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Next City: Learning from Cities during COVID-19 to Tackle Climate Change

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Abstract: Fundamental principles of modern cities and urban planning are challenged during the COVID-19 pandemic, such as the advantages of large city size, high density, mass transport, free use of public space, unrestricted individual mobility in cities. These principles shaped the development of cities and metropolitan areas for more than a century, but currently, there are signs that they have turned from advantage to liability. Cities Public authorities and private organisations responded to the COVID-19 crisis with a variety of policies and business practices. These countermeasures codify a valuable experience and can offer lessons about how cities can tackle another grand challenge, this of climate change. Do the measures taken during the COVID-19 crisis represent a temporal adjustment to the current health crisis? Or do they open new ways towards a new type of urban development more effective in times of environmental and health crises? We address these questions through literature review and three case studies that review policies and practices for the transformation of city ecosystems mostly affected by the COVID-19 pandemic: (a) the central business district, (b) the transport ecosystem, and (c) the tourism–hospitality ecosystem. We assess whether the measures implemented in these ecosystems shape new policy and planning models for higher readiness of cities towards grand challenges, and how, based on this experience, cities should be organized to tackle the grand challenge of environmental sustainability and climate change.

Keywords: smart cities; health crisis; COVID-19; pandemics; intelligent ecosystems; connected intelligence; environmental sustainability; climate change

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1. Introduction

The COVID-19 pandemic brought significant disruptions in the foundations of economies, societies, countries, and cities all over the world. Starting from the changing USA–China relationships, the restructuring of global supply chains, decline of global trade, travel and mobility restrictions, we discuss in Section 2, significant disruptions occurred also at the level of policies. These include among others the demise of neoliberal policies, the return to strong state intervention and social-democracy, most evident in the recent US presidential elections and the European Union recovery and resilience plan, and a new concern for public goods, like public health, education, and the environment [1–38]. Additionally, the COVID-19 pandemic resulted in a broad acceleration of digitalisation, where all cities started working as smart cities, relying on online transactions, e-commerce, public e-services, teleworking from home. However, the pandemic also triggered new divides and forms of inequality, job losses and unemployment for all sectors that could not operate online. There is also a huge cost in human lives with more than 2.5 million deaths all over the world, documented by Worldometer-coronavirus data. Most socio-economic conditions before COVID-19 were proven unsustainable during the crisis, and new rules, regulations, behaviour changes and organisational measures were the first lines of defence against the pandemic.

Cities were hit by the pandemic in a very unequal way. Most cities quickly responded and adapted to new conditions, and those that did not paid a high cost in human lives. During the pandemic, core principles of city organisation and planning were challenged. Large city size, high density, mass transport, free use of public utilities and space, unrestricted individual mobility, which shaped the development of cities and metropolitan areas for more than a century, have turned from advantage to liability, putting at risk the urban population. Top metropolitan areas all over the world had the highest rates of infection and death. Milan in northern Italy, Paris in France, London in the UK, New York in the US revived dystopian visions of large-scale urbanization associated with infections, disruption of the health system, and mortality. People were trapped in high-density areas, mass transit and congestion. At the same time, urban sprawl, low density, rural urbanization, garden cities, and individual transport, which were strongly criticized as city planning principles, were proven more resilient in dealing with the new conditions.

Although COVID-19 cases still expand globally, there is a wind of optimism deriving from technological breakthroughs that led to the rapid large-scale production of new vaccines. However, still, there are many unknown elements that need to be considered; how intelligent is this virus, how it will evolve in the future, and whether we will be able to return before the pandemic regularity. The pandemic is, also, a learning experience and a learning curve on how to adapt collectively and individually in times of crisis. In the absence of effective drugs and medicine, other measures prevailed, organisational, behavioural, and technological. The lessons learned from the way cities addressed the COVID-19 crisis, towards reducing its impact and maintaining the highest feasible level of activity, can help them tackle other types of crises and grand urban challenges. This is the research gap we address in this article: build on the knowledge gained in tackling the current major crisis to meet another grand challenge, namely climate change. As far as we know, this research has not been done.

The paper aims to focus on this question and assess the COVID-19 crisis as a learning experience to deal with environmental sustainability and climate change. The research question is about the lessons we can take from the way cities confronted the current pandemic towards tackling climate change. To this aim, the paper is structured in five sections. Following this introduction and problem statement, Section 2 presents the framework of reference and literature to assess whether the way cities addressed the COVID-19 crisis represents a radical change in city management and development models, and if yes, towards what direction. We also investigate the reasons why it is important to have a clear understanding of current changes in cities, and how these changes are placed in the perspective of 21st-century cities and city planning. Section 3 focuses on the transformation of city ecosystems during the COVID-19 pandemic, where we discuss changes in three different city ecosystems: an area-type ecosystem, the central city district of offices and businesses; a network-type ecosystem, the transport and urban mobility ecosystem; and an activity-type ecosystem related to tourism and hospitality. We look for transformations and new trends within these ecosystems most affected by the COVID-19 pandemic. The last two Sections, 4 and 5, present the lessons learned from city and planning changes during the current health crisis and the conclusions about wider trends that are spread out in city ecosystems. We discuss how the organisational measures and technologies towards more radical changes in cities improve their readiness against the grand challenge of environmental sustainability and climate change.

2. Cities and the COVID-19 Pandemic: Literature and Theory Framework

A survey on publications that appear on Google Scholar, related to cities and the COVID-19 pandemic since 2020, reveals a total of 299 publications. Among these publications, we identified a corpus of 40 publications that are more relevant to the research question and topic of this paper. Table 1 provides an overview of this data. By analysing the arguments and the methods used in these 40 publications, we identified a set of 7 main

thematic areas which we use as a basis to study the relationship between cities and COVID-19 pandemic.

Table 1. Publications on Google Scholar on cities and COVID-19 since 2020.

Search Terms on Google Scholar	Number of Publications	Most Relevant Publications According to Google Scholar	Publications Relevant to the Topic of the Paper
“city COVID-19”	190	60	11
“cities COVID-19”	105	60	25
“city planning COVID-19” and “urban planning COVID-19”	4	4	4
Total	299	124	40

Source: Google Scholar.

2.1. COVID-19, Cities, and Global Challenges

It is commonly accepted that COVID-19 is a global challenge and both researchers and policymakers should consider the multiple dimensions of the crisis that go beyond the domain of health. The pandemic has exposed complex global interdependencies highlighting six connected global challenges related to: (1) food systems; (2) education; (3) cities and sustainable infrastructure; (4) security, protracted conflict, refugee crises, and forced displacement; (5) environmental resilience; and (6) global health, and their potential alternative futures [1]. As the fight against the COVID-19 pandemic continues, it becomes clear that the post-coronavirus world will be different in many ways, economically, socially, and health-wise. Major changes are expected in many fields, such as individual and social freedoms, international order, the role of international institutions, developing countries' dependence on debt, oil and essential technologies, IT and digital services, use of tracking devices to monitor citizens, potential conflict with human rights concerns in favour of security and safety, tourism and global mobility crises [2].

However, this view of radical socio-economic changes is not fully shared. Florida et al. [3] discussed the economic, fiscal, social and political impact of COVID-19 on cities and metropolitan regions and assessed the effect on urban economic geography at the intra- and inter-regional scales. They argue that “the pandemic is unlikely to significantly alter the winner-take-all economic geography and spatial inequality of the global city system”, but at micro-geographic scale, “it may bring about a series of short-term and some longer-running social changes in the structure and morphology of cities and suburb”, such as long-lasting transformations of work and shopping, changes in city functions, and creation of new local opportunities for reinvention [3].

The COVID-19 pandemic has affected all cities but in different ways. Scribano et al. [4] examined the experiences of COVID-19 across cities, by approaching cities as complex organisms with metabolism, and daily flows of people, materials, and information. In this context, Liu et al. [5] constructed a health index of cities using human mobility big data to evaluate the real-time impact of COVID-19 on a city's economy and society. Pilot use of the index in the city of Baidu in China shows that both internal and intercity population movements have been significantly affected by the pandemic. The index was significant in provincial capitals, such as Beijing, Shanghai, Guangzhou, and Zhengzhou, and urban agglomerations, altering the metabolism of the entire urban systems. Evidence on the relationship between COVID-19 and the size of cities is controversial. A mathematical analysis of COVID-19 patterns in India shows a common exponential growth, but with differences in the form of the curves between cities. For instance, in the city of Delhi, the COVID-19 curve flattens slower compared to other states and cities [6], whereas in Turkey larger cities do not indicate diversified behaviour, as infections are normally distributed within the country and the deaths from the pandemic do not grow in proportion to the city size [7].

2.2. Socio-Economic and Spatial Disparities in Cities during the Pandemic

COVID-19 has also exposed the effects of the unequal social geography within cities, as socio-spatial inequities in cities have played a critical role in the pandemic. In the US, data show that the overall COVID-19 mortality rate for Black Americans is 2.4 times higher compared to the rate of white populations, and 2.2 times higher compared to the rate for Asians and Latinos [8]. For indigenous American people, the mortality rate is five to eight times higher compared to the mortality rate of the white population [8]. In New York City, social and racial disparities have also affected healthcare access and the public health response to the pandemic. The tests have not been proportional to population groups across the city and increased significantly with the proportion of white residents in different city districts [9].

The different typologies of regions have also been found to affect the evolution of the pandemic. In Italy, both city centres and suburbs were affected by the pandemic. The urban region of Milan, the mid-size towns, such as Bergamo and Cremona, and suburban areas such as Codogno and the small municipalities of Southern Lombard, have witnessed a dramatic magnitude of contagion. The suburbs, usually spaces of escape, away from the high density of central city areas, places of fresh air and open space, have also become epicentres of transmission and infection through travel and community spread [10]. Another study in Italy has focused on assessing the correlation between infections and the different rural landscapes of the country. Rural landscapes are classified into four types: (a) areas of peri-urban agriculture surrounding the metropolitan cities, (b) areas of intensive agriculture with a high concentration of agroindustry, (c) hilly areas with highly diversified agriculture and valuable landscape, and (d) high hills and mountains with forests and protected areas. Evidence suggests that provinces with 10% more type C and D rural areas show 10% fewer cases of infection [11].

Additional spatial and social factors have also been investigated throughout the literature. In Indonesia, a statistical analysis showed that variations in the population size, distance to the capital city, number of people under observation, number of patients under surveillance, and number of health facilities, were able to explain variations in the number of positive cases of COVID-19 in the city of Bandung [12]. Moreover, Guadagno [13] explores the challenges that migrants have encountered during the pandemic, due to restricted mobility during the pandemic and mounting xenophobia in cities all around the world. Finally, in the case of informal settlements, the pandemic has been associated with further social exclusion. In Africa, informal settlements being a large part of African cities, have seen their residents moving to the urban periphery, indicating the need to upgrade these settlements in terms of socio-economic conditions, for reducing social inequalities and the dispersion of infectious diseases [14].

2.3. COVID-19, Environment and Climate Change

There is a two-way relationship between COVID-19 and the environment. On the one hand, is the effect of geographical conditions on the pandemic. The study of Yang et al. [15] investigated whether the relationship between climate conditions and COVID-19 transmission is subject to seasonal and geographical specificities, showing that temperature and relative humidity were driving factors of transmission, but their relations varied with season and geographical location. At the same time, Bolaño-Ortiz et al. [16] evaluated the spread of the pandemic in Latin America and the Caribbean region, analysing the correlation between climate and air pollution indicators in 10 cities: Mexico City (Mexico), Santo Domingo (Dominican Republic), San Juan (Puerto Rico), Bogotá (Colombia), Guayaquil (Ecuador), Manaus (Brazil), Lima (Perú), Santiago (Chile), São Paulo (Brazil) and Buenos Aires (Argentina). The results show significant associations between average temperature, minimum temperature, and air quality with the spread of infections. Moreover, humidity, wind speed, and rainfall were significantly related to daily cases, total cases, and mortality rates at various cities [16]. Moreover, in the case of India, evidence suggests that the COVID-19 epidemic trend evolution is closely related to the air quality improvement due to the nationwide lockdown in the 10 most polluted cities across the

country [17]. Similar results also derive from the study of Fernández et al. [18], who used the global database of the World Health Organization to show that environmental aspects, such as loss of biodiversity, high level of air pollutants, and diminished air quality were positively connected with the spread of infections and mortality in several countries.

On the other hand, lies the impact of COVID-19 on the environment and climate change, and the pandemic as an opportunity to advance the climate agenda and sustainable solutions in production and consumption. Markard and Rosenbloom [19] argue that this favourable conjecture to environment transition can be accomplished in two primary ways: (a) by harnessing the disruptive forces of the pandemic to accelerate the decline of carbon-intensive industries, technologies, and practices, and (b) by leveraging responses to drive low-carbon innovation. From these two strategies, they formulate five principles to Sustainability Transition Policy (STP). First, STP should promote both innovations in low-carbon technologies and decline to erode lock-ins that perpetuate carbon-intensive arrangements. Second, STP should be tailored to transition phases, niche markets in early stages and market formation in later periods. Third, STPs are context-sensitive, depending on sectors, jurisdictions, and regions. Fourth, STP should carefully monitor the progress of the environmental transition. Finally, fifth, STP should engage users and stakeholders as effective transition policies cannot be realised without the support of key stakeholders.

2.4. Measures and Policies to Address the Pandemic

Governments and health departments have elaborated and implemented various practices to prevent the spread of COVID-19 and promote the health and well-being of citizens. Nichols and Mays [20] reviewed the approaches applied in several large urban agglomerations and, the most frequent practices, such as increasing housing options, on-the-ground outreach and resource allocation, and integrated communications. The measures taken to address the pandemic vary with respect to the urban and regional context and resources available. Without a vaccine, practising social distancing, and protective hygiene are the most effective measures to limit the spread of the virus.

The survey of Durizzo et al. [21] in 1400 poor households in two African cities with the most infections, Accra and Greater Johannesburg, found that even though urban poor already followed the appropriate rules in terms of hygiene, and despite citywide lockdowns, events like large gatherings, receiving guests at home and leaving the house more than once per week continued to be common amongst them. In many of these cases, a lack of compliance with institutional rules derives because of deprivation instead of unwillingness to change behaviour. Additional conclusions refer to the fact that efficiency of measures relies on increased information, positive perceptions and approval of the government's actions, as well as having access to the infrastructure required to follow safety regulations [21]. In the case of New York, one of the most affected areas of the pandemic in 2020, the biggest takeaway was about maintaining daily life, the contribution volunteers and health workers who provided essential services; but also, about small things such as having a place to shelter, own a home with a porch and backyard, and even more not being alone, keeping a job and continue working from home [22].

2.5. Addressing the Pandemic with Rules and Restrictions

Amongst the first restrictive responses that have been applied during the COVID-19 pandemic came from the Chinese government in Wuhan City that applied quarantine and isolation control at a city and regional level. The study of Hou et al. [23] showed that quarantine measures effectively reduced and delayed COVID-19 infections, which is essential for controlling the pandemic outbreak. At the same time, migration control has been another restrictive practice against the transmission mechanism of COVID-19. A survey in 103 county-level regions of Hubei Province showed that COVID-19 indicates significant spatial autocorrelation, and the spatio-temporal differentiation affects the spread

of infections [24]. The authors argue that the evolution of COVID-19 has spatial concentration and temporal continuity, and therefore, timely prevention measures are of great significance to combat the spread of the epidemic.

Isolation hotels have been used as alternate sites to address the needs of guest populations affected by the pandemic [25]. In New York, the isolation hotel programme emerged as a community-based public health intervention to mitigate the community spread of the coronavirus. The hotel programme operates on all suspected or confirmed COVID-19-positive individuals, individuals experiencing symptoms of illness, or individuals vulnerable to COVID-19 requiring physical, emotional, social, and family support to aid their recovery. The programme also offered support to homeless individuals living in crowded or congregate houses, and families did not use their homes out of fear of potential exposure to infection [25].

At an individual behaviour level, restrictions on mobility have also been implemented as policy measures promoting mostly self-protecting behaviours by the population. The survey of Armstrong et al. [26] in 75 Canadian and American cities estimated the effect of these policies on mobility patterns in each city, indicating evidence that the applied measures—state of emergency declared, school closures, day-care closures, limits on nursing home visits, shelter-in-place rules, non-essential business closures, public mask-wearing, restaurant closures, fitness centre closures, and cinema closures—had a strong impact on mobility, as all different forms of mobility decreased and remained at low levels even after the measures were suspended.

Moreover, market access restrictions have also been applied as common quarantine measures. In this case, market-related measures came with a dilemma: what is the maximum amount of consumption that a utilitarian welfare function would be willing to trade-off to avoid the deaths associated with COVID-19? The survey of Hall et al. [27] tries to address this question arguing that the answer depends crucially on the mortality rate: If the mortality rate is 0.81%, then the amount is 41% of one year's consumption. This share is defined by the expected number of deaths from the pandemic at each age, weighted by the value of life at those ages as a share of consumption.

From the above, we can see that flattening the curve of COVID-19 infections and deaths required a mix of health care, government, and community measures and policies. However, the impact of the COVID-19 pandemic extends these domains, as there have been side effects resulting from the applied measures that have affected various expressions of everyday life, like the most vulnerable groups in terms of food, housing, health, mental health, and other essential resources [8].

Restrictions and quarantine controls cannot last over long periods. A clear exit strategy is needed in every city and country. Rawaf et al. [28] suggest four guiding principles of an exit strategy, considering a broad set of public health conditions, rather than the decline of infections alone. These include (a) the infection status, (b) community acceptance, (c) public health capacity and measures, and (d) health system spare capacity. In Chinese cities, the reopening was related also to citizen discontent and economic conditions, and early reopening occurred in cities with high debt repayments, indicating responsiveness to local fiscal conditions [29]. A survey of Manchein et al. [30] on infected cases from countries of Asia, Europe, North and South America showed that power-law growth is observed for all countries and the power-law curves between countries are statistically highly correlated. Soft quarantine strategies alone were not sufficient to flatten the growth curves. Instead, they proposed a strategy to flattening of the power-law curves, combining social distance measures and identification and isolation of infected individuals. As the pandemic evolves, there is increasing realisation that at the end of COVID-19 restrictions does not lead to returning in the pre-pandemic normal, but about moving to a new normal defined by high alert and resilience and the diverse conditions of each country [31].

2.6. Addressing the Pandemic with Digital Means

The use of digital technology and smart city solutions have significantly complemented the policy frameworks that have been imposed to control the pandemic. Insights deriving from recent literature reveal three directions in which we can categorise actions and measures that are related to digital means.

First, digital means have helped in tracing the spread of infections. In this context, Shamil et al. [32] developed an agent-based model that simulates the spread of COVID-19 infections across locations and daily practices. Each person is considered as an agent that can transmit the coronavirus and the model assesses how transmission takes place via various actions. The model is validated with real data from Ford County in Kansas (USA), by comparing estimated and real cases. Experiments using this model show that the spread of infections can be contained by combining contact tracing via smartphones and a city-wide lockdown.

Second, digitalisation can improve communication efficacy by using the new media environment for better communicating health strategies, insights and scientific outcomes to support moving from the acute phase of the pandemic to the “next normal”. In this case, we can identify three areas that need further attention regarding communication capacity building: (a) the pandemic is creating an unprecedented high volume of information, and hence, health communicators may need to compete for the attention of their audience, while “the loudest voices in the room may be perpetrators of false information, which is often the case with anti-vaccination disinformation”; (b) it is essential to consider and acknowledge potential uncertainties that follow the growing number of scientific evidence and articles on COVID-19, that are being published without undergoing traditional peer-review processes; and (c) it is essential to focus on promoting health literacy, towards helping users on how to navigate on social media platforms and access accurately the available information [33].

Finally, deploying digital systems and solutions can facilitate and support the enforcement of social distancing. Smart city initiatives had a great impact on living conditions during the pandemic and smart city systems brought significant changes to everyday life. However, the COVID-19 pandemic has also revealed limitations of available smart city solutions and the need for systems providing mechanisms to assist in limiting the spread of infections. Shorfuzzaman et al. [34] proposed a data-driven deep learning-based framework using information from mass video surveillance. Social distancing monitoring becomes feasible by real-time object detection models for the detection of people in videos captured with a camera. Additionally, several IoT applications have been envisioned to facilitate data-driven and smart application for the user. Smart City and Intelligent Transportation System (ITS) offer a futuristic vision of smart, secure and safe experience to the end-user, and at the same time efficiently manage the sparse resources and optimize the efficiency of city operations. Additionally, the pandemic has revealed limitations of IoT solutions, and the existing applications and technology systems need for swift and timely enforcement of guidelines, rules and government orders to contain the spread of infections. Gupta et al. [35] proposed a new architecture and AI-assisted applications that can be used to enforce social distancing measures.

2.7. Addressing the Pandemic with Urban Planning

Many principles of urban planning have been questioned during the COVID-19 pandemic, due to the different ways cities and city districts behaved in the transmission of infections. The critique of high-density urban environments and mass transit transport systems was one of the most frequent aspects, followed by the need to reassess most city planning theories.

In this direction, Balcı and Türk [36] discussed possible changes in the urban planning in the era of the pandemic, such as population density planning in urban parcels, increase in the amount of open and green areas in the city, changes in real estate demand, changes in working conditions, education and businesses, institutional changes, increase

in agricultural areas in cities, changes in standards in street planning, diversity in transportation. Moreover, Gallo et al. [37] discussed the relationship between epidemics and cities, including issues of density and urban infrastructure, as well as others the health crisis has revealed, such as housing, public spaces, distance work and learning, human adaptability, and environmental conditions. They point out to urban conditions that contribute to the spread of the virus, the strong social connectivity in informal urban settlements, the barrier to social distancing in homes with minimal space, limited ventilation and conditions of comfort, public spaces heavily occupied making the necessary distance even more difficult, and cities are questioned as places of meeting, civility and urbanity.

Restrictions, quarantine and lockdown measures, behaviour changes in mobility and travel, as well as remote working, have been widely practised to reduce the spread of the coronavirus. As a result of these practices, there has been a reduction of activity in aviation (−75%), surface transport (−50%), industry (−35%), public buildings and commerce (−33%), power production (−15%), air pollution is diminished, and the levels of atmospheric nitrogen dioxide (NO₂) and carbon dioxide (CO₂) (Gupta 2020). These changes are provisional, and therefore, a return to the previous condition is expected at the end of the pandemic. However, a more permanent change in reducing air pollution would be feasible by the adoption of novel city planning principles, such as Transit-Oriented Development, smart city planning, green city planning, habitat prevention and restoration, and in general sustainable planning [38].

3. City Ecosystems during the Pandemic: Three Case Studies

The literature we have reviewed discusses the impact of COVID-19 on cities, considering cities as homogenous entities without internal differentiation and fragmentation. However, this does not reflect accurately the real urban conditions, and cities are systems of systems, composed of ecosystems that behave and respond differently during a pandemic. In this section, we focus on ecosystems that make up cities and look at the trajectories of three ecosystems that were strongly affected by the current health crisis: the central business district, the urban transport ecosystem, and the ecosystem of tourism and hospitality. We examine common trends that appeared in many cities and the measures that have been taken by public and private organisations to address the pandemic in each of those ecosystems. We try to identify aspects that will probably remain after the pandemic (e.g., work from home, e-commerce, e-meetings, restructuring of supply chains), and lessons about adaptability, intelligence, and resilience of each ecosystem. The case studies are based on data collected for cities all over the world and have been presented in policy reviews, online repositories, such as the “Cities4GlobalHealth” [39] which gathers more than 650 initiatives from 104 cities in 34 countries, and other city-related reports.

3.1. The Restructuring of Central Business Districts and Environmental Impact

COVID-19 and its restrictions have led to significant spatial transformations of the business centres and traditional office districts. The impact on the social vibrancy in the centralized office areas is apparent. Several business leaders express their concern that pre-pandemic vibrancy might never be restored, while other theorists support that families and older people may leave city business centres for the suburbs or the countryside, but their departure will create opportunities for younger people.

Traditionally, the need to be present in the place of work was spatially expressed with large office buildings, spacious meeting rooms and lately with tenderness for open floor plans and co-working spaces supported by other adjacent amenities such as canteens, cafeterias, gyms, all leading to high-priced business operations. Until the beginning of 2020, this model appeared to be the most successful in creating thriving business and innovation ecosystems, as large urban centres have been managing to attract young and talented professionals from different parts of the world. However, this need for large business offices in central districts has skyrocketed the rent prices, while urban cores have stayed deserted during night and weekend. On the other side, this model has provided

what Castells and Hall [39] discussed in their book “The Technopoles of the World” as a “generation of synergy”. “Technological innovation depends on the process of learning by doing, rather than off-the-shelf operation manuals”, while the success of various technopoles was evaluated with regard to the “milieux of innovation” [40] (p. 9). Jacobs [41] also argued for the return to tenderness in urban street life. The idea that “serendipity” in cities fosters innovation has been a mainstay of urban theorists for many years [41]. However, physical collaboration is one of the work aspects most hit during the pandemic.

Since the first days of the lockdowns, numerous corporate businesses and public organisations have given a great emphasis on the improvement of their IT systems and the encouragement of their office-based employees to connect remotely and telework. In support of the decrease of the COVID-19 spreading and the maintenance of social-distancing, online meeting platforms substituted on-site collaboration, physical meetings and charrettes. Rather unexpected, working from home increased companies’ efficiency and productivity, despite some initial challenges that workers faced through the transition to teleworking. At the same time, the necessity to live in proximity to work has been reconsidered and a large number of employees, able to work remotely from anywhere, have escaped from urban centres, resulting in the most dramatic drops in their vibrancy and pedestrian activity. Families have fled for spacious and more affordable peri-urban homes. Suburban areas, villages or even islands [42] have been transformed into receptors of digital nomads. People are escaping from the problems and the high living costs of urban centres and start taking advantage of the benefits of working in the countryside, surrounded by green landscapes.

Such is the current exodus happening in the San Francisco Business District. At the beginning of 2020, the San Francisco business centre was facing the highest cost of living and rent prices during the last decades [43]. The constant arrival of talent from all over the world, the great concentration of technology companies and start-ups, the high salaries along with several other factors helped the city to be considered the most attractive global start-up ecosystem, ranking first in the United States and globally [44]. The city of San Francisco as many other global cities has been replicating the traditional model of the business centre with the large, centralized office buildings in strategic spots in and on the outskirts of it. However, this model has led to the nation’s longest commute times [45], the highest rates of traffic, congestion and pollution levels, drive-alone long commutes, overloaded means of public transportation during pick hours, and other urban, mobility and environmental problems that the city has been facing during the last years. According to the study “San Francisco’s Carbon Footprint” [46], in 2018 emissions from cars and trucks were responsible for 46% of total emissions.

During the pandemic, this situation has changed, and the city has been facing a massive exodus, which has pushed to a huge increase of workspace and housing vacancy and the rents in the prohibitively expensive business centre to their lowest in years [47]. During the same period, Bay Area Rapid Transit ridership was down 50–70% and nearly 90% during the first months, as is indicated by the TomTom Traffic Index for San Francisco. This trend was supported by the perception that urban density and mobility with mass transit increased the risks of infection from COVID-19.

In support of the city’s goal to market the business centre and bring back the population that left, the San Francisco planning department initiated rapid zoning amendments allowing for flexibility in zoning and outdoor space such as the “Shared Spaces” programme [48], which helps residents and businesses adapt to living and operating through the pandemic, or the “Slow Streets” programme that enhances micro-mobility and a healthy post-car urban living [49]. At the same time, the city is pursuing a Clean Transportation Future for the Business Center Area by replacing car travel with more sustainable transportation modes to reduce greenhouse gas emissions and create a healthier environment for its residents, workers, and visitors. San Francisco has set the goal of achieving 80% of trips by transit, biking, walking, and carpooling by 2030 [50]. The congestion pric-

ing programme in Downtown Business District was another measure in the same direction, which found enthusiastic support for the environmental and livability benefits that would come with a congestion-pricing plan, while officials estimate that would mean 15 percent fewer vehicles on downtown streets [51].

The initial dystopian vision of the business districts has now been replaced by a new business district and workspace model which will allow for flexible schedules and shared spaces [52]. A hybrid model balancing between presence in the office for important physical meetings and remote working is considered as the most preferable future “normal” work experience for most US workers [53], which could potentially solve traditional problems of business centres and advance climate change. The current behavioural shifts and the decreased need for office space, buildings and headquarters, could finally result in fewer commutes, less congestion, more affordable housing units and green space in the urban centres. It can become a global opportunity to restructure business ecosystems to tackle climate change.

3.2. *The Urban Transport and Mobility Ecosystem*

The COVID-19 crisis and the containment measures that followed to restrict the spread of the virus had a direct and profound impact on transportation and mobility like in no other city domain. Data from Moovit and Google mobility reports show a significant decline of mobility which in many cities was as high as 90% during total lockdown (e.g., London, Lyon) but remained relatively low even after the restart of some economic activities. Public mass transportation was significantly affected, with citizens preferring individual means of mobility (car, bike) as safer alternatives [54].

Since the beginning of the pandemic, governments and transport operators adopted measures that restricted travel and commutes and/or posed significant alterations in the operation of transportation. The reduction of transit services, due to the drop in demand and the need to mitigate the spread of the virus, was also accompanied by a reduction of the maximum capacity of trains, buses, and other means of urban mobility, to ensure social distancing [55]. Many operators have promoted the purchase of tickets online or through automated vending machines to reduce physical contact; transport fleet and transit areas were frequently sanitised, and, in many cases, cameras were used for tracking the temperature of passengers or their compliance with mask-wearing rules [56].

Apart from general policies which were taken at the national and regional level depending on the epidemiological condition at the time, city authorities themselves adopted a wide variety of additional measures depending on the characteristics of the city's transport network structure, the type of flows of the local population and/or other emerging mobility needs. Many repositories and reports were created presenting such case studies, based on policy responses towards transport and mobility and allowing other cities and transport operators to review ideas while confronting this unprecedented crisis. Similar to the Cities4GlobalHealth is the COVID-19 Mobility Works repository [57], an independent platform dedicated to collecting, synthesizing and sharing mobility initiatives that are keeping the world moving during the COVID-19 pandemic. The OECD [58], as well as the National Association of City Transportation Officials (NACTO) with its “Streets for Pandemic Response and Recovery” [59], have also developed libraries of city policy responses to COVID-19 and emerging practices with case-studies from cities and transit agencies around the world. By reviewing these policy measures, it becomes clear that most have a temporal character, focusing either on operational issues of the transportation service itself or urban planning-related changes to adapt to the new reality and allow the city and its citizens to function and move safely and efficiently.

The first set of responses we identify are new transport rules and regulations, such as the reduction of the speed limits in certain city areas (in many cities, among which San Francisco, Milan, Brussels, Oakland), the suspension of parking enforcement policy (mainly in US cities like Denver, Los Angeles, New York) and even some financial policies that allow essential workers and medical staff to use transport services for free (e.g., in

Lima, Manchester, Budapest, Nice). Second, we identify changes in transportation planning and operations, including changes in the services offerings similar to what is described above or new services creation adapting to emerging needs. In Gurugram (India), for example, the inactive bus fleet was repurposed as a utility bus carrying essential food commodities from wholesalers to retail points [60], while in Barcelona (Spain), buses were used to transport medical teams and COVID-19 patients to hospitals and isolation facilities. In other cases, ICT was used to improve certain transport service components, like the in-app metro reservation system that was used in Beijing to avoid clustering and reduce the waiting time [61]. Additionally, to the measures above, many cities have made efforts to inform citizens on the alterations of services making signal adjustments or developing online dashboards and to teach/train them (e.g., free bike lessons provided in Sydney and Newcastle or awareness campaigns on new safety measures while using transport services) to gain support for a position or to influence their behaviour. Fourth, many cities have implemented solutions to improve monitoring and alerting, usually taking into advantage the advancements already developed in the field of smart transport. Drones, smart surveillance cameras, mobile applications, and the use of open data and IoT infrastructure have created many opportunities for cities to inform about availability and improve performance while limiting the health dangers of mobility. Fifth, many cities have made improvements in infrastructures, like the use of automated pedestrian crossings implemented in many Australian cities (Sydney, Brisbane) to avoid people having to touch surfaces to crossroads or the use of robots for transport fleet sanitation in Hong Kong.

The most widespread response though was the promotion of active mobility (like walking and cycling), as well as of micro-mobility (e.g., e-bikes, scooters, e-scooters, and other alternatives to motorised transport shrinking the physical footprint of human mobility). These measures were accompanied by spatial planning changes, i.e., changes in the land use of cities considering patterns of flows and emergent mobility patterns/behaviours. Such measures, mostly in the form of reversible adaptations, aim to integrate alternative mobility options (active mobility and micro-mobility) in the urban transport network with the provision of interconnected infrastructure. Therefore, financial incentives for bike purchase and bike donations were complemented with the pedestrianisation of many streets, the development of pop-up cycleways and the expansion of existing ones either accelerating the implementation of existing strategies or posing new ambitious targets.

Finally, a set of measures that probably relate to the future of the transport industry and might play a significant role in the transformation of urban mobility post-COVID19 focus on the promotion of demand-responsive transit, meaning the promotion of flexible routing/services and micro-transit services. Much like the services developed based on the emerging sharing economy paradigm, the pandemic has increased the interest in flexible microservices that serve more efficiently the needs of the customers and manage the risk more easily.

3.3. The Tourism and Hospitality Ecosystem

The effects of the COVID-19 crisis on tourism and hospitality have been investigated thoroughly, as the current pandemic situation encloses significant drawbacks for these sectors. Evidence suggests that over 150 million jobs related to tourism are at risk worldwide [62], whereas a significant number of jobs related to food services will be also affected on a large scale by the pandemic outbreak [63]. However, the extent to which this crisis will affect these sectors in different geographical areas depends not only on the spatial characteristics [64] but also on the policy responses that each city or region implemented during and after the pandemic.

Recent studies on the field of tourism and hospitality have started to emerge as a response to the COVID-19 crisis [65–68], trying to investigate the key challenges that these two sectors face amidst the pandemic outbreak, as well as to provide key insights for these

industries for the future. Most analyses focus on identifying the main factors affecting overall resilience in the tourism and hospitality sectors. In the first case, the literature suggests that several forms of capital are closely related to processes towards forming and enhancing disaster resilience in the tourism sectors, including cultural, economic, human, natural, physical, and social capital [69]. In the latter case, evidence suggests that innovation and creativity are the key elements that can build resilience in the hospitality sector, towards responding to changing market dynamics closely related to variations in consumer demands [70]. At the same time, several forms of capital, like physical, human, and social, are also highly recommended for building resilience in the hospitality industry [71].

Although previous studies have identified the factors affecting resilience in these two sectors, the recent pandemic restrictions and policy measures have revealed significant vulnerability aspects related to them [68]. Policy interventions towards flattening COVID-19 curves, including social distancing, stay-at-home suggestions, local lockdowns, alongside travel and mobility restrictions, significantly affected market demand for these two industries [72]. Therefore, significant changes need to be made in terms of operation, referring to both the employees' and customers' side, covering mostly health and safety aspects [67]. Initial findings indicate that returning to normality will not be sufficient to restore the pre-COVID-19 demand on hotels and restaurants, and hence, additional actions need to be taken mostly related to behavioural and operational marketing [73,74].

Regarding the different types of strategies that have been and will be used during and after the pandemic outbreak, three discrete dimensions have been identified by Alonso et al. [75], including: (i) a self-reliant dimension, which focuses on identifying and using alternative processes for revenue, such as delivery and takeaway options for the case of restaurants, as well as reducing work hours and rotating staff; (ii) a vigilant dimension aiming at increasing health and safety measures, as well as applying for relief measures provided by local governments; and (iii) an inoperative dimension which refers to a potential discontinuity of operations and novel approaches for reopening the business [75]. Efforts have been made to assess the effectiveness of such policy and business-based interventions towards identifying differences between them, not only in terms of their effectiveness but also regarding their applicability potential. When focusing on policies related to advanced health and safety protocols, such as more rigorous and frequent cleaning and a limited number of customers, evidence suggests that these are the most effective safety interventions that can boost demand-side trust in tourism and hospitality businesses [73]. However, additional research on behavioural interventions is needed to further investigate the differential effects of these measures on customers' attitudes and behaviours. At the same time, concerning more technology-oriented practices for flattening the COVID-19 curve, findings indicate that technological innovations can bring a novel approach to how many services are delivered by minimizing human-to-human interactions through contactless payments and access to information, as well as online communication [74]. Additionally, new technologies have provided the opportunity to promote remote working practices in several sectors, a fact which has not been feasible in the cases of tourism and hospitality due to the nature of work in these industries [76].

When exploring the policies related to COVID-19 response on tourism and culture, it is essential to take a closer look at the various city-specific responses that have been introduced in different settings. Concerning the tourism sector, two different policy lines have been applied. First, some cities tried to promote a more international profile as a travel destination. In this case, the city of Reykjavik (Iceland) has promoted actions focusing on developing marketing campaigns for the city as an international travel destination when returning to normality [77]. Another interesting approach is the one promoted by Milan (Italy) where the city-branding approach is related to a "Safe City" fully aligned with health protocols [78]. Second, there is a group of cities aiming to follow a more sustainable business model, shifting away from large-scale tourism. To this end, Florence's (Italy) recovery plan for tourism focuses on posing restrictions on touristic buses to the

city centre, alongside promoting investments relevant to local uses for residents and businesses there [79]. At the same time, Barcelona (Spain) and Budapest (Hungary) follow a similar approach by reorientating their tourism models towards cultural and family-friendly models [80].

In the case of the hospitality sector, various approaches have been introduced within the different city settings, without forming any broader categories. More specifically, in the case of Yokohama (Japan), significant efforts have been made towards supporting the restaurants, including the development of an online platform, named “Takeout and Delivery Yokohama”, aiming at assisting businesses offering meal takeaways or deliveries [81]. In the same spirit, Düsseldorf (Germany) has launched a similar online service through which citizens can get information regarding which local shops and restaurants offer delivery service [82]. Apart from access to online delivery systems, advertising campaigns have also been used to balance the demand for the hospitality sector. More specifically, Frankfurt (Germany) has started to offer promotion campaigns of local businesses as part of its economic support programme. Encouraging and informing citizens on how to exploit the benefits offered by a large number of local delivery options is essential for managing to overcome any COVID-19 drawbacks in the hospitality sector [83]. An alternative approach comes from the city of Saga (Japan), which has introduced an innovative measure for boosting the future demand for hospitality businesses, by using public pedestrian spaces as part of a new style of restaurants and bars. The programme is called “SAGA Night Terrace Challenge” and provides a collaboration between Saga City and the local business association [84]. Finally, Tel Aviv-Yafo (Israel) followed a more economic-benefits practice by excluding hospitality businesses from paying municipal taxes for three months, alongside other fee exemptions, such as night-time operating and public spaces licenses [85].

4. Discussion: Learning from COVID-19 to Tackle Climate Change

“COVID-19 is awful. Climate change could be worse” [86]. This Bill Gates warning underscores the need for a comprehensive understanding of the current global health crisis to provide insights related to the next, namely climate change [86]. Since the Kyoto Protocol, global emissions of greenhouse gases, especially carbon dioxide, have increased, ocean heat rises, arctic ice melts, heatwaves intensify, and rising sea levels endanger near-sea level and river delta settlements. Climate change has a direct effect on human health through events such as heatwaves, floods and storms, and indirect ones related to the transmission of infectious diseases, the availability of freshwater and changes in the food supply chain [87], setting the scene for the next health crisis. Three directions of action and measures on how cities and societies have addressed the COVID-19 pandemic stand out as lessons to tackle climate change and mitigate its risks: (a) measures based on restrictions and rules for using and planning cities, (b) measures based on digital means and smart city solutions, and (c) measures based on research, technology, and innovation.

4.1. Fight Climate Change with Rules, Restrictions, and City Planning

As described earlier, demographics and mobility patterns depict a current exodus out of crowded urban business centres and a return to the suburbs. However, it remains unclear if and how current mobility patterns will be restored when the reopening of the economy will occur when restrictions on the use of public space and social distancing policies will have been lifted [88]. Until now, we see that the majority of the planning measures are temporary with some of them having a purely sanitary scope, such as the closing of access to parks in France, in the waterfront in many cities in Greece or the limitations of circulation per age group in Spain. These measures affected the use of public space and mobility but without contributing to the future development of urban space. However, to reflect better on policy recommendations with a long-term vision, we need to focus on measures that were brought up in the context of the pandemic to serve sustainable urban and mobility planning beyond this crisis.

Pandemic revealed pre-existing inefficiencies in spatial planning efforts and accelerated the cities' changes to meet their global goals outlined in the Paris Agreement, the Sustainable Development Goals, or the New Urban Agenda, shifting from oil-based economies to social, environmental and economic sustainability. The public health crisis along with the enforced lockdowns constitute an opportunity for cities to test planning policies and other tactical urbanism interventions in a short time but most important, to rethink how these proposed spatial and transportation planning policies and measures could make our urban environments more resilient and flexible to adjust to unforeseen events.

As a first urban planning response after the first lockdowns, more and more city leaders started testing the "complete neighbourhood" and the "walkable city" concepts, creating more space for pedestrian access, towards a less car-oriented city model. By implementing the model of "complete neighbourhoods", cities aim at bringing inclusion and accessibility by reducing the need for long commutes and mass transit, while residents retain all the benefits of a large city and the access to basic amenities one needs in a sustainable urban environment (housing, employment, retail, schools, libraries, health centres) within a walking distance, such as the example of the "Twenty Minute Neighbourhood" city model introduced by Gil Kelley, the Planning Director for Vancouver and formerly Portland. This concept, which manages to create healthier mobility behaviours by decreasing traffic, essential commute and the barriers to amenities, has been a mainstay for city authorities during the last decades. However, as the confinements started to loosen up, the concept of the "15–20 min city" [89] was brought up again by city leaders as a good planning concept to combat the consequences of both the pandemic and climate change.

Another approach that could be transferred through the COVID-19 pandemic towards the climate change fight is the need for rapid zoning amendments which became gradually evident, as the impacts on social vibrancy were more present. City authorities are now allowing for mixed land use and flexibility in zoning, building adaptive uses such as turning hotels and vacant buildings into temporary housing, and other examples of retrofitting public spaces, such as turning parks into pop-up medical facilities or other amenities as meanwhile solutions with a long-term vision to combat infectious diseases. This provision of flexibility in land use distribution and the increase of adaptive reuse will eventually enhance the vision of a post-fossil fuel city, while it will reinforce the creation of areas, less dependent on private automobiles, with a lower carbon footprint and equal access to basic amenities (food, healthcare, retail etc.).

4.2. Fight Climate Change with Digital Means and Smart Cities

When it comes to digital means and smart cities, we need to highlight that much like the COVID-19 crisis described earlier, climate change and environmental sustainability constitute great challenges that question fundamental aspects of modern cities, like the growth model, based on industrialisation and endless consumption, or significant urban routines and behaviours, like mobility and daily commuting. Against such problems, technological developments and the emergence of the smart cities' paradigm bring innovative solutions that can not only relieve their impacts but can also lead to transformational changes at their root causes. Digital transformation of urban activities and operations can not only increase flexibility and resilience of cities against the consequences of climate change but also lead to a pathway towards sustainable development. There are many ways in which this can happen.

First, with dematerialization through the opportunities provided by digital technologies. Transferring many urban activities at the digital level, such as remote working or education, assisted with platforms and apps that enhance online communication/collaboration and monitor productivity, can reduce GHG and CO₂ emissions, the main cause of climate change [90]. However, this is not a shift that can occur overnight. Response to the challenges of sustainability and climate change with such profound impacts on cities and the society — as a whole — requires large-scale changes to city operations but also to norms,

values and societal behaviours shaped through generations. Systems need to be re-designed considering citizen's shifting needs and changing patterns of customers' demand.

The second is through the exploitation of big data and data analytics for monitoring, forecasting and knowledge-based decision making. Big data in combination with smart city technologies and applications (e.g., sensors, data analytics, AI, IoT, monitoring systems of urban operations and infrastructures) can improve efficiency, awareness, and flexibility of urban ecosystems through real-time adjustments and better decision making [91,92]. Potential areas of application involve energy use in buildings, transportation and urban mobility, waste management, climate-related crisis management and many more [93]. The exploitation of ICT solutions and big data do not only improves the resilience of cities in terms of responding to climate change implications but also in terms of adapting and transforming themselves as sustainable, net-zero cities. Overall, their use can convey and manage urban complexities in a meaningful way, detect patterns and create connections in a service-specific approach, and also, establish synergies [94,95].

Third, by leveraging the power of social media and digital infrastructures for crowdsourcing innovative solutions harnessing the users' collective intelligence. Social media and digital platforms provide new environments of social interactions that cultivate learning, networking, collaborative innovation, and behaviour adaptation based on a specific problem/need [96]. Through these flexible areas for participation, collaboration and creativity, innovative solutions to great societal challenges can emerge, facilitating thus and increasing the capacity of the official authorities with limited resources [97,98].

4.3. Fight Climate Change with Scientific Discovery

The real end of COVID-19 is expected through scientific discovery and innovations in drugs and vaccines. A rapid decline in infections and deaths is already recorded in countries where vaccination has moved rapidly (UK and Israel). Zero carbon technologies, fighting climate change through research and innovation, will be the equivalent of COVID-19 vaccines in the field of environmental sustainability. They will provide long-term solutions addressing the deep causes of CO₂ production and anthropogenic climate change.

The literature on technologies and innovations that can address climate change is wide, as well as the variety of technologies proposed, ranging from new materials and technologies (photocatalysis, self-cleaning and coatings material, paints and glass for urban use that can eliminate greenhouse gases) [99], new renewable energies (Seawater Steam Engine) [100], to food production technologies (aquaculture) [101], and other technologies.

Carbon capture and removal technologies hold a preeminent role in this agenda of technological engineering for climate change. Several greenhouse gases (GHG) removal technologies have been proposed, called negative emissions technologies also, but still are uncertainties in the estimation of their real impact on GHG removal [102,103]. No doubt, there is a need to remove carbon from the atmosphere to stabilize the world's temperature. The amount of removal is estimated from the Intergovernmental Panel on Climate Change at 3 to 7 gigatons of CO₂ per year by 2050 to limit warming to 1.5° C. There is also high hype in the domain with the recent Elon Mask offering of 100 million USD prize for the best carbon capture technology [104].

A safer estimation is that no single technology will be sufficient to tackle climate change and a mix of interrelated technologies and innovations would be needed to achieve absolute zero carbon emissions. This mix should include [105]:

- Energy generation and storage such as photovoltaic, wind, and thermal renewable energy production, storage infrastructure
- Interconnection and usage optimisation, with the extension of smart grid to support higher renewable penetration and prioritisation, and electrification of heat and transport

- Conversion to electric mobility with electric vehicles, e-bikes, e-scooters, and mobility-as-a-service (MaaS) solutions, as well as fast-charging infrastructure
- Building technologies for better insulation and less thermal energy loss; passive building construction, green roofs, and heat-island reduction
- Nature-based solutions, regeneration of green spaces, planting trees, encouraging urban agriculture, and restoring wildlife habitats.

The key is the integration of the above technological solutions. It can be achieved in cities at the level of urban ecosystems and city districts, where energy, ICT, and building technologies can be combined. Net-zero emissions are not feasible unless some of the human and livestock-generated GHGs are compensated by nature-based solutions, planting trees, and restoring grasslands.

This orientation of research, towards integration for achieving the zero-carbon target, is reflected in the large-scale Smart Cities and Communities lighthouse projects of the EU Horizon 2020 Programme. Each lighthouse project that was implemented from 2017 till the end of H2020 had to cover all of the following aspects: (a) significantly improve energy efficiency through integration of existing buildings with new buildings, (b) incorporate renewable energy sources and maximising the use of local RES, (c) integrate electricity fuelling infrastructure for electric vehicle fleets, (d) use digital solutions for improved planning, management, control and maintenance of physical urban infrastructure, and (e) ensure interoperability between software modules to allow effective management of components and information flows [106].

5. Conclusions: Tackle Climate Change with Connected Intelligence

Tackling grand challenges related to health, society and environment will be among the priorities of urban planning during the coming years and will shape the “next city”. Given the high complexity of these challenges, cities need to adopt a holistic perspective and combine knowledge from various fields of science and technology. Merging different scientific fields and creating holistic solutions to grand challenges needs cross-discipline research, that can only be achieved through scientific collaboration and interdisciplinarity. The complementarity of ways and thinking deployed to address the COVID-19 crisis provides some important lessons to this end.

First, the recent COVID-19 pandemic was a large-scale social experiment on the ways a health crisis can provide insights on how to improve the rule-based functioning of cities and update urban planning principles. It revealed drawbacks and gaps that traditional urban planning did not consider, related not only to health and safety issues but also to environmental ones. Experimental policies and new rules of city function, which have been applied in different urban settings during the pandemic period, indicate that even though it was a health-oriented reason that triggered changes in the design and implementation of urban processes, including land use, mobility and hospitality, the effects deriving had a positive impact on broader conditions, like the urban environment and climate change. Policy measures and city planning during the pandemic have documented the capacity of rules and regulations to improve the working and resilience of cities.

Second, digital services and e-tools have been proven essential instruments for helping all urban actors to develop more resilient and environmental-friendly behaviours. Digitalisation has shown great potential in terms of transferring urban activities and interactions from the physical space to digital environments, enabling cities to function with restrictions imposed for social distancing. Cities maintained a good level of activity due to digital transactions, e-commerce, and teleworking. In parallel, digitalisation offered alert about environmental conditions, like air quality and waste residuals, reducing also the risk to spread of infections.

Third, lessons learned from the recent pandemic crisis have shown that scientific discovery is essential for addressing grand challenges. Considering that the environmental crisis and climate change can be received as equal challenges compared to a health crisis,

the recent experience has shown that any applied policies and measures cannot achieve the desired outcomes without being accompanied by relevant scientific discoveries. The 2nd year of the pandemic made clear the high impact of vaccines in the fight against the pandemic. In the case of climate change, equivalent technology breakthroughs related to renewable energy generation and storage, interconnection and usage optimisation, CO₂ capture, as well as nature-based solutions, are needed.

The lesson from the COVID-19 crisis is that all three types of action, (a) new regulations and city planning, (b) digital services and e-tools, and (c) scientific discovery and innovations must be combined to leave the pandemic behind. A holistic approach must be applied to achieving the desired changes.

Summing up, the COVID-19 crisis shows that a connected intelligence approach based upon multidisciplinary and knowledge bridges between different scientific fields and forms of intelligence can be highly effective [107–109]. The lesson learned from the recent pandemic is that the rules of cities organisation and functioning, the digital tools supporting their operation, and continuous scientific discovery, in combination, can provide the necessary mix to address the crisis. However, there is evidence, also, that the same mix of actions can change the city routines and behavioural patterns that are responsible for the environmental and climate change crises.

This is the main social implication of this paper, which examines both the health and climate change crises from the perspective of connected intelligence. Cities would be more effective in dealing with grand challenges, climate change included, if they combine multiple sources of intelligence: human intelligence expressed in scientific discovery, collective intelligence expressed in regulations and rules, and machine intelligence based on digital infrastructure and e-services.

Regulations of urban operation introduced by urban policy and planning, digital systems introduced by smart city projects, and scientific discovery can provide the necessary mix to tackle climate change. However, one-size-does-not-fit-all and a connected intelligence approach should be adapted to specificities of climate change, the rules, the digital systems, and the technologies proper for this domain, allowing a common architecture for connected intelligence to be applied [110].

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