Shifting Streets COVID-19 Mobility Data:
Findings from a global dataset and a research agenda for transport planning and
policy

Tabitha S. Combs, PhD
University of North Carolina at Chapel Hill

Carlos F. Pardo
New Urban Mobility Alliance (NUMO)

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Abstract: The COVID-19 pandemic brought a dramatic shift in demand for spaces for safe, physically distanced walking, bicycling, and outdoor commerce. Cities around the world responded by instituting a variety of policies and programs meant to address this shift, such as carving out roadway space for non-car uses, putting pedestrian walk signals on recall, reducing speed limits, and subsidizing bike share schemes. The extraordinarily rapid pace and global scale of these responses—and the public’s reactions to them—suggest that the transport planning, policy, and engineering professions may be at an inflection point with respect to equitable accommodation of non-car transport modes. In this paper we describe an effort to support potential shifts in practice by documenting and cataloging over a thousand COVID-19-related mobility responses into a publicly available database. We provide detailed guidance on using the database, along with preliminary summaries of key variables in the database. We also put forth a research agenda intended to build understanding about the processes that led to these actions, their implications for future efforts to design and implement pedestrian and bicycle infrastructure, and ways in which the transport professions might evolve in response to lessons learned during and after the pandemic.

Keywords: COVID-19, transport planning, infrastructure, walking, bicycling, practice change

1 Introduction & motivation

Since the earliest days of the COVID-19 pandemic, cities around the world began noticing a shift in demand for walking and cycling. This shift was driven by loss of confidence in public transit, closings of schools and recreational facilities, an urgent need to reduce traffic injuries in order to lessen burdens on hospital, and dramatic reductions in driving (Abdullah et al., 2020; De Vos, 2020; Mitra et al., 2020; Slater et al., 2020; Tirachini et al., 2013; Wang et al., 2020; Wilbur et al., 2020), among other factors. In some cases, governments and public health agencies recognized the potential of active transport as a way to lower risks of COVID-19 contagion and boost public health (Slater et al., 2020; World Health Organization, 2020b). Cities (and later, state and national governments) responded swiftly to these new demands by reallocating roadway space away from motor vehicles and toward walking, bicycling, and active recreation.

The primary aim of this paper is to inspire and support efforts to evaluate the global response to changing demands on street space during the COVID-19 pandemic. We do this by introducing an open-source global database—the Shifting Streets COVID-19 Mobility Database—which documents and catalogs public sector responses to COVID-19 that affect use of and access to transportation infrastructure in over 500 cities, states, and countries around the world. We also summarize some of the key variables contained in the database. Finally, we advance a research agenda to build understanding about the processes that led to these actions, their implications for future efforts to design and implement active mobility infrastructure, and ways in which the transportation planning, policy, and engineering fields might evolve in response to lessons learned during the pandemic.

The Shifting Streets database contains a nonrandom sample of 1,313 discrete actions taken in direct response to changing demands for mobility in 524 cities, states or provinces, or countries around the world. The database consolidates, harmonizes, and builds on three independent efforts to document responses to changing mobility demands around the world, with a focus on public sector-led actions with direct impacts on walking, cycling, and other non-car modes of travel. Data were collected through crowdsourcing, professional networks, and systematic internet searches during a five-month period between March 9 and August 9, 2020, corresponding to the first five months of the World Health Organization’s pandemic declaration. The database is housed at the University of North Carolina’s Pedestrian and Bicycle Information Center (PBIC) and is available for public use under a Creative Commons license. It can be accessed at pedbikeinfo.org/shiftingstreets (Combs et al., 2020).

1.1 Background

The need to react quickly to the COVID-19 pandemic changed the pace, urgency, and priority of creating safe spaces for physically distanced walking and cycling for governments around the world. In many regions emergency declarations gave local leaders broad powers to bypass conventional planning processes, which may have been a necessary enabler of their responses (e.g., COVID-19 Presidio Order June 2, 2020). As the concept of pandemic-adapted streets diffused across the globe, the transport sector displayed a growing tolerance for experimentation,

rather than strict adherence to conventional—and often car-centric—engineering standards, and a willingness to deploy infrastructure with temporary materials. Political resistance, in many cities, was replaced with enthusiasm to ‘get on board’ with what was rapidly becoming a global movement, often spurred by pressure from public health and active transport advocates.

The shift in demand for walking and cycling and the rapid responses by governments ushered in a new, if temporary, era of transportation planning: where previously pedestrian and bicycle infrastructure projects took years if not decades to plan, fund, and build, agencies were starting to introduce temporary measures that went from inception to installation in a matter of weeks and sometimes days. These moves have been widely praised by advocates for active, low-carbon mobility (Haubold, 2020; Walker, 2020), and have led to the publication of at least 220 articles, guides, webinars, surveys, and collaborative compilations focusing specifically on these responses in transport and how to facilitate them (Pardo & Escovar, 2020). The phenomenon has also spawned the development of a myriad platforms to track them systematically, including Covid Mobility Works (World Economic Forum et al., 2020), the National Association of City Transportation Officials’ COVID-19 response (National Association of City Transportation Officials, 2020), and the European Cyclists’ Federation’s COVID-19 cycling measures tracker (European Cyclists’ Federation, 2020).

However, the rapid changes to how street space is allocated, designed, and in some cases planned and funded is not without controversy. Many observers and experts have pointed out that the transportation profession’s long history of eschewing public engagement has been further entrenched by the pandemic and the ‘emergency planning’ mentality it has engendered (Agyeman, 2020; Butler, 2020; Lopez, 2020; Thomas, 2020). A straw poll of North American walking and cycling advocates and professionals by AmericaWalks in May, 2020 revealed that over half of survey participants felt their city’s changes to street space allocation in response to COVID-19 involved no or little public consultation (AmericaWalks, 2020). Furthermore, the Shifting Streets data indicate that the vast majority of responses (95%) were neither called for in relevant adopted plans, nor closely aligned with on-going planning efforts (Combs et al., 2020).

Top-down decision-making and lack of robust participatory components in the planning and implementation process has given rise to concerns over the equity of these responses, and backlash in many cases has been vigorous. Pop-up bikeways in Berlin were taken down after a legal dispute (Krause et al., 2020); discussions about the right to use the space by “those who paid taxes” became very visible in the UK (Reid, 2020) and most of Latin America. In North America, much of the controversy has focused on how access to opportunities for safe active mobility—before and during the pandemic—is shaped by law enforcement, land use, and housing policies that have systematically excluded racial and ethnic minorities (e.g., Badger, 2020; Barajas, 2018; Braun et al., 2019; Seay, 2020).

There are potential benefits to be realized from this more rapid, experimental approach to providing active transport infrastructure, including shortened implementation timelines, reduced costs, and creation of new opportunities for improved public engagement through real-time adjustments based on feedback. There are also deleterious impacts that can arise from rushed and

exclusionary planning processes. By documenting and analyzing the global “COVID-19 streets” phenomenon we hope to support research that identifies promising best practices for inclusive processes that maximize benefits while ensuring those benefits accrue equitably.

The remainder of this paper is structured as follows: Section 2 describes the data collection and validation process for the Shifting Streets COVID-19 Mobility database and serves as an introductory user guide to the data. In Section 3 we summarize the responses recorded in the database along several key dimensions, including what actions were taken, where, by whom, and why. Section 4 presents a timeline of responses, showing broad trends about what kinds of responses were gaining traction at certain points in the pandemic. Section 5 presents key takeaways from the preliminary analysis of the data and outlines five potential research areas to deepen understanding of the motivations, processes, impacts, and implications of COVID-19 mobility responses in the medium and longer term. We conclude by discussing limitations in the dataset and suggests ways it can be improved through ongoing data collection and validation.

2 Methods: developing the Shifting Streets database

2.1 Data collection

Most of the responses recorded in the Shifting Streets database come from the “Local actions to support walking and cycling” dataset. This dataset, initiated and managed by Tabitha Combs and supported by PBIC, documents 841 actions taken by 394 cities, states, and countries between March 10 and July 15, 2020. These data were assembled via requests for first-hand information distributed through social media, transportation planning listservs, webinars, and word of mouth (these crowdsourced data were entered by contributors into either a Google spreadsheet or a Qualtrics form); data swaps with others researchers documenting pandemic-related mobility responses on local or regional scales; and through following Google alerts and social media hashtags for relevant key words in English, Spanish, French, and German.

The Combs/PBIC data collection efforts focused on official responses taken at the local, state, or national level with direct implications for walking and bicycling. Data were recorded on the dates the response was announced and implemented, the type of response, a description of the response, whether the response was intended to be temporary or permanent, whether the response had already been planned but implementation was accelerated due to the pandemic, contact info and comments from the source (where provided), and web links to news articles, city websites, and/or social media accounts providing additional information. Sources also provided information about adjustments to transit services, provision of non-roadway space for outdoor dining and retail, about explicit actions to restrict walking and bicycling, and about unsanctioned ‘tactical urbanism’ actions. The Combs/PBIC dataset is archived for public use at the [Pedestrian and Bicycle Information Center](#) (Combs, 2020).

Concurrently, Street Plans, a US-based consultancy focusing on urban transportation planning and design, began crowdsourcing data about street-level design changes in cities around the world. Their “COVID19 Livable Streets Response Strategies” dataset was developed to inform

and support on-going implementations of roadway reallocations, and data collection was largely limited to the first two months of the pandemic. The approximately 300 actions recorded in Street Plans' dataset includes many of the same responses as the Combs/PBIC dataset, but adds critical details about physical implementation, scale, and enforcement strategies.

The Covid Mobility Works website is a collaborative effort between several organizations led by the New Urban Mobility Alliance (NUMO) and the World Economic Forum. When consulted for this database, this website described 556 interventions, with a focus on the drivers and motivations behind them. The Covid Mobility Works data were drawn from other data collection efforts and from internet searches; full methods and contributor information are available with the data at <https://www.covidmobilityworks.org/> (World Economic Forum et al., 2020).

2.2 Data integration, harmonization, and validation

During July and August of 2020, the authors integrated and harmonized these three datasets into a single database, while continuing to add new actions through August 9, 2020. Our focus was on developing a complete, single record for each response that included all of the variables from each of the three original datasets, constructing and populating new variables to support a wide range of uses and research interests, and verifying all records with available information sources. The result was the Shifting Streets COVID-19 Mobility Database.

Simultaneously, an open-source platform and corresponding GitHub repository were developed to produce visual summaries of actions according to the categories of the database in coordination with Datasketch, a Colombian open data initiative. This platform is available from <https://datasketch.github.io/mobility-actions/>.

The Shifting Streets database documents a wide range of aspects of mobility sector responses to COVID-19, and contains variables recording location, start and end dates, brief descriptions, physical, spatial, and temporal dimensions, and sources of published information about each response. Many of these variables are closely related and, in some cases, overlapping. This overlap—wherein different variables contain many of the same or similar values—is a product of the original datasets used to seed the Shifting Streets database. All three original datasets cataloged a phenomenon as it was unfolding, and each original contributor documented actions through lenses that reflected their own perspectives and interests in the phenomenon. Most of the original variables were constructed on the fly, with values added on an *ad hoc* basis as each novel form of COVID-19 response appeared. Many of the variables were text-based, without distinct categories into which actions could be sorted and analyzed.

As we worked to integrate the datasets into a single database, we recognized a need to standardize the information encoded in the original datasets to facilitate analysis. However, we also wanted to maintain all the original data as it contains valuable contextual information that may aid other researchers' efforts to respond to different research or policy questions.

We achieved both aims—creating a set of standardized variables suitable for summarizing and analyzing the COVID-19 mobility phenomenon as a whole while maintaining the valuable contexts and perspectives of the original datasets—using the following process:

1. Assess and harmonize all entries of the separate datasets so that each response was recorded as a single entry, as needed (example structure shown in Figure 1a). If one city undertook more than one kind of response, they would be recorded as separate entries.
2. Merge the three original datasets into one and add a source data variable indicating which original datasets provided information about each response. When two or more original datasets contained similar information about a response, merge the records into a single entry (Figure 1b, new information shown in **boldface**).
3. When original datasets did not include a response recorded in another dataset, populate the missing values with available information sources (i.e., other datasets, linked information sources; Figure 1c).
4. Generate new standardized variables for all response, populate with available information (Figure 1d).
5. For new response implemented after data harmonization, populate all variables with available information (Figure 1e).

Part of the harmonization process involved identifying unique individual responses. A response is a unique combination of key characteristics describing both the response and the manner in which it was implemented. Unique responses are recorded as individual records. For example, a city might enact full street closures on multiple streets. If those closures began during the same time frame and were implemented in the same manner (i.e., no differences in times/days in effect, intended longevity of the action, its purpose, targeted modes, or selection process), they were considered a single response and thus recorded only once. However, if some of those streets were closed all day every day and others only on weekends, they would be recorded as two separate responses, each with its own entry in the database.

After harmonization and integration, the entire database was validated through logical checks within the data and consultation of original sources to fill in gaps and resolve disagreements between original datasets. Validation efforts were focused on essential variables, described below. As of November 1, 2020, the full integrated database included 1,313 actions documented between March 4 and August 9, 2020. After filtering out responses that did not have direct implications for walking, bicycling, or other non-car uses of public roadway space, lacked a public sector lead, and or were missing data on essential variables, we were left with a sample of 1,109 documented responses taking place across 473 cities, states or provinces, and countries. These responses include physical changes to road space (e.g., reallocation of road space to non-car modes via signage or temporary barriers), changes to transport system operation (e.g., speed limit reductions, adjustments to traffic signal timing), changes that directly affect transport costs borne by users (e.g., subsidization of bicycle share schemes), and regulatory changes (e.g., relaxation and/or tightening of restrictions on particular transport modes, dedication of funds for emergency planning).

Dataset: T. Combs/PBIC			Dataset: M. Lydon/Streeplans			Dataset: MobilityWorks		
Response	varTC1	varTC2	Response	varML1	varML2	Response	varMW1	varMW2
Response 1	x	x	Response 2	x	x	Response 1	x	x
Response 2	x	x	Response 4	x	x	Response 4	x	x
Response 3	x	x						

Figure 1a

All data, combined							
Response	source data	varTC1	varTC2	varML2	varML2	varMW2	varMW2
Response 1	TC, MW	x	x			x	x
Response 2	TC, ML	x	x	x	x		
Response 3	TC	x	x				
Response 4	ML, MW			x	x	x	x

Figure 1b

All data, combined and harmonized							
Response	source data	varTC1	varTC2	varML2	varML2	varMW2	varMW2
Response 1	TC, MW	x	x	x'	x'	x	x
Response 2	TC, ML	x	x	x	x	x'	x'
Response 3	TC	x	x	x'	x'	x'	x'
Response 4	ML, MW	x'	x'	x	x	x	x

Figure 1c

All data, combined, harmonized, and standardized									
Response	source data	varTC1	varTC2	varML2	varML2	varMW2	varMW2	newvar1	newvar2
Response 1	TC, MW	x	X	x'	x'	x	x	x'	x'
Response 2	TC, ML	x	X	x	x	x'	x'	x'	x'
Response 3	TC	x	X	x'	x'	x'	x'	x'	x'
Response 4	ML, MW	x'	x'	x	x	x	x	x'	x'

Figure 1d

All data, combined, harmonized, standardized, and expanded									
Response	source data	varTC1	varTC2	varML2	varML2	varMW2	varMW2	newvar1	newvar2
Response 1	TC, MW	x	X	x'	x'	x	x	x'	x'
Response 2	TC, ML	x	X	x	x	x'	x'	x'	x'
Response 3	TC	x	X	x'	x'	x'	x'	x'	x'
Response 4	ML, MW	x'	x'	x	x	x	x	x'	x'
Response i		x'	x'	x'	x'	x'	x'	x'	x'

Figure 1e

Notes:

1. x=value on original variable as provided in original dataset; x'=value as interpreted by data harmonization team. New information shown in boldface in each step.
2. The initials "TC," "ML," and "MW" are used in the database to identify the original source of each data point. "TC" and "ML" refer to the initials of primary creators for the T. Combs/PBIC and M. Lydon/Streetplans datasets, respectively. "MW" is used to represent data and variables provided by the Mobility Works collaborative.

Figure 1. Data integration process

Table 1 defines a selection of the variables used to describe each response, including essential variables: those which must be present for the record to be considered complete.¹ Essential variables comprise a set of characteristics that classify the response into one of 32 categories (*action*), describe the location (*country*, *state*, and *city*, as needed, including ISO codes where available), physical and temporal dimensions of the action (*space*, *time*, *intensity*), the stated intent of the action (*purpose*), alignment of the response with existing policies (*policy*); plus an

¹ A full list of variables with complete data dictionary is available for download, with the data, at pedbikeinfo.org/shiftingstreets.

open-ended text description of the action (*description*) and at least one web link to a source of information about the action (*source*). Data on the essential variables come from the three source datasets and from the news stories, press releases, and local government webpages provided in the *source* variable.

Many of the variables in the Shifting Streets database are derivations of the *action* variable and are linked to each other in critical yet complex ways. Understanding the relationships among these variables will facilitate analysis and interpretations. Table 2 shows the relationships among four of these variables: *type*, *space*, *function*, and *application*.

A note about *action*: each of the source datasets included a field for categorizing responses based on their specific nature (e.g., automation of walk signals, closing of streets to motor vehicles). As the pandemic progressed and governments began experimenting with increasingly more novel ways to address changes in mobility demands, the *action* fields in each dataset evolved, expanded, and diverged based on the interests and perspectives of the contributors. Thus, in the merged database, *action* takes on 32 different but non-exclusive values that can only be fully interpreted in concert with other variables describing specific spatial and temporal characteristics of the responses. We needed a new variable to describe the specific nature of the responses at a granular level but with values that were exhaustive and mutually exclusive. Thus, we constructed *application*, which is derived from but different to *action*. The integrated database retains the original *action* variable for context, but we use and recommend *application* for analysis.

Table 1. Select variables and definitions from the Shifting Streets COVID-19 Mobility Database

Variable name	Variable definition	Example values
<i>country*</i>	Country in which the action occurred	
<i>state*</i>	State or region in which the action occurred	
<i>city*</i>	City in which the action occurred	
<i>dateann</i>	Date action was announced or first mentioned in media	date entry
<i>dateimp</i>	Date implementation began	date entry
<i>dateend</i>	Date action ended/scheduled to end	date entry
<i>description*</i>	Description of the action	text entry
<i>name</i>	Name of the action, if applicable	text entry
<i>category</i>	General nature of the action	operational; physical; regulatory; financial
<i>type</i>	General category of the action; a collapsed version of action	full street closure; partial street closure; curb space reallocation; legal, policy, funding changes
<i>action*</i>	Specific nature of the action; describes how the action is applied	automated walk signals; reduced speed limits; closed streets to motor vehicles; reallocated curb space
<i>purpose*</i>	Purpose of the action	economic recovery; moving people; public health
<i>function*</i>	Manner in which the action is intended to affect users; a collapsed version of action	street space for ped/bike; transit supports; street space for commerce
<i>application</i>	A constructed variable derived primarily from action	Full street: pedbike; parking lane: commerce; new \$ for pedbike
<i>space*</i>	Area in which action takes places	entire right-of-way; edge/sidewalk; parking lane; intersection; N/A
<i>time*</i>	Times/days action is in effect	all day every day; specific hours during nighttime; weekends; N/A
<i>intensity*</i>	Degree to which motor vehicle movement is affected in the space in which the action takes place	100% banning of cars; only certain vehicles allowed; no ban (shared space); N/A
<i>scale</i>	The geographic scale of the implementation	one or more streets; one or more neighborhoods; entire city
<i>infrastructure</i>	Physical infrastructure affected	road space; sidewalk; beg buttons; N/A
<i>selection</i>	Process through which actions were selected	arbitrary; input from community; based on previous studies
<i>longevity</i>	Expected duration	temporary; permanent; one-time implementation
<i>modetype</i>	Primary type of mode targeted	active; freight; transit
<i>mode</i>	Specific mode targeted	automobile; bicycle; bus
<i>policy*</i>	Alignment with adopted policies	fast-track pre-COVID-19 plan; new action; unsanctioned; unknown
<i>endcircumstance</i>	Reason action ended	planned expiration; public pressure; lack of use
<i>public</i>	Role of the public in decisions about the action (to be entered only by local verifier)	text entry
<i>source*</i>	Links to press releases, civic webpages, or news articles	text entry
<i>verified</i>	Indicates that data were locally verified	yes/no

* denotes essential variables

Table 2. Relationships among variables describing COVID-19 mobility actions

Type	Space	Function	Application	Actions
Full street closures	Entire roadway	Street space for bikes/peds	Full street: pedbike	Closed streets to motor vehicles for walking & cycling (some exceptions allowed).
		Street space for commerce	Full street: commerce	Closed streets to motor vehicles for commerce (some exceptions allowed).
Partial street closures	Entire roadway	Street space for bikes/peds	Partial street: pedbike	Shared streets (motor vehicles allowed but discouraged); Filtered streets (only local traffic; some exceptions allowed).
Curb space reallocations	Curb; Parking lane; Traffic lane	Street space for bikes/peds	Traffic lane: pedbike; Parking lane: pedbike; Curb space: pedbike	Reallocated curb space or part of roadway to walking or cycling
		Street space for commerce	Traffic lane: commerce; Parking lane: commerce; Curb space: commerce	Reallocated curb space or part of roadway for outdoor commerce.
Reallocation of non-curb space	Sidewalk; private property; other (parks, plazas)	Other bike/ped supports	Non-street: pedbike	Established new/temporary recreational facilities
		Other commerce supports	Sidewalk: commerce; Non-street: commerce	Reallocated non-street space for outdoor commerce
			Loading zones	Reallocated curb space for short term free parking to facilitate take-away pickup
Automated walk signals	Intersection	Other bike/ped supports	Automated walk signals	Eliminated need to push a button to get a walk signal
Legal, policy, enforcement, & funding changes	N/A	Other bike/ped supports	Speed limit	Reduced speed limits on at least some roads
			Legal changes	Changed laws affecting use of public space by non-car modes
		Influence transport planning	New mobility plan	Developed new mobility plans in response to pandemic
	Sidewalk; Other (parks, plazas)	Restrict mobility for pedestrians or bicyclists	New \$ for pedbike	Created new funding streams for non-car mobility
			Restricted pedbike	Closed walking/cycling facilities; implemented policy or enforcement action to restrict walking or cycling; removed parking at parks & trail heads
	Parking lane; N/A	Promote driving	Free car parking	Free car parking; parking ticket forgiveness
	Intersection	Other bike/ped supports	Signal timing	Adjustments to signal timing to minimize queuing by pedestrians
Other mobility-related strategies	Other (parks, plazas); N/A	Other bike/ped supports	Improved existing	Improved existing infrastructure
			Bike parking	Installed new bicycle parking
	N/A	Expand access to bicycles	Bike share	Subsidized bicycle share
			Subsidize bikes	Subsidized bicycle purchases & repair
		Boost transit	Boost transit	Reduced/eliminated transit fares; Improved transit service
		Restrict mobility by transit	Restricted transit	Reduced transit service
	Various; N/A	Miscellaneous	Other	One-off actions with direct or indirect effects on mobility

3 Summary of COVID-19 mobility responses

We summarize COVID-19 mobility responses along a selection of essential variables and other variables of general interest: *application*, *region*, *type*, *function*, *intensity*, *space*, *policy*, and *purpose*. The values in these variables have all been “armchair” validated, meaning they have been checked for logical consistency and for agreement with news stories about the responses. We briefly describe and present summary statistics on each of these variables below. The information presented is not meant to provide comprehensive answers, but to introduce and share the data and to serve as an inspiration and foundation for further research on the massive, complex phenomenon of “COVID-19 streets.”

3.1 Application

The most common application is reallocation of some but not all traffic lanes to walking and bicycling, representing 13% of all recorded mobility responses (*application*=traffic lane: pedbike). This is followed by full and partial street closures for walking and bicycling, each with 11% of all recorded mobility responses. Partial streets closures (*application*=partial street: pedbike) is comprised of ‘shared’ streets (where active transport modes are prioritized and motor vehicles slowed or discouraged through traffic calming) and ‘filtered’ streets (where use of the affected roadway segment by motor vehicles is restricted to local traffic only). Partial street closures are sometimes known as neighborhood greenways, bike boulevards, play streets, healthy streets, and low traffic streets. Full street closures (*application*=full street: pedbike) are complete bans of all motor vehicles except emergency, public utility, and transit vehicles in order to create space for walking and cycling. These are sometimes referred to in English as ‘open streets’ and Spanish as ‘ciclovía’). They are differentiated from ‘dining streets’ or ‘streateries’ (*application*=full street: commerce) in that their primary purpose (as described in the variable *purpose*) is ‘moving people.’

Less common values of *application* include reallocating the outermost portion of the roadway (*application*=curb space: pedbike; 5%) and on-street parking lanes (parking lane: pedbike; 2%) to pedestrians and bicyclists, automating button-controlled walk signals (5%), adjusting traffic signal timing to reduce wait times for pedestrians (1%), reducing motor vehicle speed limits (3%), changing laws limiting the use of public roadway space by pedestrians and bicyclists (legal changes; 2%), and improving existing walking and cycling infrastructure (improved existing; <1%). Some jurisdictions sought to improve access to bicycles through expansion or subsidization of bike share programs (7%), subsidization of bicycle purchases or repairs (subsidize bikes; 1%), and installation and expansion of bicycle parking facilities (bike parking; 1%). Finally, a few locations established new dedicated funding streams to support construction and maintenance of pedestrian and bicycle facilities (new funding for pedbike; 1%) and created or revised mobility plans to accommodate COVID-19-related changes in demand for safe walking and cycling infrastructure (new mobility plan; <1%). The database also records 56 instances (6% of responses) in which governments restricted walking and bicycling through

policy, enforcement, or closures of parks, trails, and other walking and bicycling infrastructure (restrict mobility: pedbike).

Some values of *application* capture supports for commerce that are not directly aimed at walking and bicycling but nevertheless affect conditions for walking and cycling. Eight percent of responses were full street closures to create space for outdoor dining and retail, commonly referred to as “streateries” and market streets (*application*=full street: commerce). Other commerce-related responses included dedication of curb space for short term parking to facilitate take-away services (curb space: commerce; 3%) reallocation of non-street space (e.g., parking lots, plazas; non-street: commerce; 1.7%), sidewalk space (sidewalk: commerce; 1.6%), and on-street parking spaces (parking lane: commerce; 1.5%) to outdoor dining and retail.

Table 3. prevalence of COVID-19 mobility responses by application (n=1,109)

Value label	Value definition	Freq.	%
Traffic lane: pedbike	Reallocated one or more traffic lanes to walking and cycling	146	13.2
Partial street: pedbike	Partial street closures to support walking and cycling	122	11.0
Full street: pedbike	Full street closures to support walking and cycling	122	11.0
Full street: commerce	Full street closures to support outdoor commerce	86	7.8
Bike share	Expanded and/or subsidized bike share programs	73	6.6
Walk signals	Automated of walk signals	58	5.2
Curb space: pedbike	Reallocated curb space (not including traffic or parking lanes) to walking and cycling	58	5.2
Restrict mobility: pedbike	Restricted walking and cycling through policy, enforcement, or facility closures	56	5.1
Boost transit	Improved transit service and/or reduced/eliminated fares	44	4.0
Free parking	Suspended car parking enforcement and/or parking ticket forgiveness	34	3.1
Speed limit	Reduced speed limits on public roadways	32	2.9
Loading zones	Reallocated curb space for short term free parking to facilitate take-away pickup	30	2.7
Parking lane: pedbike	Reallocated on-street parking to walking and cycling	26	2.3
Restrict mobility: transit	Reduced transit service (frequency and/or capacity)	23	2.1
Legal changes	Changed laws affecting use of public space by non-car modes	21	1.9
Non-street: commerce	Reallocated non-street space for outdoor commerce (parks, plazas, parking lots)	19	1.7
Sidewalk: commerce	Reallocated sidewalk space to outdoor commerce	18	1.6
Parking lane: commerce	Reallocated on-street parking to outdoor commerce	17	1.5
Traffic lanes: commerce	Reallocated one or more traffic lanes to outdoor commerce	13	1.2
Subsidize bikes	Subsidized purchase and/or maintenance of bicycles by individuals	13	1.2
New funding for pedbike	Dedicated new streams of funding to support bicycle and pedestrian facility implementation	13	1.2
Bike parking	Expanded/improved bicycle parking facilities in public space	12	1.1
Signal timing	Adjusted traffic signal timing to reduce queuing by pedestrians	12	1.1
Improved existing	Improved existing walking and cycling infrastructure	9	<1.0
Curb space: commerce	Reallocated curb space to outdoor commerce	6	<1.0
New mobility plan	Revised existing mobility plans/create new mobility plans to address COVID-19-related changes in mobility demand	6	<1.0
Non-street: pedbike	Reallocated non-street space (e.g., trails; golf cart paths) to walking and cycling	3	<1.0
Other		36	3.3

Finally, a handful of responses targeted transit and driving, with knock-on effects for walking and cycling: improvements in transit service frequency or reliability and/or reduction or elimination of fares (*application*=boost transit; 4%), reduced transit service frequencies and/or

limited transit vehicle capacities (restrict mobility: transit; 2%), and encouraging driving by removing parking restrictions and/or forgiving parking violations (free parking; 3%).

3.2 World region and jurisdiction type

Nearly all of the recorded responses (98.5%) took place in four world regions as defined by the United Nations Statistics Division (UNSD, 2021): East Asia and Pacific, Europe and Central Asia, Latin America, and North America. South Asia, the Middle East and North Africa, and Sub-Saharan Africa make up the rest of the responses. It is likely that the small share of responses from these regions does not accurately reflect the efforts being undertaken there; it is more likely a reflection of language barriers and limitations of professional networks inherent in crowdsourced data collection efforts.

The majority of responses (95.6%) took place at the city level, driven by local government initiatives; the rest were state/region or national-level initiatives.

Table 4. *prevalence of COVID-19 mobility responses by world region and type of jurisdiction*

Variable	Value	Freq.	%
UNSD World region (n=1109)	North America	643	58.0
	Europe & Central Asia	328	29.6
	Latin America	67	6.1
	East Asia & Pacific	53	4.8
	Middle East & North Africa	10	<1.0
	Sub-Saharan Africa	5	<1.0
	South Asia	2	<1.0
Jurisdiction type (n=1109)	City or metropolitan area	1,071	95.6
	State, province, district, or administrative region	31	2.8
	Country	18	1.8

3.3 Type, function, and spatiotemporal characteristics of responses

We use four variables to describe the physical and operational attributes of the responses: *type*, *function*, *intensity*, and *space*. The breakdown of these attributes is shown in Figure 2.

Type collapses *application* into seven general categories: full street closures, partial street closures, curb space reallocations, reallocation of non-street space, automation of walk signals, legal, policy, enforcement, or funding changes, and ‘other’ mobility-related strategies. The most common *type* of response is curb space reallocation, in which the outermost portion of the roadway is converted to non-car uses (*type*=curb space reallocation; 24% of all recorded responses). These can be implemented either as a reduction in the width of the outermost travel lanes (*space*=curb) or conversion of outer travel lanes or parking lanes (*space*=one or more traffic lanes, parking lane), and can be intended for active mobility or commerce. Other physical changes to the roadway include full street closures for active mobility or commerce (*type*=full street closure; 19%) and partial street closures (partial street closure; 11%). Partial street closures are only used for active travel and recreation; commerce is not seen in partial street closures in

our data, probably due to the high likelihood of conflict between motor vehicles and stationary retail and dining infrastructure.

Automation of walk signals makes up 5% of the responses, and 3% involve the reallocation of non-street space (e.g., sidewalks, off-street parking, parks) to walking and cycling or outdoor commerce. The remaining response types are legal, policy, enforcement, or funding changes (13%) and other mobility-related strategies not adequately captured by any of the other categories (25%).

Figure 2. Prevalence of COVID-19 mobility responses by type, function, and spatial characteristics

The *function* variable is also a collapsed version of *application* but seeks to integrate aspects of the apparent intended function behind the response. For example, *function* differentiates between street space reallocations to support walking and cycling and street space reallocations to support outdoor commerce but does not distinguish between the physical implementation of those

reallocations (i.e., full street vs. partial street vs. curb space). *Function* includes ten categories plus a miscellaneous group of 36 (3%) of one-off responses that do not readily fit into the ten functional categories.

A plurality of responses (43%) function explicitly to create street space for pedestrians and bicyclists (expand street space for walking/cycling). Other pedestrian/bicycle supports, such as walk signal automation, speed limit reductions, signal timing adjustments (to reduce queuing by pedestrians at intersections), creation of new off-street recreational space, and changes to laws to expand protections or rights to pedestrians and cyclists, comprise 12% of the responses. Expanding access to bicycles accounts for a further 9% of responses; this value includes subsidization of bicycle share and bicycle ownership and expansion of bicycle parking facilities. This preponderance of responses explicitly geared toward supporting walking and cycling is not surprising, given that the two main data collection efforts feeding into the database—PBIC and Street Plans—were focused explicitly on local responses to changing demand for walking and cycling.

Eleven percent of responses dedicated street space—either the entire roadway or outer travel or parking lanes—for outdoor dining and retail (expand street space for commerce). This sort of response also creates de facto pedestrian space; bicycles are typically permitted as well. Other commerce supports, including dedication of non-street space (including sidewalks) and allowing use of curb space for short-term parking for pick-up/drop-off of goods, accounts for 6% of all responses.

Less commonly reported functions include boosting transit service (4%, comprising improvements to service frequency and reliability and reduction or elimination of fares), restricting transit-based mobility (2%), restricting mobility for pedestrians and bicyclists (6%), promoting driving (3%), and influencing transport planning (2%).

Intensity is a measure of the degree to which the access to road space by motor vehicles is affected by each response. *Intensity* is only applicable for actions taking place in the roadway (i.e., where motor vehicles are normally expected to operate), which comprise 714 (64% of) all responses. The vast majority of these responses involved completely removing motor vehicles (*intensity*=100% banning of motor vehicles; emergency, utility, and transit vehicles typically excepted) from the space (44% of all responses, 69% of applicable responses). This includes full street closures as well as reallocation of outer lanes and curb space, even if the response does not result in a lane reduction. Eight percent of responses (12% of applicable responses) involve bans of either residential or other specific vehicles, as is the case with “filtered streets” (*intensity*=only resident/certain vehicles allowed). Fourteen percent of all responses (21% of applicable responses) either create shared space (i.e., ‘shared streets’; *type*=no ban (shared space)) or affect walking and cycling conditions in the roadway but do not reduce the intensity of motor vehicle traffic (*type*=N/A; i.e., signal timing adjustments, automation of walk signals, and speed limit reductions).

Figure 3. Application of covid19 street adaptations in space

Space identifies the specific portion of the right-of-way directly affected by each response, regardless of its function or intensity. We were able to determine and verify *space* for 1,076 (97%) of the responses. Of those 1,076 responses, 866 (80%) were spatially defined (i.e., took place on a specific area of the roadway or right-of-way). Spatially defined responses most commonly affected the entire roadway, including full and partial street closures and speed limit reductions (*space*=entire roadway; 34% of all 1,076 responses), followed by one or more travel lanes (17% of all responses), and curb space and parking lanes (both at approximately 7.5% of all responses). Curb space actions take place at the edge of the roadway and may result in narrowing of traffic lanes, but not their removal). Seven percent of all responses take place in intersections (comprising mostly walk signal automation and signal timing adjustments, though we did see a few instances of intersection reconfigurations intended to shorten pedestrian crossing distances). Only 1% of all responses involved reallocation of sidewalk space (*space*=sidewalk), nearly all of which were intended to carve out public space for outdoor commerce, and <1.0% occurred in off-street locations (*space*=other). Twenty percent of responses did not have specific spatial component. Figure 2 provides the prevalence of responses

by the space affected by them; the *space* variable and its relationship with *application* is further illustrated in Figure 3.

3.4 Drivers of responses

The last variables we discuss address why (*purpose*) and how (*policy*) responses were implemented, rather than their mechanics and physical properties. The frequencies of the various purposes and policies recorded in the database are shown in Figure 4.

Policy captures whether the responses were called for in adopted plans but not yet implemented (fast-track pre-COVID-19 plan), consistent with ongoing programs, policies, or planning efforts (within expected pre-COVID-19 plan), expansions of existing activities, such as extending a weekend Open Streets event to weekdays (expand pre-COVID-19 action), or altogether new responses decided upon and implemented outside customary planning processes (new action). We were able to discern *policy* in 1,081 instances. The vast majority of responses (95% of 1,081) appear—based on the information available to us—to be new actions. Only in a few cases were responses expansions of pre-COVID-19 actions (2%), fast-tracking pre-COVID-19 plans (2%), or within expected pre-COVID-19 plans (<1%). We also recorded a few instances of unsanctioned responses (<1%), implemented by individuals or advocacy groups and not immediately removed by local officials.

Figure 4. prevalence of COVID-19 mobility responses by policy and purpose as specified in supporting documents

Finally, *purpose* records the primary intended outcome or goal of each action, as described in the supporting information sources and according to the logic defined below. *Purpose* can take on the following values: public health, safety, moving people, moving goods, economic recovery, public engagement, equity, and ‘other.’ We were able to discern *purpose* in 1,071 records.

Responses involving automation were always coded as *purpose*=public health, as they served the purpose of reducing wait times and/or touching shared surfaces. Other responses were coded as

public health if the supporting information sources mentioned ‘public health’, ‘physical distancing,’ ‘reducing crowding,’ ‘queuing,’ or ‘reducing transmission’ (or similar phrasings) in their descriptions of the motivation for the action. Note that this means street space reallocations for walking and cycling could be classified as ‘public health’ rather than the perhaps more obvious ‘moving people.’ Where purposes were described as both ‘public health’ and something else, they were coded as ‘public health.’

All commerce supports (street space, non-street space, and other supports) were coded *purpose*=economic recovery (unless the ‘public health’ code applies). All responses that created street space for walking and cycling (i.e., *function*=expand street space for walking/cycling) were coded *purpose*=moving people unless explicitly described as something else. Responses where *function*=expand access to walking and cycling were usually coded as *purpose*=moving people, but in a few cases the associated information sources described responses meant to support moving goods instead. Responses that limited mobility via transit or walking and cycling were always coded as public health except, in the case of transit, service reductions were due to declining revenues or demand (in which case they were coded ‘other’). Purposes for all other responses were recorded based on the team’s interpretation of the available information sources.

The most common primary purpose reported is ‘moving people,’ (i.e., the action’s primary purpose is facilitating movement of people via targeted mode(s)), at 47%. This is followed by ‘public health’ (29%, primary purpose is reducing disease transmission via, for example, enabling physical distancing, automation, contactless payments) and ‘economic recovery’ (16%; primary purpose is supporting businesses by dedicating public outdoor space to dining and shopping, allowing businesses to operate outdoors in other spaces, or creating loading zones in rights-of-way for short term parking for patrons’ pickup up takeaway orders). ‘Safety,’ which includes speed limit reductions and other explicit mentions of safety, represented 5% of the responses recorded. ‘Moving goods’ (for example, programs in Mendoza, Argentina and Syracuse, New York that provided free cargo bike share to local businesses to facilitate delivery of goods to consumers) took up 2% of actions. ‘Public engagement,’ ‘equity,’ and ‘other’ all came in under 1%.

4 Timeline of COVID-19 mobility responses

Just as our collective understanding of COVID-19 has evolved over time, so have our demands on public space and transportation systems, and on governments’ responses to those demands. Tracking the introduction of these responses over time suggests some patterns to this evolution. Figure 5 shows the growth over time of seven kinds of responses based on the *function* variable: street space for walking and bicycling, other walking and bicycling supports, street space for commerce, other commerce supports, access to bicycling, influence planning, and restrictions pedestrian and bicyclist mobility.

Figure 5. Cumulative responses over time by function

Concurrent with the World Health Organization’s declaration of COVID-19 as a global pandemic in March 2020, we see an initial flurry of mobility responses. The first response to be popularized is ‘other commerce supports,’ which primarily took the form of creating loading zones for picking up takeaway orders from restaurants and stores. By late March we see a rapid rise in creation of street space for walking and bicycling (street space for ped/bike), other pedestrian and bicycle supports, access to bikes, and restrictions on walking and cycling. “Other

bike/ped supports” is comprised primarily of automation of walk signals during this time period, reflecting both the fear that surfaces were a common form of virus transmission and the technological ease of converting actuated walk signals to automated ones. Street space reallocations at this stage mainly occurred through the expansion of existing open streets events in cities that already had the equipment and knowledge required to implement such actions quickly and with minimal public resistance. The bulk of restrictions on walking and bicycling came during this early period as well, as city officials looked to prevent crowding of public spaces, reduce maintenance burdens on public facilities, and police movement in cities under lockdown. These early responses appear largely to represent low hanging fruit: relatively simple, low-cost responses cities could implement quickly.

Early April brings a levelling off of walking and bicycling restrictions and ‘other commerce supports,’ and a slowdown in the growth of ‘other ped/bike supports’ and actions to ‘expand access to bikes.’ Meanwhile, reallocation of street space to walking and biking begins picking up steam, going from 23 responses to 172 in the span of a month. At this point we see the focus shift from open streets events (i.e., full street closures) to a mix of response types including shared and filtered streets, pop-up bike lanes, and expansions of sidewalk areas to reduce crowding among pedestrians. April also brings efforts to reduce motor vehicle speeds to reduce the risk of traffic injury and support safer sharing of roadway space among modes.

We see continued growth of street space for walking and bicycling into May, as well as efforts in a handful of cities, states, and national governments to formalize and systematize pedestrian and bicycle interventions. This includes dedication of new funding streams for pedestrian and bicycle planning and facility construction, the first rollouts of emergency transport plans, and new facility guidelines focused specifically on supporting and sustaining the increased demand for active transport.

May also marks the beginning of the era of “streateries.” The number of actions to create street space for commerce—either full street closures or opening of curb space—grows nearly ten-fold, from five to 49, during May. Cities also began allowing local business establishments to expand on-site operations into sidewalks and other off-street areas during this time. This coincides with warm weather (in the northern hemisphere), relaxation of lockdowns, and pressure on governments to ‘re-open’ economies.

The growth of all actions appears to slow by July. At this point in the pandemic, we presume most cities that were going to act had already done so. Also, pandemic fatigue had begun to set in and pressure to ‘get back to normal’ overwhelmed calls by public health experts to continue social distancing. We also saw growing impatience by motorists to reclaim street space, and even started to see the reversal of some high-profile responses, such as the court-ordered removal of pop-up bike lanes in Berlin in early August (Krause et al., 2020).

Despite the continued rise in COVID-19 infections around the world and broad interest in ‘COVID-adapted infrastructure,’ we ended data collection in early August. Governments have continued to expand room and provide supports for walking, cycling, recreation, and now,

commerce in public spaces. However, the initial waves have passed, and as of late 2020, new actions are largely arising not through emergency responses, but as expansions and maturations of earlier interventions and, in some cases, in response to new, post-COVID mobility plans (Hawley et al., 2020).

5 Discussion & planning implications

5.1 Key takeaways

Cities around the world took quick action to respond to changing mobility demands. We have recorded responses to reallocate road space and support changing mobility demands in response to COVID-19 in 60 countries and on all continents except Antarctica. All of these responses took place in fewer than five months; most took substantially less time. As was seen during the oil and manufacturing shortages in World War II, the 1970s oil embargo, and several other historical moments, crises have generated fundamental changes in society and the economy including in the transportation sector (Pardo, 2020; Ricci, 2020). This has evidently been the case for active transport in response to the COVID-19 pandemic. And as the pandemic has progressed, some governments have taken steps to anticipate and plan for future disruptions (e.g., Waka Kotahi NZ Transport Agency; Hawley et al., 2020), suggesting that they are already looking for ways to adapt practices based on lessons learned from this event (Flyvbjerg, 2020).

There is an appetite for new methods and new solutions. Cities clearly found workarounds to traditional barriers to implementing infrastructure and supports for walking and bicycling, and demonstrated a newfound tolerance for experimentation and use of temporary materials. Emergency regulation likely helped in achieving this change in many places, which may have implications for whether the appetite for them remains after the pandemic subsides.

Public engagement was limited, and normal public processes were often sidelined. Few of the responses involved a robust participatory component, likely due in part to urgency of the moment, the temporary nature of the interventions, and the logistical challenges of in-person public engagement during a pandemic. Surprisingly, only 5% of responses appear to have been identified in existing plans or part of on-going planning efforts, meaning decisions about their design and implementation likely occurred outside normal public processes. While our data on public perceptions about these temporary measures is still limited (but improving), stories about backlash abound in the media, and it is worth considering whether and to what extent lack of public involvement has contributed to backlash. Where the public has pushed back against changes to the transportation network, governments have responded in some cases by rolling actions back, and in others by working with communities to better tailor the interventions to local interests. In a few cases, governments (e.g., Emergency Transport Plan, 2020) have rolled out plans for monitoring impacts of the interventions to inform future decisions about their ultimate fate, consistent with existing best practices for pilot projects (Stecker et al., 2020).

The timeline of rollouts and the increasing diversity of responses raise interesting questions about what prompted cities to act. As of the end of March, there were only a handful of

interventions publicized broadly enough to be captured in our database. However, the idea caught on quickly around the world after the pandemic declaration and the World Health Organization's April 29th recommendation to “whenever feasible, consider riding bicycles or walking” (World Health Organization, 2020a). New actions were being added throughout the middle of 2020, and these actions diversified over time; the data collection teams were continually adding new categories and reclassifying data to keep up with the increasingly creative and diverse strategies cities were using to respond to the pandemic. The loosening restrictions around May and thereafter may have also prompted some of the interventions.

It would be useful to know what prompted cities to act, and to what extent cities were learning from each other. Were their actions opportunistic (i.e., were COVID-19 and its direct impacts the catalyst for city leaders to fast-track actions they had been wanting to do anyway, even if not called for in an adopted plan), responsive (were cities recognizing a need for creative solutions to meet rapidly changing demands), or reactionary (were cities simply reacting to peer pressure, advocacy, or public input)? We include two variables in the dataset—*strategy* and *selection*—that are intended to capture these drivers of specific changes, but these questions are likely better addressed through in-depth case studies.

5.2 The future of transport planning and policy and agenda for further research

The transport sector's actions in 2020 point to several issues that dominated the year's policy actions, in addition to the COVID-19 pandemic. Some of these actions were driven by growing recognition of climate change as a crisis. Others, by the widespread awakening about systemic injustices in how transport networks are designed, funded, used, and enforced. All of these separate factors have potential to cause a dramatic and overdue shift in transport policy and planning (Flyvbjerg, 2020). However, this shift depends on timely efforts to document and deeply analyze the changes taking place in the transport realm during the year. To that end, we have teased out what we believe to be the most fruitful and informative lines of inquiry about responses to changing mobility demands, based on the data and information we know to be available about the global “COVID-19 streets” phenomenon, and shape them into an actionable agenda for further research. These lines of inquiry are presented below as five distinct research areas, developed along five major themes: building the COVID-19 response knowledge base, travel behavior, safer systems, equity and mobility justice, and informing practice change.

Research area 1: How did cities' COVID-19 responses arise?

Themes: building the COVID-19 response knowledge base, informing practice change

This research area is critical for supporting further policy evaluation of COVID-19 responses. It also informs efforts to emulate successful COVID-19 responses by identifying how institutional cultures, regulatory frameworks, public engagement processes, and other local factors may be associated with particular outcomes.

Suggested research questions:

- What enabled governments to act quickly? How did cities overcome conventional barriers to creating spaces for walking, cycling, and recreation?
- Are there institutional factors, characteristics of planning culture, and/or existing mobility demands that influence the likelihood and nature of cities' responses?
- Where did cities go for information and guidance on their COVID-19 responses?
- In what ways did cities engage the public in identifying potential actions to take, implementing those actions, and evaluating their impacts?

Research area 2: Have cities' COVID-19 responses led to changes in travel behaviors?

Themes: travel behavior, informing practice change

A critical measure of success for a mobility investment is usage. In the case of COVID-19 mobility projects, tracking use is necessary not just for understanding whether and when to roll back temporary measures, but also for predicting impacts of future projects. If the increased tolerance for experimentation we have witnessed during COVID-19 outlasts the pandemic, then it presents new opportunities for testing and evaluating potential utility of pedestrian and bicycle investments *in situ*. Tracking pedestrian and bicyclist behavior during and after the pandemic will help determine whether COVID-19 responses released latent demand for active transport, which will have implications for traffic impact assessment and travel demand modeling and may indicate useful changes to policies and funding structures for active travel facilities.

Suggested research questions:

- How have cities documented changes in travel behavior?
- Did cities that undertook substantial measures to support walking and cycling during the pandemic see an increase in use by active modes, relative to other cities and compared to pre-pandemic travel behavior? Similarly, did streets with temporary walking and bicycling facilities see an increase in use by active modes, relative to streets without such facilities and compared to pre-pandemic behaviors?
- Will changes in travel behavior be sustained over time, after the pandemic has subsided? In what contexts are changes sustained (e.g., are changes associated with planning processes, the type of responses employed, or the longevity of those responses?)

Research area 3: How were benefits from cities' COVID-19 responses distributed?

Themes: travel behavior, safer systems, equity and mobility justice, informing practice change

Racial and ethnic minorities and residents in lower income neighborhoods have historically had relatively poor access to safe walking and bicycling facilities and are disproportionately represented in pedestrian and bicycle crashes, injuries, and deaths (Barajas, 2018; Barajas et al., 2019; Braun et al., 2019). The cost of such facilities is often held up as a barrier to more

equitable distribution of benefits, as is the reality that minority and lower income communities are disproportionately located along major thoroughfares and arterials, where concerns over mitigating traffic congestion frequently take precedence over provision of walking and bicycling infrastructure. The precipitous drop in motor vehicle traffic seen during lockdowns and the increased acceptability of creating facilities with low-cost temporary materials should, in theory, have enabled a more equitable spatial distribution of pedestrian and bicycle facilities. Whether distributions of facilities were, in fact, equitable, and whether that distribution translated to equitable benefits in terms of how facilities were used and by whom remains to be seen.

Suggested research questions:

- How were measures distributed across cities, and were spatial distributions of new facilities correlated with race, income, or other sociodemographic characteristics?
- For what purposes were new facilities used, and by whom?
- Did new facilities and programs attract new users—individuals who did not walk or cycle for transport before the pandemic—or increase use among those who already walked and cycled?

Research area 4: Are pedestrian and bicycle facilities implemented quickly with temporary materials as safe or safer than conventionally deployed facilities?

Themes: safer systems, informing practice change

COVID-19 mobility responses dramatically shortened timelines for implementation of pedestrian and bicycle facilities. In many cities, these new facilities may also represent substantial departures from ‘tried and true’ designs planners and engineers have conventionally relied upon. Do these new approaches a similar degree of safety (or better yet, more safety) for users than conventional measures? If so, then how should practice evolve to take advantage of the safety benefits of faster, broadscale implementation of lower cost facilities even beyond the pandemic?

Suggested research questions:

- How many crashes or near-misses have taken place on streets with rapid rollout pedestrian and bicycle facilities during the pandemic, compared to similar streets without such facilities?
- How closely have rapid-rollout facilities conformed to best practices for safe pedestrian and bicycle facility design?
- Assuming rapid-rollout facilities were implemented on roadways that would eventually include conventional walking and bicycling infrastructure, how many crashes, injuries, or deaths could be avoided by more rapid implementation?

Research area 5: How has COVID-19 shaped public engagement, and how has public engagement shaped cities' responses to COVID-19?

Themes: equity and mobility justice, informing practice change

Transport planning has had a poor track record with respect to public engagement in many western countries. The compressed time frame and greatly expanded scale of and spotlight on changes to street space during the pandemic has increased awareness of this history and its consequences. Emergency legislation has enabled many communities to forego public processes that might otherwise shape both implementations and outcomes. However, some cities (e.g., Oakland, California) have been praised for developing novel approaches to reaching out to, learning from, and working with community members to identify and trial COVID-19 responses most likely to benefit those communities (Logan, 2020). The ways in which the public has been both engaged and ignored during the COVID-19 pandemic likely holds clues to the longevity of pandemic mobility responses. Careful evaluation of cities' planning processes may uncover new best practices that can shorten timeframes for implementation of pedestrian and bicycle facilities without simply replicating top-down transport planning processes that have historically dismissed the public at best, and built and maintained structures of oppression at worst.

Suggested research questions:

- How are regulatory, public engagement, and implementation processes related to public acceptance, longevity, and ultimate resolution of COVID-19 mobility responses?
- What novel approaches did cities employ to connect with and engage with the public during the pandemic?
- Do street-level planning and/or use of experimental designs and temporary materials improve public engagement and allow for more responsive planning processes?

5.3 Limitations

There are many limitations inherent in a database built to record a deeply complex phenomenon via crowdsourcing during a pandemic. We present the Shifting Streets COVID-19 Mobility database with caveats about how we believe it should be used in light of these limitations, and suggest ways in which the impacts of these limitations can be minimized. The data collection efforts for the three datasets upon which the Shifting Streets database was built were not intended to be comprehensive or even to be a representative global sample. The sample is likely to be skewed toward the US and Europe and toward actions that support walking, bicycling, and transit use due to the interests, language skills, and professional networks of the individuals collecting the data. As such, we do not recommend using the data to support statistical inference; rather, we suggest using the data to support qualitative analyses, case studies, deeper dives into processes and outcomes.

There are several steps that can be taken to improve the database and its usefulness. In addition to recording more actions and validating existing data on the ground, tracking the “lifetime” of

all actions, including how long they were in place and whether (and why) they were transformed from temporary to permanent or removed would be a useful addition that could also speak to an additional lesson related to the potentially ephemeral nature of many of these actions. Variables exist to capture such information, but as yet have been lightly populated. Information on public engagement and decision-making processes would also help, although such nuanced contextual information is often subject to challenge (and bias) and difficult to encapsulate in a large database.

Finally, the Shifting Streets COVID-19 Mobility Database is a living document, meaning that numbers presented here may change as records are added and validated by local experts. The data in the database were largely crowdsourced, and while we made every effort to track down original news articles and press releases about each response and ensure the recorded data are consistent with those sources, we cannot guarantee the accuracy of our information for all responses. We are attempting to contact local experts in each jurisdiction to review and validate the data and welcome inquiries and input from anyone with professional or personal experience with any of the responses recorded in the database. We also encourage contributions of new information to the database from other researchers and professionals with expertise on local, regional, or national responses to changing mobility demand during the COVID-19 pandemic. Instructions for contacting the database team and sharing information are available on the Shifting Streets website.

6 Conclusions

Between March 9 and August 9, 2020, over 500 cities, states, and countries adjusted the allocation of street space and other transport resources in response to changing mobility demands brought on by the COVID-19 pandemic. The main goals of this paper are to provide an initial descriptive assessment of this broad array of actions, and to inspire and support efforts to understand and evaluate the impacts and implications of these actions, with a focus on responses intended to increase opportunities for walking and cycling. We achieved these goals in two ways. First, we introduced and described the data contained in the Shifting Streets COVID-10 Mobility Database, a collaborative global effort to identify and document changes to the allocation of street space and mobility resources in direct response to the pandemic. We also explained how others in the field can contribute to ongoing collection and validation of the data.

Second, we built on preliminary observations from the Shifting Streets data to advance a research agenda to improve understanding on the factors shaping these responses, their implications for sustainable, equitable mobility, and the ways in which the transportation planning, policy, and engineering fields might evolve in response to lessons learned during the pandemic. It is our sincere hope that the data and insights provided in this paper inform and inspire research to identify promising best practices for inclusive transport planning and engineering processes that create more sustainable, just, and resilient mobility systems. We acknowledge that this paper is just a first step towards understanding this overall phenomenon.

More work is needed to understand the evolving nature of this phenomenon and its implications for policy and planning.

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