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*Article*

# Building Smart and Resilient Urban Futures by Setting a Mission for Sustainability in the Post COVID-19 Era

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**Abstract:** The COVID-19 pandemic has put lifestyles in question, changed daily routines and limited citizen freedoms that seemed inalienable before. A human activity that was greatly affected since the beginning of the health crisis is mobility. Focusing on mobility, we aim to discuss the transformational impact that the pandemic brought on this specific urban domain, especially with regards to the promotion of the smart growth agenda and the acceleration towards the smart city paradigm. We collect 60 initial policy responses related to urban mobility from 86 cities around the world and analyse them based on the challenge they aim to address, the exact principles of smart growth and sustainable mobility that they encapsulate and the level of ICT penetration. Our findings suggest that emerging strategies, although mainly temporary, are transformational, in line with the principles of smart growth. As a result the pandemic becomes an opportunity for shifting towards more sustainable urban planning and mobility practices. However, most policy responses adopted during the first months of the pandemic fail to leverage advancements made in the field of smart cities, and to adopt off-the-shelf solutions such as in monitoring, alerting and operations management.

**Keywords:** Urban planning, COVID-19, urban mobility, sustainability, smart cities, smart growth, pandemic, resilience

## 1. Introduction

The world today evolves rapidly facing both unpredictable and long-lasting crises. Climate change and the COVID-19 pandemic challenge the resilience of cities, but also reveal the need to reshape the urban space (Scott, 2020). Crises urge for quick and efficient recovery planning and crisis management, yet traditional planning mechanisms in most cities are slow and relatively rigid. Crises create emergencies and transformational needs that require more responsive and agile planning, as opposed to traditional urban planning which as a political, technical and social process requires setting long-term growth targets and identifying the conditions for these in terms of potential land-use needs. Crises disrupt the urban environment and urge for transformation of the urban structures not only in terms of the physical space (land uses, infrastructures, buildings etc.) but also in terms of operations and behaviours. The concept of resilient urban planning encapsulates a new kind of responsive and flexible planning that considers both the need to accelerate change that leads to recovery and the complexity of urban ecosystems and their various interrelations and systemic interactions (Karuri-Sebina et al., 2016).

The current global pandemic has profoundly affected major urban centers all over the world (Sharifi et al., 2020). Confinement has put lifestyles in question, changed daily priorities and limited citizen freedoms that seemed inalienable before. Citizens have finally found the opportunity to assess the environment in which they live and value the importance of key elements which contribute to their health and well-being, such as the quality of air and the availability of open and green space. On the other hand, a new set of rules on social interactions and urban operations are fundamentally transforming the

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way we live, work and experience public space. These rules can be hardly seen as a temporary condition before going back to normal. The great impact of the crisis, as well as its long duration, has already started to affect human behaviours and routines which have been gradually formulated throughout the course of time. These changes are magnified in large cities where the population is concentrated in higher density. In this context, urban planning is facing a major challenge: it has to create a balance between the urban engine of growth that operates through concentration of talent and social interactions and at the same time contain contagions. The outcome of this task will become the new normal.

The new rules of social distancing and the restrictive policies that were adopted in most places around the world had a disruptive impact on the way we live and have reshaped urban mobility (Cui et al. 2020; Batty et al., 2020). As a result, two diametrically opposite forces were created that may be dependent on the specific cultural and economic environment. The first force poses new barriers for sustainability with a decline in the demand of public transport and the shift towards individual motorised mobility. The second force relates to an acceleration of sustainable mobility. In this case, citizens might shift from shared mobility and public transit towards walking, cycling, and other forms of micromobility, while the actual need for commuting is also reduced due to remote working. Based on these, the role of urban mobility in resilience planning comes again to the front (EIT, 2020).

Responsiveness and resilience of cities against crises is argued to be greatly affected by technology in the sense that it can convey and manage complexities in a meaningful way, improve responsiveness and create flexible areas for participation and creativity (Papa et al., 2015; Baron, 2012; Deal et al., 2017). Smart city technologies and applications (e.g., sensors, data analytics, Artificial Intelligence, IoT, monitoring systems of urban operations and infrastructures) can improve efficiency, awareness, preparedness and flexibility of urban environments through alerts, real time adjustments and better decision making. These applications and technologies also offer new platforms for social interactions (e.g., through social networks and digital platforms) that cultivate networking, collaborative innovation and behaviour adaptation based on a specific problem or need (Kakderi et al. 2018; Komninos et al., 2019; Komninos and Panori, 2019). Yet, the type of each crisis and the challenges that it creates may vary significantly from the previous one (Kakderi and Tasopoulou, 2018), therefore, with each crisis the value of these technologies must be re-assessed. This is certainly the case with COVID-19 which is a worldwide unprecedented crisis with a detrimental impact on urban life.

With a focus on this specific urban domain, mobility, several questions arise about the short-term and the long-term transformations created in the urban settings.

- What kind of policies did cities adopt during the pandemic with regards to urban mobility? How did they respond to the pandemic when the factors of their vulnerability are bound in the built environment itself and the urban planning paradigm encourages density?
- When the solution to the problem seems to be social distancing, how have urban planners and city authorities adapted to the emerging needs and what was the impact of their actions on urban growth and sustainability?
- In this opportunity for change, what is the role of technology?

We aim to address these questions by investigating 60 different urban mobility policy responses to the COVID-19 crisis in cities across the world. We pursue this by grouping the cities' responses based on the type of challenge they want to address, their timeframe and implementation mode as well as the level in which they incorporate digital technologies and smart city applications. Our research is at the intersection of urban planning and mobility planning with the evolving concepts of smart and resilient cities, exposing weaknesses in the way smart solutions have penetrated urban land-use and mobility planning. The results of the paper fuel the discussion on the transition of urban centers towards more inclusive, sustainable, and intelligent spaces.

## 2. Setting the scene: three challenges for the urban centers

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The COVID-19 pandemic reshaped our world in multiple ways and has dramatically affected people's routines and their everyday life. The spread of the virus has led governments to adopt unprecedented measures including extensive restrictions on travel and commutes, the temporal shut down of businesses and the widespread use of teleworking. Among the hardest hit domains, experiencing the most abrupt shock in modern times, is mobility. Using map services like Google Maps and Apple Map, or data from companies such as Mapbox and TomTom we saw a significant decline in the urban traffic volume starting from the first few months of 2020 in many cities that traditionally had high levels of traffic (Batty et al., 2020; Cui et al., 2020).

Sadly, once the temporary restrictive measures were lifted, people's behaviour tended towards their old routines. Therefore, besides many parts of the world being in lockdown for several months and the human activities pausing, the earth overshoot day for 2020 was on August 13 (Global Footprint Network, 2020). The environmental burden linked to the workers being requested to go back to work is very likely to increase for the months to come with the spread of car use, since public transportation is associated with a high risk for contamination. On July 30th 2020, data published by Apple Maps on searches for directions to travel by car show notable increases compared with volumes recorded on 13 January and corresponding to a 16% rise in the USA and 14% in Germany .

The disruption caused by the pandemic must become an opportunity for change towards sustainability, since the transport sector in many cities causes negative environmental and health costs. Sustainable transport has emerged as a key policy priority and requires changes that exceed this specific domain spanning from urban planning, education, the use of digital technologies and so on. Even before the current pandemic, urban centers needed to significantly change their spatial planning approaches to meet the global goals outlined in the Paris Agreement, the Sustainable Development Goals, or the New Urban Agenda with regards to social, environmental and economic sustainability. The pandemic crisis and the enforced lockdowns caused great confusion, revealed inefficiencies and highlighted new challenges, but they also created opportunities to run pilots (e.g., infrastructure for active mobility, equal distribution of green spaces, adoption of innovations in the transport sector) and re-evaluate spatial planning policies and urban strategies for resilience and sustainability.

*2.1. Re-inventing urban density through mixed use environments*

During the last decades, urban centers have been growing at an unprecedented pace and the reaction of many urban dwellers, architects and planners, such as Jane Jacobs and Jan Gehl, is that dense compact neighbourhoods can enhance social cohesion. Over the last 50 years, numerous land-use planning policies following this approach determined high density mixed-use development in town centers.

The importance of these priorities was challenged and questioned at the beginning of the COVID-19 crisis. Demographics and mobility patterns showed an exodus out of crowded cities like New York and San Francisco, towards suburbs and smaller cities (Baker et al., 2020; Chamings, 2020). Evidence on the association between density and COVID-19 transmission is still contrasting and inconclusive (Scott, 2020), and data analysis has shown that the correlation between urban density and virus spread ignores the comparative experiences of cities. New York and Singapore have a similar density of upwards of 20,000 people per square mile, however Singapore managed to keep the initial outbreak in low numbers in comparison to New York City. Nevertheless, it is far more challenging to secure social distancing in high density cities especially when the urban design poses additional constraints. A Social Distancing Dashboard created by TU Delft shows that social distancing in Dutch cities is practically impossible due to the physical constraints of the urban environment (width of sidewalk) combined with other variables

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(e.g., number of residents in the neighbourhood, typology of places like bus stops, supermarkets etc. where people are more likely to concentrate) (Bozzon and Psyllidis, 2020).

The pandemic also revealed lack of proximity to green and open space in urban centers and especially less privileged neighborhoods. Access to green space within the allowed displacement limits (in the case of France this corresponded to 2km radius from the residence during spring 2020) was for many urban dwellers practically impossible. As a result, several academics call for a new paradigm of urbanism that rethinks our transit systems, our green spaces, our city services, our built environment and redesign them considering inequalities (Catherine D' Ignazion, 2020).

The provision of flexibility in land use distribution and the increase of mixed-use environments will eventually enhance the vision of a safe and sustainable city and take into consideration the deep inequalities. In support of that vision, neighbourhood planning can enhance the concept of 'complete neighbourhoods', compact, walkable neighbourhoods that include all the services one needs in a sustainable urban environment (housing, employment, retail, schools, libraries, health centers) within a walking distance (Pozoukidou and Chatziyiannaki, 2021). By implementing the model of complete neighbourhoods, one can retain all the benefits of a big city and bring inclusion and accessibility, while reducing the need for long commutes and mass transit.

This concept has become a goal for many urban policy makers. Such is the example of 'The Twenty Minute Neighbourhood' that Gil Kelley, the Planning Director for Vancouver introduced. The concept of the '15-minute city' was brought up as a key element of the successful re-election campaign of Paris' Mayor, Anne Hidalgo. A nation-wide change of behaviour makes the '15-minute city' proposal for Paris more promising. After the lifting of the first lockdown in June, the traffic in the french bike lanes rose by 29 % on average, with differences being observed between urban (raise by 33%), peri-urban (+17%) and rural zones (+16%), while the number of cyclists passing in the bike lanes monitored by 182 meters rose by 67 % between June and August, in comparison to the same period in 2019 (Cosnard 2020).

In the context of the pandemic, we also observe the rise and evolution of the concept of smart growth. The smart growth principles proposed by the Smart Growth Network and also used in the work of Ye et al. (2005) focus on the exact components of smart growth which are directly linked to urban transport and mobility. These are pedestrianisation of spaces previously allocated to cars, creation of facilities for cycling and other forms of micromobility, public transit promotion through reduced fees as well as systems integration and nodal networks.

### *2.2. The rise of active mobility and the challenges for public transport*

The COVID-19 health crisis profoundly impacted public transportation, due to the nature of the measures imposed and the change of behaviours. Moovit (2020), a popular transit app, released a public transport index, with near real time public transit data showing a decline in the usage of public transit reaching record low levels in many large cities, immediately after the introduction of mobility restrictions (e.g., 90% in London, 92% in Lyon). Public transport ridership has fallen sharply during the lockdown and beyond, due to the widespread use of teleworking and e-learning as well as the fear of infection. Public transport systems, especially mass-transit who already had the stigma of being unreliable, 'dirty and crowded' (Basu and Ferreira, 2021). Apart from losing passengers' trust, operators also carry the burden of implementing new hygiene protocols (e.g., frequent sanitization of public transportation vehicles and stations) and adopting new rules of operation (e.g., reduction of maximum occupancy) (Tirachini and Cats, 2020). The fall of demand and the significant financial distress leads to the reduction of services and the restriction of available routes for citizens who increasingly turn towards alternative modes of mobility, such as the use of private cars, shared mobility and active mobility (cycling and walking). However, it is worth mentioning that this shift is not possible by all, and that the decline to the quality of service in public transportation could particularly marginalise

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residents of poorer suburbs that have to commute daily to blue collar jobs that cannot be conducted remotely.

The rise of sustainable individual mobility modes such as walking and cycling is impressive: in the UK, bicycle sales in the first months of 2020 increased by 63% (Bernhard, 2020; Reid, 2020). The shift towards less commutes and active mobility was accompanied by wider positive impacts on the environment. At the peak of the pandemic in early April, the slowdown of road, rail and maritime transport contributed the largest drop in global emissions (Le Quéré et al., 2020). It also accelerated government led changes and investments towards sustainability, such as the European Green Deal[1] (European Commission, 2019a). On the other side of the Atlantic, economists, academics and policymakers have presented the COVID-19 pandemic as an opportunity to fix the American economy and the planet for the long term, by including the Green New Deal or parts of it, in the recovery program in the US (Mock, 2020).

For the moment, it is still unclear whether these trends and changes will remain in the long term and what will be the final output on the environment (Kanda and Kivimaa, 2020). China and Spain, among other countries, are providing incentives for the purchase of new cars (although hybrid and electric) in an effort to support the automotive industry, while many cities in the US, such as Denver and Boston, adopt measures that favour the use of cars by loosening or suspending parking enforcement penalties.

The challenge for sustainable mobility, however, does not merely depend on transport policy but requires collaboration across different policy areas and the users. At the spatial planning domain, recommendations focus on complete street policies and multi-modal access to transportation. Complete streets, as a paradigm in which roads are designed to accommodate diverse modes, users and activities (Litman, 2015), had already become popular before the pandemic, with many cities reducing drive-alone streets, expanding their cycling networks and creating more pedestrian friendly streets both in neighbourhoods and downtown areas (Carlsson et al., 2017). Other contributions focus on the need to improve the efficiency of the transport system with the use of digital technologies, in ways which are described in the section below. The overall success will depend on the level of horizontal and vertical integration (Komninos, 2019; Komninos and Kakderi, 2019).

### *2.3. Smart city technologies: an unexplored pool of potential solutions*

The pandemic showed like no crisis before the power of technology. This became evident since the first lockdown with the immediate prevalence of teleworking, aimed to secure social distancing while mitigating the economic impact of the crisis, but also with the acceleration of digitalisation of services including remote education, e-health, e-administration (OECD, 2020a). Technology also offered plenty of opportunities paving the way for the emergence of bottom-up initiatives targeting community self-help and mutual support through social media and online platforms. These initiatives bring communities together and shape social resilience by mobilising collective intelligence (Panori et al., 2020; Komninos, 2020).

At a more technical level, the use of data, the exploitation of analytics and the exploitation of smart city technologies have been proven very useful to understand the magnitude of the current crisis and to design effective mitigation strategies. The pandemic acted as an accelerator in the experimentation of many emerging technologies from drones and delivery robots to scanning of human encounters through cell phone location data (Government Technology Platform, 2020). Several institutions have been collecting data of the

[1] The European Green Deal is a new growth strategy, included in the recovery program from the COVID-19 pandemic (European Parliament, 2020) that aims to transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use. To achieve this, both mobility and urban matters are relevant.

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new outbreaks and statistics, scientists correlate COVID-19 cases and environmental variables (e.g., air pollution), urban formations (e.g., population density) and other societal data (such as income, poverty rates and demographics) of the affected areas. Yet, the level of adoption of scientific and academic efforts by policy makers is still unclear.

Smart services have been developed and applied at all levels of urban mobility, from monitoring and optimising performance of existing infrastructure to solutions focusing on user experience and satisfaction. The digital transformation of the urban transport ecosystem using these technologies can lead to the development of network effects at the physical and digital space, but also to digital externalities that altogether strengthen the sustainability and resilience of this urban domain (Komninos et al., 2020).

Smart city advancements could be utilised in the context of the pandemic to address new needs that emerged in the urban mobility sector. The economic, social and environmental benefits of public transport cannot be ignored and, therefore, its future should be re-examined in terms of the provided services and customer experience. New rules of operation (e.g. IoT and smart systems for monitoring and controlling occupancy), securing complete functionality, improvements on infrastructure (e.g. ventilation systems, thermal cameras for monitoring passengers' temperature), the use of automated systems and services (informing about occupancy level and alternatives, online ticket purchase), integration with other, more flexible, modes of transportation like micromobility services (e.g. apps for scooter and bike sharing systems) in addition to planning interventions (wider bike lanes) are among the proposed options.

The future of urban sustainability depends on the recovery of mass transit ridership, and complementary to it to other sustainable means in order to avoid auto-dependence, congestion and increase of pollution (Bassu and Ferreira, 2021). However, this challenge can only be addressed in combination to changes in city planning and the success of this effort will reflect cities' readiness towards dealing with grand challenges (Kakderi et al., 2021).

## 3. Research design and methodology

The pandemic imposed a state of emergency for city planners and urban operators in order to address the rapidly changing conditions. Although many of the responses and emerging practices had a temporary character, it is important to further examine them since they show a trend in the course of action. Our aim is to discuss whether these policies are targeted towards smart growth and sustainable mobility. Considering that smart city technologies create opportunities for efficiency, optimisation and intelligence, we also analyse the level of ICT adoption of the responses.

To address the questions posed at the beginning of the paper, we collected 60 different initial policy responses (adopted during the first 8 months of 2020) related to urban mobility from 86 cities around the world, which are listed in the table below (Table 1.). We included in our analysis cities of different sizes and levels of complexity. Our aim was not to exhaustively examine all measures taken by the cities examined, but to create an extensive catalogue of different initiatives and policy measures adopted during the first months of the COVID-19 crisis and are directly affecting urban mobility. We should clarify that the measures adopted are dependent on the specific epidemiologic condition of each area an to the restrictions imposed by the national government. Additionally the measures reflect the existing transportation modes in each area, the level of development etc. We focused on measures and initiatives that have been designed and implemented either by the municipality itself or by the local service (mobility) provider. To collect these practices, we have accessed the platforms and repositories of international organisations, which have been subsequently reconfirmed through other official resources. We specifically used the following repositories:

- The COVID Mobility Works (https://www.covidmobilityworks.org/) an independent platform dedicated to collecting, synthesizing and sharing mobility initiatives that are keeping the world moving during the COVID-19 pandemic.

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- Cities for Global Health (https://www.citiesforglobalhealth.org/) a repository launched by Metropolis and the Euro-Latin-American Alliance of Cooperation among Cities (AL-LAs) with initiatives, projects and actions started by cities showing how local and regional governments are managing the crisis and planning their recovery.
- The OECD library of city policy responses to COVID-19 (OECD, 2020 b). Additionally, the International Transport Forum (ITF) of OECD has published 3 relevant transport briefs: Re-spacing our cities for resilience, Electric mobility-taking the pulse in times of coronavirus, How transport supports the health system in corona times. All reports compile case studies from around the world.
- The National Association of City Transportation Officials (NACTO) library 'Streets for Pandemic Response and Recovery' (https://nacto.org/program/covid19/) documenting pandemic rapid response strategies and emerging practices from cities and transit agencies around the world.

Apart from these, we also used some additional information from the following three sources:

- The EIT Urban Mobility COVID-19 repository (https://www.eiturbanmobility.eu/covid-19-what-is-happening-in-the-area-of-urban-mobility/) an initiative of the European Institute of Innovation and Technology (EIT) publishing news and articles with regards to what is happening in the area of mobility during the pandemic.
- The Polis Network EU (https://www.polisnetwork.eu/document/resources-covid-19-mobility/), a network of European cities and regions working together to develop innovative technologies and policies for local transport created a section showcasing both cities' and regions' mobility-related responses during confinement measures and plans for after confinement measures have been lifted.
- The Pedestrian and bicycle information center (Pedbikeinfo), which has collected 879 initiatives that promote cycling through different means, in the context of the pandemic and beyond.

**Table 1.** Measures analyzed.

| | City | Measure description |
|---|---|---|
| 1 | Seoul | Use of advanced tracing techniques like geolocalisation data, bank card usage, and video surveillance for contact tracing and for ensuring social distancing. |
| 2 | Beijing | Trains outfitted with smart surveillance cameras that can detect passengers who are not wearing masks. |
| 3 | Kinshasa | An SMS system developed in a hackathon makes it possible to trace the chain of contamination by identifying people who have used the same public transport vehicle with a virus carrier. |
| 4 | Bogotá | A Hackathon is organised for the exploitation of data to monitor the impact and reduce the probability of transmission in public transportation. |
| 5 | Kigali, Nice | Drones with megaphones ask people to stay home. |
| 6 | Cape Town | The Department of Health has surveillance systems for screening and monitoring cases with a travel history and close contacts within the affected areas. |
| 7 | Mexico City | The city partners with google maps and waze to monitor mobility trends and telesurveillance the concentrations of people. |
| 8 | Portland | Micromobility companies offer data for studying transport behavior and design COVID-19 responses. |
| 9 | Barcelona | App shows bus occupancy levels. |
| 10 | Fukuoka | The municipality provides congestion information during weekday morning rush hours. |
| 11 | Tokyo | Digital contact tracing service notifies users in case someone that used the same facilities is tested positive for COVID-19. |
| 12 | Katowice | Open source database with on demand travel services. |

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| | | |
|---|---|---|
| 13 | Tokyo | One-stop database on the real-time COVID-19 situation, including the number of infected people, their status, features, number of inquiries to the call centre, number of people using the subway. |
| 14 | Sydney, Newcastle | Free cycling lessons. |
| 15 | Vancouver | Online dashboard to inform people of the city's emergency response to the spread of COVID-19 and how vehicle, bicycle and pedestrian traffic has evolved. |
| 16 | Austin | Signal adjustments to optimize timing for essential trips. |
| 17 | Chicago | Public awareness campaign to educate transit riders and workers on new safety and preventative measures to reduce community transmission. |
| 18 | Santa Monica, Stuttgart | Unlimited rides in shared bicycles. |
| 19 | Bogotá, Vancouver, Denver, Los Angeles,Washington, D.C., San Diego, Kansas City, New York, Boston, Chattanooga, California and Santa Monica, Cardiff, Glasgow, London, Moscow | Free access (limited or unlimited time or membership) to an e-bicycle fleet for medical workers / volunteers and couriers. |
| 20 | Baltimore, Denver, Detroit, Los Angeles, Portland, San Francisco, Tampa, Washington D.C | Free access (limited or unlimited time or membership) to a scooter for medical workers or volunteers. |
| 21 | Budapest | Reduction of the fees in the bicycle sharing system. |
| 22 | Nottingham | Financial incentives for bike purchase and bike donations. |
| 23 | Amsterdam | Offer of free bikes to students. |
| 24 | Birmingham | Free bicycle stands are offered to companies, hospitals, schools and other organisations. |
| 25 | Medellin, Rotterdam | Increased fleed of shared micromobility ( bikes and scooters) to prevent crowding in public means fo transport. |
| 26 | Sydney, Brisbane | Automated and smart pedestrian crossing. |
| 27 | Abu Dhabi, Paris, Nancy (not free) | A free on-demand microtransit shuttle service to healthcare workers. |
| 28 | Columbus | On demand micromobility service using the surplus vehicles. |
| 29 | Columbus | On-demand transit pilot in specific areas to help customers who are experiencing lost fixed-route service |
| 30 | Auckland, Santiago, Buenos Aires, Brooklin, Athens, Victoria, Montreal, London, Paris | Extend sidewalks to create more space for physical distancing using asphalt ramps, white safety posts, and paint. |
| 31 | Sydney | Allocation of funds for pop-up streets improvement. |
| 32 | Jinja | Redesign of central market and traffic flow to maintain social distancing. |
| 33 | Montevideo, Palo Alto, Salt Lake City, Brussels | Pedestrianisation of streets. |
| 34 | Amsterdam, Cardiff | Transform a shopping street into one-way street for pedestrians and bikes. |
| 35 | Birmingham | Creation of jogging lanes. |
| 36 | Sydney, Aukland, Cali, Mexico City, Bogotá, Quito, San Borja, Lima, Montreal, Paris, Brussels, Turin, Leeds, Leicester | Pop up (temporary) cycleways and acceleration of the extension of the cycling network. |
| 37 | Berlin | Expansion of cycling lanes. |
| 38 | Buenos Aires | Provision or expansion of transit-only/ transit-priority lanes to ensure that surface-level transit. |

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| | | |
|---|---|---|
| 39 | Banjarmasin | Adapting school zone drop-off and pick-up areas to ensure social distancing. |
| 40 | Montreal, Vancouver | Increase the number of green spaces/ pop up plazas. |
| 41 | Thessaloniki, New York, Milan, Paris | Closure of open space such as parks or waterfronts. |
| 42 | Denver | Closure of parking space and allocation to pedestrians. |
| 43 | San Francisco, Montreal, Oakland, Portland, San Diego, Seattle, Milan, Brussels, Douglas (Island of Man) | "Slow streets": reduced speed limits and closed streets for cars. |
| 44 | Chattanooga,Athens, Hoboken | Wider sidewalks (through conversion of parking spots) for restaurants and businesses. |
| 45 | Córdoba Warsaw (only for health workers) | Free parking 24 hours a day in the central area to avoid the concentration of people and free circulation of vehicles. |
| 46 | Kazan, San Francisco | Essential workers are allowed to make use of taxi services for free. |
| 47 | Lagoa da Pampulha | Restriction of the circulation of pedestrians and vehicles on most visited spots in the city. |
| 48 | Denver, Mississauga, San Jose, New York, Madison, Los Angeles, Columbus, Boulder, Annapolis | Suspension of the parking enforcement policy. |
| 49 | Boston | Cancelling of the parking tickets given to healthcare workers. |
| 50 | Chicago | Subsidies for cab drivers and owners, to make sure they can keep operating. |
| 51 | New York, Columbus, San Francisco | Deem bicycle shops as essential businesses |
| 52 | Lima | Suspend, temporarily, the collection of tolls for the health personnel. |
| 53 | Nice, Budapest, Manchester, Madrid | Free public transport for medical workers. |
| 54 | Taipei | Discounted Uber rides for medical professionals. |
| 55 | Chicago | Survey the business community's ridership demands and support related planning efforts. |
| 56 | Taipei | Quarantine Taxi Service for people in need of medical attention. |
| 57 | Beijing | In-app metro reservation system. |
| 58 | Gurugram | Busses transport passengers/travelers from the airport to quarantine locations. |
| 59 | Gurugram, Barcelona | Busses transport medical teams and COVID-19 patients to and from hospitals. |
| 60 | Hong Kong | Use of a robot for deep cleaning and decontamination in train compartments and stations. |

To analyse the measures taken at an urban level as a response to the challenges posed by the pandemic, we used a set of criteria. Firstly, we focus on the type of the policy instrument, the challenge it wants to address, as well as its time horizon. We classify all policy responses into the following types of instruments:

- Legislative and regulatory, including guidelines, rules, limits and binding requirements, which in cases of noncompliance will be followed by sanctions, as well as any authorization, licence or permit under transport-related legislation.
- Planning, including land use, urban planning, zoning
- Public or private investments, particularly investments on infrastructures
- Economic and financial, like revenue generating instruments, subsidies, licenses, user benefits, cost reductions, redistributions.
- Educational/information based, including education and training, information campaigns, capacity building, monitoring, and access to information.
- Organisational and cooperation-based instruments such as voluntary commitments, negotiations, networks, improvements/changes in the transport services offerings, adapting to the emerging needs etc.

With respect to the challenges they aim to address, policy measures are grouped as follows (potentially in more than one group):

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- relieve the pressure to the health system and facilitate medical professionals, essential workers and COVID-19 patients;
- provide alternative means of transport;
- promote green and active mobility;
- management of public space;
- secure health standards in the transport system, reduce the risk of contamination.

In terms of time horizon we divide the measures into permanent and temporary, although both cases depend significantly on the epidemiological condition of a place at any given time, the citizen's acceptance level and the decisions of the policy makers.

Second, since many of the policy measures identified constitute planning interventions, we aim to identify the relevance and contribution of these to the smart growth paradigm which is conceptually very close to the paradigm of "compact city" as shown in section 2.1. The principles of smart growth seem to have been reformulated over time, seeking to respond to the realities of planning.

We assess whether the policy measure examined is linked to each one of the abovementioned principles (yes/no) and, if yes, its contribution (positive/negative).

Third, we focus on sustainable mobility and associate each of the measures to the principles of sustainable mobility. As a method of assessment, we use the list of sustainable mobility indicators, developed by the World Business Council for Sustainable Mobility (WBCSD, 2015). These indicators are well aligned to the objectives of European Union's Sustainable Urban Mobility Plans (SUMP) which promote access to key destinations and services, transport safety and security, reduction of pollution and energy consumption caused by transport, improvements in efficiency and cost reduction, as well as improvements in the attractiveness of the urban environment (European Commission, 2013).

The sustainable mobility indicators are associated with the policy measures with a yes/no if they are relevant and contribute to a positive change of the respective indicator.

**Table 2.** Sustainable mobility indicators.

| Sustainable mobility indicators | |
|---|---|
| 1. Emissions of greenhouse gases | 13. Comfort and pleasure |
| 2. Energy efficiency | 14. Accessibility for mobility impaired groups |
| 3. Net public finance | 15. Affordability of public transport for poorest group |
| 4. Congestion and delays | 16. Security |
| 5. Economic opportunity | 17. Functional diversity |
| 6. Commuting travel time | 18. Intermodal connectivity |
| 7. Mobility space usage | 19. Intermodal integration |
| 8. Quality of public area | 20. Resilience for disaster and ecologic/social disruptions |
| 9. Access to mobility services | 21. Occupancy rate |
| 10. Traffic safety | 22. Opportunity for active mobility |
| 11. Noise hindrance | |
| 12. Air polluting emissions | |

Finally, advancing on the specific characteristics of each measure we focus our attention on the innovation mechanism that is activated and the level of ICT penetration. To do this, we initially explore if there is an ICT component (yes/no) and if there is, we evaluate it using the three scales of digital transformation as proposed by Komninos et al. (2021), which are:

- Digitization: activities performed in digital space but routines that govern these activities (and their underlying rules) remain unchanged, as performed in the physical or social space of cities.
- Optimization: characterizes activities performed in digital space but routines that govern these activities are optimized to the best configuration by automation and AI.
- Innovation: characterizes activities performed in digital space but routines that govern these activities are replaced by more fit ones, defined within a cyber-physical system of innovation.

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The results of the analysis are described in section 4.

## 4. Analysis of the urban responses to the pandemic

Our analysis is based on a collection of 60 policy responses/actions that have been retrieved from 86 cities of different size and characteristics across the globe (Table 1.). These are initial responses to the pandemic since our analysis was conducted during the first 8 months of 2020, therefore they reflect aspects of responsiveness, flexibility and adaptability of the respective urban ecosystems. The geographic location of the cities of our analysis is shown in Figure 1.

**Figure 1.** Geographic location of the cities whose policy measures are analysed.

With regards to the type of policy (Graph 1.), most policy responses are organisational and co-operation based and refer to changes, improvements and offer of new services, like the transfer of patients to and from the hospitals using buses (Gurugram) or the development of demand-responsive micromobility services to help health workers (Abu Dhabi) and/or customers who are experiencing lost fixed-route service (Columbus). Such responses reflect active engagement and a bottom-up organisation of mobility providers and stakeholders and create a fertile ground for the emergence of innovative, flexible routing micro-transit services that require the use of instant exchange of information, enabling an extra real-time matching of demand and supply on top of an in-advance matching, extending thus its accessibility to a wider group of people.

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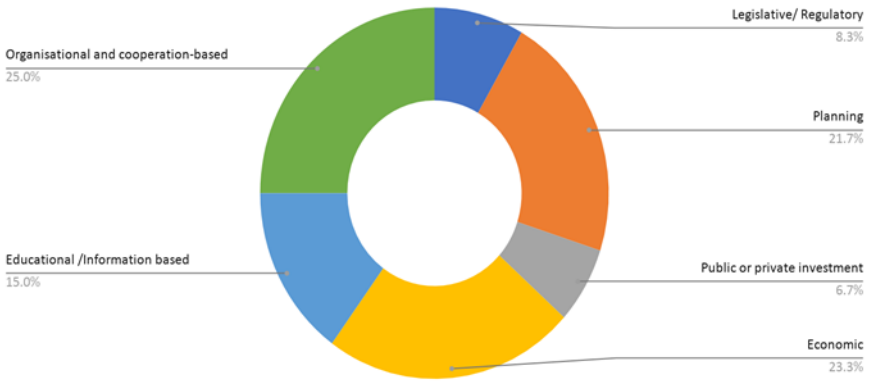
Graph 1. Type of policy measure




Next, are the financial along with the planning responses which have been widely adopted by many cities. The economic and financial responses mainly refer to free access or reduced fees in the use of mobility services and related infrastructure, of micromobility or of other types (taxis, public transit, toll fees) and they are primarily targeted to medical professional and essential workers. Financial responses may also include financial incentives for bike purchase (Nottingham) or bike donations (Amsterdam) both of which could positively affect mobility behaviours in the long term. On the other side we find subsidies given to taxi drivers to keep them operating (Chicago). The spatial planning responses include changes in the land use considering patterns of flows and the relationship between the spatial structure of cities and emergent mobility patterns/behaviours. Among the most popular measures are the pedestrianisation of streets, the creation of jogging lanes, the development of pop up (temporary) cycleways and the extension of sidewalks and of the bike lanes network.

Fourth, are the *information and educational* measures aiming at teaching a skill and at the collection and utilisation of useful information targeting both citizens, with the aim to influence behavior, and mobility stakeholders, aiming to improve capacity building and optimise or increase their mobility services. Examples here include dashboards and open data portals collecting, organising and providing mobility and health related information (Vancouver, Fukuoka), public awareness campaigns to educate transit riders and workers on new safety and preventative measures to reduce community transmission, and even free bike lessons to promote safer alternatives of transport (Newcastle). A more detailed analysis of such measures as well as their direction with regards to the smart growth paradigm is given later in the text.

Fifth are the *legislative and regulatory measures* (mostly temporary), such as the declaration of bicycle shops as essential businesses during the lockdown (Columbus, San Francisco) and the suspension of parking enforcement policy, a measure widely adopted in North American cities (Los Angeles, New York, Denver and Mississauga among others). In this category we find measures of a somehow spatial planning character, like the closure of open spaces such as parks, waterfronts and other leisure-related areas to avoid crowding (Milan, Thessaloniki). These responses were not included in the 'planning' group, since they do not reflect a change of land use, but a temporal restriction of access to these sites.

Finally, a small share of responses refers to *public and private investments* and upgrading of physical infrastructures, like the installation of surveillance cameras on trains (Beijing), automated mechanisms on pedestrian crossings that do not require physical touch (Brisbane) and the significant increase of the bike and scooter fleet to meet the increasing demand (Rotterdam).

The measures described above aim to **address the challenges of the pandemic** in relation to the emerging needs of the mobility sector. Although most of the city responses analysed have more than a single challenge to address, the majority of them focus on improving

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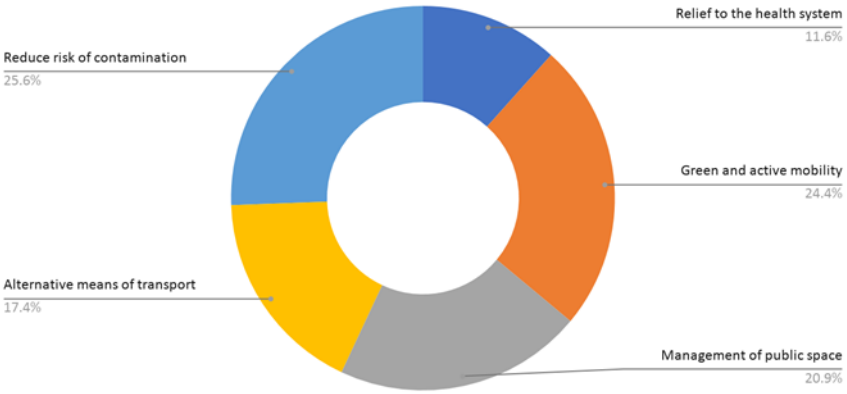
the monitoring systems, mechanisms, and health safety standards of urban transportation in order to *reduce the risk of contamination* (Graph 2.). Furthermore, a large share of responses focuses on promoting *green and active mobility* and the *management of open and public space*, since the success of the first requires redesign of the public space not only in terms of infrastructure development but also in terms of land use and regulations managing contradictory uses. It has to be mentioned though that while the management of open spaces can be considered supplementary to the ones promoting green mobility, there are cases where they act in a reverse mode (e.g. restricting the access of pedestrians to open spaces). Finally, we find policy responses aiming at the promotion of *alternative modes of transport* as well as services targeted to the health professionals and essential workers, by offering a wide range of free or low-cost mobility options.

Graph 2.Addressing pandemic related challenges in mobility




In terms of their **time horizon**, most of the policy responses examined have a temporary character, highlighting the evolutionary nature in which new planning paradigms often evolve and new rules are adopted, especially when these cause significant alterations in existing trajectories of policies and outcomes (Howlett, 2019). Among the temporary planning and regulatory responses are the expansion of transit areas to ensure social distancing and the ban of access to parks and open spaces. In many cases, the measures were fragmented and exposed implementation deficiencies, while in others, they were an opportunity to implement bold strategies that will completely transform urban living beyond the pandemic.

This is the case in Milan, where a transportation strategy carefully designed before the pandemic was implemented earlier due to the pandemic (Laker, 2020). On the other side, in the case of Athens, the mayor's plan to create the ''Great Walk'' by blocking the access of cars in central avenues without extensive prior preparation and through a pilot was hardly criticised and cancelled. Nevertheless it revealed the need for further debate on the urban transformation of the city (Ethnos, 2020).

Focusing on **smart growth**, we reveal that even short-term and immediate responses of cities to the challenges of the pandemic create an underlying advancement towards this planning paradigm, although only four out of ten smart growth principles seem to be relevant (given that they only give emphasis on mobility). These are i) create walkable neighborhoods, through actions of pedestrianization and extension of sidewalks , ii) preserve open space, with street improvements and pop-up plazas, iii) provide a variety of transport choices, by providing supplementary transit services, expanding the bike lanes network, and integrating the overall mobility network and iv) encourage community and stakeholder collaboration in development decisions through the organization of hackathons the provision of data portals and the collaboration of different mobility stakeholders to develop new mobility services.

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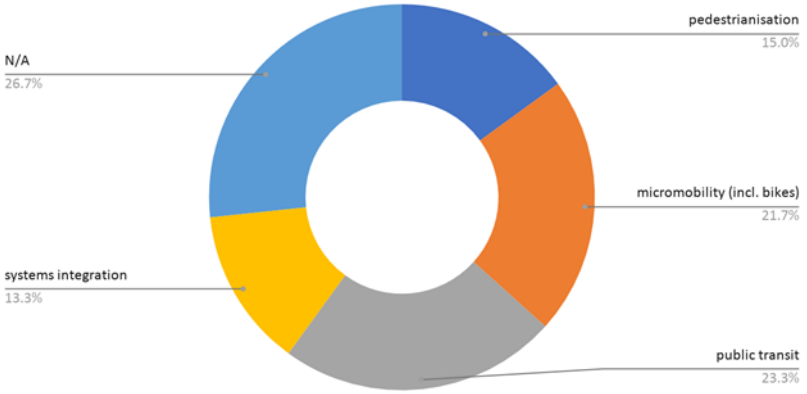
Graph 3. Smart growth objectives




Using the smart growth components that are directly linked to urban transport and mobility (Graph 3.), we find that more than 70% of the policy measures collected are positively relevant to smart growth, aiming firstly at the promotion of public transit through activities that monitor safety regulations (use of mask, distancing, passenger limits) and turn public transport into safer choices for their users. Other measures focus on the development of facilities for cycling and other forms of sustainable micromobility, promote pedestrianization and systems integration by providing collective information of different transport means to allow citizens adopt their behavior based on the existing situation and by surveying the community ridership demands to support related planning efforts. More than a quarter of the total policy measures are not relevant or have a contradictory nature to smart growth, such as the suspension of parking enforcement policy which encourages the use of cars the closure of open spaces and even the extension of sidewalks for the benefit of restaurants and businesses.

Comparing the total policy responses with the ones of a spatial planning character, we reveal a different set of priorities. Spatial planning as a mitigation strategy against the pandemic relates more to the promotion of individual active mobility, such as walking and cycling. More specifically, eight out of the thirteen responses promote pedestrianisation, three aim at facilities for cycling, including other forms of micro-mobility, one measure focuses on public transit promotion and one is not considered relevant (wider sidewalks for restaurants and businesses), since it does not promote any of the smart growth principles. In fact, the existence of many measures promoting cycling is confirmed by the European Cyclist Federation that tracked the commitment of local and other public authorities to create new bike lanes in Europe, with their total length exceeding 2000 km in October 2020.

Overall, the combination of spatial planning and mobility (Graph 4.) related measures create a complete pool of actions that a city could use to articulate an integrated reaction to the pandemic. For example, reducing the speed limits and the access of cars to specific blocks of different neighbourhoods, the widening of pavements and cycling lanes, while creating a multi-modal transportation system with better connections to transit stations, provide a healthy alternative to urban mass transportation. Emphasis on interconnected cycling and pedestrian networks combined with an approach for adaptive emergency reuse of infrastructure and means of transportation, identified as one of the most successful strategies to bring resilience in urban centers during the pandemic. Measures taken reveal the need for new and innovative business models in urban mobility, more flexible and personalised. These alternatives are linked to micromobility and typically promote the use of shared bikes, e-bikes, scooters, e-scooters and other vehicle types which are shrinking the physical footprint needed to move people over relatively short distances.

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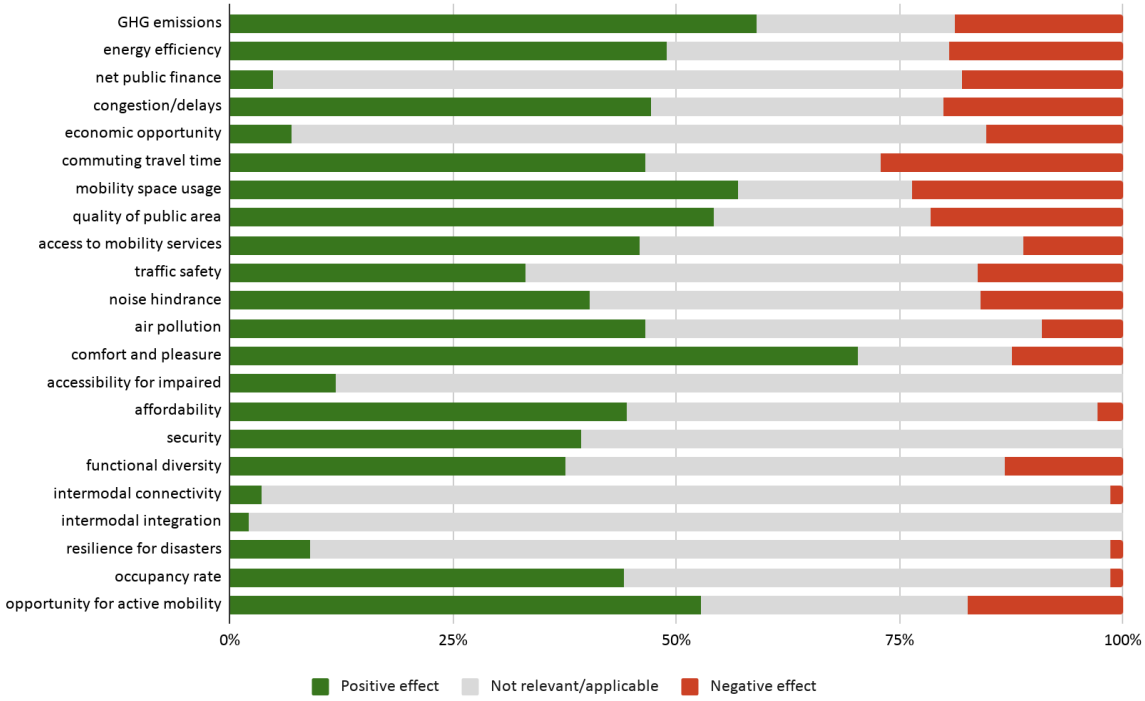
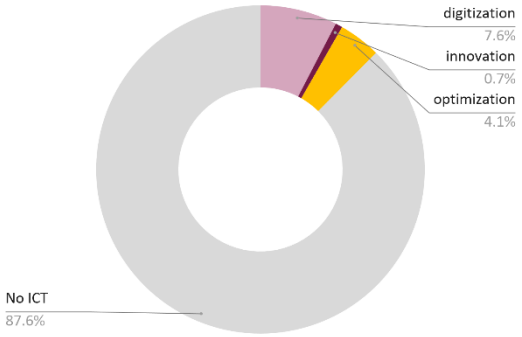
Graph 4. Contribution of the measures to the principles of the sustainable mobility (each measure is analyzed against all principles).




Graph 5. Level of ICT penetration




With regards to ICT penetration, it is impressive that most policy responses do not incorporate ICT and those that do, remain at a low level of digital transformation. More specifically, the vast majority of the policy responses examined do not incorporate ICT at all and only 12.4% of them include an ICT component. Although it is difficult to accurately assess the exact level of digital transformation without an in-depth study of the policy measures and the changes made in behaviours, routines and processes after their implementation, we observe that most measures that are ICT based (or at least include some level of automation) constitute activities that are performed digitally while the routines that govern these activities remain unchanged. This is the case of Hong Kong (pilot action) where the cleaning and disinfection of train compartments and stations is being performed by robots instead of people or Beijing where cameras are used to check compliance to mask wearing. Optimisation of routines is observed only in 10% of the policy measures, such as the apps showing bus occupancy (Barcelona) or the in-app metro reservation system (Beijing) which can shift the mobility routines of citizens towards more safe hours/schedules, or the efficiency created by the use of automated pedestrian crossings

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(Brisbane) in reducing the potential contamination of pedestrians. Only one policy response is considered to reach the level of innovation, since it combines efficiency from different ICT-based solutions changing the governing routines of these operations into more-fitted-to-the-problem ones. This is the case of Seoul's effort to use advanced tracing techniques like geolocalisation data, bank card usage, and video surveillance for contact tracing and ensuring social distancing.

## 5. Conclusions

The recent COVID-19 health crisis has greatly affected all aspects of urban life and brought cities into the frontline of responses. This did not happen only because they offer the suitable scale for implementation of the measures but also because they 'provide laboratories for bottom-up and innovative recovery strategies' (OECD, 2020).

A basic human activity that was greatly affected by the health crisis is mobility. The timeframe of this impact and its trajectory remain unknown. Our analysis on the initial responses of cities across the world revealed significant opportunities for urban planning and mobility. The actual long-lasting impact on mobility will depend on the preservation of healthy and sustainable alternative urban design and sustainable mobility strategies, and on the responsiveness of city authorities in the use of new technologies allowing them to create services and cooperation models that respond to the emerging reality and needs.

From the sum of smart growth principles, urban responses to the pandemic mainly focus on a variety of transportation choices and the promotion of walking. We saw that the change in the lifestyle and behaviour of citizens resulting from the lockdown was perceived by many cities as an opportunity to promote sustainable development patterns through open spaces, parks and alternative models of urban transportation. The transition to inclusive, green and smart mobility is not a given as measures continue being of a temporary and experimental basis.

The need to envision the new normal in fair and sustainable terms and on a long term basis, enabled by ICT, remains. With regards to ICT adoption, it is impressive that most policy responses do not incorporate ICT and those that do, remain at a low level of digital transformation focusing mainly on the use of open data and IoT infrastructure to inform about availability, performance, and health dangers. Although smart, digital and intelligent cities have been an objective for policy makers across the world for several years, emergency responses fail to follow a similar path. There are a lot of unexploited technologies for the transformation of mobility services that could address the challenge of each city without compromising sustainability. We also see examples of local or national governments that position themselves against the massive tracking of citizens and collection of private data. All the above create expectations for a new approach, a re-thinking of the concept of smart cities and their contribution to sustainability in urban mobility and development.

A question that remains unanswered is how means of public transportation can effectively adapt to the current situation. Cycling and walking solve local problems during confinements. However when restrictions are lifted people have to cover longer distances, re-integrate in public life and therefore use public transportation which has to be safe and reliable. It is pivotal not to waste the efforts made in the last years towards sustainability and the promotion of public transport and collective mobility.

As the situation evolves and the challenges of urban living in the pandemic remain, there are many transformations to happen. According to studies by the United Nations (UN, 2018), urban centers will need to accommodate 68% of the world population projected to live in urban areas by 2050. In contrast to this prediction, during the last months people have been leaving cities for smaller cities, peri-urban and rural areas. As a result, cities will need to market themselves to bring back this population.

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