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Cycling in the Era of COVID-19: Lessons Learnt and Best Practice Policy Recommendations for a More Bike-Centric Future

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Abstract: The COVID-19 pandemic has affected our cities in monumental ways with no sector likely being more severely impacted than transport. Lockdowns, physical spacing, transport restrictions and stay-at-home guidelines have transformed personal mobility and highlighted the mistakes of an unbalanced pro-car culture that defined a century of urban planning. One immediate effect of the virus in relation to travel demand and supply was the emergence of active travel modes because of their unique ability to provide a socially distanced way of transport. Cycling is one of the modes that has enjoyed significant attention. Numerous cities have reallocated street and public space to cyclists and introduced pro-bike interventions like pop-up cycle lanes, e-bike subsidies, free bike-share use and traffic calming measures. This newly found outbreak-induced momentum creates an opportunity to establish a new ethos that allows the promotion of potentially permanent strategies that may help cycling to be (re-)established as a robust, mainstream and resilient travel mode for inner city trips and not as a second-class alternative operating under the automobile's giant shadow. This paper provides a state-of-the-art description of the anti-COVID cycling-friendly initiatives that have been introduced globally, the successes and failures of these initiatives, the lessons learnt that can help us redefine the bicycle's role in local societies today and a best cycling practice policy guide for planning a more bike-centric future.

Keywords: cycling; COVID-19; transport planning; cycle lanes; bike-sharing; e-bikes; road space reallocation

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1. Introduction

The COVID-19 pandemic has brought radical change to what was considered normal up until January 2020 profoundly transforming the way local communities and cities function. No sector perhaps has been more critically impacted by the pandemic than that of transport. Local and national lockdowns, physical spacing, business and school shutdowns, social mixing restrictions, face covering mandates, self-isolation measures, remote working prioritisation and stay-at-home guidelines have disrupted personal mobility and crafted a new travel behaviour ethos that has led to wider social impacts. For instance, curtailing mobility generates significant repercussions for work, but also for fulfilling everyday duties, shopping and seeing friends and family [1]. One of the pandemic's key influences in relation to travel demand and supply was the emergence of active travel modes (especially walking and cycling) because of their unique ability to provide a socially distanced way of moving, lessening overcrowding in closed spaces (i.e., travellers do not need to be seated inside a vehicle).

COVID-19, at the same time, has highlighted several important problems in urban areas that have been generated by a monolithic car-centric urban development philosophy,

that make active transport prioritisation and support a difficult proposition. These problems were partly to be expected, due to narrow streets and sidewalks and underwhelming pro-cycling and pro-walking transport infrastructure and legislation in many countries worldwide. At the same time, public transportation is proving to be particularly problematic at this stage with ridership being hit hard compared to other travel modes [2] leading to a major reduction in service capacity compared to the pre-COVID-19 era [3], in some cases exceeding 90%. The first reaction of people to this mobility challenge was to reduce their travel altogether and when necessary, use their private vehicle for longer trips and active transport for shorter trips. The restrictive measures and the required safety distance undoubtedly created a new landscape for urban transportation.

Some cities started to realise the opportunity for reducing more permanently motorised traffic creating change that could lead to the transformation of their local urban environments. This transformation could turn them to healthier and more environmentally friendly cities. For instance, since COVID-19 led in most cases to reductions in traffic, roads became instantly much safer for cyclists and pedestrians [4]. "Active mobility" found a new momentum to become a main transport mode to move around the city. During 2020 and early 2021, several cities made it easier for people to walk and cycle with emergency measures. At the same time, cities were encouraged to take pilot measures to limit the traffic congestion and maintain low speeds. Cycling, as a result of this newfound momentum experienced a renaissance; there has been an increase in bike trips for exercise and leisure, but also in some cases where restrictions allowed, for commuting purposes too. Research assessing road user views actually suggests that there will be more use of bikes after the crisis [5].

This paper reviews case study examples across the world looking at how local, regional and national authorities introduced COVID-19 induced cycling interventions and initiatives as a means of informing academia, policymaking and professional transport practice about the successes and failures ahead.

The paper consists of 7 sections. Section 2 presents the methodological framework used that combines a narrative literature review with a case study analysis. In Section 3, a narrative academic literature review, organised in themes, discusses the pandemic, cycling and its benefits, and the potential role of cycling initiatives in the midst and after this global crisis. Next, Section 4 explores the case studies going through local, national and regional best practices, as well as bad ones. Section 5 contains the lessons to be learnt thus far, along with some viable policy recommendations. In Section 6, we present the reflections, limitations and future research implications of this paper. Finally, in Section 7, we provide the conclusions of the study and express the need for this bicycle rebirth to go on but be part of a more holistic sustainable transport offer.

2. Methodology

This work is the result of a mixed method approach that ultimately offers a conceptual investigation of the bicycling phenomenon in the era of COVID-19, identifying and contextualising the best practices and lessons to be learned and making informed policy recommendations about the initiatives and the way that these should be adopted to support cycling uptake. The research combines a thematic literature review examining peer-reviewed Scopus-indexed research published in English determining the role of cycling in society today and how this evolves because of COVID-19 with a case study approach using evidence from a selection of representative international case study examples reviewing real-world successes and failures.

The thematic areas discussed on our literature review are described by the five subheadings and sub-sections below. These themes were chosen and structured after a systematic process involving a round table discussion where consensus was reached about the critical topics that needed coverage and the references that would be chosen. In this round table-synthesising exercise, all the authors presented the results of their own individual independent thematic review and their selected international case studies. The selection of

material for the academic review per se was made based on the subject-specific relevancy and recency of the research output, the host journal impact factor and each paper's impact as measured by the number of its citations (as a proxy for "some older" papers). This process was underpinned and supported by principles of a systematic literature review including Scopus-indexed keyword searches. Table 1 provides a synopsis of the key searches that took place and defined the narrative of the paper. It should be acknowledged that some peripheral references of a more generic urban mobility and travel behaviour nature were also used to support some of the key arguments articulated herein.

Table 1. Scopus searches underpinning the academic literature review.

Academic Literature Key Searches	**Number of Journal Papers**		
Keyword combinations	*Initial search*	*Passing screening*	*Papers included in the final review*
Covid AND Cycling	74	17	15
Pandemic AND Cycling	88	18	15
Coronavirus AND Cycling	64	16	15
Cycling AND Health AND Sustainability	204	68	43

-The three first searches had a very big overlap; the papers listed herein are ultimately the same. -The last update of the table happened on 20 March 2021.

The agreed case study examples we chose to present, on the other hand, refer to some of the most emblematic examples available to date. They were chosen based on their significance, the lesson learnt from the measures that were successfully or unsuccessfully implemented, the reliability of the medium that presented them, and the proximity and access that the authors had to these particular case studies. For describing the case study examples the work identifies and utilises the most topical and high-quality grey literature (i.e., media news) to fill in some critical knowledge gaps that exist since the publication cycle of peer-reviewed scientific articles, on many occasions, is usually longer from the current life course of COVID-19.

The authors acknowledge an element of subjectivity in the choice of the material used for the finalised literature review and case study selection (i.e., some degree of selection bias is unavoidable in human decision-making). However, when they set out the "bigger picture" narrative they acted as checks and balances to each other, eliminating this bias and highlighting key points of the literature (academic and non-academic) that a single author could not have captured.

This particular method mix helped the authors to develop a more holistic understanding of how temporary cycling measures contributed to allowing people to achieve social distancing and of how bicycles can maximise their potential, in the aftermath of this crisis, as an often-neglected mode of transportation. A similar methodology involving this two-way structure has been used in the lead author's previous work [6,7] meaning that this is a tested and proven methodological formula that provides an extra layer of reliability and validity to the present study.

3. Background

3.1. Pandemics in Urban Areas and the Role of Mobility

Urban areas have experienced throughout history disruptions, turning points, crises and schisms [8]. Pandemics have affected significantly cities and altered their path to urban development [9] becoming, on some occasions, the critical turning points for establishing a different philosophy in urban policy. Viruses such as the black plague, Spanish influenza and more recently the acute respiratory syndrome (SARS) posed great dangers for people, especially those living in urban environments, where the population concentration is significantly higher [10,11]. Cities are at the forefront of pandemic disasters and this will continue to be true in future health crises [5] since cities and public health are inherently interlinked [12].

Population movement and transportation infrastructure that boost inter- and intra-urban connectivity, are considered as principal factors contributing to disseminating viruses [1,13–16]. In this context, the transport networks and urban fabric configurations that facilitate human interactions have the potential to lessen or exacerbate infection transmission rates and influence their frequency and asperity. Built environments and the level and quality of mobility provision they provide have therefore a critical role to play before, during and after pandemics in the way these develop [17]. From past evidence, pandemics have considerably transformed urban built environments since national, regional and local stakeholders tried to lessen the risk and fear of infection [18] by making amendments to the use of public spaces, to the way transportation modes and systems operate, and to mobility infrastructure and service provision [19].

3.2. The Era of COVID-19: Changes and Perspectives for Urban Mobility

In December 2019, the city of Wuhan (Hubei, China) experienced a cluster of pneumonia cases that were monitored by the Chinese health authorities. This was caused by the new Coronavirus SARS-CoV-2 pathogen, also known as COVID-19 or Coronavirus [20]. Since then, it has developed into a fully-fledged pandemic that has infected many countries across the globe [21,22]. Research indicates that COVID-19 has spread with enormous speed, mainly due to the increased globalisation, urbanisation and cross-border accessibility, verifying the usual advance of a pandemic disease [23,24].

Even after a full calendar year, the world continues to be in the midst of a pandemic crisis that has transformed the very way we live. Governments were forced to re-assess the relationship between mobility, urban space and health in order to ensure physical distancing while meeting the travel needs of their inhabitants [25]. Mobility provision is pivotal for the COVID-19 induced adjustment that societies had to make [8]. This adjustment, which was defined by transport restrictions, and the fear of the virus itself, resulted in a social and economic crisis, which has changed people's life patterns and daily routines all over the world [26–28].

The full socio-economic impact of the pandemic is displayed in urban mobility patterns [29]. Mobility styles are usually resistant to change in normal conditions [30–33], but this is an exceptional crisis scenario that transformed the status quo. Passenger mobility has been hit due to travel restrictions, stay-at-home orders, and closure of any business activities deemed as "non-necessary" [27]. There is a limited yet, but drastically growing, number of studies focusing on the impact of the COVID-19 pandemic on transport (e.g., [28,34–37]. These works present significant evidence that transport is changing. One common finding is that business and profit in the public transport sector have experienced a solid fall due to the reduction in the demand of its services. Freight transport, on the other hand, experiences an ambiguous demand pattern [38] due to a rapid increase in home deliveries. Research in Spain [39] revealed an overall mobility fall of 76% (smaller for the private car and up to 93% for public transport), NO_2 emissions reduction by up to 60%, and traffic accident reduction up to 67%. An interesting surprise is the role and the use of alternative modes of transport and specifically active mobility. Cycling and walking have increased during the COVID-19 pandemic as people simultaneously travel and socially distance, suggesting that these activities are already becoming a more common element of daily life [40,41]. Berk [42] mentions that cities are witnessing a resurgence in scooters and bikes, as well as an increase in the popularity of e-bikes and e-scooters.

This significant shift to active mobility can be justified since modes like cycling and walking are meant for individual use, thus, opposed to public transport, they ensure both physical distancing and low contacts with shared surfaces, if any [27]. Moreover, quieter roads, combined with official advice on taking limited daily outdoor exercise, encourage more people to walk and cycle in their neighbourhoods [34,43].

Nevertheless, the existing urban fabric has demonstrated itself to be unfit for this purpose. Roads have been dominated by automobiles which are still placed at the centre of attempts to keep cities moving, despite evidence of being a public health liability [44].

Nurse and Dunning [8] wonder if COVID-19 is a turning point for our urban transport systems that could redirect mobility priorities beyond a monolithic car-centric model that does not work well. The knowledge we thus far have accumulated from this major disruption shows that the COVID-19 crisis entails an excellent opportunity for planners and policymakers to take transformative actions towards creating cities that are more just, resilient, and sustainable [45]. Supporting the current demand for active mobility and micromobility will probably be a critical prerequisite, if cities want to survive the pandemic by keeping their liveability and retaining the COVID's positive by-products, that according to Lai et al. [27] refer to a decrease in air pollution and reduction in road accidents.

3.3. Cycling as a Driver for Healthier and More Sustainable Cities

Cycling is one of the most popular alternative transport modes. It can be considered as a key component of any urban mobility policy intervention package looking to increase the quality of life in urban areas [46,47]. Specifically, it constitutes a crucial pillar of sustainable mobility, that provides a flexible, private and environmentally friendly way of travelling around the city [48–50]. Notably, during the past decade, bicycling has become an important travel mode in various cities [51], mainly because of the multiple benefits that it produces in terms of public health, wellbeing, clean air, sustainability and active lifestyle adoption [52–55] and the rise of cycling-centric interventions like: bike-sharing [56,57]; bike lanes and bike paths [58,59]; bike parking and storage [60,61]; e-bikes [62,63]; traffic calming and traffic safety infrastructure improvements [64,65].

More specifically, cycling can produce considerable environmental benefits such as the reduction of air pollution in the city level and climate change in a global scale [66]. In this direction an international study compared different future scenarios of increased active transport (including cycling) and found a significant reduction in CO_2 emissions in cases where bicycle usage rates were enhanced [67]. Moreover, cycling demands less infrastructure than automobiles, is more energy-efficient and contributes to a healthier life standard [68,69]. Additionally, cycling results in social benefits since for many people cycling means socialising [70].

Considering health benefits, previous studies [71–73] have quantified the gains of replacing cars with bicycles for urban travel purposes. These benefits have been attributed mainly to increased levels of physical activity [74]. For active commuters that are walking or cycling when meeting the minimum physical activity guidelines, there is evidence of a consequential lower risk of morbidity and mortality [75]. More specifically, regular cycling reduces the risk of a variety of long-term conditions including coronary heart disease, stroke, cancer, obesity and type 2 diabetes, reducing the risk of cardiovascular disease by around 30% and all-cause mortality by 20% [76]. These cycling-related health benefits could also lead to significant economic savings by reducing long-term healthcare expenditure and thus releasing valuable resources to fund other policy initiatives that could support societal wellbeing and prosperity [77].

In addition to all these benefits, cycling is particularly significant for the current public health conditions, since it can contribute effectively to social distancing, thus limiting person-to-person contact [28,78]. Therefore, the role of cycling gained newfound political and social prominence at the height of the COVID-19 crisis for safety reasons but has also been promoted as a means of staying fit during the lockdown when all other options (including swimming pools, indoor gyms, leisure centres, and playgrounds) were closed [21]. In this light, scholars highlight the need for maintaining and promoting active mobility and especially cycling [34,79]. In addition, because of the decrease in motor traffic and more prioritisation measures, bicycles have become more effective (i.e., safer and faster) in meeting the mobility demands of citizens during the pandemic [45].

3.4. The Role of Cycling in the Travel Eco-System and the COVID-19 Disruption

Globally, cycling is considered either as an independent travel mode for relatively short trips or as an integrated part of combined travel (e.g., trips to access public transport),

and an alternative to driving a car [49,73,80,81]. This gives cycling either a primary or a secondary role in urban transport schemes. However, the disruptions caused by the COVID-19 pandemic have significantly changed the status quo in transport [45]. Cycling enjoys a new enlarged role; its use has been radically increased [82]. Evidence for a large increase in cycling kilometres during the first lockdown which was sustained into the summer 2020, for instance, has been reported in Switzerland [37]. Findings in three USA cities (Houston, New York, Seattle) suggest significant changes in bicycle counts between the time before the stay-at-home orders and during that; referring mostly to increased cycling usage especially in cases where there were more relaxed rules [83].

This new reality, though, disrupted the relationships between cycling and public transport, isolating one from the other. In typical conditions, cycling can function as a complementary mode, working adequately in conjunction with public transport [84]. Indeed, these systems are characterised by considerable levels of multimodality, which constitutes an efficient way of travelling in complex urban systems [85]. But the pandemic shaped completely different conditions for travel behaviour and mode choice in urban environments and disrupted modal synergies.

As the fear of overcrowding is intensified by the risk of contagion, people are showing reluctance to use mass transit systems, which are perceived as a vector for the distribution of the virus [86]. Hence, public transport ridership plummeted greatly in the early phases of the pandemic [45] and as we previously mentioned people have shifted to other modes such as cycling, walking, and private vehicle use (this shift is in line with previous studies investigating the case of SARS outbreak in China, e.g., [87]). According to Teixeira and Lopes [29], who investigated the case of New York, the ridership of the subway system experienced a decrease of around 90%. They also found evidence illustrating a modal shift to the bike-sharing system from some subway users. A similar argument is made by Bucsky [82] who dealt with the case of Budapest and found that public transport use has declined by 80%. Research in Sweden [2] showed a decrease in public transit ridership that was 60% in Stockholm and 40% in Västra Götaland; some of these people chose to travel by other modes, including bicycle, instead. In particular, Kazemzadeh and Koglin [88], recognised again for the context of Sweden, e-bikes as a promising substitute for public transport during COVID-19.

The relationship between cycling and cars, is quite different, because both these modes ensure social distancing and can help travellers to avoid crowded public transport stations, trains, trams, metros and buses. Therefore, their role in these disruptive conditions is somewhat alike. Nevertheless, Teixera and Lopes [29] highlight that cycling can position itself as a viable, healthy and flexible alternative both to public transport and to car use, especially for short trips. However, for this transport mode switch, alternative modes to the car in general and cycling in particular need to improve their infrastructure; otherwise, as Schubert et al. [89] suggested, road users will maintain their usual pre-COVID choices after the crisis is over.

3.5. Strategic Urban Planning for Cycling Prioritisation. How to Integrate Cycling?

The development of a holistic urban transport system that accommodates all modes (i.e., walking, cycling, micromobility, public transport and private motor vehicles) is an important issue for the prosperity, safety and sustainability of future cities [51]. This integration perspective will be one of the key issues related to transport and mobility affairs in a post-COVID world [21]. For an integrated transport system to be achieved an efficient planning approach is required that corresponds to the complex contemporary and future passenger transport needs. That is why a strategic planning approach is essential, particularly in the case of cycling. Iacono et al. [90] argued that the current trend in strategic planning, brings alternative transport modes at the forefront (with cycling playing a prominent role among them) combined with automobile use reduction.

A basic tool for integrating cycling into the urban transport system is the formulation of a proper road network hierarchy [91] that should prioritise sustainable modes and active

mobility by taking into consideration urban, transport and social dimensions [92]. In a classification system like this, it would be possible to transform street space from a mere traffic conductor to capacitors of interactions and exchanges where different speeds and modes co-exist [93]. Indeed, a considerable body of literature has already addressed the need for an alternative hierarchy through different methods (e.g., [94–98]) which share a common objective; the making of an accessible and inclusive road environment that, among other goals, helps cycling prosper.

As part of this new approach, novel planning methods for integrating cycling might emerge as either supply or demand based [99]. Nonetheless, there are already some substantial research contributions, proposing methods for an attractive and functional cycling network. For instance, Milakis et al. [70] suggested a participative multicriteria analysis approach in order to detect the preferences of cyclists effectively and then the authors composed their planning scheme for the metropolitan area of Athens. The aim of their study was to plan a strategic cycling network that will cover daily activities, while providing safety, directness, convenience and attractive routes. Another study conducted by Zhang et al. [100] developed an individual-based model of cycling potential for Belo Horizonte, Brazil, to prioritise where to build cycle paths in order to produce benefits for the city host. This model has taken into account multiple data such as survey data on cyclists' stated preferences and origin-destination data on travel to work. The final outcome of this model is a "usage intensity index" for possible cycle paths. In the same direction, Larsen et al. [101] formulated an area-based prioritisation index for Montreal, Canada. This index consists of four variables: existing infrastructure, its cycling potential (based on the shortest path between the origin and destination of short car trips from a travel survey), the number of injuries to cyclists and locations indicated by current cyclists for improvement. This process results in a heatmap that is used to recommend the construction or upgrade of cycle paths on specific roads.

It is evident that the strategic planning of cycling routes under the principles of sustainable mobility is a challenging process. Planning new cycling paths is a complex process and many decisions need to be made, including in relation to the width [102], quality [103], directness [104], geographic location of paths [105]. However, bicycle routes located where traffic safety is advanced and accessibility is good, that support integrated transport systems will also increase the safety of the system [51].

At last, facilitating cycling in urban areas, apart from a functional network in terms of geography and connectivity may also require redesigning streets to accommodate the needs of citizens and ensure a fair accessibility level [106]. The way public space is designed could be reconsidered by reallocating and prioritising some uses over others [107]; in fact, this is a process that a number of cities have been following since the beginning of the COVID-19 pandemic [27] that this paper is going to discuss in the next sections.

4. Case Studies

The pandemic brought at the forefront of attention the need to turn to active mobility and especially cycling. Many cities worldwide recognised this situation as an opportunity, and therefore expanded the existing or developed a new cycle network, supported bike-sharing and e-biking, implemented traffic calming measures, reallocated road space and limited private car use. Some key examples of cities that took progressive pro-cycling measures as a response to COVID-19, with a view to possibly make the most successful ones permanent, are presented below grouped to geographical regions; for completeness and representation purposes we deemed important to present examples from all the continents even in cases where the pandemic had less impactful results and restrictions did not have the same severity. It should be noted that due to limited information availability (little is written about cycling interventions still especially at the level of an academic study), choice was fairly narrow; most of the cases included herein are around well-known cities and mega-cities for whom the authors could verify the interventions and their impacts from more than one source.

4.1. Cycling Measures in Europe

Europe has a plethora of cities taking up cycling initiatives. Public transport, especially in peak hours, poses great risks since overcrowded places such as buses, trains and even public stations could facilitate the dissemination of the virus. To avoid this pressure and minimize possible risks, the city of Brussels has implemented a 24.9 km cycle lane, a 23.4 km traffic calming road and a 5.15 km long restriction of entrance for private cars where pedestrians and cyclists have priority. As a result, cycling has increased by 44% in 2020 compared with 2019 [108]. The city has also applied a speed reduction in the road network segments within the ring road zone from April 2020. The maximum speed limit in this zone is 20 km/h, aiming to reduce the possibility of traffic accidents and extra pressure on the health system by protecting vulnerable road users like cyclists.

Before the pandemic, the mayor of Paris, Anne Hildago, announced that the French capital would be genuinely cycling-friendly by 2024 [109] through an effort to reinvent the formula of urban proximity. Reaching this goal, through implementing some of the principles of Transit Oriented Development (see [7]) will make the city of Paris the "city of fifteen minutes" [110] where people will be able to get to all their key neighbourhood destinations by walking and cycling. The fear of COVID-19 and the possible increase of the private cars number, led to accelerate the planning of "Plan Vélo". Thus, Paris added 29.23 km of cycling infrastructure and a 4.31 km long traffic calming street during the lockdown period. The pop–up cycle lanes are marked with traffic wands. In conjunction with other measures that have been implemented, cycling levels have increased by 27% in 2020 compared to 2019. Another French city, Lille, has implemented 9.23 km of pop-up bike lanes and 2.22 km of traffic calming roads. These interventions were a consequence of the large increase (about 60% compared with the pre-COVID period) in bicycle use during the pandemic [111].

In the Iberian Peninsula, Barcelona extended its cycling network and added 21 km of cycling infrastructure and 12 km of traffic calming roads for the management of COVID-19 [112]. These interventions focused on the city centre giving space to pedestrians and bikes. The local public authority is willing to convert the temporary lanes into permanent ones to boost the modal share of bicycling. The increase of cycling has been estimated at about 12% in the post-pandemic era. On the other hand, Madrid launched 12 km of provisional cycle lanes. However, these are not adequately connected and most of them are located on the edge of the central area. As a result, there is a lack of cycle lanes (permanent and pop-up) in the city centre, meaning that the existing network is somewhat incapable, for now, of connecting points of interest, leisure activities and public spaces [112].

Another example of a temporary cycle lane addition occurred in London, UK, which implemented 25 km of pop-up cycle lanes. Generally, London faces significant traffic congestion issues and this action in combination with the low vehicle traffic flows occurring during the lockdown could encourage more on-street cycling. However, the increase of traffic congestion after this period is a risk that could reduce bicycle use [113]. Many people support this scheme, but more measures should be planned in order to improve road safety in junctions. In addition, there are bike lanes whose use is very low and create problems in the function of the central street. For example, cycle lanes in Euston Road will be removed as the monitoring process demonstrated low levels of acceptance [114].

Another UK city, Portsmouth, has installed pop-up cycle lanes encouraging people to cycle during the pandemic era. The duration of the trial version of the cycle lanes was six weeks. However, two of the selected road interventions, namely those referring to Elm Grove and Kings Road, gathered negative feedback from various stakeholders like cyclists, residents and businesses [115]. The conducted survey demonstrated the removal of these cycle lanes as 67% of the respondents thought that the trial had mostly a negative impact. These roads have a high number of accidents and on-street parking prevents the function of the existing cycle lane. The rest of the programme roads continue to function as originally planned benefiting local populations and promoting cycling [115].

Edinburgh and Glasgow in the UK have launched free bike-share services to encourage people to consider cycling for commuting purposes. The initiative came into effect as COVID-19 restrictions eased over the summer of 2020 to help alleviate the pressure on public transport, encourage active travel and help people without access to bikes. The scheme made possible via Scottish Government's funding located over 1300 bikes that were available for free in the two cities for the first 30-min of every journey on a temporary basis [116]. Stirling is the third Scottish city now providing free 30-min rides.

Commuter activity referring to the nation-wide UK bike-sharing market fell sharply in late March 2020 as lockdown started, reaching a nadir of around 20% of pre-lockdown levels, at the end of the month, for London (Santander Cycles and Freebike), and 45% for the other large systems in the UK that remained open (Cardiff, Edinburgh, Glasgow, Liverpool, Brighton, Bournemouth, Watford and Hereford). In London, activity remained declining at around 25% throughout April 2020, before seeing a gradual increase throughout May 2020 to 45% at the end of the month, and a further slight increase to 50% in the first half of June. Conversely, the other systems outside of London recovered more quickly, increasing to around 65% by the end of April 2020, and back to 100% by the end of May 2020. Bike-sharing use for leisure and recreation purposes in the UK, on the other hand, was not affected much by the lockdown; indeed, there is strong evidence of a substantial increase in bike-share usage especially during the weekends [117]. There is research that goes a step beyond and reports that non-commuting cycling activities in the UK increased significantly after the government interventions [118] on both typical roads and safe cycle lanes; much higher increases were observed on safe cycle lanes than on other roads [4].

In Germany, Berlin has implemented 24 km of temporary bicycle infrastructure in major roads. The cycle lanes are separated with yellow delimitation and barrier posts from the traffic lane so that the users are protected. An important role in the rapid construction of these interventions played the guideline "Temporary Installation and Extension of Cycling Facilities" standardised in April 2020 by the Senate Department for the Environment, Transport and Climate Protection [119]. Another German metropolis, Munich, installed cycle paths at the beginning of the pandemic on a number of main streets [120]. Although residents approved a scheme aiming to encourage them to cycle and protect the public health, the City Council decided to remove it. The argument for this proposal was, on the one hand, that cycle lanes were created for a specific purpose during the lockdown and, on the other hand, that their monitoring showed decrease of bicycle use in combination with the weather conditions contributing to worse congestion problems [121].

Dublin, Ireland's capital city, has constructed a 7.35 km cycle lane, a 7 km traffic calming street and 2 km of roads with widening of sidewalks. The measures affected the modal share and as a result traffic volume in the first lockdown decreased by 70% and without the restrictions this amount is equal to 35% lower than the one before the pandemic [122].

In Hungary, Budapest has pushed cycling uptake by implementing a network of 9.9 km of cycle lanes and 3.63 km of traffic calming roads. The new cycling network has been created at the side of multi-lane central roads [123]. The reduction of the price of the local bike-sharing system, made the scheme more popular [123]. Although the percent of bicycle usage more than doubled, car usage increased to 65% from 43% in the modal share due to the significant reduction in the rate of public transport's use [82]. As such, this was not an ''all-win" result.

In Lisbon, Portugal, the cycling network has been extended during the COVID-19 crisis by 12 km. Pop–up bike lanes have been constructed creating a network that connects the main centres of various uses like working places and residential areas. The number of traffic lanes has been reduced and given to bikes and speed limits have been reduced too to support traffic calming [124].

Milan, one of the most polluted cities in Italy and Europe, had its local authorities announcing in April 2020 the regeneration of 35 km of city road network in order to improve the residents' quality of life. The plan included low-cost temporary bike lanes, new

pavements, maximum speed limit of 30 km/h and pedestrian- cyclist priority streets [125]. The idea of "Strade Aperte" aims to decrease traffic congestion and encourage cycling in central roads such as Corso Venezia and Corso Buenos Aires, but residents' opinions vary. Some believe that this project was implemented rapidly without taking into account the real problems in the main streets of Milan. Restaurant owners complained of the limited space and the traffic congestion especially after the summer vacation's end. Others though are in favour of the initiative and desire the permanent change of the road scheme [125].

In Greece, Athens, following the global model for the construction of temporary infrastructure, implemented the pilot project "Great Walk" in June 2020 which included the creation of bus lanes, public spaces, cycle lanes and pedestrian zones. These interventions concerned main roads in the centre of the capital, such as Vassilisis Olgas Ave., Patision str., Ermou str., Mitropoleos str., Panepistimiou Ave. and Herodes Atticus, the area of Plaka as a car-free area and the Commercial Triangle in order to increase the rate of active travel, improve the quality of public transport services, and reduce the use of private cars. Particularly, in Panepistimiou Ave. the traffic lanes were reduced from six to two for private cars, one was converted into a bus lane, the other three were given to pedestrians and cyclists; temporary cycle lanes were therefore created. Vasilisis Olgas Ave. was pedestrianised, and Syntagma Square was regenerated. There were many reactions from car users especially in the first days of the measure's launch because restricting car traffic space led automatically to traffic jams around the city centre. One month later, one more car traffic lane was added. A lot of locals considered the Great Walk as a failed project. Four months after its implementation, the results showed a reduction of the car use by 2% with a similar increase in motorcycle use while a significant increase in pedestrian traffic (about 28%) was observed. However, bicycle use remained at the same low levels. By 2022, about 50,000 m^2 will be attributed to public space use, 900 m of new cycle lanes will be available in Panepistimiou Ave. and 6.3 km will be rehabilitated [126].

In Greece's second largest city, Thessaloniki, a survey study based on 223 respondents showed that COVID-19 will not affect significantly the number of people using bike-sharing for their trips [41]. However, for some participants, bike-sharing is now more attractive, meaning that bike-sharing could become a more preferable mobility option for people who were previously commuting with private cars as passengers (not as drivers) and people who were already registered users in the local bike-sharing system.

Another interesting policy measure that was adopted in Greece in a national basis is the launch of a subsidy support scheme, from the Hellenic Ministry of Environment and Energy, that funds people turning to electric vehicles. The purchase of an e-bike by individuals or businesses was particularly promoted; the government budget pays up to €800 or 40% of the bike's total value. There are 400 new applications in a daily basis, with about 20% of them referring to e-bike purchases, from 24 August 2020 when the programme initiated.

The Hellenic Ministry of Environment and Energy also published an implementation guide to help local authorities design and implement emergency cycling interventions and the Energy Municipal Quality of Life Committees to create temporary cycle lanes (as well as pedestrianised areas). The goals of this guide, that echoes the strategies of many other countries, looked at: protecting public health; ensuring physical distancing; tackling traffic congestion and local air pollution; reducing cycling accidents; lowering illegal and excessive car parking and movement; increasing physical exercise; diminishing energy overconsumption; promoting cycling investments; and helping cities and their local societies become more sustainable and resilient.

4.2. Cycling Measures in America

Across the Atlantic, Toronto, Canada, continues to install on-street bike lanes. Until today, the network consists of 25 km pop-up cycle lanes in main and local streets. The major advantage of these measures is the fact that can easily be improved or even removed. The decision depends on the overall impact of the measure (social, economic and envi-

ronmental). For example, cycle lanes in Brimley road were removed in December 2020 based on feedback from citizens, stakeholders and on-going data collection [127]. Also, in Canada, Vancouver has turned well-trafficked roads into one-way streets, setting aside a temporary extra lane for walking and cycling; Calgary has taken a similar approach as well [128].

In the US, the city of New York has also seen a surge in cycling due to the COVID-19 outbreak [129]; NYC's Department of Transportation stated that a 50% increase in cycling activity was recorded on all East River Bridges, compared to 2019 figures. Cycling traffic increased by 151% on trails in Philadelphia alerting the local authorities to establish the mission Vision Zero initiative to reduce traffic accidents for cyclists. Vision Zero specifically, is looking into the construction of more parking-protected bike lanes, the creation of safer interchanges, and the institution of automated speed enforcement [130]. Recent research [131] revealed a 138% year-on-year increase in recreational activity at 40 intersections across Phoenix, Arizona. Oakland, California, is credited with kickstarting a slow-streets movement in April 2020 that spread across the US after it set aside 119 km of its streets, or 10% of its entire grid, for recreation prioritising cyclists and pedestrians over cars [132]. Seattle plans to permanently close 20 miles of roads to car traffic. It should be noted that major bike suppliers in the country claimed to have ran out of stock on some of their top selling models as bicycle sales have surged during the pandemic.

The effect of COVID-19 on bike-sharing trips on the other hand in the US is diversified according to a recent study in New York, Boston and Chicago; while trip frequency decreased in all three cases, the average trip duration increased significantly especially for the latter two cities [133]. Another study in Chicago showed that: the proportion of commuting bike-share trips is substantially lower during the pandemic; the trend of bike-sharing usage follows an "increase-decrease-rebound" pattern; and bike-sharing is now framed as a more resilient option compared with transit, driving, and walking [134].

Finally, COVID-19 reinforced, accelerated and gave meaning to a national plan to build a 6000 km long Great American Rail-Trail that will enable mostly cyclists, but also hikers and riders, to traverse the entire US. The multi-use trail will run from Washington DC in the east to Washington state on the Pacific coast. Launched in May 2019, the route will eventually connect over 145 existing paths. So far more than 3200 km of it has been completed [135].

South America's capital cities such as Bogota, Lima, Quito, Santiago and Buenos Aires have expanded bike lanes, closing off miles of roads to cars, in an effort to ease crowding on public transport to curb the spread of COVID-19 and maintain safe distancing [136]. A prime example of good practice and responsiveness when it comes to emergency cycling interventions is Colombia's Bogota. Bogota added from the very first few months of the crisis 76 km temporary cycle lanes in its existing 550 km cycle network to reduce crowding on public transport and help prevent the spread of COVID-19, as well as to improve air quality [129]. Also, the local bike-sharing provider MUVO, with the support and financing of some organisations (i.e., New Urban Mobility Alliance and Despacio), delivered 400 electric bicycles as a loan for medical workers in the city [137].

In Mexico, several cities have implemented similar initiatives. In Puebla, which has an existing 41.05 km cycling network, 26 km of new bike lanes have been installed since the beginning of June 2020. Moreover, in San Pedro Garza García, 6.5 km of bike lanes were created on main roads, such as Corregidora Ave. and Manuel Clouthier. The city of Mexico in the summer of 2020 announced the creation of 54 km of new bike lanes in different areas. After three months the results show that bicycle use has increased even on main roads; the number of cyclists on the 54 km of new paths down major arteries has doubled [138]. For instance, in Insurgentes Av., one of the city's key streets, the number of cycle trips has doubled making the City Council to urge the government to convert the cycle lanes there into permanent.

4.3. Cycling Measures in Asia

Since the virus started in China, the continent of Asia was the one that had to adopt new measures to battle the virus and its impact first and more rapidly than the rest of the world. Bicycles and cycling played and continue to play an important role during the pandemic; indeed, COVID-19 is sparking a new enthusiasm for cycling in many parts of Asia and especially in China, as people avoid buses and subways for fear of infection.

Throughout the two-month lockdown of Wuhan, China, ground zero of the COVID-19 outbreak, volunteers used bicycles to deliver necessities to residents stuck at home and some bike-sharing companies amped up sanitising efforts and made their services free of charge to allow access to medical workers and those with urgent needs [139]. From 23 January to 12 March 2020, Meituan Bikeshare (formerly known as Mobike) provided around 2.3 million trips in Wuhan, according to its own data collection, accounting for more than half of all non-walking trips in the city during the epidemic. A total of 286,000 people used the service, with a total cycling distance of more than 2 million miles. Meanwhile, the average daily distance for a single ride increased 10%, showing an increased reliance on bicycles for longer trips [139].

In March 2020, the use of bike-share systems increased by roughly 150% in Beijing [140] while local bike-share companies showed that trips averaged more than three km, which had been uncommon before COVID-19, when longer trips were typically taken by car or public transit [141]. China that published national standards for electric vehicles in 2019, which included requirements for centralised charging and charger replacement, is also investing on making its urban environments more fitting for e-bikes. The revival of China's bike-sharing economy that almost died two years ago was inspired by a new type of synergies and approaches. These are based on the use of better business models, Artificial Intelligence and big data tools that can recognise dynamically demand and partnerships with battery makers to meet better the technological challenges of e-bike sharing. Hellobike, for example, provides at its kiosks, e-bike users with the opportunity to swap their flat or faulty batteries out for new ones without having to plug in and wait [142].

India, the country with the second largest number of coronavirus cases in the world, has implemented similar bike-friendly policies to those discussed to promote bicycles. Chennai set up pop-up bike lanes and the impact is positive thus far [143]. Until October 2020, there has been a significant increase in the total number of cycling trips in comparison with the past years, setting the bicycle as one of the most basic commuting travel modes. According to data from Strava, the central roads presented a high intensity of cycling activity in 2020 due to COVID-19 [143]. Significant role for the impact of the new cycle lanes plays the connection with the existing network according to stakeholders and citizens' opinions [143].

The level of cycling in another city of India, Bengaluru, traditionally amounts to 2.2% compared with motorcyclists (about 30%). Road safety and illegal parking are both deterrents to its use. The pandemic has, however, made it clear that walking and cycling can help to ensure public health. For this reason, the council decided to install a 16 km pop-up cycle lane on the Outer Ring Road at the end of November 2020 [144]. In the current state, this road serves almost 1000 commuting cyclists and an increase in the usage of cycling is expected with this effort [145]. Gurgaon also established the first pop-up cycle lanes with a total length 10 km in the beginning of October 2020. After two months, the local authorities announced that a network of 25 km of pop-up cycle tracks will be soon added [146].

Cycling as a mode of transport is on the rise in Japan as the COVID-19 pandemic led to a shutdown of public transport systems [147]. In South Korea, the most measurable results evidencing the rise of cycling in the country comes from the usage rate of Ttareungi, the public bicycle scheme of Seoul. Between February and March 2020, the usage rate of Ttareungi increased by 66.8% compared to the same period of time in 2019. While the number of bus and subway passengers during commuting hours decreased by over 20%, the number of Ttareungi users increased by 20.46% during the hours when commuters go

to work and by 93.33% during the hours when they go home. The accumulative amount of Ttareungi users from 16 million in 2018 reached at the end of March 2020, about 40 million, which shows a rapid growth [148].

As a whole, Asia is home to some of the most successful countries that have so far managed to get virus numbers down and keep transmission to very low numbers, such as Vietnam and Thailand. This was possible because they implemented a set of very strict reductions on mobility including tight controls on entry and exit from the country at the early stage of the pandemic [149] and secondary because of the generic public's ability to replace public transit trips with walking and cycling trips that are already popular in these countries anyway.

4.4. Cycling Measures in Oceania

Australia, Sydney, from July to September 2020, set up six pop-up cycleways in the context of safer travels covering the city to a large extent and serving a large percentage of residents [150]. The new cycling network is integrated and connects various land uses namely: education, public spaces, parks and commercial uses. The next step includes monitoring and evaluating, which will illustrate whether these changes can be permanent. In Melbourne, car parks will make way for footpaths and 12 km of pop-up cycling lanes will be built to allow people to socially distance in the city centre as COVID-19 restrictions start to ease [151]. A mixture of line markings and separation barriers are used along the temporary cycle lanes. These cycling interventions will be supported and safeguarded by shared-use zones on Melbourne's "Little" streets and by lower speed limits that refer to 30 km/h.

New Zealand, one the countries with the fewer casualties over this pandemic, was the first country to provide funding to make tactical urbanism an official government policy during the pandemic [152]. Tactical urbanism is a notion that can involve many forms of interim improvements to the public realm, including creating or widening sidewalks and bike lanes with brightly painted concrete blocks and planters. The government reduced speed limits to 30 km/h and installed temporary bike lanes. Research undertaken in Canterbury showed that some people used the lockdown to pick up a new form of exercise with cycling being the most popular, at 78%, on top of walking (64%), at-home workouts (38%), and running (37%). Similarly, in Auckland, cycling and walking accounted for over 60% of the local trips taken over the lockdown [153].

4.5. Cycling Measures in Africa

The pandemic triggered a surge of interest in cycling in Africa because of its capacity to provide for social distancing and help road users avoid crowded public transport services. Cycling infrastructure is scarce and traffic safety for cyclists is very problematic in most African countries so progress is not easily comparable and cannot be described in line with that of other continents; many streets in Africa lack pavements let alone bike paths, bike lanes or charging stations for e-bikes. COVID-19 made more people experiment and learn how to ride a bicycle and inspired local bicycling activists to try and push cyclist safety and bike-friendly laws and investments in the continent's mainstream political agenda.

4.6. Mapping the Real-World Cycling Policy Experience

The real-world cycling policy and planning measures that were identified and discussed in this section are mapped in Table 2, which provides a unique snapshot of the pro-cycling initiatives taken and their immediate results.

Table 2. Policies and outputs related to each case study.

City/Region	Country	Policies									Measurable Outputs
		Infrastructure Based				Measures					
		Cycling Infrastructure	Bike Sharing	Tactical Urbanism	Regeneration of Roads	Traffic Calming	Car Bans	SpeedLimits	One-Way	E-Bike Subsidies	
Brussels	Belgium	√ (+24.9 km)	x	x	x	√ (23.4 km)	√ (5.15 km)	√ (20 km/h)	x	x	44% increase of cycling compared with 2019
Paris	France	√ (29.23 km pop-up cycle lanes)	x	x	x	√ (4.31 km)	x	x	x	x	27% increase of cycling compared with 2019
Lille		√ (9.23 km pop-up bike lanes)	x	x	x	√ (2.2 km)	x	x	x	x	60% increase of cycling compared with pre-COVID period
Barcelona	Spain	√ (21 km)	x	x	x	√ (12 km)	x	x	x	x	12% increase of cycling in post-pandemic era
Madrid		√ (12 km provisional bike cycle lanes)	x	x	x	x	x	x	x	x	Focus on suburbs, and thus lack of cycle lanes in the city centre
London	UK	√ (25 km pop-up bike lanes)	x	x	x	x	x	x	x	x	Concerns of high traffic volumes. Removed cycle lanes in Euston Road
Portsmouth		√ (pop-up bike lanes)	x	x	x	x	x	x	x	x	Two of the selected road interventions removed after stakeholders' feedback
Edinburgh		x	free 30 min	x	x	x	x	x	x	x	UK bike-sharing use for commuting rebounded back to pre-COVID rates but leisure bike-sharing rates especially over weekends have increased
Glasgow		x	free 30 min	x	x	x	x	x	x	x	
Stirling		x	free 30 min	x	x	x	x	x	x	x	
Berlin	Germany	√ (24 km temporary bicycle infrastructure)	x	x	x	x	x	x	x	x	Guideline "Temporary Installation and Extension of Cycling Facilities"
Munich		√ (pop-up cycle paths)	x	x	x	x	x	x	x	x	Removed cycle paths
Dublin	Ireland	√ (7.35 km cycle lanes)	x	√ (2 km widening)	x	√ (7 km)	x	x	x	x	Traffic volume in the first lockdown decreased by 70%
Budapest	Hungary	√ (9.9 km cycle lanes)	x	x	x	√ (3.63 km)	x	x	x	x	Bicycle usage more than doubled, car modal share increased to 65% from 43%

Table 2. *Cont.*

City/Region	Country	Policies									Measurable Outputs
		Infrastructure Based				Measures					
		Cycling Infrastructure	Bike Sharing	Tactical Urbanism	Regeneration of Roads	Traffic Calming	Car Bans	SpeedLimits	One-Way	E-Bike Subsidies	
Lisbon	Portugal	√ (12 km pop-up bike lanes)	x	x	x	x	x	√	x	x	Cycling is more visible
Athens	Greece	√	x	√	√	x	x	x	x	€800/40%	Reduction of car use by 2%, 28% increase in pedestrian traffic, however bicycle use in the same low levels
Milan	Italy	√	x	√	√ (35 km)	x	x	√ (30 km/h)	x	x	Various conflicting opinions from citizens and stakeholders
Toronto	Canada	√ (25 km pop-up cycle lanes)	x	x	x	x	x	x	√	x	Cycle lanes in Brimley road were removed after monitoring
Vancouver		√	x	x	x	x	x	x	√	x	Extra cycle lanes in roads that turn into one-way roads
Calgary		√	x	x	x	x	x	x	√	x	
Oakland	USA	x	x	x	x	√ (119 km)	x	x	x	x	Slow-streets movement origin
Philadelphia		√ (25 km protected bike lanes)	x	x	√	x	x	√ (20 km/h)	x	x	Cycling traffic increased by 151% on trails
Seattle		x	x	x	x	x	√ (20 miles)	x	x	x	Two out of four counters saw a significant bike count increase
New York		√ (to be made)	x	x	x	x	x	x	x	x	50% increase in cycling activity on all East River Bridges
Multi-state		Great American Rail-Trail (6000 km)	x	x	x	x	x	x	x	x	3200 km has been implemented
Bogota	Colombia	√ (76 km temporary cycle lanes)	400 bikes free for medical staff	x	x	x	x	√	x	x	Cycling is more visible
Lima	Peru	√	x	x	x	x	x	√	x	x	Cycling is more visible
Quito	Ecuador	√	x	x	x	x	x	√	x	x	Cycling is more visible
Santiago	Chile	√	x	x	x	x	x	√	x	x	Cycling is more visible
Buenos Aires	Argentina	√	x	x	x	x	x	√	x	x	Cycling is more visible

Table 2. *Cont.*

City/Region	Country	Policies									Measurable Outputs
		Infrastructure Based				Measures					
		Cycling Infrastructure	Bike Sharing	Tactical Urbanism	Regeneration of Roads	Traffic Calming	Car Bans	SpeedLimits	One-Way	E-Bike Subsidies	
Puebla	Mexico	√ (26 km new bike lanes)	x	x	x	x	x	x	x	x	Cycling is more visible
San Pedro Garza Garcia		√ (6.5 km new bike lanes)	x	x	x	x	x	x	x	x	
Mexico City		√ (54 km new bike lanes)	x	x	x	x	x	x	x	x	In Insurgentes Av. the number of cycle trips has doubled
Wuhan	China	x	Free	x	x	x	x	x	x	e-bike sharing support	The average daily distance for a single ride increased by 10%
Beijing		x	x	x	x	x	x	x	x		The use of bike-share systems increased by roughly 150%
Seoul	South Korea	x	improved operations	x	x	x	x	x	x	x	The use of bike-sharing system increased by 20.46% when commuters go to work, and by 93.33% when they return to home
Chennai	India	√ (pop-up bike lanes)	x	x	x	x	x	x	x	x	The central roads presented a high intensity of cycling activity in year 2020
Bengaluru		√ (16 km pop-up bike lanes)	x	x	x	x	x	x	x	x	High increase in cyclist numbers (especially recreational)
Gurgaon		√ (10 km pop-up cycle lanes)	x	x	x	x	x	x	x	x	The local authorities announced that 25 km of pop-up cycle tracks will be added
Sydney	Australia	√ (6 km pop-up cycleways)	x	x	x	x	x	x	x	x	More cyclists ride than usual; favourable road conditions traffic-wise for cycling
Melbourne		√ (12 km pop-up cycling lanes)	x	x	x	x	x	√ (30 km/h)	x	x	
Canterbury	New Zealand	√	x	√	x	x	x	√ (30 km/h)	x	x	Cycling most popular exercise trend over lockdown
Auckland		√	x	√	x	x	x	√ (30 km/h)	x	x	Walking and cycling accounted for over 60% of local trips

Measure adopted: √; measure non-adopted: x.

5. Lessons to Be Learnt and Policy Recommendations

The academic literature and the case studies discussed provide conclusive evidence to suggest that cycling, in all its forms and variations including bike-sharing and e-bikes, has emerged during the pandemic as a sustainable and economically feasible solution for relatively risk-free travel. In general, more bike trips are generated by more users and longer distances are covered by bike both for commuting (with the exception of bike-sharing in some cases) and physical exercise/leisure purposes especially in the cities not facing a hard lockdown. Thus, the usage rates of cycling have increased across the world benefiting already environmental, economic and social sustainability while temporary interventions including the introduction of pop-up cycle lanes, road space reallocation, traffic calming measures, car bans, free use of bike-sharing schemes and subsidies for e-bikes have been widely adopted. Even in cases when hard lockdowns led to the reduction of commuting-related cycling travel (as opposed to recreational, exercise and leisure cycling that rapidly and universally increased when allowed) acceptance of cycling in all its forms has increased substantially.

Sustaining the current levels of cycling usage and pro-cycling policymaking is not a given. Some of the measures had a purely temporary nature. Many of them worked as short-term pilots and quite a few, despite the policymakers' best intentions and a relatively careful planning, failed. The post-COVID-19 transition to permanent cycling interventions and the establishment of a pro-cycling ethos that sees bicycles as a mainstream travel mode that can rival, for short trips at least, the use of cars is a challenging one. It requires a strategic and holistic approach that should focus on the needs of people and the all-important changes that need to happen so that the public space allows the renaissance of cycling to continue. Much like Lozzi et al. [154] suggested, new interventions should be integrated into a coherent and balanced transport mix that distinguishes between short-term buffer measures and long-term strategies.

Our research contextualises some best practice approaches that may be a source for reference and inspiration for policymakers, mobility planners and transport scholars. Our research proposes the following guidelines for facilitating cycling success.

- Temporary cycle lanes are easily implementable and economically feasible and combine the needs for providing both physical spacing and sustainable transport. These can work as an (un)official pilot exercise that tests the functionality and usage of permanent cycle lanes. There will be some wins and some losses in terms of their ability to work in a permanent basis but nonetheless they can be an apparatus, even if short-lived in some cases, for actively prioritising bikes over automobiles.
- Pop-up cycle lanes are necessary for the remainder of the pandemic since they can provide viable solutions especially for people that had to abandon public transport and shared mobility options like ridesharing. These lanes should serve commuting purposes and not only recreation trips.
- Traffic calming measures and road safety enhancement initiatives through road space reallocation, stricter speed limits, car bans, physical road design favouring bikes over cars are necessary complements to support cycling road infrastructure investments. Without making the road environment safer for bicycles and actively promoting accident prevention the pure cycling measures cannot succeed.
- Cycling parking, bike storage, e-bike charging stations and workplace showers should be available to support cycling road infrastructure initiatives and facilitate the needs of cyclists.
- Information about and communication of the new cycling measures is crucial for their uptake.
- Subsidies for the purchase of e-bikes will significantly increase their popularity and use. E-bikes could be of critical importance since they can be a substitute for longer car trips and there is evidence that people covered longer distances with bikes during the pandemic.

- In cities where bike-sharing thrived authorities should explore the possibility of expanding local schemes or supporting private companies running these schemes to invest more. The free 30-min use of schemes is a good example of incentivising more use. Cities with no schemes should seriously think to plan (on their own or through bike-share suppliers) their own systems.
- Policymakers, especially in cases where their long-term planning already involved cycling investments, should be decisive and take immediate action. This time framework favours pro-cycling investments. Cities in their current state (i.e., with less traffic) are at their best to be testbeds for cycling interventions.
- Cycling successes should be celebrated so that people are encouraged to continue on the same path. Failures should be analysed thoroughly to identify what went wrong; using "trial and error" wisely is a robust problem-solving apparatus.
- Some interventions failed due to their inability to fulfil their purpose (e.g., to appeal to commuters). When short and focused public consultation exercises and participatory events via online resources can take place with local road users these should be utilised. Building trust and a sense of community responsibility can help measures to be better designed, more functional and more acceptable.
- Temporary bike lanes and reallocation of space to cycling were sometimes questioned and heavily criticised by drivers. Taking road space from cars needs sometimes a powerful brand of public relations and marketing; infrastructure work alone is not entirely convincing. Transport providers should consider that social acceptance is a crucial factor and is not given that it will always be positively oriented towards cycling measures.
- When change-makers can do so, they need to lead by example; for example, communities having their Mayors cycling to work instead of using a car, are usually more appreciative of pro-cycling interventions.
- The temporary character of some cycling investments raised issues about cost. In general, there should be a better and more transparent distribution of funds. Significant capital should be spent only in situations where these measures have potential, if successful, to be permanent solutions. This potential should be communicated clearly to the general tax-paying public.
- Some stakeholders doubted the merits of temporary interventions; when implementing emergency cycling or mixed-use solutions, policymakers need to make cost-effective investments with non-controversial aesthetic value.
- Loosening restrictive legislations (like strict helmet laws for example) in a temporary basis is a trial worth taking forward now that motor traffic is considerably lower than normal in most cities and cyclist safety is thus enhanced.
- Educating people and especially younger citizens and children about cycling and its merits should be another investment. Interactive workshops, mobile apps and school classes can help. The ''cycling lessons" might be more convincing now than ever before with the emergence of cycling experienced in 2020.

The lessons learnt by the success and failure stories helped us to create this versatile policymaking guide for the implementation, promotion and management of cycling measures that must be used during the pandemic to avoid unnecessary fiascos and can also inform the post-pandemic transport decision-making.

6. Reflections, Limitations and Future Research

The present study provides a state-of-the-art narrative review that describes cycling initiatives that came as transport policy responses to the new realities imposed by COVID-19. Despite an emerging volume of pandemic-centric research in all facets of transport and many real-life cycling interventions, the academic (and technical) literature on bicycling and COVID-19 per se is scarce and still exploratory, immature and basic. This is a pro-active effort, that utilised at the best of our abilities, the available body of academic research and

grey literature, choosing representative cases that reflect the whole spectrum of measures that have been implemented and some of their short-term impacts.

A key criterion for our case study selection was geographical representation; we tried, despite difficulties arising from the still limited records of policy and planning experience, to represent all the corners of our planet with examples from cities that dared to be pioneering and responsive. The availability of data is scarce in some countries like New Zealand that faced perhaps less severe COVID problems, and a lot more well defined in countries like Greece or the UK for whom the authors have a greater access to detailed information. Also, Africa, a continent with a less established bike-friendly culture, could not be systematically evaluated in terms of cycling developments over the pandemic. We made a cautious decision, however, to present cycling in all the continents and in as many countries and cities as possible because we believe that by providing varying levels of data and information, we help in identifying places and cases where more cycling interventions and research on them should be taking place. So, in a way, the ''inconsistency" or ''imbalance" of the present work (i.e., not reporting the same level of detail for every local case study presented) leads not only to unravelling valuable lessons worth transferring and generalising to a wider extent during and after the pandemic, but also highlighting research gaps and identifying localities were more measures need to be implemented and more studies need to be commissioned and conducted.

The authors intend to review the literature again in the next two years, providing an added longitudinal dimension to this work, when many more academic papers looking in more detail and depth at the impacts of bicycling measures will be available.

7. Conclusions

There are many aspects of life that we want to see back to normal as soon as possible, but there is also a ''new normal" [8] which has emerged that has redefined how the transport network operates and how it functions within cities and societies. We might like to keep some of it, when it comes to cycling, but we should also try to complement this with the positive aspects of the pre-COVID era (e.g., find ways to help public transport re-emerge after a strong hit). A monolithic pro-car ethos and an urban development narrative strongly tied to it, is something that we need to leave behind; this was simply not ''good enough" and this is an opportunity for a positive and permanent change fuelled by the success stories of active mobility, in general, and cycling, in all its facets, in particular.

However, we should not forget that investing in cycling is not a panacea on its own but one key piece in the diverse and multi-dimensional toolkit of travel demand management. There are more tools that need to be utilised; funding should be allocated to walking, public transport, Mobility-as-a-Service and Mobility-on-Demand initiatives. We should not forget that cycling is only an option for those who are able to self-mobilise and those who are able and can purchase, maintain and securely store a bicycle/e-bike or subscribe to a bike-sharing scheme if available (not always the case for every city). Moreover, even when dedicated bike lanes, parking areas, traffic calming measures and purchase subsidies are provided, cycling may not be accessible to all due to bad weather, hilly topography and lack of in-vehicle storage. Cultural and social barriers also continue to limit the number of women and ethnic minority cyclists [21,50].

The way forward is to build on the opportunity given during this crisis that exposed the mistakes of the past; transport as a whole can be reborn and century-long challenges like automobility fixation and poor road safety for active mobility users should be mitigated more effectively. In addition, it should be ensured that the disruption and the policy responses to it do not further disadvantage vulnerable groups. Learning from this experience provides a chance to act now, but also to enhance resilience against future disruptions, in a way that reflects sustainable transport policy goals. The cycling emergence can inspire and help in creating a new mobility paradigm where smart transport will be entirely synonymous (and not different) to sustainable transport.

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