			0,0719	-0,06897	2,24				

Table 24 - Regressions' results, deaths, Model III, London

Variables	*OLS R2*	*OLS I*	*OLS p-value*	*OLS β*	*OLS VIF*	*OLS AICc*	*GWR R2*	*GWR I*	*GWR AICc*
SVI	0,28	0,11	0,0000	0,334981	1,1	11405,90	0,35	0,05	11325,66
POP_DEN			0,0124	-0,10225	2,28				
GREEN_DEN			0,4204	0,025177	1,33				
CYCLE_DEN			0,0089	-0,08732	1,51				
INT_DEN			0,0124	-0,10517	2,4				
HOSP_DEN			0,1973	0,038593	1,22				
SPRMKT_DEN			0,4209	-0,02555	1,37				
PHARMA_DEN			0,6871	0,013017	1,42				
HOSP_DIST			0,0397	0,068505	1,51				
PHARMA_DIST			0,8456	0,007028	1,77				
GREEN_DIST			0,0000	0,17999	2,02				
SPRMKT_DIST			0,2369	0,047997	2,24				

* *Statistically significant p-value (p < 0,05)*

Figure 221 - Model III – Cases, Std. Residuals by MSOA (OLS), London

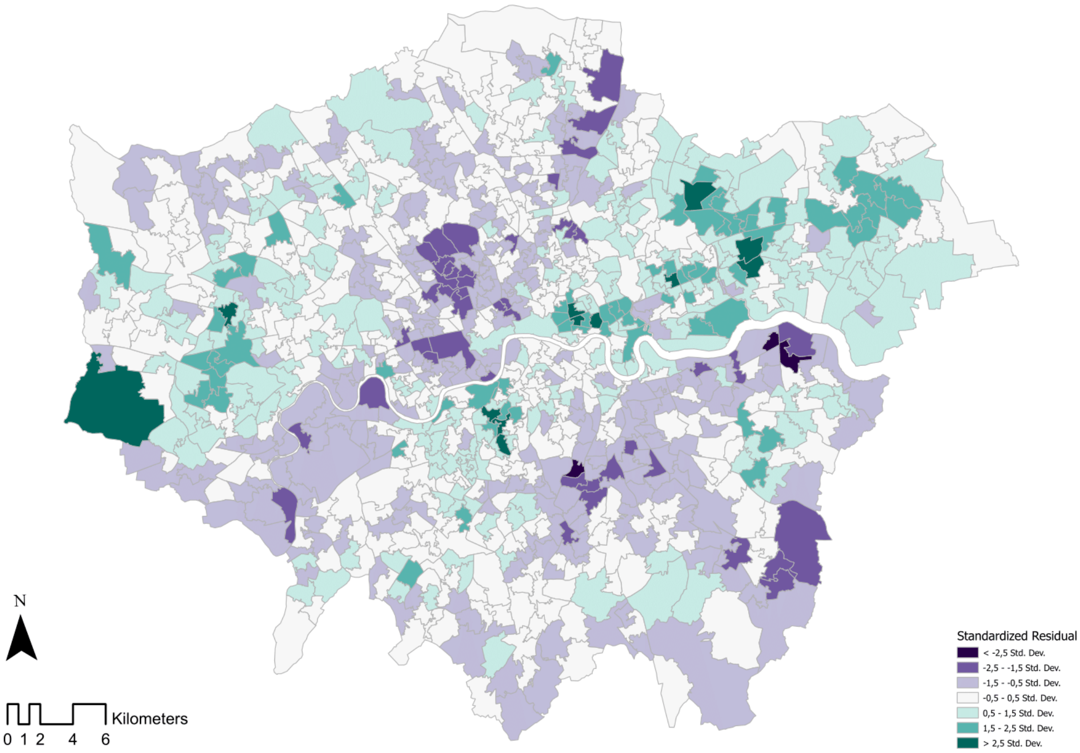


Figure 222 - Model III – Cases, Std. Residuals by MSOA (GWR), London

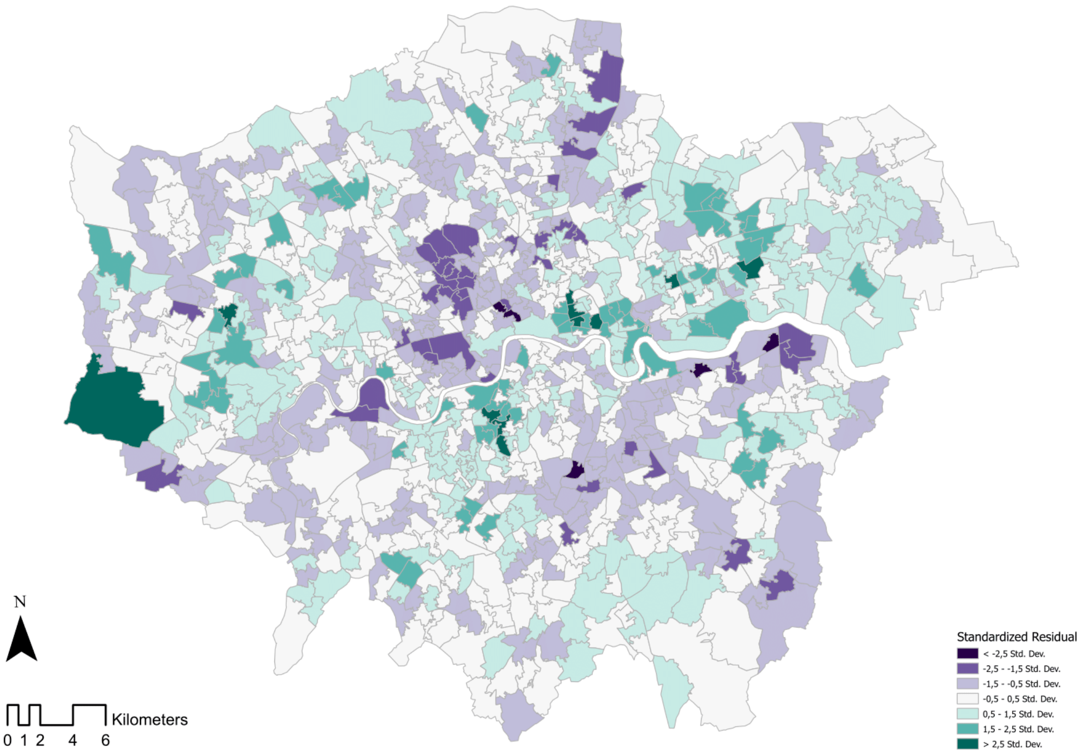


Figure 223 - Model III – Hotspots of the Std. Residuals of the cases by MSOA (OLS), London

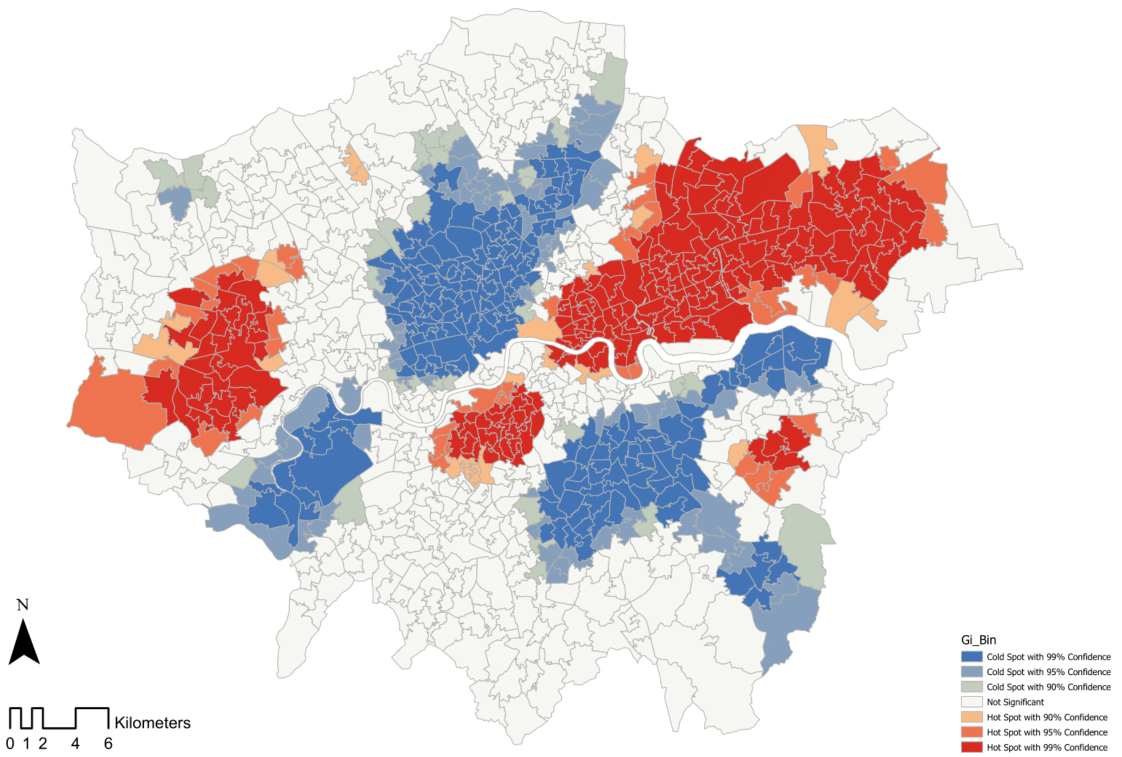


Figure 224 - Model III – Hotspots of the Std. Residuals of the cases by MSOA (GWR), London

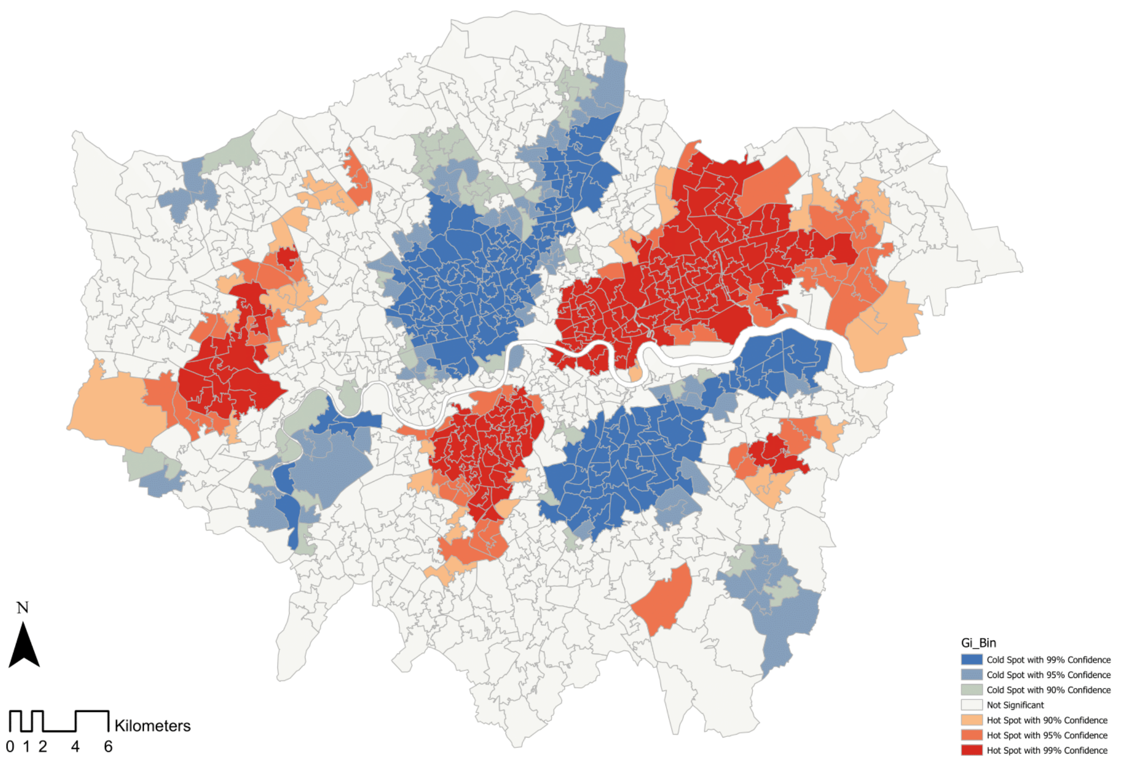


Figure 225 - Model III – Deaths, Std. Residuals by MSOA (OLS), London

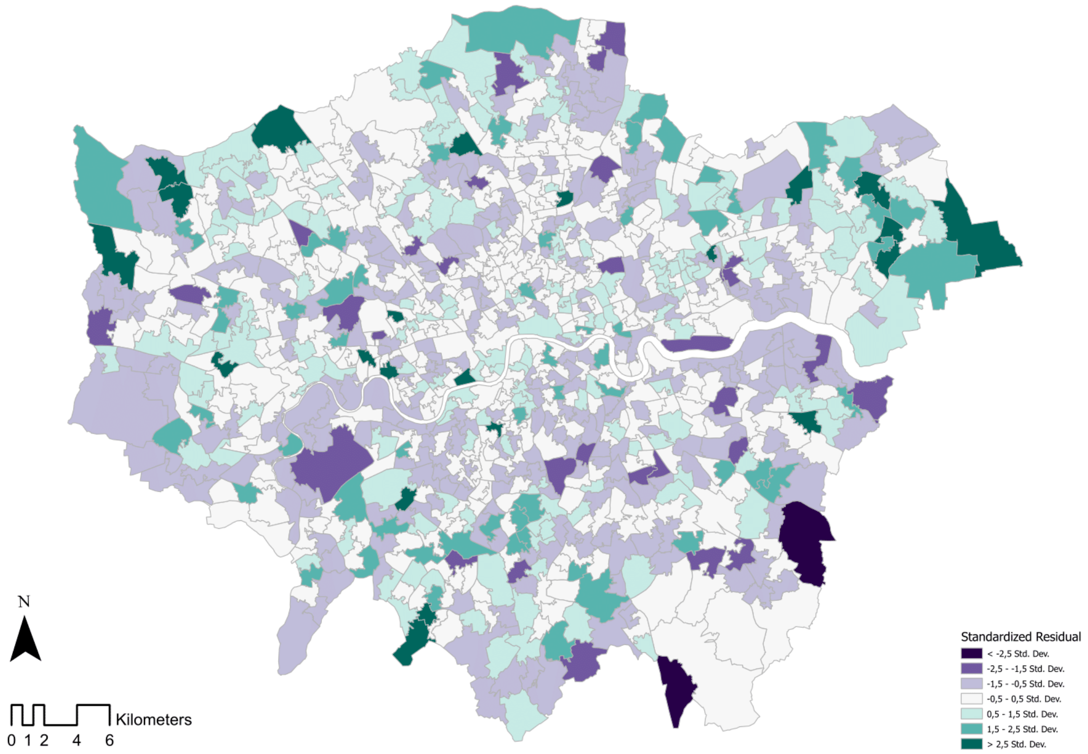


Figure 226 - Model III – Deaths, Std. Residuals by MSOA (GWR), London

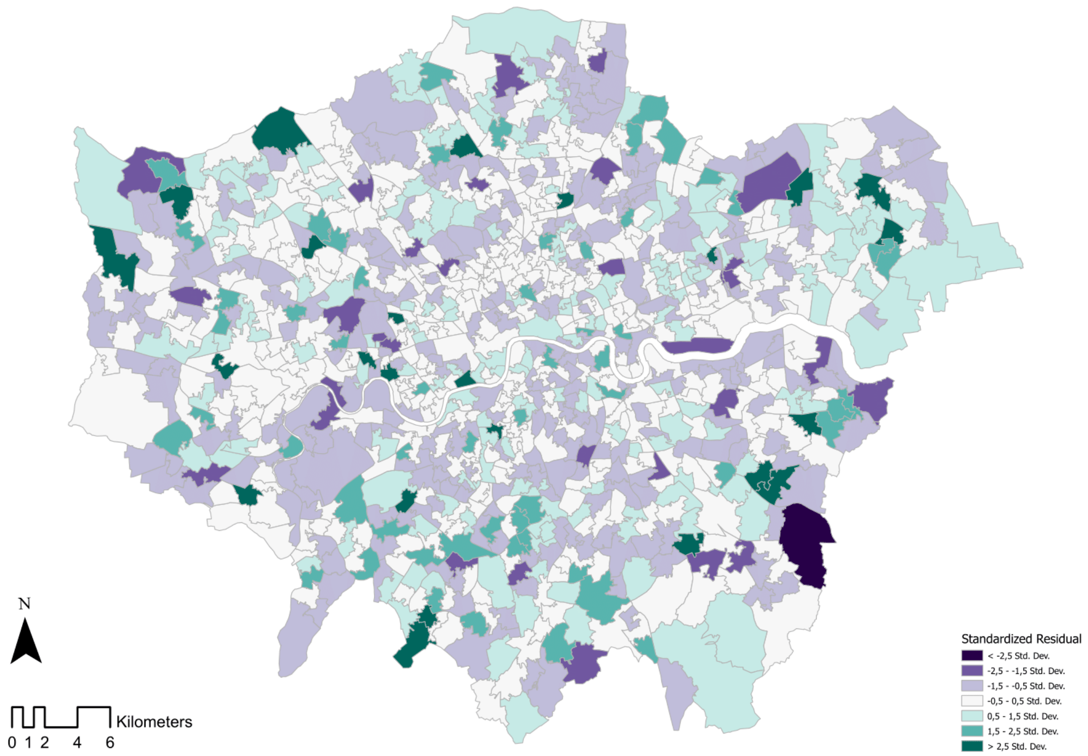


Figure 227 - Model III – Hotspots of the Std. Residuals of the deaths by MSOA (OLS), London

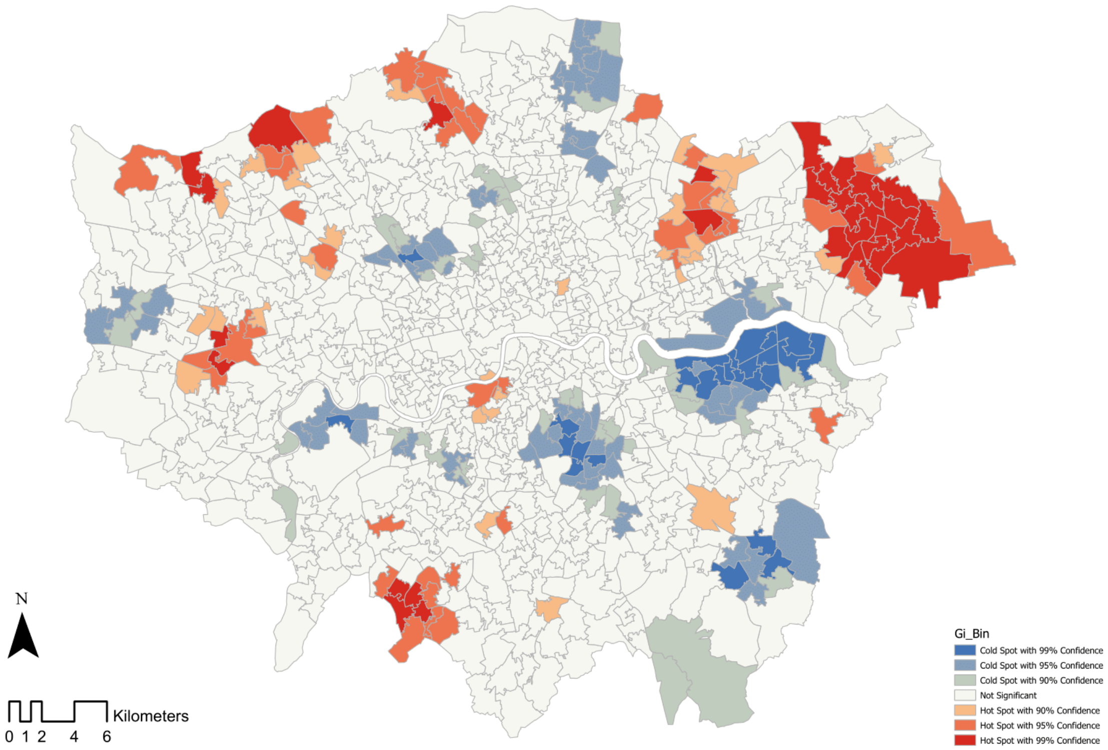
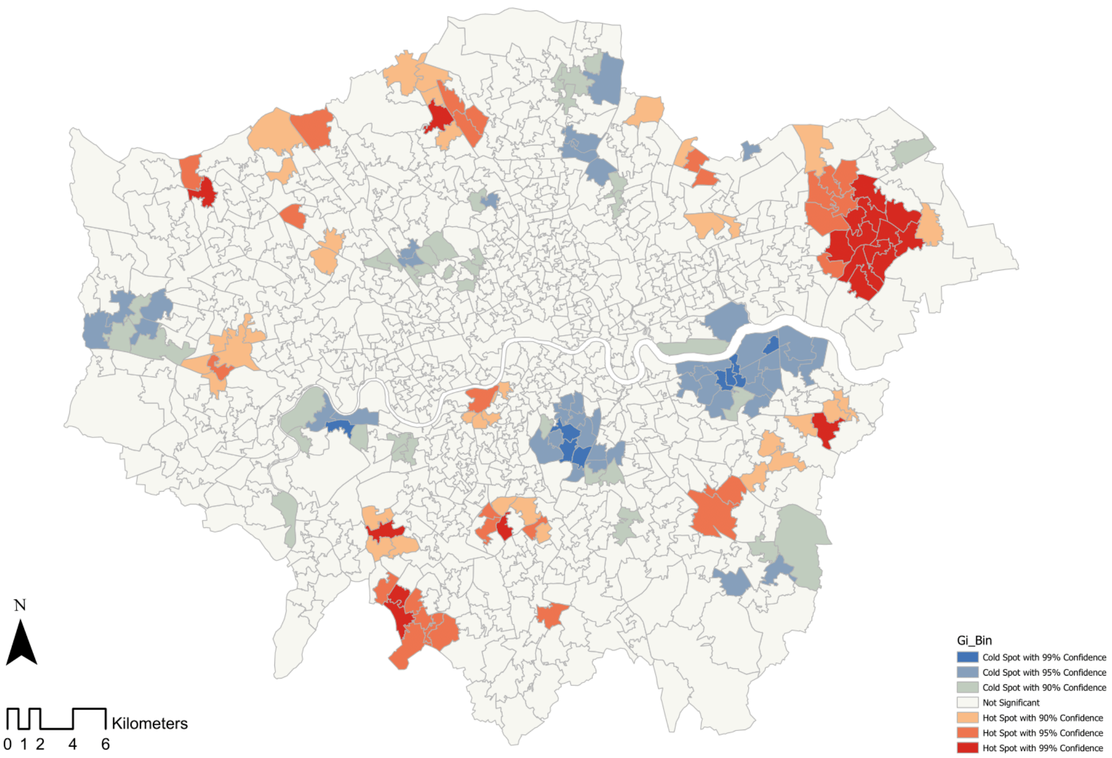


Figure 228 - Model III – Hotspots of the Std. Residuals of the deaths by MSOA (GWR), London



From the Hotspots analysis (Fig. 223, 224, 227 and 228) carried out on the standardised residuals of the four regressions, it is possible to notice where the model is still presenting issues related to spatial autocorrelation. The maps demonstrate that the regressions involving mortality are not significantly affected, except for some hotspots in East London. The GWR, as mentioned earlier, helps to reduce spatial autocorrelation as it can be asserted from Fig. 222 and 226, where, despite the visible level of clustering characterising both maps, there is a noticeable improvement in some areas, specifically, East, South and West London. However, the regressions involving the cases still present a relevant level of spatial autocorrelation (as proved by the Moran's Is), thus suggesting that a part of the story is missing, which, hopefully, can be further explored in future studies.

Table 25 - Summary of the results by model (Regressions on cases), London

Model	*OLS* R^2	*OLS* *I*	*OLS* *AICc*	*GWR* R^2	*GWR* *I*	*GWR* *AICc*
Model I	0,26	0,54	17140,24	0,39	0,45	16937,84
Model II	0,13	0,50	17302,87	0,31	0,39	17083,30
Model III	0,36	0,45	17006,08	0,48	0,35	16821,78

Table 26 - Summary of the results by model (Regressions on deaths), London

Model	*OLS* R^2	*OLS* *I*	*OLS* *AICc*	*GWR* R^2	*GWR* *I*	*GWR* *AICc*
Model I	0,08	0,27	11636,17	0,20	0,17	11501,37
Model II	0,18	0,13	11534,06	0,24	0,07	11466,23
Model III	0,28	0,11	11405,90	0,35	0,05	16821,78

Tab. 25 and 26 display a summary of the different models' results. It is possible to notice how, as mentioned before, there is an improvement and increasing predictive power by employing Model III. Although the final values are not exceedingly high (0,48 and 0,35), the upward trend observed as we "complexify" the analysis of the pandemic concerning the socio-spatial dimension is undoubtedly promising. Fig. 229 to 234 instead show the coefficients of each variable for each model, both in terms of cases and deaths. The diagrams substantially summarise the various findings and facts that have been analysed through the different models. Once more, it is quite clear that the SVI has a larger explanatory power than the other indicators for London. Nevertheless, complexifying the analysis, creating a more multifaceted framework of analysis, employing a variety of indicators help improve the model, as demonstrated by the results of the regressions. Moreover, the β values of some indicators show a relevant figure, underlying the importance of urban infrastructures and resources. Lastly, it is possible to notice how, for the analysis of the spread and mortality, the indicators with the highest coefficients are approximately the same, whereas only a few (e.g., bicycle paths density) perform differently.

Figure 229 - Model I coefficients (cases), London

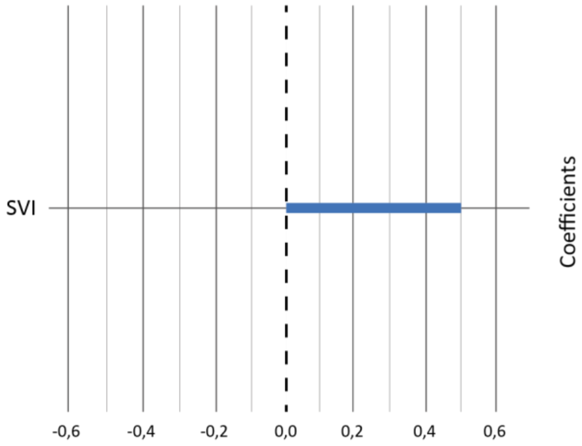


Figure 230 - Model I coefficients (deaths), London

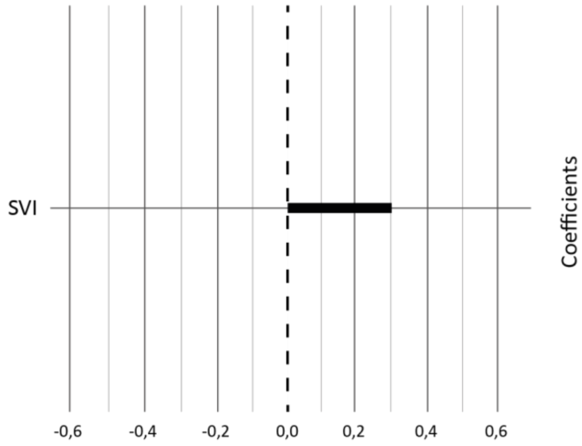


Figure 231 - Model II coefficients (cases), London

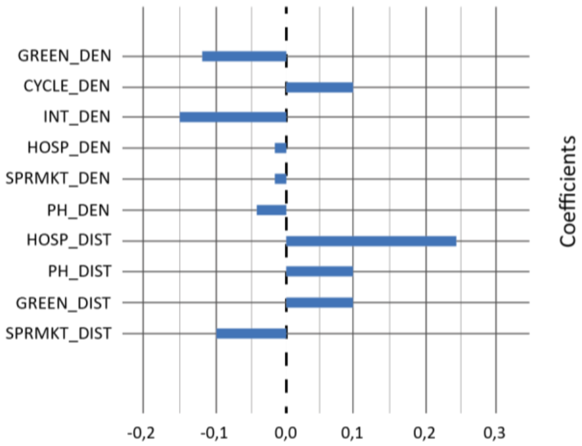


Figure 232 - Model II coefficients (deaths), London

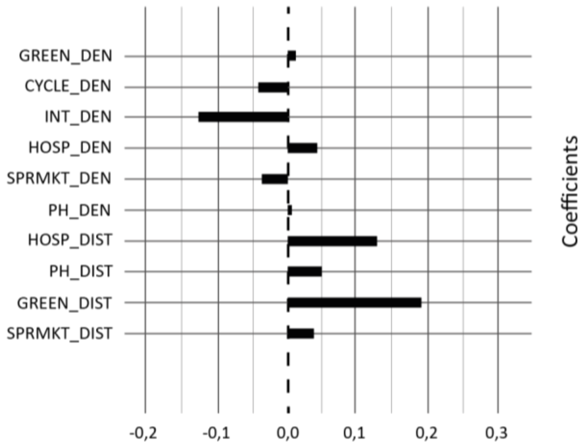


Figure 233 - Model III coefficients (cases), London

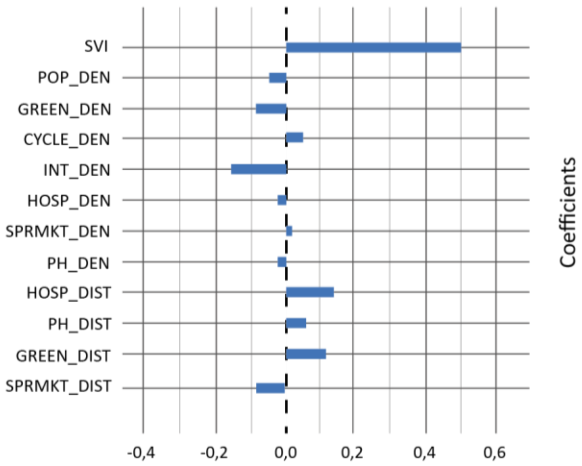
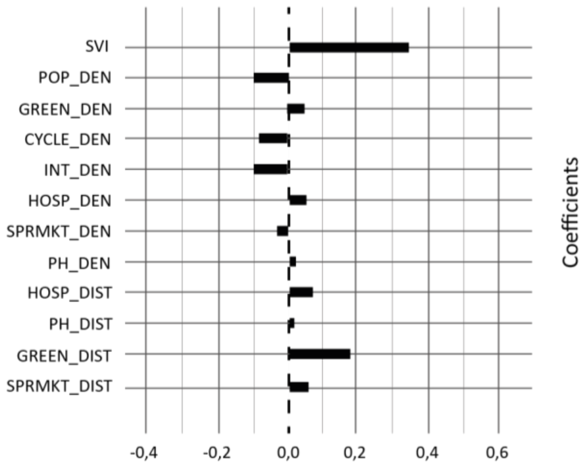


Figure 234 - Model III coefficients (deaths), London



5.4.2 New York City

Besides the results already discussed, the correlation matrix (Tab. 27) shows what type of correlation exists between population density and the SVI and the rest of the indicators. The SVI has no high correlation with any variables (except the cases and deaths, as already noted in Model I). Population density displays some stronger correlations with the spatial indicators, although all being below 0,60. The highest correlations are found with bicycle paths density (0,59), distance to hospitals (-0,59), supermarkets (-0,50) pharmacies (-0,53) and green areas (-0,51). Therefore, as a trend, population density is negatively correlated with all the indicators of proximity. Moreover, it shows moderately correlated figures also in relation to the spread and mortality of the pandemic (-0,50 and -0,30 respectively).

Table 27 - Correlation matrix Model III, London

	Variables	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
1	SVI	**1**													
2	POP_DEN	0,01	**1**												
3	GREEN_DEN	-0,03	**-0,17**	**1**											
4	CYCLE_DEN	**-0,18**	**0,59**	-0,09	**1**										
5	INT_DEN	-0,09	**0,27**	**-0,18**	**0,48**	**1**									
6	HOSP_DEN	0,02	0,09	-0,04	**0,23**	0,13	**1**								
7	SPRMKT_DEN	**-0,41**	**0,20**	0,10	**0,45**	**0,20**	-0,04	**1**							
8	PHARMA_DEN	**-0,42**	0,14	0,06	**0,42**	**0,43**	0,01	**0,46**	**1**						
9	HOSP_DIST	**-0,17**	**-0,59**	0,14	**-0,55**	**-0,30**	**-0,29**	**-0,20**	**-0,26**	**1**					
10	PHARMA_DIST	0,10	**-0,53**	0,10	**-0,50**	**-0,31**	-0,05	**-0,33**	**-0,41**	**0,55**	**1**				
11	GREEN_DIST	-0,03	**-0,51**	**0,29**	**-0,59**	**-0,52**	-0,03	**-0,25**	**-0,29**	**0,52**	**0,47**	**1**			
12	SPRMKT_DIST	-0,01	**-0,59**	0,10	**-0,54**	**-0,32**	-0,04	**-0,45**	**-0,40**	**0,60**	**0,77**	**0,49**	**1**		
13	TOTAL CASES	**0,43**	**-0,50**	0,04	**-0,59**	**-0,26**	-0,10	**-0,40**	**-0,36**	**0,41**	**0,55**	**0,42**	**0,53**	**1**	
14	TOTAL DEATHS	**0,60**	**-0,31**	0,05	**-0,41**	**-0,25**	0,04	**-0,42**	**-0,40**	**0,18**	**0,40**	**0,29**	**0,30**	**0,61**	**1**

Values in bold statistically significant p-value ($p < 0,05$).

Tab. 28 shows the results of the regressions concerning the spread of the pandemic. It is possible to notice how the model's overall performance (R^2) is improved compared to Model I and II. In this case, the GWR helps increase the model's predictive power concerning the spread (+0,04) but not the one involving the total deaths, where the figure remains equal. Looking at the coefficients, instead, it is clear how the SVI has a more significant figure (0,46) compared to the other indicators, as it occurred in London. Nevertheless, the indicators of proximity have relevant coefficients, ranging from 0,10 to 0,21. The spatial indicator with the strongest coefficient is bicycle paths density (-0,25). Population density has a β of -0,10, approximately. Concerning the spread, it is possible to notice how the residuals are still affected by spatial autocorrelation. Despite the improvement brought by the GWR, which reduced Moran's I from 0,50 to 0,43, the value is still in the range of values indicating that there is still clustering.

Tab. 30, which lists the outcomes of the regressions concerning mortality, shows some similar trends and some divergences. In this case, the overall R^2 is equal regardless of the type of regression model used. The GWR also does not reduce spatial autocorrelation, as Moran's Indices are equal (0,09). Nevertheless, the values indicate minimal clustering, thus differing from the model on the cases—this difference in spatial lag when analysing cases and deaths was also observed in London. The SVI has the highest coefficient (0,46), and the population density's coefficient is equal even when studying the mortality or the spread (around -0,10). In general, Model III has higher explanatory power than Model I and Model II. The indicators of proximity are the ones with the most significant coefficients, with values ranging from -0,08 to 0,21. The two R^2 values obtained, 0,61 and 0,50, although only explanatory of part of the outbreak, are still promising as a base for future improvements.

Table 28 - Regressions' results, cases, Model III, NYC

Variables	*OLS* R^2	*OLS I*	*OLS p-value*	*OLS β*	*OLS VIF*	*OLS AICc*	*GWR* R^2	*GWR I*	*GWR AICc*
SVI	0,57	0,50*	0,0000	0,464254	1,71	3148,37	0,61	0,43*	3126,33
POP_DEN			0,1898	-0,09777	2,23				
GREEN_DEN			0,2376	-0,06394	1,17				
CYCLE_DEN			0,0022	-0,25203	2,66				
INT_DEN			0,3501	0,060285	1,67				
HOSP_DEN			0,9857	-0,00099	1,25				
SPRMKT_DEN			0,4440	0,051932	1,85				
PHARMA_DEN			0,1198	0,109355	1,97				
HOSP_DIST			0,1691	0,107211	2,43				
PHARMA_DIST			0,1109	0,133469	2,80				
GREEN_DIST			0,1264	0,113847	2,22				
SPRMKT_DIST			0,0294	0,208166	3,63				

Table 29 - Regressions' results, deaths, Model III, NYC

Variables	*OLS R2*	*OLS I*	*OLS p-value*	*OLS β*	*OLS VIF*	*OLS AICc*	*GWR R2*	*GWR I*	*GWR AICc*
SVI	0,50	0,09*	0,0000	0,560445	1,71	2163,25	0,50	0,09*	2162,08
POP_DEN			0,1618	-0,11242	2,23				
GREEN_DEN			0,9939	-0,00044	1,17				
CYCLE_DEN			0,3431	-0,08313	2,66				
INT_DEN			0,5982	-0,03661	1,67				
HOSP_DEN			0,1227	0,092947	1,25				
SPRMKT_DEN			0,3867	-0,0633	1,85				
PHARMA_DEN			0,6440	0,034886	1,97				
HOSP_DIST			0,4650	0,061241	2,43				
PHARMA_DIST			0,0181	0,214125	2,80				
GREEN_DIST			0,2866	0,085383	2,22				
SPRMKT_DIST			0,4541	-0,07665	3,63				

* *Statistically significant p-value ($p < 0,05$)*

Figure 235 - Model III – Cases, Std. Residuals by MODZCTA (OLS), NYC

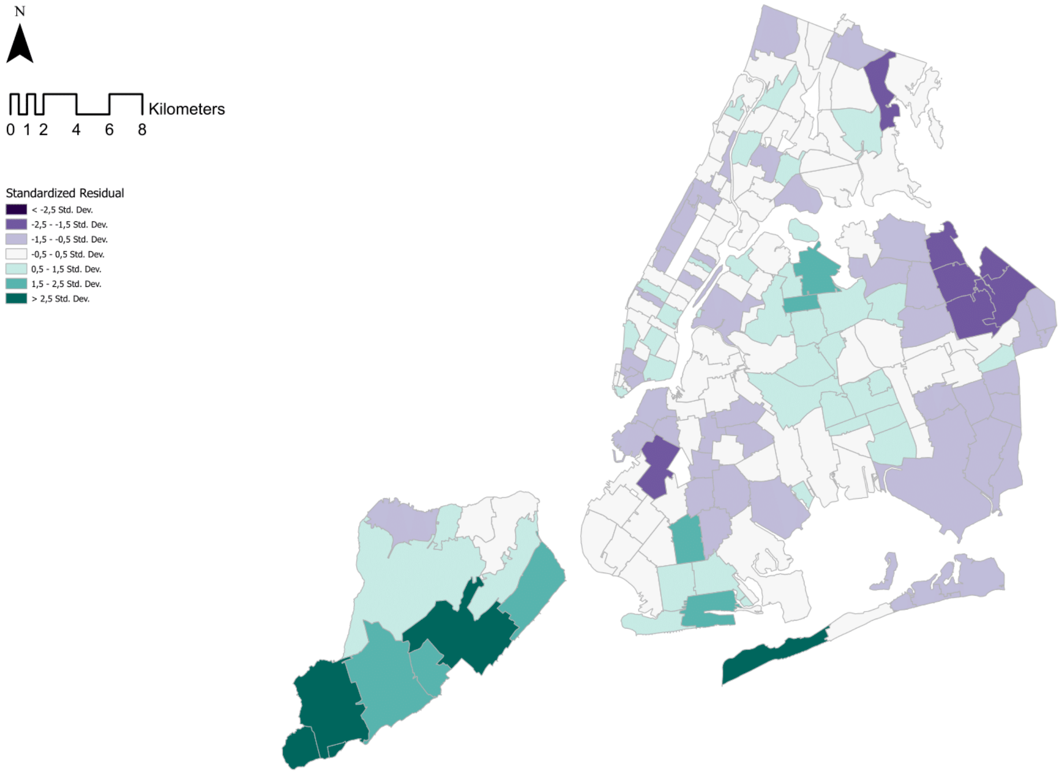


Figure 236 - Model III – Cases, Std. Residuals by MODZCTA (GWR), NYC

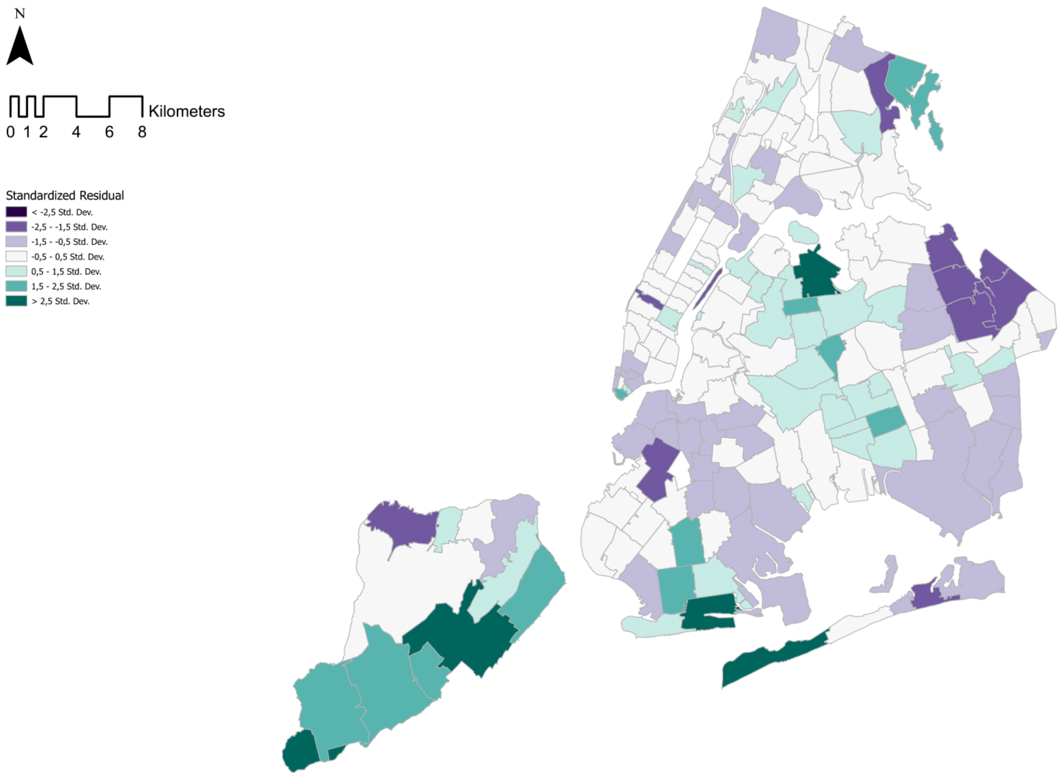


Figure 237 - Model III – Hotspots of the Std. Residuals of the cases by MODZCTA (OLS), NYC

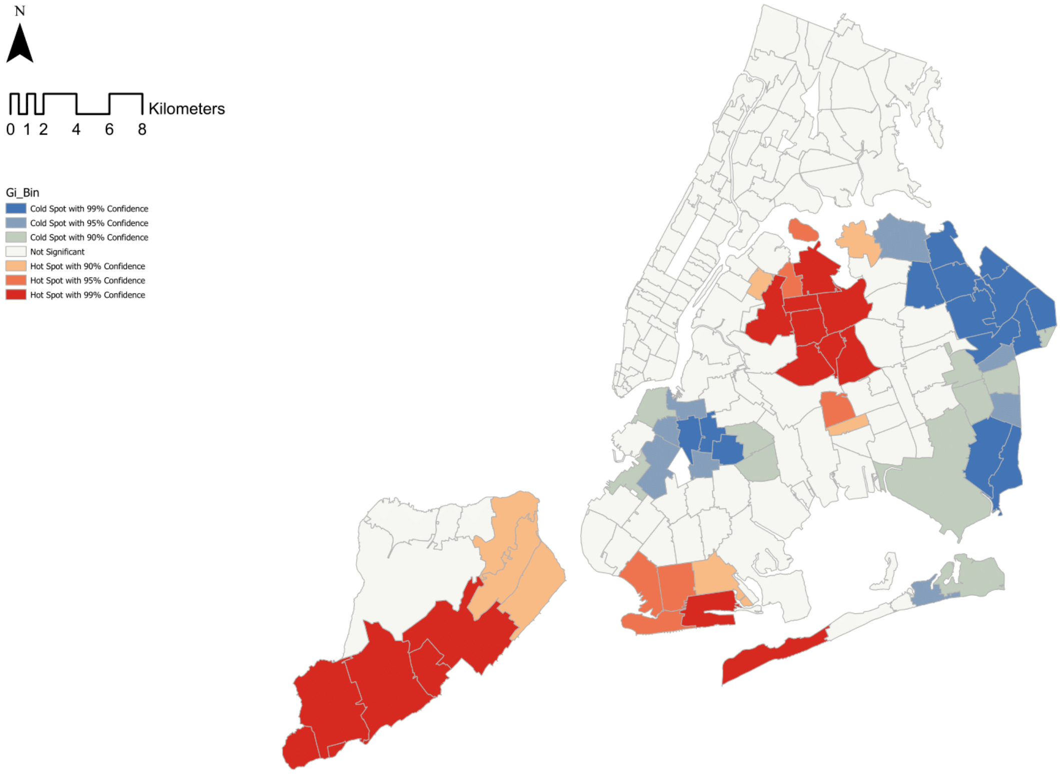


Figure 238 - Model III – Hotspots of the Std. Residuals of the cases by MODZCTA (GWR), NYC

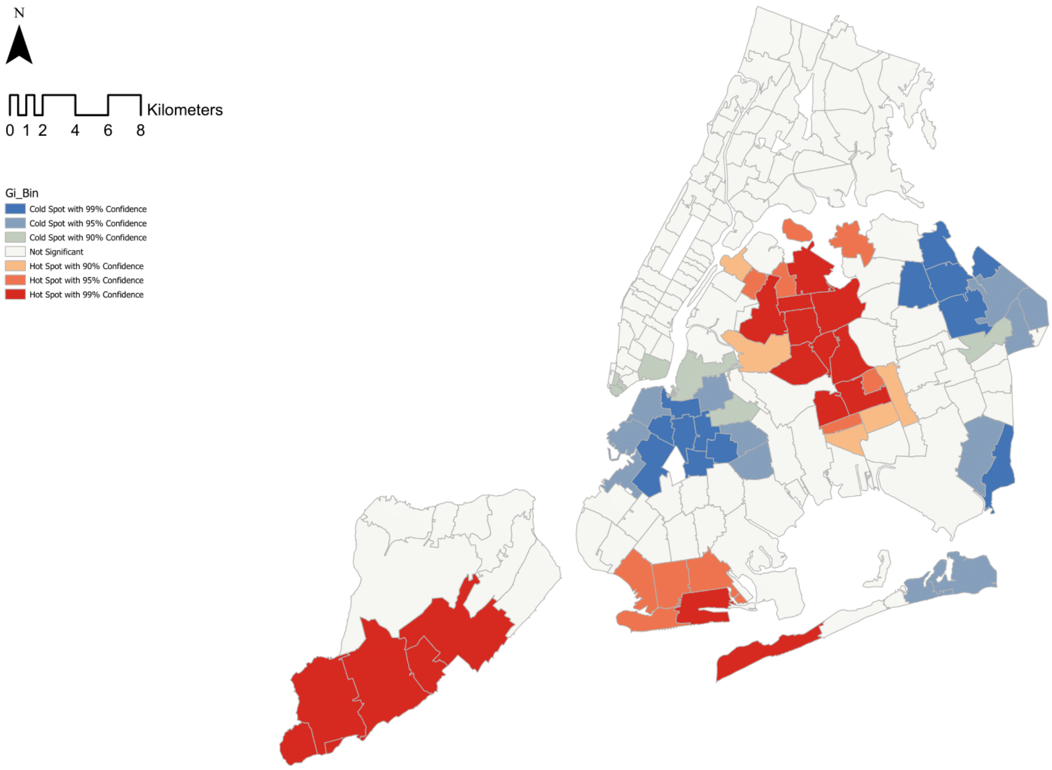


Figure 239 - Model III – Deaths, Std. Residuals by MODZCTA (OLS), NYC

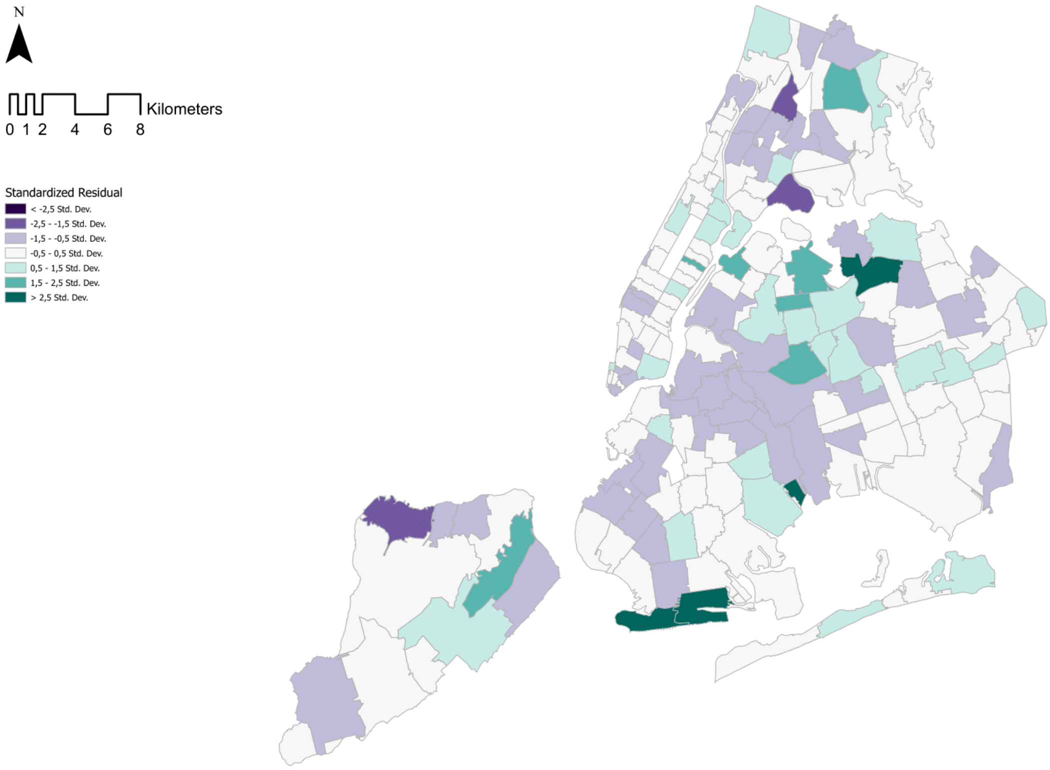


Figure 240 - Model III – Deaths, Std. Residuals by MODZCTA (GWR), NYC

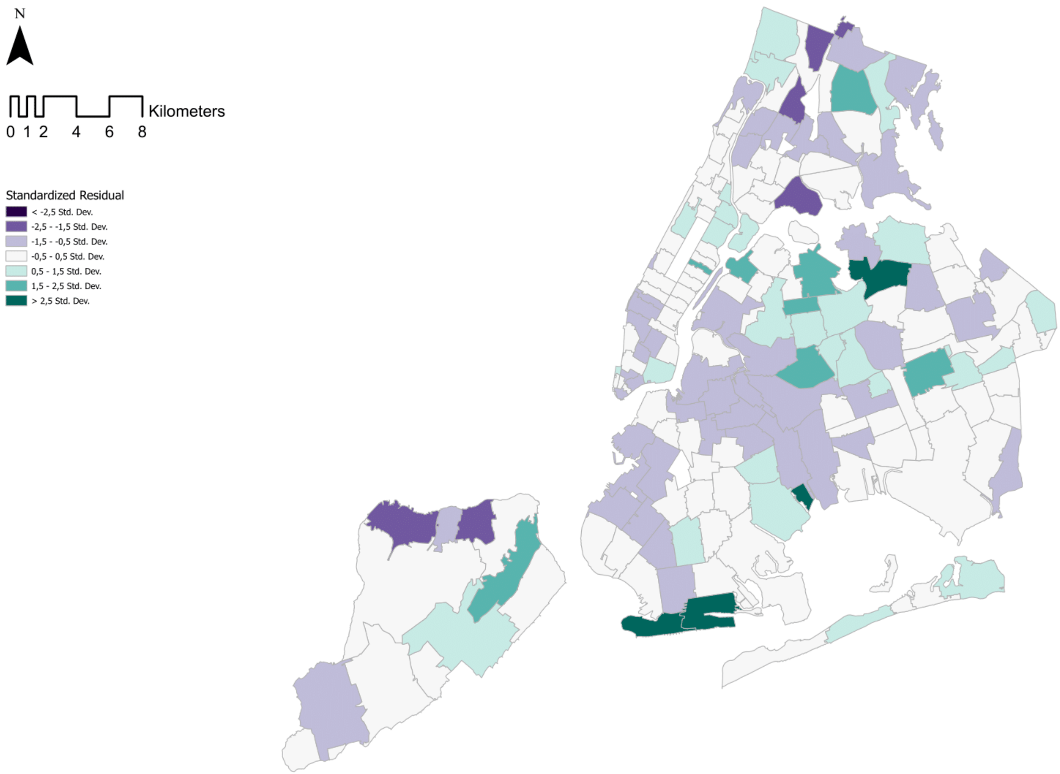


Figure 241 - Model III – Hotspots of the Std. Residuals of the deaths by MODZCTA (OLS), NYC

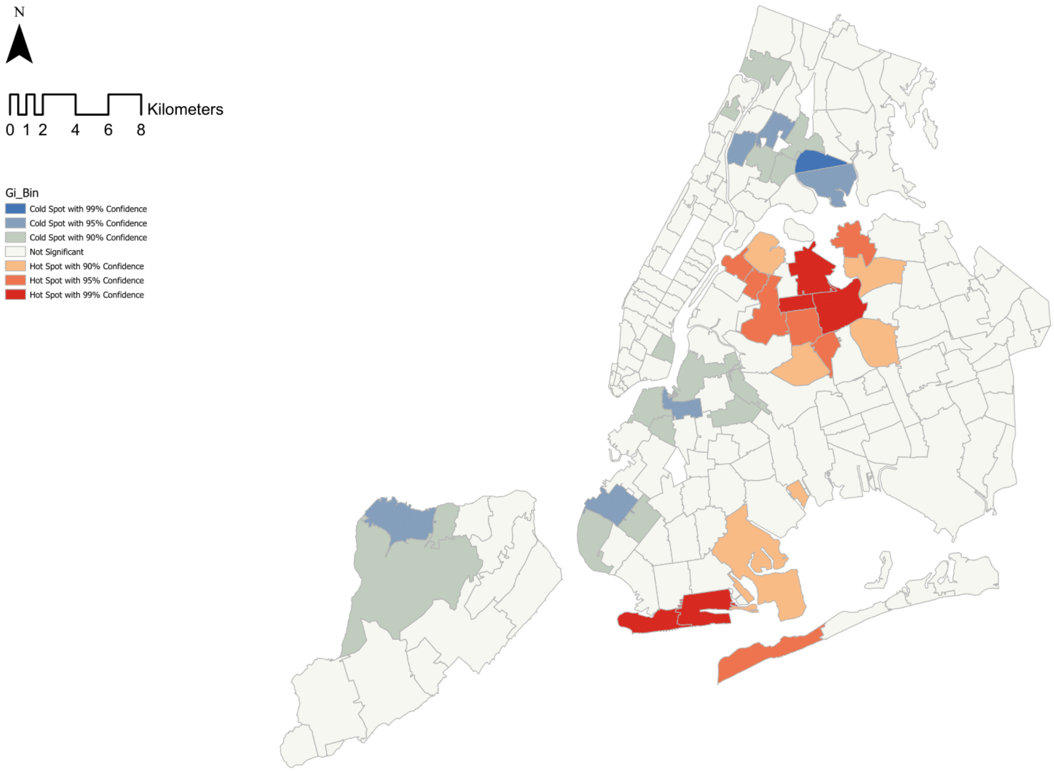
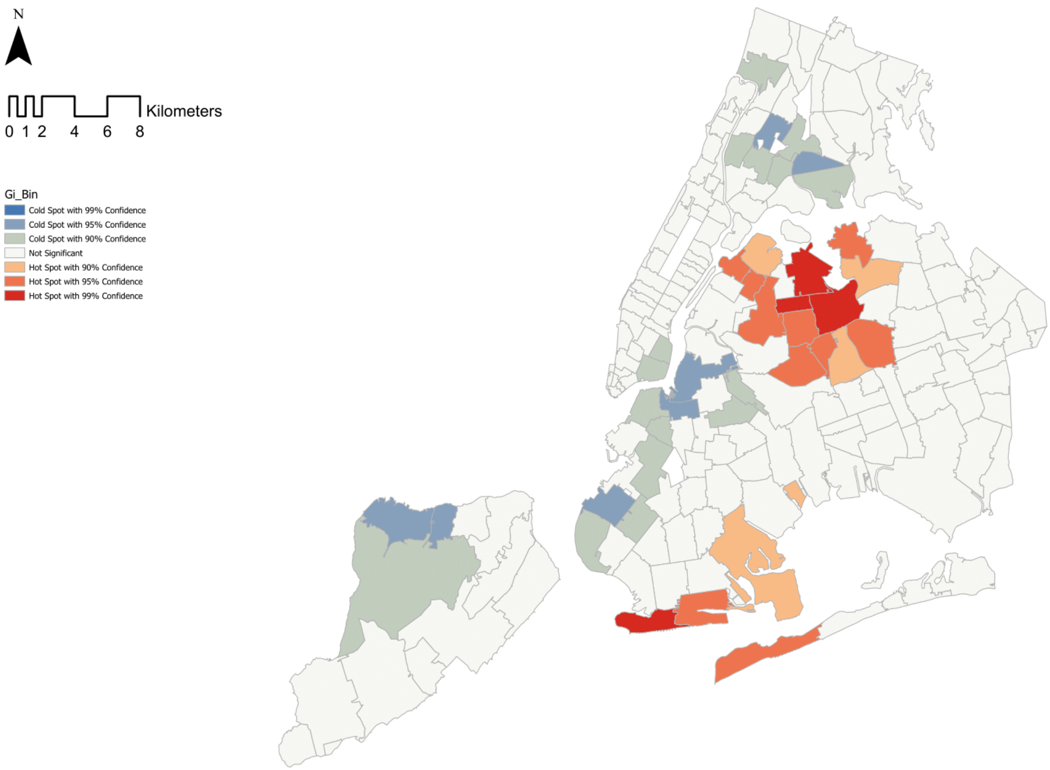


Figure 242 - Model III – Hotspots of the Std. Residuals of the deaths by MODZCTA (GWR), NYC



From the Hotspots analysis (Fig. 237, 238, 241 and 242) carried out on the standardised residuals of the four regressions, it is possible to notice where the model is still presenting issues related to spatial autocorrelation. When it comes to the analysis go the spread, in Staten Island, specifically, there seem to be some units that are still affected by clustering. Whereas Manhattan is not affected by spatial autocorrelation, Queens and Brooklyn have several hot and cold spots. For future analytical improvements, these areas might be vital in understanding the missing parameters in this research. The GWR does help to reduce spatial autocorrelation when analysing the cases. Looking at Fig. 236 and 240, despite the visible level of clustering characterising both maps, there is a noticeable improvement in some areas, specifically, East Queens and some areas in Staten Island. As demonstrated by the tables before, the regressions involving mortality are not significantly affected, as shown in Figures 241 and 242. However, there seem to be some hotspots in Queens, specifically in the MODZCTAs around La Guardia airport.

Table 30 - Summary of the results by model (Regressions on cases), NYC

Model	*OLS* R^2	*OLS* *I*	*OLS* *AICc*	*GWR* R^2	*GWR* *I*	*GWR* *AICc*
Model I	0,18	0,70	3247,86	0,23	0,68	3235,57
Model II	0,42	0,44	3195,72	0,47	0,38	3179,79
Model III	0,57	0,50	3148,37	0,61	0,43	3126,33

Table 31 - Summary of the results by model (Regressions on deaths), NYC

Model	*OLS* *R2*	*OLS* *I*	*OLS* *AICc*	*GWR* *R2*	*GWR* *I*	*GWR* *AICc*
Model I	0,35	0,31	2193,43	0,37	0,29	2189,63
Model II	0,29	0,15	2221,47	0,29	0,14	2221,37
Model III	0,50	0,09	2163,25	0,50	0,09	2162,08

Tab. 30 and 31 display a summary of the results of the different models. It is possible to notice how, as mentioned before, there is an improvement and increasing explanatory power by employing Model III. The final values are significant (0,61 and 0,50). The upward trend observed as we "complexify" the analysis of the pandemic in relation to the socio-spatial dimension is certainly promising. Fig. 243 to 248 instead show the coefficients of each variable for each model, both in terms of cases and deaths. The diagrams substantially summarise the various findings and facts that have been analysed through the different models. Once more, for NYC, as well as for London, it is quite clear how the SVI has a larger explanatory power compared to the other indicators. Nevertheless, complexifying the analysis, creating a more multifaceted framework of analysis, employing a variety of indicators helps to improve the model. The coefficients are quite stable when studying the spread and the mortality. This fact is not surprising, as deaths and cases had similar patterns across the city.

Figure 243 - Model I coefficients (cases), NYC

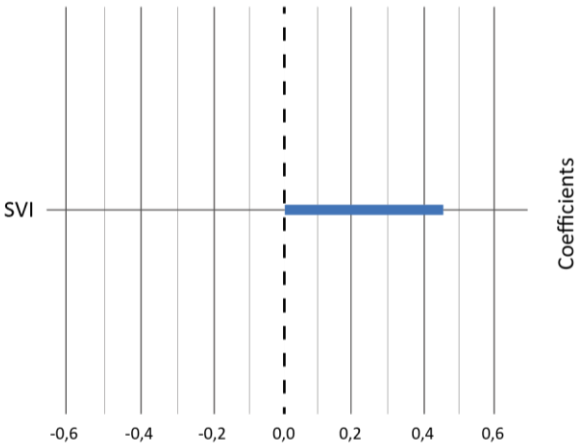


Figure 244 - Model I coefficients (deaths), NYC

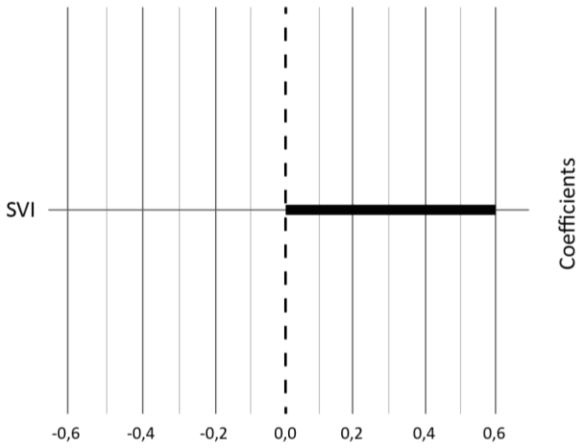


Figure 245 - Model II coefficients (cases), NYC

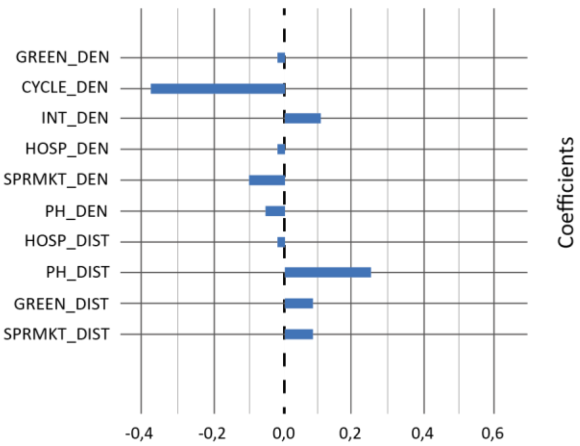


Figure 246 - Model II coefficients (deaths), NYC

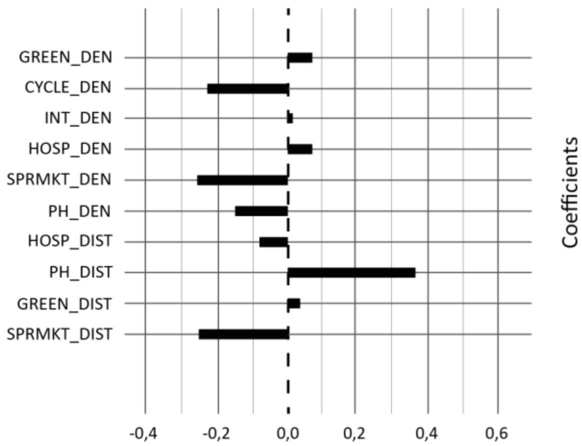


Figure 247 - Model III coefficients (cases), NYC

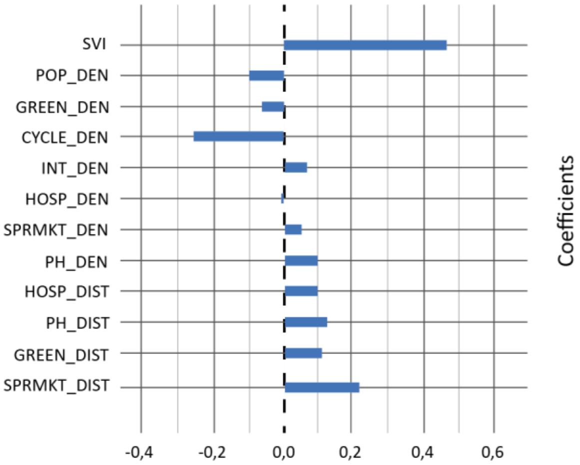
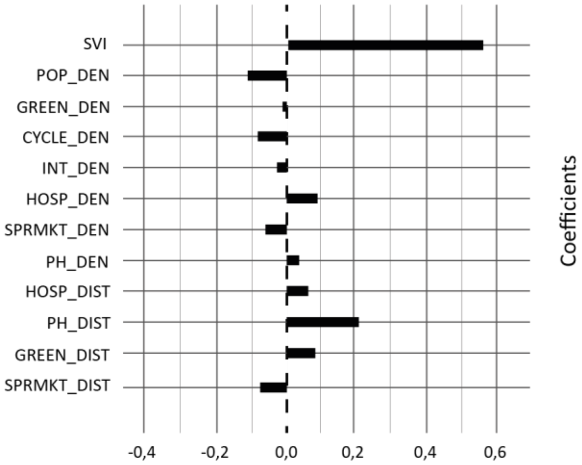


Figure 248 - Model III coefficients (deaths), NYC



5.4.3 Rome

The correlation matrix (Tab. 32) shows the correlation between population density and the SVI and the rest of the indicators. The SVI has no high correlation with any of the variables. On the other hand, population density displays some stronger correlations, although all being below 0,50. The highest correlations are found with the indicators of proximity (distance to hospitals, pharmacies, green areas, and supermarkets), with values ranging from -0,40 to -0 49. Therefore, as a trend, population density is negatively correlated with all the indicators of proximity. Moreover, a moderately strong correlation exists with the density of intersections (0,50).

Table 32 - Correlation matrix Model III, London

	Variables	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
1	SVI	**1**													
2	POP_DEN	**-0,25**	**1**												
3	GREEN_DEN	**0,18**	**-0,21**	**1**											
4	CYCLE_DEN	-0,11	**0,33**	0,03	**1**										
5	INT_DEN	-0,14	**0,50**	-0,03	**0,35**	**1**									
6	HOSP_DEN	0,05	-0,12	**0,47**	-0,02	**0,30**	**1**								
7	SPRMKT_DEN	**-0,24**	**0,29**	-0,11	**0,19**	**0,49**	-0,02	**1**							
8	PHARMA_DEN	**-0,25**	**0,33**	-0,08	**0,20**	**0,59**	0,01	**0,77**	**1**						
9	HOSP_DIST	**0,29**	**-0,45**	-0,08	**-0,30**	**-0,52**	-0,16	**-0,33**	**-0,36**	**1**					
10	PHARMA_DIST	**0,34**	**-0,49**	-0,06	**-0,30**	**-0,48**	-0,08	**-0,38**	**-0,43**	**0,72**	**1**				
11	GREEN_DIST	**0,35**	**-0,40**	-0,08	**-0,25**	**-0,39**	-0,07	**-0,23**	**-0,27**	**0,74**	**0,85**	**1**			
12	SPRMKT_DIST	**0,36**	**-0,42**	-0,07	**-0,24**	**-0,39**	-0,06	**-0,36**	**-0,34**	**0,72**	**0,92**	**0,91**	**1**		
13	TOTAL CASES	**0,29**	**-0,33**	**0,49**	-0,08	**-0,18**	**0,56**	**-0,27**	**-0,27**	0,06	0,02	-0,10	-0,04	**1**	
14	TOTAL DEATHS	0,15	-0,04	**0,59**	0,10	0,07	**0,68**	-0,09	-0,05	-0,10	-0,07	-0,08	-0,05	**0,70**	**1**

Values in bold statistically significant p-value (p < 0,05).

Tab. 33 shows the results of the regressions concerning the spread of the pandemic. It is possible to notice how the model's overall performance (R^2) is significantly improved compared to Model I and II. In this case, the GWR helps increase the model's predictive power concerning the spread only limitedly (from 0,59 to 0,60). Looking at the coefficients, the SVI has a relevant figure (0,27), although not the highest amongst the indicators. Whereas for London and NYC, the SVI had the strongest β, in this case, the spatial indicators show a higher correlation. Specifically, the density of hospitals, intersections and distance to green areas show the strongest coefficients (0,58, -0,33 and -0,48, respectively). Concerning the spread, it is possible to notice how the residuals are still affected by spatial autocorrelation. Despite the improvement brought by the GWR, which reduced Moran's I from 0,20 to 0,14, the value is still in the range of indicating clustering, as it occurred for London and NYC in the previous analyses.

Tab. 34 lists the outcomes of the regressions concerning mortality. In this case, the overall R^2 is equal regardless of the regression model used. The GWR does bring an improvement in terms of reduced spatial autocorrelation, as Moran's Indices indicate (from 0,05 to 0,01). The values, contrarily to what was observed for the regression on the spread, indicate minimal clustering. This difference in spatial was also observed while analysing London and NYC. The SVI, in this regression, has a coefficient of 0,11. The indicators with the highest βs are the same as the ones identified while analysing the spread, namely, hospitals density (0,65), distance to green areas (-0,2) and intersections density (-0,30). Notably, population density has a higher coefficient (0,21) when analysing deaths than the spread study (β=-0,09). In general, Model III's performance is higher compared to Model I and Model II, as occurred in London and NYC.

Table 33 - Regressions' results, cases, Model III, Rome

Variables	*OLS R^2*	*OLS I*	*OLS p-value*	*OLS β*	*OLS VIF*	*OLS AICc*	*GWR R^2*	*GWR I*	*GWR AICc*
SVI	0,59	0,20*	0,0000	0,266867	1,28	2431,60	0,60	0,14*	2425,78
POP_DEN			0,2214	-0,0888	1,80				
GREEN_DEN			0,0712	0,119118	1,48				
CYCLE_DEN			0,2984	0,062568	1,23				
INT_DEN			0,0003	-0,33085	2,75				
HOSP_DEN			0,0000	0,584172	1,70				
SPRMKT_DEN			0,7747	-0,02586	2,80				
PHARMA_DEN			0,9647	0,00427	3,20				
HOSP_DIST			0,0357	0,188503	2,72				
PHARMA_DIST			0,2707	0,173444	8,48				
GREEN_DIST			0,0009	-0,47931	6,88				
SPRMKT_DIST			0,5407	-0,11276	11,66				

Table 34 - Regressions' results, deaths, Model III, Rome

Variables	*OLS R^2*	*OLS I*	*OLS p-value*	*OLS β*	*OLS VIF*	*OLS AICc*	*GWR R^2*	*GWR I*	*GWR AICc*
SVI	0,59	0,05	0,0570	0,11638	1,28	1721,73	0,59	0,01	1720,48
POP_DEN			0,0033	0,214826	1,80				
GREEN_DEN			0,0000	0,302543	1,48				
CYCLE_DEN			0,0316	0,129392	1,23				
INT_DEN			0,0006	-0,3098	2,75				
HOSP_DEN			0,0000	0,652157	1,70				
SPRMKT_DEN			0,9127	-0,00984	2,80				
PHARMA_DEN			0,2741	0,105286	3,20				
HOSP_DIST			0,7479	0,02845	2,72				
PHARMA_DIST			0,9817	-0,00358	8,48				
GREEN_DIST			0,1543	-0,20119	6,88				
SPRMKT_DIST			0,3586	0,168394	11,66				

* *Statistically significant p-value ($p < 0,05$)*

Figure 249 - Model III – Cases, Std. Residuals by ZUB (OLS), Rome

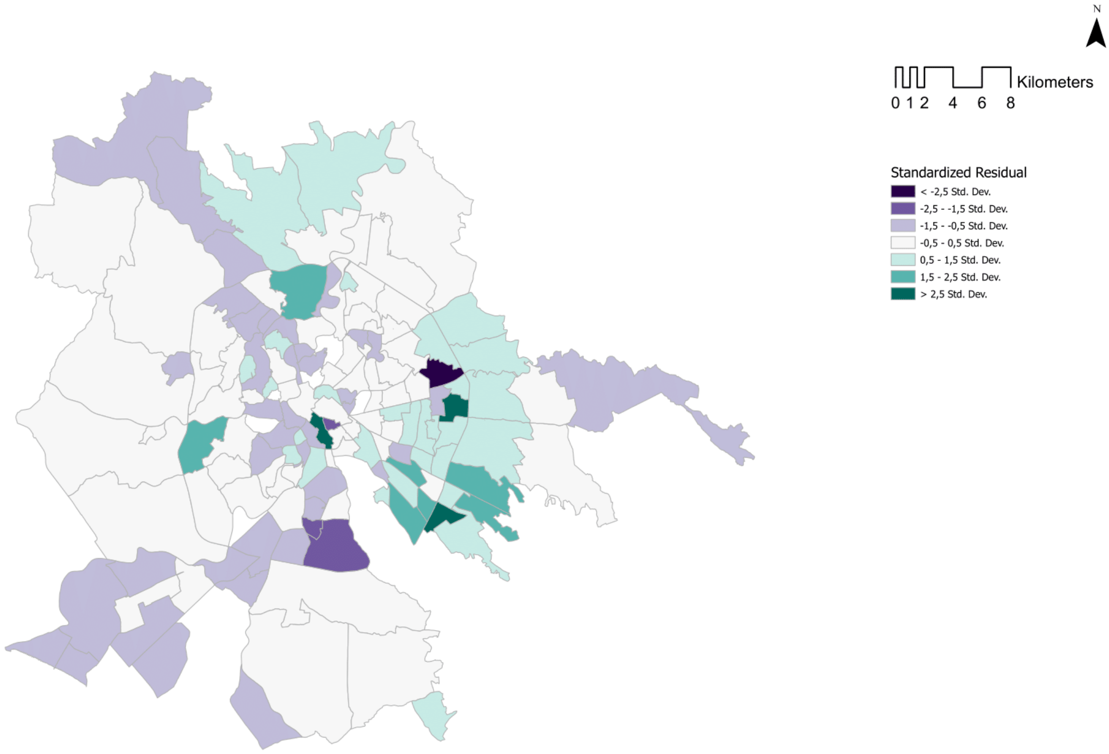


Figure 250 - Model III – Cases, Std. Residuals by ZUB (GWR), Rome

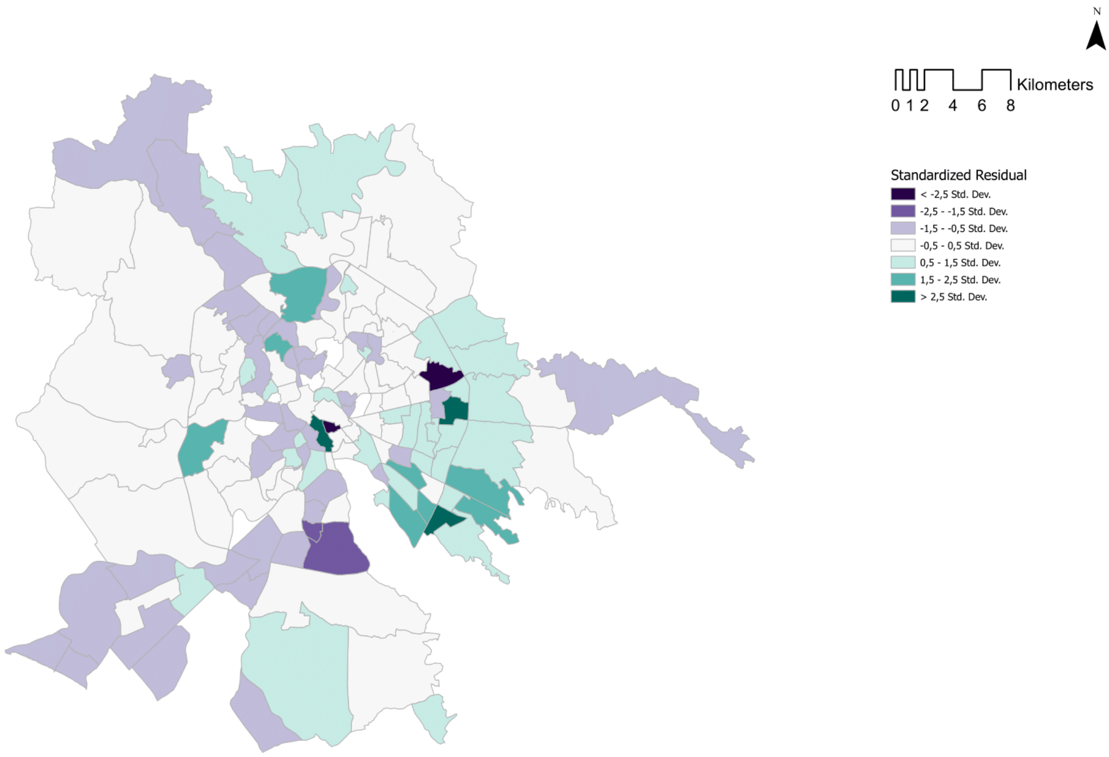


Figure 251 - Model III – Hotspots of the Std. Residuals of the cases by ZUB (OLS), Rome

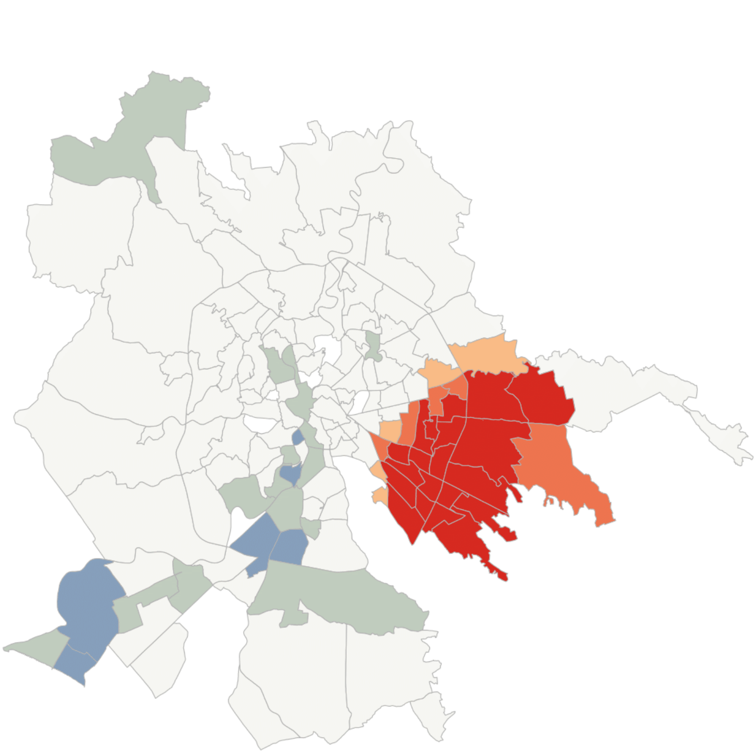


Figure 252 - Model III – Hotspots of the Std. Residuals of the cases by ZUB (GWR), Rome

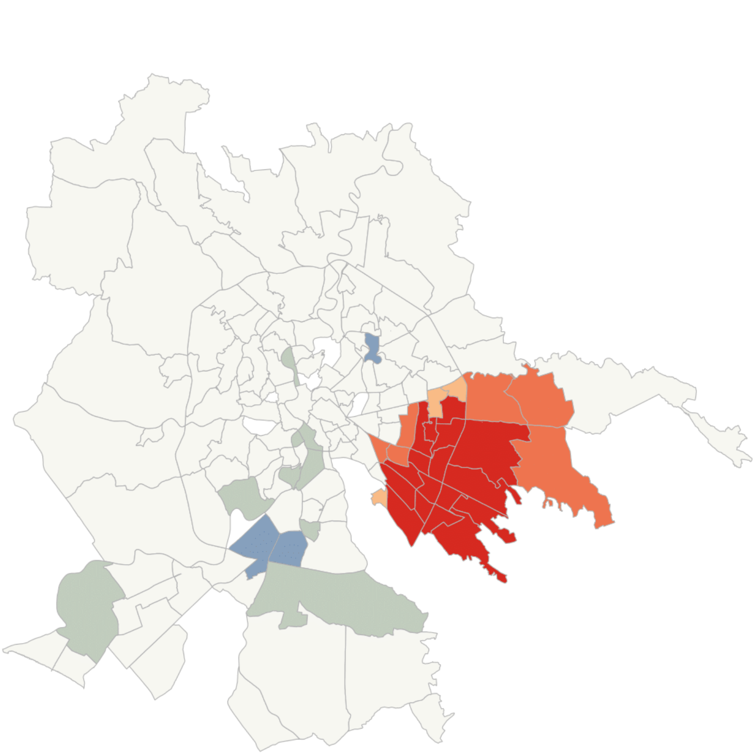


Figure 253 - Model III – Deaths, Std. Residuals by ZUB (OLS), Rome

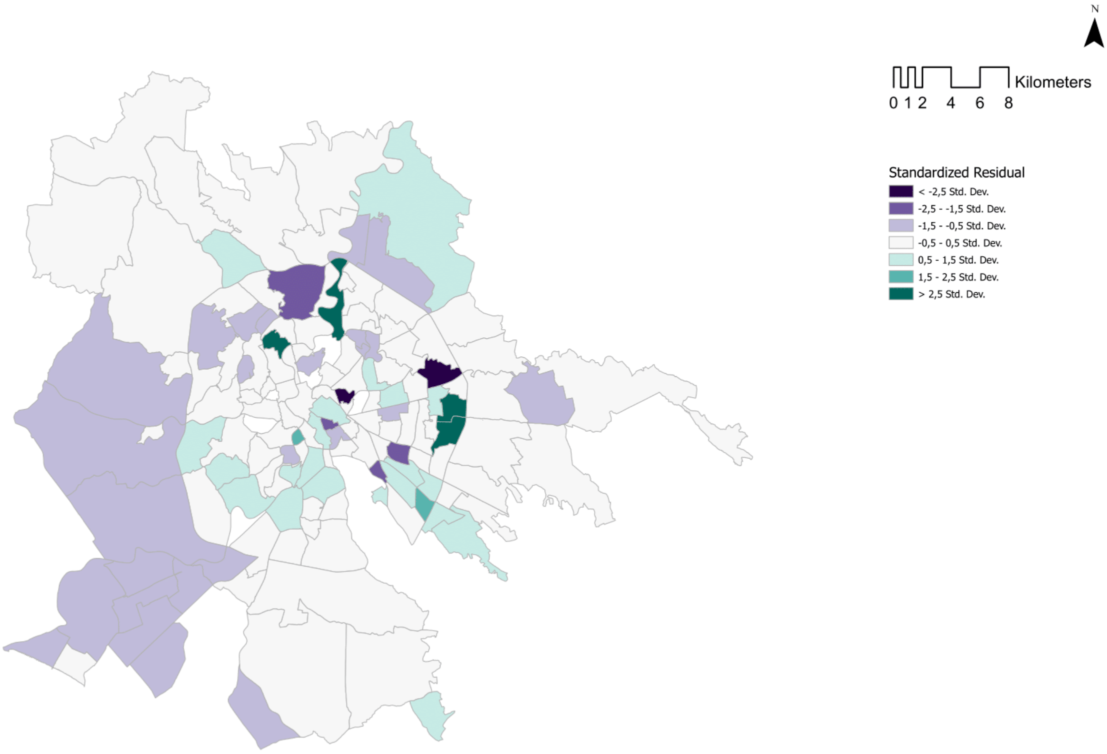


Figure 254 - Model III – Deaths, Std. Residuals by ZUB (GWR), Rome

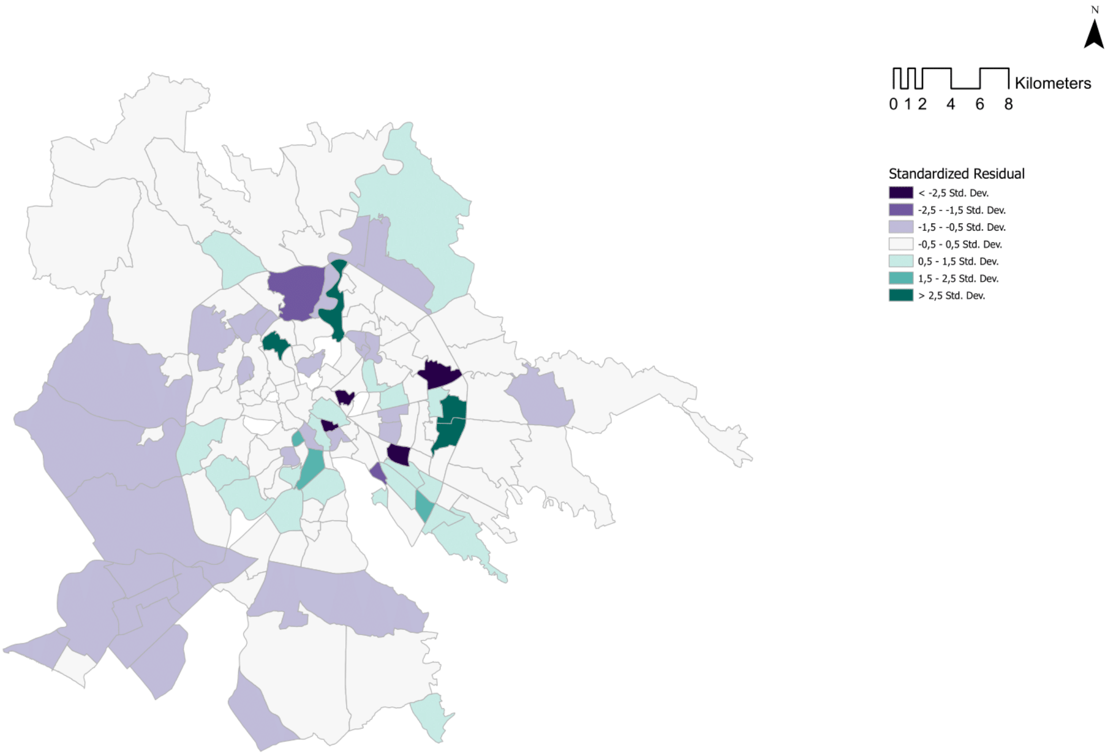


Figure 255 - Model III – Hotspots of the Std. Residuals of the deaths by ZUB (OLS), Rome

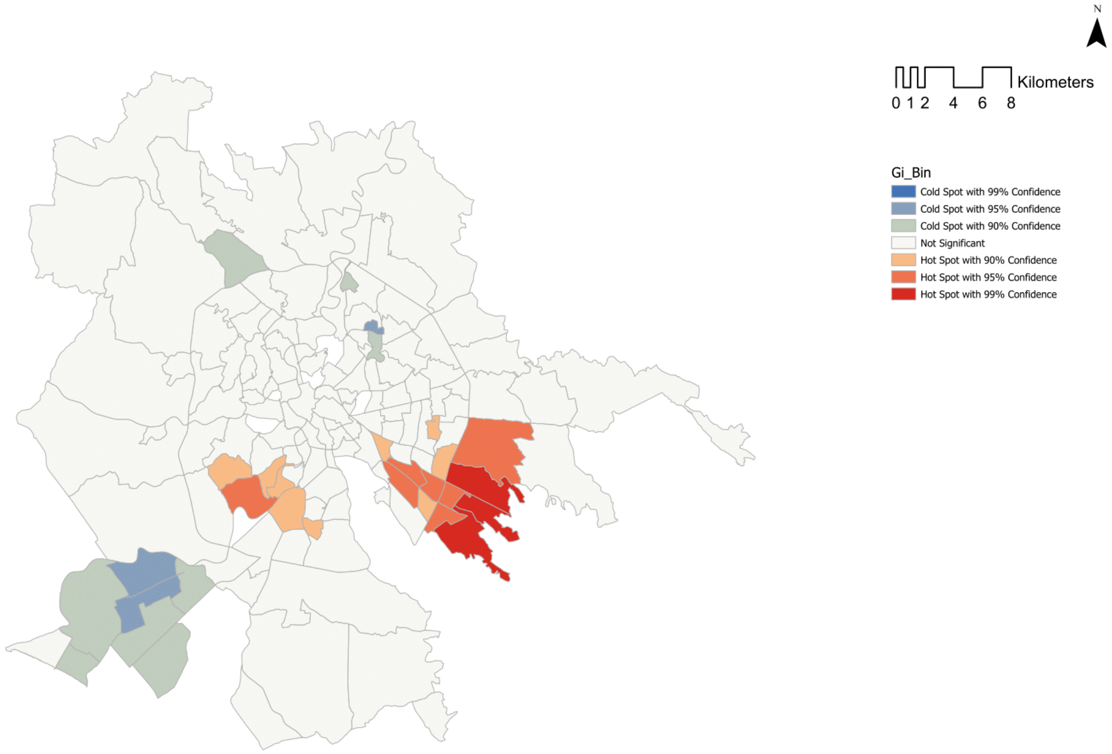
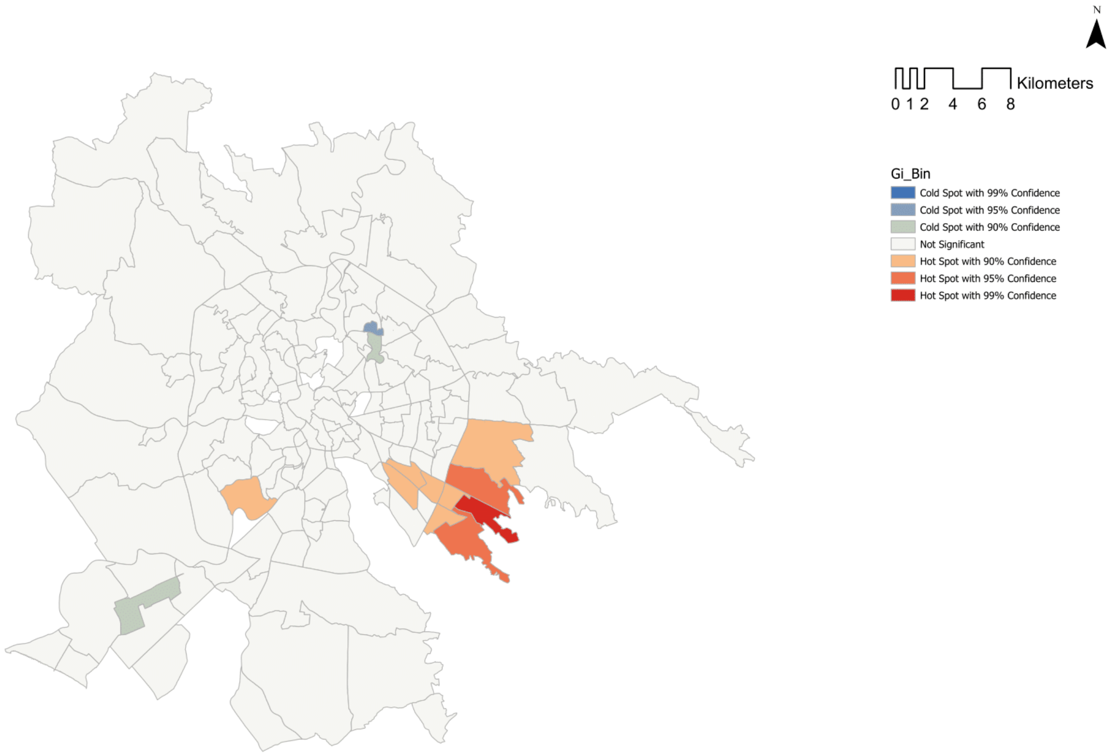


Figure 256 - Model III – Hotspots of the Std. Residuals of the deaths by ZUB (GWR), Rome



From the Hotspots analysis (Fig. 251, 252, 255 and 256) carried out on the standardised residuals of the four regressions, it is possible to notice where the model is still presenting issues related to spatial autocorrelation. Both models have similar outputs in terms of areas affected by clustering. In fact, by observing the maps, it is possible to notice how the eastern part of Rome, for both the analysis of cases and deaths, is still accounting for a significant share of the overall spatial autocorrelation. This seems to worsen when it comes to the spread analysis, where the hot spots encompass more units. This part of the municipality includes ZUBs such as *Morena, Barcaccia, Torre Angela,* and *Tor Vergata*. For future analytical improvements, as already mentioned, these areas might be crucial in understanding the spatial missing parameters of the research. The GWR helps reduce spatial autocorrelation when analysing the cases. In fact, Looking at Fig. 250 and 252, there is a noticeable improvement in some areas, specifically, the eastern and southern parts of the municipality.

Table 35 - Summary of the results by model (Regressions on cases), Rome

Model	*OLS* R^2	*OLS* *I*	*OLS* *AICc*	*GWR* R^2	*GWR* *I*	*GWR* *AICc*
Model I	0,08	0,13	2533,49	0,10	0,12	2530,98
Model II	-0,01	-0,01	3462,00	-0,02	-0,01	3462,33
Model III	0,59	0,20	2431,60	0,60	0,14	2425,78

Table 36 - Summary of the results by model (Regressions on deaths), Rome

Model	*OLS* R^2	*OLS* *I*	*OLS* *AICc*	*GWR* R^2	*GWR* *I*	*GWR* *AICc*
Model I	0,02	0,02	1834,51	0,01	0,02	1834,69
Model II	0,50	-0,01	1932,23	0,50	-0,02	1932,20
Model III	0,59	0,05	1721,73	0,59	0,01	1720,48

Tab. 35 and 36 display a summary of the different models' results. It is possible to notice how, as mentioned before, there is an improvement and increasing explanatory power by employing Model III. The final values are significant (0,60 and 0,59). The upward trend observed as we "complexify" the analysis of the pandemic in relation to the socio-spatial dimension is certainly promising. Fig. 257 to 262 instead show the coefficients of each variable for each model, both in terms of cases and deaths. Different from what was observed in the previous case studies, the SVI does not account for the highest coefficient. Some spatial indicators, instead, show higher values, as discussed before. Notably, some variables perform differently when studying the spread and the deaths. For instance, the distance to supermarkets has a negative coefficient when analysing the cases (-0,11), whereas it shows a positive value when examining deaths (0,17). This "multidimensional" power of the indicators will be discussed in the last chapter.

Figure 257 - Model I coefficients (cases), Rome

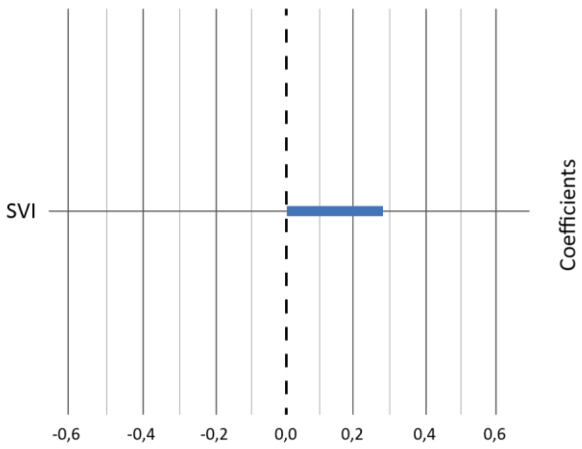


Figure 258 - Model I coefficients (cases), Rome

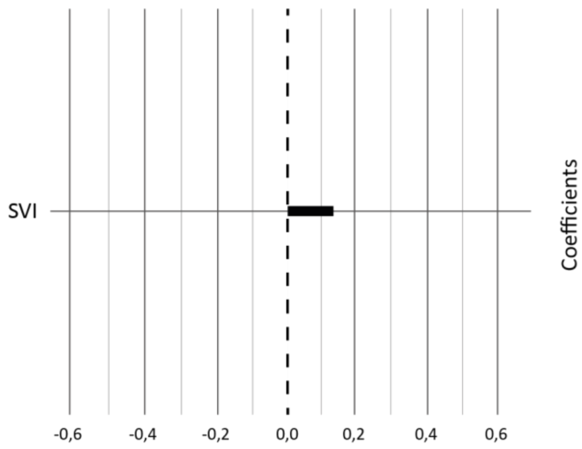


Figure 259 - Model II coefficients (cases), Rome

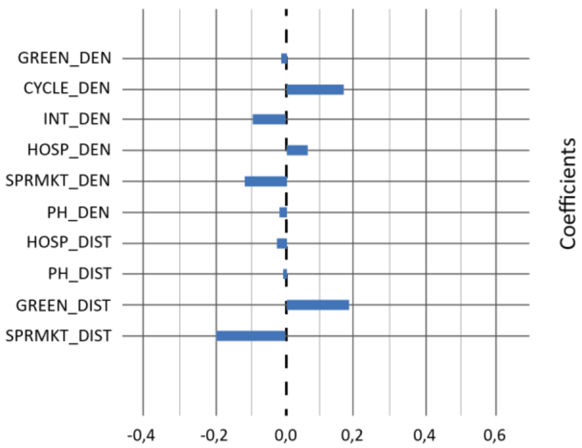


Figure 260 - Model II coefficients (cases), Rome

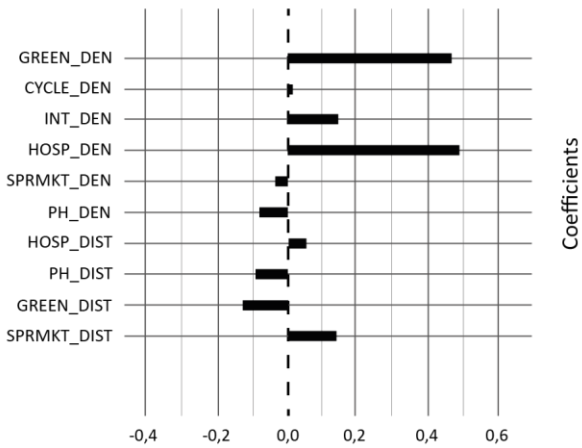


Figure 261 - Model III coefficients (cases), Rome

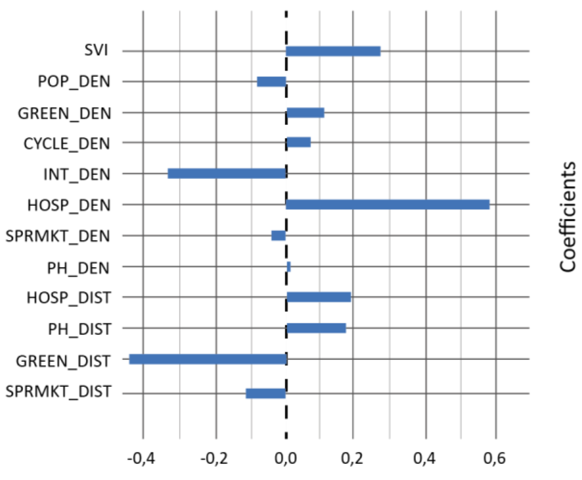
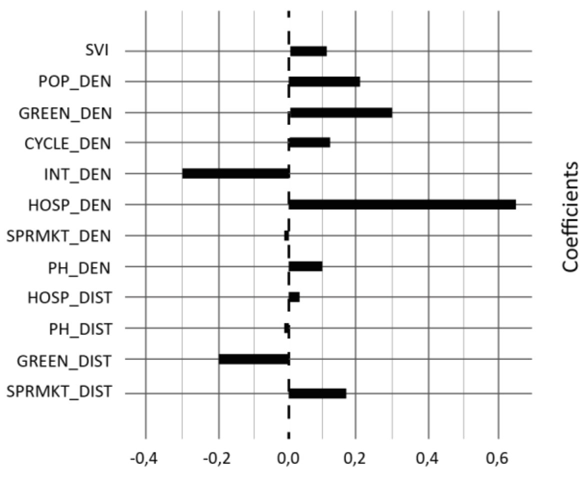


Figure 262 - Model III coefficients (cases), Rome



5.4.4 Sao Paulo

Besides the results already discussed, the correlation matrix (Tab. 37) shows what type of correlation exists between population density and the SVI and the rest of the indicators. The SVI is moderately correlated with most of the indicators, although all being below 0,60. On the other hand, population density displays weaker correlations, except for the correlation with intersections density, where a value of 0,74 is found. The rest of the coefficients range from -0,37 to 0,16. Moreover, as a trend, population density is negatively correlated with all the indicators of proximity, as observed in the other case studies.

Table 37 - Correlation matrix Model III, Sao Paulo

	Variables	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
1	SVI	**1**													
2	POP_DEN	-0,10	**1**												
3	GREEN_DEN	**0,24**	**-0,30**	**1**											
4	CYCLE_DEN	**-0,51**	**0,29**	-0,19	**1**										
5	INT_DEN	-0,08	**0,74**	**-0,40**	**0,23**	**1**									
6	HOSP_DEN	**-0,54**	0,11	-0,10	**0,37**	-0,09	**1**								
7	SPRMKT_DEN	**-0,46**	0,16	-0,12	**0,61**	0,14	**0,47**	**1**							
8	PHARMA_DEN	**-0,49**	0,11	-0,10	**0,53**	0,13	**0,46**	**0,85**	**1**						
9	HOSP_DIST	**0,51**	**-0,39**	**0,78**	**-0,44**	**-0,49**	**-0,41**	**-0,38**	**-0,36**	**1**					
10	PHARMA_DIST	**0,44**	**-0,38**	**0,89**	**-0,38**	**-0,48**	**-0,24**	**-0,28**	**-0,27**	**0,89**	**1**				
11	GREEN_DIST	-0,09	**-0,30**	**0,60**	-0,02	**-0,28**	-0,02	-0,01	0,00	**0,40**	**0,50**	**1**			
12	SPRMKT_DIST	**0,52**	**-0,37**	**0,77**	**-0,48**	**-0,45**	**-0,32**	**-0,44**	**-0,36**	**0,86**	**0,89**	**0,37**	**1**		
13	TOTAL CASES	**0,24**	-0,08	0,00	**-0,26**	-0,05	-0,09	**-0,23**	**-0,38**	0,11	0,10	-0,04	0,13	**1**	
14	TOTAL DEATHS	-0,10	0,07	**-0,25**	0,02	**0,27**	-0,13	-0,13	-0,19	**-0,24**	**-0,28**	0,00	**-0,24**	0,13	**1**

Values in bold statistically significant p-value (p < 0,05).

Tab. 38 shows the results of the regressions concerning the spread of the pandemic. It is possible to notice how the model's overall performance (R^2) is not significantly improved compared to Model I and II. The GWR helps, although minimally, increase the model's predictive power concerning the spread (from 0,11 to 0,13). Turning to the coefficients, the SVI has a lower figure (0,09) than other indicators. Specifically, the density of supermarkets and pharmacies show the strongest coefficients, although with opposite signs (0,43 and -0,67 respectively). Therefore, despite the overall low R^2 value, some indicators have relevant coefficients when it comes to analysing the spread of the pandemic. The level of spatial autocorrelation indicates some clustering, despite the improvement brought by the GWR, which reduced Moran's I from 0,10 to 0,08.

The regressions concerning mortality (Tab. 39) show some similar trends as well as some divergences. The overall R^2 is minimally improved when the GWR is carried out. This latter also brings an improvement in terms of reduced spatial autocorrelation, as Moran's Indices indicate (from 0,35 to 0,31), indicative of clustering. However, this trend differs when compared to the other case studies. In fact, for London, NYC and Rome, the models on mortality presented lower spatial autocorrelation than the spread analysis. In Sao Paulo, instead, it seems to be the opposite. Another divergence is the value of the SVI. Whereas for the other case studies the SVI's coefficients were always positive, in this regression, it has a negative coefficient of -0,13. The indicators with the highest βs are not the same as those identified while studying the spread. For example, the density of supermarkets, previously pointed out as one of the indicators with the highest coefficient, does not seem to be equally important when analysing the deaths (β= 0,05). Pharmacies density instead retains some of the relevance encountered in the analysis of the cases, although with a reduced coefficient (-0,38). On the other hand, some variables that did not account for significant coefficients before, have higher figures in this analysis, namely, distance to pharmacies and green areas (-0,29 and 0,17 respectively).

Table 38 - Regressions' results, cases, Model III, Sao Paulo

Variables	*OLS R^2*	*OLS I*	*OLS p-value*	*OLS β*	*OLS VIF*	*OLS AICc*	*GWR R^2*	*GWR I*	*GWR AICc*
SVI	0,11	0,10*	0,5458	0,089318	2,30	716,53	0,13	0,08*	1713,54
POP_DEN			0,413867	-0,12956	2,64				
GREEN_DEN			0,6397	-0,1201	6,93				
CYCLE_DEN			0,3070	-0,14189	2,02				
INT_DEN			0,4582	0,128915	3,17				
HOSP_DEN			0,2664	0,157309	2,09				
SPRMKT_DEN			0,0458	0,429866	4,76				
PHARMA_DEN			0,0009	-0,67235	4,01				
HOSP_DIST			0,8717	-0,04243	7,27				
PHARMA_DIST			0,9830	0,007593	13,32				
GREEN_DIST			0,9996	0,00068	1,84				
SPRMKT_DIST			0,5805	0,142978	7,04				

Table 39 - Regressions' results, deaths, Model III, Sao Paulo

Variables	*OLS R2*	*OLS I*	*OLS p-value*	*OLS β*	*OLS VIF*	*OLS AICc*	*GWR R2*	*GWR I*	*GWR AICc*
SVI	0,16	0,35*	0,3568	-0,13189	2,30	1131,65	0,18	0,31*	1129,78
POP_DEN			0,088718	-0,26266	2,64				
GREEN_DEN			0,8681	0,041153	6,93				
CYCLE_DEN			0,987488	0,002099	2,02				
INT_DEN			0,027704	0,374639	3,17				
HOSP_DEN			0,5018	-0,09169	2,09				
SPRMKT_DEN			0,788225	0,055212	4,76				
PHARMA_DEN			0,0443	-0,3840	4,01				
HOSP_DIST			0,8755	-0,03978	7,27				
PHARMA_DIST			0,3947	-0,29304	13,32				
GREEN_DIST			0,1767	0,173779	1,84				
SPRMKT_DIST			0,8397	-0,05053	7,04				

** Statistically significant p-value (p < 0,05)*

Figure 263 - Model III – Cases, Std. Residuals by Distrito (OLS), Sao Paulo

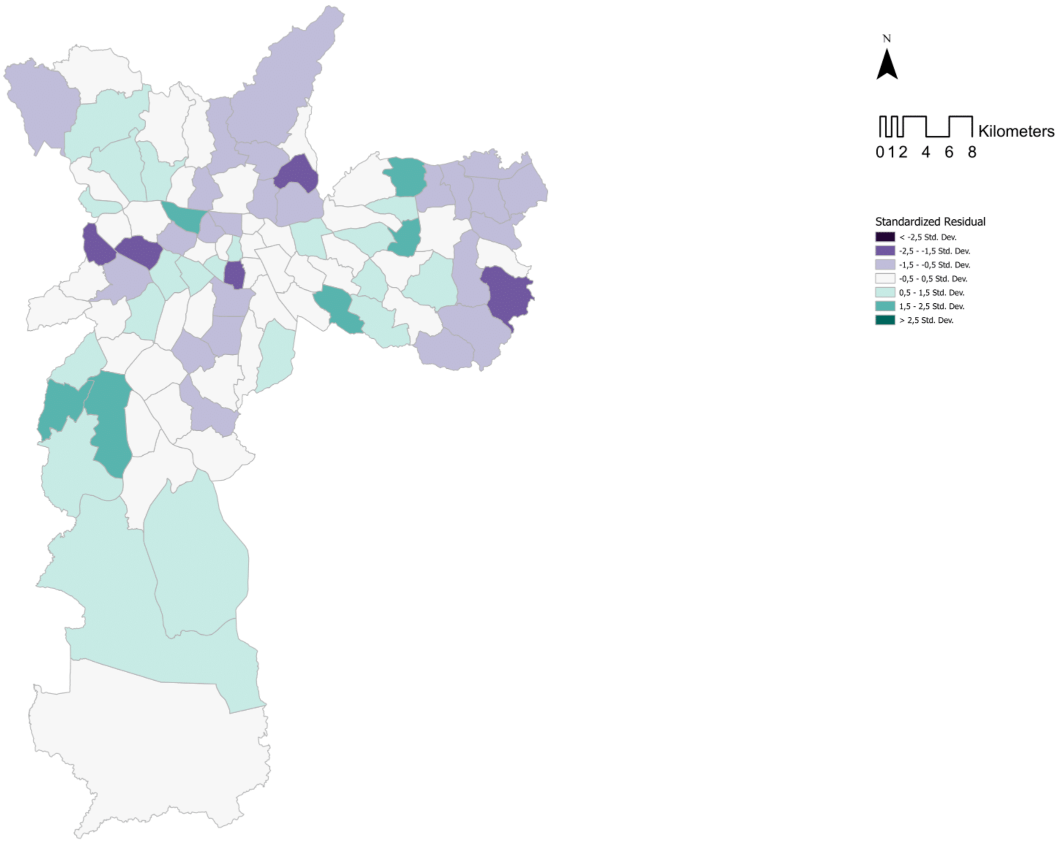


Figure 264 - Model III – Cases, Std. Residuals by Distrito (GWR), Sao Paulo

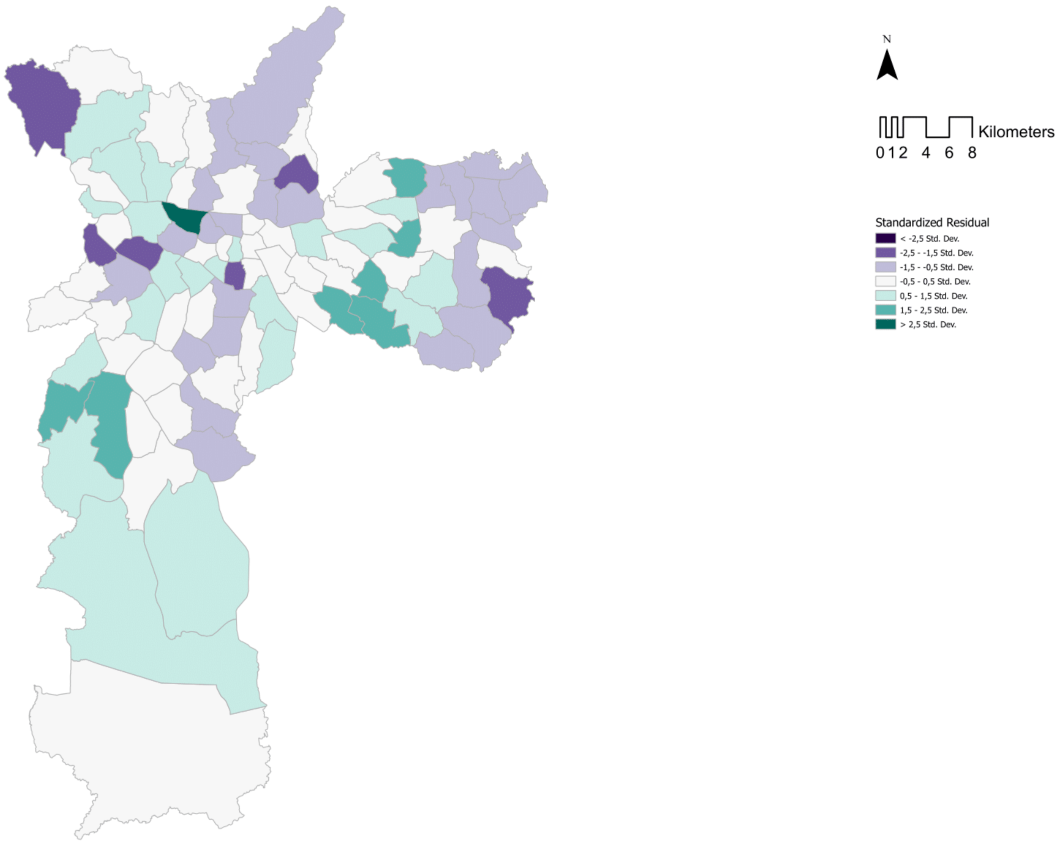


Figure 265 - Model III – Hotspots of the Std. Residuals of the cases by Distrito (OLS), Sao Paulo

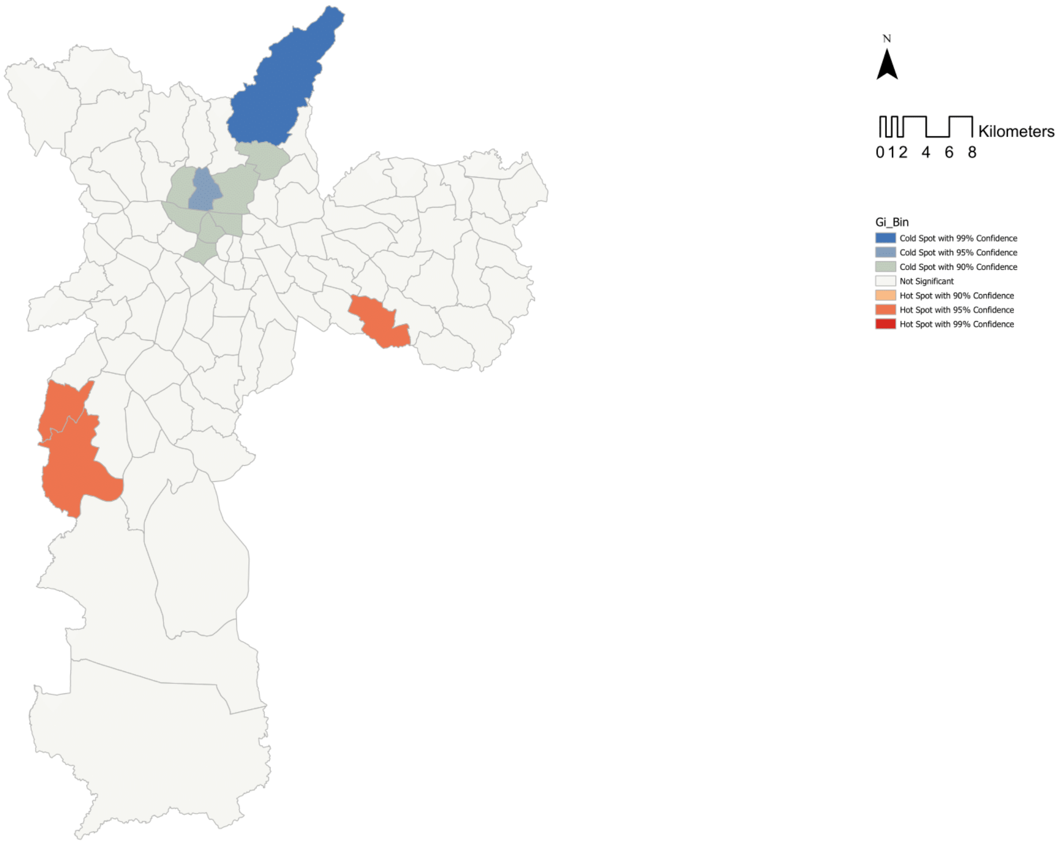


Figure 266 - Model III – Hotspots of the Std. Residuals of the cases by Distrito (GWR), Sao Paulo

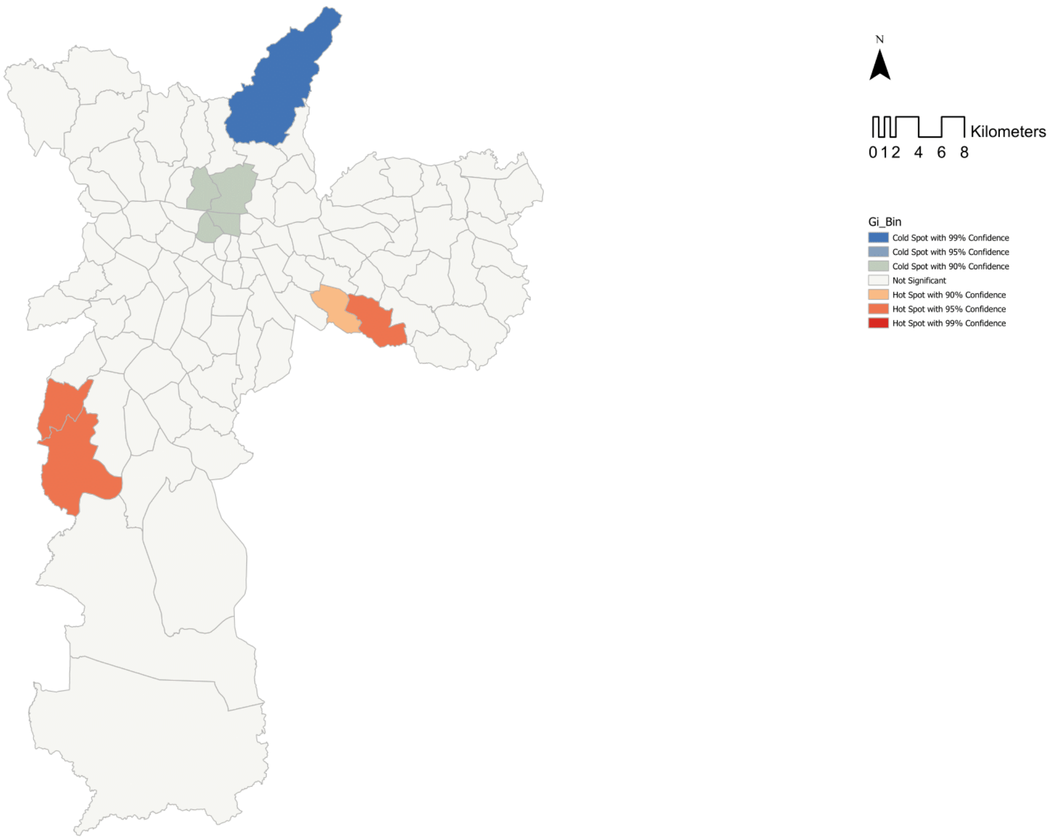


Figure 267 - Model III – Deaths, Std. Residuals by Distrito (OLS), Sao Paulo

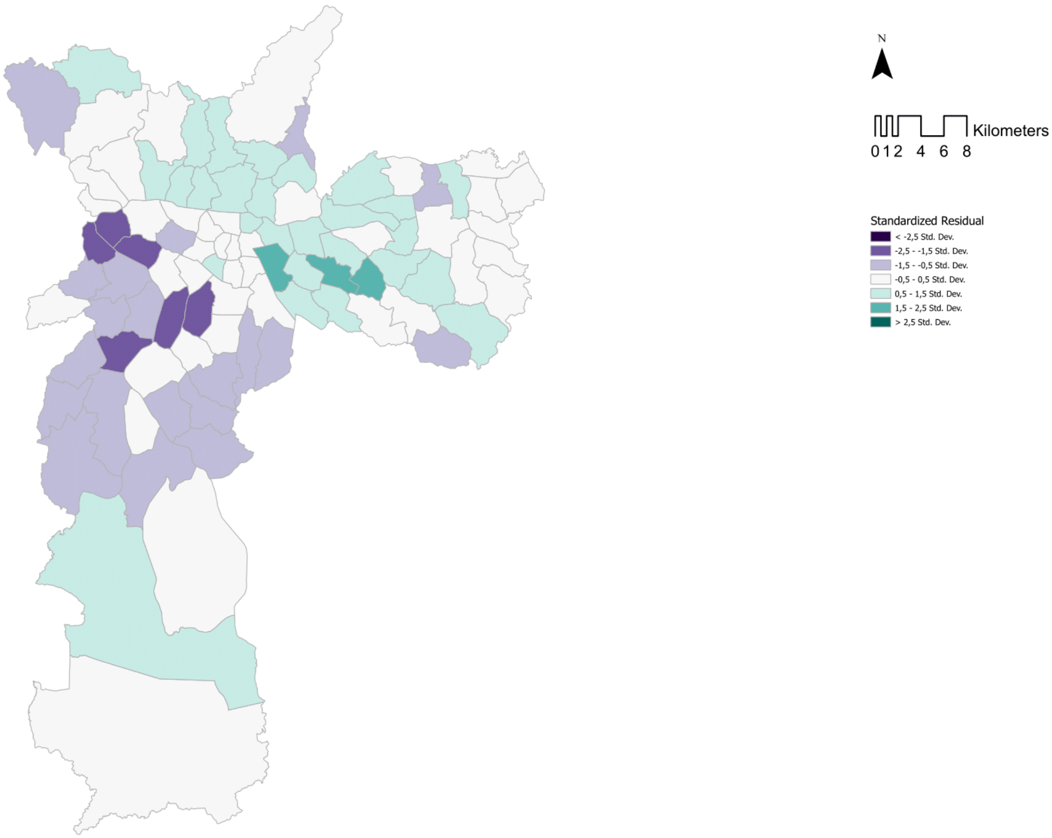


Figure 268 - Model III – Deaths, Std. Residuals by Distrito (GWR), Sao Paulo

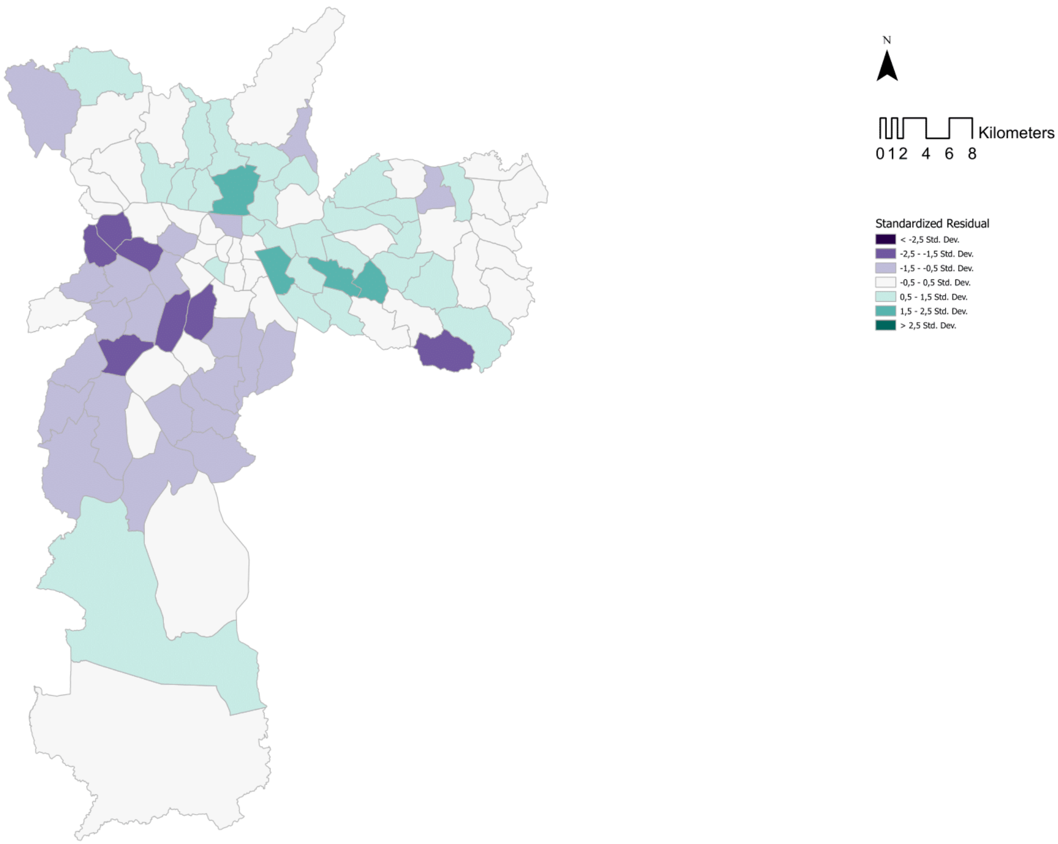


Figure 269 - Model III – Hotspots of the Std. Residuals of the deaths by Distrito (OLS), Sao Paulo

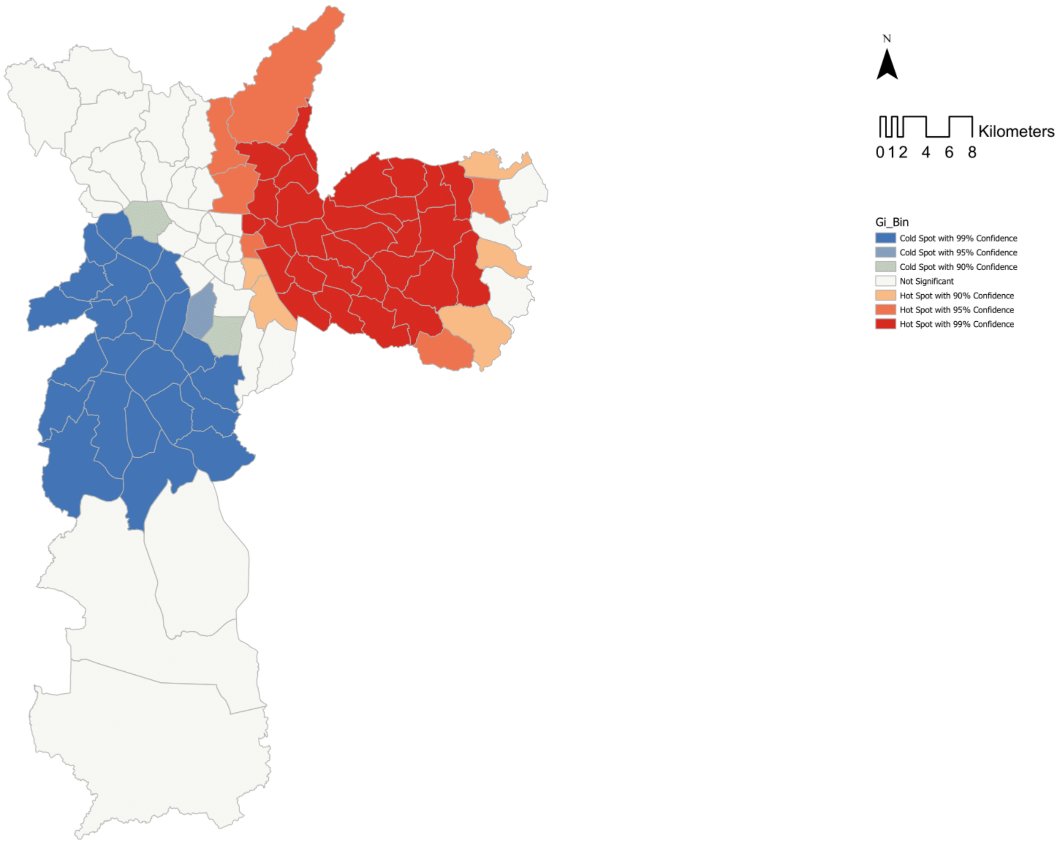
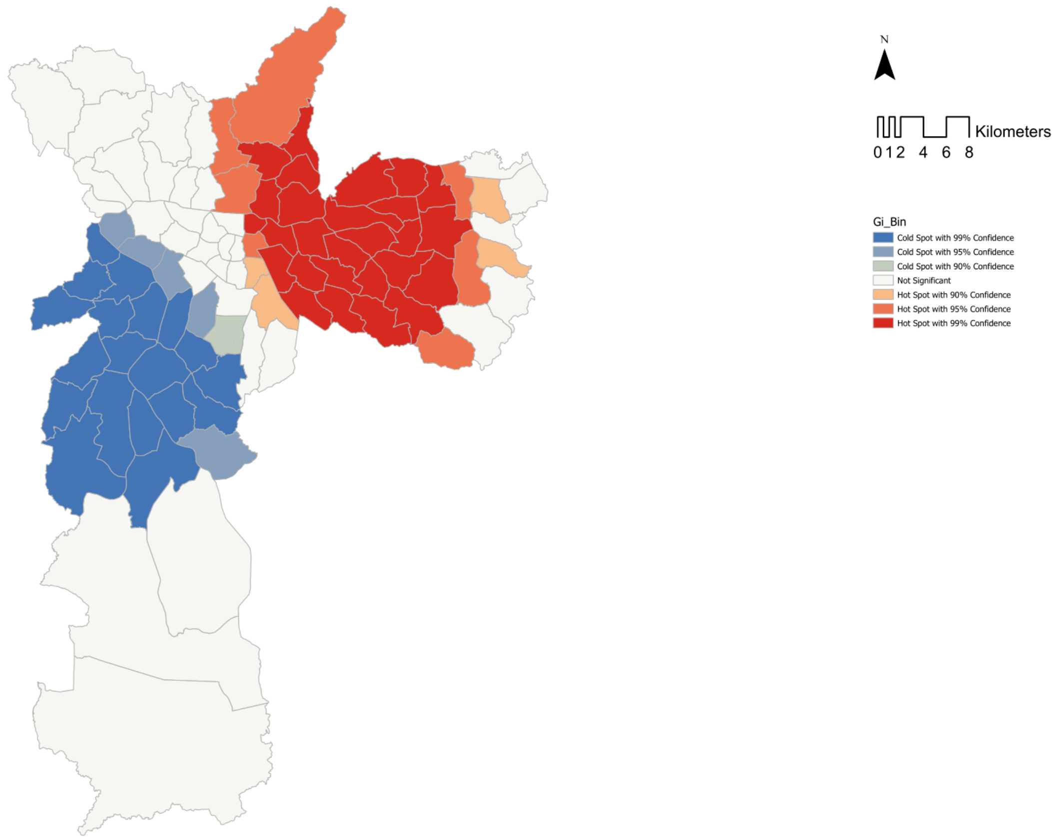


Figure 270 - Model III – Hotspots of the Std. Residuals of the deaths by Distrito (GWR), Sao Paulo



The Hotspots analysis (Fig. 265, 266, 269 and 270) carried out on the standardised residuals of the four regressions provide important insights. The residuals of the regressions on the spread, as previously mentioned, are limitedly affected by spatial autocorrelation, and this is confirmed by the hot spots analysis, where only a few *Distritos* are still showing clustering. Turning to Fig. 269 and 270, which display the hot spots and cold spots concerning the residuals obtained via the regressions on the deaths, it is possible to assert that a part of the story is missing. The city is divided into two "blocks": the north-eastern region and the south-western area. This issue, which affects the performance of the models, is key to understanding what variables have not been investigated. Hopefully, it can lead to new analytical findings concerning both the city and the pandemic.

Table 40 - Summary of the results by model (Regressions on cases), Sao Paulo

Model	*OLS* R^2	*OLS* *I*	*OLS* *AICc*	*GWR* R^2	*GWR* *I*	*GWR* *AICc*
Model I	0,05	0,10	1707,39	0,05	0,09	1706,46
Model II	0,11	0,10	1712,25	0,13	0,09	1709,63
Model III	0,11	0,10	716,53	0,13	0,08	1713,54

Table 41 - Summary of the results by model (Regressions on deaths), Rome

Model	*OLS* R^2	*OLS* *I*	*OLS* *AICc*	*GWR* R^2	*GWR* *I*	*GWR* *AICc*
Model I	0,00	0,37	1133,76	0,03	0,34	1129,99
Model II	0,14	0,29	1130,72	0,15	0,26	1129,30
Model III	0,16	0,35	1131,65	0,18	0,31	1129,78

Tab. 40 and 41 display a summary of the results of the different models. It is possible to notice how, as mentioned before, there is no significant improvement and increasing explanatory power by employing Model III. The final values are low (0,13 and 0,18) even though a minimal upward trend can be observed as we "complexify" the analysis of the pandemic in relation to the socio-spatial dimension. However, this case study differs from the ones analysed in the previous chapters, thus rendering it the whole more important in comparative terms. The difference encountered in the overall performance of the models is also reflected in the coefficients of the various indicators and their relative importance when analysing the spread and mortality of the pandemic. Fig. 271 to 276 summarise these changes and provide a comprehensive picture of all variables' importance from model to model. Some elements diverge in "absolute" terms compared to the other case studies. For instance, as mentioned before, the negative value of the SVI when analysing deaths, which opens up to different interpretations. Moreover, there is higher variability across the indicators when investigating the cases and the deaths. This insight will be further discussed in the "comparative" chapter of this research.

Figure 271 - Model I coefficients (cases), Sao Paulo

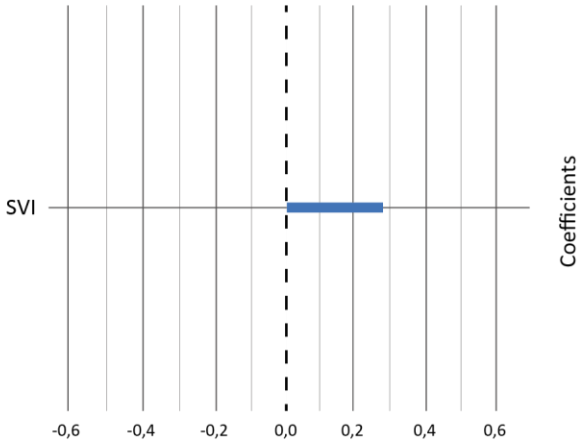


Figure 272 - Model I coefficients (deaths), Sao Paulo

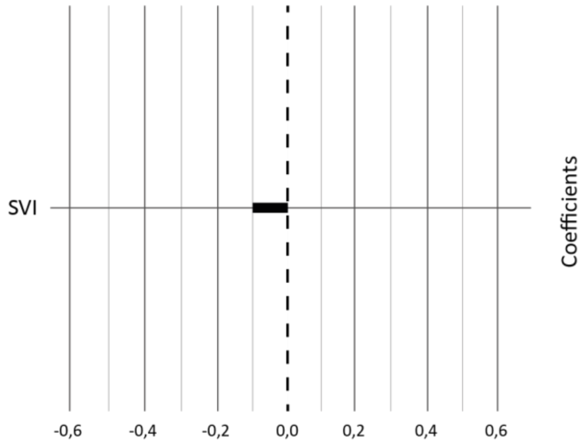


Figure 273 - Model II coefficients (cases), Sao Paulo

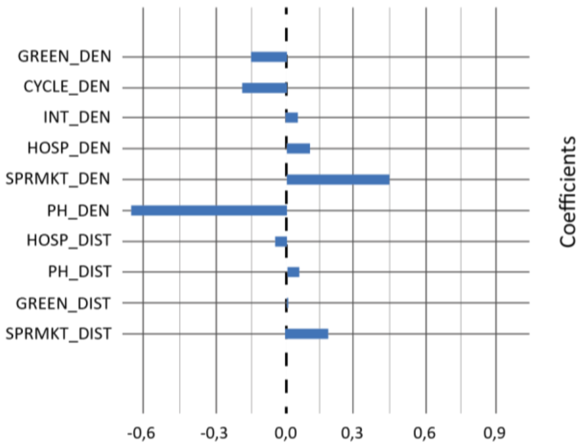


Figure 274 - Model II coefficients (deaths), Sao Paulo

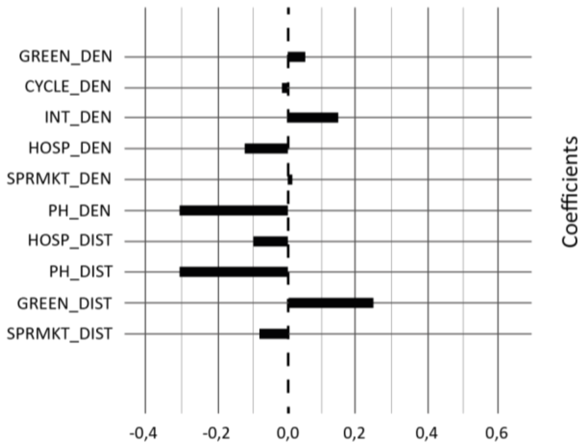


Figure 275 - Model III coefficients (cases), Sao Paulo

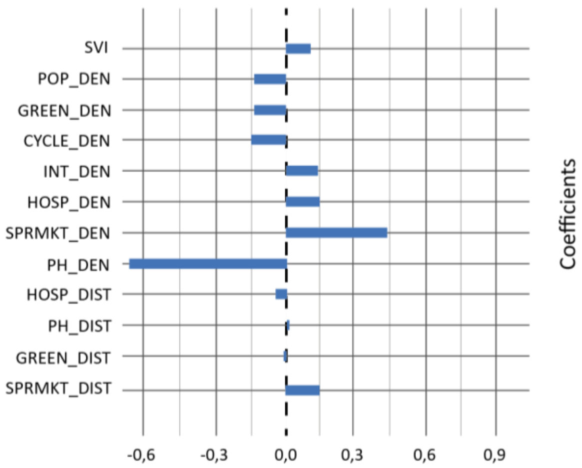
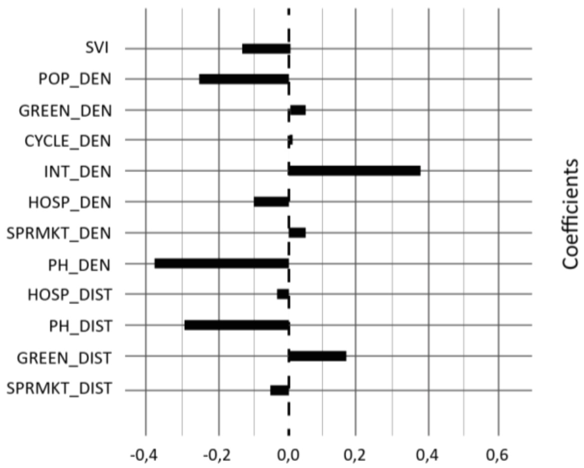


Figure 276 - Model III coefficients (deaths), Sao Paulo



5.4.5 Model III: Wrap-up

This third and last model provides critical insights and findings. Firstly, complexifying the socio-spatial dimension of the pandemic does bring to overall improvements in the explanatory power of the regressions. This happens to be the case in London, NYC, and Rome, where the R^2 values of the models analysing the spread and mortality of COVID-19 show significant results. However, in Sao Paulo, the results obtained differ significantly from the other case studies. In fact, none of the three models could provide high performance, although Model III showed minimal improvements. Nevertheless, in the form of their coefficients, the spatial indicators were relevantly connected to the pandemic. Taken alone, however, they do not suffice, at least for what concerns the indicators selected in this research. Even though diverging from the other instances, the different results obtained in Sao Paulo are more critical, as this dissertation is centred around these differences, as they can open to reflections about all case studies. In other words: learning from difference, but how?

Another finding was that, when analysing cases and deaths, we find higher levels of spatial autocorrelation in the former, while the latter is only limitedly affected by it. This was true, once again, for London, NYC, and Rome, while in Sao Paulo the trend was reversed. With the risk of being repetitive, this difference should not be "banished" but rather empowered. Spatial autocorrelation has practical and theoretical implications that need to be revised through these differences in trend. Why do we find in Sao Paulo higher spatial autocorrelation when analysing deaths? What are the elements in Sao Paulo that reverse the findings of the previous instances? But more importantly, what is the "line" between spread and deaths? Are the two the same phenomenon? Or are we talking about different, independent dynamics? If so, what are the elements that make the two distinct? Or what are the components that do eventually bind them?

Turning to the indicators, and their coefficients, several observations derive from the third, as well as the first two models. Firstly, the relative role of the SVI in the different case studies is not equal. Whereas in London and NYC, the SVI's coefficient is significantly higher than the other indicators, in Rome and Sao Paulo, the latter have higher figures than the Social Vulnerability Index. This difference can foster the debate around the "socio-spatial" divide. Is there any benefit in "splitting" (figuratively) these two domains? Is it possible to do so? Last but not least, the comparison of the different models, within cities and between cities, has shown similar as well as different spatial indicators' performance. In London, NYC and Rome, the relative strength of the coefficient of the various indicators remained approximately equivalent while analysing deaths and cases, indicating a similar relationship between the set of indicators and the two "sides" of the pandemic. The bar charts at the end of every sub-chapter show this feature. Indeed, it is possible to see from the last two graphs at the bottom of each case study ending page that the distribution and relative power of the coefficients do not diverge significantly when analysing deaths and cases. This trend, however, is not found in Sao Paulo, where we see significant variations for most of the indicators as we move from the analysis of the spread to the scrutiny of the mortality. This finding is decisively important, as it shits focus on another aspect that distinguished Sao Paulo from all other case studies: the type of restrictions implemented during the pandemic and the possible effect on the population. From this point of view, Sao Paulo can be used as a "What if?" Scenario.

6. The comparative gesture: divergences and convergences

This last chapter, before the conclusion, attempts at drawing together the findings encountered in the individual case studies. As explained before, this comparative gesture is carried out qualitatively to reduce to a minimum the issue of statistical bias brought by different datasets and, most of all, the matter concerning the Modifiable Area Unit Problem (MAUP). This chapter is not only for listing findings; instead, it aims to show the power of a comparative global approach to studying inequalities and generate questions for further research. This last point is particularly relevant considering the nature of this research: it attempted to provide a framework, a pilot project, to show the potential of comparative urbanism in drawing together diverse instances and to learn about any place looking "elsewhere". For the sake of clearness, the chapter is structured following the previous one; in this way, it is possible to move back and forth to verify claims, results, findings and, eventually, questions.

6.1 Time, spatial patterns, and COVID-19

Even though it might seem trivial, a first finding is that in all case studies, and for both the spread and the mortality of the pandemic, the distribution of the rates was heterogeneous. The degree to which this divide is visible, however, changes from case to case. This first observation was also what drove the research in the first place: why did the pandemic hit neighbourhoods differently across cities? Of course, there is no easy answer to it, as many researchers have attempted to find correlations and reasons behind it.

Another significant finding of this study is that by analysing the pandemic throughout the different waves and by scrutinising its development over time, there were different spatial patterns. COVID-19 hit cities differently across the different periods. This finding acquires specific importance for several reasons. Firstly, being such an evolving phenomenon, it calls for new, different ways of tracking it and investigating it over time, possibly with specific socio-spatial indicators. The performance over time of such variables can provide essential insights concerning the reasons behind specific spatial patterns and factors correlated to the outbreak. Secondly, it casts reasonable doubt on the studies carried out so far on the pandemic, which only considered part of the crisis because of time constraints. The difference in spatial patterns over time is not stark in all case studies; in some instances, the trends are closer, so the bias on the results would be less significant. However, as it happens to be the case in London, the distribution of cases varies significantly. Therefore, the results that come from analysing only a part of the pandemic might lead to very different conclusions compared to the analysis of the overall phenomenon. Nevertheless, the work of research carried out in the past year and a half acquires even more importance if framed within the principle of partiality: to have a "complete" picture, we need to put pieces together, relate findings in a framework that considers the spatial variability of the pandemic in time.

A further aspect investigated by this thesis is the extent to which cases and deaths converge. After all the analyses and the discussions, a question still needs addressing: are the two the same phenomenon? Or are they distinct dynamics? The evidence gathered by this work is not sufficient to claim either. Indeed, the observations of the spatial patterns, confirmed later by the matrix of correlations, show that there is a divide: in NYC and London, the spatial distribution of deaths and cases have, to some extent, similar patterns. The correlation matrix found a 0,47-coefficient value for London and 0,61 for NYC. In Rome and Sao Paulo, mortality and spread do not seem to coincide (0,04 and 0,13 respectively). This difference is, in the author's view, a possible starting point for some future research. Why do we witness such a divide? What factors are beyond this diversity in patterns? Some scholars have suggested that mortality is more influenced by comorbidities and previous conditions. Of course, this is a possibility. However, given the limited availability of studies in Rome and Sao Paulo, this claim is yet to be ascertained.

There are then trends which span across different contexts. For instance, it was noticed how, in all case studies, the spread seems to show an inward-outward trend, meaning that as we analyse the spatial distribution from the beginning to the end of each wave, the concentration of cases moves from central areas to peripheral units. On the other hand, when it comes to analysing deaths, the trend seems to be reversed; hence, the concentration of mortality is initially localised in external regions and moves toward more central neighbourhoods as we approach the end of a specific wave. These patterns were observed in all the instances selected for this study, although the shifts have different paces. Several hypotheses can be brought forward. For example, concerning the inward-outward trend of cases, it might be possible that the virus initially spread in central areas due to a higher density of relations, activities, interactions. Then, especially at the beginning of the pandemic, commuters might have involuntarily been the means to bring the virus in external areas where also other issues, such as overcrowding, might have favoured the spread of the pandemic more significantly than in central units. At this stage, this hypothesis is only qualitative and is not supported by empirical evidence since it was not the primary concern of the thesis. Nevertheless, it is a possible starting point for future scrutiny.

One last finding concerning the first part of the analysis is that in London, NYC, and Rome, a few areas displayed high infection rates when most units presented little if no cases during general low spread and mortality periods. From this perspective, these singularities could tell us more about the pandemic and the cities, stretching the claims of Ananya Roy and the belief that the "urban" can be conceptualised starting from a punctual observation. Therefore, it might be worth analysing these neighbourhoods during the specific period of interest to evaluate the possible reasons behind the difference in trend. Furthermore, it is possible to compare the different units among each other, see if there is a "unique" set of explanatory variables, or if, in case, borrowing the term from Pickvance (1986), there is a "plurality of causalities". Thus, besides enhancing the difference *between* case studies, diversity *within* cities can also result in a precious source of investigation.

Even though the first part of the analysis was qualitative, significant findings, insights, and questions emerged. As expected, the analytical framework proposed in this thesis gathers and collects different experiences, leading to a comparative gesture that fosters debate. However, it was not possible (or forecasted) to investigate every one of the unaddressed questions in detail. That is why it is crucial to empower a collective effort to explore the questions that arose from this project, sharing knowledge and bringing together different points of view. The study proposed in this work can act as a framework within which these can be collected, connected, and discussed.

6.2 Is Social Vulnerability sufficient to explain the pandemic?

The second part of the analysis evaluated the correlation between Social Vulnerability and the pandemic. In general, the SVI, although showing significant coefficients in some instances, is not, taken alone, sufficient to provide a complete picture of the pandemic, nor in terms of spread or deaths. Nevertheless, the values of the coefficients in London and NYC (ranging from 0,33 to 0,56) are higher than Rome and Sao Paulo (values between -0,10 and 0,26). Particularly relevant is the negative figure obtained when correlating the mortality of the pandemic with the SVI in Sao Paulo. It seems indeed counterintuitive to find that the less vulnerable the population is, the more likely it is to be lethally infected. In the author's view, it is necessary to sift through this result. The governmental initiatives to curb the pandemic in Brazil have been different compared to other case studies. This fact, arguably, might have played a significant role in shifting the results. The results obtained, therefore, acquire even more importance. Studying a city such as Sao Paulo can shed light on certain aspects of urban life concerning the pandemic that have not been clarified yet. The negative sign of the SVI is a starting point for further research. In this work, there is not enough empirical evidence to support any claims about its determinants. Nevertheless, it is possible to put forward some hypotheses based on the analyses carried out.

One possible interpretation might be linked to two factors: on the one hand, the different limitations imposed by the government to contain the pandemic and, on the other hand, the stark centralisation of services across the city. The former has given the population freedom of movement across the municipality despite the burden of the outbreak, exposing the inhabitants to contagion. The limitations imposed in other cities, instead, reduced life to a minimum area, in the author's view, that of the neighbourhood, which is why this specific unit was selected to analyse the pandemic. For Sao Paulo, instead, this did not apply. The lack of delocalisation of facilities and urban infrastructure might have played a complementary role. As observed while mapping the spatial indicators, services and facilities are strongly centralised. This was also proved by the correlation matrix, where, specifically for Sao Paulo, the distances to all facilities were strongly correlated among each other, meaning that being far from one facility corresponds to being away from all services. The polarisation of infrastructure in specific (less vulnerable) places, together with no restrictions of movement and precautions, might have led to a greater concentration of clusters in wealthier areas, thus exposing the inhabitants to more significant risks. This claim would also be supported by analysing the other case studies in periods of loosened restrictions. Indeed, it is possible to observe how the central and "richer" areas display higher spread figures than outer neighbourhoods at the beginning of the waves. However, to prove these claims, it would be necessary to use different indicators or elaborate further on the determinants.

All in all, the SVI is part of the picture, to a greater or lesser extent. However, it is not sufficient to provide a comprehensive analytical framework for the pandemic, as mentioned in the first paragraph. Cities are complex organisms, and, although it might sound trivial, their analysis must be moulded accordingly, especially with phenomena we know little about, such as the pandemic. Many studies have focused on "classic" indicators, on mechanic analyses of organic dynamics. The aim of this work, among others, was to give a "complexified" outlook, a critical analysis that places spatial features at the centre of a global comparative project. The following paragraphs discuss the results of such an attempt.

6.3 The role of urban infrastructure and facilities

Significant findings emerged from analysing the role of urban infrastructure and facilities during the outbreak. Firstly, in all case studies, several indicators were correlated to the pandemic, either in terms of spread or mortality. This finding was detected by obtaining and analysing the coefficients (β) of each indicator used in the correlation matrices and the regression models later. This observation alone is crucial, as it ascertains the relevance of planning, urban governance, and distribution of resources in relation to the events of the past year and a half. However, even more relevant findings stem from the critical scrutiny of the results. The outcomes suggest two different lines of influence related to urban infrastructure:

- An indirect role played over the inhabitants due to past non-equitable spatial planning practices which aided the sedimentation of inequalities that, as a result, exposed the population to the outbreak
- A direct role during the pandemic itself, especially in cities where infrastructure is highly polarised, thus favouring the formation of clusters and hotspots

Each variable needs, therefore, to be carefully examined in its different dimensions. In this case, the two mentioned above. Far from claiming that the two lines of influence capture the phenomenon in its entirety, they do, however, provide a base to start framing the discourse. The first point is supported by the analysis of the coefficients, which, as mentioned above, show the indicators' relevance concerning the pandemic's spread and mortality. However, the variables that deliver the highest correlation vary from city to city, meaning that each town must consider the specific spatial inequalities taking place within it. For instance, whereas in Sao Paulo the density of pharmacies is negatively correlated with COVID-19 mortality and spread (β= -0,38 and -0,67 respectively), in other case studies, such as London, the values indicate no correlation. On the other hand, in NYC and London, the distance to hospitals is positively correlated, whilst in Rome and Sao Paulo, the correlation is weaker. These results suggest, therefore, that municipalities must elaborate local contextualised responses. General guidelines are not to be doomed, but each city needs to be conscious of the specific spatial deficits affecting the neighbourhoods. For that, a data-driven approach might help let them emerge, as it occurred with this thesis. There is no one fit-all solution. Inequalities need investigation at a granular spatial level, and responses need to stem from it. In other words: think globally, act locally.

The second point was briefly mentioned in the previous paragraph in connection to the results of the Social Vulnerability Index, and it is resumed here, as it acquires even more importance due to empirical evidence. The centralisation of facilities and infrastructure, which, in the author's view, belongs to unjust spatial planning practices, seem to be a highly relevant factor while analysing the pandemic. From this perspective, Sao Paulo and Rome's polarisation of infrastructure is more marked. This is also reflected in the results. In Rome, for instance, the density of hospitals has a correlation coefficient of 0,58 with the spread and 0,65 with deaths. These figures are highly relevant. They suggest that many infections and fatal cases have concentrated in geographical areas proximate to hospitals. The author suggests that, in this case, the affluence of people within these areas might have caused the rapid spread of the pandemic. The lack of a capillary health system on the territory might have, arguably, played a crucial role in containing the virus. In the other case studies, where healthcare facilities are more evenly dislocated across the city, the coefficient is less significant. In Sao Paulo, despite the centralisation of hospitals, the correlation is not as strong as it occurs for Rome. This difference might be linked to the employment of UBS (Unidades Básicas de Saúde) – translated Basic Health Units. The UBS aim to promote and protect health through preventive actions of complaints, conducting a diagnosis, treatment, rehabilitation, harm reduction and health maintenance. In addition, they aim to provide comprehensive care to the population, impacting the health status and autonomy of individuals and on the determinants of health and conditions of communities. They were also designed to increase the proximity to basic healthcare units. In this sense, they might have helped to avoid the concentration of population within some city regions, thus reducing the risk of contagion. On the contrary, the density of supermarkets in Sao Paulo is positively correlated with the spread (coefficient 0,43), indicating that they might have facilitated the diffusion of the virus, becoming hosts to clusters and overcrowding. Supermarkets have been used in this analysis because they provide, arguably, a variety of products, ranging from cheaper to more expensive. In these terms, supermarkets are more economically accessible compared to convenience or grocery stores. However, as the results seem to support, they also gather a more extensive customer base, especially when the facilities are polarised. Similarly, a significant positive coefficient regarding the density of green areas concerning the spread and mortality (0,10 and 0,30 respectively) was found in Rome. Green spaces in Rome are mainly concentrated within the GRA, and it is possible that, especially during some phases of the pandemic, they became points of aggregations.

The two "dimensions" analysed above seem to point in one direction: we need to rethink spatial planning practices and carefully scrutinise the existing inequalities affecting cities at a granular spatial scale. General planning guidelines are essential to set specific goals; however, institutions need to tailor responses based on contextual issues, which are yet to be ascertained. According to the research carried out in this thesis, the dislocation of facilities and resources on the territory is a first step towards more equitable cities. This claim is in unit with recent proposals of "autonomous communities", among which the 15-minute city (FMC) is gaining momentum. Although initially not so popular, it has received increasing attention due to the pandemic's outspread. Anne Hidalgo, mayor of Paris, has included the model in her program "*Paris en Commun*" for her re-election in June 2020 (Reid, 2020). This "new" model is part of the stream of thought called "chrono-urbanism", supporting the idea that the quality of urban life is inversely proportional to the time needed for transportation. (Moreno et al. 2021). The critical issue the model aims to address is the fragmentation of the physical and social fabric of the city caused by modernist planning (Moreno et al., 2021). The inherent assumption is that by allowing residents to fulfil essential social functions (living, working, commerce, health, education, and entertainment), their urban life will be improved. Proximity to services is among the "pillars" of the model. It is intended as temporal and spatial. The vicinity of essential services is seen as optimal to reduce commuting time and reinforce social interactions within the community. Moreover, the model implicitly re-proposes the neighbourhood as a pivotal unit from which greater urban transformations can be envisioned. Nevertheless, there are shortcomings to address and aspects that have not been thoroughly investigated. The FMC is not critically inserted within the complex mechanisms of appropriation and the market conditions under capitalism. It does not provide significant directions concerning how to insert the model within current political-economic conditions. The centralisation of services results from a system that aims to maximise economic gains from redistributing the surplus product (Harvey, 2008). In this sense, the FMC stands a different ground, claiming the need to provide equitable distribution across the cities. There are, therefore, significant challenges to overcome. However, COVID-19 has brought a (permanent?) paradigmatic shift in the relationship between work and living, which, possibly for the first time, are spatially coupled. This might lead to a redistribution of human capital on the territory, possibly fostering the interest in decentralising amenities even in a neoliberal economic framework. This redistribution, nevertheless, might not affect all sectors equally, thus creating further ruptures. Although not part of the work of research envisioned for this thesis, It is worth investigating how changes in the geographical relationship between work and living might influence the reallocation of inhabitants and services, and if it can aid the development of more equitable spatial planning practices.

6.4 A "complexified" picture

The last part of the analysis showed that by complexifying the socio-spatial dimension of cities, there is an improvement in the performance of the models in all case studies. Nevertheless, there are still variables missing from the picture, as the results of the regressions and the maps of the residuals demonstrate. Identifying the "absent" indicators and verifying the missing pieces of the story could be one possible line of future research. To support this kind of investigation, the author provided the maps displaying hot spots and cold spots of the standardised residuals. Thus, any scholar who will embark on these analyses would know where the residuals were localised and if there are any relevant contiguities to be scrutinised. Whereas for London, NYC and Rome, the regression on the cases presented higher spatial autocorrelation on the residuals, for Sao Paulo, the analysis of the deaths was more affected by clustering. The Brazilian city's hot spots map shows a great divide between the northeast and southwest. In this case, not only there are spatial determinants that have not been encompassed in the analysis, but, given the extension of the areas and the patterns observed, the optimal scale of observation for the mortality might not be that of the neighbourhood. It would be worth exploring different spatial scales of analysis to verify changes in the performance of the models.

Lastly, the population density was included as a control variable in the last part of the thesis, and it was found to have a negative correlation coefficient for both spread and deaths in almost all cases. Therefore, the assumption that areas with greater density are more affected by the pandemic can be, at least, questioned. Nevertheless, the author would like to offer a different critical perspective on density, starting from how the outbreak was contained. The measure imposed by governments to curb the pandemic was to implement lockdowns, thus limiting interaction among people. As amply demonstrated, it was effective in reducing cases and deaths. However, there might be a conceptual bias in considering that population density can be used as a proxy for density of relations, and that might be the reason why unexpected results are obtained. Having more people concentrated in an area does not automatically imply that they will interact more. In unity with Keil (2020), these claims open new avenues of exploration concerning what density means in the first place. How can the density of relations be tracked then? What kind of indicator can be used? What data is necessary? Hopefully, these questions can foster further research on this specific aspect of the thesis and the valuable research that has been produced before this study.

7. Conclusion

The dissertation sought to demonstrate that the pandemic's effects were not uniform across cities, but rather were more severe in urban units with long-standing spatial inequalities. Moreover, the thesis explored the impact that urban infrastructure and distribution of facilities have had on the territory during the pandemic itself, where the centralisation of services seems to have played a role in some instances. The global comparative approach provided a multifaceted framework of analysis, drawing together different dynamics and experiences. It enriched the study of COVID-19 and fostered the emergence of findings. It also aided the development of questions, paths for future research and items that need further investigation.

The findings demonstrated that the way cities are shaped and how resources are distributed affect the way citizens live. COVID-19 accelerated this trend, leading to heterogeneous spatial impacts across the different case studies. Nevertheless, the thesis's findings also show that there is no one fit-all solution: local urban governance needs to elaborate contextualised responses to the issues affecting communities at a spatially granular scale. The case studies support this last claim. They show how the different shortcomings were connected to the outbreak, and what policies can be developed in the future to cope with them. Another finding is the role played by the centralisation of certain facilities and infrastructure: the lack of a capillary system on the territory, in some case studies specifically, might have fostered the spread of the pandemic in specific units across the cities. Issues of polarisation are linked to appropriation mechanisms and the way surplus product is distributed on the territory. There are, therefore, challenges to overcome, especially if urban governance and planning want to move to the development of models favouring more equitable cities, at least for what pertains to the distribution of resources on the territory.

Secondly, the choice to study COVID-19 through the lens of a global comparative project has favoured the scrutiny of impacts across different contexts. Thus, the set of questions deriving from the analysis has expanded considerably. Unfortunately, due to the specific timeframe a master's thesis implies, it was not possible to pursue every line of research that emerged by relating case studies to one another. The unaddressed questions, or findings that need further investigation, have been discussed in chapter six, and, hopefully, can represent a base for future studies. Ideally, the present project can represent a framework within which results can be discussed, question can be forwarded, and different experiences and be drawn together. I believe a collective effort must take place, if we want to unveil the reasons behind certain patterns and events brought by the pandemic.

Finally, the thesis has shown that COVID-19 has spread across cities dynamically over time. Thus, the spatial patterns observed differ from wave to wave, both in terms of cases and deaths. Therefore, the analysis of only a part of the whole phenomenon might lead to biased results, depending on the extent patterns different from period to period. As a result, the studies produced in the past year and a half need to be scrutinised in relation to the whole extent of the pandemic. The results evidenced by "partial" analyses need to be inserted in a broader picture, relating findings to one another. In this way, the changes become a starting point to understand the different determinants of spread and mortality over time.

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Appendix A – Data sources

Theme	Variable	Source	Link
COVID-19	N° of cases	PHE (Public Health of England)	https://coronavirus.data.gov.uk/details/download
	N° of deaths	PHE (Public Health of England)	https://coronavirus.data.gov.uk/details/download
STATISTICAL BOUNDARIES	MSOAs Boundaries	London Datastore	https://data.london.gov.uk/dataset/statistical-gis-boundary-files-london
	LSOAs boundaries	London Datastore	https://data.london.gov.uk/dataset/statistical-gis-boundary-files-london
DEMOGRAPHY	MSOAs population estimates	ONS (Office for National statistics)	https://www.ons.gov.uk/peoplepopulationandcommunity
	LSOAs population	ONS (Office for National statistics)	https://data.london.gov.uk/dataset/lsoa-atlas
INFRASTRUCTURE AND FACILITIES	Green areas (private excluded)	London Datastore	https://data.london.gov.uk/dataset/green-and-blue-cover
	Hospitals	NHS (National Health Service)	https://data.gov.uk/dataset/f4420d1c-043a-42bc-afbc-4c0f7d3f1620/hospitals
	Pharmacies	Geofabrik	http://download.geofabrik.de/europe/great-britain/england/greater-london.html
	Supermarkets	Geofabrik	http://download.geofabrik.de/europe/great-britain/england/greater-london.html
	Street network	Geofabrik	http://download.geofabrik.de/europe/great-britain/england/greater-london.html
	Cycling infrastructures	TFL (Transport for London)	https://cycling.data.tfl.gov.uk/
SVI	% Unemployed out of economically active	London Datastore	https://data.london.gov.uk/dataset/msoa-atlas
	Total Mean Annual Household Income (£)	London Datastore	https://data.london.gov.uk/dataset/msoa-atlas
	% Population with no High School Diploma	London Datastore	https://data.london.gov.uk/dataset/msoa-atlas
	% population >65	London Datastore	https://data.london.gov.uk/dataset/msoa-atlas
	% population <15	London Datastore	https://data.london.gov.uk/dataset/msoa-atlas
	% Of population with a disability	London Datastore	https://data.london.gov.uk/dataset/msoa-atlas
	% Lone parents with dependent children	London Datastore	https://data.london.gov.uk/dataset/msoa-atlas
	% Of households overcrowded	London Datastore	https://data.london.gov.uk/dataset/msoa-atlas
	% Of households with no car	London Datastore	https://data.london.gov.uk/dataset/msoa-atlas

Appendix A1 – London datasets sources and metadata

Theme	Variable	Source	Link
COVID-19	Case rates	NYC DOHMH (NYC Department of Health)	https://github.com/nychealth/coronavirus-data
	Death rates	NYC DOHMH (NYC Department of Health)	https://github.com/nychealth/coronavirus-data
STATISTICAL BOUNDARIES	MODZCTAs boundaries	NYC Open Data	https://data.cityofnewyork.us/Health/Modified-Zip-Code-Tabulation-Areas-MODZCTA-Map/5fzm-kpwv
	Census tracts	U.S. Census Bureau	https://www.census.gov/geographies/mapping-files/time-series/geo/carto-boundary-file.html
DEMOGRAPHY	MODZCTAs population estimates	U.S. Census Bureau	https://data.census.gov/cedsci/
	Census tracts population estimates	U.S. Census Bureau	https://data.census.gov/cedsci/
INFRASTRUCTURE AND FACILITIES	Green areas	NYC Open Data	https://data.cityofnewyork.us/Recreation/Green-Spaces/mwfu-376i
	Hospitals	NYC Open Data	https://data.cityofnewyork.us/Health/Hospitals/833h-xwsx
	Pharmacies	GeoFabrik	http://download.geofabrik.de/north-america/us/new-york.html
	Supermarkets	GeoFabrik	http://download.geofabrik.de/north-america/us/new-york.html
	Street network	NYC Open Data	https://data.cityofnewyork.us/City-Government/NYC-Street-Centerline-CSCL-/exjm-f27b
	Cycling infrastructures	NYC Open Data	https://data.cityofnewyork.us/Transportation/Bicycle-Routes/7vsa-caz7
SVI	Below poverty	Centres for Disease Control and Prevention (CDC)	https://www.atsdr.cdc.gov/placeandhealth/svi/documentation/SVI_documentation_2018.html
	Unemployed	Centres for Disease Control and Prevention (CDC)	https://www.atsdr.cdc.gov/placeandhealth/svi/documentation/SVI_documentation_2018.html
	Income	Centres for Disease Control and Prevention (CDC)	https://www.atsdr.cdc.gov/placeandhealth/svi/documentation/SVI_documentation_2018.html
	No high school diploma	Centres for Disease Control and Prevention (CDC)	https://www.atsdr.cdc.gov/placeandhealth/svi/documentation/SVI_documentation_2018.html
	Age 65 or older	Centres for Disease Control and Prevention (CDC)	https://www.atsdr.cdc.gov/placeandhealth/svi/documentation/SVI_documentation_2018.html
	Age 17 or younger	Centres for Disease Control and Prevention (CDC)	https://www.atsdr.cdc.gov/placeandhealth/svi/documentation/SVI_documentation_2018.html
	Older than age 5	Centres for Disease Control and Prevention (CDC)	https://www.atsdr.cdc.gov/placeandhealth/svi/documentation/SVI_documentation_2018.html
	With a disability	Centres for Disease Control and Prevention (CDC)	https://www.atsdr.cdc.gov/placeandhealth/svi/documentation/SVI_documentation_2018.html
	Single-parent household	Centres for Disease Control and Prevention (CDC)	https://www.atsdr.cdc.gov/placeandhealth/svi/documentation/SVI_documentation_2018.html
	Minority	Centres for Disease Control and Prevention (CDC)	https://www.atsdr.cdc.gov/placeandhealth/svi/documentation/SVI_documentation_2018.html
	Speaks English "less than well"	Centres for Disease Control and Prevention (CDC)	https://www.atsdr.cdc.gov/placeandhealth/svi/documentation/SVI_documentation_2018.html
	Multi-unit structures	Centres for Disease Control and Prevention (CDC)	https://www.atsdr.cdc.gov/placeandhealth/svi/documentation/SVI_documentation_2018.html
	Mobile homes	Centres for Disease Control and Prevention (CDC)	https://www.atsdr.cdc.gov/placeandhealth/svi/documentation/SVI_documentation_2018.html
	Crowding	Centres for Disease Control and Prevention (CDC)	https://www.atsdr.cdc.gov/placeandhealth/svi/documentation/SVI_documentation_2018.html
	No vehicle	Centres for Disease Control and Prevention (CDC)	https://www.atsdr.cdc.gov/placeandhealth/svi/documentation/SVI_documentation_2018.html

Appendix A2 – NYC datasets sources and metadata

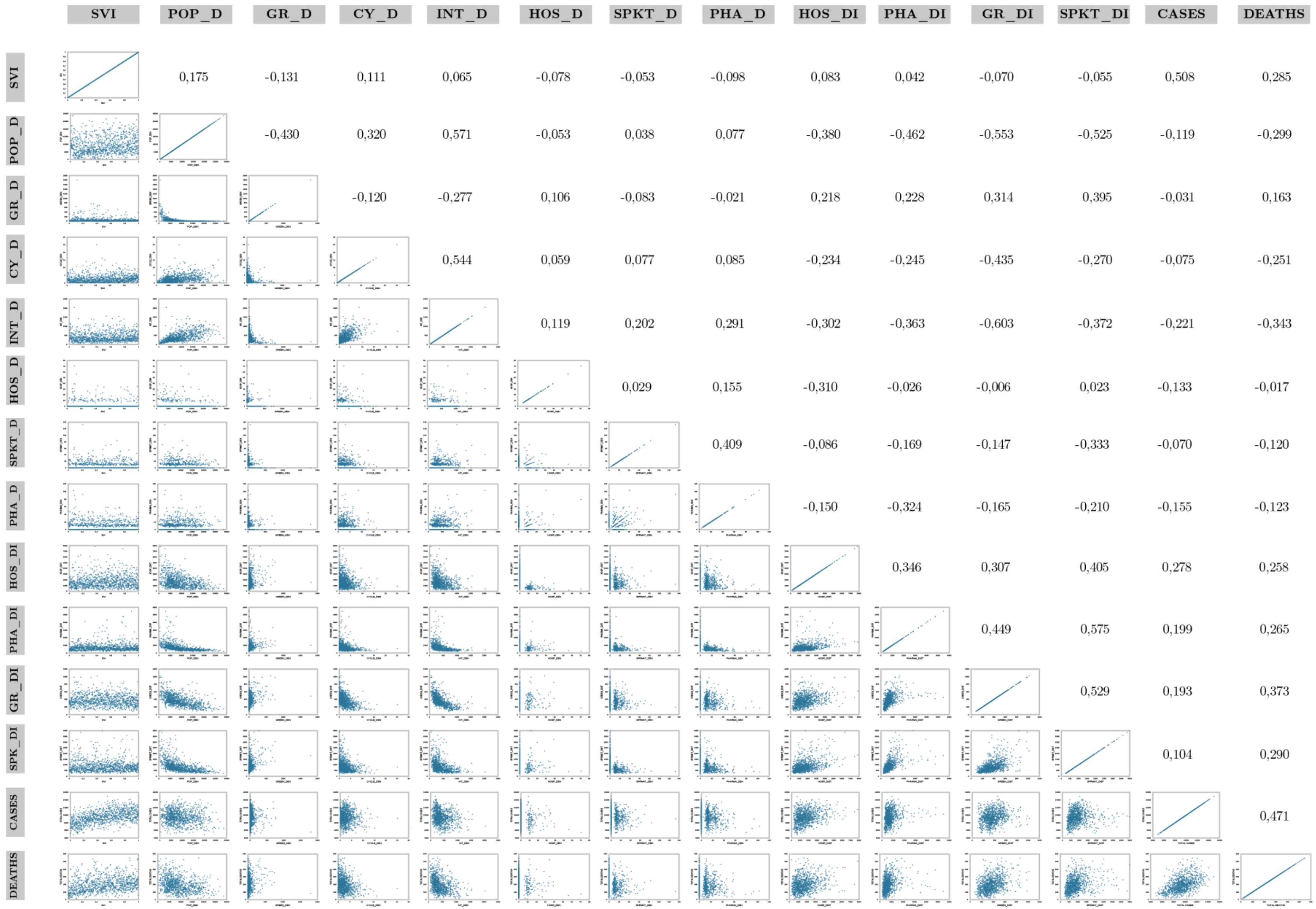
Theme	Variable	Source	Link
COVID-19	Case rates	DEP Lazio	Data provided upon official request to the DEP
	Death rates	DEP Lazio	Data provided upon official request to the DEP
STATISTICAL BOUNDARIES	ZUBs boundaries	Roma Capitale Open Data	https://www.comune.roma.it/TERRITORIO/nic-gwt/
	Census tracts	Roma Capitale Open Data	https://www.comune.roma.it/TERRITORIO/nic-gwt/
DEMOGRAPHY	ZUBs population estimates	Italian National Institute of Statistics (ISTAT)	https://dati.istat.it/
	Census tracts population estimates	Italian National Institute of Statistics (ISTAT)	https://dati.istat.it/
INFRASTRUCTURE AND FACILITIES	Green areas	Roma Capitale Open Data	https://www.comune.roma.it/TERRITORIO/nic-gwt/
	Hospitals	Roma Capitale Open Data	https://www.comune.roma.it/TERRITORIO/nic-gwt/
	Pharmacies	GeoFabrik	http://download.geofabrik.de/europe/italy/centro.html
	Supermarkets	GeoFabrik	http://download.geofabrik.de/europe/italy/centro.html
	Street network	GeoFabrik	http://download.geofabrik.de/europe/italy/centro.html
	Cycling infrastructures	Roma Mobilità	https://romamobilita.it/it/tecnologie/open-data/dataset-geografici
SVI	% population 25-64 with no diploma	Italian National Institute of Statistics (ISTAT)	https://www.istat.it/it/archivio/202052
	% families with more than 6 components	Italian National Institute of Statistics (ISTAT)	https://www.istat.it/it/archivio/202052
	% Lone parents	Italian National Institute of Statistics (ISTAT)	https://www.istat.it/it/archivio/202052
	% of families composed by elderlies (>65)	Italian National Institute of Statistics (ISTAT)	https://www.istat.it/it/archivio/202052
	Overcrowding	Italian National Institute of Statistics (ISTAT)	https://www.istat.it/it/archivio/202052
	% working age population unemployed	Italian National Institute of Statistics (ISTAT)	https://www.istat.it/it/archivio/202052
	% households financially vulnerable	Italian National Institute of Statistics (ISTAT)	https://www.istat.it/it/archivio/202052

Appendix A3 – Rome datasets sources and metadata

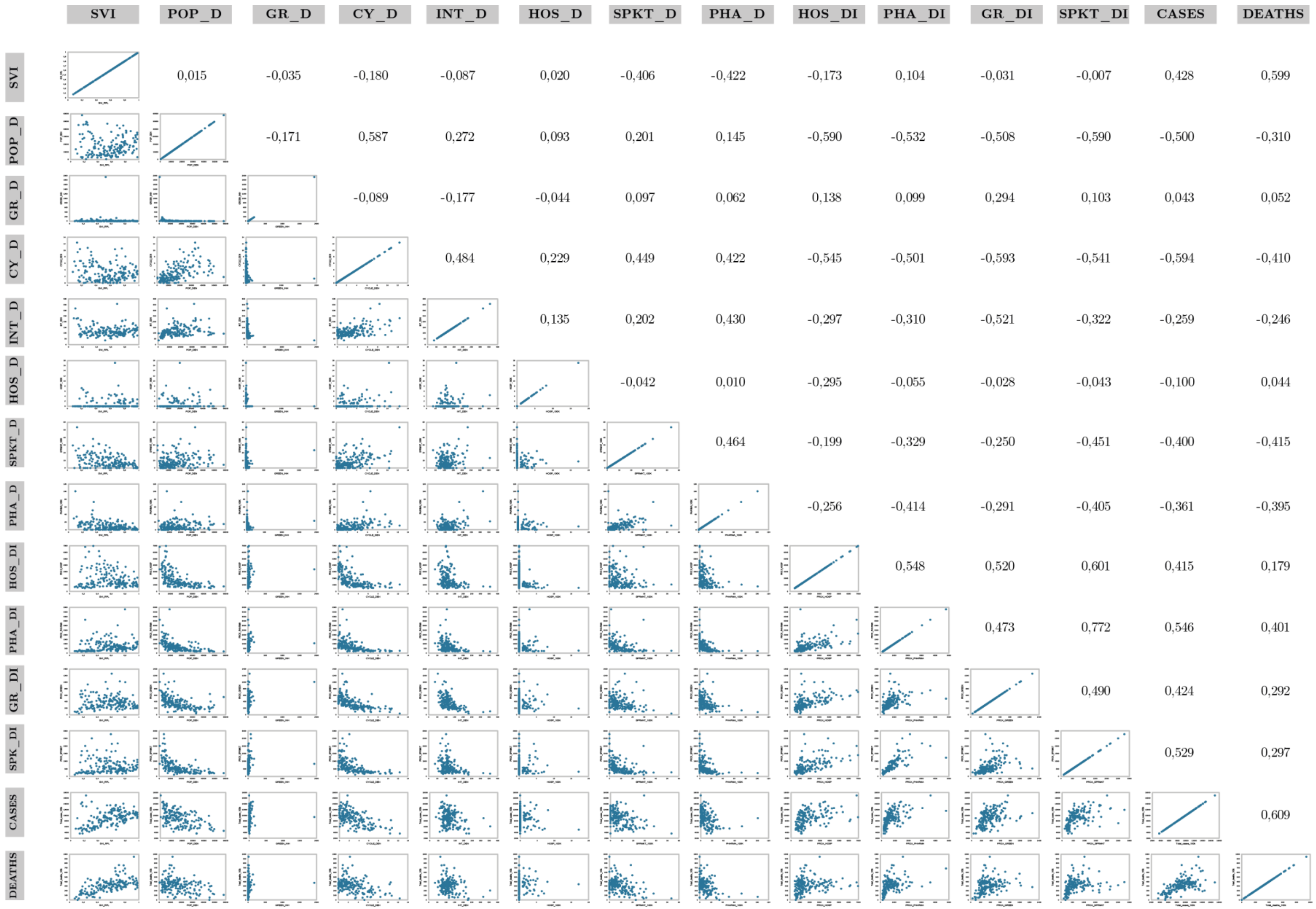
Theme	Variable	Source	Link
COVID-19	Case rates - E-SUS-VE	Citade de Sau Paolo Saude - TABNET	https://www.prefeitura.sp.gov.br/cidade/secretarias/saude/tabnet/
	Death rates	Citade de Sau Paolo Saude - TABNET	https://www.prefeitura.sp.gov.br/cidade/secretarias/saude/tabnet/
STATISTICAL BOUNDARIES	Districtos boundaries	Prefeitura de Sao Paulo - Dados abertos	http://dados.prefeitura.sp.gov.br/
	Census tracts	Prefeitura de Sao Paulo - GeoSampa	http://geosampa.prefeitura.sp.gov.br/PaginasPublicas/_SBC.aspx
DEMOGRAPHY	Districtos population estimates	Fundação SEADE	https://repositorio.seade.gov.br/
	Census tracts population estimates	Instituto Brasileiro de Geografia e Estatística	http://geosampa.prefeitura.sp.gov.br/PaginasPublicas/_SBC.aspx
INFRASTRUCTURE AND FACILITIES	Green areas	Prefeitura de Sao Paulo - Gestao Urbana	https://gestaourbana.prefeitura.sp.gov.br/3827-2/
	Hospitals	Geo SEADE	https://portalgeo.seade.gov.br/
	Pharmacies	GeoFabrik	http://download.geofabrik.de/south-america/brazil/sudeste.html
	Supermarkets	GeoFabrik	http://download.geofabrik.de/south-america/brazil/sudeste.html
	Street network	GeoFabrik	http://download.geofabrik.de/south-america/brazil/sudeste.html
	Cycling infrastructures	CET - Companhia de Engenharia de Tráfego	http://www.cetsp.com.br/consultas/bicicleta/mapa-de-infraestrutura-cicloviaria.aspx
SVI	Illiteracy rate of the population aged 25 and over	Prefeitura de Sao Paulo - Dados abertos	http://dados.prefeitura.sp.gov.br/
	% Population >25 with high school diploma	Prefeitura de Sao Paulo - Dados abertos	http://dados.prefeitura.sp.gov.br/
	% Of poor population	Prefeitura de Sao Paulo - Dados abertos	http://dados.prefeitura.sp.gov.br/
	Average per capita income	Prefeitura de Sao Paulo - Dados abertos	http://dados.prefeitura.sp.gov.br/
	Unemployment rate for the population >18	Prefeitura de Sao Paulo - Dados abertos	http://dados.prefeitura.sp.gov.br/
	% Population living in households with density greater than 2 people per bedroom	Prefeitura de Sao Paulo - Dados abertos	http://dados.prefeitura.sp.gov.br/
	% Mothers without complete primary education and with at least one child <15	Prefeitura de Sao Paulo - Dados abertos	http://dados.prefeitura.sp.gov.br/
	% People in households vulnerable to poverty and dependent on the elderly	Prefeitura de Sao Paulo - Dados abertos	http://dados.prefeitura.sp.gov.br/
	% population <17	Prefeitura de Sao Paulo - Dados abertos	http://dados.prefeitura.sp.gov.br/
	% population >65	Prefeitura de Sao Paulo - Dados abertos	http://dados.prefeitura.sp.gov.br/

Appendix A4 – Sao Paulo datasets sources and metadata

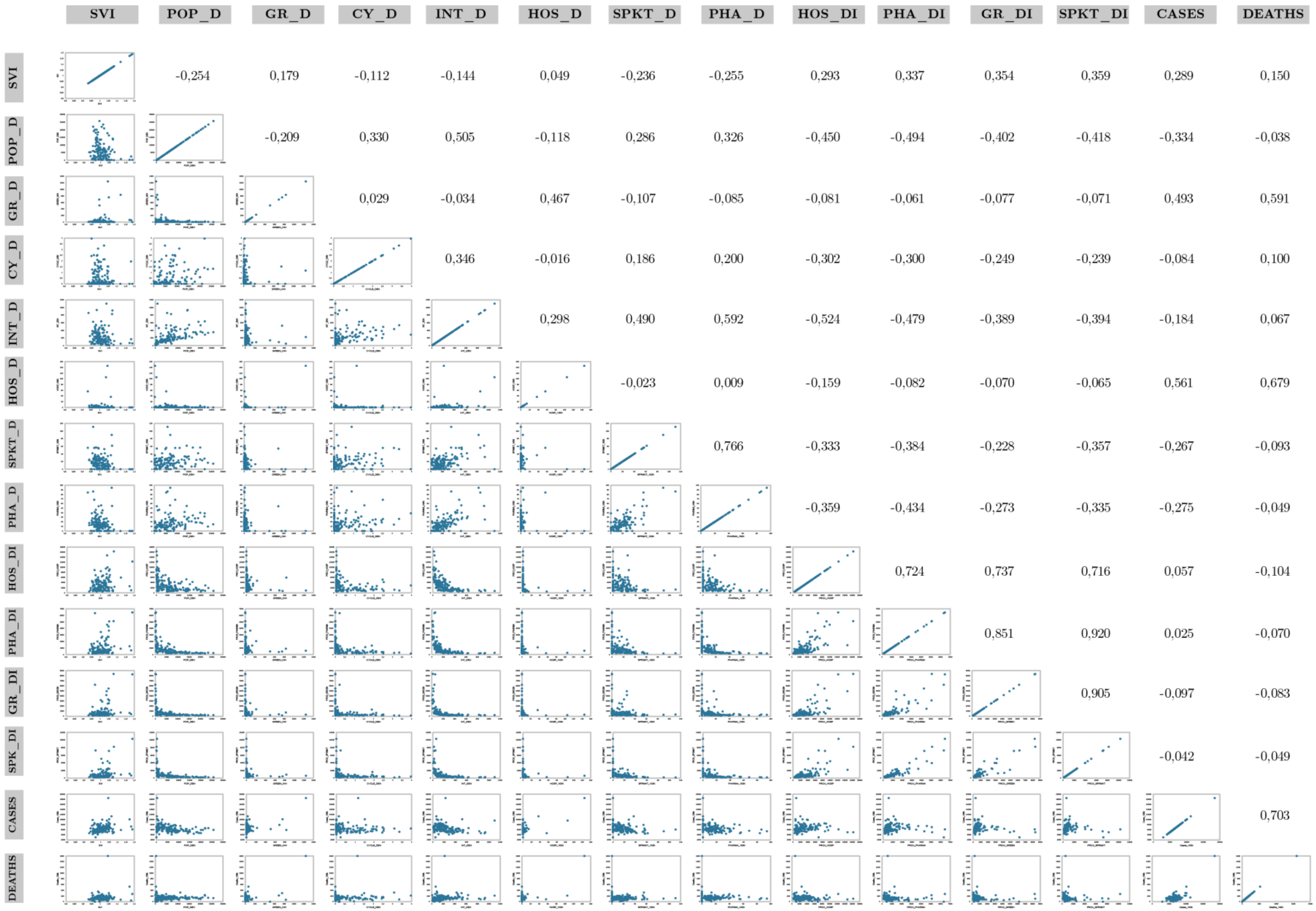
Appendix B – Scatterplots



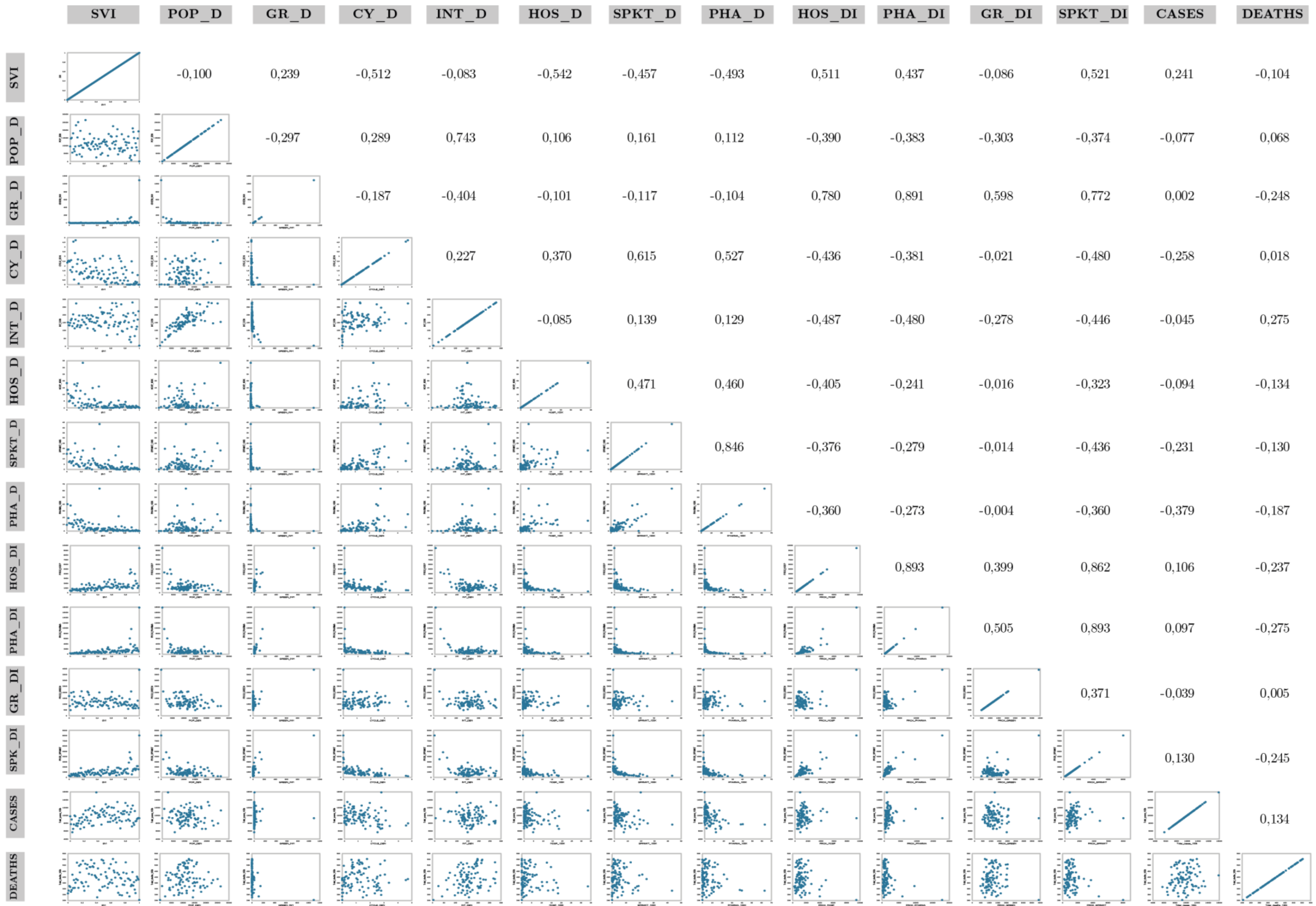
Appendix B1 – Scatterplots London



Appendix B2 – Scatterplots NYC



Appendix B3 – Scatterplots Rome



Appendix B4 – Scatterplots Sao Paulo