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Long, medium, and short-term effects of COVID-19 on mobility and lifestyle

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ABSTRACT

The outbreak of SARS-CoV-2 has led to the COVID-19 pandemic in March 2020 and causes over 2 million deaths worldwide (by January 2021). Besides the public health crisis, the infection affected the global economy as well. It also led to change in people's lifestyles, amount of teleworking and teleshopping, mode choice preference, the value of time, etc. In addition to these short-term changes during the COVID-19 outbreak, this drastic transformation of the world might account for the potentially disruptive medium- and long-term impacts. Recognizing the adverse effects of the COVID-19 pandemic is crucial in mitigating the negative behavioral changes that directly relate to psychological well-being. It is important to stress that citizens and government face an uncertain situation since nobody knows the exact parameters, which explain congestion or when the vaccine will be distributed (and its efficiency, for example, with respect to mutations). The major sources of uncertainty in the context of mobility, which have an impact on short-run (route, departure time, and mode used), medium-run (car ownership), and long-run (location of job, residential location, and choice of job) mobility, are mostly listed in this paper.

KEYWORDS: COVID-19, Mobility, Housing, Teleworking, Teleshopping, Residentia location, Heath.

JEL: H12, H84, I14, R4

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1. Introduction

On March 11, 2020, COVID-19 was declared as a global pandemic due to the outbreak of coronavirus infectious disease in Wuhan, China, in December 2019 (with symptoms observed, but to interpret, as early as September 2019). The first wave occurred during April and May in most countries. This led to a call for preventive actions against the spread of COVID-19 since many countries around the world face active cases. After summer, the world faced a second wave of the coronavirus pandemic. As shown in Figure 1, most countries experience a severe second wave compared to the first wave. It was expected, yet not really taken into account before it started. According to a census revealed on January 25, 2021, by Statista, the number of people worldwide infected with the COVID-19 is 99.8 million.

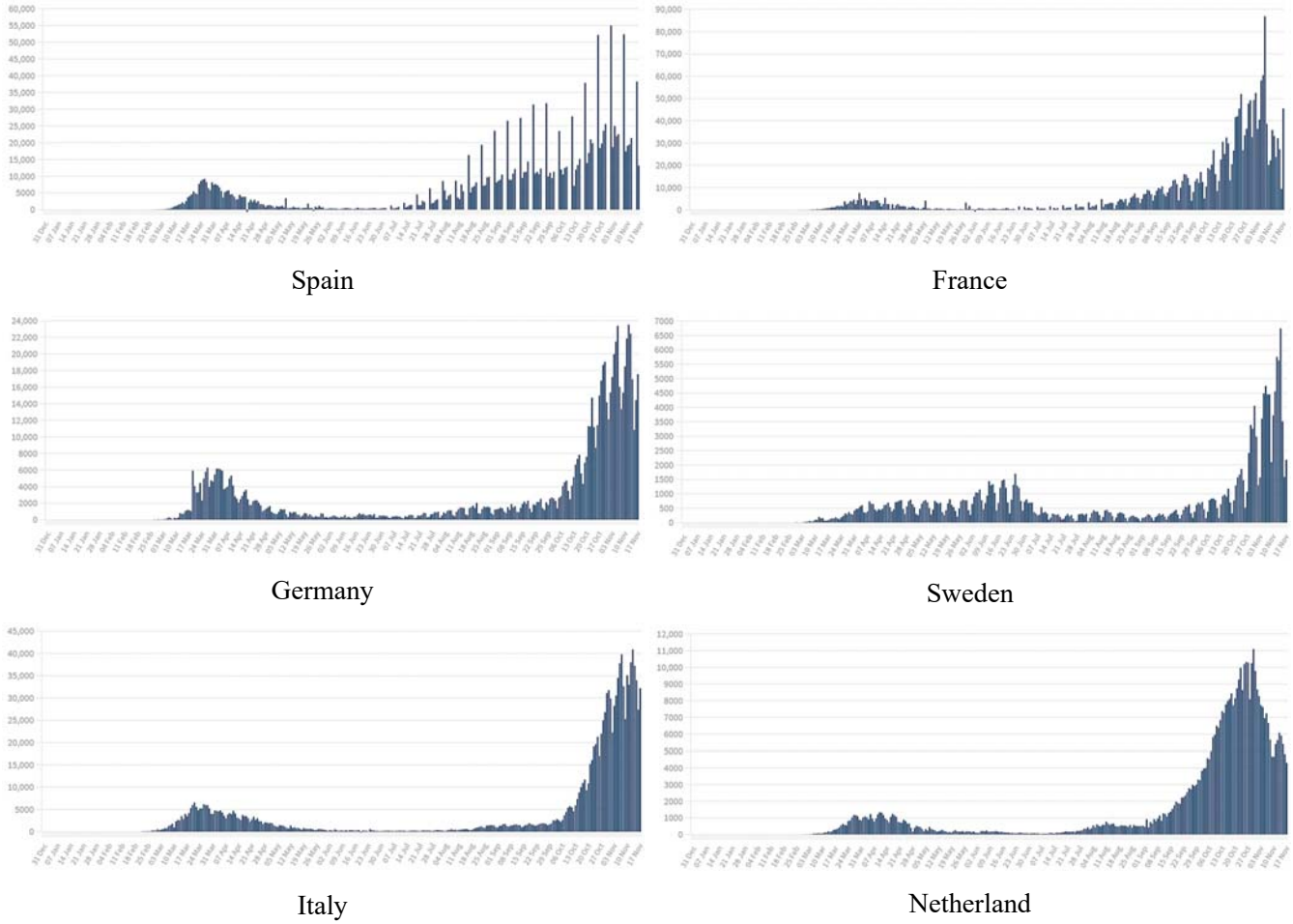


Figure 1: The number of daily new COVID cases in some European countries, Jan-Nov 2020[1]

[1] Available at https://www.euronews.com/2020/10/28/is-europe-having-a-covid-19-second-wave-country-by-country-breakdown (Access: December 2, 2020)

To manage the health crisis, public authorities have taken various actions including confinements, lockdowns, compulsory wearing masks in public, and social distancing. Governments' actions against the pandemic have and will play a vital role in reducing the number of cases. Figure 2 depicts a list of European countries that set various rules to deal with the new virus in March. Besides, Figure 3 is a map showing various constraints implemented by countries across Europe (as of 14 May). This figure illustrates, in most European countries, public gatherings are banned and schools are closed. However, other activities such as land transportation, non-essential shopping and services are restricted. Also, Figure 4 shows the lockdown period in African, Asian, and European countries, where over 100 countries worldwide had inaugurated either a full or partial lockdown by the end of March 2020, affecting billions of people.

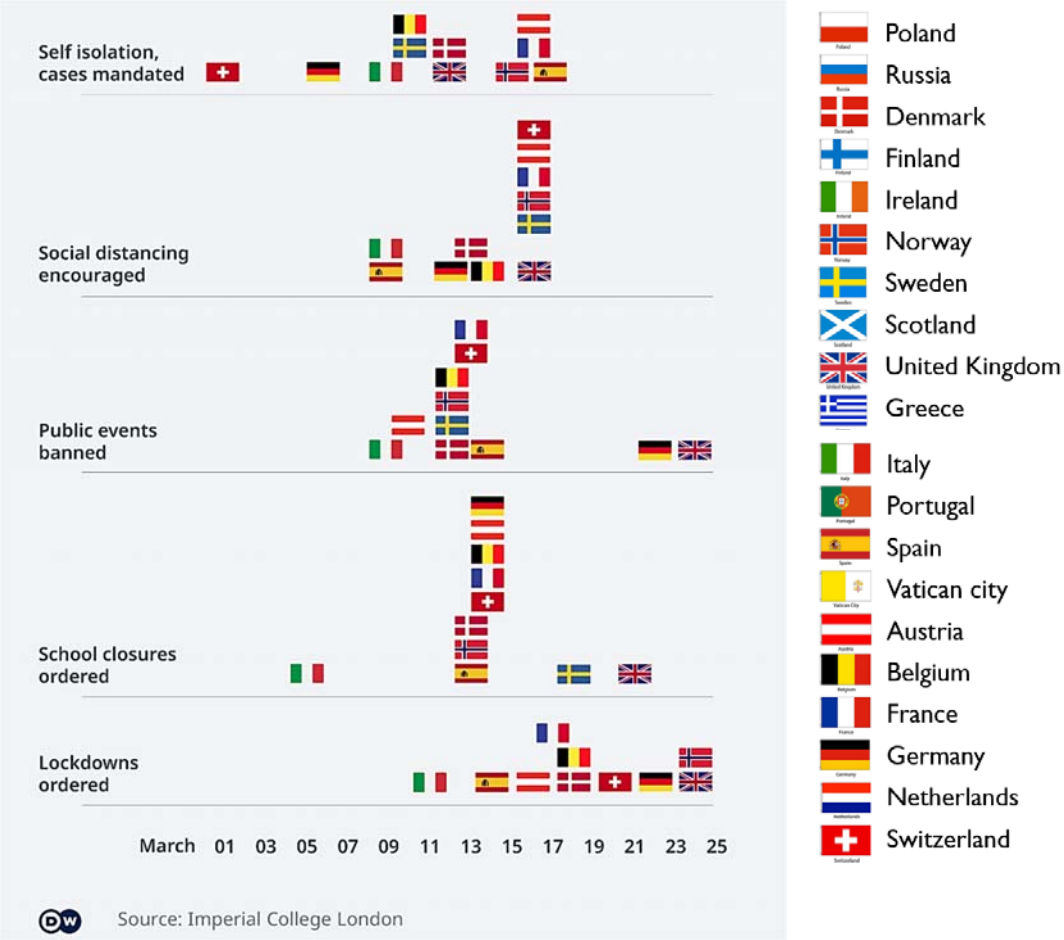


Figure 2: European countries COVID intervention, March 2020[2]

[2] https://www.dw.com/en/coronavirus-what-are-the-lockdown-measures-across-europe/a-52905137

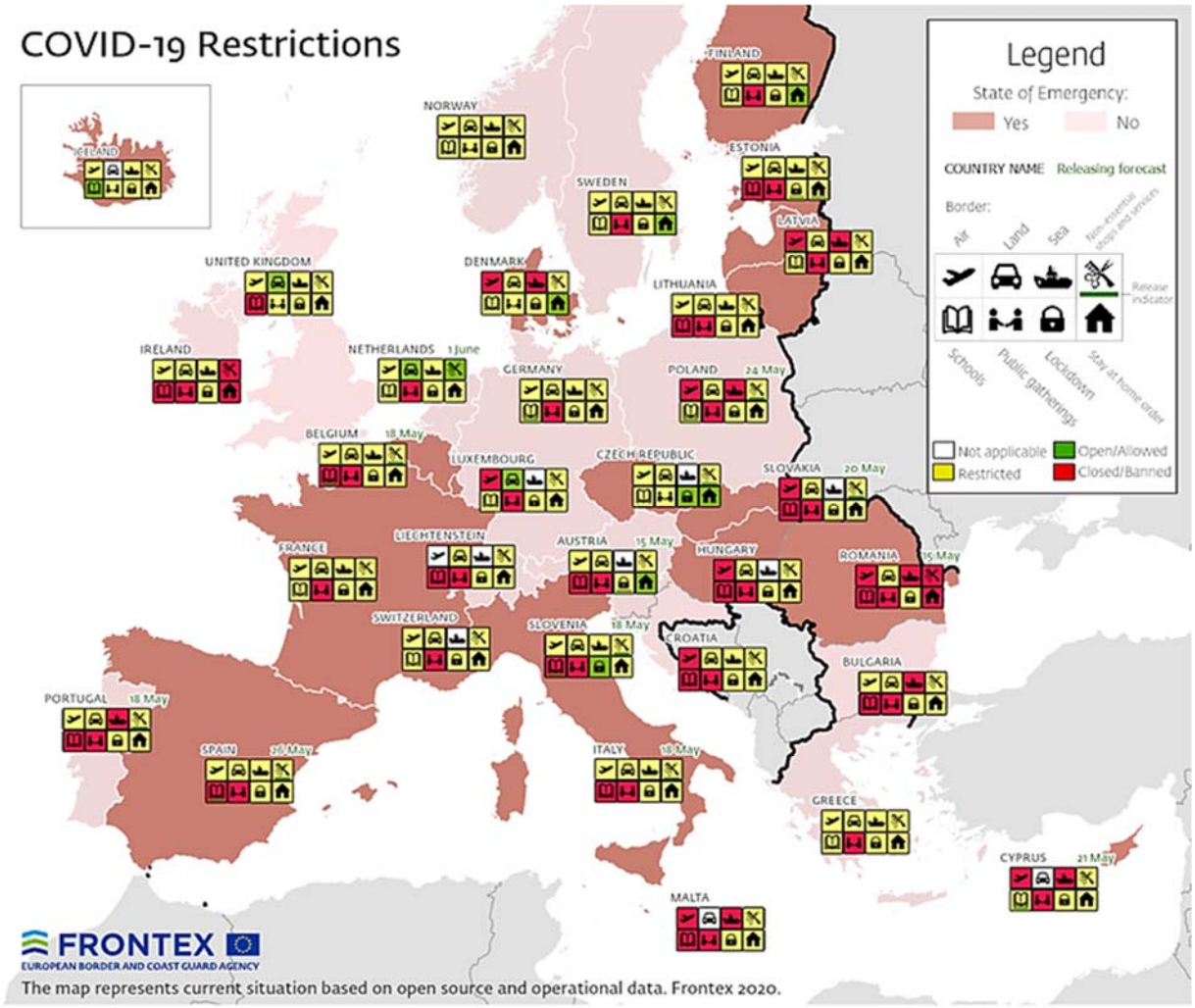


Figure 3: COVID restrictions in European countries, March 2020[3]

[3] https://frontex.europa.eu/media-centre/news-release/covid-19-restrictions-4IdY3J

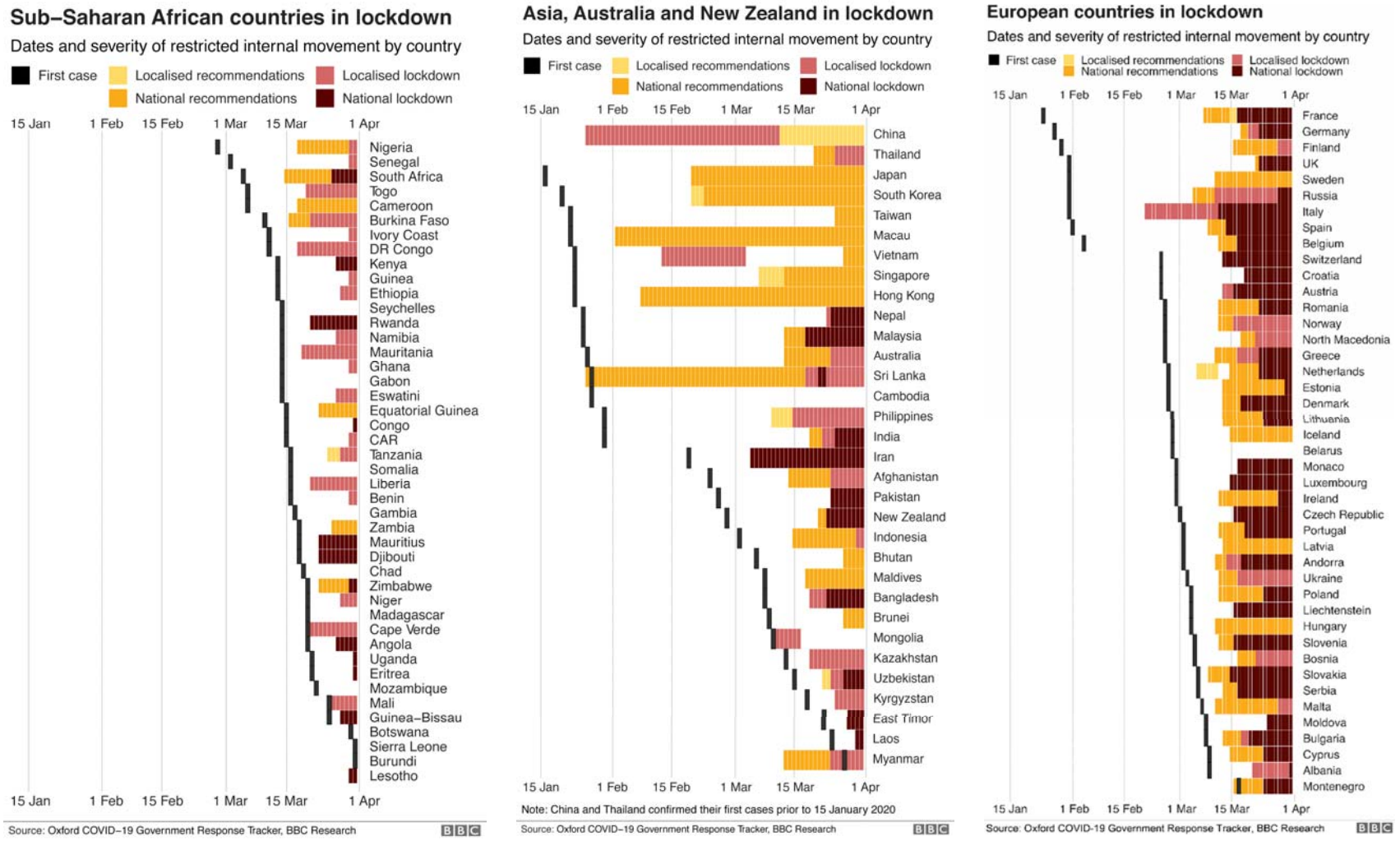


Figure 4: African, Asian, and European countries actions against COVID-19, Jan-Apr 2020[4]

[4] https://www.bbc.com/news/world-52103747

The wide range of governments' responses to the COVID-19 outbreak is measured by the Oxford COVID-19 Government Response Tracker (OxCGRT) which aims to track and compare the government's preventive actions worldwide rigorously and consistently.[5] This tracker introduces the Stringency Index which is a number between 0 and 100, and a higher index score indicates a higher level of stringency.[6] Figure 5 shows the Stringency Index which is a composite measure of nine response indicators including school closures, workplace closures, gathering restrictions, public events ban, public transportation closures, stay-at-home requirements, restrictions on internal movement, international travel bans, and public information campaigns, on April 20 and December 4. Based on this figure, most countries were strict about the restrictions but over time the stringency index drops. IMF report (2020) shows a negative correlation between the stringency of the lockdown measures and the real GDP growth forecast error[7], suggesting that countries with a tighter lockdown stringency experienced larger output losses.

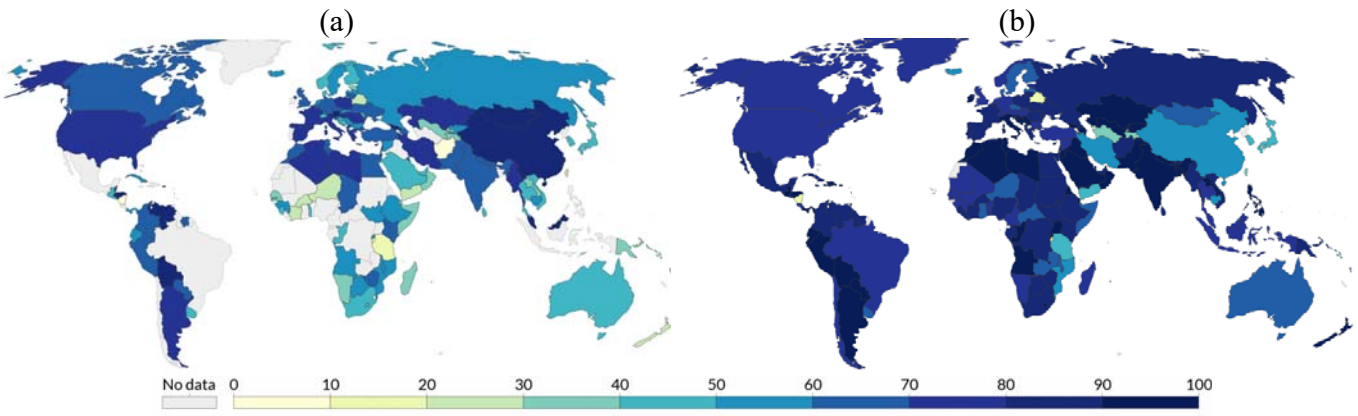


Figure 5: Government Response Stringency Index: (a) December 4, 2020; (b) April 20, 2020[5]

Social distancing, temporary lockdown (to varying degrees), and other preventive actions have become the priorities to delay and alleviate the epidemic and reduce its adverse effects on the population. The lockdown affects businesses around the world. For instance, a two-part survey (on 9-11 March and 23-25 March) in India demonstrates that COVID-19 has hit sales functions

[5] https://data.humdata.org/dataset/oxford-covid-19-government-response-tracker
[6] https://www.civilsdaily.com/news/what-is-stringency-index/
[7] The forecast error is defined as the deviation of real GDP growth from the January 2020 World Economic Outlook projections, which are the latest ones before the COVID-19 outbreak.

hardest, followed by production and supply chain (see Figure 6). Figure 7 also depicts the potential effects of partial or complete shutdowns on activity in the G7[8] economies. According to this figure, the overall direct initial hit to the level of GDP is typically between 25-30% in G7 economies. Germany has the largest reduction in transport manufacturing, and Japan has the largest drop in retails and wholesale trade resulting in the largest drop in GDP. Another survey among 410 young entrepreneurs across Asia-Pacific shows that COVID-19 has adversely affected business so that 88 percent of respondents have experienced reduced customer demand, 34 percent have experienced supply chain disruptions, and 25 percent have experienced distribution disruption.[9]

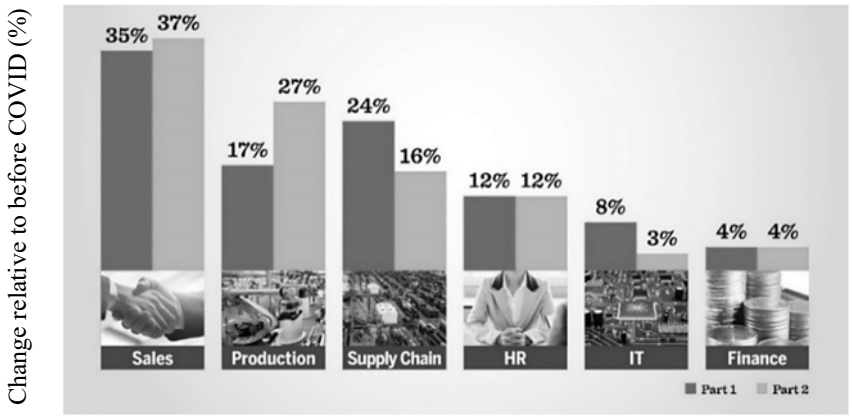
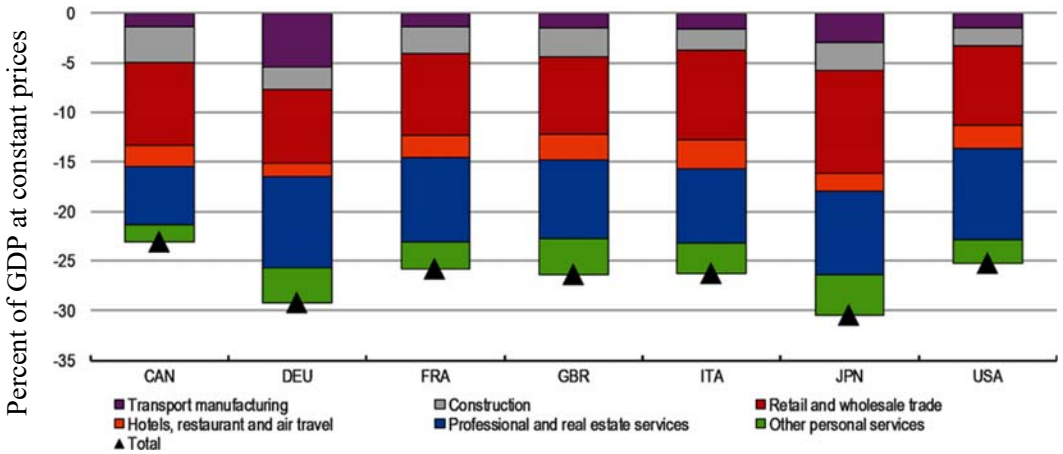


Figure 6: Effect of COVID on different parts of the economy in India, March 2020[10]



[8] The Group of Seven is an intergovernmental organization consisting of Canada, France, Germany, Italy, Japan, the United Kingdom and the United States.
[9] Available at https://www.asia-pacific.undp.org/content/rbap/en/home/presscenter/articles/2020/youth-co-lab-survey-reveals-how-covid-19-is-affecting-youth-led-.html
[10] Available at https://www.cio.com/article/3532487/sales-and-production-most-affected-by-covid-19-lockdown-cio-india-survey.html

Figure 7: Potential impact of partial or complete shutdowns on activity in the G7 economies[11]

Clearly, this crisis had, have, and will have tremendous impacts on societies including lowering physical activities, increasing working from home, and reducing public transport usage, both in the short and in the long term. Such changes in people's behavior might result in enormous economic and transportation changes. Therefore, it is necessary to recognize the possible changes and raise awareness about the disruptive shocks to mitigate the adverse effects of the current crisis, design appropriate policy responses, and invest in the preparedness of the probable future pandemics. As a result, this deliverable aims at analyzing the effects of COVID on various aspects of human life such as personal activities, travel behavior, and work-related decisions, through a literature review. These effects will be short, medium, and long term, and the major effects include lifestyle change, increasing telework and teleshopping, change in mode choice and travel preference such as VOT, and change in the tourism industry and air transportation are discussed in this deliverable. This provides policymakers with a cautionary lesson for addressing the importance of paying attention to the future of urban development, public transportation, and behavioral strategies to tackle COVID-19 negatives consequences. We list below, informally, the major sources of uncertainty in the context of mobility, which have an impact on short-run (route, departure time, and mode used), medium-run (car ownership), and long-run mobility (location of job, residential location, and choice of job). It is important to stress that citizens and government face an uncertain situation (and not a risky situation), since nobody knows the exact parameters, which explain congestion or when the vaccine will be distributed (and its efficiency, for example, with respect to mutations).

Since COVID-19 is a brand-new issue in the literature, experts' opinions can provide us with a better understanding. Appendix A provides the idea of experts (in mobility and urban planning) about the potential changes due to COVID-19 in various aspects of life. Also, Appendix B lists the immediate and long-term effects of COVID-19 on population, economics, resources, governance, technology, information, and security.[12] But the views of experts differ. For example, Bhat (2020) believes that COVID-19 will not change long-term travel behavior. He brings September 11th terrorist attacks to the attention and states that like that event, the coronavirus pandemic has

[11] https://www.oecd.org/coronavirus/policy-responses/evaluating-the-initial-impact-of-covid-19-containment-measures-on-economic-activity-b1f6b68b/
[12] https://www.csis.org/analysis/covid-19-reshapes-future

brought the air travel industry and most forms of transportation to its knees. "Although the nature of current risk perceptions may be different from that event, we are again seeing major shocks to the travel industry." He believes that large-scale shifts in the amount of travel may be the case over the next three to four years, but likely not permanent. As in the post-September 11th world of air travel, he does not expect travel volumes to change dramatically over an extended period. Over the long haul, people will find their own equilibrium. Causal discussions show that several people believe that after the crisis will be just as before, (as worse, as far as environment), but we do not base our analysis of such predictions but rather on the paper published in respectable journals.

2. Effect of mobility on spreading COVID-19

Studies show that people who travel by public transport, especially subways, are more likely to prone to the virus (Fathi-Kazerooni et al., 2020). In other words, the congested public transport system can be responsible for propagating infection across the city many times in a day. In addition to the correlation between the COVID-19 spread and in-vehicle infection, stations are densely crowded indoor environments with insufficient ventilation. This increases the risk of transmission of airborne infections while using public transportation. Fathi-Kazerooni et al. (2020) show a strong correlation between turnstile usage and COVID-19 deaths and reported cases, for the first time, using time series data for New York City through a long short-term memory neural network.

To show the effectiveness of restrictions on geographic mobility in limiting the spread of the COVID-19 pandemic, Harris (2020) uses zip code data for New York and estimates that for a 10-percentage point reduction in subway ridership during the first three weeks of March, the cumulative number of infected people declined by around 12 cases per 10,000. Almost 5 million rides per working day usually take place by New York's subway system. The observational evidence on the number of turnstile entries and the number of COVID-19 cases in New York is compatible with the conclusion that the subway system is a major disseminator, so a reduction in its usage results in reduced transmission of the virus. In another study, a 17 to 27 percent reduction in the total COVID-19 cases per capita is estimated for every 10-percentage point fall in mobility in Atlanta, Boston, Chicago, and New York (Redding et al. 2020). This estimation is not uniform and is larger in New York, Philadelphia, and Boston. This is probably due to the initial infection rate rather than the nature of mobility since public transportation is also used in Chicago but city-

specific estimates lower coefficients in Chicago. This study claims that "mobility seems to spread COVID-19 in the northeastern cities, but not in other cities." A correlation of 0.44 is also computed between change in the number of daily trips and the number of COVID-19 cases per capita (Redding et al. 2020).

A more recent study (Schwarts, 2020) found that mass transit played no significant part in the spread of COVID-19, as shown in Figure 8, based on 150 million rides on New York City Transit between June 1 and August 18. This study states that taking the train or bus to work is perfectly safe when proper precautions are taken. This suggests that the accompanying measure matter (e.g. one seat out of two available), as well as masks, and less crowding in the train and platforms. Yet, little is known (see below) on the effects (and how to combine them) of these measures.

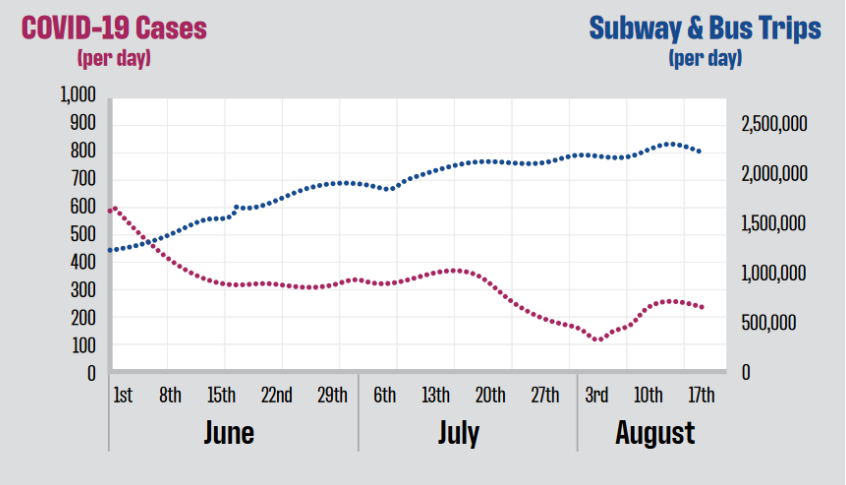


Figure 8: Public transport usage and number of COVID cases in New York City, June 1 to August 18 (Schwarts, 2020)

Other studies distinguish the impact of various parameters on the correlation between the spread of COVID-19 and public transport usage. For instance, Zhou and Koutsopoulos (2020) apply a Wells-Riley model (see below) to develop a risk metric and evaluate the effectiveness of various strategies to reduce the associated risk in public transport.

Wells-Riley model

The Wells-Riley model was proposed by Riley et al. (1978) to evaluate the probability of infection in indoor premises, considering the intake dose of airborne pathogens in terms of the number of quanta. Wells-Riley model is based on the concept of 'quantum of infection', which indicates the transmission capability of a certain disease. The model has been used extensively by researchers to study the transmission risk inside hospital wards, classrooms, offices, and transit vehicles for various respiratory diseases, including measles, influenza, SARS, etc.

$$P = 1 - \exp(-\frac{I.p.q.t}{Q})$$

where, P is the probability of infection, I the number of infectors (carriers), p the breathing rate per person (m3/hour), q the quanta generation rate (1/hour) (infectiousness = n quanta per hour), t the exposure time length (hour), Q the room ventilation rate of clean air (m3/hour).
In the case of both infectors and susceptible persons wearing a mask, the probability of infection can be expressed by adding a discounting factor towards p and q:

$$P = 1 - \exp(-\frac{I.(F_m.p).(R_m.q).t}{Q})$$

The results show that mask-wearing and ventilation are effective mitigation methods under several demand levels. When the demand levels are lower than 30 percent of the base case (pre-COVID-19) the risk is relatively low, and the differences among the various strategies are small. When the demand level exceeds 70 percent of the base case demand level, the risk increases more rapidly (Zhou and Koutsopoulos, 2020). The correlation between COVID-19 cases and the use of public transport might be a result of public transport usage itself or be the result of what the commuters are exposed to after they get to the final destinations. These two effects made governments restrict human activities by implementing various degrees of lockdown and encouraging a high number of teleworking. Thus, the COVID-19 outbreak causes a wide range of changes in personal lifestyle, work, and transportation behaviors, which will be discussed in the following sections.

3. Finding the optimal lockdown

Before talking about the effect of the COVID-19 outbreak on transportation, work-related behaviors, etc. this section briefly discusses the problem of finding the optimal lockdown and reopening policy during a pandemic like COVID-19. Note the impact of lockdown for a municipality (or for a country) depends on the policy considered in related neighbors. In this case, policy-makers should prioritize health and short-term welfare and quantify the tradeoff between them. Thus, the planner's objective is to determine the policy that contains the spread of infection

below a tolerable incidence level and that maximizes social welfare (that is taking the economic impact into account). Two concerns should be addressed: 1) lockdown start time, and 2) lockdown duration. IMF (2020) indicates that countries that tighten lockdown measures early in the pandemic have considerably fewer COVID-19 infections per thousand people than countries that wait until the number of cases is higher to adopt lockdowns.

Pongou et al. (2020) show that the planner's problem (to decide about lockdown duration) has a unique solution and the optimal policy depends both on the configuration of the contact network and the tolerated infection incidence.

The social planner's problem

The planner chooses $l \in [0; 1]^n$ to maximize the aggregate surplus:

$$\underset{(l_i)}{\text{Maximize}} \quad \int_0^{\infty} e^{-\delta t} \sum_{i \in N} \{pY_i(k_i, l_i, x_i, d_i) - w_i h(l_i, x_i, d_i)\}\, dt$$

$$\text{subject to} \quad \dot{x}_i = \beta[1 - l_i - x_i - r_i - d_i](1 - l_i) \sum_{j \neq i} [A_{ij}(1 - l_j)x_j] - (\gamma + \kappa)x_i$$

$$\dot{x}_i \leq \lambda, \ \lambda \geq 0$$

$$\dot{r}_i = \gamma x_i$$

$$\dot{d}_i = \kappa x_i$$

$$\dot{s}_i = -\beta[1 - l_i - x_i - r_i - d_i](1 - l_i) \sum_{j \neq i} [A_{ij}(1 - l_j)x_j]$$

$$X_0 \text{ given, with } s_i(0) + x_i(0) + r_i(0) + d_i(0) = 1 - l_i(0)$$

Where $\dot{s}_i, \dot{x}_i, and\ \dot{r}_i$ denote the derivative of the probabilities of an individual i is in each of the following states: Susceptible (s_i), Infected (x_i), Recovered (r_i), dead (d_i), and sent into lockdown (l_i), respectively, with $s_i + x_i + r_i + d_i + l_i = 1$. $\beta > 0$ represents the expected amount of people an infected person infects per period. $1/\gamma$ represents the number of days that an infected person has and can spread the virus. $\kappa > 0$ is the death probability.

$A_{ij} \in [0, 1]$ represents the intensity at which individuals i and j are connected. λ is tolerable threshold of infection incidence level. The upper bound of the parameter λ could be equal to the reproduction rate $R_0 = \beta/(\gamma+\kappa)$ for a planner who seeks to eventually eliminate the disease. They optimize the model with respect to different values of λ (0.01, 0.05, 0.1). At any given period t, each individual i possesses a capital level k_i, and a labor supply $h_i = h(l_i; x_i; d_i)$; with h assumed to be continuous and differentiable in x_i, l_i, and d_i. Without loss of generality, capital is assumed to be constant over time ($k_i(t) = k_i$, for each t). A combination of capital and labor supply generates output $y_i = Y_i(k_i; h_i) = Y_i(k_i; l_i; x_i; d_i)$. ω_i is the individual cost of one unit of labor. p is the price per unit of output. δ is the social planner's discount rate.

The social planner's problem has a unique solution.

4. Effects of COVID-19 on lifestyle

As a result of forced isolation and lockdown during COVID-19, daily lifestyle-related habits and mobility have changed in a significant manner. Lockdowns, voluntary distancing, and other preventive actions are likely to have a different impact depending on many factors such as the prevalence of teleworking, the share of people that do not depend on labor income (e.g., retirees), the presence of contactless delivery services, the amount of personal savings that can sustain periods of temporary unemployment (IMF, 2020).

Changes in mobility demand in some European countries are shown in Figure 9 and Figure 10 in wave 1 (February to April) and Wave 2 (February to October), respectively. These changes may continue as the pandemic progresses through its different phases.

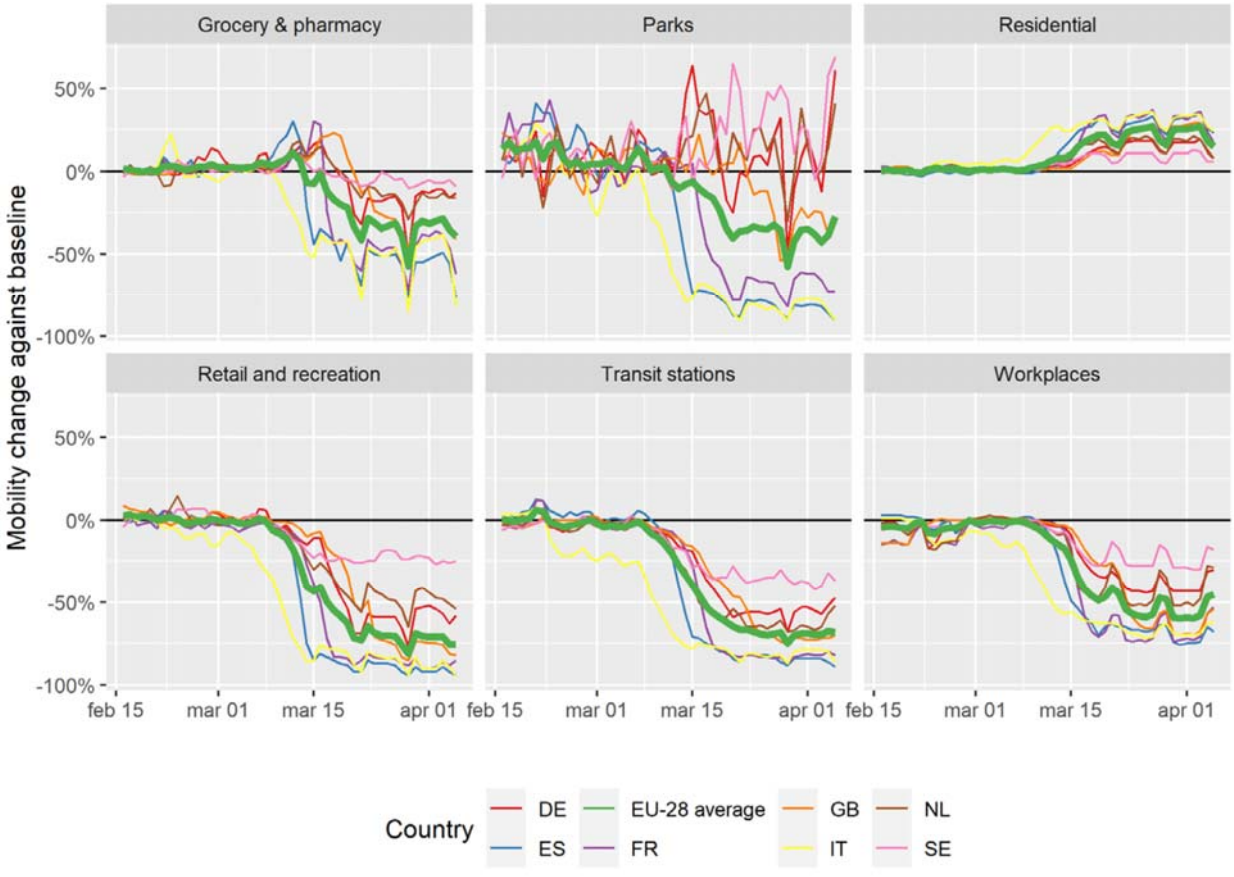


Figure 9: Different mobility demand change in several European countries in the first wave, Feb-Apr 2020 (Falchetta & Noussan, 2020)

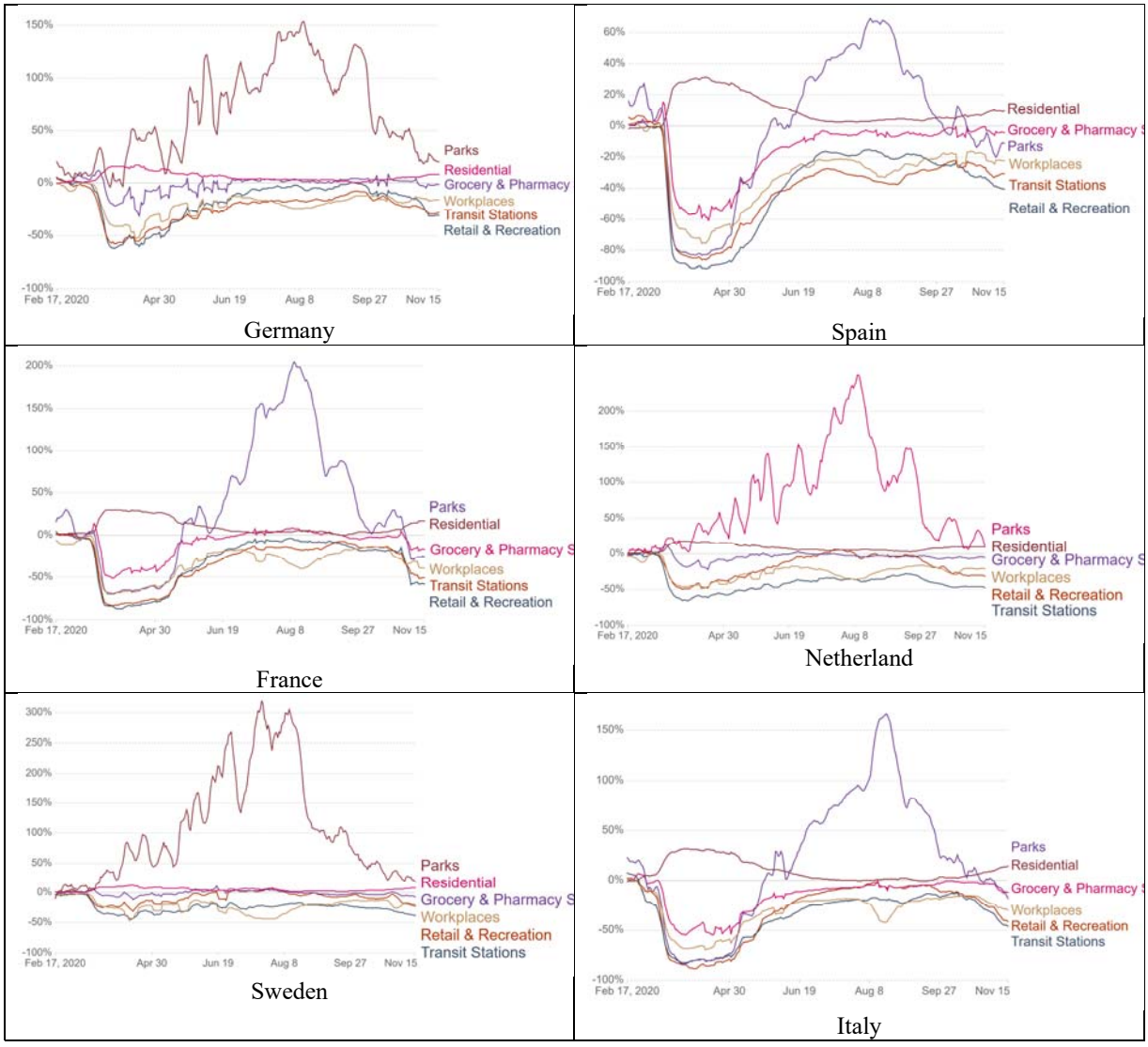


Figure 10: Different mobility demand change in several European countries in the second wave, Feb-Nov 2020[13]

IMF (2020) estimates regressions with data of 128 countries from early February until mid-July, 2020 to show the impact of lockdown on mobility. The results indicate that, in response to a full lockdown, mobility declines after a week by almost 25 percent relative to the level before the lockdown. They illustrate that tightening and loosening lockdown measures have asymmetric effects on mobility. While a full lockdown leads to reduced mobility of about 25 percent one week after the tightening, lifting restrictions boosts mobility only by about 18 percent over the same

[13] Available at https://ourworldindata.org/grapher/changes-visitors-covid?tab=chart&stackMode=absolute&time=earliest..latest&country=~ITA&region=World

period. The stay-at-home orders also lead to a sharp drop in the share of moving both men and women moving. However, the share of women drops by a larger extent. Besides, people in the age group 18-24 experience the largest drop in mobility, nearly 30 percent (IMF, 2020).

A detailed list of changes in every aspect of the personal life of citizens is reported in Table 1. According to this table, quarantine, with various durations depend on countries, is associated with stress and depression (and sometimes suicide), and leads to reduced physical activity including aerobic exercises as well as leisure-related activities. The changes in daily exercise and steps per day are inversely correlated with the changes in body weight (He et al., 2020). Many studies prove that gaining weight during the pandemic carries some long-term effects on cardiovascular disease. Although a study (Chopra et al., 2020) confirms the improved eating behavior during COVID-19, other studies demonstrate food consumption and sugary drinks intake increased significantly during the lockdown (Górnicka et al., 2020; Pietrobelli et al., 2020).

Also, during the lockdown, people experience distortion to the passage of time (define as the subjective speed at which time feels as though it is passing, for example, more quickly than normal, as normal, or more slowly than normal.) A slowing of the passage of time was associated with increasing age, increasing stress, reduced task load, and reduced satisfaction with current levels of social interaction (Ogden, 2020).

An increase in screen time is another impact of the COVID-19 outbreak analyzed in numerous studies. Górnicka et al. (2020) show that 49 percent of respondents reported an increase in screen time (time spend in front of the screen of a computer, TV, tablet, or telephone during working or non-working day), and Pietrobelli et al. (2020) show that screen time increased by 4.85 hours per day (with SD = 2.40 and $p < 0.001$) for children during the lockdown. This may affect the quality of life and result in mental health distress in long run.

In some EU countries, Conservative estimations indicate that students will suffer a learning loss. It is also suggested that COVID-19 will not affect students equally. It will influence negatively both cognitive and non-cognitive skills acquisition, and may have important long-term consequences in addition to the short-term.

the coronavirus pandemic is placing additional tension on relationships since many couples are stuck in the house, homeschooling children, and facing financial issues. Moreover, support systems have become more difficult to access (e.g. people cannot spend time with friends over

coffee or staying a night in the countryside). By April, the number of divorces had increased by 34% in the US, with newer couples being the most likely to file for divorce. 20 percent of couples who had been married for five months or less sought divorce during this period, compared with only 11 percent in 2019.[14] Ministry of Justice figures show that in the 12 months before lockdown (ending 31 March 2020), the number of divorce cases finalized in courts in England and Wales had already increased by nearly a quarter year on year, to 112,284.[15]

5. Effects of COVID-19 on teleshopping

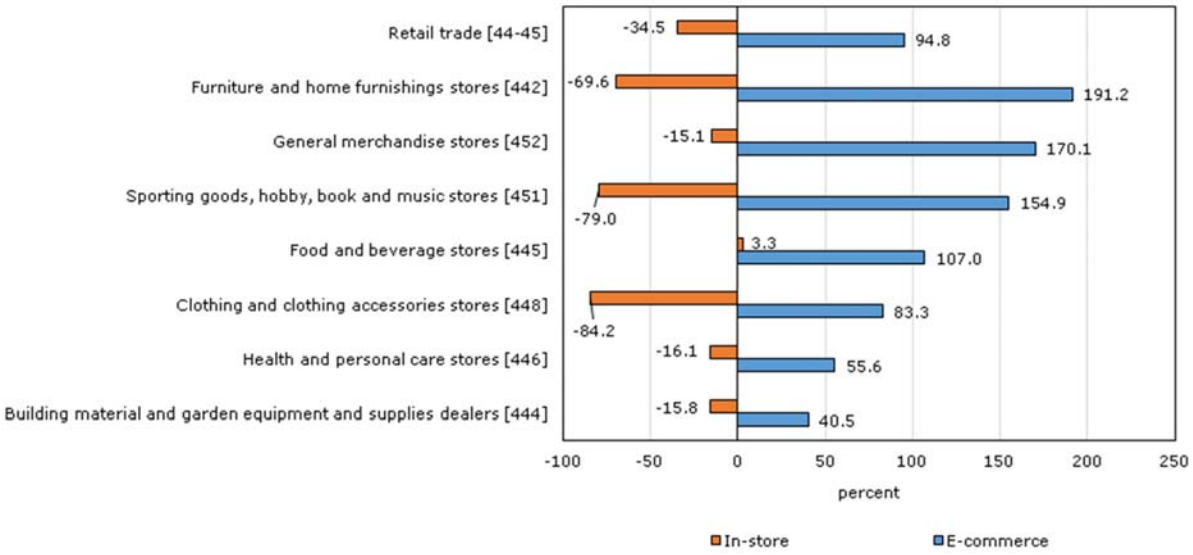
Regarding shopping activities, Carvalho et al. (2020) investigate the purchasing behavior of individuals in the first two months of the COVID-19 in Portugal, and identify a massive shock on overall purchases from a decrease of 45 percent to a growth rate of 10 percent. They find that people go less often to supermarkets and buy more each time, and visit local groceries more during the COVID-19 outbreak.

Teleshopping also increased among customers during the pandemic. For instance, online shopping has been nearly doubled in Canada from February to May 2020.[16] Figure 11 shows how in-store and e-commerce sales vary among different products. According to this figure, all retail trade subsectors increase in online sales as a result of COVID-19 while only the food and beverage subsector experience an increase in in-store sales (+3.3%). Other retail trade subsectors such as furniture and home furnishings stores (-69.6%), sporting goods, hobby, book and music stores (-79.0%), and clothing and clothing accessories stores (-84.2%) decline sharply in in-store sales.

In the U.S., online shopping has increased by 30.1% in the first six months of the year compared to the same period in 2019. In May 2020, the increase in online shopping was 78% compared to May 2019.[17] Unnikrishnan and Figliozzi (2020) analyze home delivery changes brought about by COVID-19 and the factors affecting online purchase, using a survey conducted in the Portland-Vancouver-Hillsboro Metropolitan area. By applying ordinal logit models, they show that higher

[14] https://www.natlawreview.com/article/divorce-rates-and-covid-19
[15] https://www.blandy.co.uk/about/news-and-insights/insights/the-impact-of-the-covid-19-pandemic-on-divorce-proceedings
[16] Static Canada. Available at https://www150.statcan.gc.ca/n1/pub/45-28-0001/2020001/article/00064-eng.htm
[17] Available at https://www.digitalcommerce360.com/2020/08/25/ecommerce-during-coronavirus-pandemic-in-charts/

income and higher levels of technology utilization are positively correlated with the levels of deliveries and expenditures.



Source: Statistics Canada; Monthly Retail Trade Survey; February to April 2020

Figure 11: Changes in in-store and e-commerce sales during COVID-19 in Canada, Feb-Apr 2020[18]

There is a reported increase in South Korea's online food purchases and daily necessities by 92.5% and 44.5%, respectively, in February relative to last year due to the COVID-19 pandemic. Also, there is a surge in online shopping by 12–57% in countries like Vietnam, India, China, Italy, and Germany during the same period. A market research firm has reported 50% more growth than the annual 20% growth in online shopping in the U.S. from March to mid-April (Vanapalli et al., 2020). Amazon sales of colored lipsticks and lip care (wax-like lipsticks to moisturize and relieve chapped or dry lips) dropped 15% for the month ending on April 11 while, sales of eye makeup grew by 204% in the three months ending on June 28.

France introduced a ban on the sale of all 'non-essential' items in supermarkets from November 3, 2020.[19] Online sales of all types of items (essential and non-essential) are still allowed from all

[18] Static Canada. Available at https://www150.statcan.gc.ca/n1/pub/45-28-0001/2020001/article/00064-eng.htm
[19] https://www.france24.com/en/france/20201101-french-pm-announces-ban-on-sale-of-non-essential-items-in-supermarkets-from-tuesday

types of retailers. Thus, supermarkets would be ordered to close sections that sell 'non-essential' items during the lockdown.[20] This does not affect food or drink (including alcoholic drinks), household items, or DIY products. Anything not on the list below is therefore barred from sale in supermarkets:

- All types of food, fresh frozen, or tinned
- All types of beverages, including alcoholic ones
- Toiletries and hygiene products
- Cleaning products
- Childcare products
- Maintenance, repair, and technical items for vehicles, motorbikes, or bikes
- Fuel
- Communication and IT equipment
- Stationery and newspapers
- Pharmaceutical or medical products
- Seeds, fertilizers, and pet food
- Building materials, hardware, DIY equipment, and paint

A ban on the sale of non-essential items also implemented during Wales' firebreak lockdown has caused confusion and frustration among some shoppers but others say it has kept them at home.[21] Of course, the definition of "essential" and "not essential" is debatable. Public acceptability may have played some role when setting those definitions.

[20] https://www.thelocal.fr/20201102/french-supermarkets-ordered-to-close-non-essential-aisles
[21] https://www.bbc.com/news/uk-wales-54692441

Table 1: Observed changes in lifestyle

Activity	Range of change	Impact on health	Study area	Sample	Reference
Physical activity	Decreased	-		Concluding from other studies	1*
	Decreased among 30% of sample (48% of sample does not change)	-	India	995 responses (58.5% male, mean age 33.3 years)	2
	Decreased to 8.6 min for women (61%) Decreased to 11.8 min for men (79%)	-	China	158 males with a mean age of 36.4 and 181 females with a mean age of 37.6 years	4
	Decreased among 43% of sample (38% of sample does not change)	-	Poland	2381 residents aged 18 years and older	5
	Share of people who spent more than an hour exercising drops from 26.6 to 14.7%	-	Spain	1065 Spanish above 16 years old (72.8% female)	6
	Decreased by 2.3 hour/week		Italy	41 children and adolescents with obesity	7
Cardiovascular risk	Increased	-		Concluding from other studies	1
Stress, anxiety, and depression	Increased	-		Concluding from other studies	1
	Increased among 33% of sample (52% of sample does not change)	-	India	995 responses (58.5% male, mean age 33.3 years)	2
Eating diet	Balance diet increased among 30% of sample (46% of sample does not change)	+	India	995 responses (58.5% male, mean age 33.3 years)	2
	Fast food intake decreased among 37% of sample (55% of sample does not change)	+	Poland	2381 residents aged 18 years and older	5
Gain weight	Increased	-		Concluding from other studies	1
	Increased 2.2 kg for women with BMI < 24 Increased 1.7 kg for men with BMI < 24 Increased 0.9 kg for women with BMI ≥ 24 Decreased 0.9 kg for men with BMI ≥ 24	-	China	158 males with a mean age of 36.4 and 181 females with a mean age of 37.6 years	4
	37.3% of sample gained between 1 and 3 kg	-	Spain	1065 Spanish above 16 years old (72.8% female)	6
	Increased 2.8 kg among 34% of women who gain weight (18% of women reduced weight)	-	Poland	1769 women	9
Screen time	Increased among 43% of sample (49% of sample does not change)	-	India	995 responses (58.5% male, mean age 33.3 years)	2
	Increased among 49% of sample (46% of sample does not change)	-	Poland	2381 residents aged 18 years and older	5
	Increased by 4.85	-	Italy	41 children and adolescents with obesity	7
Leisure (grocery, shopping, walking in park, gardening)	Decreased among 46% of sample (39% of sample does not change)	-	India	995 responses (58.5% male, mean age 33.3 years)	2

Sleep time	Increased among 26% of sample (68% of sample does not change)	+	India	995 responses (58.5% male, mean age 33.3 years)	2
	Increased among 30% of sample (61% of sample does not change)	+	Poland	2381 residents aged 18 years and older	5
	Increased by 0.65 hour/day		Italy	41 children and adolescents with obesity	7
Smoking	Smoking prevalence decreased from 23.3% to 21.9% Number of cigarettes per day increased from 10.9 to 12.7 prevalence of e-cigarette increased from 8.1% to 9.1%	+ - -	Italy	6003 adults aged 18-74	3
Walking	Average steps per day decreased by 3297 for women (47%) Average steps per day decreased by 4593 for men (55%)	-	China	158 males with a mean age of 36.4 and 181 females with a mean age of 37.6 years	4

* 1: Mattioli et al. (2020)
2: Chopra et al. (2020)
3: Odone et al. (2020)
4: He et al. (2020)
5: Górnicka et al. (2020)
6: Sánchez-Sánchez et al. (2020)
7: Pietrobelli et al. (2020)
8: Sultana et al. (2020)
9: Drywień, M.E., et al. (2020)

6. Effects of COVID-19 on teleworking

In addition to individual-based preventive efforts such as handwashing and wearing a mask, some preventive measures require social efforts such as telework (or telecommuting or work from home). In many countries telework is recommended as a means of preventing the propagation of COVID-19. Kawashima et al. (2020) evaluate the relationship between telework implementation and the presence of a fever (above 37.5°C). This study shows that teleworking has a significant relationship with fever as a symptom of COVID-19 among company employees aged 15 to 59 (non-teleworkers: 7.64 percent vs. teleworkers: 6.45 percent with p=0.02).

Another study (Knittel and Ozaltun, 2020) analyze the effects of modes of commuting on COVID-19 related death rates across the US. They show that all modes of commutes (public transport, walking, and driving), except for biking, result in higher death rates relative to telecommuting. Their regression model is as follows:

$$\text{Deaths per 1,000 people} = \ldots + 6.9(\text{share of driver}) + 12.1(\text{share of public transport}) + 7.8(\text{share of walk}) + 7.5(\text{share of other modes}) - 7.0(\text{share of bike}) \quad R^2=0.53$$

Therefore, a 10-percentage point increase in public transport ridership results in 1.21 increase in deaths per 1000 people compared to telecommuting.

Di Domenico et al (2020) evaluate the impact of school closure and telework on the COVID-19 outbreak in France and show that school closure alone would have limited benefit in reducing the peak incidence. But, when 8-week school closure coupled with 25 percent adult teleworking, the peak would be delayed for nearly 2 months, and the case incidence at the peak would reduce by 40 percent.

Therefore, due to COVID-19, telework has been increased among many organizations worldwide. However, everyone in a firm is not capable of remote working. Some studies (Saltiel, 2020; James, 2020) show that 37% of jobs could potentially be done from home across the US firms. Another study in the US (Bartik et al., 2020) using data from 1,770 leaders of US small businesses finds that 27 to 31 percent of employees could feasibly work remotely. Figure 12 shows a 33 percent correlation between the potential for remote work and the actual prevalence of remote work across US industries in March and April 2020.

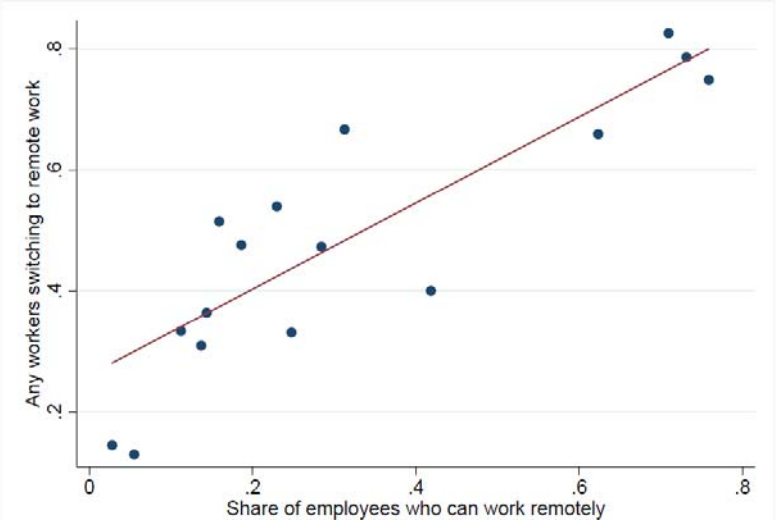
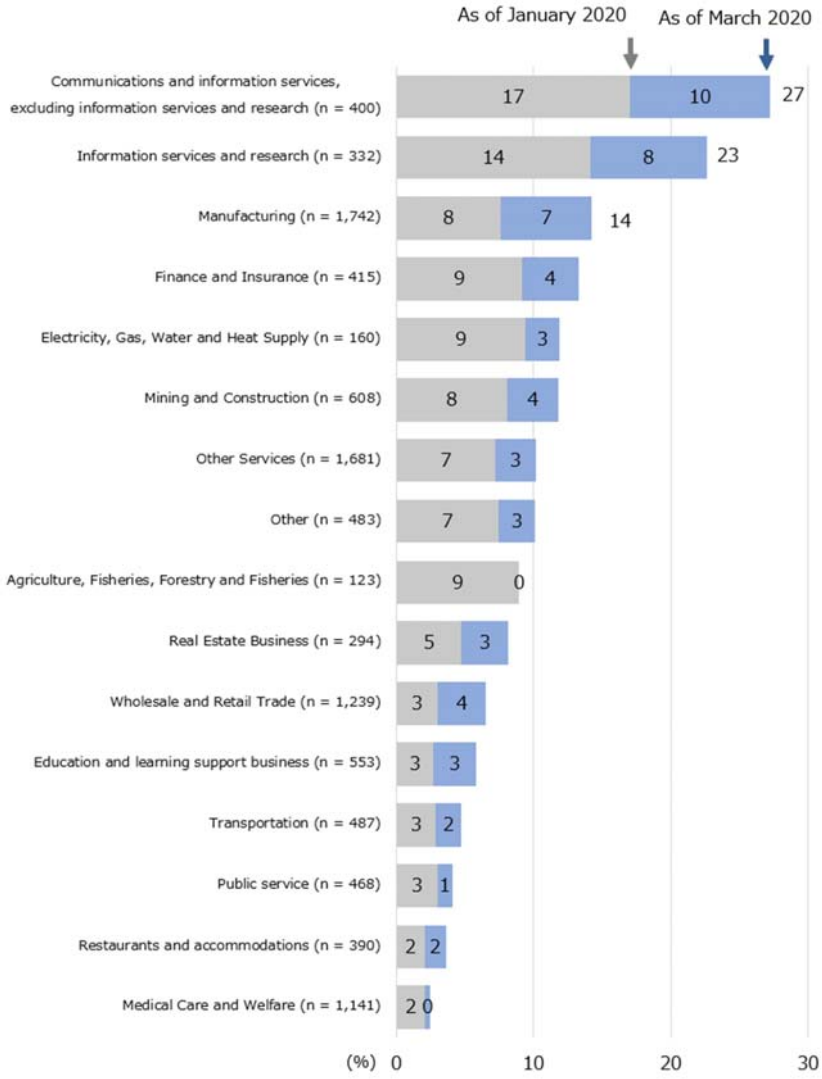


Figure 12: Probability of switch to remote work and the share of industry employees capable of working remotely, US, March-April 2020 (Bartik et al., 2020)

The prevalence of teleworking affects many aspects of life, especially transportation behavior. In this section, we intend to examine the factors affecting the pervasiveness of working from home. Since teleworking has strong impacts on lifestyle and commuting behavior, one of the main challenges is to determine that if teleworking is going to stay even after the COVID-19 crisis. To answer this question, one may need to know how work from home will change productivity. Clearly, if workers are more productive at home than in the workplace, employers prefer to assign more remote work to the employees than before COVID-19.

I. Factors affecting the tendency to teleworking

The use of telework as a response to the crisis is heterogeneous among jobs and it depends on the activity of the organization. For instance, companies in the service sector present higher rates of telework (Belzunegui-Eraso and Erro-Garcés, 2020). Figure 13 shows how the number of teleworking days varies among various sectors before and during COVID-19. According to this figure, all types of industries in Japan except for the medical care category, during COVID-19, work from home more than before COVID-19. The highest increased day of work from home belongs to communications and information services that have increased 10 days during COVID-19 resulting in a total of 27 days of teleworking.



Source: Questionnaire Survey on the effects of the Spread of the COVID-19 on Telework-based Work Styles, Lifestyle, and Awareness; Sample of 10,516 Japanese workers; March 2020.

Figure 13: Rate of the utilization of telework by industry category in Japan, March 2020[22]

Bartik et al. (2020) by merging their survey with pre-crisis industry-level characteristics from the American Community Survey found that remote work during the crisis is more common in highly educated industries. According to their study, remote workers were found in 64 percent of firms in the most educated quartile of industries, while 36 percent of firms in the least educated quartile

[22] Available at https://voxeu.org/article/covid-19-and-teleworking-japan

of industries had remote workers. This suggests that more educated workers are more likely to have - and take - the option to work from home.

Using a survey of owners or managers of small US businesses in May 2020, Bartik et al. (2020) show that as the share of workers in the industry who are women increases by ten percentage points, the share of remote workers increases by 1.7 percentage points. Using a survey of 70 business economists who are members of the National Association of Business Economists (NABE) in April 2020, they show that as the share of women in the industry increases by ten percentage points, the share of employees working from home increases by 5 percentage points.

Another study in Japan (Masayuki, 2020) using an original survey conducted in June 2020 demonstrates that highly educated, high-wage, white-collar employees who work in large firms in metropolitan areas tended to practice work from home, which suggests that infection risk and social distancing policies may exacerbate economic disparity among employees.

II. How teleworking affects productivity

Telework occurs to affect employee's productivity. Although teleworking productivity varies by country, sector, firm-size, occupational skill intensity, and so on (see Figure 14), many studies strive to address the productivity of widespread telework during COVID-19. Baert et al. (2020a), who examine employee's perceptions of telework in various life and career aspects, show that respondents mainly attribute positive characteristics to teleworking, such as increased efficiency and a lower risk of burnout. OECD (2020) introduces theoretically the relationship between teleworking and worker efficiency as an inverted U-shaped curve (Figure 15) in which by increasing telework, first, efficiency increases, and then it decreases. The maximum depends on the sector, size, etc. In line with this, Raišienė et al. (2020) show that respondents who worked remotely for up to two days a week emphasize the advantages of telework, and more telework results in highlighting more conflicts.

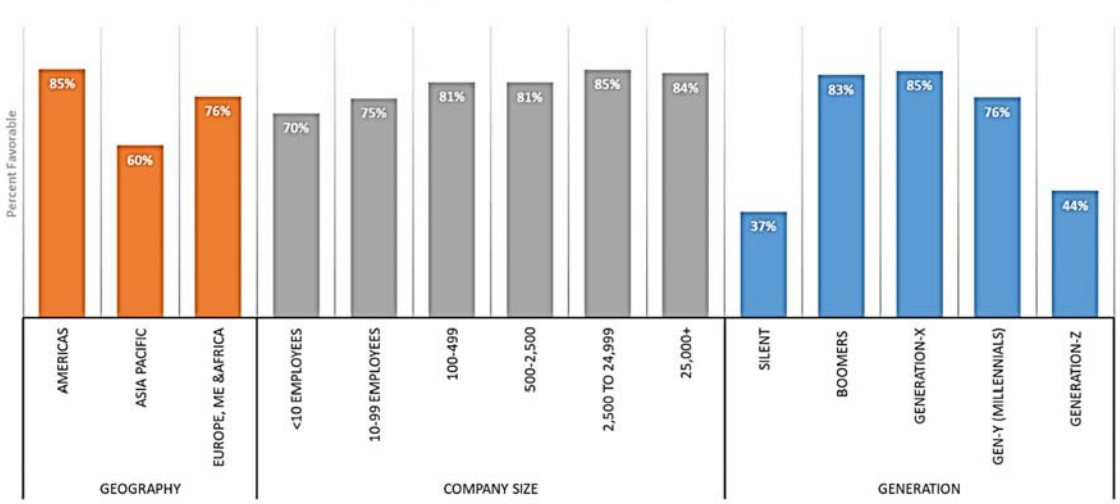


Figure 14: Global teleworking productivity for different groups, May 2020[23]

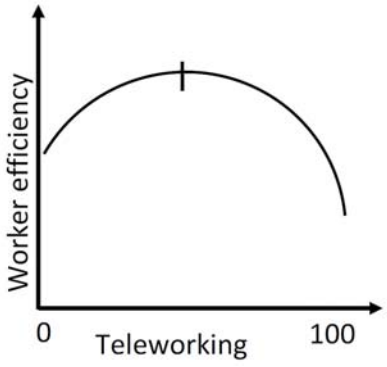


Figure 15: Theoretical relationship between telework and worker efficiency (OECD, 2020)

OECD (2020) explains Figure 14 as follows:

"*Overall, for firm-level productivity to increase with telework it is therefore crucial that worker satisfaction increases enough to offset the potentially negative effects on communication, knowledge flows and managerial oversight. The relative strength of these channels in turn is likely to depend on the intensity of telework: the negative effect due to the lack of personal interactions likely becomes stronger with telework intensity, as opportunities for in-person communication*

[23] Global Work-from-Home Experience Survey Report (2020). Page 41. Available at https://we.ifma.org/wp-content/uploads/2020/04/WFH-Experience-Survey-Overview-4-4-2020.pdf

diminish, while worker satisfaction improves with low levels of telework but may suffer from 'excessive' teleworking, e.g. due to solitude or a fusing of private and professional life. Worker efficiency therefore improves with low levels of telework but decreases with 'excessive telework', implying a 'sweet spot' where worker efficiency – and thus productivity – is maximised at intermediate levels of telework, although it should be noted that the exact form of this relationship likely varies with the relative importance of these factors by sector and occupation."

Employees' characteristics also play a vital role in the efficiency of telework. For instance, employees with children tended to emphasize the disadvantages of increased teleworking (Baert et al., 2020a). Also, Raišienė et al. (2020) show that the assessment of the advantages and disadvantages of telework requires remote workers' characteristics, including gender, age, education, work experience, and experience of telework. They demonstrate that men assessed working from home more negatively than women, and older generations are less satisfied with telework.

Bartik et al. (2020) used two types of data in order to analyze the productivity of teleworking among US firms: First, a survey of 1,770 leaders of small businesses who are part of the Alignable network (March and April 2020). Alignable[24] is the largest network and community of Small Business Owners in North America. Second, a survey of 70 business economists who are members of the National Association of Business Economists (NABE) in April 2020. NABE is a professional organization for business economists who mainly work in company settings. The firms in the NABE survey are predominantly larger, with almost 40 percent have more than 1000 employees, and the firms span a broad set of industries. In the Alignable network, 45 percent of firms report having any workers switch to remote working during the COVID-19 pandemic while, in the NABE survey, 50 percent of firms have more than one-fifth of their employees working remotely. Remote working is more likely in the NABE firms because more of these firms are in white-collar industries where remote working is easier.

The NABE respondents were generally positive about remote working productivity. A majority believed that remote working did not involve any productivity loss and 28 percent thought that workers had become more productive through remote working. The Alignable respondents were

[24] https://www.alignable.com

less optimistic, reporting an average productivity change of -0.198 (on a -1 to 1 scale, with 0 representing no change).

Bartik et al. (2020) investigate the effect of workers' education, firm size, and gender on productivity. As the share of the workers in the industry with a college degree increases by 10 percentage points, the perceived productivity of remote work increases by 0.33 percentage points. As firm size doubles, the productivity of remote work appears to fall by almost four percent. As the share of women in the industry increases by 10 percentage points, the probability that a respondent says that remote workers are actually more productive than they were before increases by 11.4 percentage points.

Masayuki (2020) using data from an original survey conducted in June 2020 examines the prevalence, frequency, and productivity of working from home during the COVID-19 pandemic, in Japan. The results of this study demonstrate that the productivity at home for a large majority of employees (about 82%) was lower than that in their usual workplace. The mean teleworking productivity relative to working at the usual workplace was about 60% to 70%, and it was lower for employees who started teleworking only after the spread of the COVID-19 pandemic. Meanwhile, high-educated, and high-wage employees, as well as long-distance commuters, tended to exhibit a relatively small reduction in working from home productivity.

The major reasons for the reduced productivity were the loss of quick communication possible only through face-to-face interactions at the workplace, poor telecommunication environment at home relative to that in the office, and the rules (in some cases, for security reasons) and regulations that require some tasks to be conducted in the office. Thus, some tasks must be performed at the workplace, even for workers whose jobs can mostly be conducted at home. Hence, telecommuting may have a positive impact on employee's productivity for creative tasks but a negative impact for dull tasks (Masayuki, 2020). To achieve further improvements in telework productivity, innovation in telecommunication infrastructure and software that enables human interactions in a way that is similar to face-to-face communication is necessary.

III. Will teleworking persist once the crisis ends?

Introducing policies to deal with teleworking challenges on a large scale may catalyze wider adoption of teleworking practices. So, widespread telework may remain a permanent feature of the working environment even after the COVID-19 crisis. The results of a survey show that around

half of the respondents perceive the possibility of teleworking becoming more important following the COVID-19 crisis (Baert et al., 2020b). Another study explains that employees believe that teleworking and digital conferencing will remain in the future, at least in Belgium, with probabilities of 85 and 81 percent, respectively (Baert et al, 2020a). Beck et al. (2020), using data collected during COVID-19 in Australia, also present that there is an attitude towards working from home even after the Pandemic. The medians of days per week working at home are estimated to be 0.5, 5, and 2 for before-COVID-19, during COVID-19, and post-COVID-19, respectively.[25] Figure 16 depicts the number of days working from home during and post-COVID-19 compared to the teleworking before COVID-19, based on a survey of 2,865 responses from all over the world. Figure 17 also shows the results of another study based on 1,200 American office workers who express how many days they would like to work from home after COVID-19.

[25] Global Work-from-Home Experience Survey Report (2020). Page 28. Available at https://we.ifma.org/wp-content/uploads/2020/04/WFH-Experience-Survey-Overview-4-4-2020.pdf

Figure 16: Global work from home during pandemic and post-COVID-19, May 2020[26]

[26] Global Work-from-Home Experience Survey Report (2020). Page 11 and 26. Available at https://we.ifma.org/wp-content/uploads/2020/04/WFH-Experience-Survey-Overview-4-4-2020.pdf

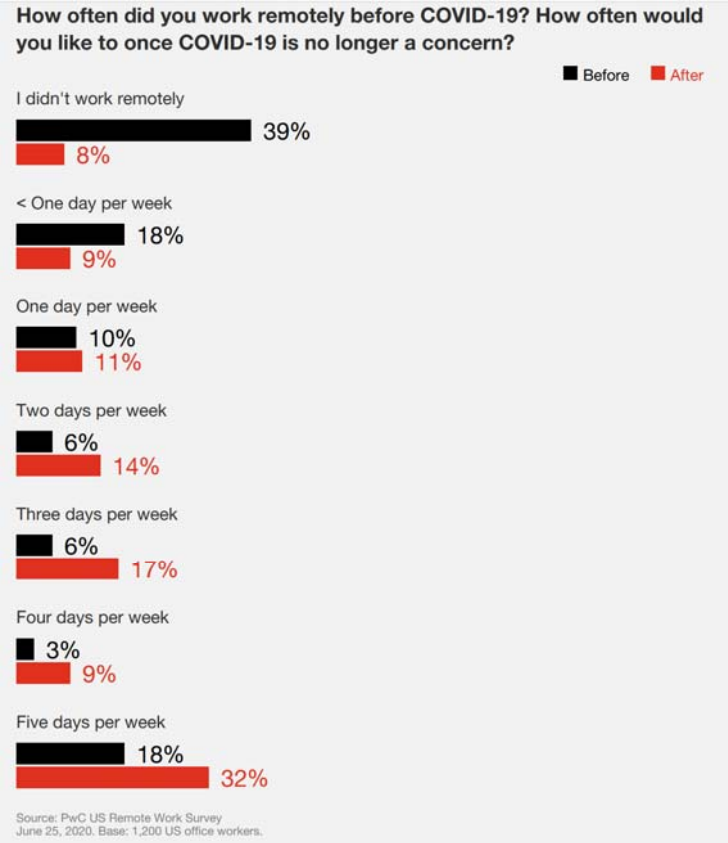


Figure 17: Employees' willingness to telecommuting after COVIDi n the US, June 2020[27]

Bartik et al. (2020) indicate that, in the NABE survey (leaders of large professional organizations for business economists), 36 percent of respondents believe that more than 40 percent of workers who had switched to remote work during the COVID-19 crisis would continue working remotely after the crisis ends. This number for the Alignable survey (1,770 leaders of the largest network and community of Small Business Owners in North America) were quite similar where 40 percent of firms thought that at least 40 percent of their workers that switched to remote work during the COVID-19 crisis would continue working remotely after the crisis ends. If these projections prove true, this suggests a significant reduction in future demand for office space and a huge change in transportation behavior compared to before COVID-19.

[27] Available at https://www.pwc.com/us/en/library/covid-19/us-remote-work-survey.html

IV. Changes in transportation due to teleworking

In addition to short-term changes during the COVID-19 outbreak, this drastic transformation of the world of work might account for the potentially disruptive medium- and long-term impacts on the careers of citizens. It is likely to bring major changes to mobility, transportation, and the environment. Crowley et al. (2020) examine the capability of people to engage in remote work and social distancing by commuter type in Ireland. The outputs of this study illustrate that those who commute by car have a relatively high potential for remote work (relative to walk, bike, and motor modes but not more than public transport users), but they are less likely to be able to engage in social distancing (relative to all other modes of commute) in their workplace. Thus, workers who cannot practice social distancing are encouraged to work from home or to remain off work. As a result, the number of workers commuting by car will probably drop in the short term and bring positive environmental impacts due to a reduction in car usage and greenhouse gas emissions. Although increased remote working can have immediate and direct environmental benefits, in the longer run, indirect costs associated with non-urban residential relocation, increased non-work-related trips, and car dependency may nullify any benefits.

Another study (Riggs, 2020) represents that while total work-based trips and VMT (vehicle-miles-traveled) decline slightly due to telework in the COVID-19 era, an increase happens in total trips from 3.97 to 4.45. This means that while VMT and the share of driving may decline, the number of trips and engine cold starts may go up. Figure 18 which shows workers' mode of commute to work and share of telecommuting before and during COVID-19, illustrates that 22% of Canadian workers work from home during COVID-19 (more than five times higher than before the pandemic) while the share of private vehicles drops slightly. As a result, the share of public transport and private vehicles reduce significantly. The drop in public transport share is tangible since it decreases to a quarter of before COVID-19.

This provides policymakers with a cautionary lesson for addressing climate and congestion goals through the telework era and highlights the importance of paying attention to the future of urban development, public transport, and behavioral strategies. Without any intervention, the trend could yield more trips and vehicle cold starts particularly on local roads, especially in places that auto vehicles continue to rely on internal combustion engines and without the wealth to facilitate a clean energy transition.

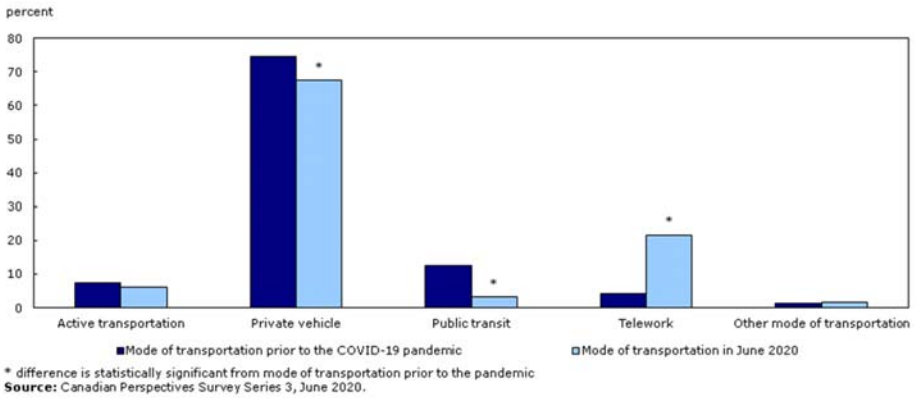


Figure 18: Canadian workers' mode of commute to work before and during COVID, June 2020[28]

7. Effects of COVID-19 on air pollution and the environment

On one hand, the introduction of stay-at-home restrictions to slow the spread of COVID-19, have greatly reduced transport-related emissions. On the other hand, changes in commuting behavior, related to an increase in remote working, will have implications for transport emissions and environmental outcomes. For example, in early April, lockdowns led to a 17 percent reduction worldwide in carbon pollution compared to the same period last year. Total emissions from industry and energy last year came to a record 37 billion tonnes. China, the United States, the European Union, and India are accounted for two-thirds of the downturn across the first four months of 2020, equivalent to more than one billion tonnes of CO_2.[29] Also, NO_2 has significantly reduced during lockdown (Crowley et al., 2020; Orro et al., 2020). Table 2 shows a summary of the studies that analyze pollutant concentrations in various parts of the world and compared the air pollution during COVID-19 to the pre-COVID-19 era. Figure 19 also shows the 14-day moving average NO_2 concentrations over five major European cities in 2019 compared to 2020. Nearly 40 - 50% reduction took place in the first stage of the lockdown in southern Europe. Based on the diagrams, NO_2 concentrations are still 10 - 20% lower than pre-COVID-19 levels. While many studies demonstrate a significant drop in air pollution, some studies explain that the decrease in pollutant concentrations is similar in magnitude to that observed during the same time in the previous years (Zangari et al. 2020; Orro et al., 2020). In other words, COVID-19 does not have

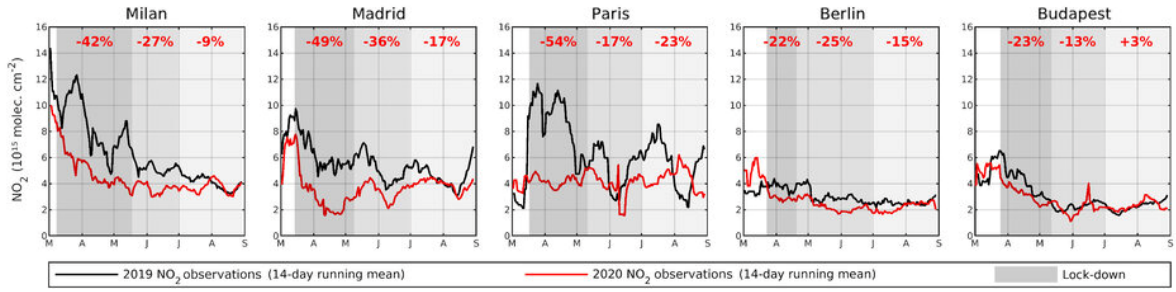
[28] Available at https://www150.statcan.gc.ca/n1/pub/45-28-0001/2020001/article/00069-eng.htm
[29] https://www.france24.com/en/20200520-co2-emissions-could-fall-7-percent-in-2020-due-to-covid-19-study-shows

any impact on air pollution. Therefore, temporal variability and long-term trends of pollutant concentrations should be taken into account when analyzing short-term differences in air pollutant concentrations related to the COVID-19 shutdowns. Even those who find a significant reduction between air pollution and COVID-19 lockdown believe that the reduction did not solely depend on COVID-19, and other factors, such as weather conditions, industrial activities, and biomass burning should be considered for further investigations.

Table 2: Change in air pollution during COVID-19 relative to pre-COVID

Study	Study Area	Pollutant				
		NOx	$PM_{2.5}$	PM_{10}	O_3	CO
Berman & Ebisu (2020)	The U.S.	-25.5%	-4.8 ppb			
NASA[30]	Northeast U.S.	-30%				
European Environmental Agency (EEA)[31]	Milan, Italy Bergamo, Italy Rome, Italy Barcelona, Spain Madrid, Spain Lisbon, Portugal	-21% -47% - 26 to 35% -55% -41% -51%				
Zangari et al. (2020)	New York City	Not significant	Not significant			
Orro et al. (2020)	A Coruña, Spain	-2.7 g/m^3N		Not significant		
Abdullah et al. (2020)	Malaysia		-50%			
Adams (2020)	Ontario, Canada	-2 ppb (29%)	Not significant		-1 ppb (3%)	
Ju et al. (2020)	Korea	-20.4%	-45.5%	-35.6%		-17.3%
Rodríguez-Urrego (2020)	50 most polluted capital cities		-12%			
Faridi et al. (2020)	Tehran, Iran		+20.5%	+16.5%		

[30] Available at https://www.nasa.gov/feature/goddard/2020/drop-in-air-pollution-over-northeast
[31] Available at https://www.eea.europa.eu/highlights/air-pollution-goes-down-as



Source: European Space Agency (ESA), Sentinel-5P data

Figure 19: Nitrogen dioxide concentrations observed over major European cities, Mar-Sep 2020[32]
(The shades of grey denote the lockdown periods in 2020, darker grey represents more strict restrictions.)

In addition to the effect of COVID-19 on air pollution, some studies seek the impact of pollutant concentration on COVID-19 propagation and mortality. For instance, Wu et al., 2020 find that a 1 $\mu g/m^3$ increase in $PM_{2.5}$ leads to an 8 percent increase in the COVID-19 mortality rate. Another study in Italy investigates the impacts of surface levels $PM_{2.5}$ or PM_{10} on the fast diffusion of COVID-19 because these pollutants have significant adverse effects on the human immune system (Zoran et al. 2020).

This section tends to address this question: can emissions savings be gained in the short and long term from changes that happened in the COVID-19 era. For instance, Fu et al. (2012) estimated that a 5 percent shift of the regular commuting workforce to full-time remote working would result in net energy savings of 0.36 percent relative to total transport energy use. Based on the study of Carvalho et al. (2020) who explore the purchasing behavior of individuals in the first two months of the COVID-19 in the Portuguese, Gas stations display a small contraction compared to transportation, probably reflecting a preference for private cars and relying on private cars for non-work trips in the COVID-19 era.

Another study shows that commuting 3 days per week instead of 5 days per week has the following impacts on the environment (for 100 employees per year)[33]:

- Reduction in vehicle-mile traveled: 154,000 VMT

[32] Available at https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Sentinel-5P/Air_pollution_in_a_post-COVID-19_world
[33] Global Work-from-Home Experience Survey Report (2020). Page 55-56. Available at https://we.ifma.org/wp-content/uploads/2020/04/WFH-Experience-Survey-Overview-4-4-2020.pdf

- Reduction in barrels of oil: 390 barrels
- Reduction in greenhouse gasses: 70 tons
- Saving trees: 1800 trees

Electricity demand dropped under lockdown, with dramatic reductions in services and industry only partially offset by a higher residential use. Figure 20 illustrates year-on-year changes in weekly electricity demand, weather corrected, in some European countries and India. Electricity demand in China dropped quickly with confinement. After decreasing by 11% in February, demand rebounded quickly and in August 2020 was 7% higher than in August 2019.

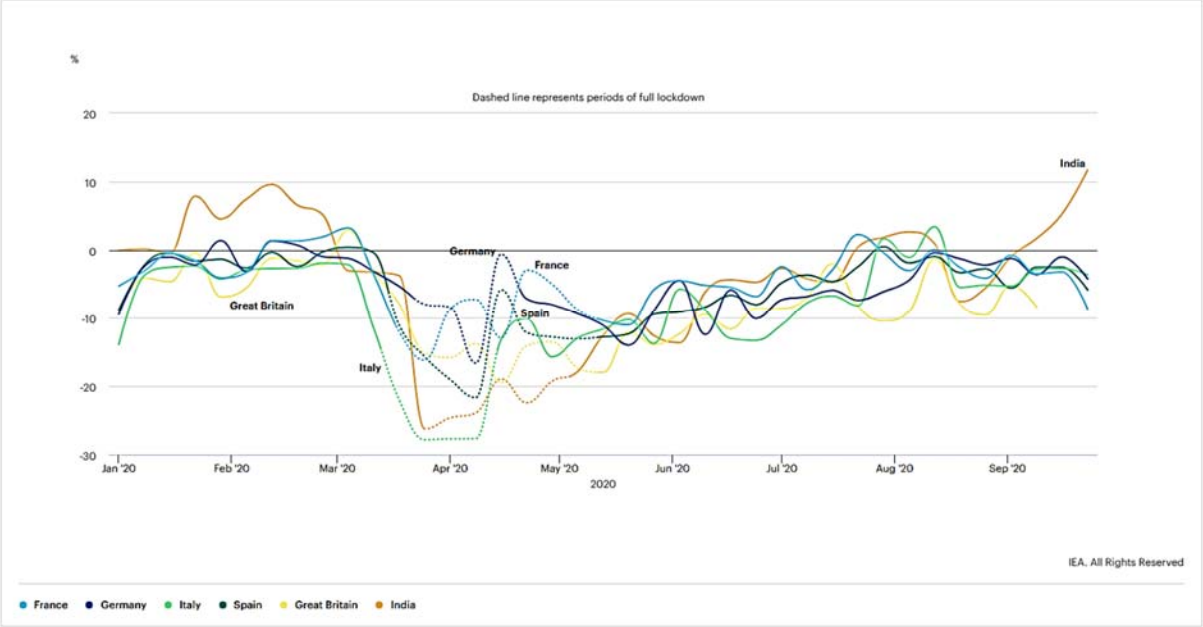


Figure 20: Year-on-year change in weekly electricity demand, weather corrected, in selected countries, Jan-Sep 2020[34]

World Health Organization (WHO) has called for an increase in the production of plastics by 40% to meet the rising global demand, due to the COVID-19 outbreak. According to the world energy council, the production of plastic is predicted to increase significantly by 2050. Discrepancies in the recycling industry could lead the waste to incineration, which could promote more greenhouse

[34] Available at https://www.iea.org/reports/covid-19-impact-on-electricity

gas emissions into the environment than expected, ultimately fueling global warming (Vanapalli et al., 2020).

8. Effects of COVID-19 on transportation

Studies from all over the world show that using public transportation decreased dramatically right after the initial lockdown. It continues to reduce during March and April, but it starts increasing in June when some restrictions are released (for example see Figure 21). However, all these papers agree on the fact that the demand for public transport in the "new normal" condition is still less than before COVID-19, and it might never come back to the previous normal. There are two reasons for this reduction: 1) risks of exposure to the virus are high in public transport, and 2) work from home, which may continue after COVID-19, results in lower commutes. In contrast, using auto vehicles is increasing, in part due to lower travel time, adequate free parking, and the absence of road pricing due to pandemic. As a result of all these changes, monitoring of adjustments in travel behavior is necessary to identify the changes including changes in ride-sharing and public transportation share required in the metropolitan transport models as well as in future transport and land use policymaking. Several studies that represent changes in travel behavior during the pandemic are discussed in this section.

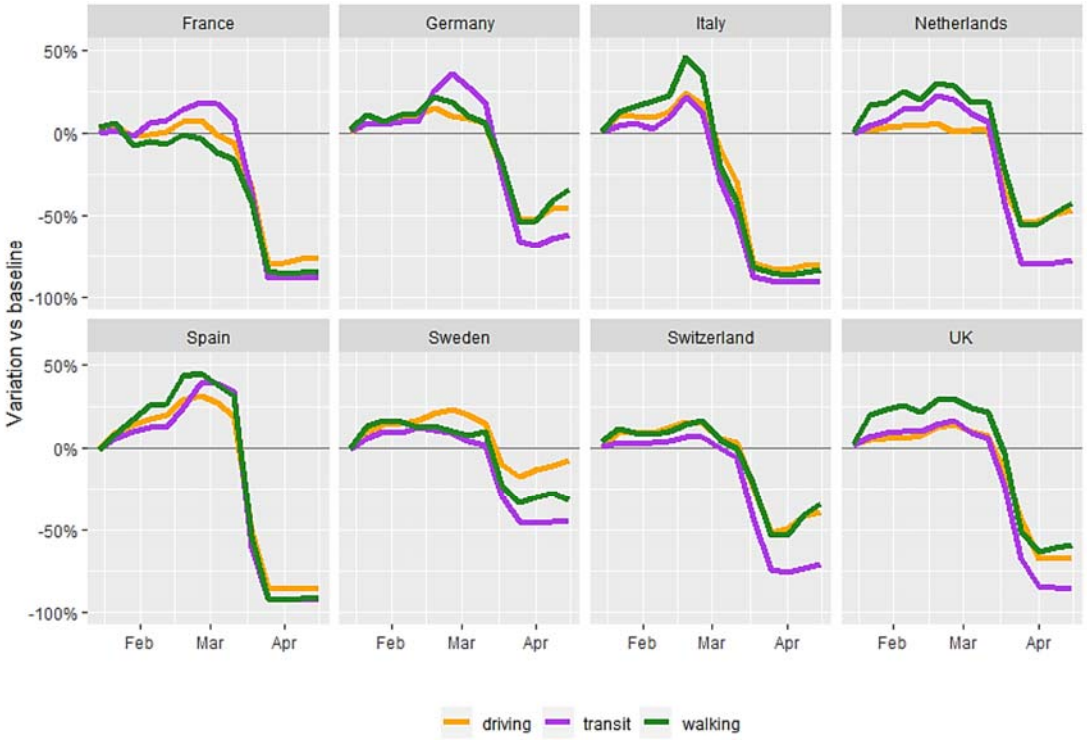


Figure 21: Variation of different transportation modes in some European countries, Feb-Apr 2020 (Falchetta & Noussan, 2020)

I. Mode choice changes during the COVID-19 outbreak

Beck and Hensher (2020), using data collected in Australia, compare the trip preferences in the second wave of the survey (in June) with the trips during the first wave of the survey (in April) and before COVID-19. Their analysis includes concerns about using public transport, number of trips, mode, and purpose of trips. They find out that aggregated travel demand has increased by 50 percent since initial restrictions but is still less than two-thirds of that it was before COVID-19.

Orro et al. (2020) distinguish the changes in public transport ridership, use of stops, OD flows, transit supply, travel time, and reliability of busses. For this purpose, the authors compared data from the first half of 2020 to data of 2017-2019 in A Coruña, Spain. The results are provided in Table 3. They find that the general traffic and the shared bike system recovered a higher percentage of their previous use than the bus system.

Table 3: Traffic volume and mode share changes during COVID-19 in A Coruña, Spain, the first half of 2020 (Orro et al., 2020)

	Before	Initial lockdown	Severe lockdown	Open up Phase 0	Open up Phase 1	Open up Phase 2	Open up Phase 3	New normal
Traffic Volume	100	30	17	32	55	70	75	85
Bus demand	100	15	9	12	20	35	45	60
Bicycle usage	100	0	0	40	50	70	50	70

Source: Orro et al. (2020), Figures 5, 6, and

A survey of 10,000 responses from across the US, with 78% of respondents working full-time, compares commute modes among US workers before and during COVID-19. Based on the information provided in Table 4, before COVID-19, 51% of respondents reported driving alone, less than 2% reported telecommuting, and less than 5% reported biking as their main commute mode, while, during COVID-19, 44% responded choose to drive alone, 12% plan to telecommute, and 11% plan to bike (or scooter).

Table 4: Share of commute modes before and during COVID-19 among American workers[35]

Era \ Mode	Drive alone	Public bus	Carpool	Bike/Scooter	Subway/Train	Walk	Commuter rail	Other	Telework	Vanpool	Private bus	Ferry	Taxi	Sum
Pre-COVID-19 (%)	51.1	19.4	9.4	4.9	4.1	2.8	2.6	1.9	1.8	0.9	0.7	0.2	0.2	100
During COVID-19 (%)	44.0	7.5	8.9	11.2	3.7	3.0	2.1	4.7	11.7	0.8	0.8	0.6	1.1	100

Pawar et al. (2020) identify the factors influencing the mode choice during the transition period (between no lockdown and lockdown), using data of 1,542 commuters in India. According to the survey results, 41% of commuters stopped traveling during the transition to the lockdown phase, 51.3% were using the same mode of transport and 5.3% of commuters shifted from public to private mode. They use a 5-fold decision tree technique and show that travel time, the distance between home and work, age, income, frequency of travel, and safety perception are the most

[35] https://www.actweb.org/i4a/headlines/?controller=headlines&action=headlineDetails&id=281&categoryID=0&startVal=1&newWindow=true

important decision factors of mode choice, respectively. Pawar et al. (2020), in Figure 22, show how commuters feel about the safety associated with personal health. Although 75.5% feel unsafe about the public mode of transport, safety perceptions of commuters interestingly did not play a significant role in mode choice behavior during the transition phase.

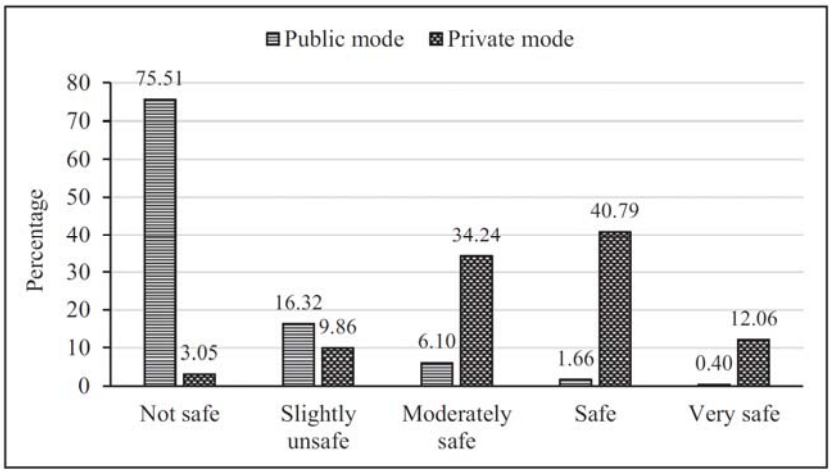
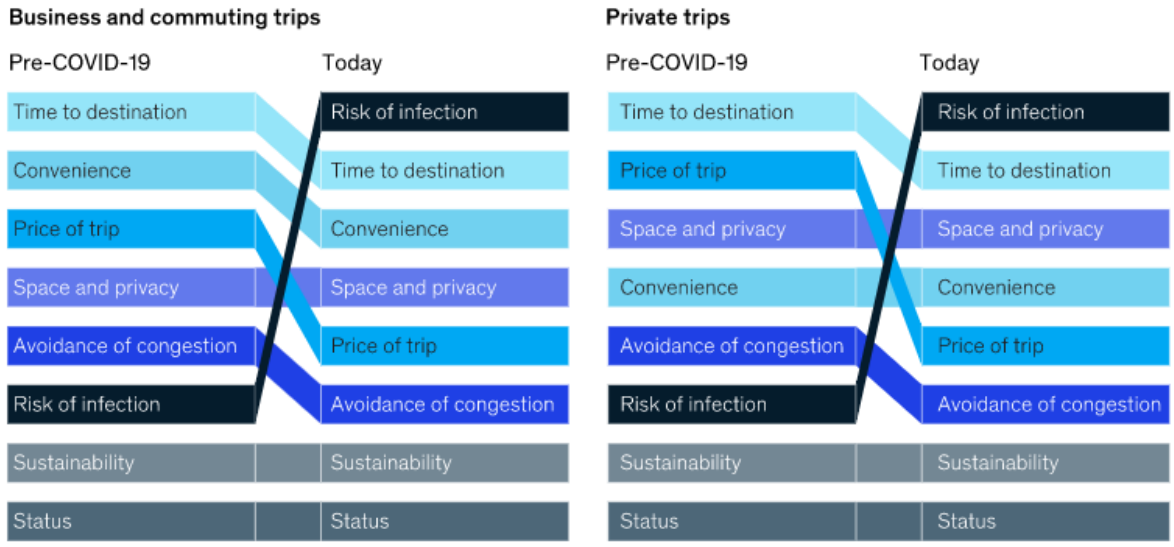


Figure 22: Commuters' safety perception during the transition to the lockdown phase of COVID-19 in India, March 2020 (Pawar et al. 2020)

A recent McKinsey survey[36] (in the United States, United Kingdom, Germany, France, Italy, Japan, and China) investigates the factors affecting mode choice. Figure 23 illustrates how key factors in mode choice have changed compared to pre-COVID-19 for private and business trips. Cost and convenience have traditionally played key roles when travelers choose transportation modes. Now "reducing the risk of infections" is the top reason many travelers make those choices, even much more important than travel time for both private and business trips. Interestingly, the trip price has lost relevance, especially for private travel.[37]

[36] Five COVID-19 aftershocks reshaping mobility's future September 2020, svailable at https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/five-covid-19-aftershocks-reshaping-mobilitys-future#

[37] https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/five-covid-19-aftershocks-reshaping-mobilitys-future#



[1]Question: What were/are your key reasons to choose a mode of transportation? Aggregated results from China, France, Germany, Italy, Japan, UK, and US. Reasons ranked by number of respondents.
Source: McKinsey Center for Future Mobility

Figure 23: Rank of key reasons to choose a mode of transportation in France, China, Germany, Italy, Japan, UK, and US, September 2020[38]

II. Public transport usage and the financial issues

Figure 24 demonstrates how public transportation usage around the world drops at first and starts to recover in June 2020, however it does not reach the previous normal by the end of October.

[38] https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/five-covid-19-aftershocks-reshaping-mobilitys-future#

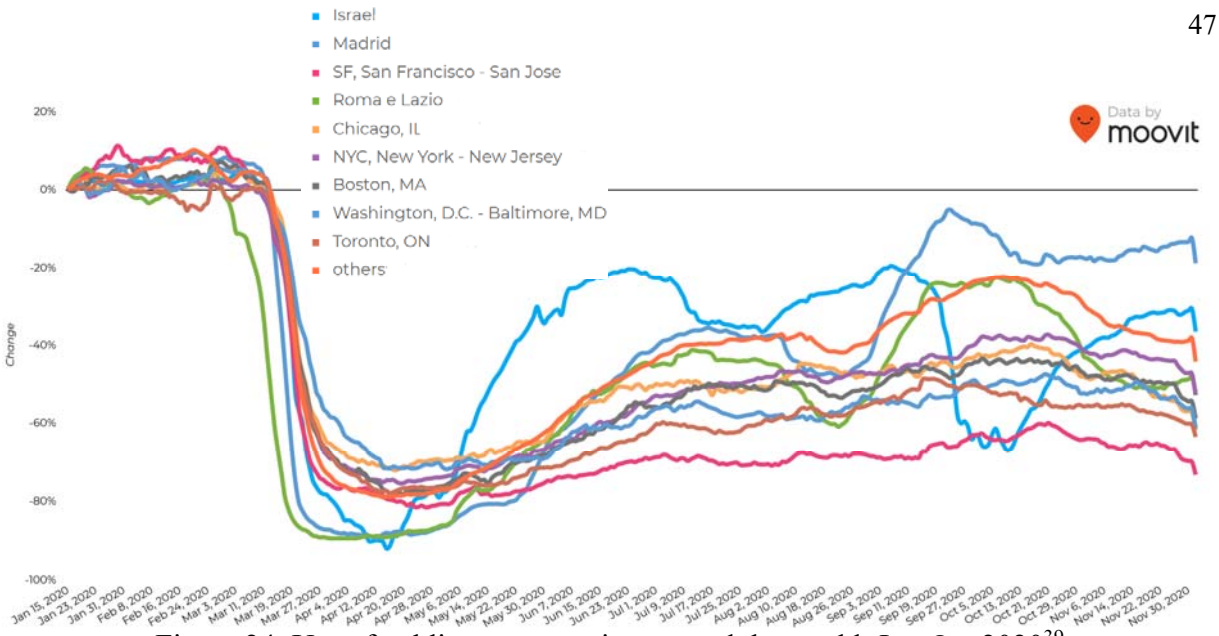


Figure 24: Use of public transportation around the world, Jan-Oct 2020[39]

The significant drop in public transport rideshare raises the concern that the pandemic could pose an existential threat to public transport operators around the world. The sector is now facing financial distress while the plummeting ridership during the lockdown and post-lockdown periods has led to a significant decrease in fares revenues. As a result, Systems that were originally more dependent on fares (as opposed to subsidies/tax revenues) might become bankrupt during or after the pandemic.

In the three most populated regions of Sweden (Stockholm, Västra Götaland, and Skåne) during spring 2020, travelers switched from monthly period tickets to single tickets and travel funds, while the use and the sales of short period tickets, used predominantly by tourists, dropped to almost zero (Jenelius and Cebecauer, 2020). In the data submitted by UITP members by May 7 and released on May 13, many European countries face (expected to face) huge losses in the public transport sector:[40]

- **France:** outside of Paris, local transport farebox revenue is expected to fall by more than €1bn with losses relating to accessing public transport estimated at €2bn. In Ile-de-France region centred on Paris, Ile-de-France Mobility has already reported losses of €2bn since the beginning of lockdown restrictions in mid-March. Paris Transport Authority (RATP) has lost around €320m with ridership dropping by 95%.

[39] Available at https://moovitapp.com/insights/en/Moovit_Insights_Public_Transit_Index-countries
[40] https://www.railjournal.com/financial/uitp-projects-e40bn-hit-for-european-public-transport-in-2020/

- **Germany**: public transport sector is expected to report a loss of €5-7bn, including €150m by BVG in Berlin.
- **Netherlands**: urban and regional public transport operators are projected to report a loss of €0.8-1bn in 2020
- **Spain**: public transport operators are currently losing €250m per month in fare revenues
- **Portugal:** public transport operators are currently losing €80m per month in fare revenues.
- **Sweden:** public transport operators are currently losing around €100m per month
- **Finland**: urban public transport market losses are expected to total €192m by the end of the year. Helsinki is expected to account for €150m of this figure.
- **Norway:** a reduction in income from tickets in March and April resulted in losses of around €100m, by the end of the year it is expected to be €400m. Additional costs due to safe distancing in school buses will be around €134m for a total loss of about €625m in 2020.
- **Italy:** the loss of farebox revenues will result in a €1.5bn shortfall in 2020 with a 50% reduction in passenger numbers. Milan Transport (ATM) is expecting losses of around €250m, while the Emilia-Romagana region is reporting losses of €20-25m per month.
- **Austria:** Wiener Linien has experienced an 80% drop in passenger numbers since mid-March and is expecting revenue losses of around €150m by the end of the year

Stimulus packages will have a direct impact on local jobs. To ease the pressure, some governments are providing short-term support in the form of contingency subsidies. Many other countries are struggling to funnel money to their systems, especially at a time when they are also under pressure to rescue labor-intensive sectors like tourism, hospitality, and manufacturing. Governments should begin drafting recovery measures to ensure the financial sustainability of transport companies, particularly as the pandemic pushes the global economy to a significant slowdown.

III. Paris Transportation

Figure 25 to Figure 27 depict Paris transportation before, during, and after the lockdown. Figure 25 shows that the daily tickets available are higher for rail compared with bus and tram. These available tickets drop approximately to zero during the lockdown. Right after the lockdown, daily tickets available starts to increase, however, rail transportation (Transilien, RER, Métro) appears to recover faster. Figure 26 and Figure 27 demonstrate the daily car count in Porte Maillot and A13 motorway, respectively, from 7 am to 8 am. In both locations, traffic drops significantly during the lockdown. However, the drops more intensive in Porte Maillot because it provides access to boulevard Peripherique and then more likely to be impacted by the lockdown. A13 is for

interurban and interurban usually suffer less than urban. The point is that car traffic rapidly increases in these two locations right after the lockdown.

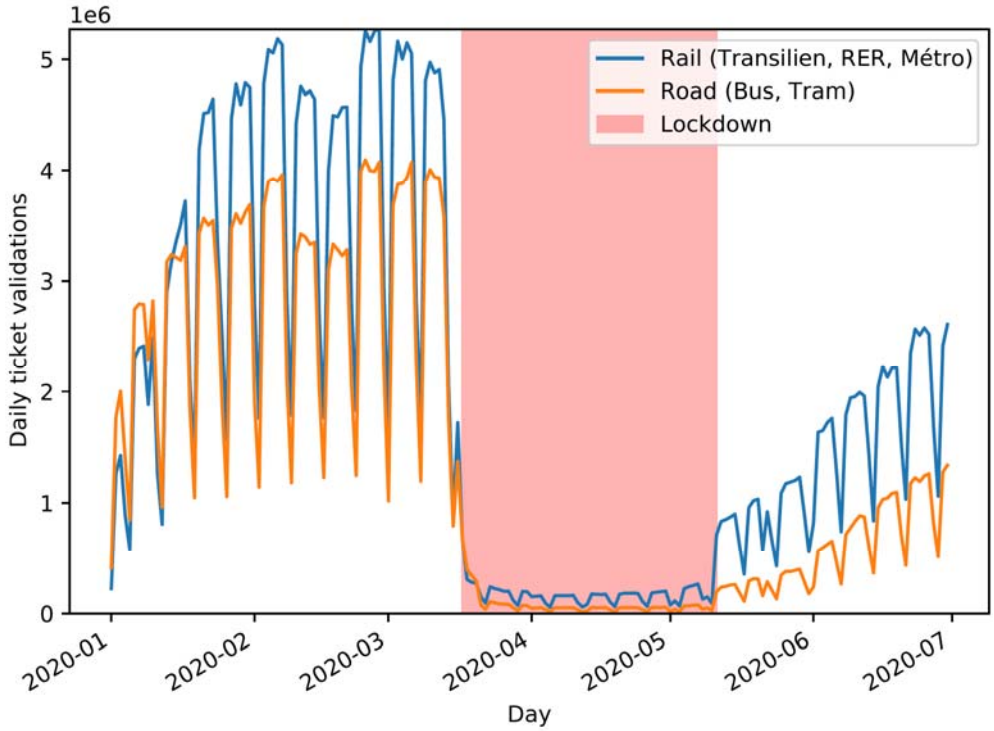


Figure 25: Daily ticket available for public transport in Paris, Jan-Jul 2020[41]

[41] Data from https://data.iledefrance-mobilites.fr/explore/dataset/validations-sur-le-reseau-ferre-nombre-de-validations-par-jour-1er-sem/ and https://opendata.paris.fr/explore/dataset/comptages-routiers-permanents/.
Diagram is extracted by Lucas Javaudin.

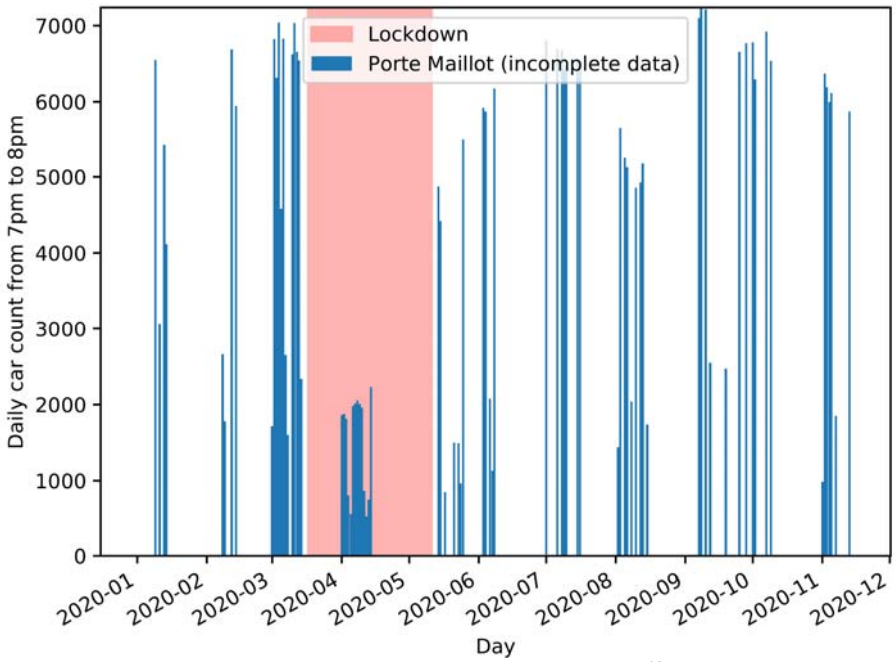


Figure 26: Daily car count at peak hour in Porte Maillot[42], Paris, Jan-Dec 2020[41]

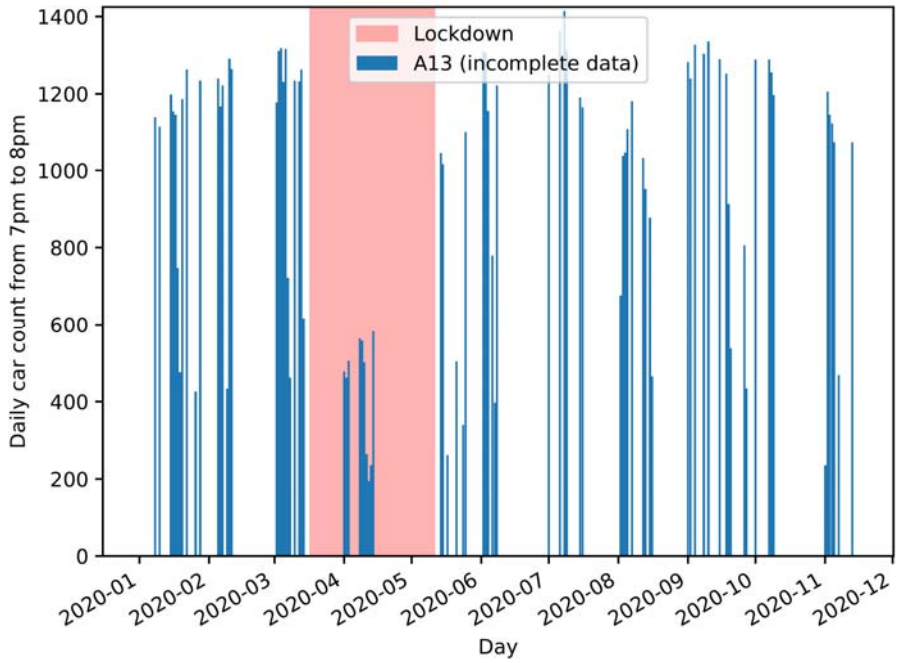


Figure 27: Daily car count at peak hour in A13[43] motorway, Paris, Jan-Dec 2020[41]

[42] Porte Maillot is a station on Paris Métro Line 1 and as Neuilly – Porte Maillot on the RER C.
[43] Autoroute 13, or L'Autoroute de Normandie starts in Paris at the Porte d'Auteuil, a former gate of the Paris walls, and ends at Mondeville's Mondeville 2 exchange junction on the Boulevard Périphérique.

IV. Peak spread

San Francisco-based research firm StreetLight Data[44] looked at traffic patterns in five major metropolitan areas and found that, by August 2020, vehicle miles traveled in each city had rebounded to previous highs. What is changed is that the morning rush hour has been almost eliminated but a much-more-intense rush hour occurs from 9 a.m. to 3 p.m. In other words, COVID-19 killed rush hour while spread pain all day.

The following maps (Figure 28 to Figure 31) compare traffic volumes in major European cities based on peak time travel at 8 AM on April 8th, 2019, and the same time and roads on April 6th, 2020. The data is a combination of real-time and historical and the maps are color-coded to show traffic volumes: red routes have heavy congestion, yellow is moderate, and green is clear.

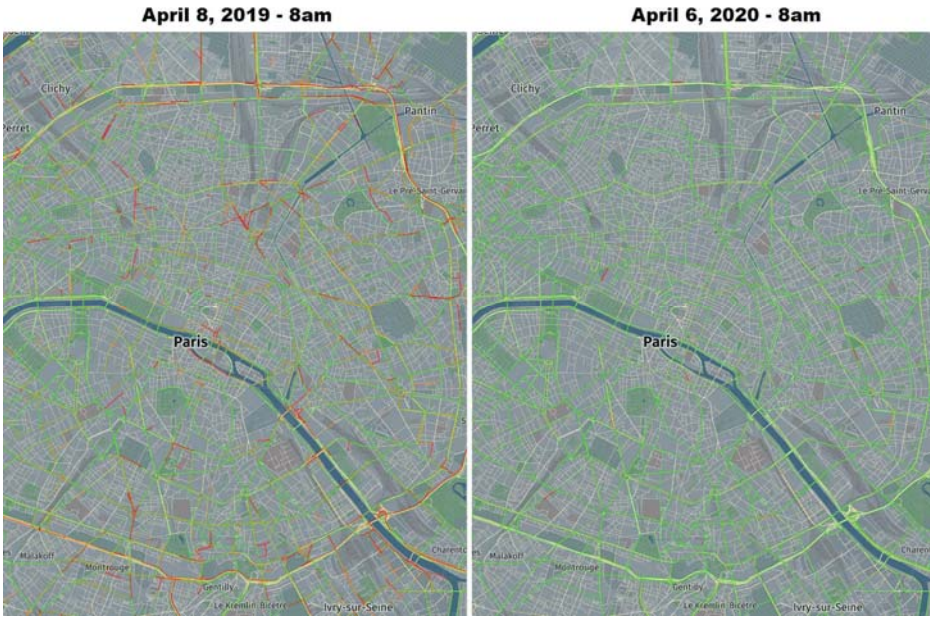


Figure 28: Paris peak spread – 96.8% reduction in traffic[45]

(State of confinement on 6th April 2020, in Paris: Ban on all travel except relating to professional activity, buying essential goods, health or family reasons, or brief individual exercise. Those outside the home were required to carry identification and a signed and dated declaration for any travel.)

[44] https://usa.streetsblog.org/2020/10/13/covid-killed-the-morning-rush-but-spread-the-pain-all-day/
[45] https://360.here.com/covid-19-impact-traffic-congestion

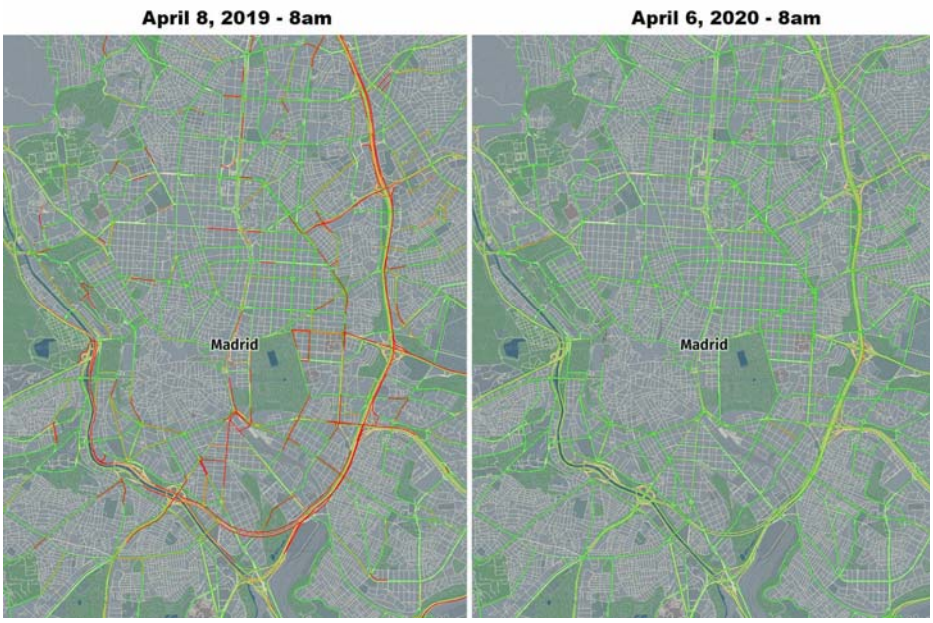


Figure 29: Madrid peak spread – 96.0% reduction in traffic[45]

(State of confinement on 6th April 2020, in Madrid: All non-essential workers were ordered to remain at home and temporary closure of non-essential shops and businesses, including bars, restaurants, cafes, cinemas, and commercial and retail businesses)

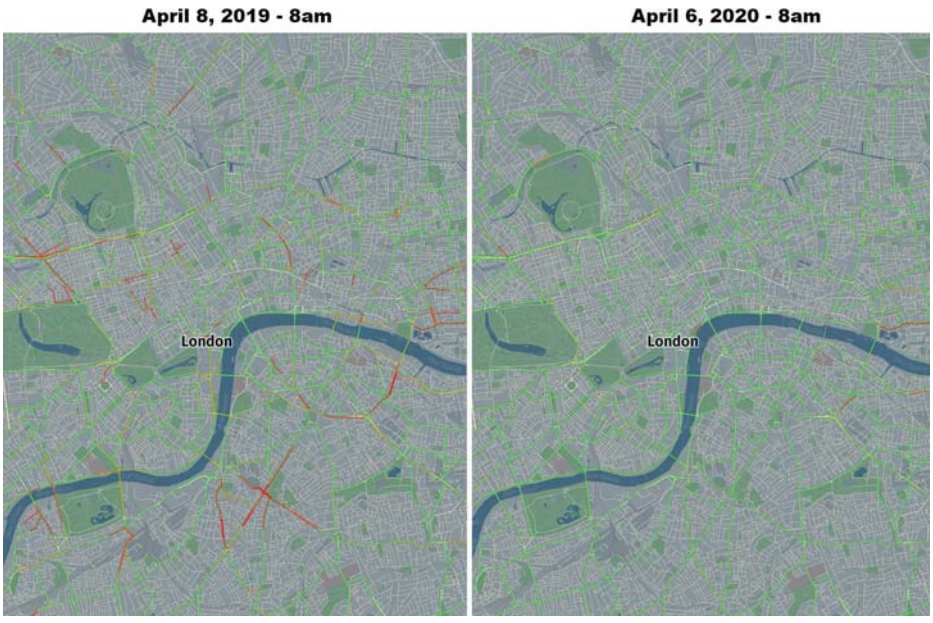


Figure 30: London peak spread – 90.2% reduction in traffic[45]

(State of confinement on 6th April 2020, in London: Wide-range restrictions on freedom of movement, enforceable in law under a stay-at-home order)

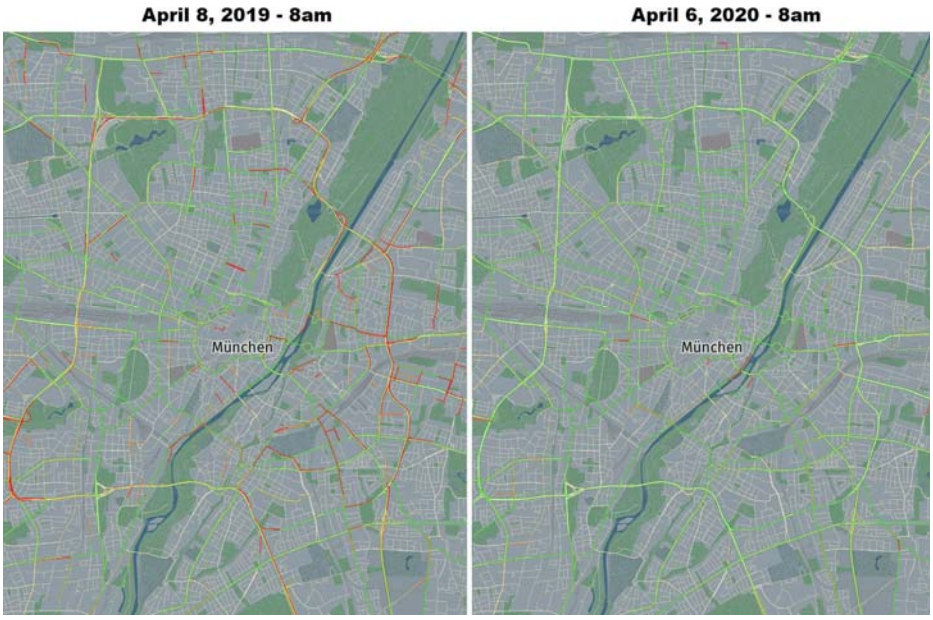


Figure 31: Munich peak spread – 88.6% reduction in traffic[45]

(State of confinement on 6th April 2020, in Munich: Non-essential shops, schools, all sports and leisure facilities were closed. Restaurants were ordered to limit their dine-in.)

The following figures show how the daily patterns of public and private transportation have changed in Paris during COVID-19. Based on Figure 32, the morning peak congestion level in Paris on Monday 28th Dec 2020 is 63% lower than the average Mondays in 2019 and the evening peak congestion level is 18% less than the average Mondays in 2019. Also, based on Figure 33, demand for public transportation in Paris on Sunday 27th Dec 2020 and Monday 28th Dec 2020 are 67% and 78% less than the normal, respectively. Figure 34 also depicts Paris congestion at morning and evening rush hour in all months in 2020 compared with 2019. Accordingly, April has the sharpest drop in rush hour traffic compared to 2019 while in August rush hour traffic has slightly increased compared to 2019.

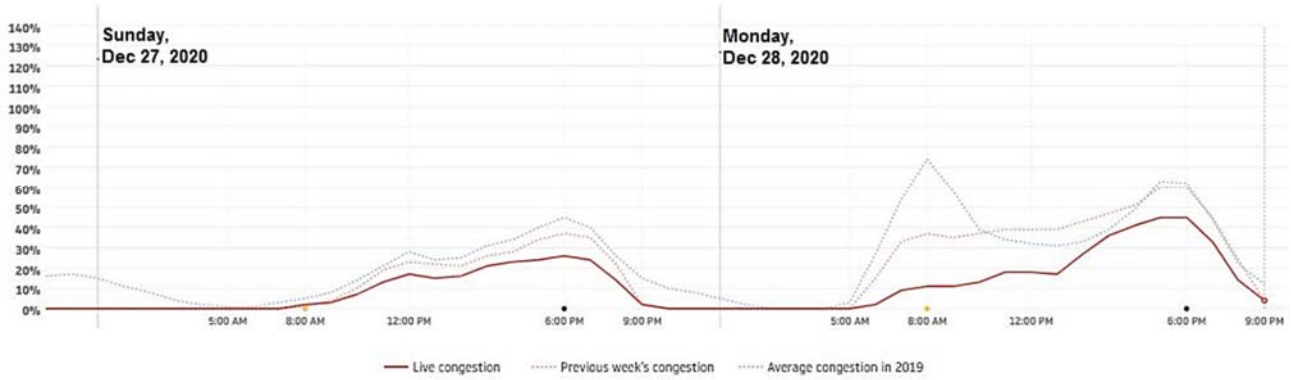


Figure 32: Hourly congestion level in Paris, Dec 27 and 28, 2020[46]

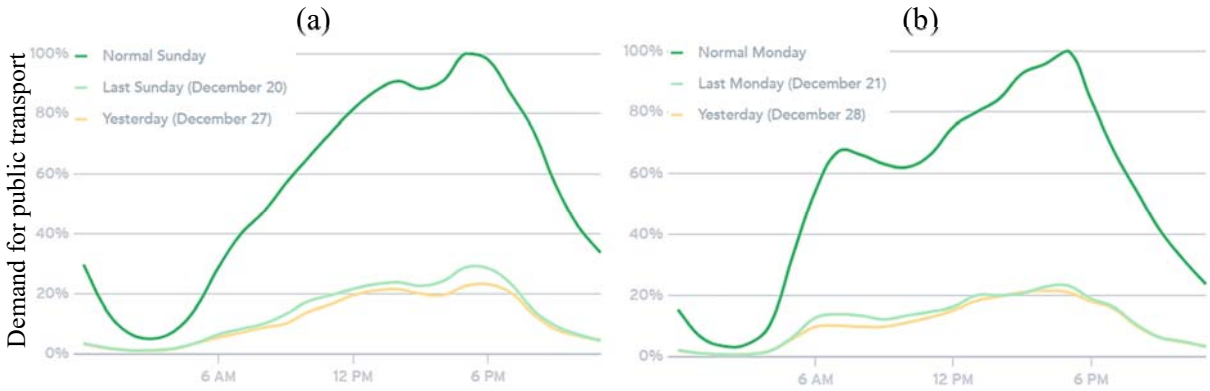


Figure 33: Demand for public transit by time of day in Paris[47]

(a) Sunday 27th Dec 2020, compared to normal Sundays, and (b) Monday 28th Dec 2020, compared to normal Mondays

Note that peak demand on a normal day is considered as "100 percent"

[46] https://www.tomtom.com/en_gb/traffic-index/paris-traffic/
[47] How Coronavirus is disrupting public transit, available at https://transitapp.com/coronavirus

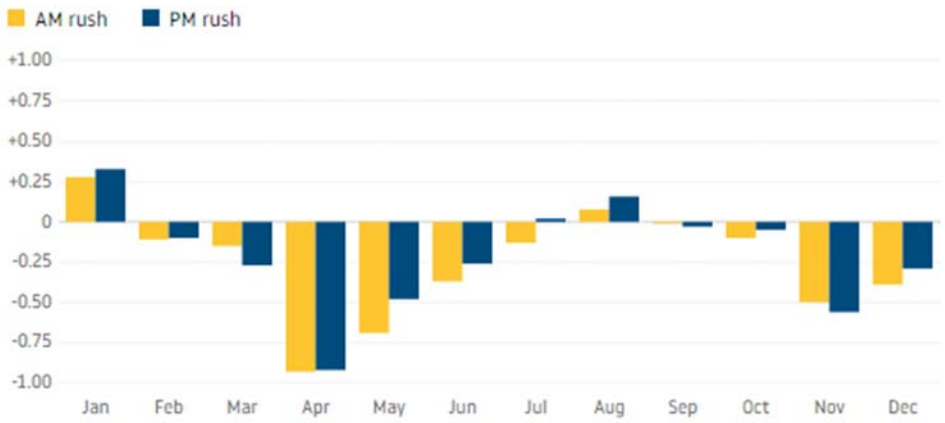


Figure 34: Paris congestion at morning and evening peak hour in 2020 compared to 2019[48]

With the spread peak worldwide since the onset of the COVID-19 crisis, more light public transportation can meet the more dispersed demand. In this situation, lightweight vehicles such as bicycles or scooters (micro-mobility), especially electric ones that may be borrowed as part of a self-service scheme in which people hire vehicles for short-term use within a town or city would be useful. To determine the full impact of the pandemic on this sector, as well as on future developments, micro-mobility is examined over three time horizons (Figure 35): Short term, medium term, long term.

[48] Available at https://www.tomtom.com/en_gb/traffic-index/paris-traffic/

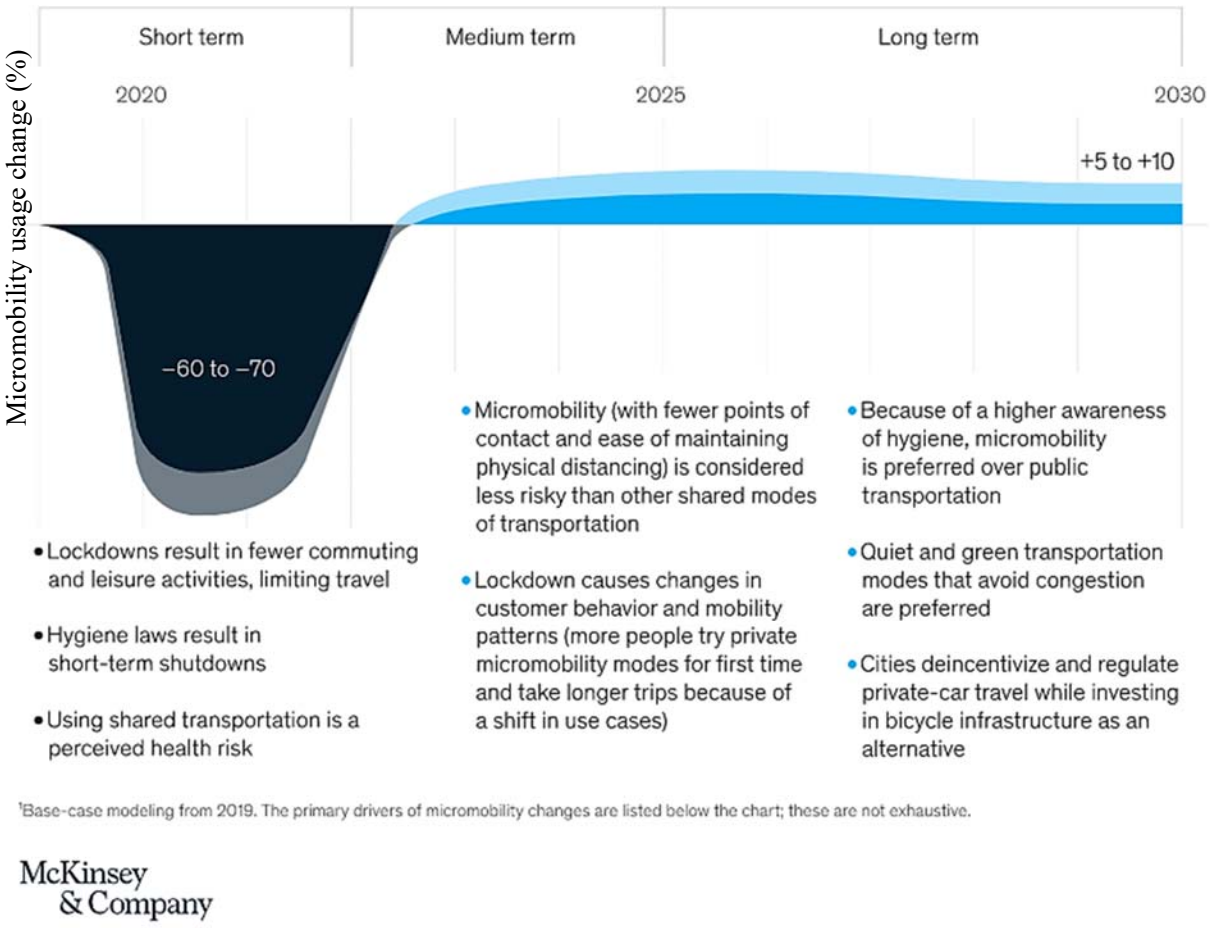


Figure 35: Impact of COVID-19 crisis on global shared and private micro-mobility[49]

V. Taxi and ridesharing usage

Nian et al. (2020) investigate the impact of COVID-19 on taxi travel behavior in Chongqing, China. The origin and destination of taxi trips are modeled as dependent variables. The results display that the number of taxi trips dropped sharply during the pandemic, and travel speed, travel time, and spatial distribution of taxi trips have been significantly influenced. The authors also develop a model to assess the social activity recovery level via the evaluation indicator system. Accordingly, the evaluation score in February is estimated to be 8.8 percent of May 2019. The assessment score started to rise from March and reached 81 percent of May 2019, followed by a

[49] https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/the-future-of-micromobility-ridership-and-revenue-after-a-crisis#

marginal decline in June to 74 percent. The rainy weather is known as the main reason for the decline in June.

Activities Recovery Level Evaluation Model

All indicators are extracted from the taxi travel datasets, including: Total trips, Total operating income, Proportion of night trips, Proportion of trips from transport hubs, Time utilization ratio, Mileage utilization rate, Average trip time, and Relative trip time of the morning peak.

The score of each indicator for each characteristic day are calculated and then converted to a 0–1 point by a standardization formula: $S_{ij} = (V_{ij} - V_{min,j})/(V_{max,j} - V_{min,j})$. The total score of each characteristic day is then aggregated by adding each indicator points and a higher total score represents a higher recovery level of social activities during the post-epidemic period.

- **Total trips**: Total number of taxi trips in one day
- **Total operating income**: Total operating income of taxi in one day
- **Proportion of night trips**: The number of taxi trips from 8 PM to 2 AM in the morning TNi account for the proportion of all-day taxi trips.
- **Proportion of trips from transport hubs**: The number of taxi trips departing from the transport hubs THi account for the proportion of all-day taxi trips.
- **Time utilization ratio**: Occupy time as a proportion of operating time
- **Mileage ultization rate**: Occupy mileage as a proportion of operating mileage
- **Average trip time**: Average travel time of taxi trips on the day W7
- **Relative trip time of the morning peak**: The ratio of the average taxi trip time during morning peak AMTi to the average trip time on the day

Ivaldi and Palikot (2020) explore the impact of the COVID-19 outbreak on the level of mobility and the price of ridesharing, using data collected from BlaBlaCar, one of the most popular ridesharing platforms in France. They show an increase in prices of city-to-city rides, which is determined by non-professional drivers, compared to the pre-pandemic. This indicates that a low supply of transportation alternatives (including restrictions in public transportation, lower number of BlaBlaCar, and the limited number of allowed sold seats) and higher health risks felt by drivers to have someone in their car are dominant in determining the price. Therefore, a decision-maker encouraging the use of ridesharing during or right after the COVID-19 outbreak should take the likely increase in prices into account.

With the impact of COVID-19, the global car-sharing market including key players (e.g. Uber (US), Lyft (US), DiDi (China), Grab (Singapore), Gett (Israel), Ola (India), BlaBlaCar (France), Lime (US), and Herts (US)) loses its share by 50–60% during 2020. Furthermore, by 2021, its share will increase and it will gain its market by 70–80% because of new strategies like providing partitions to keep the distance between driver and passenger, equipping the vehicle with sanitizers,

and installing devices to measure the body temperature of passengers to eliminate the threat of such infections in future. Figure 36 demonstrates how much ridesharing is projected for 2021.

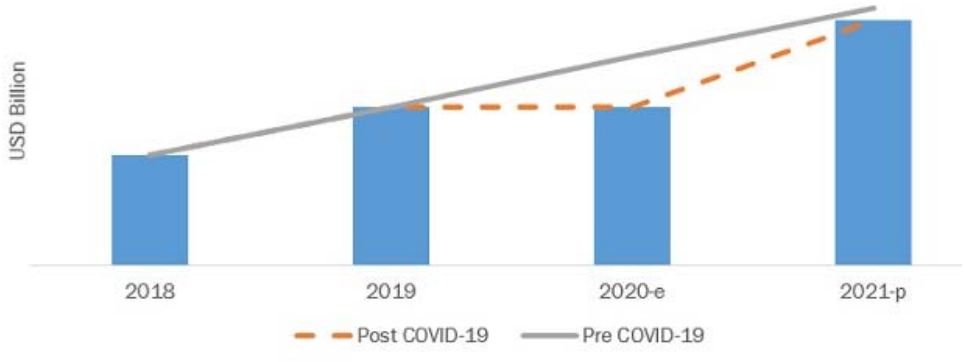


Figure 36: Global ridesharing market pre- and post-COVID[50]

including Uber (US), Lyft (US), DiDi (China), Grab (Singapore), Gett (Israel), Ola (India), BlaBlaCar (France), Lime (US), and Herts (US)

Table 5 shows how selected ride and share transport companies were affected and responded to the threat of total business collapse due to the threat of COVID-19. The companies profiled are some of the largest corporations with a presence (in most cases) across the world.

[50] Available at https://www.marketsandmarkets.com/Market-Reports/covid-19-impact-on-ride-sharing-market-15098676.html

Table 5: The impact of COVID-19 on the ride and share companies: Uber and Lyft (Nhamo et al., 2020; Figure 7.2)

Uber impact and response to COVID-19	Lyft impact and response to COVID-19
• First quarter results show revenue of $3.54 billion and a net loss of -$2.9 billion • Trip volumes fell −5% from year-on-year. However, on the company's earnings call, it was indicated that the rides business was down around −80% in comparison to the same period in 2019 • Instituted a hiring freeze and reduced customer support and recruiting teams by 14% of its corporate employees (about 3700 full-time employee roles) • Folding JUMP e-bike and e-scooter business into Lime • Discontinued Uber Eats in the Czech Republic, Egypt, Honduras, Romania, Saudi Arabia, Uruguay and Ukraine, due to losses in those areas in Q1 2020 • Transferred Uber Eats operations to its subsidiary, Careem, in the United Arab Emirates • Sued by the state of California for allegedly misclassifying drivers as contractors, instead of employees, to avoid paying for health benefits and other worker protections • Loss of $1.70 per share • Uber Eats was 50% up year-on-year as more people ordered food for delivery at home, and more restaurants signed up for deliveries • CEO waived his base salary of around $1 million, for the rest of 2020	• May rides went down more than 70% year-on-year • Sued by the state of California for allegedly misclassifying drivers as contractors, instead of employees to avoid paying for health benefits and other worker protections • Termination of approximately 17% of its employees and furloughed approximately 300 other employees • Reduction in base salary for exempt employees for about 3 months, ranging from 10% for most non-hourly employees and up to 30% for the senior leadership team • Board members voluntarily agreed to forego 30% of their cash compensation for the second quarter of 2020 • Expected to incur approximately $28 million to $36 million of restructuring and related charges, mostly related to employee severance and benefit costs, exclusive of stock-based compensation related charges • Loss from operations was $414.1 million in Q1 2020 • Realised a net loss of $398.1 million in the first quarter of 2020

9. Re-designing and re-spacing cities for resiliency

Cities and government planners are constantly making mobility decisions. They must design car lanes, pedestrian walkways, EV charging infrastructure, and much more. As consumer behavior has shifted during the pandemic, decision-makers have increasingly put cities at the center of their concerns. Bereitschaft and Scheller (2020) consider how COVID-19 might influence where and how people live, work, recreate, and discuss how cities might use planning and design strategies to improve resilience in the face of future pandemics. Their recommendations for cities to successfully combat the COVID-19 and/or future pandemics theoretically include:

- Planning, promoting, funding, constructing, and maintaining public green spaces and corridors near residences to allow individuals to exercise and maintain a healthy lifestyle during times of lockdowns and restricted mobility.

- Expansion of outdoor walk spaces near businesses and the easing of permitting processes during pandemics to allow businesses (especially restaurants) to use these spaces for de-densified business activities.
- Implementation of increased and innovative public transportation sanitation practices to not only mitigate the spread of pandemic diseases but to also prevent more common viruses and bacteria such as the common cold, influenza, staphylococcus, etc.
- Designing municipal and intergovernmental strategic plans for future pandemics that focus on contact tracing, mitigation strategies, patient housing, resource allocation, information provision, and intergovernmental cooperation.

Optimists argue is that COVID-19 is an opportunity for city planners to liberate more street space for pedestrians and cyclists, moving us closer to greener cities and a low carbon economy. Some examples are:

- Milan announced it transforms 35 km of streets previously used by cars to walk and cycling lanes after the lockdown (May through December 2020).
- Paris devoted 50 km of lanes usually reserved for cars to bicycles during the lockdown in summer; it also plans to invest $325 million to update its bicycle network.
- Brussels has continued transforming 40 km of car lanes into bike paths in May 2020.
- Seattle permanently closed 30 km of streets to most vehicles at the end of May, providing more space for people to walk and bike after the lockdown.
- Montreal announced the creation of over 320 km of new pedestrian and bike paths across the city beginning in June till summer.
- Berlin has repurposed some residential streets as “play streets” on Sundays during the lockdown and is also discussing the possibility of extending the program to other days of the week.

Current sidewalk widths in many cities, for instance, simply cannot accommodate more pedestrians in safe ways if physical distancing is required. Paris and New York, two very densely populated cities, currently recommend a distance of two meters (Figure 37). These constraints are exacerbated where access restrictions to shops require queuing.

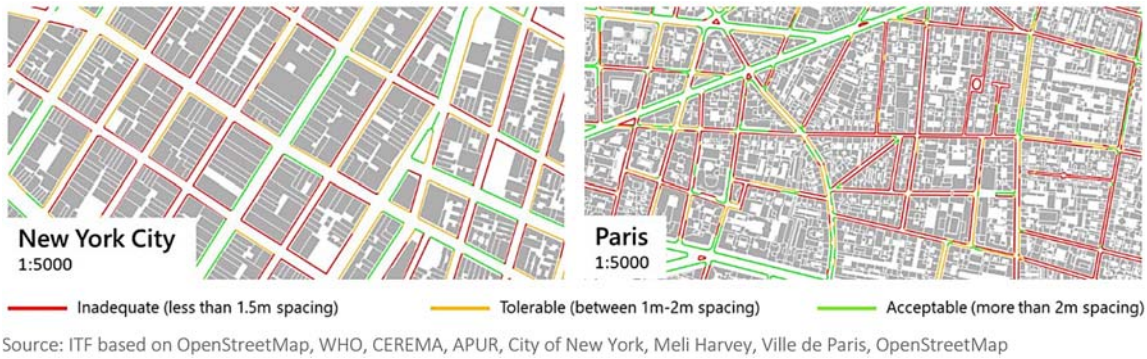


Figure 37: Space Walk: sidewalk conformity to physical spacing requirements in Paris and New York[51]

To make positive incentives for active transport modes, in several European countries, cyclists can claim rebates for every kilometer cycled into work. For instance, in the Netherlands, where cycling rates are the highest in the world, cyclists can claim €0.19 for every kilometer cycled to work. In response to the Covid-19 crisis, the French government announced a Sustainable Mobility Package, which includes up to €400 per year, tax-free, for employees who can prove the use of sustainable transport modes, including car-sharing and cycling.[52]

Besides, many food-delivery companies around the world benefit from cycling for much safer and economical delivery during COVID-19. Deliverloo[53], for instance, had 7,000 riders as of Apr 15, 2020. About 75 percent of these riders are on motorcycles, 22 percent are on bicycles and 3 percent are walkers or on e-bicycles. Only in the second week of April, their riders have been increased by 15 percent. It helps them to cope with the increased demand for food delivery with more people ordering since restaurants are currently unable to serve dine-in customers.[54]

Cities are repurposing streets to meet higher demands for walking and cycling. But not everyone can walk or ride a scooter or bike to their destination. Public transport must remain at the heart of urban mobility. Public transport should be redesigned to enable physical distancing, even though it reduces capacities such as shown in Figure 38.

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[51] International Transport Forum, OECD, COVID-19 transport brief: Re-spacing Our Cities For Resilience. May 2020. Available at https://www.itf-oecd.org/sites/default/files/respacing-cities-resilience-covid-19.pdf

[52] https://www.iea.org/articles/changes-in-transport-behaviour-during-the-covid-19-crisis

[53] Deliveroo is an online food delivery company founded in 2013 in London. It operates in over two hundred locations across the United Kingdom, the Netherlands, France, Belgium, Ireland, Spain, Italy, Australia, New Zealand, Singapore, Hong Kong, the United Arab Emirates and Kuwait.

[54] https://www.channelnewsasia.com/news/singapore/covid-19-food-delivery-platforms-spike-rider-signups--12651732

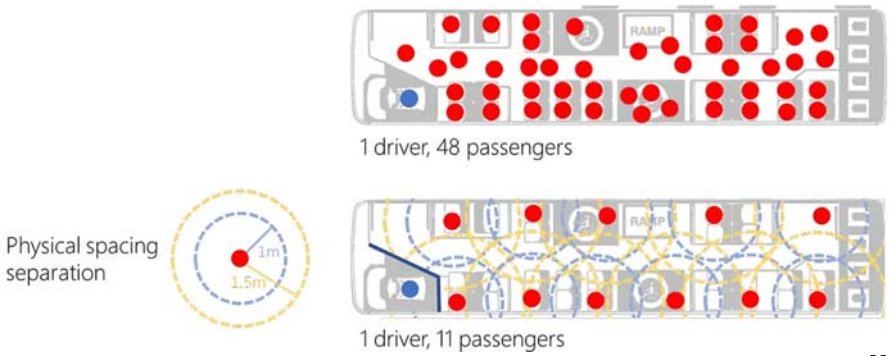

Figure 38: Impact of physical distancing on public transport capacity[55]

Some cities change their public transport fare to survive the pandemic. The Berliner Verkehrsbetriebe (BVG) - Berlin, Germany - provides free transportation to essential healthcare workers. It also altered the hours of operation to better align with medical shifts and capped all vehicles at 50 percent capacity.[56] Abu Dhabi's transportation system provides services for healthcare professionals. The service covers 36 local hospitals and clinics, offering door-to-door on-demand free rides to and from the local healthcare facilities. Vancouver's transportation network, TransLink, made its bus ridership free during the lockdown (April - June) to decrease the contact between passengers and their drivers.

Parking policies have been changed in some cities due to COVID-19 as well. For instance, in France, on-street parking was free in many places during the first lockdown in Spring. Meanwhile, free on-street parking is not available in Paris, Toulouse, Caen, Nancy, Nantes, and Lyon during the second lockdown.[57] In Paris, and to support the reopening after the first lockdown, the City Council exempted businesses from paying terrace fees until September 2020 and allowed them to be enlarged by using parking spaces.[58] In Paris, the plan is for 650 new kilometers of pop-up "corona cycleways", and the removal of 72% of on-street parking.[59] In Rotterdam, the program allows businesses to take over the parking spaces directly in front of their building, without a permit.[39]

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[55] International Transport Forum, OECD, COVID-19 transport brief: Re-spacing Our Cities For Resilience. May 2020. Available at https://www.itf-oecd.org/sites/default/files/respacing-cities-resilience-covid-19.pdf

[56] https://www.masstransitmag.com/alt-mobility/shared-mobility/article/21135013/via-transportation-10-cities-that-have-redefined-public-transportation-during-covid19

[57] https://www.connexionfrance.com/Practical/Your-Questions/France-lockdown-Will-on-street-parking-be-free-again

[58] https://iglus.org/reinventing-cities-in-a-post-covid-19-era-france/

[59] https://www.theguardian.com/world/2020/oct/12/liveable-streets-how-cities-are-prioritising-people-over-parking

10. Effects of COVID-19 on the tourism industry and air transportation

I. Air transport demand reduction and its impacts

The outbreak of COVID-19 resulted in a decline in global departures. As shown in Figure 39 in about 10 days after the pandemic declaration on 11 March 2020, global departures dropped to less than 10,000 aircraft globally. By the end of April 2020, there were fewer than 2,000 departures on average. Globally an estimated 95% of the departures were lost. According to CANSO (2020), flying hours declined by 56% in North America, and by 76% in Asia (Nhamo et al., 2020).

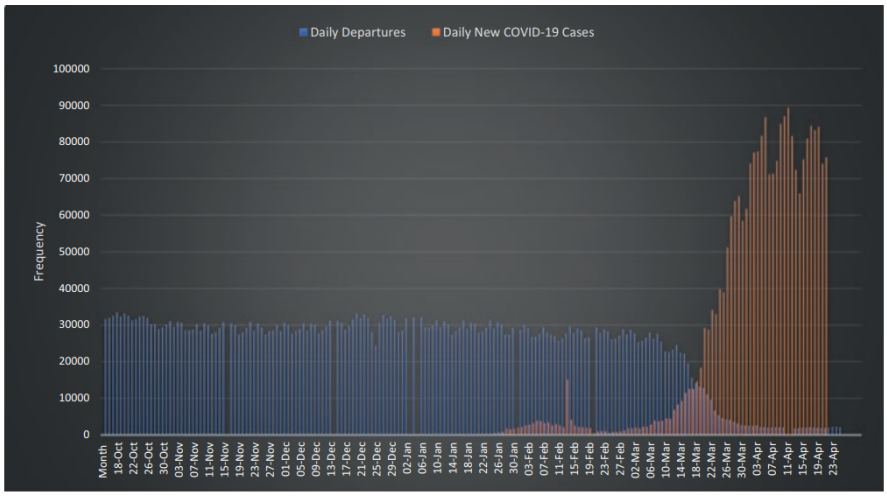


Figure 39: Daily traffic departures at all the airports and daily new COVID-19 cases, Oct 2019-Apr 2020 (Nhamo et al., 2020; Figure 5.2)

At the pandemic's peak in the United States, there was a 96% reduction in air travelers, which had shifted to a 73% reduction by mid-summer.[60] Figure 40 also depicts the reduction in daily traffic departures in North America and the Caribbean airports.

[60] Available at https://www.nationalacademies.org/trb/blog/covid-19-trends-impacting-the-future-of-transportation-planning-and-research

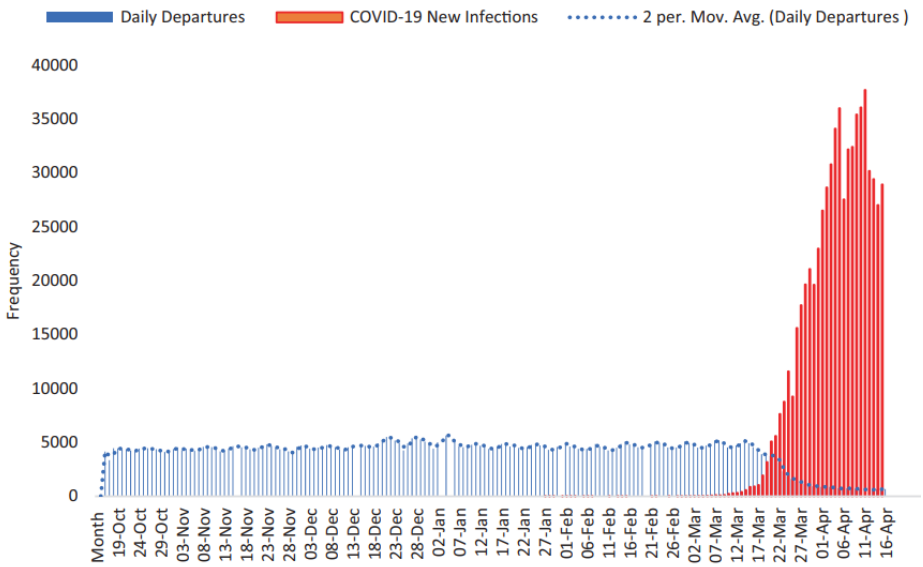


Figure 40: Impact of COVID-19 on daily aircraft departure in North America and the Caribbean, Oct 2019-Apr 2020 (Nhamo et al., 2020; Figure 5.6)

Due to COVID-19 travel restrictions and a decrease in air travel, aircraft were grounded across the world. Figure 41 shows a situation playing out across several airports in the world, with aircraft parked on pavements and runways. This led to pavement damage at some airports.

Figure 41: Aircraft parked at Paris' Charles de Gaulle Airport on April 26, 2020 [61]

[61] Available at https://spacenews.com/satellites-reveal-striking-impact-of-covid-19-on-people-and-air-quality/

Besides airport parking challenges, many economies and employment issues have occurred because of COVID-19 travel restrictions. Table 6 demonstrates the impact of COVID-19 on worldwide airline labor and employment. Accordingly, as air traffic halted during COVID-19 and is not expected to return to pre-crisis levels in a short time, total employment in the airline industry will also come under increasing pressure. Total employment by airlines is estimated to decline to 1.9 million in 2020. Productivity is likely to fall with the average employee generating 521,348 ATKs (Available Tonne-Kilometers) a year. Wages in the industry will decline by 13.6 percent in 2020 but despite declining unit labor costs, the squeeze on airline profit margins will continue. Table 7 also shows the impact of COVID-19 on the employment and economies of some airports around the world ("F" in this table means forecast).

Table 6: Impact of COVID-19 on worldwide airline labor and employment[62]

Worldwide airline Industry	2018	2019	2020F
Labour costs, $ billion	174	187	103
% change over year	2.5%	7.5%	-45.1%
Employment, million	2.79	2.90	1.87
% change over year	-0.7%	4.2%	-35.5%
Productivity, atk/employee	536,079	529,688	521,348
% change over year	6.8%	-1.2%	-1.6%
Unit labour cost, $/ATK	0.117	0.122	0.105
% change over year	-3.4%	4.4%	-13.6%
GVA/employee, $	99,858	98,498	80,289
% change over year	5.1%	-1.4%	-18.5%

Note: ATK = Available Tonne Kilometers, GVA = Gross Value Added (firm-level GDP). Sources: IATA, ICAO, ATAG, Oxford Economics

[62] Available at https://www.iata.org/en/iata-repository/publications/economic-reports/airline-industry-economic-performance-june-2020-report/

Table 7: Impact of COVID-19 on selected airport labor and employment (Nhamo et al., 2020; Table 5.1)

Name of airport/ground handling company	Number of dismissed/furloughed employees
Leeds Bradford Airport	Up to 250 people directly employed by the airport were laid off
Houston Airport	Swissport temporarily laid off at least 50 full-time employees of its airport staff
	United Airlines, which uses 60% of the airport and employs nearly 14,000 people in the Houston area, indicated the intention to lay off airport staff
Charlotte Douglas Airport	112 airport workers lost their jobs
	More than 600 HMSHost employees lost their jobs after the airport closed restaurants and bars
John Menzies Axes	17,500 employees in 200 countries were dismissed globally, which was 50% of its workforce (BBC 2020)
Airports in India	35,000 ground handling agents were placed on forced leave without pay (Simhan 2020)
Heathrow Airport	Security guards and firefighters accepted a 10% reduction in their pay for 9 months
	Other airport staff were forced to take a 15% salary reduction after business fell by 90% (Partridge 2020)
	In 2019, the airport had, on average, 7827 monthly employees (Heathrow 2019b)
Bristol Airport	Furloughed 80% of staff (Gogarty 2020)

In the near-term, consumers will face lower real travel costs as airlines are significantly discounting ticket prices to stimulate demand. The average return fare (before surcharges and tax) of $254 in 2020 is forecast to be 68% lower than in 1998, after adjusting for inflation. The share of world GDP spent on air transport is expected to be halved in 2020, totaling $434 billion (0.5% of GDP) during widespread lockdowns. Revenue Passenger-Km is estimated to fall by 55% in 2020 compared to last year. More details on the economic performance of the airline industry are shown in Table 8 (“F” in this table means forecast).

Table 8: Worldwide economic performance of the airline industry[63]

Worldwide airline Industry	2019	2020F	2021F
Spend on air transport*, $billion	876	434	598
% change over year	3.6%	-50.4%	37.7%
% global GDP	1.0%	0.5%	0.6%
Return fare, $/pax. (2018$)	317	254	257
Compared to 1998	-61%	-68%	-68%
Freight rate, $/kg (2018$)	1.82	2.31	2.26
Compared to 1998	-64%	-54%	-55%
Passenger departures, million	4,543	2,246	3,384
% change over year	3.8%	-50.6%	50.6%
RPKs, billion	8680	3929	6099
% change over year	4.2%	-54.7%	55.2%
CTKs, billion	254	211	263
% change over year	-3.2%	-16.8%	24.6%
World GDP growth, %	2.5%	-5.0%	7.1%
World trade growth, %	0.9%	-12.9%	21.3%

Note: RPK = Revenue Passenger Km, CTK = Cargo & mail Tonne Km
GVA = Gross Valued Added (firm-level GDP). *Airline revenue + indirect taxes.
Sources : IATA, ICAO, OE, CPB, PaxIS, CargoIS, WTO

Based on Table 9, the fuel used by airlines declines to $78 billion in 2020 (which will represent around 15% of average operating costs) and $85 billion in 2021. Although the estimation of 2021 is a bit higher than in 2020, it is still less than half of the fuel used in 2019. This decline is a reflection of less traffic given the collapse in demand and the sharp decrease in oil prices. As much of the industry was grounded throughout the second quarter of the year, CO_2 emissions are expected to be 37.1% lower compared to 2019 ("F" in this table means forecast).

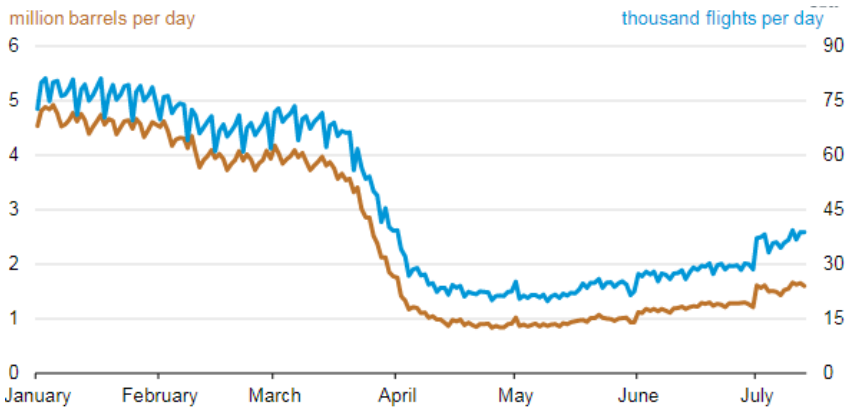
[63] Available at https://www.iata.org/en/iata-repository/publications/economic-reports/airline-industry-economic-performance-june-2020-report/

Table 9: Fuel-related statistics of the worldwide airline industry[64]

Worldwide airline Industry	2019	2020F	2021F
Fuel spend, $billion	188	78	85
% change over year	4.7%	-58.8%	9.1%
% operating costs	23.7%	15.0%	13.6%
Fuel use, billion litres	363	228	297
% change over year	1.0%	-37.1%	30.3%
Fuel efficiency, litre fuel/100atk	22.4	22.1	21.9
% change over year	-1.9%	-1.0%	-1.1%
CO_2, million tonnes	914	574	748
% change over year	1.0%	-37.1%	30.3%
Fuel price, $/barrel	77.0	36.8	51.8
% change over year	-10.6%	-52.3%	40.8%
% spread over oil price	18.5%	5.0%	15.0%

Note: ATK = Available Tonne Kilometers. Sources: Ascend, ICAO, IATA.

Other statistics show that commercial jet fuel consumption has a similar pattern with commercial passenger demand, as shown in Figure 42, falling from an average of 4.3 million barrels per day in January and February to 1.0 million barrels per day in April. Consumption of jet fuel by commercial passenger flights is estimated to be averaged 1.6 million barrels per day during the first two weeks of July, 69% less than the level one year ago. Figure 43 depicts the daily fuel consumption for different parts of the world.

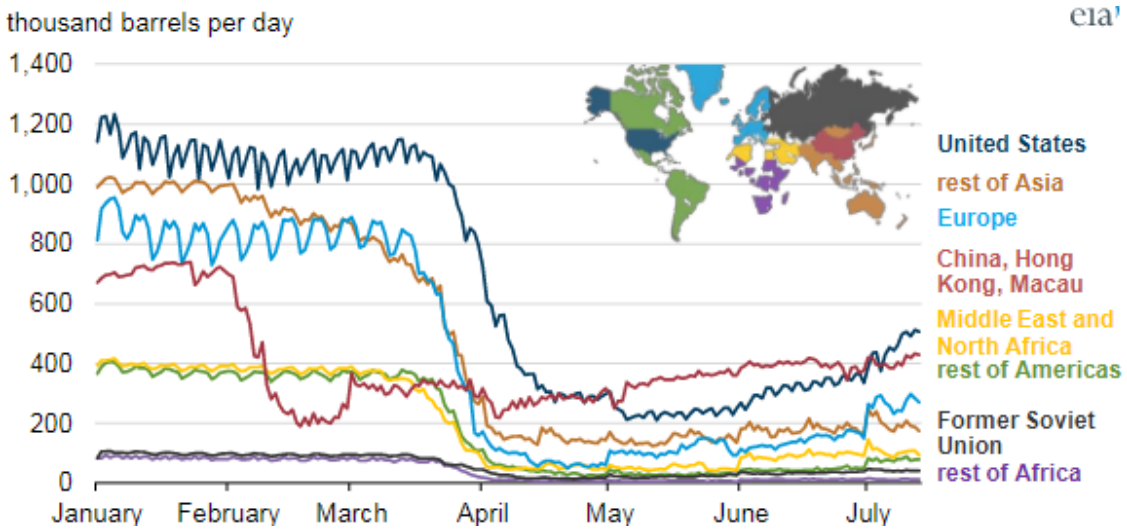


Source: U.S. Energy Information Administration (EIA)

Figure 42: Global commercial passenger flights and jet fuel consumption, Jan-Jul 2020[65]

[64] Available at https://www.iata.org/en/iata-repository/publications/economic-reports/airline-industry-economic-performance-june-2020-report/

[65] Available at https://www.eia.gov/todayinenergy/detail.php?id=44676



Source: U.S. Energy Information Administration (EIA)

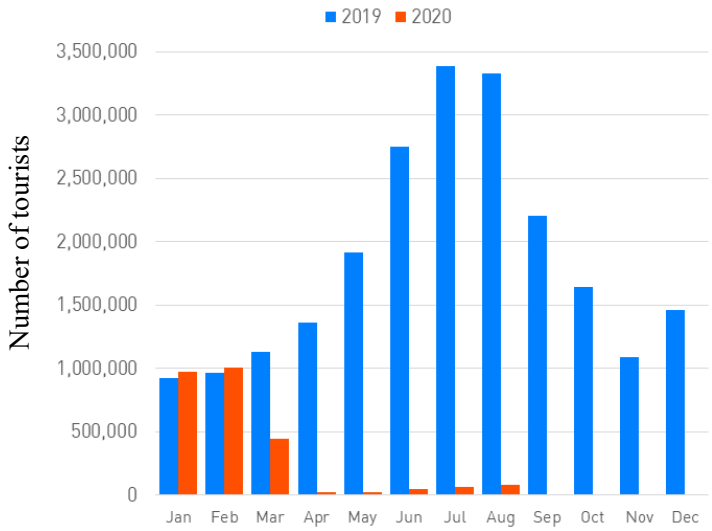
Figure 43: Jet fuel consumption by commercial passenger flights in different regions, Jan-Jul 2020[66]

II. International tourist reduction

Global tourist arrivals dropped significantly during the pandemic, as shown in Figure 44. Blue columns show the growth rate of tourist arrivals relative to the previous year in various regions while orange columns demonstrate the drops in tourist arrivals in 2020 during the pandemic relative to 2019. The drop-in tourist arrivals cost the world close to $80 billion in export revenue in the first 3 months of the year 2020. Data from UNWTO shows that various global tourism regions have been severely affected by the pandemic, albeit variations in impact can be observed across various regions with the least impact noted in the Middle East and Africa. Another statistic from Canada shown in Figure 45 represents that international tourists entering or returning to Canada sharply decreased in 2020 compared to 2019.

[66] Available at https://www.eia.gov/todayinenergy/detail.php?id=44676

Figure 44: Global tourism growth rate for the first quarter of 2019 compared to 2020 (Nhamo et al., 2020; Figure 7.1)



Source: Statistics Canada; Table 24-10-0043-01; September 2020.

Figure 45: International tourists entering or returning to Canada[67]

[67] Available at https://www.mortgagesandbox.com/vancouver-real-estate-forecast

III. Air passenger forecast for Paris-Charles de Gaulle and Paris-Orly airports

Paul Chiambaretto, who is an associate professor at Montpellier Business School, provides predictions of Instrument Flight Rules (IFR) and the number of air passengers in France. His research theme includes strategy, alliances, coopetition, and air transport industry. He uses various data sets and defines three different scenarios about COVID-19 vaccine availability since no one knows what will happen in the future. The details of his computation are as follows:

III-a) Databases used for the forecasts

These forecasts are based on 2 different sources of data:

- The French Civil Aviation Authority (DGAC)'s database concerning the number of passengers flown in France from 2016 to 2019[68]. This database was used for:
  - The total number of air passengers in France from 2016 to 2019
  - The total number of air passengers at Paris-CDG from 2016 to 2019
  - The total number of air passengers at Paris-ORY from 2016 to 2019

- Eurocontrol's five-year forecasts for air traffic in Europe from 2020 to 2024[69]. This database was used for:
  - The total number of IFR flights in France from 2016 to 2019
  - The forecasted number of IFR flights in France from 2020 to 2024 based on 3 different scenarios
    - Scenario 1: Vaccine available in 2021
    - Scenario 2: Vaccine available in 2022
    - Scenario 3: No vaccine found in the near future

III-b) A 3-step method to provide forecasts

Step 1: Building on the DGAC and Eurocontrol's statistics for the 2016-2019 period, we aim at obtaining average ratios between IFR flights, the number of passengers in France and at both Paris airports, as shown in Table 10. We also use these values to compute the average annual growth rate over the 2016-2019 period that will be used in step 3.

[68] https://www.ecologie.gouv.fr/statistiques-du-trafic-aerien
[69] https://www.eurocontrol.int/publication/eurocontrol-five-year-forecast-2020-2024

Table 10: Average annual growth rate over 2016-2019 at both Paris airports[70]

	2016	2017	2018	2019	Average Annual Growth (2016-2019)
Number of IFR flights (thousands)	3124	3241	3328	3372	2.6%
Number of air passengers in France (millions)	154.6	164	172.5	179.6	5.1%
Number of air passengers in Paris CDG (millions)	65.9	69.5	72.2	76.2	5.0%
Number of air passengers in Paris ORY (millions)	31.2	32	33.1	31.9	0.7%
	2016	**2017**	**2018**	**2019**	**Average value (2016-19)**
Ratio Passengers in France/IFR	49.49	50.60	51.83	53.26	51.30
Ratio CDG/Passengers in France	42.6%	42.4%	41.9%	42.4%	42%
Ration ORY/Passengers in France	20.2%	19.5%	19.2%	17.8%	19%

Step 2: Using the forecasts made by Eurocontrol for the 2020-2024 period regarding the number of IFR flights in France and relying on the ratios obtained in step 1, we calculate for the following scenarios and present the results in Table 11.

- The number of passengers in France
- The number of passengers at Paris-CDG
- The number of passengers at Paris-ORY

Table 11: IFR and number of air passengers forecasts for 2020-2024[70]

Scenario 1 (Vaccine in 2021)	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Number of IFR flights (000)*	3372	1,394	2,353	2,875	3,147	3,374
Number of air passengers in France (000)	179,600	71,507	120,700	147,476	161,429	173,073
Number of passengers at Paris CDG (000)	76,200	30,263	51,082	62,415	68,320	73,248
Number of passengers at Paris ORY (000)	31,999	13,701	23,127	28,258	30,931	33,162
Scenario 2 (Vaccine in 2022)		**2020**	**2021**	**2022**	**2023**	**2024**
Number of IFR flights (000)*	3372	1,369	1,638	2,351	2,701	3,042
Number of air passengers in France (000)	179,600	70,224	84,023	120,597	138,551	156,043
Number of passengers at Paris CDG (000)	76,200	29,720	35,560	51,039	58,637	66,040
Number of passengers at Paris ORY (000)	31,999	13,456	16,100	23,107	26,548	29,899
Scenario 3 (No vaccine in the near future)		**2020**	**2021**	**2022**	**2023**	**2024**
Number of IFR flights (000)*	3372	1,365	1,597	1,883	2,178	2,443
Number of air passengers in France (000)	179,600	70,019	81,920	96,591	11,1723	125,316
Number of passengers at Paris CDG (000)	76,200	29,633	34,670	40,879	47,283	53,036
Number of passengers at Paris ORY (000)	31,999	13,416	15,697	18,508	21,407	24,012

**Based on Eurocontrol's forecasts*

[70] Computed by Paul Chiambaretto

Step 3: Using the values obtained for the year 2024 as a reference, we make forecasts for the 2025-2030 period based on the average annual growth rate of the pre-COVID-19 phase (2016-2019) showed in Table 12. We apply the different growth rates obtained in Step 1 for the number of IFR flights (2.6%), the total number of air passengers in France (5.1%), in Paris CDG (5.0%), and Paris ORY (0.7%).

Table 12: IFR and number of air passengers forecasts for 2025-2030[70]

Scenario 1 (Vaccine in 2021)	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Number of IFR flights (000)	3,462	3,552	3,644	3,739	3,836	3,936
Number of air passengers in France (000)	181,900	191,177	200,927	211,174	221,944	233,263
Number of passengers at Paris CDG (000)	76,910	80,755	84,793	89,033	93,485	98,159
Number of passengers at Paris ORY (000)	33,394	33,628	33,864	34,101	34,339	34,580
Scenario 2 (Vaccine in 2022)	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Number of IFR flights (000)	3,121	3,202	3,285	3,371	3,459	3,548
Number of air passengers in France (000)	164,001	172,365	181,156	190,395	200,105	210,310
Number of passengers at Paris CDG (000)	69,342	72,809	76,450	80,272	84,286	88,500
Number of passengers at Paris ORY (000)	30,108	30,319	30,531	30,745	30,960	31,177
Scenario 3 (No vaccine)	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Number of IFR flights (000)	2,507	2,572	2,639	2,707	2,778	2,850
Number of air passengers in France (000)	131,708	138,425	145,484	152,904	160,702	168,898
Number of passengers at Paris CDG (000)	55,688	58,472	61,396	64,466	67,689	71,073
Number of passengers at Paris ORY (000)	24,180	24,349	24,519	24,691	24,864	25,038

III-b) Limitations

While these forecasts may provide valuable insights, it is worth noting that the values obtained do not take into account:

- The possibility of additional waves of COVID-19 cases in Europe
- The potential constraints generated by the airport and Air Traffic Management (ATM) limited capacities
- The political decisions associated with the reopening of borders for international flights or regarding the limitation of domestic flights for environmental reasons.

Airports are essential to the economic development of cities. They directly contribute to economies by providing services to airlines, moving passengers, and transporting cargo. However, the COVID-19 outbreak has hit airports hard. As a result, air travel has fallen sharply, which has prompted airlines to cut capacity. Given the importance of airports to the economic development of cities, the broader impact of COVID-19 on the global economy is enormous. The economic

crisis that will follow the pandemic will continue to drive lower demand for air travel in the immediate aftermath. As a result of dramatic revenue losses and ongoing uncertainty surrounding COVID-19, major airport operators are revising their earnings expectations (IFC, 2020). For this purpose, they need to estimate future demand. This section provides a prediction of the air transport's demand in order to help airports to plan for the future and minimize losses.

11. Effects of COVID-19 on land price, relocation, and amenities

COVID-19 pandemic has led to a greater decline in the demand for housing in neighborhoods with higher population density due to the diminished need of living close to jobs that are telework-compatible and the declining value of access to consumption amenities. Home sales in central cities and dense neighborhoods dropped considerably more relative to other comparable locations since the outbreak. The negative effect of the pandemic on the demand for dense locations persists even after the aggregate housing market recovers (Liu and Su, 2020). Hence, the COVID-19 outbreak and the decline in GDP are a real challenge for Real Estate markets. Firstly, the lockdown and closures of most shops have an immediate dramatic impact on retailer sales. Moreover, with air traffic down by 80% overall and borders almost closed, the fall in tourism will have some specific knock-on effects on retail real estate. For instance, a 15-20% drop in overnight stays in 2020 is assumed for big European cities due to the collapse in tourism numbers. Housing prices are expected to drop by a maximum of 5% this year in Europe, 10% to 20% reduction in offices, and up to 30% drops for retail real estate.[71] Figure 46 depicts how house price changes in each quarter of the year from 2018 to 2020. Predictions show that, despite the sharp drops in the second and third quarter of 2020, house price starts to increase in the last quarter of 2020 in European countries.

[71] https://www.globalpropertyguide.com/news-covid-19-effects-on-the-european-real-estate-market-4097

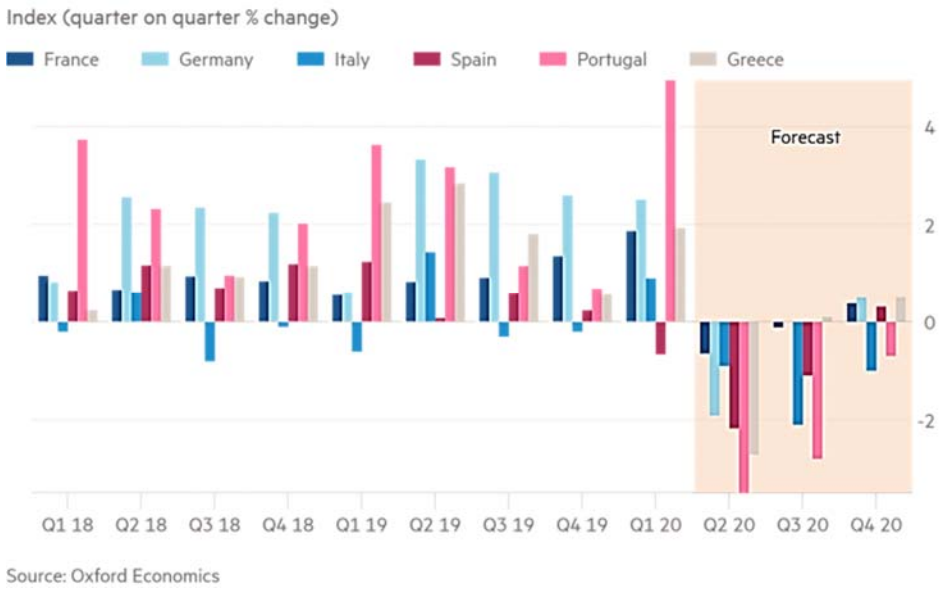


Figure 46: European house prices in selected countries, Jan 2018-Dec 2020[72]

As a result of the pandemic, land price changes. For instance, in Metro Vancouver, apartment prices have been falling recently. They appear to be falling out of favor as people seek larger living spaces where they can work-from-home. Figure 47 shows the condo apartment price in Metro Vancouver over the past 16 months.

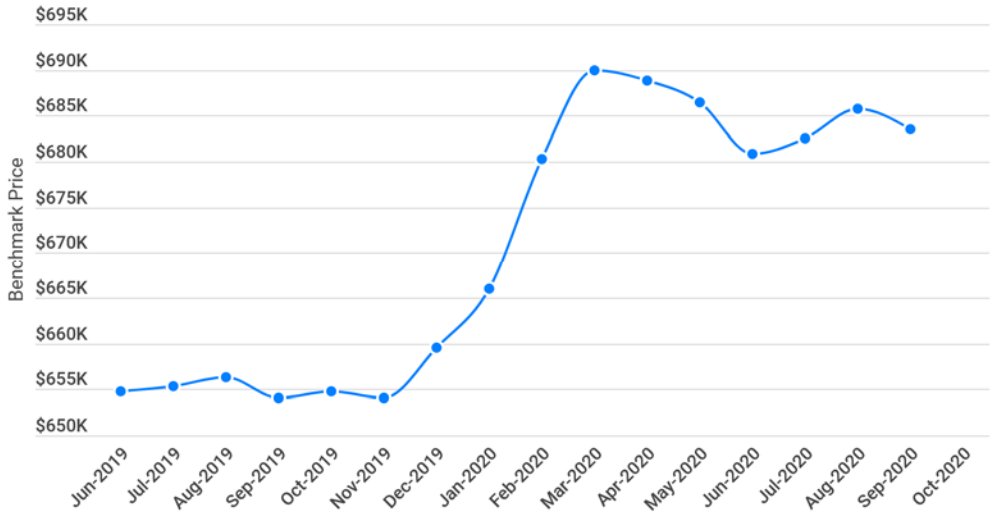
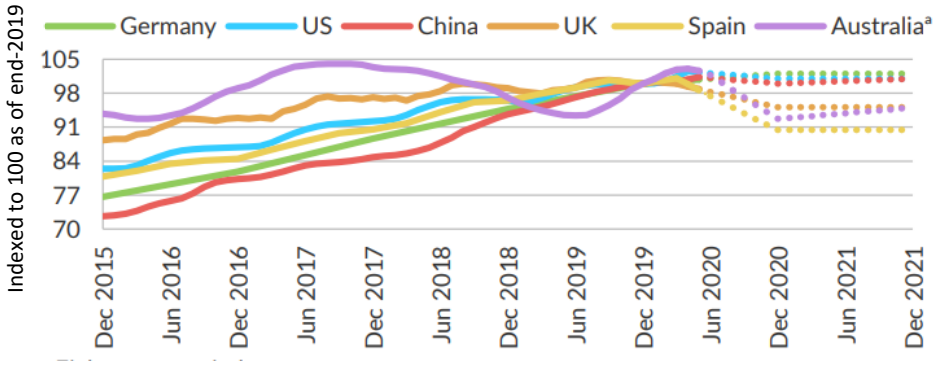


Figure 47: Condo Apartment Price in Metro Vancouver, Jun 2019-Oct 2020[73]

[72] Available at https://www.ft.com/content/0896aafc-7f61-438b-8a99-da01d47ec372
[73] Available at https://www.mortgagesandbox.com/vancouver-real-estate-forecast

Figure 48 illustrates the results of another study that expects nominal home prices to fall in the UK, Spain, and Australia in the rest of 2020 due to the impact of the coronavirus pandemic. Under this forecast, Spain suffers the most significant fall in house prices, decreasing by 8%-12% for the full year 2020. Australia will suffer a decline of 5%-10%, whereas the UK will experience a decline of 3%-7%.



Source: Fitch Ratings, S&P/ Case-Shiller, CoreLogic, HM Land Registry, BulwienGesa AG, INE Spain, National Bureau of Statistics China, Haver Analytics

Figure 48: Nominal homes price indices and midpoints of forecasts[74]

RE/MAX[75] Europe's most recent survey (August 2020) interviewed more than 2,000 top RE/MAX agents and brokers from 27 countries (e.g. France, Germany, the Netherlands, Finland, the Czech Republic, Greece, Slovakia, Slovenia, Bulgaria, Poland, Turkey, Malta, and Montenegro) about the implications of the pandemic on European real estate valuations and transactions. Most countries expect a price decrease between 5-10% for apartments more than for family houses. However, Germany anticipates a price increase of 10% for apartments in urban areas and no change for rural areas. France, Finland, the Netherlands, Turkey, and the Czech Republic also expect a small price increase for houses, both in urban and rural areas.

A survey among Americans in early June shows that 3% say they moved permanently or temporarily due to the coronavirus pandemic, and 6% say someone moved into their household because of COVID-19. An additional 14% of those who did not personally experience relocation

[74] Available at http://cdn.roxhillmedia.com/production/email/attachment/810001_820000/Fitch%20Home%20Prices%201407-20.pdf
[75] https://www.remax.eu/en/blog/european-survey-the-impact-of-covid-19.html

say they know someone else who has moved. 37% of those ages 18 to 29 say they moved, someone moved into their home or they know someone who moved because of the outbreak. By race and ethnicity, 28% of Hispanics have had one of these experiences, compared with 20% of white adults, 19% of Black adults, and 24% of Asian Americans. Among U.S. adults who moved due to the pandemic, 28% say the most important reason was to reduce their risk of contracting the virus. Another 23% say it was because their college campus closed, and 20% say they wanted to be with family. An additional 18% say the most important reason was financial – either job loss (8%) or another money-related reason (10%).[76] Figure 49 presents a detailed summary of this survey.

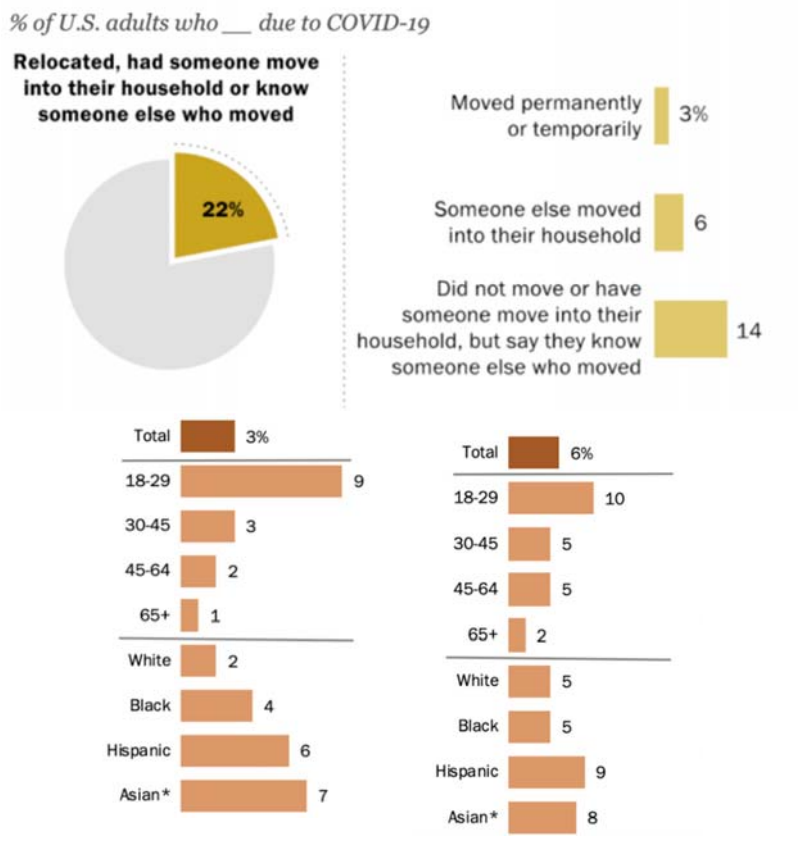


Figure 49: OCVID impact on Americans' relocation, June 2020[77]

In a May report by British property firm Savills, 71 percent of younger UK homebuyers said outdoor space and rural locations had become more important to them since COVID-19. This points to a potential geographical decentralization of the country and its urban economies. It will

[76] https://www.pewresearch.org/fact-tank/2020/07/06/about-a-fifth-of-u-s-adults-moved-due-to-covid-19-or-know-someone-who-did/
[77] https://www.pewresearch.org/fact-tank/2020/07/06/about-a-fifth-of-u-s-adults-moved-due-to-covid-19-or-know-someone-who-did/

be positive in terms of a better distribution of density and activity across many cities. Figure 50 represents how the share of Londoner applicants who want to buy a house in Southern England rises significantly in 2020.

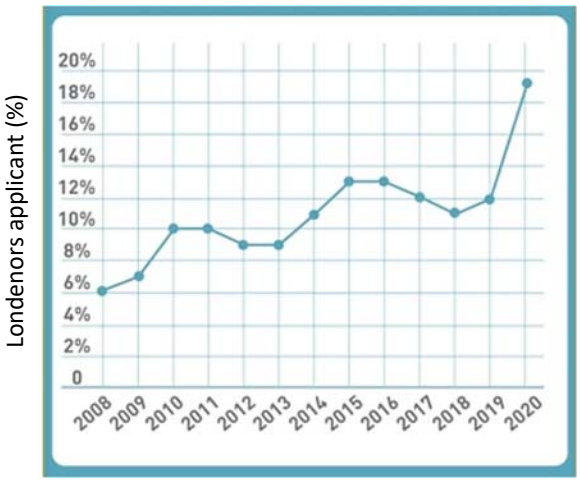


Figure 50: Proportion of applicants from London registering to buy a house in Southern England[78]

According to smartphone location data, hundreds of thousands of residents left New York City due to the Pandemic. Roughly 5 percent of residents — or about 420,000 people — left the city between March 1 and May 1, 2020. A survey conducted in June 2020 among 9,654 U.S. adults showed that 22% of U.S. adults say they either changed their residence due to the pandemic or know someone who did. 3% of US adults say they moved permanently or temporarily due to the coronavirus pandemic.[79]

In support of this trend Figure 51 displays that shares of the companies that facilitate suburbanization are up substantially, particularly leading distributors, suppliers, and construction companies for U.S. residential homes. S&P Homebuilders ETF is up 63.54%, Home Construction ETF is up 74.44%, and BlueLinx is up a very considerable 319.61%. BlueLinx is the leading distributor of building products in the United States and announced that their earnings indicate strong builders' confidence and single-family housing starts. This aligns with reports from builders

[78] https://newseu.cgtn.com/news/2020-07-20/COVID-19-and-the-city-How-pandemics-could-break-up-our-metropolises-Ru1y8NY2Jy/index.html

[79] https://seekingalpha.com/article/4364779-suburbanization-covidminus-19-and-oil-demand

on increased demand for single-family homes in lower density markets, small metro areas, and large metro suburbs.[79]

Figure 51: Performance of BlueLinx Holdings (BXC), the S&P Homebuilders ETF (XHB), and iShares U.S. Home Construction ETF (ITB), May-Aug 2020[80]

The suburban lifestyle is more oil-intensive compared to its urban counterpart, which has interesting oil consumption implications. This is generally attributed to higher vehicle miles traveled and higher home energy use from larger and more spread-out homes. Although the direct oil demand impact of growing suburbanization may be smaller than other demand factors such as work-from-home and reduced air travel, it is likely more sustainable and may be substantially understated. Generally, COVID-19 leads to significant disruptions in global petroleum supply and consumption. In the Spring of 2020, oil prices collapsed amid the COVID-19 pandemic and economic slowdown. OPEC and its allies agreed to historic production cuts to stabilize prices, but they dropped to 20-year lows. As we move past this turbulent year, we look to implications that COVID-19 may have for the future of oil supply and demand.

Using data on gas consumption per capita by county and estimates on COVID-19 related migration, the incremental increase in oil use as a result of pandemic-related moves into suburbs is estimated and shown in Table 13.

[80] https://seekingalpha.com/article/4364779-suburbanization-covidminus-19-and-oil-demand

Table 13: Increase in oil use as a result of pandemic-related moves into suburbs[81]

City	Population	Migrated due to COVID-19 [a]	Added Oil Use in Suburbs (per year) [b]
New York City	8,399,000	419,950	4.6 MMbbl
Los Angeles	12,447,000	373,410	4.1 MMbbl
Chicago	8,865,000	265,950	2.9 MMbbl
Total	**29,711,000**	**1,059,310**	**11.6 MMbbl**

[a] Estimated using a migration rate of 5% in NYC and 3% migration rate for other metros
[b] Calculated with gas use average of 462 gals. per year, based on information by the NRDC

According to this table, the additional oil use due to COVID-related migration from NYC and the next 2 largest metropolitans, is estimated to be 11.6 million barrels per year. At a conservative 3% migration rate, there is an added 9.7 million barrels of oil used to suburban cities in the US. At a 5% migration rate (such as that seen in NYC), 16.2 million barrels of added annual demand is estimated.

Urban designers aim to create places where people feel welcome, comfortable, and safe. Perceptions of public space are an important field of research and public perceptions may dictate what is designed and how. However, the current pandemic threatens to profoundly change our relationship with these spaces.

Honey-Roses et al. (2020) review the emerging questions about the impact of COVID-19 on public spaces. A summary of the emerging questions about how the COVID-19 may change the design, use, behaviors, and perceptions in public spaces are listed below:

- Design
  1. Will streets be re-designed?
  2. Will the pandemic accelerate the mainstreaming of health criteria into the design of public spaces?
  3. Will green space planning need new designs, uses, and practices?
  4. What is the future of large public spaces?
  5. Do we need a new typology for public space?

[81] https://seekingalpha.com/article/4364779-suburbanization-covidminus-19-and-oil-demand

6. Will the temporary transformations seen during the crisis inspire more permanent changes?
7. What will happen to micro-mobility and mobility sharing?
8. What will be the impacts on public transit?

- Perceptions, Use, and Behavior

9. Will we observe fewer people in public?
10. Will we change what we do in public?
11. Will our intuitive carrying capacity for public spaces decrease?
12. Will we observe changes in the use and regulation of interior public spaces?
13. Will we experience infringements on civil liberties?
14. Will our perceptions of public space change?

- Inequities and Exclusions

15. How will the needs of vulnerable groups such as women, racial minorities, immigrants, low-income residents, the elderly, children, and the homeless be accounted for in future public space designs, practices, and rules?
16. Will cities in the Global South attempt to constrain or regulate the informal street economy?
17. Will the pandemic permanently disrupt the interconnected global settlement system?

According to the answers to these 17 questions, Honey-Roses et al. (2020) conclude that the COVID-19 crisis may fundamentally change our relationship with public space. For instance, a pivot toward healthy cities is likely to be accompanied by a more serious effort to make cities greener. Yet the pandemic may change the type and distribution of green spaces we want, as well as our expectations about what green spaces should provide. We foresee a greater demand for smaller green spaces or neighborhood parks. Green space designers might need to create more spaces for individualized and introspective use over team sports. Running trails and paths might be widened. Another obvious potential consequence of COVID-19 is a generalized aversion to large crowds. Concerts, cultural events, sporting events, ceremonies, markets, and political protests all bring together many people, often in public squares and plazas. A permanent aversion to large public gatherings might change how cities are designed. A post-COVID-19 world might value these large flexible spaces as assets. Public spaces are a key feature of a resilient city, in part because of their ability to be transformed for emergency health purposes.

12. Effects of COVID-19 on poverty

Based on the World Bank predictions, COVID-19 pushes about 49 million people into extreme poverty in 2020.[82] IMF (2020) demonstrates that lockdowns have a negative and significant effect on job postings. Their estimations suggest that a full lockdown is associated with a decline in job postings of about 12 percent two weeks after the introduction of the lockdown. As a result, the unemployment rate increases around the world.

Sumner et al. (2020) estimate the potential short-term economic impact of COVID-19 on global monetary poverty through contractions in per capita household income or consumption. Their estimates are based on three scenarios: low, medium, and high global contractions of 5, 10, and 20 percent; They calculate the impact of each of these scenarios on the poverty headcount using the international poverty lines of US$1.9, US$3.2, and US$5.5 per day. They found that assuming a 5 percent contraction in per capita incomes, while everything else equal, the world could witness a potential increase in the number of poor people, relative to the 2018 figures of more than 80 million for the US$1.9/day poverty line, of more than 130 million for theUS$3.2/day standard, and almost 124 million for the higher line of US$5.5/day. Under a contraction of 10 percent, while keeping everything else equal, the increases in poverty headcount at US$1.9, US$3.2, and US$5.5 is respectively, about 180, 280, and 250 million people, but if the contraction is 20 percent, then the increases could be about 420, 580, and 520 million people, respectively.

Based on region, they figure out that the concentration of the potentially new poor under the US$1.9/day and US$3.2/day poverty lines would occur in the poorest regions of the world, notably in Sub-Saharan Africa and South Asia, which could accrue together between two thirds and 80–85 percent of the total poor as shown in Figure 52. For the higher poverty line of US$5.5/day, the majority (about 40 percent) of the new poor could be concentrated in East Asia and Pacific, about a third in both Sub-Saharan Africa and South Asia combined, and about 10 percent each in the Middle East and North Africa and Latin America and the Caribbean.

[82] https://blogs.worldbank.org/voices/covid-19-will-hit-poor-hardest-heres-what-we-can-do-about-it

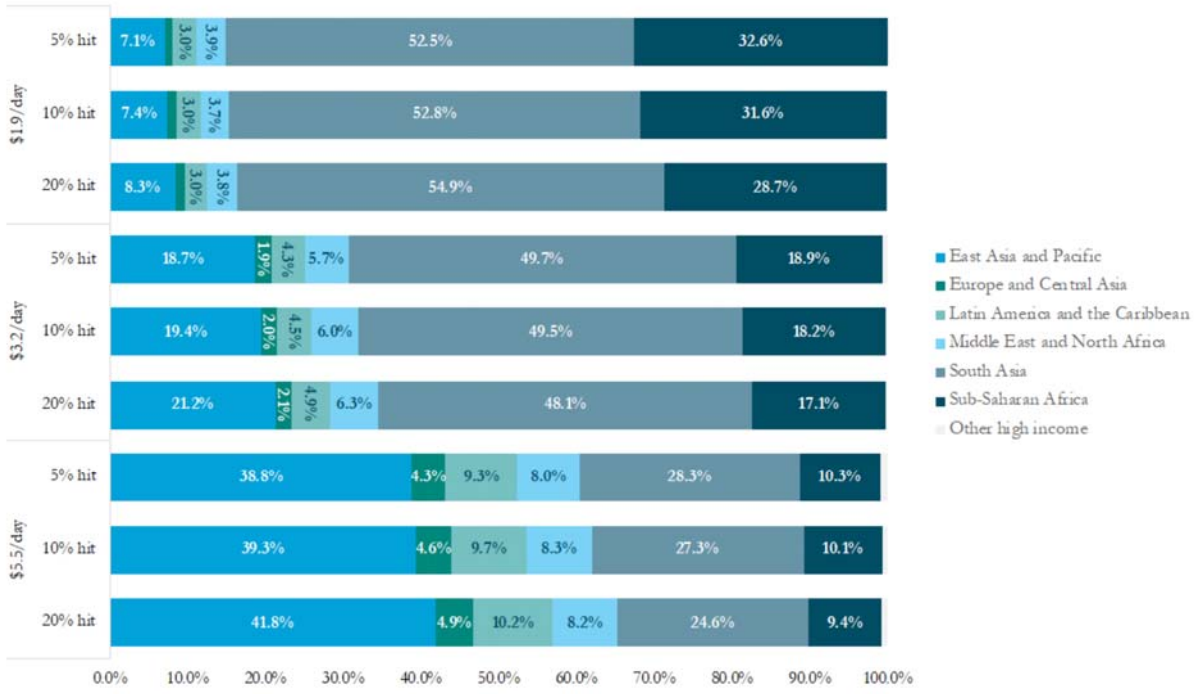
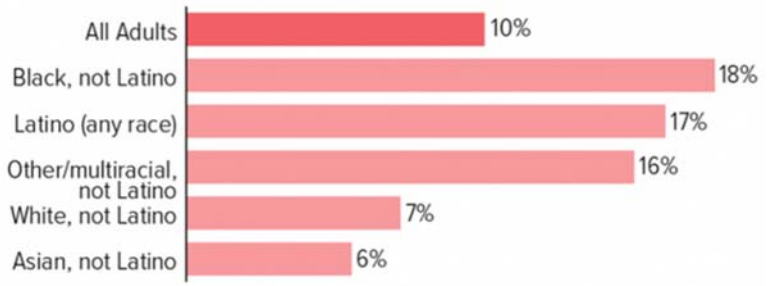


Figure 52: Distribution of the additional number of poor by region and contraction scenarios (Sumner et al., 2020; Figure 3)

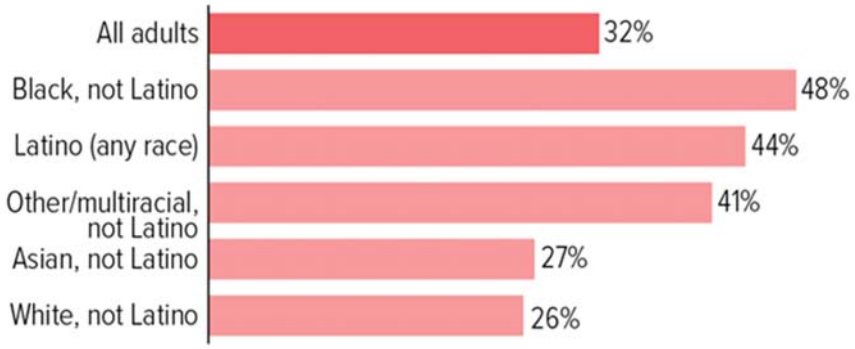
(2018 is the reference)

During the pandemic, the unemployment rate is very high and millions report that their households did not get enough to eat or are not caught up on rent payments. The impacts of the pandemic and the economic fallout have been widespread, but are particularly prevalent among Black, Latino, Indigenous, and immigrant households. These disproportionate impacts reflect harsh, longstanding inequities — often stemming from structural racism — in education, employment, housing, and health care that the current crisis is exacerbating. For instance, as shown in Figure 53, based on Bureau Household Pulse Survey in October 2020, Black and Latino adults are more than twice as likely as white adults to report that their household did not get enough to eat: 18 percent and 17 percent, respectively, compared to 7 percent of white adults (Food, D. G. E., 2020). See for more details. In addition, Black and Latino adults reported difficulty covering expenses at higher rates: 48 percent and 44 percent, respectively, compared to 27 percent for Asian adults and 26 percent for white adults (See Figure 54).



Source: Analysis of Census Bureau Household Pulse Survey; September 30 to October 12, 2020.

Figure 53: Share of adults saying that their household sometimes or often did not have enough to eat in the last 7 days in the US, October 2020[83]



Source: Analysis of Census Bureau Household Pulse Survey; September 30 to October 12, 2020.

Figure 54: Share of adults reporting difficulty to pay for household usual expenses in the US, October 2020[83]

Figure 55 shows how the poverty rate will change due to COVID-19. Regardless of COVID-19, the poverty rate was supposed to drop to 7.5% by 2021. However, the pandemic pushes the poverty rate to be 9 – 9.5 % in 2021.

[83] https://www.cbpp.org/research/poverty-and-inequality/tracking-the-covid-19-recessions-effects-on-food-housing-and#:~:text=Difficulty%20Getting%20Enough%20Food,-The%20Pulse%20survey&text=How%20to%20read%20this%20table,all%20adults%20in%20the%20country.

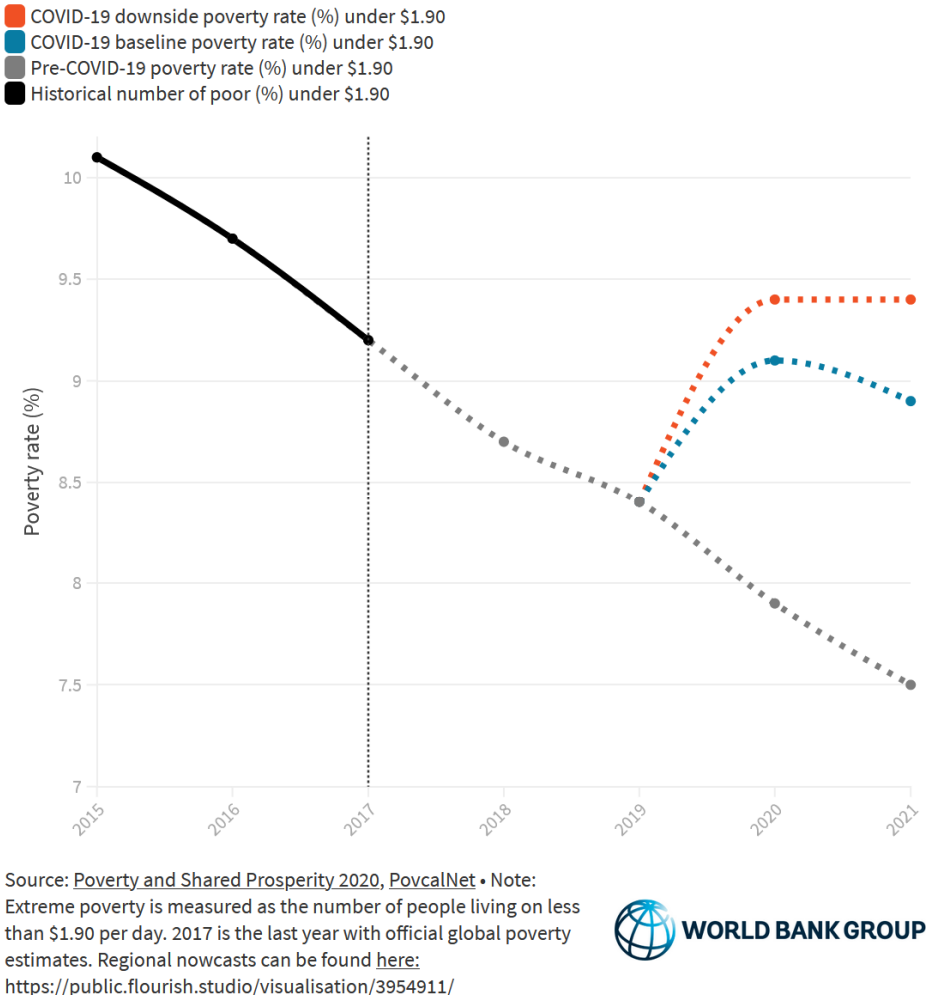


Figure 55: Impact of covid-19 on global extreme poverty[84]

The International Monetary Fund (IMF) (and many central banks) have developed models to assess the evaluations of GDP during this and the following year (see Figure 56). The prospect seems rather optimistic and is in line with the assessments of many observers: after the crisis, the world will be just as it was before, as was observed for many crises before.

[84] https://www.worldbank.org/en/who-we-are/news/coronavirus-covid19

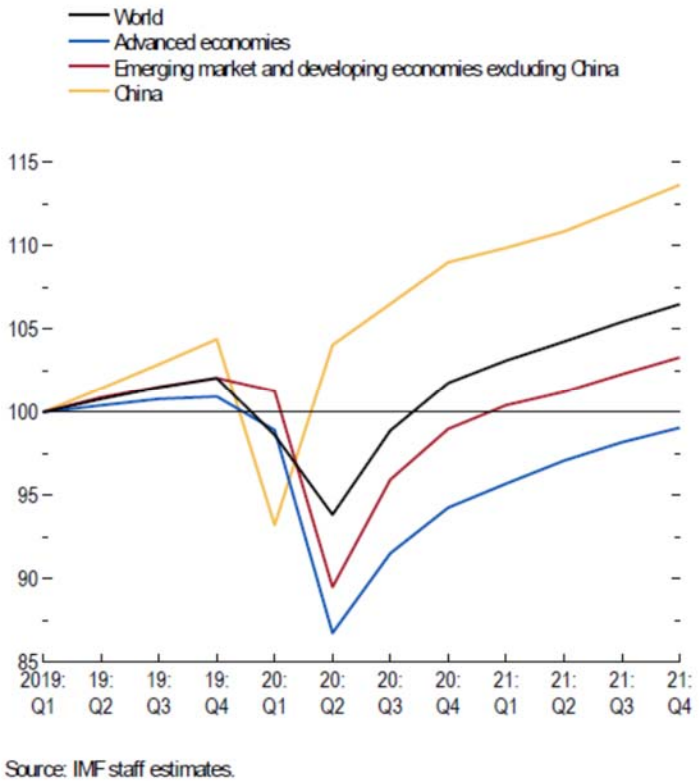


Figure 56: Quarterly world GDP (2019: Q1=100)[85]

13. Effects of COVID-19 on debt

One of the potentially important impacts of the crisis is debt. One may think that borrowing money will negatively affect growth and future generations. However, the standard IMF model assumes that the growth rate of the economy is independent of the debt (which will be no larger than 100% of GNP). Note in passing that debt is about 260% in Japan (and it has been very high for many years), with no clear and observable consequences and it is a bit more than 100% of GDP in the US. So, one should worry too much, according to central bankers (this is a rather intuitive statement given the low-interest rates, and despite the growth rate in our western economies). The governments who manage the debt should and do build a financial buffer, large enough, so as to be able to accommodate the next crisis (see Figure 57).

[85] https://stat.nbb.be/index.aspx?queryid=3038

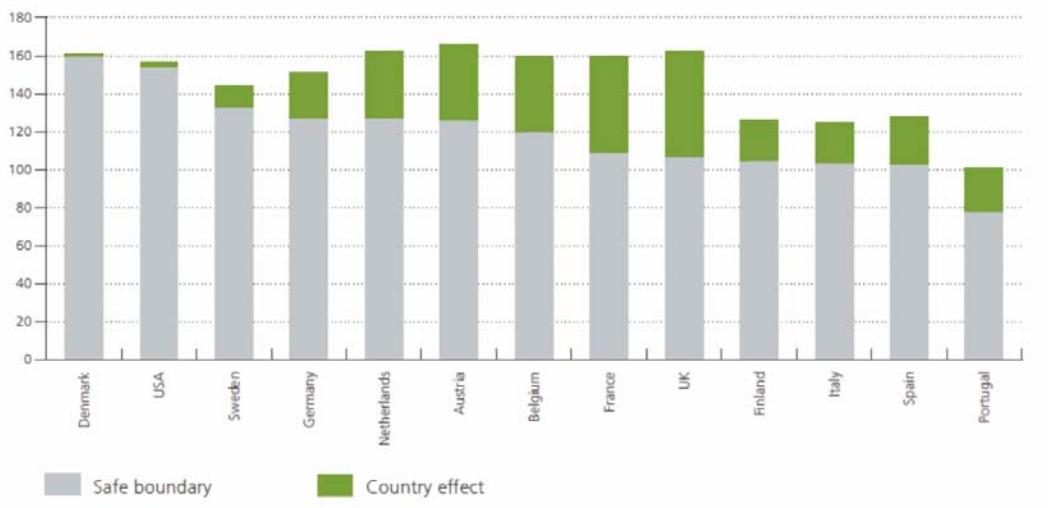


Figure 57: Safe debt boundaries considering country-specific limits and contingent liabilities (in % of GDP)

14. Future scenarios and predictions

The unknown is associated with uncertainty. No one can be quite sure about what the COVID-19 pandemic means for our futures as the pandemic is far from over, but the variation among those offering answers to this question is striking. In this extremely complex time, future planning models and scenario construction models are introduced. In the context of the future, there are always four general situations:[86]

- Growth (the future is better than what I expect),
- Breakdown (the future is worse than I expect),
- Constraint (the future is just what I expect), and
- Transformation (the future is different than what I expect).

Different organizations define a set of scenarios. For instance, in Section 9-I three scenarios including vaccine available in 2021, vaccine available in 2022, and no vaccine found soon are defined. International Monetary Fund (IMF) envisages two scenarios: Scenario 1: A Second Global COVID-19 Outbreak in Early 2021. However, the authors of the IMF report are no totally

[86] Paris School of Business webinar, available at https://www.psbedu.paris/en/news/life-after-covid-19-scenarios-future

optimistic, since they write: "*Despite the policy response, the outbreak is assumed to cause further longer-lived damage to the supply side of economies (scarring) in 2022, as increased bankruptcies lead to capital destruction, temporary increase in trend unemployment.*"[87] and Scenario 2: A faster recovery in the second part of 2020 (this was written in June 2020, and which seems a bit unlikely, by now).

These scenarios are not presented as forecasts; instead, they are imagined futures constructed to assist overall organizational thinking and discussions about how to plan future operations in light of COVID-19. The longer the time horizon, the more difficult it is to predict outcomes with any certainty, and the context is rapidly evolving. However, it is intended that these scenarios will be used to challenge thinking and prompt discussion about what the landscape might look like for humanitarian actors globally by the end of 2021.[88] For instance, in Figure 58, world maritime trade is predicted under three scenarios.

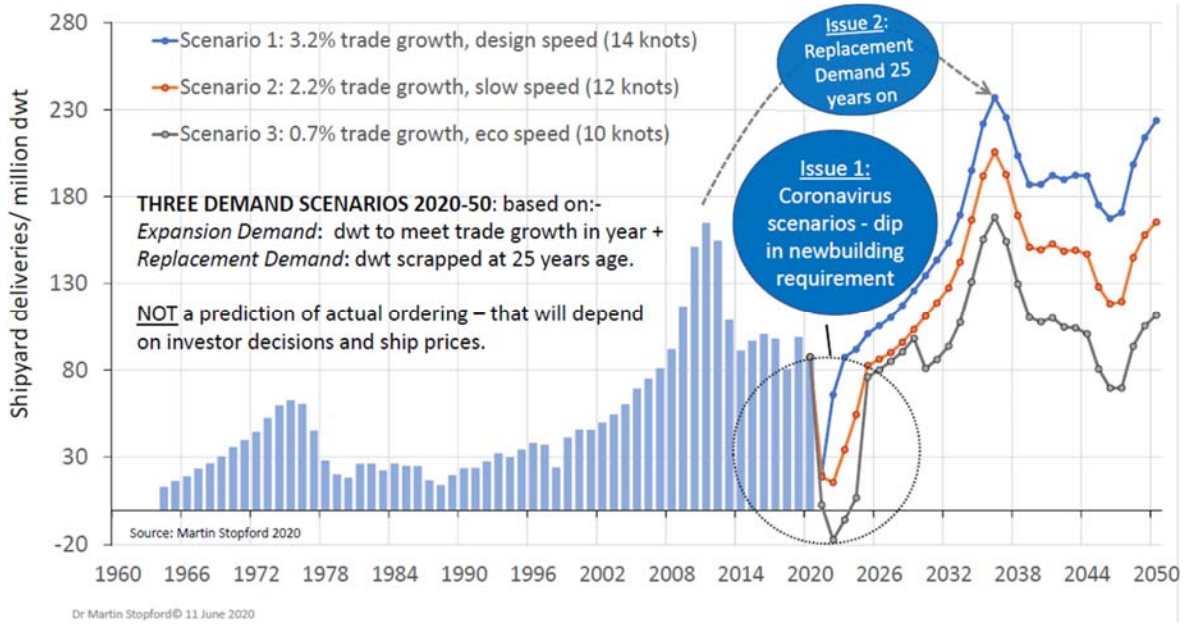


Figure 58: Shipbuilding deliveries 1964-2019 and demand scenarios 2020-2050[89]

[87] World Economic outlook, June 2020
[88] COVID-19 Pandemic*:* 24-Month Scenario Analysis and Implications For Asia, available at https://centreforhumanitarianleadership.org/wp-content/uploads/2020/08/CHL_COVID19-Asia-Scenario-Analysis_V4.pdf
[89] https://www.seatrade-maritime.com/shipbuilding/look-future-shipbuilding

Although it is entirely too soon to say what the future will look like, early indications provide some hints. Urban travel will not immediately bounce back to prior levels. Many of those who can telework will continue to do so until safe travel and safe workplaces are assured. Commuting may resume for those not able or willing to telework, but discretionary trips may become fewer and more local. Surveys from China indicate that post-confinement public transport use is down, and travel counts confirm ridership at 50% of 2019 levels for the first quarter of 2020. Conversely, car travel has risen quickly to equal and surpass pre-COVID-19 levels in large cities once travel restrictions were lifted.

Many people will feel uncomfortable traveling by public transport or sharing close quarters with drivers in taxis or ride-sourcing vehicles. These trips will have to be catered for with other travel options. Absorbing these trips will not be trivial, as this simple calculation demonstrates (see Table 14): Anywhere from 5 to nearly 10 million daily trips are taken by metro and bus (excluding regional rail) in London, New York, Paris, and Tokyo. If 30% of those trips were to be replaced by telework, 4 to 7 million trips per day would still have to be handled by public transport. 2 to 3 million trips a day remain if 50% of those remaining trips are no longer taken in public transport.

Table 14: Number of daily public transport trips to be serviced post-Covid[90]

	Daily bus and metro trips (excl. regional rail, million)	Scenario: Minus 30% teleworking	50% of remaining trips
London	9.8	6.9	3.5
New York	7.6	5.3	2.7
Paris	5.5	3.8	1.9
Tokyo	9.0	5.6	2.8

Source: ITF based on Transport for London, Municipality of Tokyo, City of Paris

COVID-19 burst the bubble that was fueled by air traffic, global economic growth, and business and leisure trends, triggering massive cutbacks in capacity, layoffs, and order cancellations all along the supply chain. Figure 59 shows aircraft deliveries (observed and forecast) from 2019 to 2024. Before COVID-19, these five years were supposed to be non-stop growth for aerospace (F in this figure means forecast).

[90] International Transport Forum, OECD, COVID-19 transport brief: Re-spacing Our Cities For Resilience. May 2020. Available at https://www.itf-oecd.org/sites/default/files/respacing-cities-resilience-covid-19.pdf

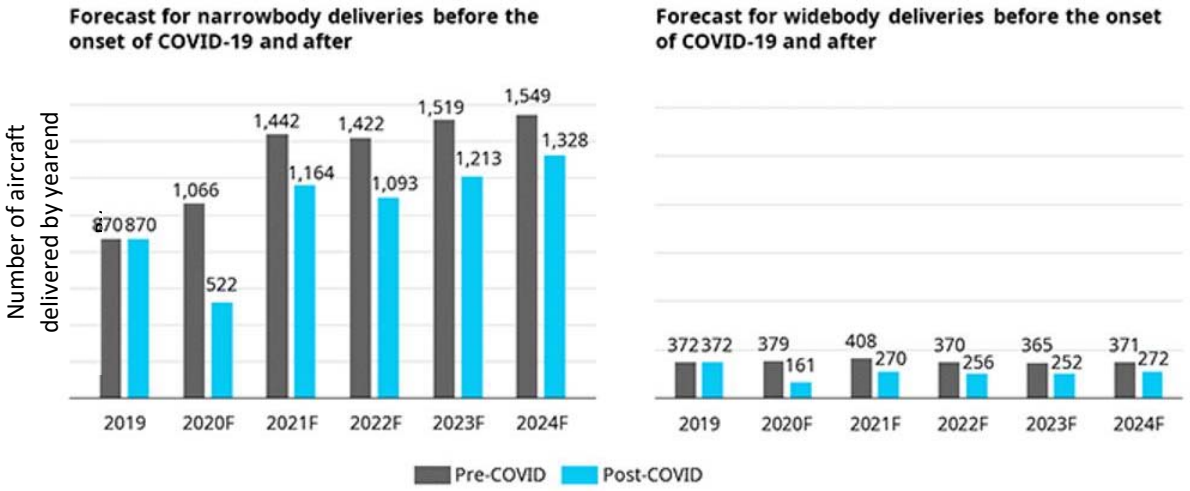


Figure 59: Aircraft deliveries from 2019 to 2024 [91]

Atkins, which is a member of the SNC-Lavalin Group and one of the world's most respected design, engineering, and project management consultancies, provides a better understanding of the likely impact of COVID-19 on the transport sector of potential future scenarios. Their New Normal scenario assumes that there will be widespread available healthcare therapies and/or a vaccine to COVID-19. That is, there will be no residual fear that would affect the behaviors of travelers, operators, and policymakers. Some of their ideas and estimations are summarized below (Atkins, 2020):

- Any new operational measures in the New Normal scenario will be a less intense version of what has been in place during the lockdown and the Transition Period. Similarly, any new habits will be more a result of a step-change in a trend already in place (e.g. working from home has been increasing slowly for some years) rather than a radical change in our lifestyles.
- The new operational measures are likely to make rail operators incur additional costs on items such as safety equipment, cleaning, and staff training. Operating costs are estimated likely to increase by 5 to 7% during the Transition Period and about 1 to 2% during the New Normal scenario due to operational measures for tackling COVID-19.

[91] https://www.forbes.com/sites/oliverwyman/2020/05/20/why-aerospaces-recovery-from-covid-19-may-take-five-years/?sh=729d6a3d947d

- Individuals and businesses will adopt new transport habits as they change some of their working, shopping, and leisure habits. Working habits are the ones which may be more affected, as a significant proportion of office workers have become accustomed to carrying out their jobs away from the offices. The habits established in the New Normal scenario could reduce rail passenger demand by 8% for long-distance, 11% for regional, and 13% in commuter markets.

As countries gradually lift lockdown restrictions, one more phase remains before we reach the next normal. Figure 60 depicts a theoretical GDP diagram in different stages of COVID-19. Although most behaviors will see a linear development trend, based on this figure, consumer's behaviors will not follow a linear curve (Fabius & Timelin, 2020).

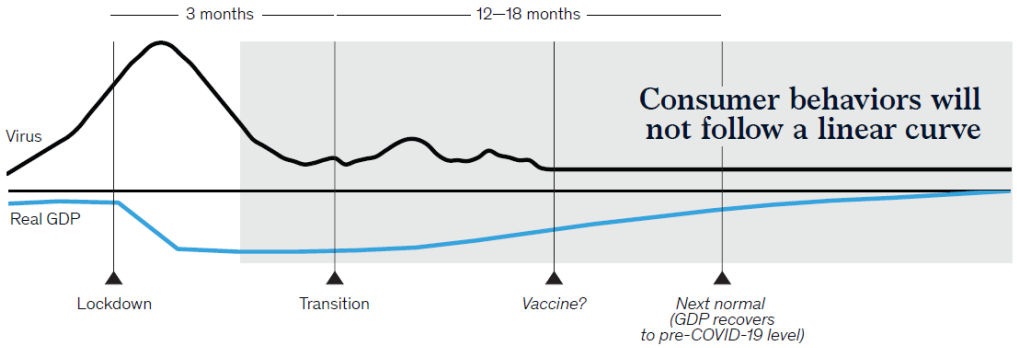


Figure 60: Theoretical real GDP in different stages of COVID-19 to reach new normal (Fabius & Timelin, 2020)

Based on a recent McKinsey survey[92] of consumer-car-buying behavior during the pandemic, nearly 70 percent of mobility users in the United States, United Kingdom, Germany, France, Italy, Japan, and China said they would choose to walk or bike at least weekly even after returning to normal life (up to six percentage points from pre-crisis levels). Likewise, private cars gained one percentage point (from 78 percent pre-crisis to 79 percent after returning to normal life). And, after intense drops in ridership, public transportation users will likely return to at least weekly usage, at

[92] How consumers' behavior in car buying and mobility is changing amid COVID-19, September 2020, available at https://www.mckinsey.com/business-functions/marketing-and-sales/our-insights/how-consumers-behavior-in-car-buying-and-mobility-changes-amid-covid-19

around 40 percent. Moreover, shared micro-mobility, e-hailing, and carsharing should all be slightly more popular, gaining 1 to 2 percent postcrisis when normal life returns. Hence, the overall desire of customers to “move” remains intact.

Bigger changes are likely to occur with long-distance travel between cities. Here we see a substantial shift from the use of planes and trains to cars. About 40 percent of global consumers said they would fly less than before in the next normal, while only 16 percent said they would fly more often. In addition, 32 percent said they would travel by train less often (versus the 18 percent who said they would more often travel by train). By contrast, many more people, 32 percent, said they would travel more frequently by private car, while only 13 percent said they would travel less by car. Because of this, miles traveled on roads might increase substantially, at least in the aftermath of the pandemic. Whether this will have an impact on private-car ownership, affect car rentals, or allow clever shared-ownership models to prosper remains unclear. [51]

McKinsey and Company compares large global cities highlights significant differences in expected regional mode-share shifts through 2030, shown in Figure 61.

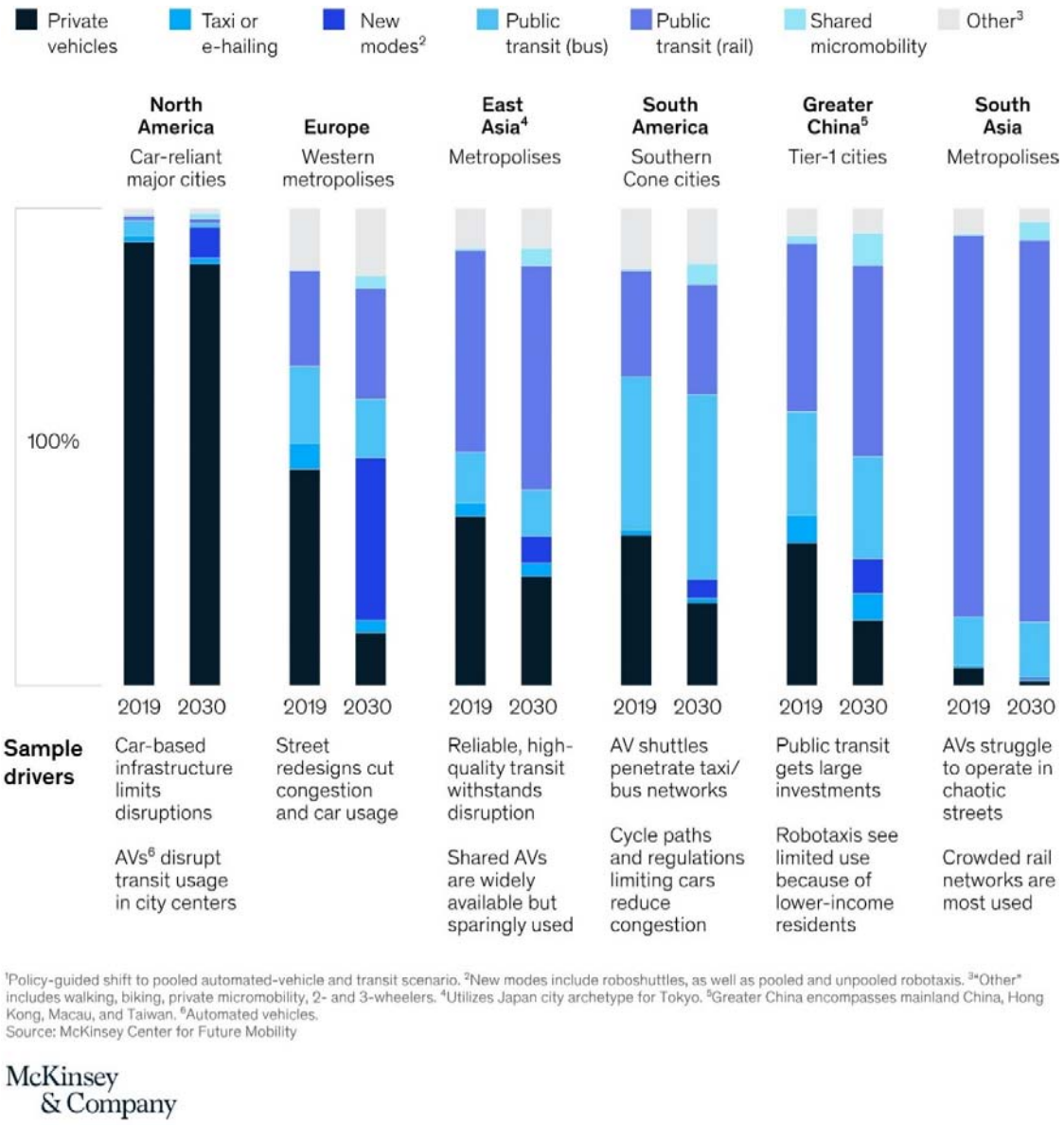


Figure 61: Passenger miles traveled by city archetype [93]

Approximately one-quarter of people who used to take the Toronto Transit Commission (TTC) before the COVID-19 pandemic say they will not hope back on a streetcar, subway, or bus until they have been vaccinated against the disease, according to preliminary results from a new University of Toronto survey. The survey found that while 63 percent of those who are not

[93] https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/five-covid-19-aftershocks-reshaping-mobilitys-future#

currently using the TTC said they would resume taking transit after reaching Stage 3 of the province's framework for reopening Ontario (end of July), 25 percent say they are waiting for a vaccine and about one percent of respondents said they will never take the TTC again. [94]

A survey that seeks to understand the impact of COVID-19 on frequent transit users in Toronto provides former riders with a roadmap of crisis recovery based on the Province of Ontario's three-stage reopening plan, plus other public health milestones such as the discovery of a vaccine. Former riders are asked to consider at which point in this timeline they would start riding transit again. We plot these results in cumulative totals in Figure 62.

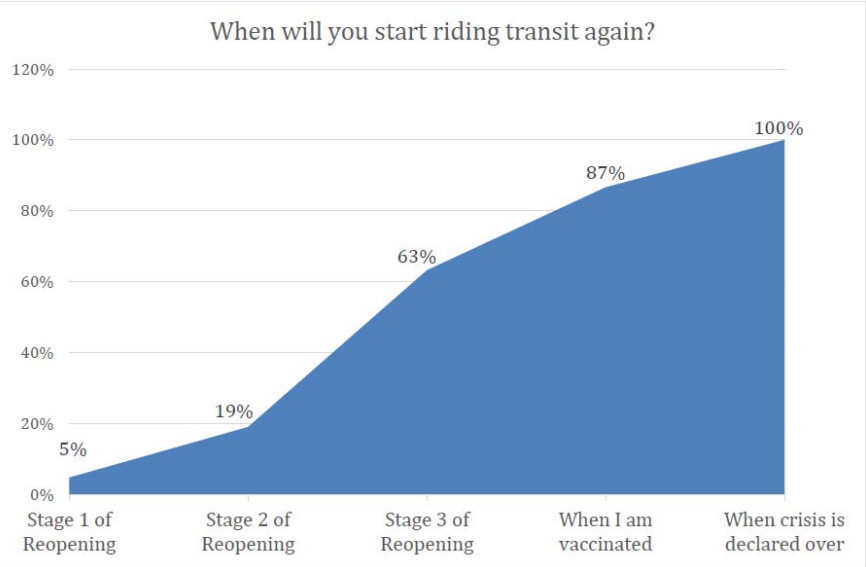


Figure 62: Percent riding transit again at each stage of a re-opening and recovery timeline in Toronto, May 2020[95]

Figure 63 illustrates tourist arrivals in 2020 and 2021 for three scenarios in Caribbean tourists' arrival. Tourist arrivals for 2020 are projected to fall by 58% in the optimistic scenario, 71% in the base scenario, and 76% in the pessimistic scenario. Domestic tourism activity is projected to fall

[94] https://www.cp24.com/news/about-25-per-cent-of-former-ttc-riders-say-they-won-t-take-transit-before-covid-19-vaccine-is-ready-survey-1.4935313

[95] Preliminary Results from the Public Transit and COVID-19 Survey, available at https://uttri.utoronto.ca/files/2020/05/Preliminary-Report-on-the-Public-Transit-and.pdf

by 30% in the optimistic scenario, 50% in the base scenario, and 70% in the pessimistic scenario (CEPAL, 2020).

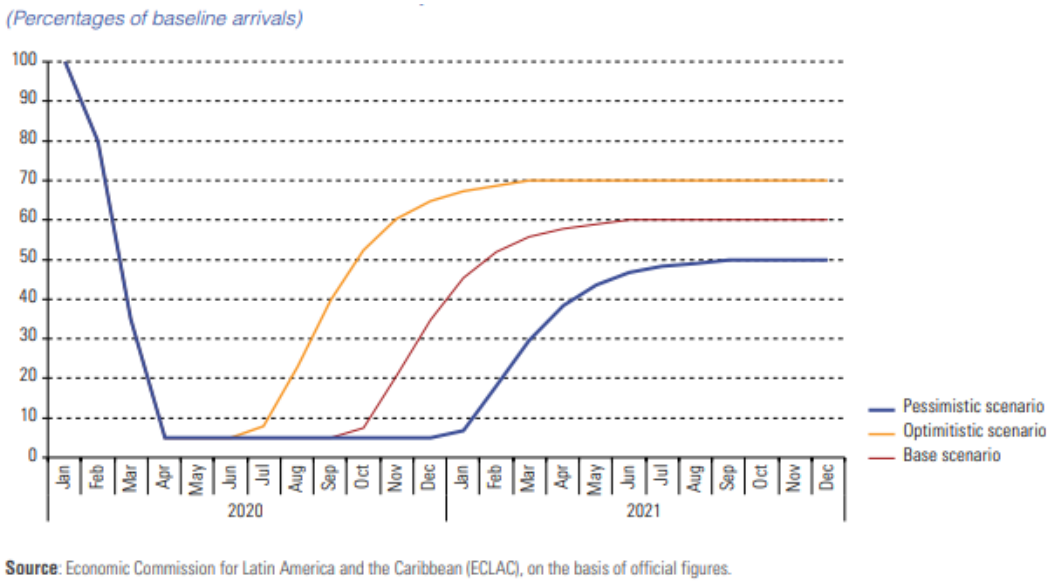


Figure 63: The Caribbean three scenarios for recovery in tourist arrivals[96]

15. Conclusion

The pandemic is not a minor event. The evaluation of the impact of the COVID-19 crisis is a general problem, which affects many or most sectors of Society. Major questions are: what will life be like after COVID-19? how long will last the COVID-19 crisis? Is it the last crisis, or will there be other crises (different, possibly more severe)? Since the COVID-19 crisis is likely to bring major changes to mobility, transportation, the environment, the tourism industry, and air transportation, the goal of this study is to recognize the changes and their adverse effects. Although some of these changes will persist even after the COVID-19 crisis, identifying the behavioral changes and their consequences will help policy-makers to mitigate the negative outcomes that directly relate to psychological well-being.

Some observers mention that equity may deteriorate and certainly, poverty has increased worldwide. Based on the World Bank predictions, COVID-19 pushes about 49 million people into extreme poverty in 2020. More than that, economics seems to catch over after the crisis, so that it will just be as a transient episode, with no long-term consequences. We are not wiser than the

[96] https://repositorio.cepal.org/bitstream/handle/11362/46192/1/S2000599_en.pdf

common wisdom but will try to argue that the situation, as far as mobility, may be somewhat different.

In a post-pandemic situation, a part of the population may avoid public transport due to disease transmission concerns and opt for more individualistic forms of mobility. Such behavior can shift demand back to private cars, biking (conventional or electric), micro-mobility, and even walking. But probably favoring own vehicles as opposed to shared mobility options. “Sharing economy” services such as ride-hailing, ride-sharing, and other emerging MaaS (Mobility as a Service) applications are therefore expected to face important viability problems as a result of the loss of income during the confinement period and the decreased demand afterward.

In our societies, death is hidden (as old people, more in France than in Italy and more in Italy than in Africa). Certainly, death is something not well understood (lack of experience), but it does change the value of life, leisure, and it may also change the objective of the individual: why do we live and what are our objectives? It is difficult to forecast how the psychology of people will change. The fact that people may be depressed is not obvious: were there more depressed people during World War II? No. But their values changed, during and after the war. The crisis has also questioned the value of human life: are we ready to increase the debt to safe life? The crisis also changed the attitude towards authority, freedom of movement, and freedom of speech. These are not innocuous changes and they are likely to deeply affect Individual psychology.

The Zoom revolution (used as a generic term) has certainly increased a slow trend towards teleworking and teleshopping. With Zoom, people do the same as before while just reducing transportation costs and changing the face to face interactions, but new opportunities are now offered. So, the Zoom provides qualitative changes in the organization of work. The extensive adoption by a large share of enterprises during the crisis will probably result in an increased share of employers who continue to telework even once the confinement measures are over. On the other hand, the increase in e-shopping during the crisis -as a response to limitations in retailing, risk aversion, and social distancing- is also expected to be sustained in the future. Either as employees or as consumers, many individuals will limit trips that can be avoided through technology, or simply because they would consider them unnecessary. This suggests that the world, after COVID-19 may not be the same as before. To reason “everything equal” is just wrong, as any transport research knows the concept of induced demand.

In all crises, there are winners and losers. The winners are merged in new financial indices (attractive for some investors), which include companies that are positively impacted by the crisis such as Amazon, Zoom, pharmaceutical companies, remote medicine, MOOC, and more generally several digital companies. The list of the 20 companies which gain the most is instructive for this study. However, we recall that other (most) firms suffer from the crisis even in the stock market one observes one of the major impacts of the crises: more inequalities.

Let the market speaks, since these figures basically expressed the opinion of consumers who vote with their feet. Amazon: + US$ 401.1 Bn; Microsoft: + US$ 269.9 Bn; Apple: + €219.1 Bn; Tesla: + €108.4 Bn; Tencent (video games): + €93 Bn, Facebook: + €85.7 Bn; Nvidia (IT company): + €83.3 Bn; Alphabet (IT company): + €68.1 Bn; PayPal: + €65.4 Bn; Mobile (telecommunication): + €59.7 Bn; Pinduoduo (online business): + €55.2 Bn; Netflix (streaming platform): + €55.1 Bn; Meituan Dianping (online business): + €53,6 Bn; Shopify (online business): + €51.4 Bn; Zoom video (IT company): + €47.9 Bn; JD.com (online business): + €44.3 Bn; Adobe (Software): €40.1 Bn; Audi (automobile): +€37.8 Bn; AbbVie (IT company): +€37.7 Bn; Kweichow Moutai (beverage trade): +€35.5 Bn. To sum up, we have a total of 805.3 Bn € gains, i.e. 1.07 times de European recovery plan (of €750 Bn). This corresponds to €1070.1 Bn for the first 6 companies, €440.4 Bn for the next 7 companies, and €294.8 Bn for the last 7 companies. Gains are not equally shared among the winners: Only 20% more lucky company, representing 50% of the whole cake (the Pareto law does not hold here). Now the question for the investors (private investors and pension funds) is: should we sell or hold? It is not the purpose of this report to advise the reader, but the underlying question for us is the same: Are these trends permanent or transient?

It is not possible to make a large micro or macro model answer those questions, since many behaviors are involved, and they are concerned, here, with extreme events, the black Swan, in a way. One may indeed rely on previous crises, and we will do so occasionally, but forecasts based on the future is not a good strategy (history never repeated itself). For example, studies by Guillaume Chapelle (2020) (CY University) have shown that the American cities which used the confinement policy for the Spanish Flue were worse off than the cities which refused to do so. Do we really believe that (so-called) Spanish Flue experience can be used to steer today's confinement policies? Likely, nobody thinks so!

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Appendix A

In this section, we intend to seek the experts' opinions about the long-term effect of COVID-19 on a wide range of aspects of life.

Feixiong Liao, who is an assistant professor in urban planning and transportation group at Eindhoven University of Technology (the Netherlands), and Hossain Poorzahedy, who is a professor at Sharif University of Technology (Iran) were asked a few questions about the long term effects of COVID-19 on residential and work location, the value of time, etc.

Poorzahedy's answers are inspired by the following points: 1. Spanish experience, as well as other flu pandemics in the 20th Century; 2. The world was on the brink of moving into a digital lifestyle when the recent pandemic emerged. This has expedited and fueled the process of materializing and spreading throughout the world by creating the demand, and thereby the investment, it needed to flourish the process; and 3. Past pandemics were controlled. It is likely to control the current one within the next year. Thus, it would not be the pandemic that will change the world (as it happened before many times), rather it is the unleashed electronic communication (by this pandemic) that would do the change.

Liao believes that COVID-19 speeds up the trends that futurists aimed for, such as digitalization/virtual reality/automation. His guesses, which are mainly from the viewpoints of passenger mobility and white-collar workers, are listed below.

- **Residential location?**

Liao: Living in the city center for being close to workplaces will be less attractive than before. People would switch attention to liveable communities (green space, children’s schools, small centers, etc.)

Poorzahedy: Rich will move to the outskirts of the cities and travel by (electric) car, when needed, to the destinations. Average and low-income people are bound to stay where they are, using e-shopping and teleworking when possible.

- **Work choice?**

Liao: People will be more technical/professional than before, as less technical/professional people will be easily replaced due to the augmented means of knowledge transfer and dissemination. More people will go to the sectors of leisure, services, or content-creation in social media. Also, people will tend to have more roles in multiple organizations.

Poorzahedy: Jobs are scares, and they continue to follow what are offered by employers, more inclined towards teleworking

- **Location of firms?**

Liao: Except for infrastructure-intensive manufacturing, most businesses will go online. Also, people have flexible working hours. Thus, firm locations are less demanding than before.

Poorzahedy: These locations will follow the freedom that will be offered by digital and automated processes.

- **Mode choice?**

Liao: Increasing modal split for shared autonomous vehicles and micro-mobility (bike/e-bike/e-scooter). A city in China launched shared autonomous vehicles. I believe the prices will be cheaper.

Poorzahedy: This depends on the residential locations and seems to be inclined towards automobiles. Public transport will have a new rival alternative, the telecommunication interactions.

- **Value of time (VOT)?**

Liao: Time will be still a scarce resource. The meaning of travel will be more.

Poorzahedy: It seems to decrease by saving travel times and the ability to work at home, where you can work more than 8 hours per day, as well as taking advantage of people all over the world!

- **Valuation of amenities (green spaces, etc..)?**

Liao: As said above, people will value amenities other than workplaces more.

Poorzahedy: By being in closed spaces most of the time, there seems to be a higher desire, demand, and valuation for the amenities.

Appendix B

Samuel Brannen, who is senior fellow in risk and foresight group at the Center for Strategic and International Studies (CSIS), writes how COVID-19 reshapes the future. The following tables provide immediate and long-term impacts of COVID-19 on population, economics, resources, governance, information, security, and technology.[97]

Revolution	Indicator	Immediate Impacts	Long-term Impacts
Population	Aging	Elderly highly vulnerable to disease	Greater use of biosecurity and technology to protect and connect elderly in the future
	Urbanization	Rapid adoption of remote work	Possible changes in urbanization and settlement patterns in some countries/regions
		Emergency measures taken by city governments to extend services and social safety nets during lockdowns; rapid infrastructure adaption a to health crisis	Expansion of universal public services (health, cash transfers, electricity)
			Data-driven city management
			Increasing urban public areas, greenspace, and bike lanes
	Migration	Migrant labor shortages	Adoption of automation and other labor-saving innovations
		Broad border, travel, and immigration restrictions	Loss of immigrant talent to advanced economies; increased South-South migration
		Severe decline in Global remittances	Economic crisis in emerging markets; potential political instability

[97] https://www.csis.org/analysis/covid-19-reshapes-future

Revolution	Indicator	Immediate Impacts	Long-term Impacts
Economics	Globalization	Synchronized recessions in developed and developing countries	Gradual global economic recovery globalization recedes further
	Supply Chains	Export restrictions on medical supplies and pharmaceuticals	Fragmentation and rationalization of supply chains; acceleration of U.S.-China decoupling in certain industries.
	Inequality	Weak companies, small businesses, and lowest wage earners disproportionately affected	First increase in global poverty since 1998; big companies get bigger
	Labor Dislocation	Largest simultaneous job losses globally in nearly a century	Uneven recovery affecting most vulnerable workers, companies, and industries; increased obstacles to new business formation
	Innovation	Jump in online commerce, surge in digital payments	Digital wallets and shadow banks proliferate; online currencies gain value and a greater share of global transactions

Revolution	Indicator	Immediate Impacts	Long-term Impacts
Resources	Energy	Severe energy market disruption; steep decline in energy demand; collapsed energy investment	Possible permanent slowdowns in fossil fuel demand and supply (early "peak oil" demand) bolstered by renewables investment
		Decreased commuting; declining public transit use; relative increase in car usage	Delayed deployment of electric vehicles
	Climate	Climate activism slowed	Increased activist ambition for significant global climate policy post-Covid 19
			Multiple national "green recovery" economic policies
	Food	Global food system shocks	Lasting supply chain and consumer changes (shortened; reduced meat demand)
		Labor shortages	Increasing agricultural automation
		Food price and supply protests	Increasing local food production, urban farming
			Greater government involvement in supply chains

Revolution	Indicator	Immediate Impacts	Long-term Impacts
Governance	Political Awakening	Surging citizen expectations for change; mass protests (core triggers: inequality and injustice)	Friction between public expectations and governement responsiveness leads to long-term unrest or structural reform
	Democratic Decline	Crisis-driven authoritarian consolidation	Continued struggle between forces of democracy and authoritarianism
		Failed responses by populist leaders and governments	
	Trust	Surge in initial trust in government and expertise	Enduring trust deficit among youngest adult generations (especially Millennials)

Revolution	Indicator	Immediate Impacts	Long-term Impacts
Information	Access/Privacy	Broad use of digital surveillance to track Covid-19	Expanded digital surveillance by countries and companies
	Data Growth	Largescale digitalization of commercial and social activities	Faster growth in data volume; shift to online-first culture
	False News and Social Media	"Infodemic" races ahead of the pandemic	Intensified geopolitical competition in misinformation/ disinformation
	Knowledge and Learning	Widescale adoption of online learning	The digital divide within societies increases inequity

Revolution	Indicator	Immediate Impacts	Long-term Impacts
Security	Expanding National Security	Health security elevated as core to national security	Growing debt pressures reduce defense spending
	Fragmentation	U.S. and Chinese leadership failures deepen global fragmentation	Future organizing principles for the international system unclear
	Gray Zone	Countries intensify gray zone actions as they avoid conventional conflict and seek advantages	Low defense budgets and increased fragmentation drive even more gray zone activities
	Return to Terror	Increased activity by violence extremist organization (VEOs)	VEOs prey on weakened states, economic vulnerability to push ideology and influence

Revolution	Indicator	Immediate Impacts	Long-term Impacts
Technology	Robotics	Heightened interest in robotics due to public health and labor shortage	Accelerated replacement of human labor across sectors (especially health, food and agriculture)
	Additive Manufacturing	Rapid production of medical components at points of need	Accelerated replacement of traditional manufacturing processes with additive technologies (especially in health sector)
	Internet of Things	IoT usage remains high, with certain sectors reporting huge increases in data flows	Increased reliance on IoT in everyday use, especially for health monitoring and surveillance
	Artificial Intelligence	Rapid adoption of AI chatbots and other applications to fill surge needs	Increased R&D spending related to AI and overall digitalization pushes up adoption timeline across sectors
	Biotechnology	Surge of investment in synthetic biology in pursuit of therapeutics and vaccines	Growing global competition for leadership in biotech; sustained high levels of national investment