Building back better: The COVID-19 pandemic and transport policy implications for a developing megacity

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Abstract:

The COVID-19 pandemic has affected human mobility via lockdowns, social distancing rules, home quarantines, and the full or partial suspension of transportation. Evidence-based policy recommendations are urgently needed to ensure that transport systems have resilience to future pandemic outbreaks, particularly within Global South megacities where demand for public transport is high and reduced access can exacerbate socio-economic inequalities. This study focuses on Metro Manila – a characteristic megacity that experienced one of the most stringent lockdowns worldwide. It analyzes aggregated cell phone and GPS data from Google and Apple that provide a comprehensive representation of mobility behavior before and during the lockdown. While significant decreases are observed for all transport modes, public transport experienced the largest drop (-74.5%, on average). The study demonstrates that: (i) those most reliant on public transport were disproportionately affected by lockdowns; (ii) public transport was unable to fulfil its role as public service; and, (iii) this drove a paradigm shift towards active mobility. Moving forwards, in the short-term policymakers must promote active mobility and prioritize public transport to reduce unequal access to transport. Longer-term, policymakers must leverage the increased active transport to encourage modal shift via infrastructure investment, and better utilize big data to support decision-making.

Keywords: *COVID-19 response; Mobility Behavior; Resilient Transport Systems; Social Equity; Big Data Analysis; Longitudinal Case Study.*

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1. Introduction

The outbreak of the COVID-19 disease caused by a novel coronavirus (SARS-CoV-2) has changed and will continue to change our world radically. First registered in December 2019 in Wuhan, China, the coronavirus has quickly spread across countries and territories. On March 11, 2020, the World Health Organization (WHO) declared the COVID-19 outbreak a pandemic (WHO, 2020a). By the end of September 2020, at least 34.2 million cases were registered worldwide, while the total number of related deaths had exceeded one million (WHO, 2020b). Undoubtedly, the current pandemic has a significant impact on everyday life. This relates to social norms, consumer behavior, habits and customs, or simply put, the COVID-19 outbreak has changed the way we live, behave and interact (Prosser et al., 2020; Sheth, 2020). Like any pandemic before, however, the COVID-19 pandemic will also end. Nevertheless, the long-term economic consequences are expected to be perceptible for several years in the form of a global recession (Lenzen et al., 2020), and we will likely have to adapt to a "new normal" in different contexts and many parts of life.

Certainly, a "new normal" is to be expected for the transport sector.

On the one hand, it is widely known that transport is a potent force in disease emergence and spread as human-incubated pathogens or disease vectors can be moved large distances in short time (Tatem et al., 2006). Several studies highlight the role of air transport in the propagation of infectious diseases even to distant locations (e.g., Findlater and Bogoch, 2018). Studies have further identified an increased risk of disease infections (e.g., tuberculosis) in public transport vehicles (e.g., Andrews et al., 2016; Feske et al., 2016). Due to this relationship, researchers frequently try to model the spreading of infectious diseases through transport data, as also in the current case of COVID-19 (e.g., Du et al., 2020; Iacus et al., 2020; Kraemer et al., 2020; Wu et al., 2020). These studies suggest that transport indeed contributes to the geographical spread of the coronavirus. However, recent studies, including a comprehensive study in Germany, found no evidence of an increased risk of SARS-CoV-2 infection while traveling on public transport[1].

On the other hand, pandemics also have an impact on transport and human mobility, considering the immediate effects of lockdowns, social distancing rules, home quarantines, and the full or partial suspension of transport services. Unsurprisingly, public transport – where it remained in operation – experienced a significant drop in ridership (Shakibaei et al., 2021; Tirachini and Cats, 2020). Individual motorized traffic has increased in many cases to avoid social contacts while traveling. Nevertheless, it is only available to those with access to vehicles and linked to other negative externalities such as noise and air pollution. Active mobility is also experiencing a renaissance, especially as an alternative to mass transit (Nurse and Dunning, 2020). However, many

[1] During the first phase of the on-going Robert Koch Institute study, a representative sample (N=1073) of Deutsche Bahn train personnel was tested for active (PCR test) and past infection (antibody test) with SARS-CoV-2. It found that train attendants with frequent passenger contact did not had a higher infection rate than the comparison groups (train drivers and craftsmen) without customer contact. Further information on this study can be found at https://www.drks.de/drks_web/navigate.do?navigationId=trial.HTML&TRIAL_ID=DRKS00022359

cities – mainly in the Global South – do not provide adequate infrastructure to enable safe and efficient walking and cycling (e.g., Bakker et al., 2018).

Even in the midst of a health crisis – or precisely because of it – essential and frontier workers, as well as many others, depend on access to mobility. Due to the mentioned constraints, the transport sector is therefore in an unprecedented situation, causing a paradigm shift in which it needs to change its role and function in society (Kim, 2020). Most likely, many of these changes are not just temporary. Indeed, scholars expect that the current pandemic will also have a long-term impact on transport infrastructure and operations, travel behavior, mode choice, and so forth (e.g., De Vos, 2020; Tirachini and Cats, 2020).

The authors of this study are particularly interested in how these changes may transform transport systems in urban areas, where people (55% of world's population) and economic activities (more than 80% of global GDP) are concentrated (World Bank, 2020a), and that are highly vulnerable to pandemics (UN, 2020). More specifically, we are interested in megacities[2] in the Global South that in the current COVID-19 crisis, in particular, were confronted with acute stresses due to larger populations and densities that accelerate disease transmissions, especially in low-income communities (Dahab et al., 2020; Das et al., 2021; Ren et al., 2020).

The objective of the study is to outline transport policy implications for developing megacities, as a resilience and mitigation strategy to forthcoming pandemic outbreaks and other disruptions, and to shape more sustainable transport systems. We argue that every crisis offers an unprecedented opportunity for structural change for the better. Given the crucial role of transport in modern societies, for economic growth, and for people's health and well-being, the urgency of effective transport policies is highlighted. Our case study focuses on Metro Manila, a developing megacity in Southeast Asia that experienced one of the longest and most stringent lockdowns worldwide (Hale et al., 2020). The study uses aggregated open-source location and trip data from two sources. Similar to existing studies (e.g., Arellana et al., 2020; Tamagusko and Ferreira, 2020; Yilmazkuday, 2021), statistical analyzes are used to compare and quantify how the population's mobility behavior has changed since and during the crisis. Based on insights from the analysis and from the available literature, we then develop evidence-based policy recommendations for developing megacities.

Our study responds to calls for more research on COVID-19 impacts in developing countries (Mogaji, 2020) and their megacities (Shakibaei et al., 2021). While many studies outline generalized findings (e.g., De Vos, 2020; Tirachini and Cats, 2020), developing megacities indeed merit a separate investigation due to their distinctive features (Canitez, 2019). Addressing this research gap, our study uses big data covering more than six months, which therefore represents one of the first longitudinal case studies on COVID-19 impacts. We also present the first transport study related to COVID-19 in Philippine context (Kutela et al., 2021). In addition, the study contributes to the very timely research fields of transport and health (Musselwhite et al., 2020) and post-pandemic urbanism (Megahed and Ghoneim, 2020).

[2] We follow the definition by the UN DESA (2019), according to which megacities are the largest category of urban agglomerations with 10 million inhabitants or more.

The remainder of the article is structured as follows. The following section presents further information on our case study. Section 3 details our data sources and methods. Results are presented in Section 4. We then discuss policy implications (Section 5) as well as research limitations and future research lines (Section 6). Finally, concluding remarks are presented in Section 7.

2. Case Study Presentation: Metro Manila, Philippines

The Philippines is an archipelagic country located in Southeast Asia that consists of more than 7,600 islands. It is classified as a lower-middle-income country and has a population of almost 110 million (World Bank, 2020b). Its national capital region of Metro Manila (MM) - located on the island of Luzon in the Northern part of the country (Fig. 1) – represents the country's center of culture, economy, education, and the seat of government. MM comprises 16 cities and one municipality and occupies an area of about 620 km². With about 12 million inhabitants (density of 20 thousand persons per km²), it is one of the most populous urban areas in the world.

MM presents many distinctive transport characteristics that developing megacities have in common (e.g., premature traffic congestion, high motorization rates, and deteriorating environmental conditions) (Gwilliam, 2003) and which are often in contrast to large metropolises in the Global North. Due to the lack of mass transit solutions (the rail transit network with three different lines only covers 75.2 km), the public transport systems in MM are predominated by road-based services that include buses, jeepneys (local 12 to 16-seater paratransit vehicles), FX (a point-to-point microbus service), and tricycles (a local auto rickshaw version). According to past transport planning studies (JICA, 2015), public modes constitute for about 49% of trips in MM, private modes for about 20% (11.5% of households are car owner), and walking for about 30%.

For more information, the reader is referred to most recent MM case studies in the transport literature that describe vehicle ownership (Rith et al., 2020), service quality of paratransit services (Tiglao et al., 2020), and on-going public transport reforms (Mateo-Babiano et al., 2020; Sunio et al., 2019; Sunio et al., 2020), among others.

2.1. The COVID-19 outbreak: Key events and government responses

Due to the geographical proximity and the close bilateral connection to China, where the outbreak originated, the Philippines was one of the first countries to report SARS-CoV-2 infections. The Department of Health - Republic of the Philippines (DOHRP) confirmed the first positive case on January 30. It concerned a Chinese citizen from the Hubei province who entered the Philippines on January 21 from Hong Kong. The second confirmed case was the first case's companion. That person's death on February 1 was the first recorded outside China (Bautista and Luz Lopez, 2020). The first local transmission of SARS-CoV-2 in the Philippines, concerning a person from one of MM's adjoining provinces without travel record abroad, was confirmed on March 7. In the following, the total number of cases in the country increased sharply. MM hereby developed into the main COVID-19 hotspot in the Philippines (Fig. 1).

In response to the evolution of the disease, several governmental measures were imposed at national and regional levels. The first measures encompassed international travel restrictions. On January 23, all flights from Wuhan (to Kalibo, Aklan) and on

January 31, all other flights from the Hubei Province to the Philippines were suspended. By February 10, all travelers from entire mainland China, Hong Kong, Macau, and Taiwan were banned. Tourist travels to South Korea, where high numbers of cases were being recorded, were prohibited on February 26. In the following, also other countries with local transmissions were banned until all visa issuances were finally suspended on March 19.

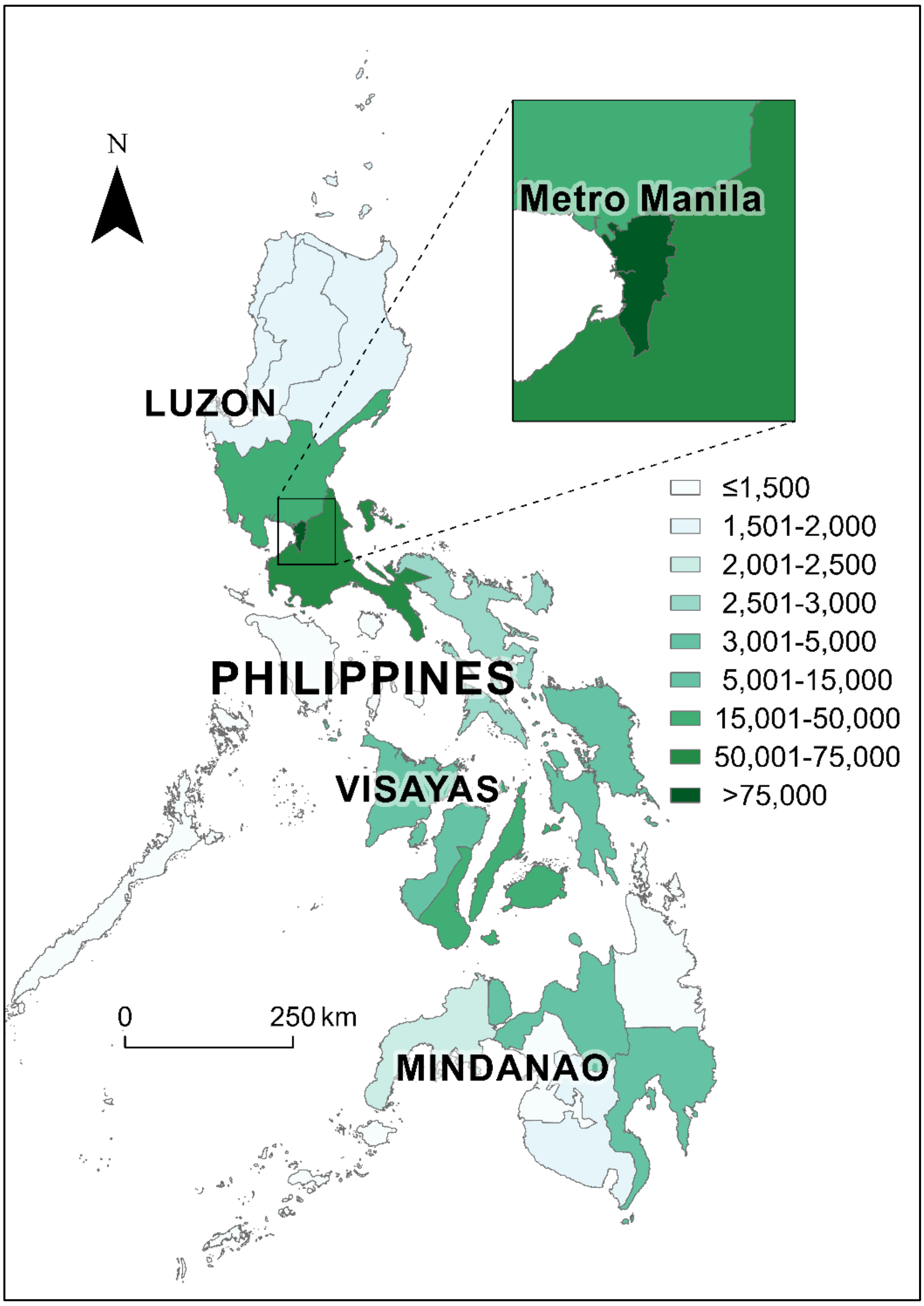

Fig. 1. Total number of COVID-19 cases per region in the Philippines (as of September 30, 2020)
Data from DOHRP, 2020; PhilGIS.org

After the first local SARS-CoV-2 transmissions were recorded in MM, the government declared a public health emergency on March 8. MM was initially placed under a strict lockdown and state of calamity on March 15, which prohibited land travel, local air travel, and local sea travel from and to the city. Two days later, on March 17, an *enhanced community quarantine* (ECQ) was extended to the entire Luzon island. In response to changing health situations in the following weeks and months, the quarantine status has been adjusted several times, i.e., into *modified enhanced community quarantine* (MECQ) and *general community quarantine* (GCQ). Table 1 summarizes the different phases of the lockdown and its associated measures. For additional insights regarding the (early) lockdown protocols in MM, the reader is referred to Ocampo and Yamagishi (2020).

Table 1. Timeline of Government response in Metro Manila: Containment and closure policies

Quarantine state	Description
ECQ (17.03.-15.05)	- strict instructions for staying at home (except for health and essential workers), restriction of people's movement, no gatherings allowed - complete suspension of public transport services (minimal level of operations only maintained for health and essential workers) - closure/reduced capacities of non-essential businesses - establishment of alternative working arrangements (e.g., teleworking) - suspension of classes at all schools, colleges, and universities - ban of public events and gatherings (except for essential government services and humanitarian activities)
MECQ (16.05.-31.05.)	- gatherings of max. 5 persons - limited reopening of selected businesses - small gatherings and selected leisure activities allowed under strict conditions (e.g., wearing face masks, practicing good hygiene)
GCQ (01.06.-03.08.)	- approval of selected mass gatherings (e.g., work assemblies) - opening of more non-essential sectors and businesses - provision of limited transport services (4,600 out of the 12,000 bus units) with reduced capacities (e.g., no seating next to each other) - permission of selected holiday and additional leisure activities - face-to-face classes remained suspended
MECQ (04.08.-18.08.)	- return to stricter measures to prevent collapse of the health system amid highest surge in COVID-19 cases since start of the pandemic
GCQ (since 19.08)	- return to more relaxed measures; effective through the information cut-off for this article at the end of September

Data from Bautista and Luz Lopez, 2020; Hale et al., 2020; WHO, 2020c

2.2. Development of Number of Cases and Global Comparison

As of September 30, 311,694 COVID-19 cases and 5,471 related deaths nationwide were officially confirmed, of which 163,780 and 2,656 respectively are related to MM (DOHRP, 2020). Thus, the capital region accounts for about half of all cases and related deaths nationwide, with the population making up only about 11% of the country.

Together with Indonesia, the Philippines emerged as the most affected country in Southeast Asia (Table 2). In a global comparison, only 20 countries have reported more cases (WHO, 2020b). However, due to underreporting, limited testing capabilities, and insufficient healthcare access, a significant number of unrecorded cases is expected (Lau et al., 2020). This assumption is supported when comparing the Philippine's positivity rate (the number of positive tested individuals as a percentage of the total tested individuals) with that of other countries. According to the official data by the DOHRP, the cumulative positivity rate for the Philippines is 10.5%. South Korea and Australia, both known for its extensive nationwide testing, only have a positivity rate of 1.0% (MOHW, 2020) and 0.4% (AGDOH, 2020), respectively.

Table 2. COVID-19 cases in some Southeast Asian countries (as of September 30, 2020)

Country	Population ('000)[a]	Total Cases[b] / (per 1M pop.)	Total Deaths[b] / (per 1M pop.)
Indonesia	273,524	287,008 (1,049)	10,740 (39)
Malaysia	32,366	11,224 (347)	136 (4)
Philippines	109,581	311,694 (2,844)	5,471 (50)
Singapore	5,850	57,765 (9,874)	27 (5)
Thailand	69,800	3,564 (51)	59 (1)
Viet Nam	97,339	1,094 (11)	35 (0)

[a] Source: United Nations World Population Prospects 2019
[b] Source: DOHRP, 2020; WHO, 2020b

The evolution of reported cases per day in Manila and the Philippines – a key metric for assessing the extent of the pandemic – is shown in Fig. 2. It shows that from the beginning of the pandemic to around August, the number of daily cases has risen steadily for both MM and the Philippines. From the first infection in the country on January 30, it took 131 days until a total of 50,000 cases were reported. It took another 26 days for that number to double to 100,000, and 13 more days until the number of cases reached 150,000. Eventually, the mark of 200,000 cases was surpassed after additional 12 days on August 26.

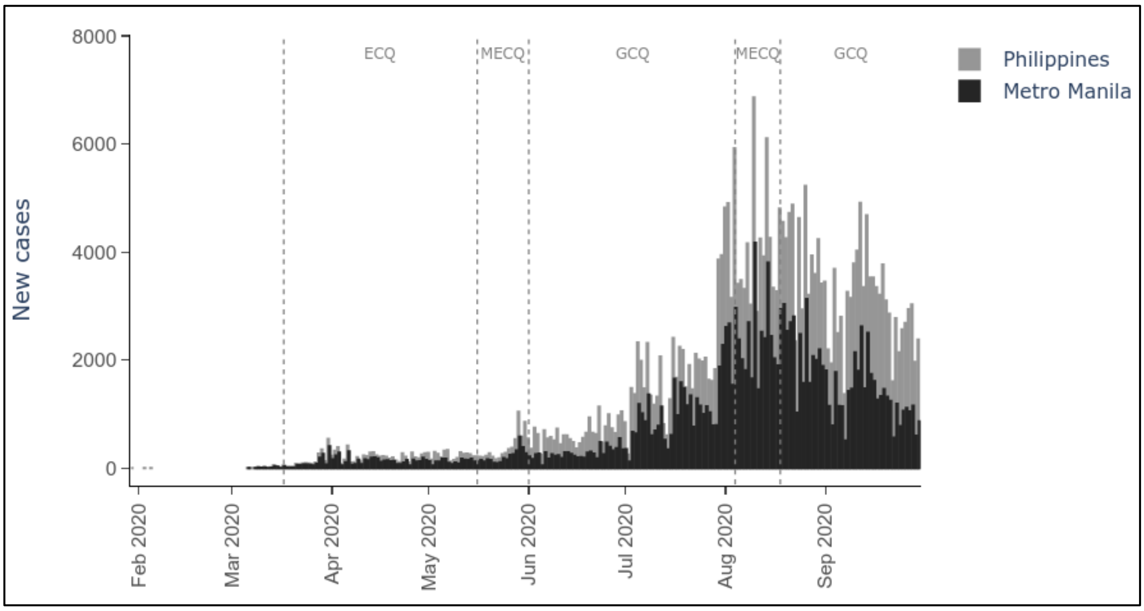

Fig. 2. Daily new cases of COVID-19 in Metro Manila and the Philippines (as of September 30, 2020)
Data from DOHRP, 2020

This rapid development during the first months could be explained by the exponential growth dynamics of the virus as well as the increase in testing capacity over time (DOHRP, 2020). However, it also suggests that the measures imposed by the government, as described in the previous sub-section, have not been effective in terms of the goal of "flattening the curve" as successfully achieved in other countries such as Thailand and Viet Nam. A very drastic increase in cases was observed in late July and the beginning of August, which appears to correspond to the (first) peak of infections. While most countries worldwide started easing COVID-19 measures during this time, the Philippines was thus forced to temporarily return to a more stringent lockdown. However, that trend has flattened since September and a decline in the number of daily reported cases was recorded.

3. Data and Methods

In this study, we use aggregated open-source cell phone and GPS data from two sources that provide a comprehensive representation of the mobility behavior of the MM population before and during the lockdown.

Specifically, we used the following data sources. First, the *Google COVID-19 Community Mobility Reports* which provide anonymized and aggregated daily data on population location patterns during the COVID-19 crisis (Google, 2020). The location patterns describe visits to different sites and locations, which are divided into six categories (Table 3). The data values vary between -100 and 100, with 0 being the baseline for the pre-COVID-19 level. The baseline corresponds to a sample period prior to the pandemic (January 3 - February 6, 2020). Positive variations relate to increases to the baseline, whereas negative values indicate a reduction. Data aggregation and the generation of reports are described in Aktay et al. (2020), while more information is also available from the data provider (Google, 2020).

Table 3. Google COVID-19 Community Mobility Reports - Report categories

Category	Subcategories
Retail and recreation	Restaurants, cafes, shopping centers, theme parks, museums, libraries, and movie theaters
Grocery and pharmacy	Grocery markets, food warehouses, farmers markets, specialty food shops, drug stores, and pharmacies
Parks	National parks, public beaches, marinas, dog parks, plazas, and public gardens
Transit stations	Public transport hubs such as subway, bus, and train stations
Workplace	Places of work
Residential	Places of residence

Second, the *Apple Mobility Trend Reports* was used. The reports record changes in route requests since January 13, 2020 and thus describe citizens' (intended) trip patterns (Apple, 2020). It uses anonymous data (received in random identifiers) based on the Apple Maps service and is grouped into three mode categories (driving, transit, and walking). The values provided by Apple are based on a macro similar to that used by Google. However, the Apple data uses a baseline of 100, with negative variations below 100, and positive variations above. In order to facilitate the analysis and comparison, we normalized the Apple data to a baseline of 0 (same as Google's). In addition, we need to mention that the data values for May 11 and 12 are not available. However, we expect the missing data only to have a marginal impact on the analysis and results. Finally, in contrast to Google's location data, requests for route instructions in Apple data are computed. In this study, both datasets are therefore treated individually, as there is no equivalence between the user's actual position (Google) and the indication of an intention to travel (Apple).

With regards to the COVID-19 cases, we rely on the official data drop by the DOHRP (DOHRP, 2020). Note that we refer to the variable *DateRepConf* (date of reporting of confirmed cases) which comprises definite and immutable values. In contrast, the values for *DateOnset* (date of onset of illness) – which is also often used in official communication – are not always available for every case and may change retrospectively.

Based on the available data, statistical analyses were used to estimate changes in mobility behavior and outline trends in location and trip patterns. A changepoint for mobility values based on Google data was obtained using the Changepoint framework (Killick and Eckley, 2014). Following the "at most one change" (AMOC) method (Hinkley, 1970), it determines at 95% confidence level on which day (threshold) the mobility values changed trends. Simply put, this statistic shows when exactly the population adapted their mobility behavior, for example, in response to a specific event or measure.

Data processing and statistical analysis were mostly performed in Python, while for the changepoint analysis R software was used. The processed data and the code for the changepoint analysis are available at https://github.com/tamagusko/manilaCovid19.

In the last step, we place the evidence from MM against a backdrop of findings from similar studies to derive and discuss policy implications for developing megacities.

4. Results

Based on the Google data, Fig. 3 shows the location patterns of the MM population by reporting category for the period between February 15 and September 30. The first notable variation was observed on February 25. This can be explained by a public (non-working) holiday that happened on that day. Thus, this variation is likely not associated with any COVID-19 related event or measure. Thereafter, a noticeable change in mobility behavior can be observed from the time the local SARS-CoV-2 transmissions started (March 7 onwards). The implementation of the ECQ on March 17, eventually, corresponds to a further drastic change in mobility activities. Also, a significant deviation relates to the mobility levels during the different phases of the lockdown. As could be expected, the state that corresponds to the least restrictions (GCQ) exhibits the closest pattern to the pre-COVID-19 baseline.

Fig. 3. Google location patterns in Metro Manila (as of September 30, 2020)

While five out of the six categories show a drastic decline that is only recovering very slowly, the *residential* category has been consistently above the baseline level since the initial lockdown. This phenomenon can easily be associated with the COVID-19 policies and the requirement/recommendation for citizens to stay at home. The category *grocery and pharmacy* shows local peaks (+10 on March 10, +/-0 on August 3) shortly before the ECQ/MECQ became effective on March 17 and August 4, respectively. This is likely to be explained by so-called "panic buying". All remaining categories fell below baseline on March 10 or earlier and remained significantly below that level through the end of the analysis period (on September 30, -42.4 on average), whereby *transit stations* clearly lags below the average (-63). The most severe decline was observed for the *transit stations* category, reaching a level of -95 on April 10, followed by *parks* (-93, May 1), *retail and recreation* (-92, April 10), *workplaces* (-87, April 10), and *grocery and pharmacy* (-80, April 10). *Residential* constantly remained on a level of +16 and above. The decline in the *workplaces* category is particularly striking, considering that on the non-working holiday in February that value only dropped to -46. It is noticeable that *parks* as well as *retail and recreation* saw a sharp rise after the return to the GCQ on August 19, suggesting that citizens started to engage more in leisure activities.

Fig. 4 compares the location patterns during the more stringent (M)ECQ and the more relaxed GCQ. It highlights that *transit stations* experienced the largest drop during both phases, on average, -87 during (M)ECQ and -66 during GCQ. This corresponds to an increase of +21 after the relaxation of the lockdown measures. Compared to the other categories, this represents the slightest recovery – which, however, could result due to the bias (section 6) that lower-income segments are underrepresented[3]. During GCQ, *workplaces* increased by +24, *retail and recreation* by +28, *grocery and pharmacy* by +29, and *parks* by +30. As can be expected, the value for *residential* decreased during GCQ (-9).

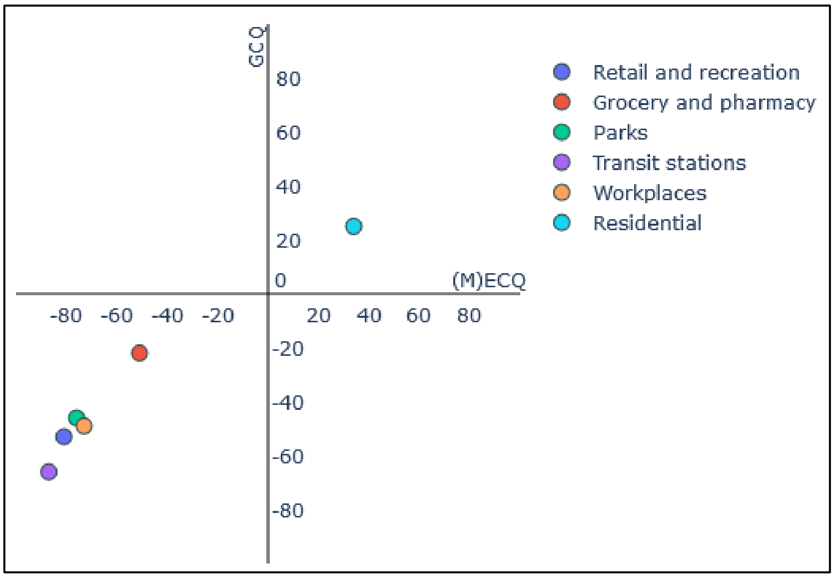

Fig. 4. (M)ECQ vs. GCQ location patterns in Metro Manila
Time period: 2020/02/15 - 2020/09/30

[3] Existing research highlights that lower-income segments are less likely to have the opportunity to work from home (Hatayama et al., 2020), which means that the recovery of public transport trips was likely higher as these segments have returned to work during GCQ.

Regarding the changepoint analysis (Fig. 5), it was possible to find the most significant threshold for each location category at which the population statistically changed their mobility behavior. The change in mobility behavior for the respective categories occurred on March 14-16 and thus shortly before the first ECQ came into force (on March 17). Given the immediate impact on the citizens' mobility behavior, this underlines the stringency of the COVID-19 containment policies, including their compliance by the population.

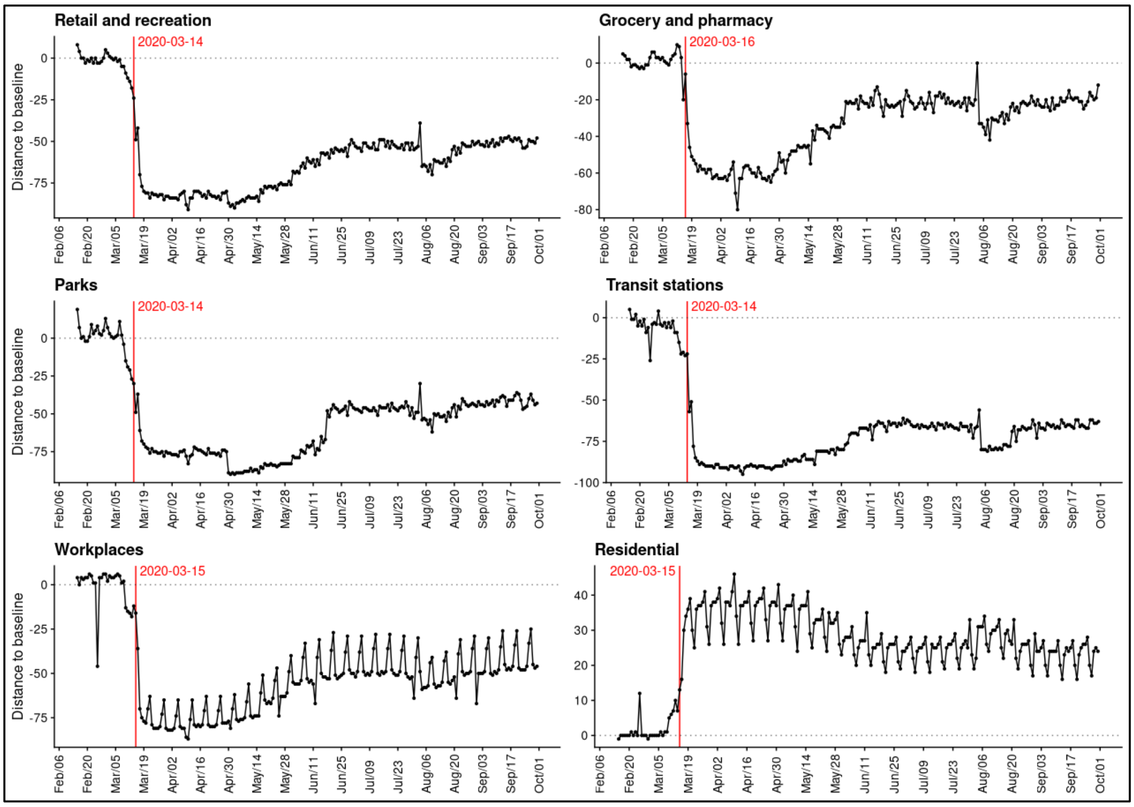

Fig. 5. Changepoint in location patterns for Metro Manila
Time period: 2020/02/15 - 2020/09/30

Based on the Apple data, Fig. 6 shows patterns of trip directions requests of the MM population by transport mode (*driving*, *transit*, *walking*) between January 13 and September 30. After the first local COVID-19 cases were reported, a decline in travel requests in all three categories can be observed more or less simultaneously and at a similar pace. While for *driving* the lowest level was reached on April 4 at -82.2, the *walking* category went down to -83.2 (April 4), and *transit* even to -85.1 (March 31). In the further course, however, it becomes apparent that the various categories recovered differently. The fastest recovery can be observed for *driving*, which reached about 50% of the baseline level by the end of September (-49.6 on September 30). *Walking* initially recovered similarly. However, with the first introduction of the GCQ, it fell behind *driving* and then reached a similar level again by the end of the analysis period (-51.8 on September 30). We expect that the first increase in *driving* and *walking* mainly relates to essential trips (e.g., work, grocery, etc.) that were allowed during MECQ. Non-essential (leisure) trips during GCQ, instead, possibly rather relate to trips by car. Finally, *transit* lags well behind the other categories (-61.8 on September 30), mainly due to the lack of or reduced supply of services.

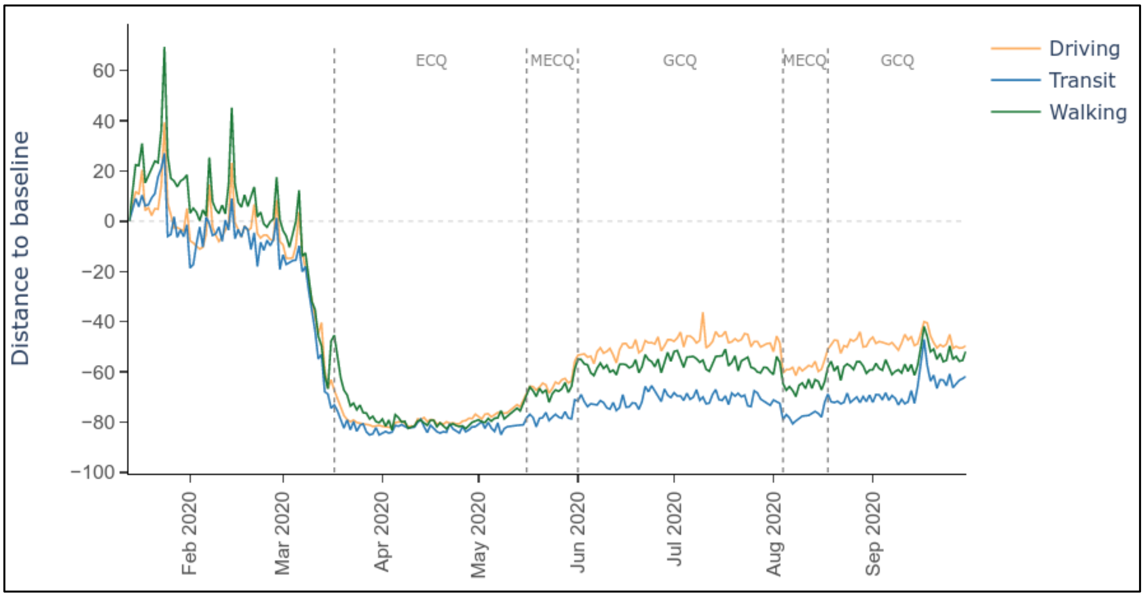

Fig. 6. Apple trip patterns by transport mode in Manila (as of September 30, 2020)

In summary, the most important results of the above analysis of mobility data relate to the following.

(i) Mobility reduced during the lockdown period, with people spending more time at home, and significant reductions were observed with regards to all location report categories (most of all at transit stations).

(ii) The impact of the lockdown on mobility happened almost immediately – there was no gradual reduction, but there is a gradual increase through to the second MECQ period, when the containment measures were tightened again. After another drop, mobility activities then quickly returned to the previous level.

(iii) Driving and walking trips have seen less reductions and are recovering more quickly than transit trips.

5. Transport Policy Implications

The results of this study are reflected by far-reaching implications for the transport systems and citizens in MM. (1) Those who rely most on public transport and without access to private cars are disproportionately affected by the lockdown, which has intensified the unequal access to transport systems. (2) It became evident that during the pandemic, public transport was not able to fulfil its service function to the public and that (3) a paradigm shift is observed, as people increasingly relied on active mobility.

A comparison with other studies helps to put our results in context and gives additional insights.

For example, while car journeys in MM recovered relatively quickly, case study results from Istanbul, another developing megacity, point to the risk of an unsustainable development, in which private cars become the dominant mode of transport (Shakibaei et al., 2021). A large part of additional car journeys could thereby result from users that previously relied on more sustainable travel options such as mass transit, active mobility, and shared mobility solutions. Accordingly, Pawar et al. (2020) found that during the COVID-19 pandemic, 5.3% of commuters in India shifted from public to private modes. To regain trust in public and shared modes, therefore, social attitudes and human factors need to be addressed more explicitly (Shokouhyar et al., 2021), while street space should be allocated to cyclists and pedestrians (Arellana et al., 2020).

Taken together, these findings provide valuable insights on how to respond to such altered situation. The following sub-sections therefore discuss policy implications – mainly related to transport planning, but also with relevance to urban planning and managing cities in general (Junior et al., 2021).

5.1. Promote active mobility and prioritize public transport (short-term)

The shutdown of public transport during the ECQ and the subsequent limitation of capacities particularly hit households without a car – which corresponds to 88.5% of all households (JICA, 2015). As a result, many non-essential trips were avoided or could not be undertaken at all. There was often no other choice for essential trips than to walk or cycle, even for large distances. Various news articles reported of individuals, in many cases health workers, who had to travel countless kilometers and hours to get to work (e.g., Mercado, 2020). Also, news articles have increasingly been reporting on cyclists involved in fatal accidents with motorized vehicles (e.g., Tiangco, 2020), which exposes one of the main obstacles to choosing a bicycle as a means of transport. In 2019 alone, the Metropolitan Manila Development Authority (MMDA) recorded 1,759 bicycle related road accidents, including 19 fatalities (MMDA, 2019). Even though there are various other reasons (cultural, climatic, topographic, etc.) why there is historically a negligible share of cycling trips in the modal split of cities in the Philippines, the lack of safe and protected cycling infrastructure is striking. Therefore, rapid action is required to meet and enable the new demand for active mobility and to relieve public transport. Similar as observed in many cities around the globe, also in MM, temporary pop-up bike lanes emerged throughout the metropolis (Fig. 7). These bike lanes are effective in quickly dedicating road space and safety to cyclists. In this sense, pop-up bike lanes require a clear demarcation (ideally physical segregations such as construction site beacons, traffic cones, bollards) to motorized traffic as well as clear labeling and the monitoring of compliance. In addition, sufficient bike racks and other cycling-friendly facilities should be installed at common origin and destination locations (malls, workplaces, restaurants, transit hubs, etc.).

a) b)

Fig. 7 (a + b). Pop-up bike lanes in Metro Manila along Ayala Avenue (left) and East Avenue (right)
Source: Hans Cecilio Bosshard (August 2020); Niño Jesus Orbeta (August 2020)

With regards to public transport, reduced capacities and other restrictions made short-term operational adjustments inevitable. The containment policies in MM required operators to enhance hygiene concepts and modify transport vehicles and stations to comply with physical distancing guidelines. While this is important in order to rebuild confidence in public transport, at the same time, it forfeits operational efficiency and places a severe financial strain on operators. As a countermeasure to such restrictions, policy makers have several options for prioritizing and making public transport services more attractive and viable. A widespread solution in times of the COVID-19 crisis, was to set up pop-up bus lanes and corridors. In MM, an interim bus rapid transit (BRT) system begun operations on July 1 along Epifanio de los Santos Avenue (EDSA), the metropolis' main north-south artery and most frequented road. The so-called EDSA Busway, which is segregated by concrete barriers and steel separators, runs along median lanes, and serves on fixed bus stops that are currently located on the curbside (Fig. 8). This service was established without fare increase and is expected to be a significant improvement over the prior bus model, as travel time along the EDSA stretch is expected to decrease from 2-3 hours to 45 minutes, including bus stops (Dela Cruz, 2020).

Financial viability of the public transport sector not only needs to be ensured to restore the livelihoods of transport workers, but also in the context of environmental targets. The COVID-19 pandemic has significantly hampered the transition to cleaner public transport vehicles in the Philippines, which was initiated by the government in 2017 through the Public Utility Vehicle Modernization Program (PUVMP) (Sunio et al., 2019). Own-account drivers of informal means of transport, who have purchased electric vehicles under loans and ran into financial difficulties due to reduced operations and the continued enforcement of occupancy limits[4], thus, require significant financial assistance (e.g., deferred loan payments) in order to keep the transition afloat.

a) b)

Fig. 8 (a + b). The newly implemented EDSA Busway BRT in Metro Manila
Source: 'Jel' (June 2020); Jack Schmidt (October 2020)

5.2. Provide adequate infrastructure and reform of public transport (mid-/long-term)

The short-term wins described above, however, are pointless if not converted into long-term, sustainable successes. For long times, cycling in the Philippines was considered

[4] This information is based on the fifths author's personal communication with Dr. Jose Bienvenido Biona, Executive Director of the Electric Vehicle Association of the Philippines (eVAP).

unviable, while infrastructure planning for active mobility has most commonly been absent due to the lack of regard for a holistic approach in urban transport planning. Therefore, it is important to leverage on the current demand for active mobility and further promote safe and prioritized walking and cycling through the provision of adequate infrastructure. Studies suggest that active mobility infrastructure is a necessary condition for inducing a modal shift (Song et al., 2017). Hence, the temporary pop-up bike lanes should be transformed into permanent, protected bike lanes and integrated into a dense and interconnected cycling network, complemented by extensive bike-sharing systems. Case study results from New York City show that bike-sharing systems have proven resilience over other transport modes and that increases in travel distance as well as modal shifts are observed in times of pandemics and during other disruptions (Teixeira and Lopes, 2020).

It is also essential to make the metropolis more pedestrian-friendly and consider walking as an actual mode and means of transport. In the current auto-centric development in MM, road widening initiatives aimed at providing more and more car lanes, while only narrow spaces have been dedicated to pedestrians, which are often additionally restricted due to street vendors, on-street parking, and other hindrances. Thus, urban planning needs to put more focus on walkability, consider pedestrians' needs, including the elderly, and re-allocate road space to make walking and cycling safer and enable proper social distancing. Besides the recognized benefits of walking and cycling on our health, well-being, and the environment, also active mobility's economic benefits should be highlighted (Handy et al., 2014). Besides reduced health care and transport (infrastructure) costs, benefits derive as well from improved access to businesses (i.e., pedestrians and cyclists are more likely to visit local shops), which in the current time is crucial for revitalizing the economy and supporting local businesses.

The COVID-10 pandemic has somehow indeed served to be an eye-opener to the Philippine Government on the importance of active mobility. On August 19, 2020, a Joint Administrative Order (2020-001) was issued by four executive departments of the Philippine government (including the DOHRP) on the "Guidelines on the Proper Use and Promotion of Active Transport During and After COVID-19 Pandemic". This was then followed by the issuance of Department Order 2020-88 by the Department of Public Works and Highways (DPWH) containing "Guidelines on Design of Bicycle Facilities along National Roads" on September 29. While these guidelines reflect positive transformations at the highest levels of governance, holistic and sustained efforts are needed in order to realize such transport systems transformations.

There is currently also an unprecedented opportunity to improve public transport through infrastructure investments and reforms. This pandemic has underscored the importance of public transport and the fact that the current regime is insufficiently performing its public service functions for the general public. Infrastructure investments and new concepts are thus required to meet demand and keep operations running efficiently despite reduced vehicle capacities. In addition to rail-based solutions (e.g., the MM Subway that is currently under construction), prioritized bus services on dedicated lanes (BRT) are required. Hence, the introduction of the EDSA busway was a logical step, but it urgently needs to be expanded in terms of adequate infrastructure and fitted into an extensive route network. Reforms of MM's public transport regime are also long overdue. The current commission-based model depends on private sector initiatives, where the main objective for bus operators is farebox maximization. Subsequently, uncoordinated supply and the passenger-striving behavior of buses significantly contribute to traffic congestion (in particular along EDSA), resulting in poor service quality and excessive travel times. Instead, a consolidation of operators and a centralized and holistic planning of the road public transport network could provide a remedy. At the same time, revenue models need to be reimagined. In order to guarantee high-quality bus operations despite reduced farebox revenue, services should be partially subsidized and tendered through service contracts (Chen et al., 2016).

In Resolution No. 69 dated September 7, 2020, the Inter-Agency Task Force for the Management of Emerging Infectious Diseases (IATF-EID) approved the implementation of service contracting and partial subsidies for public transport in the Philippines, to "incentivize operators, restore livelihoods of displaced transport workers, [and] empower the government to enforce health, safety, and operational standards […]." In addition to these mid-term objectives, indeed, the transition to service contracting could help make public transport more attractive in the long run, induce a modal shift, and increase the transport systems' operational efficiency and sustainability.

5.3. Leverage on big data, digitalization, and MaaS for sustainable and resilient transport systems

Triggered by technological advances as well as societal and market changes, urban transport is currently experiencing a major transition. This has opened doors to new mobility services based on digital platforms – such as carpooling and ride-hailing – and eventually paved the way for Mobility as a Service (MaaS). MaaS is "based on the seamless integration of all different public and commercial modes of transport and is delivered via a digital interface. The service must enable multimodal travel possibilities and thus allow for the planning and booking of multimodal journeys, support on the go and payment as well as alteration of the planned journey." (EMTA, 2019). While MaaS is mainly on the rise in the Global North (e.g., in Finland, Sweden, Germany, and the Netherlands), it is expected to diffuse quickly to developing countries as well. Moreover, the COVID-19 pandemic could accelerate its global uptake as MaaS could serve as a safe, phased reopening strategy for transport networks in cities worldwide (Singh Sehmi, 2020). Hence, initial MaaS trials and pilots are also at the planning stage in MM, including the EU-funded Solutions PLUS Project[5].

MaaS is a data-driven approach that builds on (public-private) collaboration and transport integration – all imperative ingredients to enhance situation awareness, strategic management, and resilience of transport networks in pandemic times and beyond. Cities and transport operators must work hand in hand to overcome unforeseeable challenges and respond to quickly changing situations. MaaS is a suitable setting to frame and foster these partnerships and collaborations. In MM and most developing megacities, this could be particularly valuable and challenging at the same time due to the highly fragmented and individualized operator landscape.

The MaaS platform bundles and combines different modes of transport to serve demand more efficiently. This also contributes to ensuring the mobility of citizens at any time and in any situation by not depending on a single transport mode (Megahed and Ghoneim,

[5] http://www.solutionsplus.eu/partners.html

2020). This is particularly crucial considering the significant effects of transport infrastructure on the aggregation of COVID-19 cases (Li et al., 2021). It is therefore important that the transport authorities embrace data sharing and open-source data, and support investments in ICT infrastructure. Accordingly, the National Transport Policy (NTP) and its Implementing Rules and Regulations (IRR) stipulate the “establishment and maintenance of an open database system for all government agencies […]”. This is a basic requirement for responsive space management in both shared mobility and public transport. That is, vehicle capacities and passenger flows can actively be monitored and controlled using vehicle GPS, automatic passenger count systems, CCTV, or lower-cost community-based smartphone reporting schemes. If necessary, traveler flows can be actively steered to relieve routes and transport infrastructure in real-time.

On the demand side, providing real-time passenger and crowding information is more relevant than ever before, as it enables careful trip and route planning and off-peak commuting. If required, contagion warning systems based on anonymized data could warn users about possible contacts with infected persons. MaaS is a tool for directly combating COVID-19 for another reason as well, as it stipulates the integration of electronic/mobile ticketing and payment systems. Thus, it reduces the overall physical contact during the procurement of tickets and conducting payment transactions (especially in Jeepneys). The Department of Transportation (DOTr) and the Land Transport Franchising and Regulatory Board (LTFRB) are accordingly pushing for cashless transactions for public transport services and have recently issued several circulars and statements in this regard.

Ultimately, MaaS provides massive opportunities for the generation and utilization of much needed data not only for informing time-sensitive decisions for responding to such pandemics, but also for long-term transport planning and strategy building through which the transport systems can continuously be improved and optimized.

6. Research Limitations and Future Research

Limitations mainly relate to the data used in the study. More than two-thirds of the Philippine population are internet users, of which a large percentage either use the Google Maps or Apple Maps service (StatCounter, 2020). While the data samples should thus be demographic (age, gender, etc.) representative, they are not expected to be representative in socio-economic terms. More specifically, only the mobility behavior of tech-savvy individuals (that know how to manipulate the mentioned map services) is included in our data. On the other hand, important population groups are likely to be underrepresented, such as the lower-income segments (that often do not have access to smartphones and the internet). We further stress that the available data can only reflect the situations on the ground to a certain extent. First, we have no information on the underlying reasons for changes in mobility behavior. For example, have users avoided public transport out of fear of infection with SARS-CoV-2, because no service was available, or simply because there was no demand for traveling? Second, the use of informal paratransit services (e.g., jeepneys, motorcycle taxis) are likely not adequately represented in the data. In addition, we only have limited insight into data collection and processing of the data providers. An information bias can be expected due to the relatively low number of classification categories for trip purposes in the Google data (6 categories) and transport modes in the Apple data (3 categories). As described in Section 2.2., a discrepancy in relation to the reported COVID-19 cases is expected due to underreporting. The results should therefore be viewed with some caution, especially what concerns the analysis of the causality of measures and the occurrence of cases.

However, for the purpose of this study – being conducted with a broader macroscopic perspective – the authors expect these data limitations to have a minor impact on the overall study results, which we therefore expect to be a close representation of reality. Nevertheless, additional work at the microscopic level is recommended for a deeper understanding. It is important to zoom in to the perspective of individuals and different population segments to derive better insights into modal shifts and to better understand underlying reasons for changes in mobility behavior including whether they are of temporary or permanent nature. Eventually, this could strengthen the findings presented in this study and/or provide the knowledge for a more in-depth discussion on post-pandemic policy implications for developing megacities.

Other limitations relate to the study design and working with such rapidly changing subject. Based on observed changes in mobility behavior, we draw conclusions for a post-pandemic scenario for which we outline transport policy implications. Of course, this is associated with some uncertainty. For the transport policy implications, we rely on the analysis of quantitative data, without taking account for specific implementation challenges of transport interventions in developing countries or specifying its direct and indirect benefits and costs (Berg et al., 2015). While in this study – considering the scope of the journal – our focus is on sustainability standpoints, future research should analysis how the proposed policies can be implemented, however.

7. Conclusion

In this article, we identified and analyzed changes in mobility behavior in face of the COVID-19 pandemic. The data analysis shows that the changes are closely linked to the containment measures imposed by the governments. In fact, the different phases of the lockdown can easily be read from the data. During the strictest phase of the lockdown (ECQ), public transport was completely suspended and significantly restricted as the quarantine state continued over the following months. As a result, movements at transit stations fell by as much as 95%, and public transport trips are the slowest to recover since then. This has particularly affected lower-income groups of the population, in particular, those without access to private cars. Thus, we demonstrate that another dimension of social exclusion, arising from the COVID-19 crisis, relates to transport and human mobility. This made immediate action by policy makers inevitable. In this article, three transport policy implications – addressing existing transport problems and the exposed lack of transport equity in both the short and long term – have been outlined and discussed.

The question of if and how these policies will be implemented have a significant impact on how the “new normal” for mobility will emerge. We argue that the opportunity to be seized is to anchor the choice of greener transport modes and a more sustainable mobility behavior within this new mobility paradigm. Our case study of MM shows that the national government agencies are taking initial steps in this direction and indeed are formulating strategies to build back better mobility. As a metropolis that has historically neglected sustainability (and thus, general resilience) in urban transport as a priority, this represents a long and arduous transition. In terms of exposing the otherwise unrevealed risk profile of such megacity (and the accompanying governance systems), the MM case therefore serves as an impetus for other developing megacities to set the right priorities and take appropriate actions.

Supplementary Material

Supplementary material is available at https://github.com/tamagusko/manilaCovid19. A dashboard on which the data visualizations for this study are updated at irregular intervals is available at https://bit.ly/hasselwander-tamagusko-et-al.

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